Monitoring and Evaluating Cycling in Canadian Cities

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Many cities in North America have stated goals in their Official Plans, Transportation Plans, and other municipal documents related to cycling. A common objective is to increase the number and proportion of cyclists for either utilitarian or both utilitarian and recreational trips. To determine whether they are progressing towards achieving their goals, it is necessary that cities periodically and accurately monitor and measure their levels of cycling.

This thesis aims to assess the different methods used for monitoring cycling in Canadian cities, as well as individual cities' overall monitoring programs. The advantages and disadvantages of different methodologies and technologies are discussed, and best practices are provided. Four case study cities: Vancouver, Halifax, Calgary and Toronto are assessed according to a list of best practices developed by Hudson et al. (2010). Themes and patterns emerge and the cities are compared and contrasted. A summary of Canadian cities' efforts is presented and the cities are ranked in the following order: #1 Vancouver; #2 Toronto; #3 Calgary; and #4 Halifax.

In addition, the results of two surveys from the Greater Toronto and Hamilton Area are compared at the census tract (CT) level to assess their reliability. The Bicycling Share of Work Trips (BSWT) from the Transportation Tomorrow Survey (TTS) and Statistics Canada's Canadian Census (the Census) is examined to identify whether research from different sources is producing the same results. Geographic Information Systems are used to examine and compare the spatial patterns of the survey results and descriptive statistics are used to quantify the differences. It was found that the surveys are producing significantly different results and that there appears to be little spatial pattern in the difference between them.

This research allows Canadian cities and other interested parties to learn about the various methods for monitoring cycling, to see which methods are being used in Canadian cities, to decide which methods are best for their specific needs, and to more comprehensively understand the BSWT from the Census and the TTS.

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Glossary of Terms

Term	Meaning
Bicycle	Any cycle propelled by human power on which a person may ride, regardless of the number of wheels it has (City of Calgary, 2000)
Bicycling Share of Work Trips (BSWT)	The number of work trips by bicycle divided by the total number of work trips
Cyclist	A person operating a bicycle (City of Calgary, 2000)
Estimate	Make prediction about the future or the whole city
Evaluate	Decide whether something is of value
Monitor	Collect data
Multi-modal trip	Trip that uses multiple modes of transportation to get from beginning to end, for example automobile for the first half of the journey then transit for the second half
Non-cyclists	Those who do not own or ride a bicycle
Recreational cyclists	Those cyclists who ride a bicycle for recreation or fitness purposes only (City of Toronto, 2010)
Sustainable mode of transportation	Mode that is not a single-occupant vehicle
Traffic	Vehicle movement (Litman, 2011)
Utilitarian cyclists	Those cyclists who ride a bicycle for utilitarian purposes such as commuting to work or school, running errands, going shopping or visiting friends. Utilitarian cyclists may also ride their bicycle for recreation or fitness purposes (City of Toronto, 2010)
Work Trip	A trip that is taken for the purpose of travelling to or from work

List of Abbreviations

Abbreviation	Term
APD	Alta Planning + Design
BTS	Bureau of Transportation Statistics
CSI	Cambridge Systematics Incorporated
DOT	Department of Transportation
FHA	Federal Highway Administration
HRM	Halifax Regional Municipality
ITDP	Institute for Transportation and Development Policy
ITE	Institute of Transportation Engineers
LOS	Level of Service
MTC	Metropolitan Transportation Commission
NBPDP	National Bicycle and Pedestrian Documentation Project
PBC	Pedestrian and Bicycle Council
TTI	Texas Transportation Institute
US	United States

Chapter 1
Introduction

1.1 Introduction

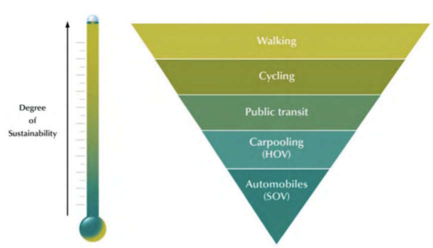
Cycling is widely considered to be an inexpensive, equitable, environmentally friendly and health-promoting mode of transportation. It is an attractive alternative to other modes as it has potential to alleviate such problems as automobile congestion; social isolation; health-related epidemics; unaffordability of transportation; climate change; social inequality; and lack of space for infrastructure (Casello, Rewa & Nour, 2012; McClintock, 2002; Pucher & Buehler, 2010; Ryley, 2006). When transportation and planning departments at all levels of government include cycling as a viable means of transportation, it benefits everyone because cities are more efficient when they offer a variety of transportation options (Casello et al., 2012; Hope & Yachuk, 1990; Porter, Suhrbier, & Schwartz, 1999). Providing these options allows a city to: enhance overall mobility; withstand increases in energy prices or other economic shocks; decrease pollution; allow transportation access for economically or socially disadvantaged people; and become a more internationally competitive city (City of Calgary, 2009). Cyclists require less road space, less parking space and less fuel (Pucher & Buehler, 2010; Tight, et al., 2011; Transporte Ativo & Institute for Transportation and Development Policy [ITDP], 2010). An increase in bicycle traffic could mean fewer cars on the road, which would benefit the overall transportation network and require less spending on expensive road infrastructure (Transporte Ativo & ITDP, 2010). The Ontario Ministry of Transportation indicates that cycling has the potential to: encourage active and healthy lifestyles; reduce greenhouse gas emissions; decrease congestion; and provide economic development opportunities (Ontario Ministry of Transportation, 2012).

Many government agencies, public health organizations, independent researchers and medical journals all promote the objective of increasing the number and proportion of people who cycle (Pucher & Buehler, 2010). The number of people who cycle refers to the absolute number, for example the number of people per day who travel through a specific intersection. The proportion refers to the percentage of total people travelling that use cycling as their transportation mode. An example of this is the proportion of workers who use a bicycle to commute to work.

Cycling is a topic that is currently receiving enthusiasm, support and interest from municipalities and professional groups in Canada (Pucher & Buehler, 2010). In 2012, an Ontario Professional Planners Institute symposium focused on active transportation; Vancouver hosted an international cycling planning conference called Velo-city; and the Cities & Environment Unit in Halifax teamed up with bicycle consultancies Mobycon and Copenhagenize to offer bicycle policy training sessions to planning professionals. North America has experienced a renaissance in cycling over the past twenty years. Although the US and Canada have witnessed slow growth as a whole, certain cities have made great progress (Pucher, Buehler, & Seinen, 2011).

In Canada, provincial governments are also involved. For example, the Province of Ontario's Growth Plan for the Greater Golden Horseshoe (Growth Plan), a policy document that directs growth in the Greater Toronto Area and surrounding regions, recommends that the modal split for cycling should be increased and that cities be designed so that cycling is a viable form of transportation (Province of Ontario, 2006). Ontario municipalities such as Niagara, Waterloo, Toronto, Ottawa, Brampton, Markham, London, Milton and Windsor are attempting to improve cycling networks and reduce automobile dependence (Halifax Regional Municipality [HRM], 2006). Other organizations that champion this objective are the Heart and Stroke Foundation Clean Nova Scotia, and Nova Scotia's Department of Health Promotion and Protection. In a 2005 nation-wide survey on Active Transportation by Go for Green, over 60% of Canadians stated that they would walk or cycle more often if safe facilities were available in close proximity to their homes, schools, and workplaces. No other public facilities or infrastructure types approach these levels of support (HRM, 2006). In the transportation hierarchy of consideration in many cities, for example in Vancouver and in Calgary, cycling comes second only to walking because these modes are said to be the most sustainable (City of Calgary, 2008; City of Vancouver, 2012). This is pictured in Figure 1.

Figure 1 Sustainability Triangle of Consideration for Transportation Modes



Source: (City of Calgary, 2010)

The movement towards increased active transportation is commendable. One problem with cities stating that they want to improve walking and cycling, however, is that most lack technology and programs to secure reliable and accurate data to confirm that investment in cycling infrastructure actually increases cycling levels (Alta Planning and Design [APD] & Institute of Transportation Engineers [ITE] Pedestrian and Bicycle Council [PBC], 2012; Hudson, Qu, & Turner, 2010; Nordback & Janson, 2010). Many municipalities seem to have plateaued as far as their cycling achievements due difficulties obtaining financing (Pucher & Buehler, 2005). Projects that receive municipal funding are often determined by cost and political will. Although reliable and periodic evaluation is an important part of acting on and achieving goals, monitoring and evaluation is not glamorous. It is central to good planning, but it is often done poorly (Seasons, 2003a). A good monitoring system can justify funding, validate or refute assumptions about "build it and they will come", and help municipalities decide when, where and what type of facilities should be implemented (Transport Canada, 2011). However, such a monitoring system has yet to be achieved not only by municipalities, but in the academic literature as well (Krizek & El-Geneidy, 2005). Many cities turn to sources of data like the Bicycling Share of Work Trips (BSWT) from Statistics Canada's Canadian Census (the Census) (City of Toronto, 2008; City of Toronto, 2010; City of Vancouver, 2009; HRM, 2002; HRM, 2006; Transport Canada, 2010).

This thesis explores the advantages and disadvantages of using the Census data to measure cycling, as well as pros and cons of other methods of monitoring. The methods are compared and contrasted and case studies of Canadian cities' approaches to monitoring are conducted. The Census is assessed to determine whether it is a reliable and accurate method of monitoring and evaluating cycling in Canadian cities.

1.2 Research Relevance

Many Canadian cities and regions aim to increase both their share and volume of cyclists (Pucher & Buehler, 2010). The first step in working towards achieving a goal is to diagnose the current state and determine baseline levels. Once this is accomplished, ongoing monitoring programs allow cities to evaluate their progress. It is important for a city to be aware of whether they are experiencing success, so they can celebrate their accomplishment and continue to build on their results. Equally, if they are falling short of their targets, monitoring can reveal missed opportunities and areas for improvement. Ideally, cities should use the most reliable and cost-effective ways to monitor and estimate their cycling activity. A proper monitoring and evaluating system keeps municipalities honest and gives them an objective way to track their progress.

As bicycle travel grows, it will be increasingly essential to quantify travel patterns and mode share to inform the implementation of new infrastructure (Nordback & Janson, 2010). Cyclists must be counted to allow the development of models that predict when and where people are cycling, project the effects of future infrastructure changes and estimate numbers for the years ahead. Models can help identify where there is a need for new or upgraded facilities (APD & ITE PBC, 2012). Cycling data are helpful in planning new infrastructure developments, informing municipalities and regions about attaining their goals, earning grant money from upper tiers of government, and demonstrating how cycling fits into the big picture of transportation planning. Monitoring allows municipalities to prioritize, evaluate projects and have access to data for reports (Wilke, Lieswyn, & Taylor, 2012). Since different cycling volumes necessitate different infrastructure types, existing bicycle traffic is often a criterion for deciding routes for future facilities (HRM, 2012). With count data, projects can be justified based on demand (Hudson et al., 2010).

Techniques for obtaining data about cycling must evolve before it can be fully integrated as a mode of transportation in existing transportation models and planning exercises (Porter et al., 1999; United States [US] Department of Transportation [DOT] Federal Highway Administration [FHWA], 1999). Few regions and municipalities count the number of people engaging in active transportation. Some count active modes only on an inconsistent basis and most do not count pedestrians and cyclists at all (US DOT Bureau of Transportation Statistics [BTS], 2000). Porter et al. (1999) identify a need for data collection guidelines and a description of potential sources. The Transportation Research Board (TRB) formed a subcommittee in 2011 to focus on the issue of lack of research into active transportation data collection and its necessary equipment. The committee is in its infancy and they are still in the phase of asking questions (Stolz, 2012).

1.3 Research Questions

1. What methods are being used to monitor cycling in Canadian cities and how do they compare to best practices?
2. How do two commonly used measures of Bicycle Share of Work Trips (BSWT), the Canadian Census and the Transportation Tomorrow Survey, compare for consistency in measuring cycling activity?

The purpose of the first research question is to provide insight into how Canadian cities are monitoring cycling and allow for an evaluation of their methods. Ideally, it will help municipalities to learn best practices from other jurisdictions and to comparatively assess themselves. To discover the methods that are being used to monitor cycling in Canadian cities, a review of policy documents, reports and plans produced by engineering, transportation, planning, parks, sustainability and other related municipal departments is performed. These include Cycling Master Plans and Cycling Statistics Update Reports. Their methods, results and conclusions are analyzed and key officials are contacted for any content that needs clarification. To evaluate the cities' methods, a list of best practices from Hudson et al. (2010) of the Texas Transportation Institute is used as a framework. These best practices were generated from a research project that aimed to investigate existing monitoring programs to recommend a suitable method of gathering cycling data for the Capital Area Metropolitan Planning Organization in Texas.

The second research question is studied for the purpose of comparing two surveys that are currently being used to determine mode share of cyclists for work trips. The Transportation Tomorrow Survey (TTS) presents another option for monitoring cycling. The TTS is a household travel survey for which residents of the Greater Toronto and Hamilton Area (GTHA) are contacted. The survey asks them about the details of each trip taken by each member of their household during a selected twenty-four hour period. The TTS can be directly compared to the Census because in both cases data are collected by census tract (CT) and a BSWT can be calculated. The Census is used much more commonly but there is motivation to determine if there are better methods available. These two data sets will be compared both statistically and spatially using Microsoft Excel and Geographic Information Systems (GIS). They are examined to see if two different surveys with different methodologies are producing consistent results. The methodologies are studied to determine if they are responsible for any inconsistencies.

The structure of the thesis is as follows: the next chapter is the literature review, which begins by outlining the planning process for cycling. It then discusses monitoring and evaluation with regards to the following topics: planning theory, planning practice, transportation and cycling. The third chapter is the methodology section, which describes the methods used to conduct the research presented in this thesis. The fourth chapter contains the results, which states the findings of the thesis. It outlines how the following case study cities monitor their cycling activity: the City of Vancouver, the City of Calgary, the City of Toronto, and the Halifax Regional Municipality. This is followed by a literature-based critical assessment of the cities' methods according to a framework by Hudson et al. (2010). The results section also includes a description and analysis of both the Census and the TTS as far as their methodology and outcomes. The two surveys are compared both spatially with GIS and through descriptive statistics. The fifth chapter is the discussion section, which discusses the results that were found and presents possible explanations. The sixth chapter provides the conclusion and recommendations and discusses limitations and directions for future study.

Chapter 2
Literature Review

2.1 Introduction

This literature review provides an overview of transportation monitoring and evaluation with a specific focus on cycling. Monitoring is defined as obtaining and interpreting data relating to performance indicators to decide if interventions are working as planned according to a standard. Evaluation is defined as assessing a program or policy's deliverables and functioning against a standard for the purpose of improvement (Seasons, 2003a). The literature review discusses the following: why we monitor; what we monitor; where we monitor; how much we monitor and how we monitor. Specific methods of monitoring cycling, including various types of surveys and counts, are described in detail to conclude the chapter.

2.2 Why monitor

2.2.1 Monitoring in Planning

Traditionally, the rational comprehensive planning process has been used to make decisions in planning. The final two steps of this model are monitoring and evaluation (Seasons, 2003b). This is done regularly for the purpose of ongoing assessment and evaluation of policies, processes, programs or plans (Seasons, 2003a). Monitoring and evaluation lead to productivity, objective decision-making, and cost-effectiveness. They contribute to the long-term improvement of planning. Municipal planners recommend benchmarking and comparing themselves to other municipalities as a way of checking their progress and success. Their work must be clearly documented (Seasons, 2003b).

Planners must be able to determine the impact of their work, define whether an intervention is a success, decide which actions should be repeated in the future and evaluate what constitutes a good or poor decision (Seasons, 2003b). Despite this need for assessment, factors such as competition for resources and organizational culture can affect whether monitoring and evaluation occurs (Porter et al., 1999).

Decisions regarding the funding of infrastructure and programs can be political, however it is essential that cities enter into decisions with sound data in order to achieve goals and objectives (Seasons, 2003a). Decision-making without information and data can lead to professional reputation damage, underutilized or mis-used resources, and wasted opportunities. Regular and consistent monitoring and evaluation allow the definition between success and failure to become clear. It also helps when writing summaries and reports, because relevant data have already been collected and organized (Seasons, 2003b).

2.2.2 Monitoring in Transportation Planning

Planning for transportation is integral to the overall planning process, as citizens must have access to transportation. This is illustrated for example in the City of Calgary, where six of the 11 principles that address the city council's goals are related to transportation (City of Calgary, 2008).

Monitoring and evaluation are emphasized in the Transportation Master Plans of many cities. The 1997 Transportation Plan from the City of Vancouver states that the city would "undertake regular monitoring and review of transportation services…to establish how transportation patterns are developing, and to recommend additional policies and measures needed to achieve the Transportation Plan's policies and targets" (Transport Canada, 2011, p. 2). Data are important to evaluate transportation network performance, plan for new transportation initiatives, develop new policies, and play a quantitative, scientific, integrated and systematic role in municipal planning. Monitoring transportation often results in projects that fix problems, for example, by identifying areas that need traffic congestion alleviation (Wen, Hu, & Sun, 2010). Vancouver aims in their 1997 Transportation Plan to design a transportation network monitoring and review program to guide future policies and budgeting (Transport Canada, 2011). Nonetheless, a section on tracking progress in the Transportation 2040 Plan states that monitoring and the ability to set targets is still limited by unreliable and inconsistent data (City of Vancouver, 2012).

Data collected during monitoring can also be useful as input for predictive models. The models help estimate how changes to the transportation network will affect other aspects of the transportation system, for example how new transit projects will affect bicycle volumes. Transportation planning models like EMME/2, which is used by over 580 organizations in 58 countries, are often used. This model emulates human behaviour by determining the fastest and least expensive mode and route for individual trips and thus assigns modes of trips across a transportation network (City of Vancouver, 2002). The Transportation Research Board (TRB) has a Highway Capacity Manual (HCM) used for transportation planning as well, an important aspect of which is the level of service (LOS) concept. Monitoring is important to determine a score for a facility's LOS. LOS evaluates transportation infrastructure and is mostly determined by the volume of traffic as compared to a facility's capacity (City of Calgary, 2009).

In Calgary, the evaluation of their transportation network has historically been focused on peak hour traffic and its congestion (City of Calgary, 2009). In the past, the goal has been to alleviate traffic problems by building new facilities. This has proven to be expensive and may actually encourage further use of automobiles (City of Calgary, 1996). Indeed, conventional travel-forecasting models commonly focus on only motorized modes, however if non-motorized modes like cycling are integrated into these models, it may increase their viability and consideration in the future (Porter et al., 1999).

An example of new multi-modal-type monitoring is reported in the Key Finding Presentation for the 2005 Calgary Transportation Plan, where patterns and conclusions are identified. For example, the number of trips downtown during rush hour from 1995 – 2005 is compared to the amount of new road infrastructure completed. There were no new roads built to serve downtown, however 26 000 morning rush hour trips were added. The existing infrastructure was sufficient because citizens were able to change their behavior and use modes other than driving. Additional holistic monitoring found jobs in the city's east grew 10 times more than expected in spite of attempts to increase employment on the west side. This has resulted in an inefficient trend of high traffic volumes driving west-east across the city as people generally live on the west side and work on the east. The City of Calgary did not achieve their goal of creating mixed-use developments within communities so people can live near jobs and places that fulfill their shopping and social needs (City of Calgary, 2005). The report identifies both successful and unsuccessful initiatives and finds root causes for Calgary's 60% increase in total traffic over the 1995-2005 decade. New indicators of change and actions for the future are suggested to help achieve the goals with which they are struggling (City of Calgary, 2005).

2.2.3 Monitoring in Planning for Cycling

Cycling is an important transportation mode because of its potential to lead to greater mobility, better air quality, less congestion, higher quality of life, and improved safety (Transport Canada, 2011). Cities are planning to increase cycling levels, often requiring investment in infrastructure which must be decided in conjunction with other transportation investment options. Information is gathered in advance of decision making, to ensure that the cycling projects selected will have the greatest benefit. Qualitative and quantitative appraisals determine whether the value gained by investing is greater than the costs. Traditional transportation investment benefits include increases in productivity, gross output or standard of living (Transportation Association of Canada, 1994). Cycling offers the potential to expand these benefits in terms of public health and quality of urban life.

As increasing cycling is generally considered to be beneficial, many transportation plans in North American cities outline goals and objectives for targets related to cycling activity. Reaching these targets involves monitoring cyclists to see if facilities and infrastructure are working as intended (Transport

Canada, 2011). It is crucial to understand the level of bicycle activity for bicycles to have a greater impact on funding and policy decisions (Caselllo et al., 2012; Griswold, Medury, & Schneider, 2011). Evaluation is one of the main steps recommended by the League of American Bicyclists (LAB) in their 5-E approach to integrating cycling into a comprehensive plan. The LAB uses these same five Es (engineering, education, encouragement, enforcement, and evaluation and planning) as bicycle-friendly city assessment criteria. Cities that have adopted the 5-E approach for their bicycle plans include: Boulder, Colorado; Portland, Oregon; and Davis, California (Ginger et al., 2010).

Monitoring can even be used to monetize the benefits of cycling (Transport Canada, 2011). For example, in the City of San Jose, their trail use data enabled city officials to obtain $2 700 000 in grant funding to improve their trail system in 2007 and 2008 from such sources as the State of California and the Bay Area Ridge Trail. The State of California noted that the count data from the City of San Jose's Trail Count Fact Sheet was integral to the awarding of grants for trail enhancements. They noted that the commuting data was particularly impressive and the state would benefit from similar data from other agencies (City of San Jose, 2011). Cycling data could be useful to engineering staff, planners, health care professionals, community health officials, school administrators, police departments, cycling advocacy groups and city councils (Transporte Ativo & ITDP, 2010). The City of Calgary was able to set priorities for important commuter routes using the results of the 2000 Commuter Cyclist Survey, an informative tool that helped determine what is important to cycling Calgarians (City of Calgary, 2006). This helps the City of Calgary work towards Council Priorities like increasing the use of sustainable modes of transportation (City of Calgary, 2006).

Other reasons for monitoring and parties that would be interested in the results of monitoring are outlined in Table 1.

Table 1 Reasons for monitoring cycling and interested parties

Reason for monitoring cycling	Interested parties
Correct traffic signal phasing	Engineering department
Determine baselines	Planning department
Analyze trends	Planning department
Access the success of projects	Council; planning department
Establish whether facilities are actually resulting in people choosing to cycle	Council
Predict demand on potential facilities	Engineering department
Determine where there is potential for additional infrastructure	Planning department
Determine which facility types are appropriate	Engineering department

Reason for monitoring cycling	Interested parties
Understand operations and maintenance needs	Engineering department
Justify further funding	Council
Determine if promotional campaigns are effective	Marketing department
Identify specific needs	Planning department
Determining seasonal variation	Planning department
Prioritize new infrastructure	Planning department
Provide data for model calibration	Engineering department
Determine exposure for the purpose of studying accidents	Public Health department; Planning department
Quantify bicycle use	Planning department
Analyze where and when cyclists are travelling	Transportation department
Set reasonable goals for the future	Planning department
Rank facilities by usage	Planning department
Inform decisions to upgrade, widen, twin or provide winter maintenance	Transportation department
Determine where pathways are under-utilized and need additional promotion or marketing	Marketing department
Develop a profile of the typical user for situations that are context-specific	Planning department
Indicate whether under-utilized pathways should be eliminated	Planning department
Compare with counts of other modes	Transportation departments
Identify problems with existing bicycle network	Engineering department

Source: City of Calgary, 2000; Hope & Yachuk, 1990; HRM, 2006; Hudson et al., 2010; Lindsey et al., 2012; Porter et al., 1999; Transporte Ativo & ITDP, 2010

Cycling infrastructure, programs and policies are rarely monitored and evaluated for a number of reasons. It may be difficult to tease out a cause and effect relationship, interventions may take time to be successful, change is normally modest, and underwhelming results might mean less funding and action in the future (Krizek et al., 2009). Benefits can be difficult to determine and quantify (City of Calgary, 1996). Cycling remains an understudied area and more research is necessary (Krizek & El-Geneidy, 2005; Krizek et al., 2009; Pucher, Dill, & Handy, 2010), as transportation decision-makers often lack the data and tools they need to make educated decisions about investing in facilities for non-motorized modes (Hankey et al., 2012; Lindsey et al., 2012). In order to maximize investment, data must be collected and bicycle traffic measured systematically (Handy et al., 2009; Hankey et al., 2012; Hunter & Huang, 1995; Jones, 2009), however few municipalities, agencies or researchers are doing this. Indeed, it has not been proven in the academic literature that building cycling facilities is actually leading to increased cycling (Krizek & El-Geneidy, 2005) and the value of the investment in cycling infrastructure must still be demonstrated (Casello et al., 2012). In Toronto, existing data sources are not sufficient to quantify levels of bicycle traffic (City of Toronto, 2001). Other examples of places that have need for additional and improved data include Calgary, Vancouver, and Puget Sound Region (City of Calgary, 2010; City of Vancouver, 2012; Ginger et al., 2010). The Toronto Bike Plan notes that counts also need to better account for the weather and season (City of Toronto, 2001).

Hunter and Huang found in their 1995 summary of cycling research that there was great variety in the detail and quality of the studies. Many reports did not use a representative sample and could not be applied beyond the participants used in the study. The *1999 Guidebook on methods to estimate non-motorized travel* from the US DOT outlined methods used to measure and model active transportation modes, but in 2000, the BTS labeled available cycling data as severely lacking. They identified a strong need for future study. In the United States, non-motorized modes like cycling lack nationally accepted methods of data collection, so transportation departments struggle to find data to justify supporting and funding cycling programs, policies and facilities (APD & ITE PBC, 2012; Stolz, 2012). Others argue that models are effective for predicting transit and motor vehicle trips, however for walking and cycling it is better to observe trends and demographics (City of Vancouver, 2002). As a result, cyclists and their transportation system benefits are often underrepresented in transportation modeling exercises (APD & ITE PBC, 2012).

One survey of municipalities in the US found that most monitoring programs had commenced since 2005 and long-term statistics are not available (Hudson et al., 2010). Even when monitoring occurs, many organizations in North America are doing it separately with individual approaches and it is hard to compare results comprehensively across jurisdictions. It is difficult to establish national trends and patterns, for example between factors like cycling volume and community there is a need for more bicycle monitoring in North America.

2.3 What to monitor

"What is measured, how it is measured, and how data are presented can affect how problems are evaluated and solutions selected" (Litman, 2011, p. 2). An example of this is the following: in North America, over 90% of households own a motor vehicle and over 90% of trips are made by motor vehicle. Active transportation is used for approximately 5% of trips and transit is used for 2%. These statistics reflect the way in which data is collected and presented. Travel surveys often only count the primary mode of transportation used and then it is only counted if the subject travelled from one Transportation Analysis Zone (TAZ) to another. Additionally, travel surveys often only count trips to work or rush hour trips. Short trips (those that occur within a TAZ), active transportation portions of longer trips, non-rush hour trips, non-commute trips, recreation trips and the trips of children are often undercounted or ignored in transport surveys, models and analysis. Indeed, lunch-time walk trips from work to a restaurant or to do errands can be neglected (Litman, 2011). Additionally, automobile and transit trips may begin or end with another mode, but they are usually only classified as automobile trips. For example, "if a traveler cycles 10 minutes to a bus stop, rides a bus for five minutes, and walks another 5 minutes to their destination, this bike-transit-walk trip is usually coded simply as a transit trip, even though the non-motorized links take more time than the motorized link" (Litman, 2011, p. 8).

A proposal can appear valuable and affordable or expensive and wasteful, depending on how its outcomes are measured. Different methods of monitoring can lead to different conclusions about a person, group or activity. Usually, single methods contain inherent assumptions and points of view, and are not comprehensive enough to give all the information necessary to make a decision. In transportation planning, relying too much on one monitoring method may mean other important considerations are being left out. Litman's (2011) summary of three main approaches to transportation planning (traffic, mobility, and accessibility) provides insight into how this can happen.

From the traffic perspective, transportation system performance is often measured based on traffic volumes and speed because they are easy to measure. This leaves out other important considerations like bicycle lane quality or the distance users must travel to access good and services. For most jurisdictions performance indicators like traffic volumes, traffic speeds, roadway Level of Service (LOS), congestion delay, parking supply, vehicle operating costs and crash rates are used (Litman, 2011).

Another way of measuring transportation systems is from the perspective of mobility. Performance indicators include person-kilometers, ton-kilometers, and travel speeds for automobiles and transit vehicles. The system is examined from a more multi-modal perspective, for example by using LOS for transit and cycling.

The third approach to monitoring transportation is accessibility, which examines the user's ability to reach goods, services, activities and destinations. With the exception of some recreational trips, this is the main goal of transportation. The transportation systems can be evaluated based on mobility principles, distance needed to travel to reach destinations, or technology used in place of transportation such as telecommunications or delivery services. It acknowledges that people cannot be grouped based on the type of transportation they use, as many people use a full range of modes to provide access. All of these options are considered equally important. This is the most difficult way to measure transportation system quality because there are so many factors involved. Evaluation considers the generalized cost of transportation: the time, money, discomfort and risk involved. Accessibility is quantified using activity-based travel models and integrated transportation/land use models (Litman, 2011).

Although in the past transportation monitoring has focused on approaches to transportation evaluation consistent with the mobility and traffic perspectives, organizations such as the TRB are moving toward incorporating more modes into their transportation manual, taking all transportation users into account in their 2010 version of the HCM. The effects of cars on other modes are being considered for the first time and there are tools for multimodal analysis. Instead of having separate chapters for bicycle, pedestrian and transit modes, they are now incorporated into roadway facility analysis (Ryus, Vandehey, Elefteriadou, Dowling, & Ostrom, 2011). Moving forward, the City of Calgary acknowledges that as a city develops, it is increasingly important to look at the other hours of the day and examine the quality of service for all modes, not just peak hour traffic congestion issues (City of Calgary, 2009).

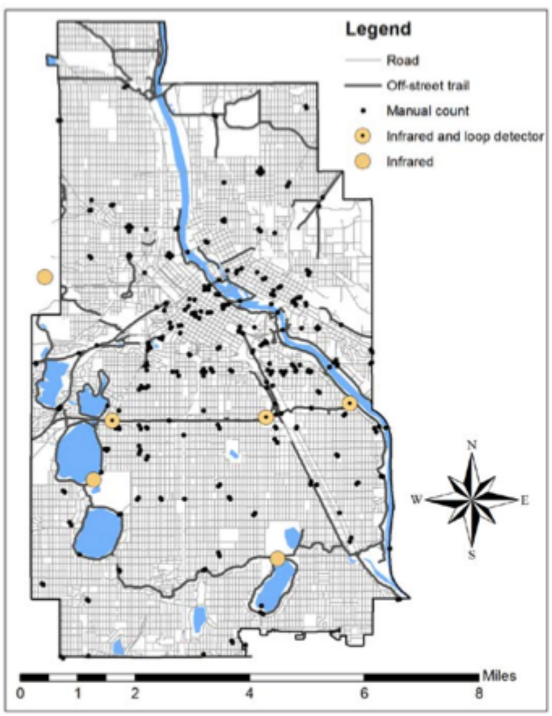
This thesis focuses on monitoring users of a non-motorized mode, cycling. This is looking at the transportation system from an accessibility perspective, because it is taking into consideration the transportation network's effects on a mode other than the motor vehicle. Measuring accessibility is the best way to measure the main goal of transportation, access (Litman, 2011). There are many important ways to monitor cycling, for example by evaluating the bikeway network for its quality of facilities, bicycle safety for the rate of accidents, or economic vitality to estimate the amount cycling is contributing to the economy (City of Portland Bureau of Transportation [CPBT], 2010), however this thesis focuses on measuring the use of bicycle facilities.

2.4 Where to monitor

An approach to monitoring and improving cycling facilities can be holistic or it can just examine one particular aspect or location (Ryley, 2006). Sites can be chosen randomly or based on specific criteria. When only one location is monitored, it is often an important area to which many people must travel, such as a downtown destination, popular trail or university campus, to maximize utility (City of San Jose, 2011; Halifax Cycling Coalition, 2010). Also, if counts are focused on areas with large numbers, the margin of error will be less, improving model predictions (Ginger et al., 2010).

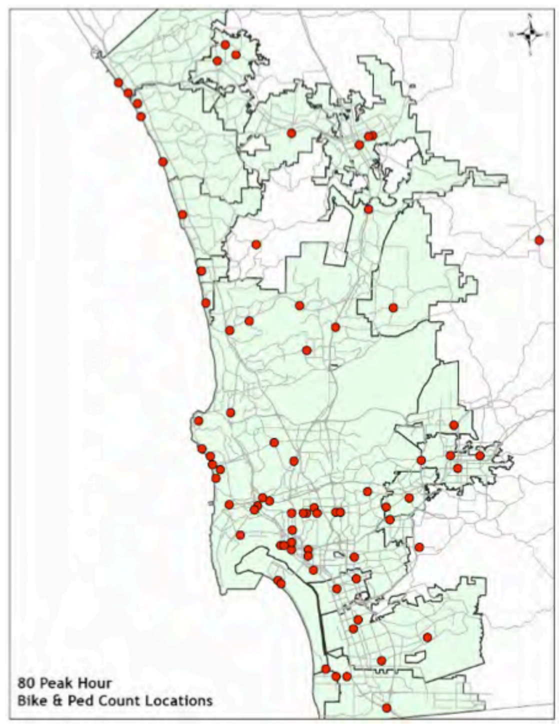
Transporte Ativo and the Institute for Transportation and Development Policy (2010) stress that locations must be randomly selected if the sample is to be extrapolated to the entire city (Transporte Ativo & ITDP, 2010). Richardson (2006) advocates for selecting sites randomly with some network stratification to ensure equal representation. Results can then be adjusted to account for these non-random selections (Richardson, 2006). Alternatively, the City of San Jose recommends choosing stations because they are near important trip generators and attractors or because they serve as important commuting routes (City of San Jose, 2011). Some researchers endorse choosing locations with a wide range of population density, employment density, land use, transportation infrastructure, geographic features, proximity to commerce, resident income, other socio-demographic characteristics and bicycle facility types to gain representation from a variety of cyclist types and trip purposes (Griswold et al., 2011; Wilke et al., 2012). By allocating a catchment area to each site and assigning each network segment to the closest count site, the data can be expanded to cover the entire network (Richardson, 2006). Figures 4 and 5 below show count locations from studies by Lindsay et al. (2012) and Jones et al. (2010).

Figure 2 A network of count locations in Minneapolis, Minnesota



Source: Lindsey et al., 2012

Figure 3 Peak hour count locations in San Diego County



Source: Jones et al., 2010

Ginger et al. (2010) recommend using fewer sites for more days of the year rather than capturing a large number of sites only briefly. Automated counts all day every day for an entire year would provide a plethora of information about the differences between seasons and the days of the week even if the number of locations is small.

Some factors to consider more specific to the actual location of monitoring are outlined by Casello & Majcherkiewicz (2012). They include: considering the physical requirements of the equipment being used, for example whether a counter must be affixed to a post or if there is a minimum degree of lighting necessary for video imaging; the visual eyesore that may result if multiple or large devices are all located in one small space; any physical obstacles that may impede a line of sight for a video camera or a beam emitted from an infrared sensor; the presence of an opaque surface that may interfere with some technologies; and the improvement in accuracy of counts if a designated corridor where people can only travel in a direction perpendicular to the counting device and not complicated by the presence of the entrance to a store/building/alleyway/other option for direction of travel or where there may be a tendency to loiter Casello & Majcherkiewicz (2012).

2.5 How much to monitor

Monitoring must occur at regular intervals to gauge the success of any program or policy, including those related to cycling (Hope & Yachuk, 1990). There seems to be some disagreement over how often monitoring should occur, as the 2000 Calgary Pathways and Bikeways Plan Report recommends that user surveys occur every five years, the City of Toronto bike plan recommends every four years, the Halifax ATP recommends every two to five years (City of Calgary, 2006; City of Toronto, 2009; HRM, 2006). With counts there is some discrepancy as well: the City of Calgary aims for every two years; the City of Toronto aims for every three years; the Halifax Bike Plan aims for yearly; the Halifax ATP aims for every five years; Hudson et al. recommends every year; and the NBPDP recommends every year (City of Calgary, 2006; City of Toronto, 2009; HRM, 2002; HRM, 2006; Hudson et al., 2010; NBPDP, 2013). In addition, many organizations recommend taking before and after measurements any time new infrastructure and programs are introduced (Transporte Ativo & ITDP, 2010).

For counts, consistent conditions are most likely when the dates used are as condensed as possible (MTC, 2003). Some cities perform both twelve-hour counts, often from 7:00 am to 7:00 pm, and peak hour counts. Peak hour counts record cyclists during what is expected to be the hours of greatest use, for example: 7:00 am to 9:00 am and 4:00 pm to 6:00 pm. Cities like San Jose prefer twelve-hour counts but conduct peak hour counts when twelve-hour counts are not feasible. The NBPDP recommends using 5:00 pm to 7:00 pm as the peak hour, but if cities have historically used a different time, they should continue with their original peak hour to maintain consistency (City of San Jose, 2011). Cities vary greatly in collection times. Ottawa counts occur for eight hours a day (7:00am-10:00am, 11:30am-1:30pm, and 3:00pm-6:00pm) (City of Ottawa, 2010). The MTC recommends using fifteen-minute intervals to record counts (MTC, 2003).

Some cities are consistent, while others are sporadic. Cities collect at an assortment of different intervals, for example annually, monthly and continuously, while some communities are not monitoring at all (Hudson et al., 2010). In Hudson et al.'s findings, municipalities identified the main barriers to monitoring cycling as: access to funding, organizing and training volunteers, motivating interns, and the affordability of accurate reliable technology (Hudson et al., 2010). Similarly, in his research, Seasons (2003a) found that respondents ranked funding as the most important factor in monitoring for municipal planning. . Also important were having evaluable plans and staff with the resources and ability to collect and analyze the data

Indeed although it is essential to plan effectively, track progress and ultimately make the best choices for communities, monitoring and evaluation is an often-neglected aspect of planning (Seasons, 2003b). The development aspects of planning are often prioritized over the monitoring and evaluation side, as work on items like development permit approvals can be seen as urgent, lucrative and time sensitive, whereas monitoring could always be done at a later date (Seasons, 2003b). Causality is difficult to establish and it can be difficult to tell if factors unrelated to the work of planners like changing market conditions or political pressure are affecting the achievement of targets (Krizek, Handy, & Forsyth, 2009; Seasons, 2003b). This is because impact may be marginal and it can be difficult to obtain statistically significant results. Advocates of cycling may avoid studies that do not produce conclusive evidence of the benefits of cycling infrastructure investments because they may lead decision-makers to disregard cycling in the future. The positive effects of cycling infrastructure and policies may not materialize for years after the investment is made (Krizek et al., 2009). Monitoring and evaluation is often neglected due to: limited resources; time constraints; fear of reputation loss; weight of great expectations; poorly defined standards; and practical and political challenges (Seasons, 2003b).

While the literature for monitoring and evaluation calls for rational, comprehensive and resource-consuming methods, Seasons (2003b) recommends that planners do the best they can with what they have, as some processes are not possible within certain constraints (Seasons, 2003b). Planners may have to rely on imperfect data, as there are problems with availability, disaggregation, accessibility and cost. Due to these limitations, benefits of projects like cycling improvements are often assumed rather than determined systematically though monitoring (Porter et al., 1999). In the City of Minnesota, the Department of Public Works and a non-profit organization, Transit for Livable Communities, struggle with maintaining a complete, multi-year database and analyzing their results for patterns due to staffing and resource limitations (Lindsey et al., 2012). Pucher and Buehler assert that complete and comparable statistics from municipalities in Canada simply do not exist (Pucher & Buehler, 2006a).

Leadership is lacking at upper tiers of government, as monitoring wasn't encouraged through grants made by the Ontario Ministry of Transportation for Transportation Demand Management projects. Applicants for the grant were selected by the following criteria: "technical quality and soundness; cost-effectiveness; feasibility of completing the project in the allotted time; and the potential to replicate the project in other Ontario communities" (Ontario Ministry of Transportation, 2008, p. 2). Requirements were not outlined for municipalities to collect data and research the effects of their initiatives.

Although the new Ontario provincial cycling strategy does recommend that cities monitor and evaluate their cycling, it does not provide any guidelines or details about how they can best accomplish this. The Ontario Cycling Strategy indicates that it will use municipal data when planning provincial cycling routes but does not acknowledge the difficulty in assimilating information acquired from multiple different sources using different methodologies and technologies to acquire data. The Ontario provincial cycling strategy mentions that its progress will be monitored, but no further detail is given about how this will occur (Ontario Ministry of Transportation, 2012). On a positive note, a Bicycle Survey for the Greater Golden Horseshoe was performed in preparation for the development of Ontario's cycling strategy, to improve cycling forecasts and find out who is cycling, why they are cycling and how cycling facilities rate.

Another example of inconsistent monitoring is in Vancouver, where although the City formed a Bicycle Advisory Committee in 1985 with a mandate to evaluate bicycle facilities (among other duties) their 1999 Bicycle Plan stated that "little information [had] been gathered to measure the effectiveness of the routes for cyclists and their acceptance by residents" (Transport Canada, 2011, p. 2).

2.6 How to monitor

Evaluation is an important aspect of holistic bicycle planning. Monitoring goals and objectives should be clearly stated and included in municipal policy documents so that they are official (Hope & Yachuk, 1990). Most agencies agree that cycling should be included in transportation master plans and some, for example a 2005 Washington State Growth Management Act amendment, require it. Goals should be established in these plans and specific objectives for the following should be identified: modal split; facility use; and determining if transportation projects and land use are conducive to cycling (Ginger et al., 2010). Monitoring is essential to setting up these important aspects of plans.

A plan that has been celebrated for its success is the *Champaign County Regional Planning Commission: Urbana Bicycle Master Plan*, from the US. It is admired for its use of Bicycle LOS designations, which are used to prioritize the introduction of Champaign County projects. Monitoring is important for Bicycle LOS, as it is scored on a scale of A-F, determined by measuring traffic volume, lane width, speed limits, parking, cycling surface conditions, and nearby vehicle use (Ginger et al., 2010).

Although best practices indicate that monitoring should be included in plans, official plans and municipal documents rarely include indicators that state how their goals and objectives will be measured and evaluated. As a result, it is hard to link the data that are collected (number of houses built, number of road lanes paved) to goals and objectives (Seasons, 2003b). A strategic implementation section, for example the one found in the *Portland Bicycle Plan for 2030*, is crucial to state: why evaluation is important; what performance measures will be used; how they will be measured; and what sources can be used to obtain data (Ginger et al., 2010; CPBT, 2010). Even the best plans will remain neglected without the one main element, financing. It is important to state the amount of money needed and the source of funding for each element of the bicycle plan, as can be viewed in the *Portland Bicycle Plan for 2030* (Ginger et al., 2010).

Aside from municipal staff, data can be collected by regional governments; federal governments; business organizations; business improvement areas; community organizations; stakeholders; local elected officials; a city clerk's office; municipal surveys; industry databases; provincial or federal statistics; NGOs; and special-purpose bodies (Seasons, 2003a). Details about monitoring and evaluation and a method to prioritize projects should be included in bicycle plans (Ginger et al., 2010).

For modes other than cycling, home interview type surveys of travel behavior are often used to estimate data for travel demand models. Participants are interviewed about their travel choices, and a computer representation of the transportation system is used to examine the choices they made and the options they did not pick. It is hard to obtain comprehensive data about cycling this way, as cycling trips are usually fewer and shorter than trips made by other modes, resulting in fewer and shorter origin-destination pairs. In most cities, the computer representation of the transportation network for cyclists is not as fully developed as it is for transit and automobile traffic, however this can be improved with more information about cyclists' preferences (Abraham et al., 2002).

In the United States (US), transportation engineers use manuals like *Trip Generation* from the Institute of Transportation Engineers (ITE), to determine demand and justify roadway improvements (APD & ITE PBC, 2012; Stolz, 2012). National surveys like the US Census and the National Household Travel Survey (NHTS), sponsored by the Bureau of Transportation Statistics (BTS) and the FHWA, collect data about mode of transportation, duration, distance and purpose of trip from American travellers, relying on self-reporting, however the amount of information is somewhat limited (APD & ITE PBC, 2012).

There are also monitoring programs that focus on monitoring for the purposes of traffic congestion and reliability (Texas Transportation Institute [TTI] & Cambridge Systematics Incorporated [CSI], 2004). Some monitoring programs even track data about agencies' monitoring systems. Washington State DOT has output measures like number of loop detectors deployed and percentage of loops functioning during a year. They also have measures that assess actual traffic performance like average vehicle volume by type of facility and frequency of severe congestion by location (TTI & CSI, 2004). Some of the technologies used to sense traffic in vehicle monitoring include: loop detectors, video imaging, microwave radar, probe vehicle (toll tags), passive acoustic detectors, passive acoustic sensors, and microloops (TTI & CSI, 2004).

Increasingly sophisticated technologies can be applied to plan for transportation networks, strategies and management. For example, the development of Intelligent Transportation Systems (ITS) has lead to growth in technologies to monitor traffic flow, including those that collect dynamic data, survey data, and spatial data (Wen, Hu, & Sun, 2010). Software like Geographic Information Systems (GIS) can also be used for the purposes of collecting and storing data, constructing and verifying models, evaluating the impact of decisions, predicting effects, monitoring transportation networks and public engagement (Gray & Bunker, 2005).

Related to monitoring cycling, some promising efforts have emerged recently. The National Bicycle and Pedestrian Documentation Project (NBPDP), which is a coordinated effort by Alta Planning and Design (a consulting company devoted to bicycle, pedestrian, and trail planning and design) and the ITE Pedestrian and Bicycle Council, aims to "establish consistent count survey methodologies, create a national database of counts, and support analyses of factors that influence non-motorized traffic" (Hankey, et al., 2012, p. 2). The NBPDP is a nation-wide effort in the United States to survey and count cyclists and pedestrians and provide guidance to local agencies and municipalities that are monitoring these modes. They aspire to establish and publish best practices so that cyclists and pedestrians can be counted in a consistent way across jurisdictions. The project assesses automated counters and provides recommendations for counts and surveys.

Findings of Hudson et al. (2010)'s survey of eleven US communities indicate that there are a variety of methods available for monitoring cycling. Manual counts, commonly performed by volunteers, are used by nine of the communities and infrared counters are the most commonly used automated device (Hudson et al., 2010). The advice municipalities gave when asked what other communities should do if beginning a monitoring program is:

- Look at counts as an ongoing activity and find resources for permanent counters;
- Try to model your program on the corresponding vehicular program;
- Data collected by volunteers may not be seen as credible to decision-makers and the public;
- Choose locations carefully and make sure the community understands your intentions on how data will be used;
- Take time to decide your objectives;
- Partner with a university civil engineering class to solicit help in counting;
- Train manual counters ahead of time;
- 24-hour count data will prove helpful – being able to show a video of people using a pedestrian bridge at 3am proves better than anything else that these facilities are needed;
- Consider ambient light; and
- Make volume counts 15 hours per day instead of 12 hours.

(Hudson et al., 2010, pp. 4-5).

The best practices in monitoring cycling found by Hudson et al. (2010) are:

- State the goals of the monitoring program to identify clearly why it exists;
- Establish a system with routine monitoring where the same locations are used yearly;
- Collect data before and after projects are introduced;
- Collect data across a metropolitan area and separate results by categories like: Downtown, Universities, Urban Core, Suburban, Rural;
- Use automated counters;
- Keep up-to-date with technology and secure new equipment whenever possible;
- Collect as much data as possible and model efforts after existing motor vehicle counting systems;
- Assign a specific staff member to be in charge of monitoring projects;
- Use the data to prioritize which projects will be implemented; and
- Publish results and have them readily accessible to the public and other agencies.

(Hudson et al., 2010, pp. 5-6). These are the best practices on which the case study analysis in Chapter 4 is based.

2.6.1 Methods of Monitoring Cycling in Cities

While methods of monitoring motorized modes of transportation are well established, cities are only just beginning to monitor cycling use. As a result, efforts thus far have been incomplete and inconsistent (Transporte Ativo & ITDP, 2010). The measurement of cycling trips varies across Canadian municipalities in both methodology and degree of data collected. Canada does not have a national travel survey, such as the NHTS from the US, so consistent data are largely unavailable. Comparing individual studies is unwise due to the varying designs, methods, and timing (Pucher & Buehler, 2006a, 2006b).

All methods of monitoring provide only estimates, have their advantages and disadvantages and may not be appropriate in all cases (Krizek et al., 2009). The technology available has evolved and progressed, still it is not often used. Using multiple methods is helpful to triangulate results (Krizek et al., 2009). For example, in a 2002 survey of residents, the City of Ottawa concluded that 2% of workers use a bicycle for their journey to work trip. Correspondingly, the Census data from 2001 reported a BSWT of 1.9% (Pucher & Buehler, 2005). Through using two different methods to measure, they were able to validate their findings. Transportation decision-makers should learn the advantages, disadvantages, assumptions and implications of each method; there is no one method that fully captures all activity conveniently and comprehensively (Litman, 2011). Unfortunately, triangulation may be too expensive for most municipalities (Krizek et al., 2009).

Krizek named three general methods of gathering information about cycling. Researchers may: ask people to report their actions themselves (self-reported) using a travel diary or survey; observe people's activity either in person or with automated devices; or attach a device to the person or their bicycle to track their behavior, for example a Global Positioning System (GPS) (Krizek et al., 2009). These methods are discussed below using the terms surveys, counts and GPS, respectively.

2.6.2 Surveys

This section will describe surveys, including cost, advantages, disadvantages, and recommendations for their use. It then describes types of surveys: household travel surveys, journey to work data from a Census, and general surveys.

2.6.2.1 Cost

The cost of a survey depends on a number of different parameters. For phone surveys, the cost varies depending on how long the survey takes and who its target participants are. A larger sample may be needed if trying to survey groups that are rare, because more people must be contacted to get enough respondents to draw conclusions. The finer the groups, the larger the overall sample will need to be. There is are economies of scale where the per interview cost drops when more surveys are performed, due to the expense of programming and developing the survey, which is fixed regardless of the required number of completed surveys. For a ten-minute survey completed by a sample size of 1000 – 2000, the cost is approximately $40 per interview or $4000 – $8000 in total (S. McConnell, personal communication, November 17, 2012). Since cycling is a fairly uncommon activity, it may be difficult to obtain the sample size of cyclists or cycling trips necessary to conclude statistically significant results. In a study of bicycle-friendly Minneapolis and St Paul, researchers were only able to obtain data for 86 cyclists after contacting 2000 households (Krizek & Johnson, 2006).

For an online survey, the cost depends on how long it takes to program the survey and how long the survey will be hosted. To host a simple survey with 30 questions for one month, the cost is approximately $5000. To host a complicated survey for two months, the price is approximately $20 000. Survey cost information was gathered from the Survey Research Centre in the Statistics and Actuarial Science department of the Faculty of Mathematics at the University of Waterloo, a small cost recovery agency with strict academic standards looking to acquire publishable data. Their prices would not be competitive with private companies such as Ipsos Reid, but they give an idea of what it costs to collect high quality data (S. McConnell, personal communication, November 17, 2012).

2.6.2.2 Advantages

Using a survey methodology allows the user to self-report their cycling activity and behaviours (APD, 2011). Surveys allow data collectors to obtain personal information and details about the trip purpose and trip-maker, rather than just volume data. The data can be broken down into sub-groups based on trip or trip-maker attributes (Porter et al., 1999). The additional information allows transportation officials to plan for specific types of cyclists, as beginner cyclists have different needs than serious cyclists (Krizek et al., 2009).

2.6.2.3 Disadvantages

Some problems with surveys are that even if clear definitions are given, respondents may interpret words and use their own personal understanding of certain terms. Also, they can be seen as personal in nature. Some groups are more likely to participate than others, for example residents who share a common mindset with city staff or those who are particularly affected by the issues addressed in the survey. Socio-economic factors play a role as well; households with low income, little time, or difficulty communicating in English may be underrepresented (City of Calgary, 2002).

Cycling is often underrepresented in travel surveys because many people do not consider it as a mode of transportation. Cycling can also be overrepresented, however, due to a "halo effect", where people regard it as a pro-social behavior and overestimate their use of cycling (Krizek et al., 2009; Ryley, 2006). Surveys are not necessarily accurate to determine how many people cycle, however they can be useful, for example, to determine the relative popularity of different routes or facilities (Abraham et al., 2002).

For surveys, the turnover of interviewing staff can be costly. It can take approximately 8 hours for each interviewer to be fully trained to administer a questionnaire and their performance should be monitored. Verification of data accuracy through logic and error checks is recommended (City of Calgary, 2002).

2.6.2.4 Recommendations

The City of Calgary recommends that effort is made to ensure typically underrepresented households have the opportunity to be involved in the survey for example by staffing call centres with employees who speak foreign languages. Spatial distribution checks can be conducted to ensure citizens from all areas of the city are responding. Efforts should also be made to check that all age groups are represented (City of Calgary, 2002).

When conducting surveys, Alta Planning and Design recommends the following:

- Allow a full menu of commute options, including the opportunity to select multiple modes like transit + bike;
- Request a maximum of one week of commuting activity, as it may be difficult to accurately recall a longer time period of travel patterns;
- Distribute surveys widely using resources like email distribution lists and social media to generate a representative sample;
- Offer the possibility to win a prize for participating;
- Send reminders to potential respondents; and
- Offer a paper survey option

(APD, 2011).

2.6.2.5 Household Travel Surveys

For household travel surveys or travel diaries, respondents are asked to describe all trips taken during a specified period of time either by themselves or by members of their household. They can be used to study trip purpose, for example, comparing the percentage of total bicycle trips that are for work, social, shopping or other purposes. They can also be studied within a purpose, for example examining the share of people who take each transportation mode (for example car, walk, bike) to work (Banister, 1988).

It can be difficult to decide on the duration for this type of survey. If the diary is for a long period of time, respondents may lose interest or not include sufficient detail. If the time period is too short, cycling trips may be missed all together. Additionally, household travel surveys can be expensive to perform (Griswold et al., 2011). Some examples of household travel surveys are the NHTS from the US and the TTS from the GTHA. Canada does not have a national travel survey (Pucher & Buehler, 2010).

2.6.2.6 Journey to Work data from a National Census

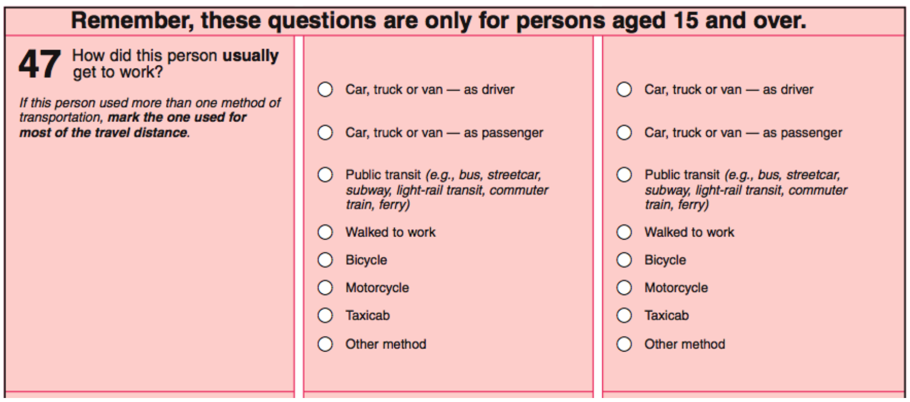
Many researchers use work trip mode of transportation data from a national census for their studies (Bassett et al., 2008; Larsen & El-Geneidy, 2011; Larsen, El-Geneidy, & Yasmin, 2010; Pucher & Buehler, 2005, 2006a, 2006b, 2008; Tight, et al., 2011; Twaddle & Hall, 2009; Winters & Teschke, 2010). Municipal, provincial and federal governments reference the Census mode of transportation to work data as well. Examples of this include Halifax's Regional Municipal Planning Strategy (HRM, 2006), Vancouver's Central Waterfront Hub Framework (City of Vancouver, 2009), Calgary's Mobility Monitor, Ottawa's Cycling Activity Monitoring Tools, Toronto's Cycling Statistics and Bicycle Count reports, Halifax's Blueprint for a Bicycle Friendly HRM and Transport Canada's Urban Bicycle Planning documents (City of Calgary, 2012; City of Ottawa, 2010; City of Toronto, 2008, 2010; HRM, 2002; Transport Canada, 2010).

Examples of reasons for using the Census BSWT are because although some Canadian cities monitor cycling, inconsistent methodologies, definitions, geographic coverage and timing do not allow for direct comparisons. Researchers will look for patterns in which provinces, cities, and districts have a large percentage or volume of people who cycle to work (Pucher & Buehler, 2005). BSWT is readily available from the Census and data for other trip purposes is more difficult to obtain. Additionally, it measures commute trips, which is important because, in theory, these non-discretionary trips reduce automobile traffic. Recreational trips do not reduce the number of car trips necessarily; they may just be additional trips. Variables such as population density, trip distance and car ownership can be examined for correlation with cycling activity. Similarities and differences between areas with a high and low percentage of people cycling to work can also be assessed (Banister, 1988).

It is important to remember that only work trips are represented in the journey to work data and it likely underrepresents the cycling share of total trips (Banister, 1988; Pucher & Buehler, 2006b). For example, the share of bicycle/walk mode for work trips from the US Census Bureau's American Community Survey is 3.5%, however their NHTS, which includes all trips, reports a bicycle/walk share of 12% (Pucher & Buehler, 2010).

Other weaknesses of the Census commute data are addressed in Section 5.3 of this thesis. BSWT data has been collected by Statistics Canada since 1996 and by the national census in the US since 1980 (Transport Canada, 2011). The Census mode of transportation to work question is shown in Figure 1.

Figure 4 Census mode of transportation to work question



Remember, these questions are only for persons aged 15 and over.

47 How did this person **usually** get to work?

If this person used more than one method of transportation, ***mark the one used for most of the travel distance.***

- Car, truck or van — as driver
- Car, truck or van — as passenger
- Public transit *(e.g., bus, streetcar, subway, light-rail transit, commuter train, ferry)*
- Walked to work
- Bicycle
- Motorcycle
- Taxicab
- Other method

- Car, truck or van — as driver
- Car, truck or van — as passenger
- Public transit *(e.g., bus, streetcar, subway, light-rail transit, commuter train, ferry)*
- Walked to work
- Bicycle
- Motorcycle
- Taxicab
- Other method

Source: Statistics Canada, 2006b

2.6.2.7 General surveys

General surveys ask less specific questions than the other surveys discussed, for instance about demographics, household compositions, motivations for cycling and obstacles they face. They may ask questions like, "How many times per week do you ride your bicycle?", "On which facility do you cycle most often" and "What cycling improvements would encourage you to cycle more?". Some examples of general surveys are the ones used in the Calgary Pathwatch research and the 1999 and 2009 Toronto Cycling Surveys.

2.6.2.8 Surveys Summary Table

Table 2 is a summary of the advantages and disadvantages of various types of surveys. Advantages and disadvantages of the Census are expanded on in Section 5.3.

Table 2 Surveys Summary Table

Monitoring Approach	Advantages	Disadvantages

Monitoring Approach	Advantages	Disadvantages
Surveys	Can capture nuances in behaviour (for example in the case of multi-modal trips) Can divide respondents into subgroups Time and resource intensity can be low if online Can obtain additional information about cyclists	Respondents may over-represent the amount of time they spend cycling Respondents may use personal definitions for terms Large sample size needed
Household Travel Surveys/Travel Diaries	May be less susceptible to "halo effect" because usually asks about a specific time period Provides detailed information about a variety of trip purposes	Can take a lot of work and time investment from respondent May miss cycling trips due to short time period Difficult to decide on time frame May be expensive
Journey to Work data from a Census	Geographic breadth Importance of commute trips Inexpensive Widely available Can obtain demographic and other statistical information Performed by Statistics Canada	Only journey to work trips Students counted in their home CMA Difficult to establish causality Conducted only every 5 years Hides variation over the course of a week, year or five year period No information about route or facility used
General surveys	Can collect additional information about cyclists Time and resource intensity can be low if online Can divide cyclists into subcategories Can capture subtle nuances in behaviour	Could lose accuracy due to self-reporting Potential for error due to people responding multiple times Respondents may use personal definitions for terms Large sample size needed

Source: APD, 2011; Krizek et al., 2009; Porter et al., 1999; Pucher & Buehler, 2006a

2.6.3 Counts

Counting cyclists is a method to obtain objective data. The counts can be combined with either manual recording of basic demographic information about the people observed or intercept interviews to learn about the cyclists. Indeed, systematic counts at regular intervals allow aggregation and comparison of data across a large area, for example even the entire country (Transporte Ativo & ITDP, 2010). A disadvantage to counts is that they don't normally obtain complex background information about cyclists (ie. trip purpose, origin and destinations). In addition, counts have limited geographic scope (Krizek et al., 2009). This section will discuss when to count, some recommendations, things to consider, methodologies and available technologies for counts.

2.6.3.1 When to count

The Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area, the Institute for Transportation and Development Policy and Transporte Ativo recommend avoiding Mondays, Fridays and school holidays for counts (MTC, 2003; Transporte Ativo & ITDP, 2010), although for recreational counts, weekends or holidays may be acceptable. On the contrary, Ginger et al.'s findings suggest that there is no more benefit to excluding Monday or Friday than there is any other day, and using these days will increase potential sample size (Ginger et al., 2010).

The City of San Jose uses September for counts because school is in session, the weather is mild, there is rarely rain, and it is still light outside after 6:00 pm (City of San Jose, 2011). Transporte Avito recommends performing counts on mild, sunny days during the spring and fall, as summer is inconsistent due to school holidays and winter deters most cyclists (Transporte Ativo & ITDP, 2010). Ginger et al. (2010) recommend May and October because the weather is fair and people tend to be in their normal routine. Conversely, Hankey et al. (2012) recommend representing a broad range of possible weather conditions by adding dates when rain, snow and humidity are likely to allow for possible conclusions about the impacts of weather on bicycle travel (Hankey, et al., 2012). The NBPDP recommends performing counts during the month of September at minimum, but ideally also in January, May and July. Dates, weather conditions and any special notes about the day (for example a large festival or street closure) should be recorded (Transporte Ativo & ITDP, 2010).

2.6.3.2 Recommendations

Other recommendations include using available resources. A few organizations produce bicycle monitoring documentation. As part of their Bicycle Friendly Program, the LAB in the US has developed resources such as bike count manuals, travel diary forms and intercept surveys (APD & ITE PBC, 2012). In 2003, the MTC developed a handbook for counting bicycles and pedestrians. The NBPDP used these and other valuable resources to recommend methodologies and produce count and survey forms. They offer adjustment factors on their website so that municipalities can extrapolate their data to estimate daily, weekly, monthly and annual numbers (APD & ITE PBC, 2012).

Data quality checks should be performed regularly to ensure that counted volumes do not differ substantially from true volumes. Data quality checks can also be performed to detect rapid fluctuations in numbers during successive time periods; detectors in adjacent locations reporting vastly different values; detectors from multiple locations reporting the same values and values presented that are significantly different from the location's history for a similar time period. The data should also be assessed for completeness and availability (TTI & CSI, 2004).

Another recommendation is to join the NBPDP by using Eco-Counter automatic count technology and uploading their data to the NBPDP's national database for bicycle and pedestrian counts. The NBPDP has guidelines and National Documentation Days to be used for these counts. The NBPDP provides a free summary report in exchange for the ability to analyze and use the community's data in their project. The NBPDP aims to determine if factors like demography, land use, density and climate are correlated with walking and cycling and if demand for different types of facilities can be estimated for different types of neighbourhoods. Participating organizations are also entitled to unlimited access to all stored data. Additionally, Alta Planning and Design will publish an annual analytical report. The National Documentation Project Count and Survey Instructions and Forms are available for download at the Alta Planning + Design Website (APD & ITE PBC, 2012).

Two cities that have taken advantage of this opportunity are San Francisco and Vancouver, whose summary report can be found in Appendix A (APD & ITE PBC, 2012). The reports help answer questions about how many people are using the facility annually, monthly, daily and hourly; when people are using the facility by month of year, day of week and hour of day; and for what purpose people are using the facility (patterns of use give an indication of utilitarian or recreational purpose) (APD & ITE PBC, 2012).

Agencies that have pledged to follow the guidelines and standards of the NBPDP for their future counts and data collection include the City of Toronto and the MTC (City of Toronto, 2010; MTC, 2011). The City of Minneapolis Department of Public Works and Transit for Livable Communities use an adapted version of the NBPDP's suggested count methods (Hankey, et al., 2012). Guidelines from the NBPDP have been used in research at the Texas Transportation Institute (Hudson et al., 2010).

Cities may wish to compare motor vehicles and cyclists. The City of Ottawa uses a Cycling Index, which is the total volume of cyclists observed at selected count stations divided by the total volume of vehicles observed at those count stations multiplied by 100 (City of Ottawa, 2010).

Alta Planning and Design recommends the following:

- Survey at minimum the peak morning commute period;
- Survey mid-week for commute counts – Monday and Friday are not representative;
- Select a time of year that is typical for students – September, October or April for example;
- Use consistent methodology each year so data can be accurately compared;

- Hire students to provide them with valuable work experience and keep costs low; and
- Make note of weather conditions and adjust count volumes for weather or seasonal variation if sufficient background data exists

(APD, 2011).

2.6.3.3 Things to consider

Some costs to consider when selecting a monitoring program are the capital cost of the equipment, the cost of the site furniture, the cost to install the equipment, the maintenance costs and the data collection cost. Wilke et al. (2012) described their monitoring program as very cost effective once set up. They emphasize its comparability to other programs in their country and its applicability to other transportation systems (Wilke et al., 2012).

Choosing the right counting methods for monitoring and estimating cycling volumes depends on where the counts are occurring and what the purpose of the count is. When choosing a technology, the type of data needed, the total funding of the project, and the total staff and volunteer time available need to be considered. Calibration is always necessary with automatic count technologies (National Bicycle and Pedestrian Documentation Project [NBPDP], 2009), but they have the advantage of being able to download data directly into computer spreadsheet software (MTC, 2003).

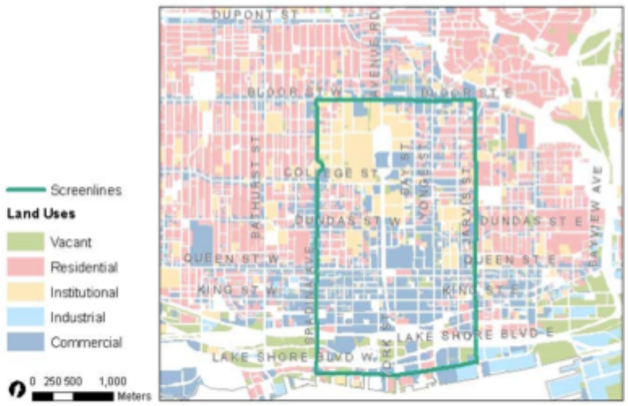
2.6.3.4 Methodologies

Some example methodologies discussed below include cordon counts and screenline counts, samples of multiple locations, counts at bicycle parking stations, and bicycle registration and licensing programs (APD, 2011; Transporte Ativo & ITDP, 2010; Wilke et al., 2012).

2.6.3.4.1 Cordon Counts and Screenline Counts

Cordon counts show how many cyclists enter and exit a particular area during a given time frame (Kosny et al., 1980; Transporte Ativo & ITDP, 2010). The ‘cordon’ is a geographic area enclosed by a number of ‘screenlines’ along which counting stations are located to enumerate inbound and outbound cyclists. The cordon is often the entire city or a specific destination like the downtown. The screenlines tend to follow natural or man-made barriers like the 400 series highways or the Humber River in Toronto to minimize the number of crossing points (City of Toronto, 2010). This counting method neglects bicycle trips that begin and end within the cordon (City of Toronto, 2001). Figures 2 and 3 are examples of cordons and screenlines.

Figure 5 Land use transition at screenlines



Source: City of Toronto, 2010, p. 3

Figure 6 Example of a screenline

Source: National Bicycle and Pedestrian Documentation Project, 2013

Screenline counts are performed along one street and all cyclists that cross the street are counted. They often occur along a boundary line or a street that separates origins and destinations, for example with residential on one side and a business district on the other (Transporte Ativo & ITDP, 2010). They can also be across a single road.

2.6.3.4.2 Sample of various locations

In this case, multiple locations for counters are chosen around the city to get an idea of overall network flows (Richardson, 2006). Depending on the city and their objectives, sites are randomly chosen or selected based on areas of interest. A limitation of this methodology is that overall bicycle volume is difficult to determine. Many cyclists will ride in areas that are not counted and some cyclists may be counted more than once. The Halifax Cycling Coalition was not able to find, through their research of count methodology, a method to extrapolate data into an overall bicycle volume for a city or area (Halifax Cycling Coalition, 2010). However, Richardson (2006) argues that the data obtained by these measures can be weighted and expanded to estimate trips and kilometers travelled per year for catchment areas around each survey site and the whole cycling network.

2.6.3.4.3 Counting Bicycles Parked at Bicycle Parking Stations

To determine the number of people cycling to a particular destination, researchers may count how many bicycles are parked at a parking station. An example of this is in Calgary, where the number of employees cycling to work can be inferred using the employee access card automated sign-in information for the secure bicycle parking facility known as “the cage”. The number of times the cage was accessed in a day can then be modeled as a function of other information like temperature and precipitation (City of Calgary, 2009).

This is an inexact method because multiple employees could access the cage at the same time with the same access card, which would make it appear as though there is only one employee using the facility. Additionally, if researchers are simply counting the number of bicycles that are parked in the cage, employees and visitors may be leaving their bicycle parked unattended for long periods of time and the bicycle would be counted although the owner is not regularly cycling.

2.6.3.4.4 Bicycle Registration and Licensing Programs

The Canadian Institute of Planners Community Cycling Manual suggests bicycle registration or licensing as a method of monitoring and estimating bicycle volumes. Bicycle registration would provide a database with information about people who cycle. This could be a useful way to facilitate communication, distribute surveys and inform cyclists of upcoming plans and programs. The bicycle registration would have to be mandatory, enforced regionally/provincially, cover its own costs, and use unique identifying numbers (Hope & Yachuk, 1990). Normally, bicycle registration occurs at the municipal level, and methods and laws vary (Kosny et al., 1980).

A further idea is to license the cyclist. In this case the cyclist must pass a test to demonstrate they can ride safely and obey the rules of the road. Cyclists would have the same system of fines, points deductions and loss of license as automobile drivers. The number of licensed cyclists per capita would be useful for monitoring purposes (Hope & Yachuk, 1990).

The 1996 Calgary Cycle Plan notes that although Calgary's bicycle licensing bylaw was deregulated in 1982 due to costs, with recent advances in computer technology it may be once again viable. The plan recommends that a licensing program offer obvious advantages and incentives for the bicycle user. It is also necessary that the rules are properly enforced (City of Calgary, 1996). Some recommendations to consider when adopting a bicycle licensing law:

- To improve acceptance of the idea, any profits should be used to improve cycling in the city;
- Stolen bicycles could be tracked with a national database;
- The program should help identify cyclists who are disobeying laws;
- The need for enforcement should be carefully considered before implementation; and
- A voluntary program could be piloted first to gauge acceptance

(City of Calgary, 1996).

2.6.3.4.5 Count Methodologies Summary Table

Table 3 summarizes the advantages and disadvantages of count methodologies.

Table 3 Count Methodologies Summary

Monitoring Approach	Advantages	Disadvantages
Cordon Counts and Screenline Counts	Accurate Easy to design and administer Provides data specific to location Easy comparison year to year Can collect basic demographic data, data about following laws, etc.	Time and resource intensive Does not obtain sophisticated level of data about demographics, attitudes, behaviours Limited geographic scope Does not capture activity within the cordon
Sample at various locations	Gives an idea of overall network flows Can collect basic demographic data, data about following laws, etc.	Time and resource intensive Does not obtain sophisticated level of data about demographics, attitudes, behaviours Limited geographic scope Difficult to extrapolate to a whole area or city Cyclists may ride through more than one count location and be counted multiple times
Count bicycles at parking stations	Accurate Easy to design and administer Provides data about bicycle parking demand Easy comparison year to year	Time and resource intensive Does not obtain additional information about cyclists Difficult to capture all cyclists and some could be counted twice due to temporal limits Does not count bicycles if brought into buildings People could be leaving their bicycles parked at parking facilities for extended periods of time, without truly being cyclists
Bicycle Registration or Licensing	Provides a list of who is cycling in a city Provides an opportunity to facilitate communication Can ensure cyclists are taught the rules of the road Can implement a system of fines, points deductions and loss of license for not following rules Advances in technology have improved cost-effectiveness Can collect demographic information	If occurs at municipal level, will be difficult to regulate in metropolitan regions Would be difficult to compare cities or provinces unless legislated for the entire country Rules must be properly enforced May be expensive to enforce Number of registered bicycles is not necessarily indicative of bicycle use throughout the city If it is voluntary or only enforced in one city of a metropolitan region, very few people register Administrative costs are high Could deter casual or non-wealthy cyclists from riding their bicycles, particularly if the system is expensive or inconvenient

Source: Hope & Yachuk, 1990; Kosny et al., 1980; Krizek et al., 2009

2.6.3.5 Technologies

The next sections discuss technologies available for counting cyclists: manual counts; manual counts with interviews; and automated detection systems.

2.6.3.5.1 Manual Counts

Manual counts are when people, normally volunteers, physically count the cyclists. Manual counters are often provided with a data sheet, perhaps one tailored to their site, on which they record counts (Nordback & Janson, 2010). The manual counters should also be provided with instructions for conducting and recording the counts and information about the study (Transporte Ativo & ITDP, 2010). Using volunteers can cut costs, however training, organizing and managing a large group of unpaid workers can be challenging (Transport Canada, 2011). Manual counts can usually occur only for a limited time and are subject to human error. The counts may be only a small sample at a few sites on a couple days of the year. The small amount of data is often weighted and expanded to estimate total numbers for an entire network for an entire year (Richardson, 2006).

In their study of manual counts from Boulder, Nordback and Janson (2010) found there was an average absolute percent difference of 6% between counters with a standard deviation of 6%. In their Minneapolis study, Lindsey et al. (2012) calculated the mean difference between observers to be 1.4% (Lindsey et al., 2012). Appendix B shows an example of a tracking sheet.

2.6.3.5.2 Manual Counts with Interviews

An intercept survey technique is possible, where cyclists are both counted and interviewed (Richardson, 2006). Detailed information can be collected: for example age, gender, and time of day for every nth cyclist, where *n* is designated for each site based on what would be possible for the surveyor (NBPDP, 2009). The selected cyclist could then be asked to participate in an interview and/or handed a questionnaire. In this type of study although all cyclists are counted, detailed data is only recorded about the nth cyclist, the interview data are only recorded for those who agree to be interviewed and the questionnaire data are only obtained for those who agree to fill out and return a questionnaire. High-volume sites may need more than one surveyor (Richardson, 2006).

One study found that of those that were asked, 65% of cyclists stopped and took a questionnaire and 40% of them returned the completed questionnaire. Those riding in a group were more likely to respond than those riding alone, female cyclists were more likely to respond than males and older cyclists were more likely to respond than younger cyclists (Richardson, 2006).

2.6.3.5.3 Automated detection systems

In theory, automated detection systems are able to count bicycles continuously, 24 hours a day, every day of the year. They are not as common as other methods, such as manual counts, because some capital investment is involved. In general, they have more continuity than manual counts and the more often they are used the more cost-efficient they become. Automatic counters are better than manual for long-term counts or determining hourly, daily, weekly, monthly or yearly variations over time. Less staff time is normally required for automatic count technologies (NBPDP, 2009).

Some automated counters are permanent and others are portable. The advantages of permanent counters are that they are relatively inexpensive, do not require much maintenance, are easily installed and result in a high volume of data (City of Vancouver, 2009). The challenges associated with permanent counters are data must be retrieved, data management can be complicated and there are limited equipment options (City of Vancouver, 2009). The advantages of portable counters are that they are easy to install, they are reliable, they are easy to maintain and they are portable (City of Vancouver, 2009). The disadvantages of portable counters, particularly pneumatic tubes, are that they have a limited useful life, they can be difficult to obtain because they are manufactured in Europe and they are not possible to repair (City of Vancouver, 2009).

Some manufacturers of automatic detection systems are: EcoCounter, Econolite, OSI LaserScan, TRAFx, and Trailmaster (NBPDP, 2009). EcoCounter's Eco-Multi, which uses a combination of different technologies, can distinguish between different types of users (NBPDP, 2009). A comprehensive analysis of four options for volume counters by Hudson et al. (2010) concluded that the EcoCounter was the best product on the market (Hudson et al., 2010).

Wilke et al. (2012) estimate that monitoring 12 sites for 1 year would cost approximately $900 - $1100 per site and monitoring 6 sites for 1 year would cost approximately $1000 - $1200 per site. They estimate a staged approach where 12 sites are monitored over the course of 3 years would cost approximately $1100 - $1500 per site and a staged plan where 6 sites were monitored over the course of 3 years would cost approximately $1100 - $1400 per site. The steps outlined by Wilke et al. (2012) for selecting options for a monitoring program are displayed in Appendix C. Alta Planning + Design and the NBPDP estimate automated counters each cost around $1500 - $5 000 (NBPDP, 2013), whereas Transporte Ativo & the Institute for Transportation and Development Policy (ITDP) estimate that the cost of most counters ranges from $1000 - $10 000, not including the price of installation. Automated detectors can be subjected to theft and vandalism and inclement weather events can lead to overcounting (Transporte Ativo & ITDP, 2010).

Many automatic detection technologies have difficulty distinguishing between cyclists and pedestrians. Another weakness of automated detection systems is that they are best for off-road pathways because they may be accidently triggered by other vehicles if they are used on the road (Transport Canada, 2011). Different technologies are best for different situations. For example, active infrared technology is useful for shared use pathways, because it can detect the difference between pedestrians and cyclists. For detecting cyclists travelling along bicycle facilities, the NBPDP argues that magnetic loops embedded in the pavement are best because they only detect metal and it is likely to be solely bicycles that use these facilities. Video recording a specific location and then analyzing the videos has the advantage of the possibility of discerning demographic information about the user and looking for interesting or unusual behaviours as well as the volume data. Some counting devices require large equipment and a major installation undertaking, whereas other technologies are barely noticeable and can be easily installed on an existing piece of infrastructure such as a pole or street light (NBPDP, 2009). A chart in Appendix D shows Automatic Count Technologies.

The main automated detector devices that will be outlined here are:

- Inductive loop detectors;
- Passive infrared sensors;
- Active infrared sensors;
- Video and computer imaging; and
- Pneumatic tubes.

2.6.3.5.3.1 Inductive Loop Detectors

The most common motor vehicle sensor, inductive loops embedded in pavement, can be used to detect cyclists as well (Nordback & Janson, 2010). They are low-cost, widely understood by transportation professionals, and do not require extensive maintenance. The City of Boulder, Colorado, for example, uses inductive loop detectors on their multiuse path network (Nordback & Janson, 2010).

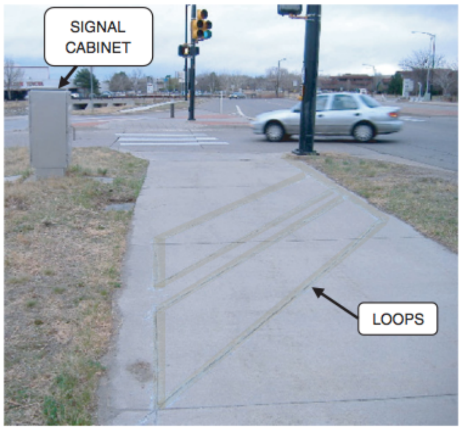
The diamond shaped loops of wire embedded 2 to 4 cm into the road form a circuit in which eddy currents are generated when metal passes over the wire (Lindsey et al., 2012; Nordback & Janson, 2010). A detector that is constantly monitoring the resonant frequency of the circuit detects this change in the circuit's inductance. Double loops can detect the direction of travel by noting which loop of two adjacent loops experienced the change in inductance first while single loops are unable to detect travel direction. Types of bicycles with fewer metal parts (for example carbon fiber) have been tested on the inductive loops in Boulder and most detectors can detect the metal in the bicycle wheels most of the time (Nordback &

Janson, 2010). The data are stored in the volatile memory on the hardware card in a signal controller cabinet until they are transferred to a laptop by a field technician (Nordback & Janson, 2010). In Minneapolis this is necessary every three months (Lindsey et al., 2012). The sensitivity of the detector can be changed on a scale of 1 to 7 to select the amount of inductance change that will register a count. Boulder sets sensitivities at 5 as an overly low sensitivity will not detect bicycles, whereas a sensitivity that is too high may overcount bicycles. A contractor is hired to cut the holes in the pavement when detectors are first installed, but city staff are capable of installing the loops and cards (Nordback & Janson, 2010).

Some small errors are inherent with sensing technology. Although under ideal test conditions they are accurate, loop detectors can be unreliable if not maintained over a period of many years. Nordback and Janson (2010) found that they are accurate when properly installed, maintained, and not subject to external inference. They must be periodically calibrated and staff time is necessary to routinely check their data against that of manual counts (Lindsey et al., 2012; Nordback & Janson, 2010). Nordback and Janson (2010) suggest doing this twice per year, when a surface is repaved and when loops or cards are first installed. Obvious errors should be noticeable after a count of 10 bicycles, whereas small errors with the equipment might not be noticeable in counts of less than 200.

In their study of Minnesota loop detectors, Lindsey et al. (2012) found manual counts were inconsistent with loop detectors; differences ranged from 5% to 27%. In some cases loop detectors returned higher volumes and in some cases manual counts returned higher volumes. The reason for this is unknown, however the Department of Public Works in Minnesota had not calibrated or validated the loop detectors (Lindsey et al., 2012). The counters occasionally malfunction, are subject to vandalism or can experience a power outage. Lindsey et al. (2012) found that of the magnetic loop detectors used in their study, on average they yielded usable data 79% of days (Lindsey et al., 2012). Nordback and Janson (2010) found automated detectors were more likely to undercount than to overcount, when compared to corresponding manual counts. Causes of error include: issues with the detector settings; cyclists riding side by side or one behind the other; problems with electrical supply to the counting site; and problems with the software setup. Nordback and Janson (2010) found one detector was not detecting 60-70% of cyclists because it had been buried six inches below the surface of the bike path after a repaving of the path (Nordback & Janson, 2010). In the Nordback and Janson (2010) study, the loop detectors counted 4% fewer cyclists than the manual counters on average, but the detectors in the study had received little or no maintenance for the past ten years. Some of these results are illustrated in Appendix E. Figures 6 and 7 show photos and illustrations of inductive loop detectors.

Figure 7 Directional inductive loops in double chevron configuration with associated signal cabinet



Source: Nordback & Janson, 2010

Figure 8 Inductive loop detectors

Source: City of Vancouver, 2009

2.6.3.5.3.2 Active Infrared Sensors

Active infrared sensors produce beams of infrared radiation from a transmitter across the area where bicycles are being counted to a receiver on the other side. Each time this beam is obstructed by someone passing by, a count is recorded. Examples of active infrared sensors include the Diamond Trail Counter and the Trailmaster ™. The Trailmaster ™ can hold 8 000 to 16 000 events, depending on the model, which can then be downloaded with a data collector and exported into Excel ©. One advantage of this machine as described by Lindsey et al. (2012) is that the error was consistent in magnitude and direction and therefore a common calibration equation can be used for all units and locations (Lindsey et al., 2012). Active infrared sensors can also be permanent overhead structures (Nordback & Janson, 2010). Figure 8 shows a picture of an active infrared sensor.

Figure 9 Active infrared sensor

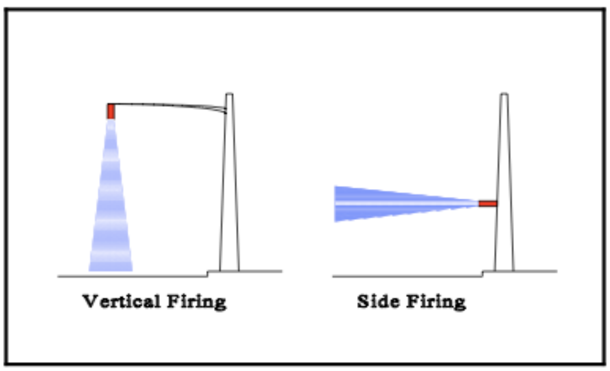
Source: City of Vancouver, 2007

Lindsey et al. (2012) found that of the active infrared sensors used in their study, 90% of days yielded usable data (Lindsey et al., 2012). When the active infrared sensors were compared to manual counts, it was found that they consistently undercount and the difference ranges anywhere between 2% and 12% (Lindsey et al., 2012). With that being said, a San Diego County study found a 15% to 21% no-detection rate for active infrared counters (Jones, Ryan, Donlon, Ledbetter, Ragland, & Arnold, 2010). Some of these results are illustrated in Appendix F.

2.6.3.5.3.3 Passive Infrared Sensors

Passive infrared sensors detect the heat of cyclists passing by. When the sensor detects a change in thermal contrast, this is recorded as a count event (Lindsey et al., 2012; Transporte Ativo & ITDP, 2010). Two types of passive infrared detectors are doppler radar and ultrasonic sensors. Beckwith (1997) found that doppler radar had a 7% no-detection rate and ultrasonic sensor types had a no-detection rate of 3% to 45% (Beckwith & Hunter-Zaworski, 1998). Jones et al. found a 12% to 48% no-detection rate for passive infrared counters (Jones et al., 2010). Examples of brands of passive infrared are Jamar Scanner and TrafX Sensor (Hudson et al., 2010). An illustration can be viewed in Figure 9.

Figure 10 Profile view of vertical and side firing sensor configurations



Source: Jones et al., 2010

2.6.3.5.3.4 Pneumatic Tubes

To use these tubes, they are put in place across the area where cycling volumes are being counted. The tubes are compressed when a cyclist rides over top of them and this emits a burst of air when they decompress. The counter measures these bursts. These counters are also used to count automobiles, but the bicycle version is smaller and more sensitive (City of Toronto, 2012). The selective pneumatic tube by EcoCounter distinguishes between automobiles and bicycles by determining the time between axels passing over the tubes (City of Vancouver, 2007). The EcoCounter brand of pneumatic tubes is used by Toronto and Vancouver and recommended by Hudson et al. (2010) and the NBPDP. Pneumatic tubes are depicted in Figures 10 and 11.

Figure 11 Pneumatic tube counter on Dunsmuir Street, Vancouver

Source: Transport Canada, 2010, 2011

Figure 12 Pneumatic tubes

Source: City of Vancouver, 2007

2.6.3.5.3.5 Video and Computer Imaging

With this technology, a video recording of the area to be counted is taken. Then, a computer analyzes the pixel changes to record counts or data are played back in high speed and analyzed by a person (Transporte Ativo & ITDP, 2010). With some vendors, for example the Miovision Scout (pictured in Figure 13), the vendor will process the data. Video imaging is often used to validate data collected by other methods, for example in the study by Casello & Majcherkiewicz (2012).

Figure 13 Miovision Scout

Source: http://www.miovision.com/products/step1-collect-video

2.6.3.5.3.6 Other technologies

Some other technologies exist that are less common. They may be too expensive, not recommended or just emerging. Some examples of less frequently used technologies include: ultrasonic waves, piezometric sensors, and radio beam detectors (Transporte Ativo & ITDP, 2010).

2.6.3.5.3.7 Count Technologies Summary Table

Table 4 summarizes the various count technologies.

Table 4 Count Technologies Summary

Monitoring Approach	Advantages	Disadvantages
Manual Count	Data collection possible for a large number of locations Can collect basic demographic information Can record turning actions Can be used to calibrate machine counters Relatively inexpensive (if labour is cheap) Easy data management Very accurate (more so than automated) Can record if cyclists are abiding by the laws of the road	Significant staff resources necessary if volunteers are not used Reliability of staff Need to train the counters Potential for human error May not be possible in times of bad weather Usually for short time periods (1-2 hours) Hard to gather long-term temporal information Limited benefit without a meaningful Peak Hour Factor
Manual Count with Interviews	Can collect more detailed information	Time consuming if cyclist is interviewed on the spot Cyclist may neglect to do interview if given a website to visit later
Automated detection systems	Consistent and long-term time frame Can track seasonal variability Eliminates need to train and manage volunteers Some can distinguish between bicycles and motor vehicles in mixed-traffic situations Can be used during inclement weather Some can record the direction of travel Some can record speed Some can distinguish between pedestrians and cyclists Low-cost once set up Can operate effectively with minimal human intervention Can count every hour of every day, all year	Can have expensive capital costs up front Limited geographic scope Each counter costs between $1000 - $10 000 Thunderstorms can lead to overcounting Possibility of theft and vandalism Normally a limited number of sites Generally less accurate than manual counts Their visual impact may be considered unappealing

Monitoring Approach	Advantages	Disadvantages
Inductive Loop Detectors	Large capacity for data Not necessary to download data often Established technology Lower cost The most accurate technology for distinguishing motorized vehicles from bicycles on shared roads Has been used extensively for years	Traffic must be shut down when they need repairs Are rarely calibrated Contractors can inadvertently pave over loops or impair communication lines Correction factors are often needed and may vary by unit Difficult to keep track of error magnitude, the length of time errors have existed and whether they vary over time for the same unit They may not count non-metal bicycles If the cyclist rides in vicinity of, but not over, the loop detector's specific area they will not be counted
Active Infrared Sensors	Continuous counts of non-motorized traffic Small memory capacity, must download data more often than other types of counters Errors are usually uniform across units and locations Good for shared pathways because it can detect difference between pedestrian and cyclist	Cannot distinguish direction of travel Normally limited to counting on trail-like infrastructure due to the need for a transmitter and a receiver Cannot distinguish between bicycles and other modes of transportation If people pass by so quickly that they do not break the beam for a long enough period of time they will not be counted Counts only a single event if multiple users pass by at the same time Extreme weather events can break the beam causing overcounting Easily subjected to tampering and vandalism Above ground and therefore exposed to vandalism
Passive Infrared Sensors	Continuous counts of non-motorized traffic Errors are usually uniform across units and locations Small memory capacity Must download data more often than other types of counters	Cannot distinguish pedestrians from cyclists Cannot detect more than one user if they pass by side-by-side Not 100% accurate Above ground and therefore exposed to threats of vandalism
Pneumatic Tubes	Eco-Counter brand was found to be the best of all possible automated counters	Limited useful life Manufactured in Europe Not possible to repair Some cyclists may ride around the counter to avoid the tube

Monitoring Approach	Advantages	Disadvantages
Video and Computer Imaging	Can collect information about interesting or unusual behaviours as well as volume data Can collect some basic demographic information Software can detect differences between various modes Provides continuous monitoring	Significant time investment to record and transcribe data The MTC does not recommend this method High cost of equipment and labour for data processing

Source: Beckwith & Hunter-Zaworski, 1998; Casello & Majcherkiewicz, 2012; City of Ottawa, 2010; City of Toronto, 2010; City of Vancouver, 2007; City of Vancouver, 2009; Hankey, et al., 2012; Hudson et al., 2010; Lindsey et al., 2012; MTC, 2003; NBPDP, 2009; Schneider, Arnold, & Ragland, 2009; Transporte Ativo & ITDP, 2010; TTI & CSI, 2004; Wilke et al., 2012

2.6.4 GPS

GPS units have been available for some time but have been considered too expensive, too bulky and too maintenance-intensive to use (Krizek et al., 2009). Recent advances have lead to a smaller and more useable unit and GPS may become common in the future (Casello, Nour, Rewa, & Hill, 2011; Krizek et al., 2009). GPS units are unique in that the device is attached to the cyclist and not the facility the cyclist is using (Krizek et al., 2009). GPS units offer an alternative to self-reporting that allows the researcher to gather data about actual cycling trips after they occur. The device can record origins, destinations, routes and travel times for participants. Trip generators and attractors can be determined from the data (Casello et al., 2011).

2.6.5 Summarize the Results of Multiple Counts and Surveys

The results of different bicycle counts from multiple studies with different methodologies by a variety of agencies and non-profits can be analyzed and normalized to standard time periods. A regression model can then be developed to predict bicycle volumes (Hankey, et al., 2012). When analyzing these counts, Hankey et al. (2012) found the volumes resulting from one-hour counts were highly correlated with those from 12-hour counts, which suggests that shorter counts can be extrapolated to obtain reasonably accurate estimates for a 12-hour period. It is necessary to first obtain enough 12-hour data to establish the scaling factors (Ginger et al., 2010; Hankey, et al., 2012). Lindsey et al. (2012) also found that peak-hour counts can be scaled to 12-hour estimates and that temporal patterns are consistent enough that hourly counts can be scaled to daily, weekly and monthly estimates (Lindsey et al., 2012). Ginger et al. (2010) concluded that evening peak hour counts were more accurate than morning peak hour counts when scaled to represent the entire day.

The results of surveys can also be summarized and integrated, either with other survey results or with the results of counts. An example of where this has been done is in Calgary with their Mobility Monitor. For the *Commuter Cycling in Calgary* issue, information is sourced from the Downtown Cordon Count Program; the Municipal Building bike cage automated sign-in system; the 2006 Downtown Commuter Cyclist Survey; and the Statistics Canada, *Commuting Patterns and Places of Work of Canadians*, 2006 Census. The results from these sources are compared and contrasted and the pros and cons of each are outlined (City of Calgary, 2009).

Finding a way to standardize data from multiple jurisdictions and sources can be a challenge, particularly in the absence of metadata. Metadata provides descriptive information about the data like its origin, subtle nuances, lineage, flaws and characteristics. Summarizing and integrating the results of multiple counts provides a good compilation of a variety of information and helps triangulate results but it is difficult to combine the results of many studies with different methodologies.

2.7 Summary

In summary, this literature review identifies several techniques for monitoring cycling. The methods are covered under two broad topics: surveys and counts.

The survey method requires participants to self-report their actions. Types of surveys can range from general to specific. Some surveys ask very general questions about the participants cycling habits, like how many times/week they cycle, why they cycle and what could encourage them to cycle more. Examples of these are the Toronto Cycling Surveys and the Pathwatch surveys from Calgary. Some surveys are very specific, such as trip diaries, which ask respondents to detail the time, duration and location of every trip they made over a period of time. Some examples of these surveys are the TransLink Trip Diaries and the TTS. Countries like the US, the United Kingdom and Switzerland have a nationwide personal transportation study or NHTS that they conduct at certain intervals to learn about transportation patterns in the country (Stopher et al., 2011). The only source of national travel data in Canada is the journey to work question in the Census, which occurs every five years. Advantages and disadvantages of using these data to make policy decisions are discussed in Section 5.3.

For the count method, researchers observe cyclist behaviour in person, by attaching a device to the subject or by using an automated counter. There are many different options for methodology to choose when devising a monitoring program. Location, times of day, purpose and resources available for monitoring are all factors that need to be considered. The cost of the monitoring program is mostly determined by the size of the city's bicycle network and the scope at which the city would like to analyze it. Other determinants of the cost include whether to pay people to count bicycles, use volunteers, or install automated counting devices (Transport Canada, 2011).

The technologies reviewed in the literature review are: manual counts, manual counts with interviews, and automated detection systems. These counts can be performed as a cordon count, screenline count, sample of multiple locations, count of bicycles at bicycle parking stations or bicycle registration and licensing program. Organizations such as the NBPDP in the US, Transporte Ativo from Brazil, the ITE Pedestrian and Bicycle Council, the ITDP and Hudson et al. (2011) from the Texas Transportation Institute (TTI) have made recommendations that are considered in this thesis. The advantages and disadvantages all of the above methods are outlined in the literature review and the results section discusses which of these methods are being used by the case study cities.

Table 5 Summary of all methods

Method of Monitoring	**Geographic Scope (Sm/Lg)**	**Volume Data (Y/N)**	**Route Data (Y/N)**	**Basic Demographic Data (Y/N)**	**Opinion Data (Y/N)**	**Best used for (List scenarios)**	**Time Scale (Sm/Lg)**	**Cost (Low/High)**
Surveys	Lg	N	Y	Y	Y	Find out generally about cyclists demographic information, opinions and behaviours	Sm	Depends on type
Household Travel Surveys	Lg	N	Y	Y	Y	Find out the mode for all trip types people in the city are taking	Sm	High
Journey to Work data from a Census	Lg	N	N	Y	N	Find out about mode used for commute to work and compare nation-wide	Sm	Low
Counts	Sm	Y	N	Y	N	Obtaining data about bicycle volumes	Depends on type	Depends on type
Cordon	Sm	Y	N	Y	N	To determine how many cyclists are entering a cordon during a given day or time period	Sm	Low

Method of Monitoring	Geographic Scope (Sm/Lg)	Volume Data (Y/N)	Route Data (Y/N)	Basic Demographic Data (Y/N)	Opinion Data (Y/N)	Best used for (List scenarios)	Time Scale (Sm/Lg)	Cost (Low/High)
Screenline	Sm	Y	N	Y	N	To determine how many cyclists cross from one end of a city to the other	Sm	Low
Sample at various locations	Sm	Y	N	Y	N	To get a general idea of how many people are cycling in the city	Sm	Low
Count bicycles at parking stations	Sm	N	N	N	N	To get an idea of how many people are cycling to a specific destination like City Hall or a university	Sm	Low
Bicycle Registration or Licensing	Sm	N	N	Y	N	Obtaining contact information for a database on cyclists	Lg	High
Manual Counts	Sm	Y	N	Y	N	Count data are desired for a few locations around the city	Sm	Low
Manual Count with Interviews	Sm	Y	Y	Y	Y	Desired data are opinion, demographic and behavioural and also count data	Sm	Low
Summarize and integrate the results of multiple counts	Sm	Y	Y	Y	Y	Situations where a lot of surveys and counts have been performed with varying methodologies	Lg	High
Automated detection systems	Sm	Y	N	N	N	Collecting a lot of data over a long period of time	Lg	High
Inductive Loop Detectors	Sm	Y	N	N	N	Collecting a lot of data over a long period of time	Lg	High
Active Infrared Sensors	Sm	Y	N	N	N	Bicycle only facilities	Lg	High
Passive Infrared Sensors	Sm	Y	N	N	N	Bicycle only facilities	Lg	High

Method of Monitoring	Geographic Scope (Sm/Lg)	Volume Data (Y/N)	Route Data (Y/N)	Basic Demographic Data (Y/N)	Opinion Data (Y/N)	Best used for (List scenarios)	Time Scale (Sm/Lg)	Cost (Low/High)
Pneumatic Tubes	Sm	Y	N	N	N	Obtaining counts for a specific facility	Sm	High
Video and Computer Imaging	Sm	Y	N	Y	N	Recording a small area for a short amount of time; multi-modal counts; collecting objective and detailed information about the cyclists and their behaviour	Sm	High
Global Positioning Systems	Sm	N	Y	N	N	Obtaining data about actual cycling trips	Sm	High

Chapter 3
Methodology

3.1 Introduction to Methodology

This thesis uses a mixed methodology to examine how Canadian cities are monitoring and evaluating their cycling. A wide range of case study cities with a variety of characteristics is used to explore the monitoring and evaluation methods being used. It also compares the results from two surveys to investigate the reliability of the commonly used Census BSWT. The methodology includes:

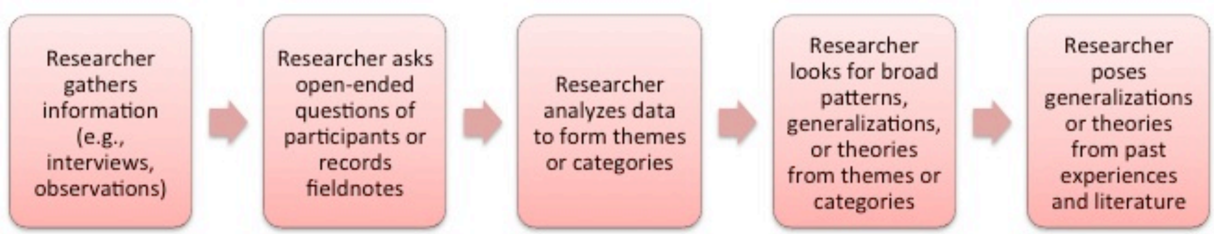
- review of peer-reviewed publications;
- research of important municipal documents;
- retrieval and analysis of the results from the Census and the TTS;
- and a GIS-aided comparison of acquired BSWT survey data.

Chapter 3 Methodology includes information about the mixed methodology, how the literature review was performed, methods for collecting the case study information, how the case study cities were selected and evaluated, how the BSWT surveys were compared and a justification of the methodology chosen.

3.2 Mixed Methodology

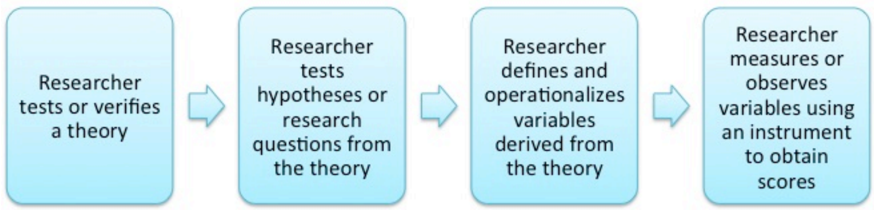
A mixed methodology, where the researcher brings together quantitative and qualitative methods, is used in this multi-faceted thesis. Mixed methods can broaden understanding by taking advantage of the strengths of both qualitative and quantitative research and addressing complex problems that cannot be examined by only one method. Each approach helps to better understand, explain, and build on the results from the other (Creswell, 2009; Stake, 1995). The two main sections of the analysis correspond to the two main research questions in this thesis, specifically, Part 1: research into how Canadian cities are monitoring and evaluating their cycling and whether they are following best practices and Part 2: a study of how the results of two common surveys, the Census and the TTS, compare. Triangulation is apparent here, because many methods are being used to determine the best ways of monitoring and evaluating cycling and answer the question of which methods Canadian cities are using. This will increase the credibility of the findings. The thesis contains qualitative and quantitative data collection and analysis (Bryman, 2012). The qualitative aspect of the first research question is the description and summary of the methods being used by Canadian cities to monitor and evaluate their cycling. Their methods are assessed according to a list of best practices and values are assigned based on how they score. The scores assigned are also qualitative because the scale used is ordinal (Hildebrand, Laing, & Rosenthal, 1977). The qualitative aspect of the second question is the examination of the motivations and methodology for the two surveys and a visual comparison of spatial patterns. The quantitative aspect is the use of descriptive statistics to numerically compare and contrast the survey results. The qualitative and quantitative aspects of the thesis will generally follow the steps shown in Figures 14 and 15:

Figure 14 The Inductive Logic of Research in a Qualitative Study



Source: Creswell, 2009, p. 63

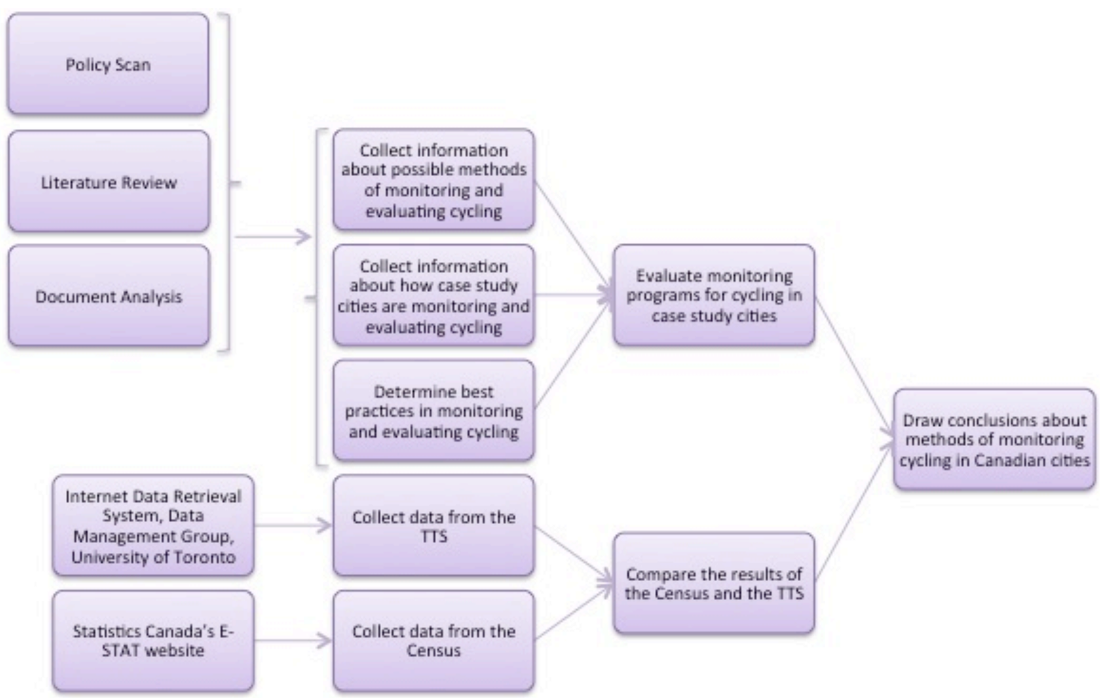
Figure 15 The Deductive Approach Typically Used in Quantitative Research



Source: Creswell, 2009, p. 57

Parts 1 and 2 are tied together in the discussion chapter according to the convergence model of triangulation to draw conclusions about methods of monitoring cycling in Canadian cities as shown in Figure 16.

Figure 16 Steps of the methodology



The hypothesis of the first research question is that Canadian cities are using similar methods to collect data and monitor cycling. Further, the literature review identifies that most cities struggle to effectively monitor and evaluate and thus the cities' methods will not be consistent with best practices. When cities' efforts are rated according to the best practice framework as described in Section 3.2.4, their scores are expected to be generally low. The hypothesis for research question 2 is that there is no significant difference between the results of the two BSWT surveys.

3.2.1 Literature Review

The literature review is used to examine the current state of understanding related to possible methods of monitoring cycling and organize them thematically. The sources for the literature review were gathered using popular search databases such as Google Scholar, Geobase, Transportation Research Information Service and Web of Science. The search terms used were: bicycle, cycling, transportation planning, monitoring and evaluation, monitoring, bicycle monitoring, bicycle volumes, cycling volumes, cycling data, monitoring data, manual counts, automated detection systems, methods of monitoring, transportation monitoring, monitoring and evaluation in planning, and cycling in Canadian cities. Canadian municipalities' websites were also sourced for information and reports on monitoring and evaluating cycling.

3.2.2 Canadian case study municipalities

The case study method is used in this research because it allows the researcher to deeply explore among programs, events, activities, processes or individuals. For each case study municipality, a document review is performed to investigate how they are monitoring and evaluating cycling. Relevant policy documents regarding monitoring cycling such as Official Plans, Transportation Plans and Bicycle Plans are obtained from the municipality's engineering, transportation, planning, parks, sustainability and other departments. Background studies, administrative reports and minutes from Council meetings are also evaluated. The first step in this process was to collect the information.

The specific information collected about case study cities' methods includes:

- Where they monitor;
- How they monitor;
- How often monitoring occurs;
- If equipment or survey instruments are used;
- Whether the monitoring can be classified as a survey or count;
- Whether the task is performed systematically or on an as needed basis;
- Whether the task is performed as part of an overall monitoring program for the city; and

- Whether Official Plans, Transportation Plans, Active Transportation Plans, and Bicycle Plans outline detailed plans for monitoring and evaluating.

Each city is studied to see if their Official Plan, Transportation Plan, or Bicycle Plan mentions monitoring and evaluation and/or outlines detailed plans concerning that activity. The general successes and challenges of monitoring are described and specific examples are given. Patterns and themes emerge, which is normal for qualitative studies. Some municipalities offer a vast amount of documentation on their practices with statistics and data available while some have less information. Peer-reviewed publications were used, as well as provincial and federal government documents and those published by national cycling organizations and research centers, such as the NBPDP, the Texas Transportation Institute (TTI), ITDP and Transporte Ativo. Lastly, an appropriate employee at each municipality (a Transportation Demand Management Coordinator or Engineering Research Assistant, for example) was contacted to clarify any remaining questions about the case study cities. Contact with each city was attempted approximately five times, however staff members were difficult to reach. It would have been ideal to speak with staff about their monitoring programs, however this was not accomplished within the time and scope of the research project.

3.2.3 Selection of case study communities

The selected case study communities are: the City of Vancouver (Vancouver), Halifax Regional Municipality (Halifax), the City of Calgary (Calgary) and the City of Toronto (Toronto), as defined by their own municipal boundaries. There was a focus on central cities instead of regions because it is generally accepted that there is much more cycling in city centres than suburban regions. Vancouver, Toronto and Calgary are cities that are commonly used as example cities by researchers like Pucher and Buehler (2006a, 2006b), Transport Canada (2010), Winters and Teshcke (2010) and Winters et al. (2011), which enhances the comparability of this research. The case study cities are also the largest in their regions, and have a leadership role in establishing best practices for monitoring cycling. These cities have major projects and programs planned, underway, or recently completed. Both cities that have shown a history of strong bicycle planning and those who have begun planning for cycling more recently were chosen. Indeed, council approved Calgary's first bicycle path in 1946 and the first Calgary Cycle Plan was introduced in 1977, while Halifax's first Bicycle Plan was in 2002 and first bicycle lanes were installed in 2001 (City of Calgary, 1996; D. MacIsaac, personal communication, January 9, 2013).

The cities cover a broad range of climates with notable differences in temperature and precipitation as measured by the yearly average over a period of 1971 - 2000. The amount of precipitation per year ranges from 412.6 mm in Calgary to 1508 mm in Halifax. The average number of days with minimum temperature at or below freezing (0 °C) ranges from 45.9 in Vancouver to 196 in Calgary and the average number of days with a maximum temperature of 30 °C or higher ranges from 0.2 in Vancouver to 9.5 in Toronto (Environment Canada, 2012). Tables 6 and 7 shows some attributes of the case study cities.

Table 6 Comparison of the characteristics of case study cities

City	Population	Area (km^2)	Total bicycle facilities (km)	Bicycle facilities per capita (m)	Total bicycle facilities per area (km/km^2)	BSWT	First bicycle lane (year)	First bicycle plan (year)	First monitoring and evaluation (year)	Precipitation (mm)	Number of days < or = 0 °C	Number of days > 30 °C
Vancouver	603 502	114	400	0.66	3.51	4.00%	1985	1988	1993	1199	46	0.2
Halifax	413 700	5 490	228	0.55	0.04	0.95%	2001	2002	2002	1508	136	0.9
Calgary	1 120 225	727	810	0.73	1.11	1.30%	1946	1977	1958	413	196	4.5
Toronto	2 615 060	630	555	0.21	0.88	1.70%	1979	2001	1982	834	107	9.5

Source: City of Calgary, 2011, 2012; City of Toronto, 2008, 2012; City of Vancouver, 2012; Environment Canada, 2012; HRM, 2002, 2011

Table 7 Rank order of city characteristics in comparison to other case study cities

City	Population	Area	Total bicycle facilities	Bicycle facilities per capita	Total bicycle facilities per area	BSWT	First bicycle lane	First bicycle plan	First monitoring and evaluation	Precipitation	Number of days < or = 0 °C	Number of days > 30 °C
Vancouver	3	4	3	2	1	1	3	2	3	2	4	4
Halifax	4	1	4	3	4	4	4	4	4	1	2	3
Calgary	2	2	1	1	2	3	1	1	1	4	1	2
Toronto	1	3	2	4	3	2	2	3	2	3	3	1

Source: City of Calgary, 2011, 2012; City of Toronto, 2008, 2012; City of Vancouver, 2012; Environment Canada, 2012; HRM, 2002, 2011

3.2.4 Comparison of Case Studies to Best Practices

To address the second part of Research Question 1, *How do Canadian cities' methods compare?*, the cities are evaluated using a summary of best practices developed by Hudson et al. (2010) at the TTI, which a well-known research agency in the United States, affiliated with Texas A & M University (TTI, 2012). The TTI makes significant contributions to safety, mobility, planning, systems, infrastructure, and environmental research and strives to improve transportation efficiency and contribute to quality of life (TTI, 2012). Hudson et al. (2010) studied best practices in monitoring cycling because they were examining whether the programs put in place to encourage people to cycle are actually having their desired effects. The goals of the project were to examine monitoring programs to find out what are the best methods of collecting information; to evaluate data collection equipment while conducting bicycle and pedestrian counts in the Austin-Round Rock Metropolitan Statistical Area; to make predictions about usage based on attributes of bicycle and pedestrian facilities; to "integrate the sketch planning tool into the Capital Area Metropolitan Planning Organization (CAMPO) transportation planning process" (Hudson et al., 2010, p. 1); and to summarize what was found. The final report for the project includes best practices and lessons learned from interviewing eleven agencies in the United States that have programs to monitor cycling and walking.

These best practices are listed in Table 8:

Table 8 Hudson et al.'s (2010) Best Practices

Best Practice Number	Best Practice
1	State the goals of the monitoring program to identify clearly why it exists
2	Establish a system with routine monitoring where the same locations are used yearly
3	Collect data before and after projects are introduced
4	Collect data across a metropolitan area and separate results by categories like: Downtown, Universities, Urban Core, Suburban, Rural
5	Use automated counters
6	Stay up-to-date with technology and secure new equipment whenever possible
7	Collect as much data as possible and model efforts after existing motor vehicle counting systems
8	Assign a specific staff member to be in charge of monitoring projects
9	Use the data to prioritize which projects will be implemented
10	Publish results and have them readily accessible to the public and other agencies

Source: Hudson et al., 2010, pp. 5-6

The analysis of each case study city on each of these points is scored as follows: a 2 if the city is following the best practice, a 1 if the city is partially following or identifies future plans to follow the best practice and a 0 if the city is not following the best practice. This is an ordinal level of measurement because while the numbers do give a rank-order for the cities' scores, the distance between each number does not have any meaning (Hildebrand, Laing, & Rosenthal, 1977). A score of 2 is not twice as good as a score of 1 and the difference between 0 and 1 is not equal to the difference between 1 and 2. An ordinal scale was chosen for its simplicity and because a numerical score was desired for the purpose of comparison. Scores of 0, 1, and 2 are easy to visualize and relate, whereas scores of higher numbers would add complexity and a challenge of determining what level of success to attribute to each number. Arguably, not much additional insight could be gained by expanding the scale, as the research objective is to understand whether cities' monitoring systems are poor, fair or good in a general sense and to know which cities are doing well, although not necessarily exactly how much better than the other cities. As there are 10 best practices, the cities' scores for each are added up to yield a number out of 20.

Hudson et al.'s (2010) framework is not the only way to evaluate a monitoring program, but it is a good starting point. A review of the literature did not return any other systematic practices for generally assessing an overall monitoring program. Other recommendations of monitoring best practices were listed on a more ad hoc basis, most with regards to specific infrastructures, technologies or methodologies.

3.2.5 Comparison of Census and TTS

To answer the second research question, the BSWTs from the two surveys, the Census and the TTS, are studied to provide a quantitative analysis of how the two survey methods compare. The Census and the TTS were chosen to be compared because they both return a mode share of cycling for trips to work at the CT level for the GTHA for the year 2006.

Statistics Canada's E-STAT website is used to obtain the BSWT from the Census. The total number of work trips and the number of work trips that are taken by bicycle are retrieved for each CT of each CMA in Canada. The number of work trips by bicycle is divided by the total number of work trips to calculate the BSWT for each CT.

Secondly, the website of the TTS is used obtain the BSWT from the TTS. Through their Internet Data Retrieval System, a number of queries are performed to collect the total number of work trips and the total number of work trips by bicycle for each CT in the GTHA. The number of work trips by bicycle is divided by the total number of work trips to calculate the BSWT.

Descriptive statistics, for example measures of central tendency and spread, are used to analyze and compare the data for BSWT from the Census and the TTS. Basic inferential statistics, where the means of the two sets of data are compared using a paired two sample t-test, are also used. The data from both the Census and the TTS are mapped separately using GIS to examine the spatial pattern of each. Subsequently, the TTS BSWT is subtracted from the Census BSWT for all CTs for which there are data from both surveys. The difference between the two surveys is mapped using GIS and descriptive statistics are used to quantify the differences. Conclusions are drawn as to whether the different data sources are producing consistent results about the rates of cycling in the GTHA.

The theory being tested in this part of the research is that two surveys conducted in the same place measuring the same thing will produce consistent results. The null hypothesis is that the CTs will have the same BSWT from each survey and they will show the same spatial pattern.

3.2.6 Justification of methodology

The reason for a mixed methods study is that there are both qualitative and quantitative parts to both research questions as described in Section 3.2.

The descriptive and exploratory nature of this thesis is well-suited to the case study method (Gerring, 2004) because cycling policies are determined mostly at the municipal level in Canada. The federal government does not make urban transport decisions so it is difficult to make generalizations about the country as a whole. Thus specific cities are studied in depth to figure out how monitoring and evaluation occurs in Canada rather than studying the phenomenon of monitoring and evaluation in general (Kitchin & Tate, 2000). National and provincial strategies, guidelines, and data do not exist (Pucher & Buehler, 2006a, 2006b) with the exception of the Census data on BSWT.

One criticism of the case study method is that external validity might be in jeopardy if the sample is not representative (Jupp, 2006). In this case it should not be a problem because of the various qualities and different attributes of the cities. The four case study cities show a breadth of example by geography, climate, income, age and ethnicity.

In this thesis, secondary data sources are used. The three main justifications for the use of secondary data are conceptual, methodological and financial. Conceptually, the data may not be available any other way. In a methodological sense, using secondary data is beneficial because it allows for replicating the analysis: other researchers can look to produce the same findings and ensure validity, can open the door to potential longitudinal studies and add additional scope. Finally, for financial reasons, because of time constraints and limited funding, collecting raw data can be a less cost-effective way to perform the research. For this research, the necessary secondary data were available, which saves a lot of money. Some of the data were collected at such a large scale that it would have been very difficult for a student to undertake (Kitchin & Tate, 2000).

Chapter 4
Results

4.1 Introduction

This chapter reports on the ways in which Canadian cities are monitoring their cycling. It begins by discussing the monitoring and evaluation practices of four case study cities: Vancouver, Halifax, Calgary and Toronto. Each city's description also includes its best practices assessment. This is followed by the results of the Census and TTS comparison.

4.2 Vancouver

Vancouver, the most populous city in British Columbia, has a population of 578 000, with a metropolitan area of 2 116 000. Vancouver first constructed bicycle lanes in 1985 and its first Comprehensive Bicycle Plan was presented in 1988. They have over 400 km of bicycle routes in the city, including painted bicycle lanes, separated bicycle paths and residential streets where bicycles have priority (Transport Canada, 2011). Automated bicycle counts were first approved as a pilot project in 1996 (City of Vancouver, 2007) and Vancouver's 1999 Bicycle Plan identifies a need for monitoring. Its recommendations are to count bicycles using automated and manual devices; conduct bicycle cordon counts regularly to measure the modal split; monitor prohibited vehicles along the bikeways; analyze crime data to ensure that there is a continued relationship between lack of criminal activity and bicycle infrastructure; and examine crash data to spot dangerous areas needing improvement (Transport Canada, 2011).

In May 2010, Vancouver funded a monitoring strategy with $400 000 to evaluate the effectiveness of their bicycle facility investments. The plan for how these funds will be distributed includes purchasing automated counting devices and designing and conducting a survey about the bicycle network. The strategy will lead to the collection of data to inform council and staff so they can establish baseline levels, receive regular feedback, better understand their cycling program, and determine whether goals are being achieved. The automatic bicycle counting technology will provide efficient, timely and transparent data (Transport Canada, 2011). According to a 2007 Administrative Report, cyclists will be monitored before and after improvements to cycling infrastructure are implemented and the data will be considered when making policy decisions (City of Vancouver, 2007). In Vancouver's Transportation 2040 Plan (2012), specific targets are listed for cycling and other modes of transportation.

Vancouver compares the volume of other modes to the volume of cyclists. When there is a cycling facility upgrade, the city looks at how the volume of other modes changes by measuring the number of people using each mode before and after the improvement is implemented. Vancouver includes cycling data in reports on other issues, for example in the Georgia and Dunsmuir Viaducts Study (City of Vancouver, 2011). They identify two main methods to monitor cycling: surveys and counts, which are elaborated on below.

4.2.1 Surveys

Vancouver commissions its own surveys, uses Census BSWT data and also considers results from partner organizations like TransLink, Metro Vancouver's regional transportation authority.

4.2.1.1 City of Vancouver Surveys

There is limited information available on Vancouver conducting surveys. One example of a Vancouver survey is a poll before the implementation of new infrastructure, for example as part of the two-month consultation process for the separated bike lane on Hornby Street (see map in Figure 17).

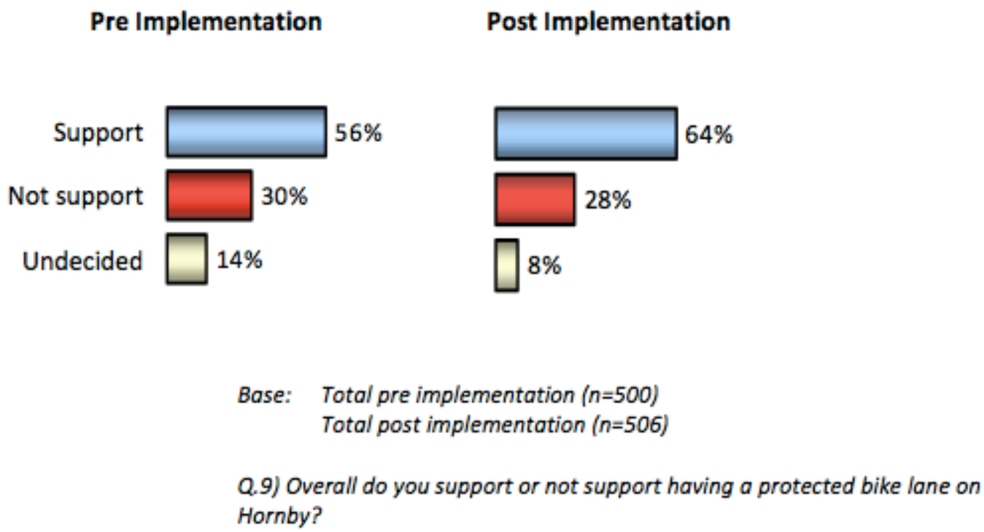
Figure 17 Location of Hornby Street separated bike lane

Source: City of Vancouver, 2013

An opinion poll asked people who were encountered on Hornby Street how they normally get there and if they support the separated bike lanes (City of Vancouver, 2012). A follow-up survey was completed in May

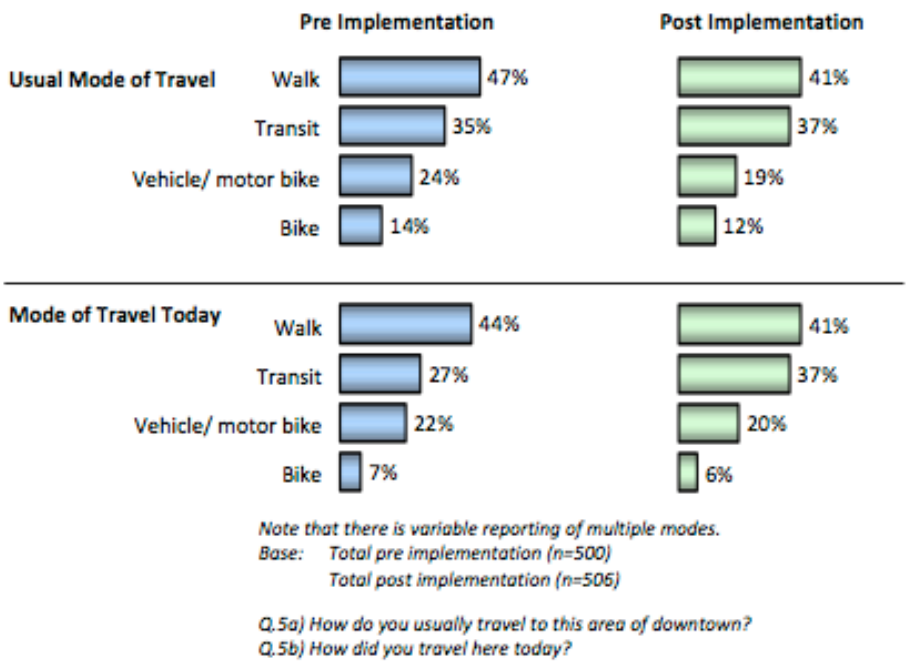
2011, after the bicycle lanes had been in place for six months (City of Vancouver, 2011). Some of the results from the poll can be seen in Figures 18 and 19. These results are discussed further in Section 5.2.2.

Figure 18 Support for Protected Bike Lane on Hornby Street, Vancouver



Source: City of Vancouver, 2011, p. 16

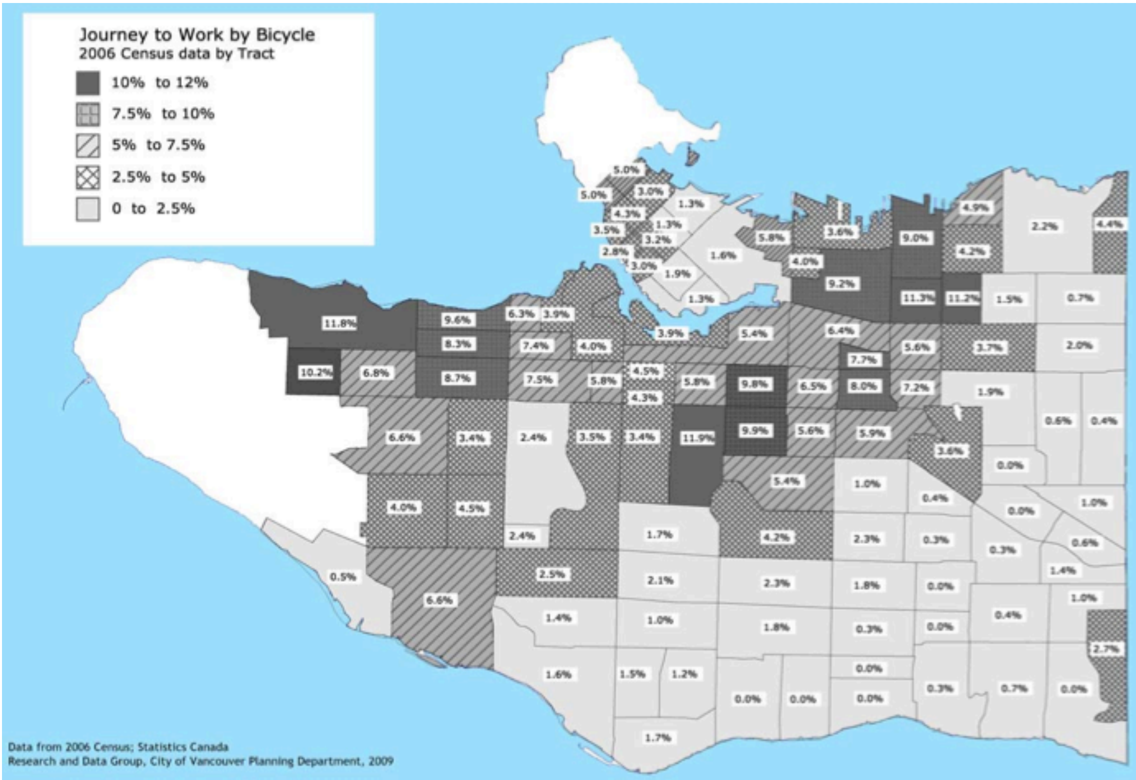
Figure 19 Mode of Travel to Downtown Vancouver



Source: City of Vancouver, 2011, p. 13

Vancouver uses information from the Census as well. In staff reports and on their website, they report the Census mode share of people cycling to work (City of Vancouver, 2009). An example of this is shown in Figure 20, which is from an Administrative Report to the Standing Committee on Transportation and Traffic.

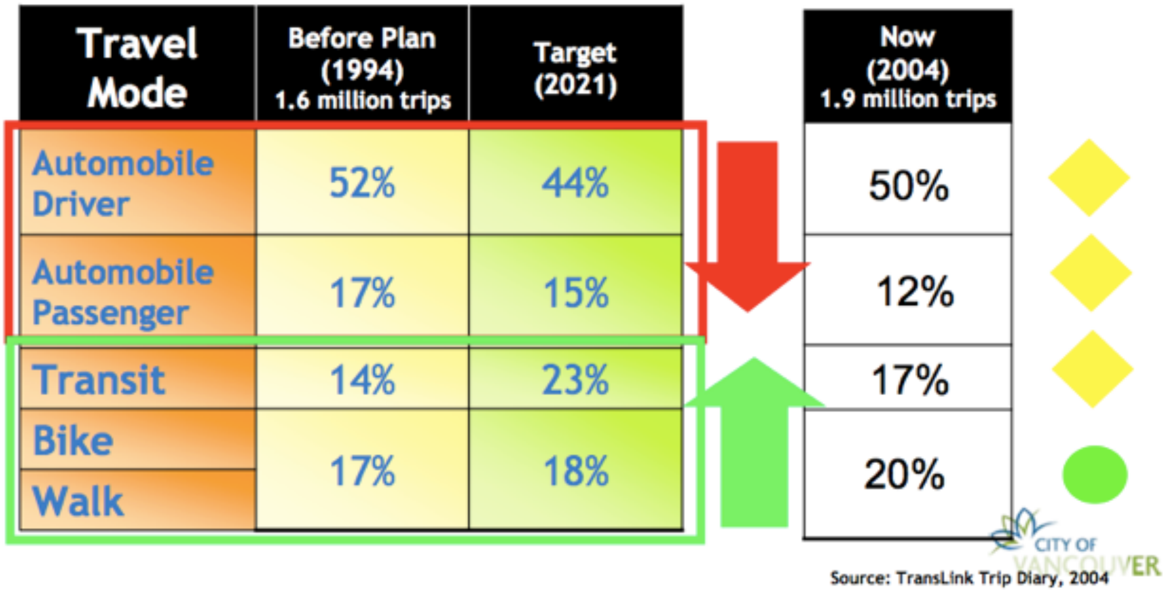
Figure 20 Journey to Work by Bicycle by CT in Vancouver, 2006



Source: City of Vancouver, 2009

Information gathered by TransLink, trip diaries for example, is also used. The trip diaries reveal a total number of trips as well as a mode split for cycling for different kinds of trips, as illustrated in Figure 21 (City of Vancouver, 2009).

Figure 21 Travel Mode Target Status, Vancouver



Source: City of Vancouver, 2010, p. 6

4.2.2 Counts

In 1993, Vancouver began including bicycle counts with their regular traffic counts. Since that time, routes like the Adanac Bikeway have had regular counts at set points along the route to track trends in overall volumes (see Figure 23). These are done manually for one hour during peak hours (7-9am and 3:30-5:30pm) (Transport Canada, 2011). Automated counting began in 1998. Vancouver uses a variety of automated counters: infrared sensors, pneumatic tubes and inductive loops (Transport Canada, 2011). For the loop detectors, the brand used is ZELT and the data logger is Eco Twin. The data logger logs data in 15-minute intervals and has storage capacity for one year of data. A Pocket PC is used to retrieve the data (City of Vancouver, 2009). Inductive loop detectors are used for both the Burrard Bridge (as depicted in Figure 22) and Dunsmuir Viaduct, while volumes on Dunsmuir Street and Hornby Street are measured with pneumatic hoses similar to those used to count vehicle volumes. In both these cases, the data from these counters are verified using manual counts (City of Vancouver, 2011). These counts are examples of Best Practices 5, 6, and 7.

Figure 22 Inductive Loop Counter on Burrard Street Bridge, Vancouver

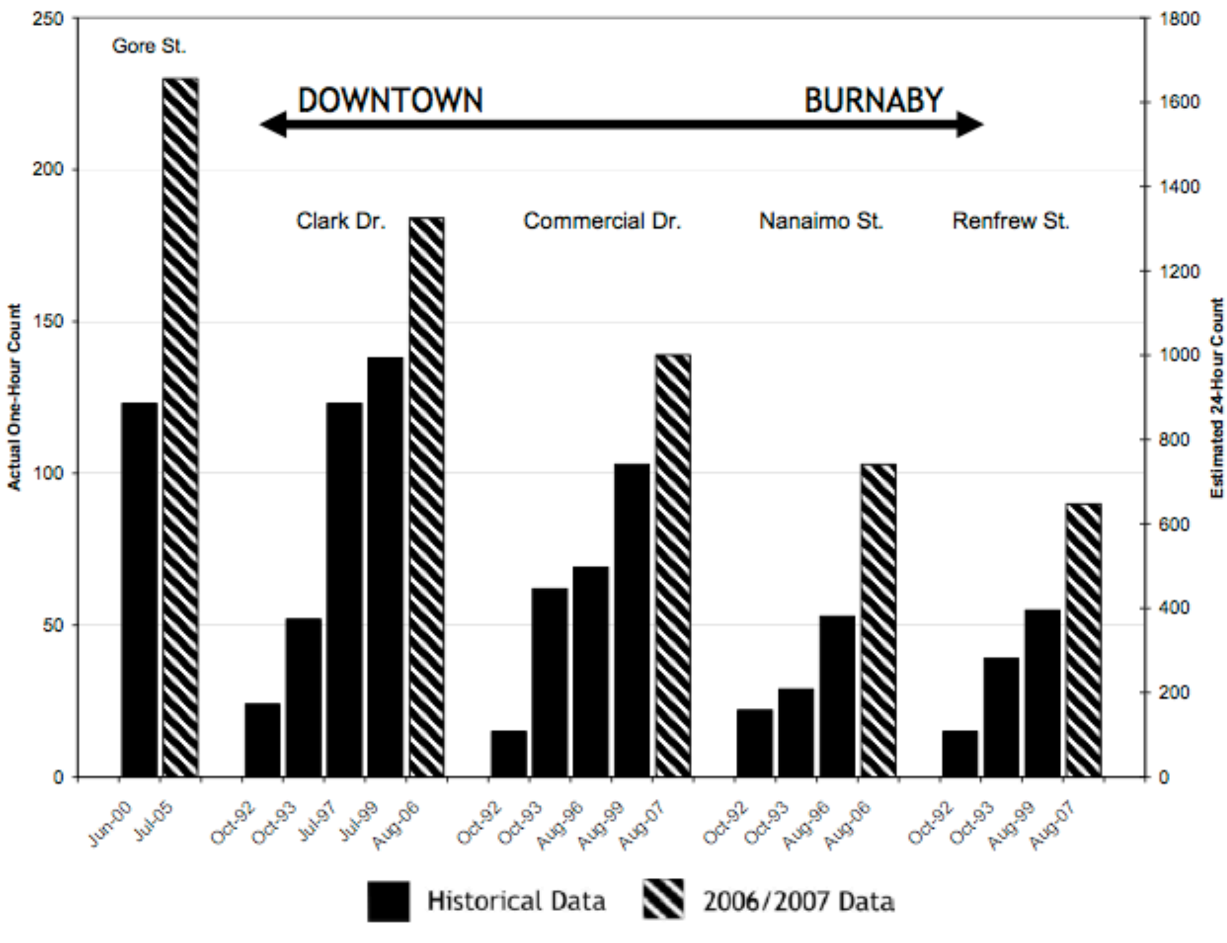
Source: Transport Canada, 2011

Vancouver begins collecting cycling data when new infrastructure is introduced, for example the separated bike lanes on Hornby Street and Dunsmuir Street (City of Vancouver, 2011). Vancouver aims to be clear and consistent with timing and locations for bicycle counts so that data from the past, present and future can be compared. This shows ambition to be in line with Best Practice 3.

Automatic counters collect data continuously throughout the year, however manual counts occur once per season (Transport Canada, 2011). Daily bike volume data for Burrard Bridge (since August, 2009), Dunsmuir Viaduct (since March, 2010), Hornby Street (since January, 2011) and Dunsmuir Street (since June, 2010) were available for download on the City of Vancouver's website in January, 2012 (City of

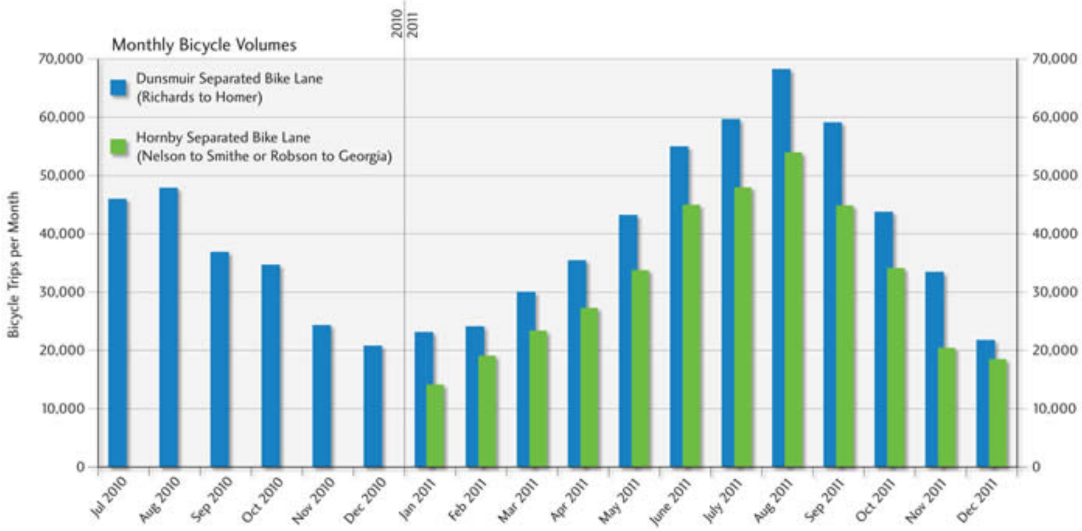
Vancouver, 2011), however as of January 2013, only monthly, seasonal, and yearly totals are posted. This is an example of Best Practice 10 and results are displayed in Appendices G and H. To choose count locations along a bikeway, staff look to locate them within 1 km of entry and exit points, at all intersecting major bikeways, between arterials, and on off-street paths along the bikeways. Staff make note of weather conditions and special occasions like the Olympic Games, holidays, construction and the opening of other facilities as they may explain unexpected or inconsistent results (City of Vancouver, 2011). Records are kept for Tuesdays, Wednesdays and Thursdays, except on days that fall before a holiday and estimates are used in lieu of counts on days that were missed due to equipment damage, vandalism and malfunction (Transport Canada, 2011). Figures 23 through 25 show some of the data Vancouver has collected.

Figure 23 Vancouver Bicycle Volumes Adanac Bikeway – One hour east and westbound



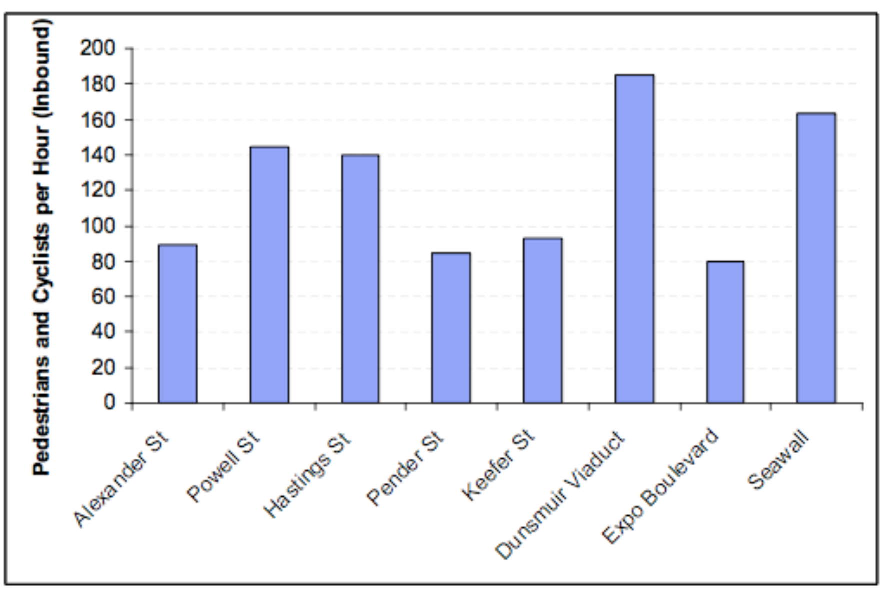
Source: City of Vancouver, 2007

Figure 24 Monthly Bicycle Volumes for Dunsmuir Street and Hornby Street, Vancouver



Source: City of Vancouver, 2011

Figure 25 Morning Peak Hour Inbound Walking and Cycling Flows



Source: 2010 City of Vancouver CBD Cordon Counts

Source: City of Vancouver, 2011

A presentation to the Canadian ITE in 2009 outlined the next steps for bicycle monitoring in Vancouver as: adding permanent counter locations; introducing screenline counts; retrieving data remotely; producing an annual report; adopting new data analysis techniques; and working on buy-in from staff (City of Vancouver, 2009).

4.2.3 GPS

There was no reference found to Vancouver using GPS units to track cyclists.

4.2.4 Best Practices Assessment

Table 9 Vancouver Best Practice Assessment

Best Practice	Description	Score
1	State the goals of the monitoring program to identify clearly why it exists	2
2	Establish a system with routine monitoring where the same locations are used yearly	1
3	Collect data before and after projects are introduced	1
4	Collect data across a metropolitan area and separate results by categories like: Downtown, Universities, Urban Core, Suburban, Rural	0
5	Use automated counters	2
6	Keep up-to-date with technology and secure new equipment whenever possible	2
7	Collect as much data as possible and model efforts after existing motor vehicle counting systems	2
8	Assign a specific staff member to be in charge of monitoring projects	0
9	Use the data to prioritize which projects will be implemented	1
10	Publish results and have them readily accessible to the public and other agencies	1
Total		12

Vancouver excels at Best Practices 1, 5, 6, and 7, receiving two points for each. This is because they state the goal of their monitoring program, which is “to improve our understanding of bicycle facility use, allowing us to plan for necessary improvements to and expansion of the bicycle network” (City of Vancouver, 2009, p. 5). Additionally, they use automated counters and (Transport Canada, 2011) they keep up with the latest methods. Indeed they took advantage of the NBPDP’s offer to provide a free summary report to all cities who contribute EcoCounter data to the NBPDP database, which helps advance the state of cycling knowledge for the purpose of building models (APD, 2012). Furthermore, with a portion of the $400 000 allocated to their new bicycle count program, they aspire to buy new automated counters (City of Vancouver, 2007) and at a 2009 ITE conference they presented plans to explore new technologies (City of

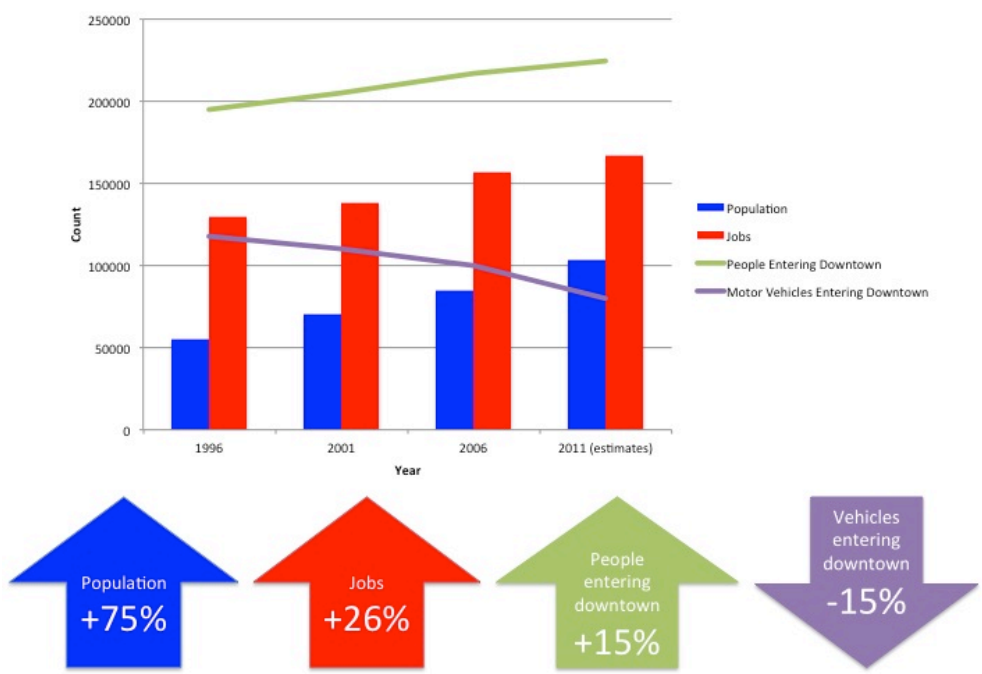
Vancouver, 2009). Vancouver communicates with other cities to confirm the reliability and accuracy of their counters before making purchasing decisions (City of Vancouver, 2007).

Vancouver collects data for many streets and bikeways, including the Adanac Bikeway, Hornby Street, Dunsmuir Street, the Dunsmuir Viaduct, and Burrard Bridge (City of Vancouver, 2011). Manual bicycle counts are integrated into Vancouver's traffic counting program and on some routes both bicycle and motor vehicle counts occur together (City of Vancouver, 2007). Examples of comparing motor vehicle counts to bicycle counts are shown in Figures 26 and 27.

Figure 26 Comparison of the volumes of different modes of travel on the 900 block of Robson Street in Vancouver with the amount of space provided

Source: City of Vancouver, 2009, p. 19

Figure 27 Population and Job Growth vs. Vehicle & Person Trips Downtown Vancouver, 1996-2011 (Peak Periods: 7-9 am, 11am-1pm, 3-6 pm)



Source: City of Vancouver, 2011, p. 16

Vancouver is moderately successful at Best Practices 2, 3, 9 and 10, receiving one point for each. Although Transport Canada states that Vancouver aims to be clear and consistent with timing and locations (Transport Canada, 2011), data published in bicycle count reports (displayed in Figure 23) show inconsistent use of counting locations for data collected at inconsistent intervals from 1992 through to 2007 (City of Vancouver, 2007). Other documents show illustrations (displayed in Appendix I) of where counts occur, but there is no mention of whether they are used yearly (City of Vancouver, 2009). The specific street block where the cyclists are measured is kept consistent for the counters on Hornby and Dunsmuir

Streets (City of Vancouver, 2011). A bicycle count methodology and schedule has been adopted for all major bikeways within the city but it was not readily available. It looks like Vancouver has plans for a consistent system but it has yet to be applied (City of Vancouver, 2007).

Vancouver has future plans to monitor cyclists on routes before and after cycling improvements are implemented (City of Vancouver, 2007), but there are not many past examples of this. On Dunsmuir Street data were collected for one week before the facility opened on June 15, 2010 (City of Vancouver, 2011). Although very limited, this is to a period of monitoring before implementation. There is some evidence of counts leading to project prioritization. The 1997 Transportation Plan encourages monitoring transportation patterns for the purpose of guiding future policies and budgeting (City of Vancouver, 1997). As indicated in Figure 28, existing bicycle volumes played a small role in locating separated bicycle lanes on Hornby Street. The Council report has exact numbers for existing bike volumes (City of Vancouver, 2012). These findings are discussed further in Section 5.2.5.

Figure 28 Criteria for selecting Hornby Street

FACTORS	Thurlow A	Burrard B	Hornby C
Existing bike route	No	Yes	Yes
Existing bike volume	Low	High	High
Existing vehicle volume	High	Medium	Medium
Existing transit	Yes	Yes	No
Existing truck route	No	Yes	No
Desired cycling route	No	Yes	Yes
On-street loading zone affected	Yes	Yes	Yes
On-street parking affected	Yes	Yes	Yes
Potential cost share	No	No	Yes
Good safety	Yes	No	Yes
Vehicle capacity loss	Low	High	Medium

Factor rating: Positive Neutral Negative

Source: City of Vancouver, 2010

Bicycle volume data played a role in deciding to keep the separated lanes on Dunsmuir Street and Hornby Street, however they were only one of many factors (City of Vancouver, 2012). It appears there are aspirations to consider cycling data and statistics when making policy decisions (Transport Canada, 2011) but they are just beginning to become a reality.

Vancouver used to rank highly for accessible monitoring results, as there were informative statistics and detailed data available on the City of Vancouver's website in January, 2012 when information was first collected for this thesis. In July, 2012 all remnants of this were gone and the website only contained basic information about cycling rules and regulations, safety tips, route planning, a potential bicycle share system, and other non-monitoring and evaluation related information. As of March, 2013 some data is back online, but the depth of available information is not what it was. There is confusion because volume data, survey results and other bicycle statistics are at the former City of Vancouver website, http://former.vancouver.ca/engsvcs/transport/cycling/index.htm instead of the current website, http://vancouver.ca/streets-transportation/biking-and-cyclists.aspx. There is no indication on the current website of how to access the relevant reports and statistics and old links are broken. Best practices indicate Vancouver should publish easily accessible data for members of the public.

Vancouver does a poor job of Best Practices 4 and 8 and received 0 points for each. The City of Vancouver does not collect data across the broad metropolitan area. They do reference survey data collected by TransLink, a regional transportation authority (City of Vancouver, 2009). Some administrative reports break Census data down by CT (City of Vancouver, 2009) or neighbourhood to share information about the best ones, for example Kitsilano and Grandview-Woodlands (City of Vancouver, 2011). There was no reference found to collecting data and breaking the city down in to categories like Downtown, Universities, Urban Core, Suburban, Rural, etc. Supplementary comments on this can be found in Section 5.2.5. It is not clear if there is a specific staff member in charge of monitoring and evaluation projects, as there are different staff member names on the Vancouver reports and there is not a specific staff member contact listed online. No response was received after writing to the given contact email: bikevancouver@vancouver.ca.

Total Score: 12/20

4.2.5 Conclusion

The documentation provided by Vancouver indicates they have a good understanding of cycling data and have many methods to monitor and evaluate cycling. They use counts in a variety of informative ways, however surveys are less used. Their overall score according to the best practice assessment is 12/20. They are collecting data; performing ongoing monitoring; looking into new technologies; and refining data collection, processing and analysis (City of Vancouver, 2009).

4.3 Halifax

Halifax Regional Municipality is the most populous city in Nova Scotia, with 408 200 residents (HRM, 2011). There are 87 km of bicycle lanes and approximately 141 km of off-road trails and paths. Halifax's first bicycle lane was introduced in 2001 and monitoring began in 2002.

Halifax's Active Transportation Plan (ATP) mentions monitoring as a step in the implementation of the plan, to examine behaviour, obtain feedback about whether initiatives are successful, and evaluate whether the ATP is accomplishing its goals and objectives. The ATP states that data collection should build upon past efforts and there should be continuous public consultation. The ATP recommends using targets for modal split, liability exposure, achievement of priorities, counting programs and surveys to evaluate its success (HRM, 2006). Halifax uses both surveys and counts and aspects of their monitoring program are discussed below.

4.3.1 Surveys

With respect to survey monitoring, Halifax refers to data collected by Statistics Canada (HRM, 2002), but the ATP suggests conducting their own surveys as well. The ATP lists plans for municipal staff, with the help of a proposed Active Transportation Advisory Committee, to conduct user surveys every two years and statistically robust attitude surveys for residents and tourists every five years. The ATP recommends the monitoring system track changes in route preference and accept feedback on where upgrades and new facilities should be located (HRM, 2006).

Halifax conducted one survey in the fall of 2001, however it had a self-selecting bias, did not obtain a representative sample, and only had 240 respondents (HRM, 2002). Although not a cycling-specific survey, the 2002 HRM Citizens Survey had questions relating to cycling, including a journey to work question (HRM, 2010).

4.3.2 Counts

Halifax has performed some counts in the past, for example the following programs:

- Intersection counts;
- Cordon counts; and
- Peninsula screenline bicycle counts (PSBC).

The ATP mentions various types of possible counts such as origin-destination counts, screenline counts, and intersection counts. Counts may be taken on routes where infrastructure is proposed, newly implemented or existing, or on routes parallel to those (HRM, 2006). The 2002 Bicycle Plan recommends that bicycle counts are conducted yearly (HRM, 2002) but the 2006 ATP recommends only every five years. Some more recommendations of the ATP are that:

- when monitoring the success of a newly implemented facility an appropriate time delay should be observed as residents need time to realize the changes have been made and modify their route preferences accordingly;
- data collection should be an internal function of the municipality; and
- monitoring should occur between late spring and the middle of fall.

The proposed Active Transportation Advisory Committee should have a role in the collection and the evaluation of the data (HRM, 2006).

The PSBC is one count that occurs in Halifax. The methodology uses a screenline that comprises a major east-west route bisecting the Halifax peninsula into a mainly residential side and a side of major employment uses. Volunteer counters record bicycle volumes at each intersection where a cross street intersects the screenline. The locations of the counters can be viewed in Appendix J. This count is important because bicycle traffic is one of the criteria for deciding on a route for the future Crosstown Connector, a proposed set of bicycle lanes that will allow users to travel the entire length of the Halifax peninsula (HRM, 2012). These counts have occurred in September 2010 and June 2011 so far (HRM, 2011). The instructions and a count form can be found in Appendices K and L respectively.

Another count in Halifax is called Trip Data Collection. Cars, buses, commercial vehicles, pedestrians, and cyclists were counted at 13 locations in October and November of 2008 (HRM, 2009). This is an example of Best Practice 7 because other modes were monitored along with cyclists. The municipality is aware of other counts that occur, for example by the Halifax Cycling Coalition (HCC). They performed a June 2009 count in areas that represent three types of bicycle facility: on-street bicycle lane, multi-use path and separate bicycle path. The HCC used input from other cities and from Halifax's municipal planning staff to develop their methodology. Other information such as whether the cyclists were observing traffic rules was recorded (Halifax Cycling Coalition, 2010).

4.3.3 GPS

There was no reference found to Halifax using GPS units to track cyclists.

4.3.4 Best Practices Assessment

Table 10 Halifax Best Practice Assessment

Best Practice	Description	Score
1	State the goals of the monitoring program to identify clearly why it exists	1
2	Establish a system with routine monitoring where the same locations are used yearly	0
3	Collect data before and after projects are introduced	0
4	Collect data across a metropolitan area and separate results by categories like: Downtown, Universities, Urban Core, Suburban, Rural	0
5	Use automated counters	0
6	Keep up-to-date with technology and secure new equipment whenever possible	0
7	Collect as much data as possible and model efforts after existing motor vehicle counting systems	1
8	Assign a specific staff member to be in charge of monitoring projects	0
9	Use the data to prioritize which projects will be implemented	0
10	Publish results and have them readily accessible to the public and other agencies	1
Total		3

Halifax does moderately well at Best Practices 1, 7 and 10, receiving 1 point for each. Although there is not a monitoring program per se, the ATP mentions monitoring as a step in the implementation of the plan, to obtain feedback about the success of cycling initiatives, examine active transportation behaviour and evaluate whether the ATP is accomplishing its goals and objectives (HRM, 2006). Data collection programs like the Trip Data Collection project, counted cars, buses, commercial vehicles, pedestrians and cyclists (HRM, 2009). This is an example of collecting data in coordination with vehicle counts. Halifax looks to its own PSBC as well as bicycle counts conducted by the HCC (Halifax Cycling Coalition, 2010; HRM, 2011). Halifax is fairly new to bicycle counting, as counts have mostly occurred from 2008 to 2011. Indeed, bicycle counts were mentioned as a Near Term Goal in the 2002 Bicycle Plan, however by 2006 there was still no indication that they had occurred (Ecology Action Centre, 2006). Results from the Trip Data Collection study are published online, which is recommended in Best Practice 10. The reports and results of other counts, such as the PSBC and the HCC count, were obtained by contacting Halifax's STPD and asking about survey or count data.

Halifax does poorly at Best Practices 2, 3, 4, 5, 6, 8, and 9, receiving 0 points for each. For example, the ATP recommends counts occur at minimum every five years (HRM, 2006). This is less often than is recommended by Best Practice 2. With that being said, the PSBC has been conducted two years in a row:

2010 and 2011, at the same locations (HRM, 2011). Some counts like the 2008 Trip Data Collection were performed one year and then not again. The 2002 Halifax Bicycle Plan recommends that bicycle counts be conducted yearly, however this has yet to occur and the ATP, which was published at a later date, recommends less frequent counts (HRM, 2002, 2006).

Moreover, the ATP suggests that counts occur where infrastructure is proposed, newly implemented or existing, but doesn't emphasize the importance of conducting counts both before and after installation (HRM, 2006). There was no evidence discovered of this occurring in the past.

Although there is reference made in the June 2011 PSBC Report to using the NBPDP standards for future counts (HRM, 2011), this is the only evidence found of Halifax keeping up-to-date. Reports do not mention using new technologies or even automated counters. As recommended by Hudson et al. (2010), existing bicycle traffic is one of the criteria for the route selection for the proposed Crosstown Connector, as shown in Figure 29. It plays a minor role, however, as there are four times as many criteria related to the existence of motor vehicle parking. The colour scale is not precise enough to differentiate between routes, as only one potential route is not marked green for bicycle volumes. There was no evidence found to conclude that data has lead to project selection in the past (HRM, 2012) and it remains to be seen if it has an impact in this case.

Figure 29 Evaluation Criteria for potential Crosstown Connector routes

Criteria	Connaught	Windsor to Vernon	Agricola to Bell Rd.	Novalea/ Gottingen
Connectivity				
Origins / Destinations	🔴	🟢	🟢	🟢
Proximity to existing AT	🔴	🟡	🟢	🟡
Proximity to future AT	🟢	🟢	🟢	🟢
On-street Parking				
Loss of parking	🟠	🟠	🟠	🟠
Demand for commercial parking	Low	Low - Moderate	High	Moderate
Demand for residential parking	Moderate	Low	Moderate	Low - Moderate
Availability of parking alternatives	Moderate - High	Moderate	Moderate	Moderate
Intersections				
Complex / busy intersections	🟡	🔴	🟡	🟡
Street Characteristics				
Flat grades	🟡	🟢	🟢	🟢
Traffic volumes	🔴	🟡	🟡	🟡
Trucks / Buses	🟢	🟡	🟡	🔴
Bicycle Volumes	🟡	🟢	🟢	🟢

Source: HRM, 2012

The Active Transportation Plan does not list existing bicycle volumes as part of the Route Selection Evaluation Criteria, which can be viewed in Appendix M. To conclude this assessment, there was no evidence found to substantiate an idea that Halifax is following Best Practices 4, 5, or 8.

Total score: 3/20

4.3.5 Conclusion

Halifax's monitoring and evaluation program appears to be in the beginning phases, mostly outlining what they will do in the future. Data collection is mostly limited to counts, however this may not be a fault; surveys are not mentioned in the best practices of Hudson et al. (2010). The PSBC is impressive for its ability to count every cyclist crossing the screenline, but it is still in the beginning phases of becoming routine. Counts generally appear to be infrequent and sporadic. There is more planned for the future, but the ATP is not specific about where, when and how monitoring and evaluation will occur.

4.4 Calgary

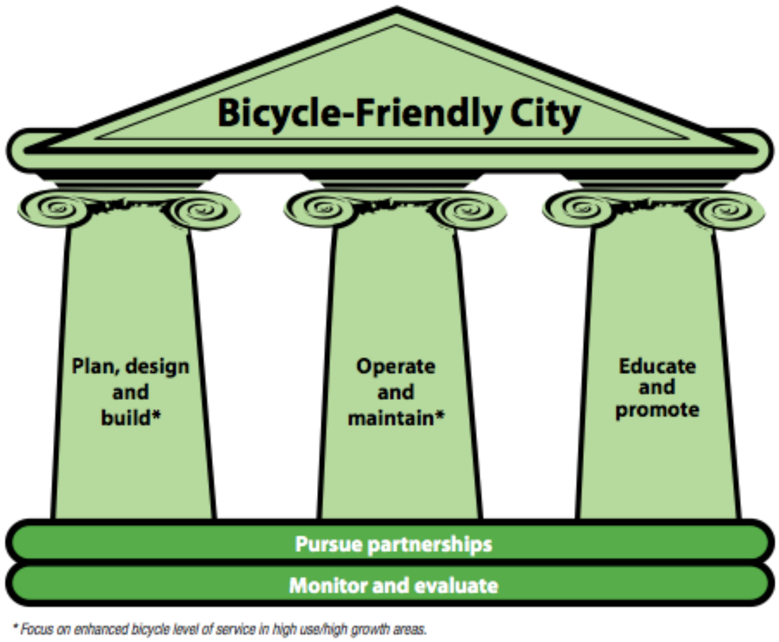
Calgary, Alberta's most populous city, has a population of 1 120 225 (City of Calgary, 2012). It has a long history of bicycle planning as evidenced by approval of its first bicycle path in 1946 and the release of the first Calgary Cycle Plan in 1977 (City of Calgary, 1996). There are approximately 550 km of pathways and

260 km of on-street bicycle routes in the city (City of Calgary, 2000). Important documents like the 2004 Downtown Urban Structure Plan are informed by cycling sources like the Calgary Civic Census Travel to Work Surveys, the Commuter Cyclist Survey and Statistics Canada (City of Calgary, 2004). In the past, Calgary has struggled with the implementation of its policies and plans because there was "lack of clarity on how the plans should be implemented, misinterpretations around terms, processes or responsibilities, and even inability to demonstrate how progress is being achieved" (City of Calgary, 2010, p. 3). Calgary Parks & Recreation is responsible for pathways while the Transportation Department is responsible for bikeways (City of Calgary, 1996).

As part of their implementation program, the Municipal Development Plan (MDP) and Calgary Transportation Plan (CTP) outline Core Indicators as proxy measures to indicate whether the MDP and CTP are successful socially, economically and environmentally. Baseline numbers are reported and targets for the indicators show where the city aims to be in 60 years. A monitoring and reporting program will be developed to report on indicators every three years so that Calgary's council, administration and citizens are kept up to date. The Core Indicator for cycling is listed under Transportation Mode Split. The metric is Walking and Cycling Mode Split (all purpose trips, 24 hours, city-wide) and the baseline level is: "in 2005, walk and bike trips contributed to 14% of all trips made" (City of Calgary, 2010, p. 4-3). The target for 60 years in the future is 20% - 25% (City of Calgary, 2010). See Appendix N for a sample of Calgary's Core Indicators.

Calgary released a new council-approved cycling strategy in 2011. The vision of the strategy is to encourage more Calgarians to cycle and for Calgary to become one of North America's best cycling cities. Pillars One and Two in the three pillar plan specifically mention monitoring through counts, which can be seen in Figure 30 (City of Calgary, 2011).

Figure 30 Pillars of a bicycle-friendly city



Source: City of Calgary, 2011, p. 3

The strategy outlines a plan to devote three staff members to its cause and a need for $100 000 to monitor and evaluate as part of the 2012-2014 capital costs. One of the four measurable goals outlined by the strategy is an increase in the number of cyclists observed entering or leaving the Central Business District (CBD) on weekdays during a 16-hour period. The Cycling Strategy shows these data from 1999 to 2010, obtained from the annual CBD cordon. Statistics Canada data for mode share to work is also referenced, as well as the 2000 and 2006 City of Calgary Downtown Commuter Cyclists Surveys and the 2009 University of Calgary Commuter Cyclist Survey (City of Calgary, 2011). See Appendix O for a list of Calgary's past policies, plans and surveys.

The 2011 Cycling Strategy states that the best source of information for monitoring mode split is the Calgary and Region Travel and Activity Survey (CARTAS), formerly known as the Household Activity Survey (HAS), where respondents provide data on all of their daily trips. CARTAS is conducted every 10 years, most recently in 2011 (City of Calgary, 2011). Chapter 8 of the Cycling Strategy is about Monitoring and Evaluation and Section 8.2 identifies a need to use technology and add bicycle performance measures into existing data collection programs. Expanding on the MDP and CTP, the Strategy also has indicators with sources of data, metrics, units, baseline figures, and 2020 targets for each (City of Calgary, 2011). See Appendix P for a list of Calgary's cycling indicators and Appendix Q for the summary of actions for data collection and reporting.

Also related to implementation of the CTP is a section of Calgary's website called *Mobility Monitor*, where transportation trends and events are reported. Some of the topics discussed are land use and mobility and trip characteristics and traffic patterns. Data for the Mobility Monitor are obtained from the Downtown

Cordon Count Program, the cage bicycle count, the Downtown Commuter Cyclist Survey, Calgary's Civic Census, and Statistics Canada (City of Calgary, 2012).

Statements from policy documents that are relevant to monitoring cycling include:

- Transportation Goal #4 from the CTP, "enable public transit, walking and cycling as the preferred mobility choices for more people" (City of Calgary, 2009, p. 3-2);
- Recommendation #17 in the 1996 Calgary Cycle Plan, "Calgary Parks & Recreation formally adopt a pathway user counting program as part of the 1998 budget process" (City of Calgary, 1996, p. 5);
- Recommendation #20 in the 2000 Calgary Pathway & Bikeway Plan Report, "the Transportation Department should expand current cyclist and pedestrian traffic counts" (City of Calgary, 2000, p. iv);
- Recommendation #23 in the same report, "the Pathway/Bikeway Coordination Team should develop a program for conducting pathway and bikeway counts every two years, as well as user surveys every four or five years" (City of Calgary, 2000, p. v);
- Recommendation #17 in the same report, "Pathways and Bikeway co-ordinator positions be established within the Parks and Transportation divisions to coordinate the planning, development, design, operations and maintenance of the Pathway and Bikeway systems" (City of Calgary, 2000, p. iv); and
- Recommendation #40 in 1996 Calgary Cycle Plan, "the Transportation Department, Transportation Planning Division establish a position of bike/pedestrian coordinator to be charged with implementing the plan", among other duties (City of Calgary, 1996, p. 81).

Calgary states that the success of new bicycle facilities will be measured by: conducting opinion surveys; counting cyclist volumes; and measuring bicycle travel times before and after the facility is implemented to see if there has been an improvement (City of Calgary, 2011). More on these surveys and counts can be found in the following sections.

4.4.1 Surveys

Calgary uses many surveys to monitor and evaluate their cycling, for example: the Calgary Downtown Commuter Cyclist Survey; the Civic Census Travel to Work Survey; CARTAS; the Pathwatch surveys; and the Comprehensive Household Travel Survey. Appendix M shows past policies, plans and surveys in Calgary and Appendix N, Calgary's cycling indicators, lists a few others.

4.4.1.1 Downtown Commuter Cyclist Surveys

Recommendation #23 of the Calgary Bikeway and Pathway Report states that a commuter cyclist survey should be performed every five years. The first survey of commuter cyclists was performed in 1992 and subsequent surveys were performed in 2000 and 2006, with many of the questions remaining consistent.

The main goals of the survey are to understand the needs of existing cyclists and to find ways to improve cycling conditions to attract new commuter cyclists. As a result of the survey, a profile of the typical commuter cyclist emerges, including statistics about gender, age, income, distance travelled, days/year cycled, car ownership, and other information (City of Calgary, 2006).

The 2006 survey allows researchers to identify which routes are most commonly used, determine which routes may be operating at or above capacity, determine average time and distance for bicycle trips, find out where most bicycle trips begin and end, analyze seasonal variations, and determine whether pathways or on-road facilities are most used (City of Calgary, 2006). The workers handing out the surveys also perform counts, recording the number of inbound, outbound, on-street and off-street cyclists (City of Calgary, 2006).

4.4.1.2 Civic Census Travel to Work Survey

The Data Management and Forecasting Division of Land Use and Mobility conducts an annual census to count dwelling units and population in Calgary. As part of this civic census, information on 'place of work' and 'travel to work' is collected. These data are used to track and predict travel demand.

In 2011, the first year of the mode of transportation to work question, one working member of each household was asked for their mode of transportation to work on the most recent day they worked. If multiple modes were used, the participant was instructed to indicate the mode they used for the greatest distance (City of Calgary, 2011). Moreover, a transportation survey was conducted in 1976, 1979, 1985, 1988, 1996, 1999, 2002, 2006, and 2011 (City of Calgary, 2012). Not all sections of the civic census are conducted each year; the mode of transportation to work question is scheduled to be asked again in 2014 and 2017 and the transportation survey is next scheduled for 2017 (City of Calgary, 2012).

4.4.1.3 CARTAS

A random sample of Calgary households record a 24-hour activity/travel diary for all trips made by the household on a randomly assigned day (City of Calgary, 2002). The demographic and behavioural data received are used to update the Calgary Regional Transportation Model. CARTAS was formerly referred to as the HAS and it has been conducted in 1958, 1964, 1971, 1981, 1991, 2001 and 2011 (City of Calgary, 2002).

4.4.1.4 Calgary Parks Pathway Research

Calgary Parks is responsible for the operation, maintenance, planning and development of Calgary's pathways. Calgary Parks conducts site reports at various locations on the pathways as well as telephone, intercept and online surveys through a program called Pathwatch (City of Calgary, 2006). There have been five Pathwatch studies, three of which occurred during the summer (1994, 2002, 2010) and two of which occurred during the winter (1999, 2006/2007).

The site reports record demographic information, activities being performed, direction of travel, compliance with bylaws and other information for each user. The people performing the site reports also use counter clickers to count pathway users (City of Calgary, 2007). In 2010, each site was observed for twelve hours on five days (three weekdays and two weekend days). Conversely, in 2006/2007, each site was observed for eleven hours per day, on two weekdays, one Saturday and one Sunday every month (City of Calgary, 2007). The same sites were not used all years, for example in 2010 only 15 sites from the list of the 39 sampled in 2002 were chosen. The 1994 count included 15 of the same sites from 2002 (City of Calgary, 2004) and the 2006/2007 version used only 12 sites (City of Calgary, 2007). Using the same locations yearly is Best Practice 2.

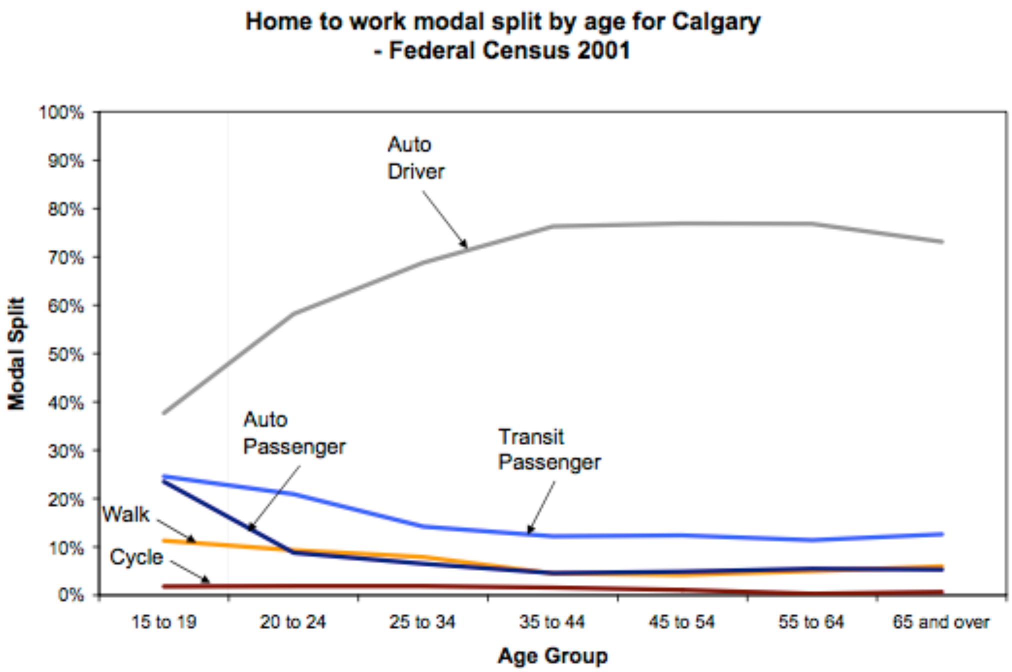
The telephone survey contacts both users and non-users of the pathways from a random and representative sample of Calgarians. It asks respondents if they use the pathways, how often they use them, why they use them, how they use them and where they live (City of Calgary, 2011). The online survey is open for anyone to complete and is used as a venue for people to express their opinions. There is a self-selecting bias and no quotas; the results are not representative of the city (City of Calgary, 2011). Intercept surveys are used to collect information from users at selected sites. Their results represent the views of pathway users during the times and dates the surveys are taken. Convenience sampling is used to interview every person that passes by in some cases and every third person in others. They do not represent Calgary or all pathway users as a whole because all pathway users are not given an equal chance to participate in the study. The data are still analyzed for patterns to inform future planning and pathway priorities because a large number of people are observed (City of Calgary, 2011).

The three surveys all ask questions about: when, how often and why respondents use the pathways; personal background information; activities performed; their knowledge of pathway regulations; pathway safety; ways in which the pathways could be improved; and the quality and importance of the pathways (City of Calgary, 2011). Details about the results are presented in the Pathway Safety Review Report and the Parks 2010 Pathway Research Comparison Summary Report (City of Calgary, 2011).

4.4.1.5 Statistics Canada Canadian Census

The City of Calgary refers to data from Statistics Canada on their website (City of Calgary, 2006) and in the Mobility Monitor (City of Calgary, 2012), as illustrated in Figure 31:

Figure 31 Example of data from the Census used for the Mobility Monitor



Source: City of Calgary, 2012

4.4.1.6 Surveys from other organizations

The City of Calgary makes reference to studies performed by other groups, such as researchers at the University of Calgary, who conducted, among other studies, a 2009 University of Calgary Commuter Cyclist Survey Report (Twaddle & Hall, 2009).

4.4.2 Counts

4.4.2.1 Downtown Cordon Count Program

Every year in May, the Downtown Cordon Count Program counts the number of pedestrians, cyclists and vehicles that enter the downtown. Cyclist data were not collected in 1993, 2003, 2004 and 2005 (City of Calgary, 2012). Conducting counts of other modes with cyclists is an example of Best Practice 7.

4.4.2.2 Other

Most other counts are held in coordination with surveys and are described in the survey section above.

4.4.3 GPS

There was no reference found to Calgary using GPS units to track cyclists.

4.4.4 Best Practice Assessment

Table 11 Calgary Best Practice Assessment

Best Practice	Description	Score
1	State the goals of the monitoring program to identify clearly why it exists	2
2	Establish a system with routine monitoring where the same locations are used yearly	0
3	Collect data before and after projects are introduced	1
4	Collect data across a metropolitan area and separate results by categories like: Downtown, Universities, Urban Core, Suburban, Rural	1
5	Use automated counters	1
6	Keep up-to-date with technology and secure new equipment whenever possible	1
7	Collect as much data as possible and model efforts after existing motor vehicle counting systems	1
8	Assign a specific staff member to be in charge of monitoring projects	0
9	Use the data to prioritize which projects will be implemented	0
10	Publish results and have them readily accessible to the public and other agencies	2
Total		9

Calgary excels at Best Practices 1 and 10, receiving 2 points for each. Although a monitoring and reporting program has yet to be designed, there are plans to develop one to guide future decisions, measure progress, provide accountability and keep city residents, council, staff and other interested parties up to date about how Calgary is progressing (City of Calgary, 2010, 2011). Full points were also given for Best Practice 10 due to the ease of accessing all the reports and results used to support this thesis.

Calgary does moderately well at Best Practices 3, 4, 5, 6 and 7, receiving 1 point for each. Among other criteria, the 2011 Cycling Strategy states that the success of new bicycle facilities will be measured by counting cyclist volumes and measuring travel times both before and after implementation (City of Calgary, 2011). There are plans for the future, but no reference to this occurring in the past. Data collected across the metropolitan area are often broken down into Calgary's communities (City of Calgary, 2006) or by ward (City of Calgary, 2011), but it is not normally separated into categories like Downtown, Universities, Suburban, etc. Even though Calgary does not yet use automated counters, a need to investigate, purchase and install new technologies is identified in the 2011 Cycling Strategy (City of Calgary, 2011). Additionally, staff have been provided with regular training in cycling policy, infrastructure design and best practices through webinars, seminars, courses, workshops and conferences (City of Calgary, 2011).

Calgary collects data in coordination with motor vehicle counts, for example with the Downtown Cordon Count Program (City of Calgary, 2012). The Civic Census also collects information for all modes with its travel to work question (City of Calgary, 2011). Programs like Pathwatch, the Downtown Commuter Cyclist Survey, and the Household Activity Surveys provide cycling-specific data. Nonetheless, the 2000 Calgary Pathway & Bikeway Plan Report recommends that "the Transportation Department should expand current cyclist and pedestrian traffic counts" (City of Calgary, 2000, p. iv) to every two years, as well as complete surveys every four or five years.

Calgary performs poorly at Best Practice 2, 8 and 9, receiving 0 points for each. This is because although some of the same sites are used for Pathwatch in multiple years, this is not always the case. In 2010, 15 sites were used (City of Calgary, 2011), in 2006/2007 12 sites were used (City of Calgary, 2007), in 2002 39 sites were used, and in 1994 15 sites were used (City of Calgary, 2004). Comparison between years can only occur on a site-by-site basis in those situations where there were identical sites used. A statistic like average number of users per hour is needed to compare sites in cases when different days and hours were used (City of Calgary, 2007). The counts don't occur yearly and the 2000 Calgary Pathway & Bikeway Plan Report recommends that "the Pathway/Bikeway Coordination Team should develop a program for conducting pathway and bikeway counts every two years (City of Calgary, 2000, p. v). Calgary does not have a staff position responsible for the management and collection of bicycle data specifically. Lastly, there is no indication of data being used to prioritize projects.

Total Score: 9/20

4.4.5 Summary

While counts are somewhat used by the City of Calgary to monitor cycling, there seems to be much more emphasis placed on surveys. There appears to be some systematic planning, however much of the data collection still occurs on an ad hoc basis. Monitoring cycling is mentioned as a priority in many of Calgary's plans, reports and strategies and they produce summary documents for their studies, often comparing and contrasting their results. Snippets of information are published in a user-friendly format with the *Mobility Monitor*. It appears as though the city is beginning a new chapter in their monitoring program, with solid baselines, sources of data and future targets established.

4.5 Toronto

Toronto, the most populous city in Ontario, has a population of 2 615 060 (City of Toronto, 2012). Toronto's first bicycle lane was constructed in 1979 and it now has 113km of bike lanes, 156km of shared roadways and 286km of off-road paths (City of Toronto, 2001, 2012). Beginning in 1993 the City of Toronto Official Plan emphasized increased bicycle use, particularly for utilitarian purposes. Toronto's current Official Plan references the Toronto Bike Plan and outlines its primary goals and recommendations (City of Toronto, 2002).

The 2001 Toronto Bike Plan calls for a bicycle-specific data collection program (City of Toronto, 2001), which will be reported in an annual progress report to Council and the Toronto Cycling Committee and will contribute to the preparation of a list of annual priorities (City of Toronto, 2001). The commitment to develop a monitoring program came from the realization, when performing background research for the 2001 Toronto Bike Plan, that Toronto's data collection needed improvement. Proposed methods included measuring ridership and conducting attitude surveys (City of Toronto, 2001).

Interestingly, eight years later the data collection program recommended in the 2001 Bike Plan was not yet developed. In the Bike Plan's 2009 update, Toronto Bike Plan – New Strategic Directions, one of the priorities is still to develop a comprehensive research and evaluation program (City of Toronto, 2009). The update states that the bicycle data collection program will consist of the following research components:

- Analysis of the Census and TTS data at both the city-wide and the CT level;
- Automatic bicycle counters at a number of bikeway network locations;
- Regular analysis of bicycle collision data every three to four years;
- A Toronto Cycling Survey every four years to collect consistent data; and
- Data collection for broader research purposes, like evaluating design, facilities and programs.

This research will guide decisions to encourage cycling through program delivery, facility design and investment (City of Toronto, 2009). The update asserts that "the City does not have reliable, high quality data for analyzing bicycle traffic patterns, ridership trends and cyclist attitudes" (City of Toronto, 2009, p. 10).

An important partner in developing the Toronto Bike Plan, the Toronto Cycling Committee, was not re-established for the Council term of 2010 – 2014. The Toronto Cycling Committee was a Citizen's Advisory

Body who advised council on bicycle policies, programs and facilities and played a role in monitoring and evaluation (City of Toronto, 2001, 2012).

Currently, cycling data are collected by Statistics Canada, the TTS, traffic counts and user surveys (City of Toronto, 2011, 2012).

4.5.1 Surveys

Toronto performs its own surveys and references others such as the TTS and Census. The various surveys are described below.

An example of their own survey is the Toronto Cycling Survey. Originally completed in 1999 as part of the Toronto Bike Plan Study and again in 2009 to track trends, it is used to collect information about opinions on cycling and the prevalence of bicycle use in Toronto. The survey establishes the cycling behaviours, attitudes and concerns of the typical Torontonian and collects information about interventions that are most likely to increase cycling (City of Toronto, 2001, 2010). Other cycling surveys were conducted in 1986 and 1991 (City of Toronto, 2001). Some neighbourhoods have their own surveys, which may ask questions about journey to work, for example the Central Area Residents Survey (City of Toronto, 2001).

The TTS is a comprehensive travel survey designed to acquire data about how and when a random sample of residents travel around the cities of southern Ontario. It aims to sample 5% of the population. The survey area generally includes 23 agencies in the Greater Toronto and Hamilton Area (GTHA) and some surrounding municipalities and counties. A complete list of the agencies can be found in Appendix R. The Ministry of Transportation Ontario and the municipalities fund the TTS for the purpose of improving transportation demand analysis, research and forecasting by the coordination and standardization of transportation data collection, summarization and distribution efforts between member agencies (Transportation Tomorrow, n.d.). The data are summarized in a database and are publically available at various aggregate levels (Transportation Tomorrow, n.d.). The survey was completed in 1982, 1991, 1996, 2001, and 2006. The 2011 survey was underway at the time of data collection for this thesis, with its second phase of data collection planned for the fall of 2012.

The results of the TTS "form the factual basis for virtually every transportation planning study carried out in the area by and for local, regional and provincial agencies" (Transportation Tomorrow, n.d., p. 1). The survey asks questions about household demographics and about each trip taken by each person in the household above the age of 11 between the hours of 4:00am and 3:59am the previous day (Transportation

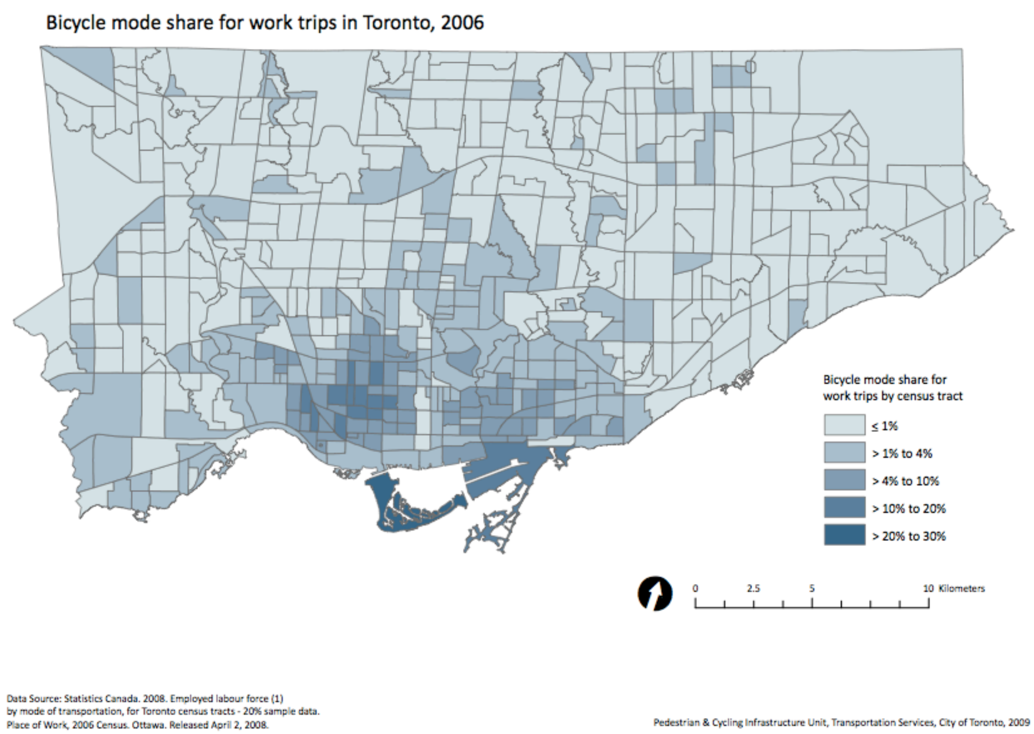
Tomorrow, n.d.). Sample questions can be found in Appendix S. A trip is defined as "a one-way journey from one location to another made by any form of motorized transportation, bicycle or walking" (Transportation Tomorrow, n.d., p. 11). The following is the level of detail that is required for each trip reported in the survey:

- From origin location to which destination location (street address preferred);
- Reason for making the trip (for example, shopping/work);
- Start time of the trip; and
- Type of transportation (for example, bus, car, bicycle)

(Transportation Tomorrow, n.d.).

Toronto also refers to data collected by the Census in their reporting of cycling statistics. They state that the number of people who ride a bicycle to work is an important indicator of how many people use a bicycle for transportation (City of Toronto, 2008). Toronto reports on change in BSWT between 2001 and 2006, an age and sex profile of bicycle commuters, and a comparison of BSWT by CT (City of Toronto, 2012), which can be viewed in Figure 32 below.

Figure 32 Map of Bicycling Share of Work Trips in Toronto, 2006



Source: City of Toronto, 2008

4.5.2 Counts

Toronto uses both automated and manual counters. In the future Toronto will expand its counting programs beyond the general road counts to collect data for all bicycle lanes and paths through autocounters. A before count and a one year follow-up count will be performed for all new bicycle lanes and paths. Once every three years all existing bike lanes and paths will be counted between May and October. The data from this count will be used to inform decisions about new facilities and decide the impact of investments (City of Toronto, 2010). Counts are performed on many city streets for example Jarvis Street and College Street and on pathways such as the waterfront Martin Goodman Trail. Figure 33 below shows some before and after counts on bicycle facilities.

Figure 33 Before and After Traffic Volumes for Selected Streets with Bicycle Lanes

		Motor Vehicle Traffic			Bicycle Traffic		
Facility	Installation Date	Before	After	% Change	Before	After	% Change
Davenport Road (North of Dupont Street)	May 1995	22 000	22 000	0%	600	850	42%
Gerrard Street (West of Sherbourne Street)	August 1995	18 000	18 000	0%	800	900	13%
Sherbourne Street (North of Gerrard Street)	September 1996	16 000	15 000	-6%	550	570	4%
Harbord Street (West of Bathurst Street)	August 1997	15 000	16 000	7%	1 100	1 500	36%
St. George Street (North of College Street)	August 1993	16 000	16 000	0%	1 500	1 650	10%
College Street (West of St. George Street)	October 1993	20 000	20 000	0%	1 450	1 900	31%
Average		17 800	17 800	0%	1 000	1 230	23%

Source: City of Toronto, 2001, p. 2-10

4.5.2.1 Automated Counts

Results of automated counts are published online for eleven locations. Automated counts are usually performed using pneumatic tubes. An example of a location for this is the bicycle lanes on Jarvis Street (City of Toronto, 2012), which staff have monitored since before their installation in July of 2010. Average bicycle volumes, vehicle volumes and vehicle travel times are given for the length of roadway between Charles Street East and Queen Street East both before and after the bicycle lanes were installed, as depicted in Figure 34. Possible explanations for the findings are displayed in a staff report (City of Toronto, 2011).

Figure 34 Jarvis Street Bike Lane Monitoring

Metric	Before (prior to July 2010)	After (June 2011)
Average volume both directions during peak 8 hours on a weekday	290	890
Average vehicle counts both directions during peak 8 hours on a weekday	~13 000	~13 000
Average vehicle travel times between Charles Street East and Queen Street East both directions on a weekday	6-8 min	Increase of approximately 2 min in both directions during am peak hour Increase of approximately 3-5 min in both directions during pm peak hour

Note. Much of the increased travel time could be attributed to the delays and queues experienced at the Jarvis Street/Gerrard Street East intersection, particularly in the northbound direction during the pm peak period. The introduction of an advanced left turn phase in the northbound direction at this intersection, scheduled this summer (2011), will reduce the delays at this intersection and the overall travel times between Queen Street East and Charles Street East.

Source: City of Toronto, 2011, p.17

Automated counts were performed on College Street in September of 2010 using an EcoCounter® brand counter. The counter is a pneumatic tube set out across the bicycle lane portion of the road. One limitation of the counter is that when compared to concurrent manual counts it was discovered that approximately 13% of cyclists chose to ride around the counter to avoid the tube. In the future, signage will be erected to inform and encourage cyclists to ride over the tube. Figures 35 through 38 depict some of the information that was collected (City of Toronto, 2010).

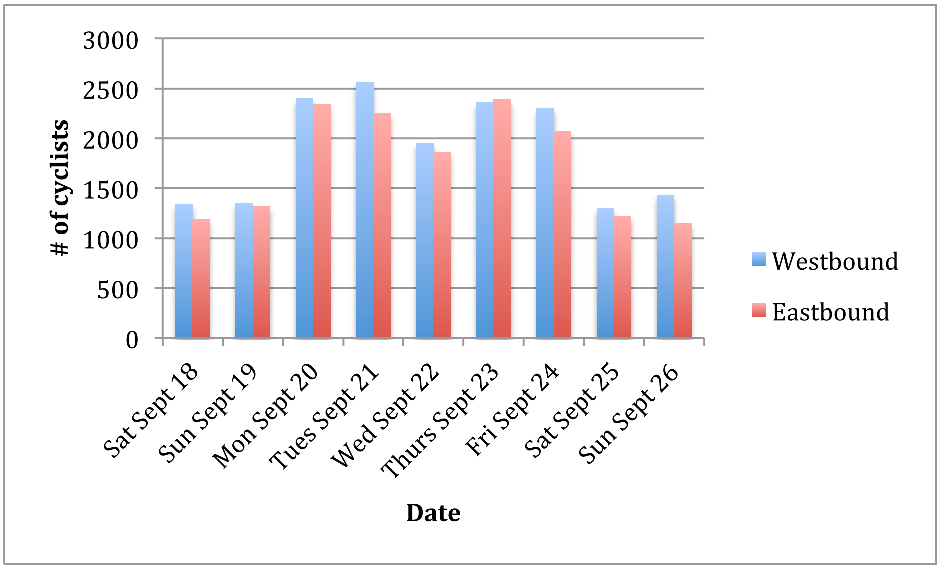
Figure 35 Bicycle Traffic Volume, College Street Auto-count at Spadina Avenue, September 18-26, 2010

Count Type	Bicycle Volume	Corrected Bicycle Volume (+13%)	
Weekday Eastbound Avg*	2,262	2,556	
Weekday Westbound Avg*	2,405	2,718	
			Volume Comparison to Dry Weekday
Saturday Eastbound Avg	1,205	1,362	53%
Saturday Westbound Avg	1,318	1,489	55%
Sunday Eastbound Avg	1,232	1,392	54%
Sunday Westbound Avg	1,391	1,572	58%
Rain Day Eastbound	1,861	2,103	82%
Rain Day Westbound	1,951	2,205	81%

*Average, excluding the rain day.

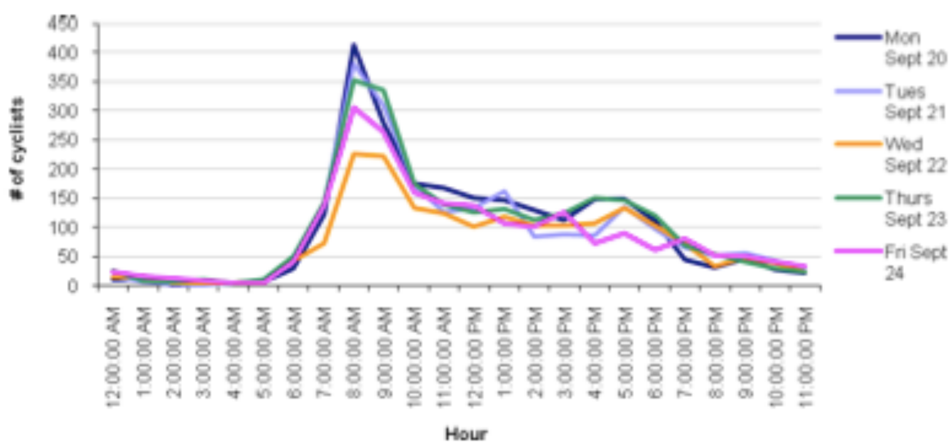
Source: City of Toronto, 2010, p. 13

Figure 36 Daily Bicycle Traffic, by Direction of Travel on the College Street Bike Lane



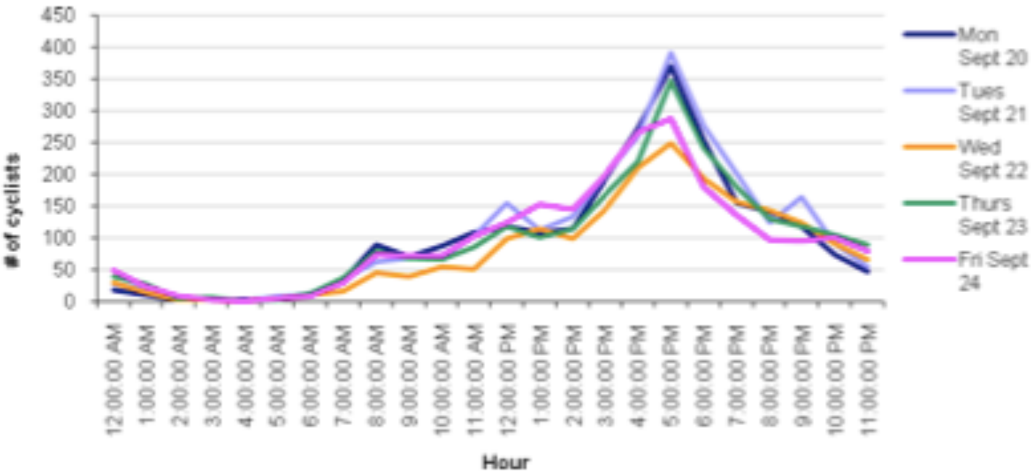
Source: City of Toronto, 2010, p. 13

Figure 37 Weekday Bicycle Volume by Hour, College Street Bike Lane Approaching Spadina Avenue, Eastbound (Inbound), September 20-24, 2010



Source: City of Toronto, 2010, p. 14

Figure 38 Weekday Bicycle Volume by Hour, College Street Bike Lane Approaching Spadina Avenue, Westbound (Outbound), September 20-24, 2010



Source: City of Toronto, 2010, p. 14

4.5.2.2 Manual Counts

Toronto uses manual counts, for example with their Screenline Bicycle Count. This count uses the four screenlines of Bloor Street, Spadina Avenue, Queen's Quay Boulevard and Jarvis Street, because they mostly separate commercial and institutional lands from residential (City of Toronto, 2010). The locations of the screenlines can be viewed in Figure 39 and Appendix U shows the bicycle counting locations.

Figure 39 Location of Bicycle Count Screenlines in the City of Toronto

Source: City of Toronto, 2010, p. 2

First performed in September of 2010, the screenline count uses NBPDP methods to collect information about demographics, cyclist volumes, where and at what time cyclist are riding, and whether they are obeying helmet and traffic laws. The data will be contributed to the NBPDP's database of bicycle count information (City of Toronto, 2010).

Figure 40 12-Hour Bicycle Traffic Volume (7:00 AM - 7:00 PM), by Screenline

Screenline	Inbound		Outbound		Total	
West (Spadina)	9,164	48%	6,469	42%	15,633	45%
North (Bloor)	3,598	19%	3,295	22%	6,893	20%
East (Jarvis)	5,723	30%	4,890	32%	10,613	31%
South (Queen's Quay)	676	4%	587	4%	1,263	4%
Total	19,162	100%	15,241	100%	34,403	100%

Source: City of Toronto, 2010, p. 6

Those counts that were conducted on a Monday or a Friday had a correction factor applied, which was determined by the observed difference in volume between a Monday/Friday and Tuesday to Thursday using automatic bicycle counter data from 1994 – 2008 (City of Toronto, 2010, pp. 4-5). In the future, this count will only occur on Tuesdays, Wednesdays and Thursdays to eliminate the need for a correction formula. The count will change to be an 18-hour count instead of a 12-hour count, which according to data collected by the College Street counter, will capture approximately 97% of bicycle traffic instead of 78% (City of Toronto, 2010).

Some of the data collected is displayed in Figures 40 and 41.

Figure 41 12-Hour Bicycle Traffic Volume (7:00 AM - 7:00 PM), by Bike Lane

Bike Lane	Screenline	Inbound	Outbound	Total	Share of Screenline Bicycle Traffic	Share of All Bicycle Traffic In/Out of the Core
College	West	2,647	2,075	**4,722**	30%	14%
Harbord	West	2,132	1,426	**3,558**	23%	10%
St George	North	1,106	1,156	**2,263**	33%	7%
Gerrard E	East	1,067	813	**1,880**	18%	5%
Wellesley	East	942	655	**1,597**	15%	5%
Shuter	East	407	305	**712**	7%	2%
Lower Simcoe	South	246	243	**489**	39%	1%
Yonge	South	109	108	**217**	17%	0.6%
Total (Bike Lanes Only)		8,657	6,782	**15,439**	-	45%

Source: City of Toronto, 2010, p. 8

Toronto expects to conduct this count at least every year, but ideally multiple times per year. One short-term priority is building permanent automated counting stations to provide continuous data for every hour of every day each year. For now the count is focused on roads in the downtown core, however Toronto will look to expand to pathways and roads in suburban areas (City of Toronto, 2010).

The final count studied is a central area cordon count conducted every two years (City of Toronto, 2001). The central area is defined as the area bounded by Bathurst Street, the Don River, the CPR line, Yonge Street, Rosedale Valley Road and Lake Ontario (City of Toronto, 2001).

4.5.3 GPS

There was no reference found to Toronto using GPS units to track cyclists.

4.5.4 Best Practice Assessment

Table 12 Toronto Best Practice Assessment Scores

Best Practice	Description	Score
1	State the goals of the monitoring program to identify clearly why it exists	2
2	Establish a system with routine monitoring where the same locations are used yearly	0
3	Collect data before and after projects are introduced	1
4	Collect data across a metropolitan area and separate results by categories like: Downtown, Universities, Urban Core, Suburban, Rural	0
5	Use automated counters	2

Best Practice	Description	Score
6	Keep up-to-date with technology and secure new equipment whenever possible	1
7	Collect as much data as possible and model efforts after existing motor vehicle counting systems	2
8	Assign a specific staff member to be in charge of monitoring projects	0
9	Use the data to prioritize which projects will be implemented	1
10	Publish results and have them readily accessible to the public and other agencies	2
Total		11

Toronto excels at Best Practices 1, 5, 7, and 10, receiving 2 points for each. The outlined goal of the Bike Plan's recommended data collection program is to monitor the Bike Plan's progress (City of Toronto, 2001) and guide decisions on programs, facilities, and investments to better encourage cycling (City of Toronto, 2009). Toronto currently uses automated counters on many streets, as mentioned in Best Practice 5, and will expand their counting program to include permanent automated counting stations downtown and suitable counters in suburban centres (City of Toronto, 2010).

Relevant to Best Practice 7, there are cases where bicycle volumes, vehicle volumes and vehicle travel times are measured together before and after bicycle lanes are introduced, for example on Jarvis Street (City of Toronto, 2011). Furthermore, bicycle counts are performed in coordination with vehicle counts during the bi-annual central area cordon count (City of Toronto, 2001). Information is readily accessible with reports and results available online. The City of Toronto's Open Data website provides current information and future counts will be added. Toronto benefits from application and analysis performed by members of the public who download the data (City of Toronto, 2010), as intended in Best Practice 10.

Toronto does moderately well at Best Practices 3, 6, and 9, receiving 1 point for each. Indeed, there are plans to perform a before count for all new bicycle lanes and paths and an after count one year after installation (City of Toronto, 2010). Past examples of this can be viewed in Figures 33 and 34. As bicycle lanes on Jarvis Street were removed in November of 2012 (as pictured in Figure 42), it is unclear whether this monitoring will continue.

Figure 42 Removal of bicycle lanes on Jarvis Street, Toronto

Source: http://torontoist.com/2012/11/jarvis-bike-lane-removal-proceeding-despite-technical-difficulties-and-an-arrest/javis-protest-day-two-1/

Toronto refers to using the data collection methods from the NBPDP and contributing data to their database (City of Toronto, 2010). They also plan to expand their use of automated counters, moving towards having them permanently installed in many locations downtown (City of Toronto, 2010). Additionally, there have been many advances in technology since the TTS was first conducted and as a result each survey methodology is slightly different as progress is made in the five years between surveys. The most recent, cost effective and reliable means of collecting large quantities of travel data is now a telephone interview with online Direct Data Entry and automated geocoding (Data Management Group, 2012).

Related to Best Practice 9, the Bike Plan calls for a data collection program that will help compile an annual list of priorities (City of Toronto, 2001) and assist in guiding decisions on program delivery, facility design and investment (City of Toronto, 2009), but no evidence has been found to suggest this has happened in the past.

Toronto does poorly at Best Practices 2, 4, and 8, receiving 0 points for each. For instance, the 2010 Bicycle Count Report states that a count will occur once every three years for all existing bicycle lanes and paths (City of Toronto, 2010). This is not frequent enough to be considered a best practice. The report also states that the Screenline Bicycle Count, however, should occur at least yearly, but ideally multiple times per year (City of Toronto, 2010). Toronto appears to be mostly in the phase of gathering baseline data and are not yet completing yearly counts.

As far as separating results by categories, Census data have been disaggregated to the point that staff know that the majority of commuting trips by bicycle occur in the downtown core (City of Toronto, 2010). TTS data are available at disaggregated levels such as by CT, traffic zone, planning district and individual municipality (Transportation Tomorrow, n.d.). The Toronto Cycling Survey in 1999 and 2009 broke down results into districts (City of Toronto, 2010), but no reference was found to separating Toronto results into categories like Downtown, Universities, Urban Core, Suburban, Rural, etc.

In relation to Best Practice 8, the Bike Plan recommends identifying which staff members will be responsible for the implementation of the plan (City of Toronto, 2001) however the contact given by the municipality did not respond to voice mails.

Total Score: 11/20.

4.5.5 Conclusion

Toronto uses many methods to monitor their cycling including counts and surveys. A variety of counting programs are used, including manual counts, screenline counts and counts with automated detection systems. Toronto refers to their own Toronto Cycling Survey and also the TTS, a survey that is a joint effort between 23 agencies in the GTHA and surrounding areas. Most of their data are fairly recent and Toronto has plans to expand their counting program in the future.

4.6 Summary of all cities

The summary of all cities indicates that overall, Canadian cities did not score well in comparison to the framework of best practices, scoring 35 out of 80. Out of a possible 20 points, Vancouver received a score of 12, Toronto received a score of 11, Calgary received a score of 9 and Halifax received a score of 3. The ordinal nature of this scale means that these numbers indicate a ranking, however the differences between the four cities are relative but not quantified. For example, Vancouver scored higher than Halifax by a factor of four, but this does not mean that Vancouver is four times better than Halifax. Vancouver merely received more points on best practice items relative to the optimum according to Hudson et al.'s (2010) framework. The best practice of *state the goals of the monitoring program to identify clearly why it exists* scored the highest, receiving 7 out of a possible 8 points from the four cities. This means that three cities are following the best practice and one city is somewhat following the best practice or has plans to follow the best practice in the future. The best practice of *assign a specific staff member to be in charge of monitoring projects* received 0 points, which means that no cities are following the best practice or have plans to follow the best practice in the future. To see how cities compare based on other measures, for example population, area, kilometers of infrastructure, and climate, please refer to Table 6 in Chapter 3. Table 13 tabulates the scores for all cities.

Table 13 Best Practice (BP) Assessment scores for all cities

City	BP 1	BP 2	BP 3	BP 4	BP 5	BP 6	BP 7	BP 8	BP 9	BP 10	Score (out of 20)
Vancouver	2	1	1	0	2	2	2	0	1	1	**12**
Halifax	1	0	0	0	0	0	1	0	0	1	**3**
Calgary	2	0	1	1	1	1	1	0	0	2	**9**
Toronto	2	0	1	0	2	1	2	0	1	2	**11**
Total	7	1	3	1	5	4	6	0	2	6	**35**

4.7 Results of the Census and TTS comparison

The 2006 results from the Census were compared to those from the TTS because with both, a percentage of people who bicycle to work in the GTHA can be calculated. For both surveys the data are available at the CT level. Table 14 shows these results.

Table 14 Results of the Census and TTS comparison

	Census BSWT data	TTS BSWT data	Census minus TTS	Census minus TTS absolute value	Census minus TTS percent difference	Census minus TTS absolute percent difference	Census minus TTS for non-zero CT	Census minus TTS for CT with greater Census	TTS minus Census for CT with greater TTS
n	1543	1377	1370	1370	1370	1370	1036	754	282
mean	1.18%	0.87%	0.40%	0.91%	74.06%	108.40%	0.53%	1.19%	1.24%
median	0.59%	0%	0.28%	0.59%	33.16%	104.50%	0.55%	0.82%	0.89%
standard deviation	1.97%	1.93%	1.42%	1.16%	119.77%	89.87%	1.62%	1.23%	1.12%
min	0%	0%	-6.32%	0%	-200%	0%	-6.32%	0.01%	6.32%
max	29.09%	18.31%	11.53%	11.53%	200%	200%	11.53%	11.53%	0.01%

range	29.09%	18.31%	17.85%	11.53%	400%	200%	17.85%	11.52%	6.32%

The results show that there are 166 more CTs that returned BSWT data from the Census than the TTS, as there were 1543 CTs with data values from the Census and 1377 CTs with data values from the TTS. There are 1370 CTs that return BSWT data from both the Census and the TTS, which shows that there are many cases of overlap, in fact all but 7 CTs that have a value for TTS BSWT have a value for Census BSWT as well.

When comparing the two surveys, the Census returns overall higher rates of cycling in the GTHA. Descriptive statistics reveal that the Census returns a mean BSWT of 1.18% and a median of 0.59%, while the TTS returns a mean of 0.87% and a median of 0%. The mean difference when the TTS BSWT is subtracted from the Census BSWT is 0.40% and the median is 0.28%. The mean being higher than the median indicates that there are many outliers for which the Census is much larger than the TTS. If all the CTs in which both surveys report a BSWT of 0% are taken out of the analysis, the mean difference when the TTS BSWT is subtracted from the Census BSWT for each CT is 0.53% and the median difference is 0.55%.

There are 754 CTs in which the Census BSWT is higher than the TTS and 282 CTs in which the TTS BSWT is higher than that of the Census. In the case of both surveys, the overall levels of bicycle commuting are low, however there are higher rates in the downtown. This is evidenced by the fact that in 333 CTs, both surveys report a BSWT of 0%, however in CT 5350002.00, 5350047.01, 5350055.00, 5350058.00 and 5350001.00, which are located in downtown Toronto, the Census and TTS both return a result between 12% and 29% respectively.

The null hypothesis was that the two surveys would find the same result for BSWT for each CT. The Paired Two Sample T-Test returned a t-obtained value of 10.39 and a t-critical value of 2.33, so the null hypothesis is rejected. There was a significant difference between the BSWT for the Census (M = 1.27, SD = 2.05) and the BSWT for the TTS (M = 0.87, SD = 1.93), $t(1369) = 10.39$, $p = 1.06 \times 10^{-24}$. The results of the BSWT from the Census (2006) and the BSWT from the TTS (2006) are significantly different at a 99% confidence level.

Graphs in Appendix T display the results visually. They comprise:

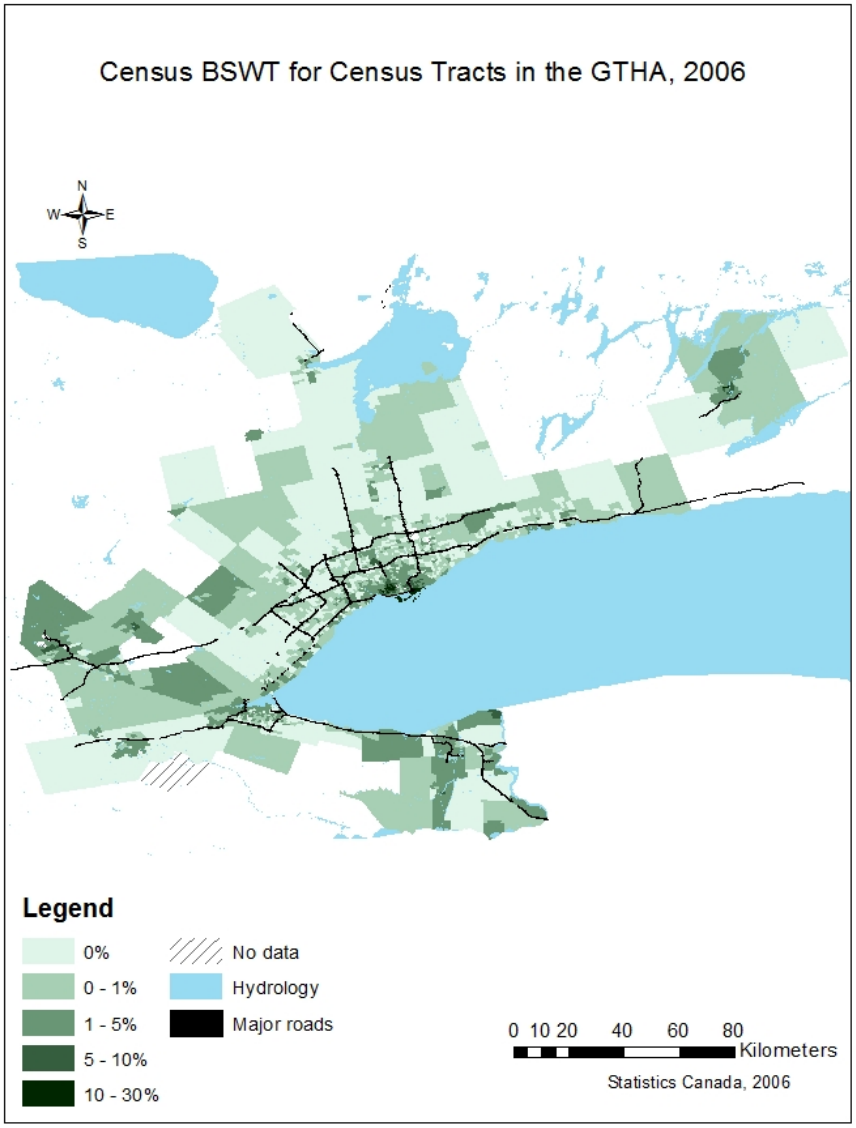
- Number of CT by Census BSWT;
- Number of CT by TTS BSWT;

- Number of CT by Census and TTS BSWT;
- Percent of CT by Census and TTS BSWT;
- TTS BSWT by Census BSWT for each CT;
- Number of CT by the difference Census BSWT – TTS BSWT;
- Number of CT by the absolute difference Census BSWT – TTS BSWT;
- Percent difference between Census BSWT and TTS BSWT for each CT; and
- Absolute percent difference between Census BSWT and TTS BSWT for each CT.

Figures 43 through 55 (Maps 1a through 6c) are visual representations of the Census and TTS results. In all cases, the maps labeled "a", (1a, 2a, 3a, etc.) show the entire GTHA, while the maps labeled "b" (1b, 2b, 3b, etc.) show a zoomed in version of Toronto's downtown core and its immediate area. The map labeled 6c shows an intermediate map, depicting the City of Toronto and a few of the municipalities that surround it.

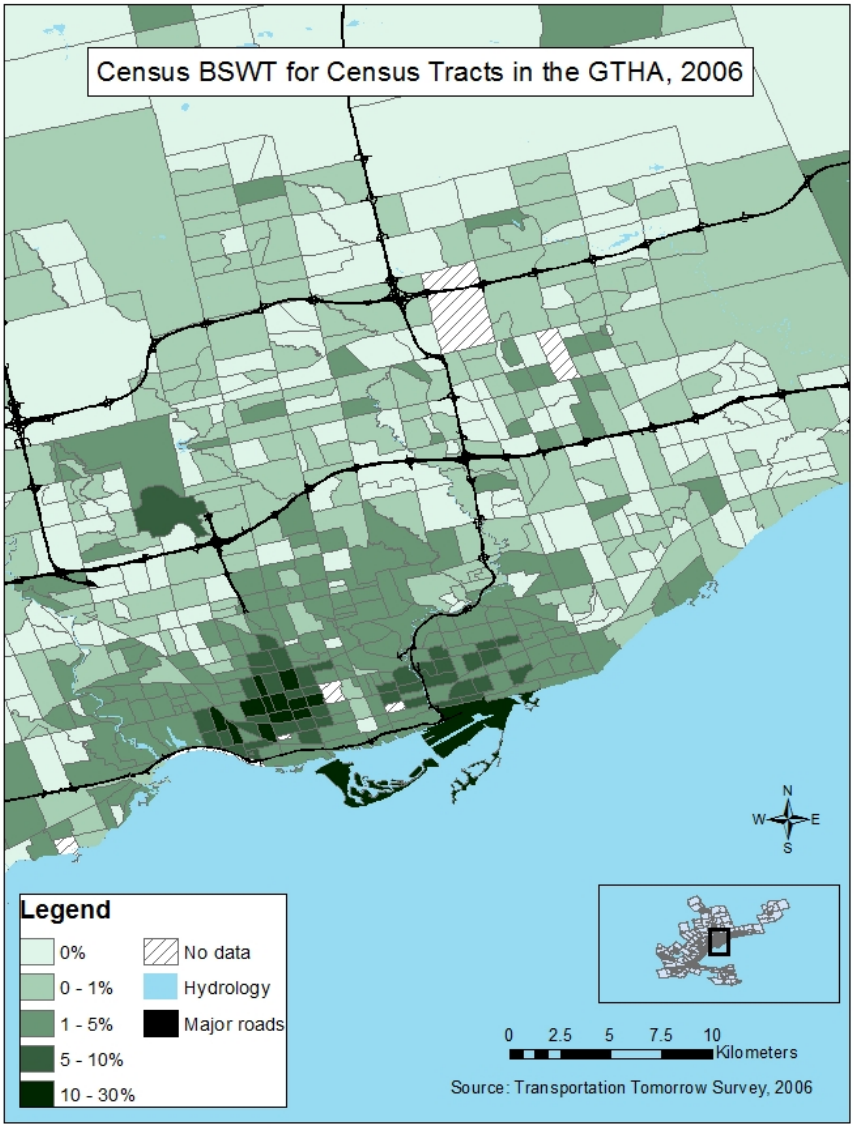
Figures 43 and 44 (Maps 1a and 1b) show the spatial pattern for BSWT according to the Census data and Figures 45 and 46 (Maps 2a and 2b) show the spatial pattern for the TTS data. Similar to the descriptive statistics, visually comparing these maps show it is clear that the Census returns a higher result for BSWT. It is also obvious that there are higher levels of cycling in areas with higher population density, for example in the downtowns, and fewer people cycling to work in the suburbs, as low as 0% in some areas.

Figure 43 Map 1a



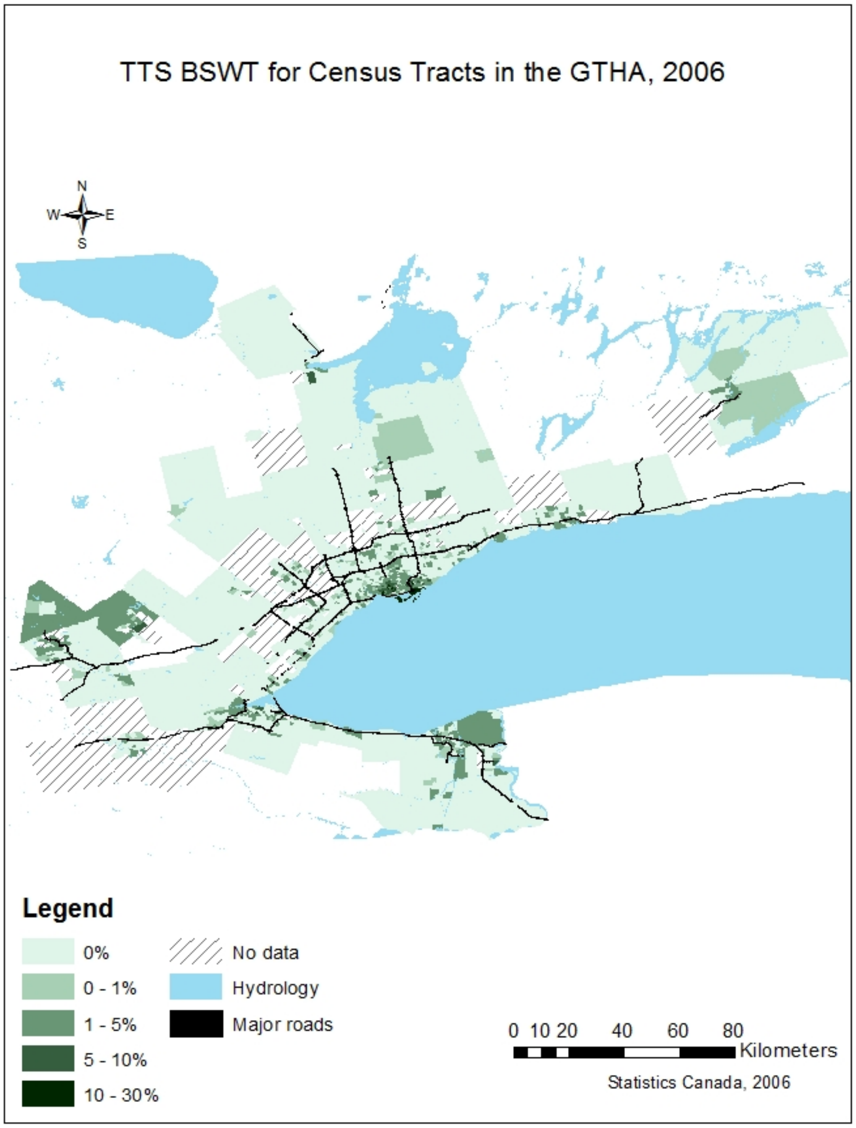
Source: Statistics Canada, 2008

Figure 44 Map 1b



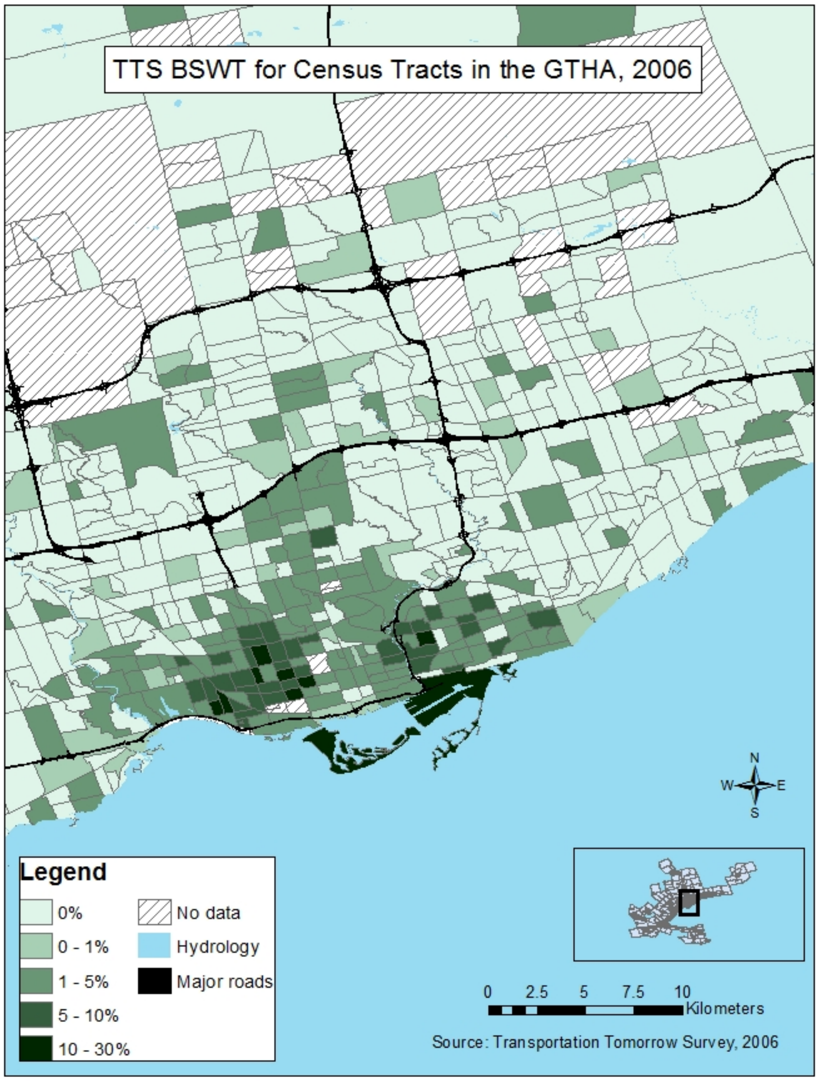
Source: Statistics Canada, 2008

Figure 45 Map 2a



Source: Transportation Tomorrow, n.d.

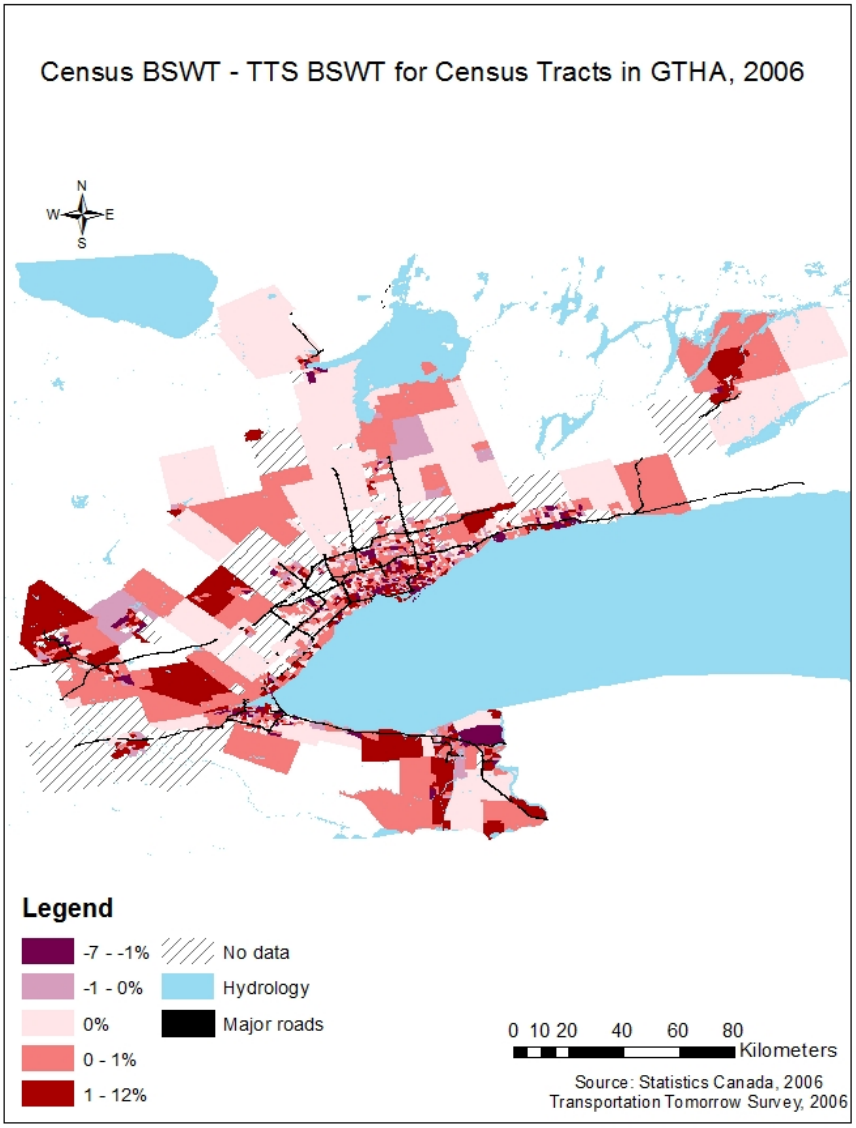
Figure 46 Map 2b



Source: Transportation Tomorrow, n.d.

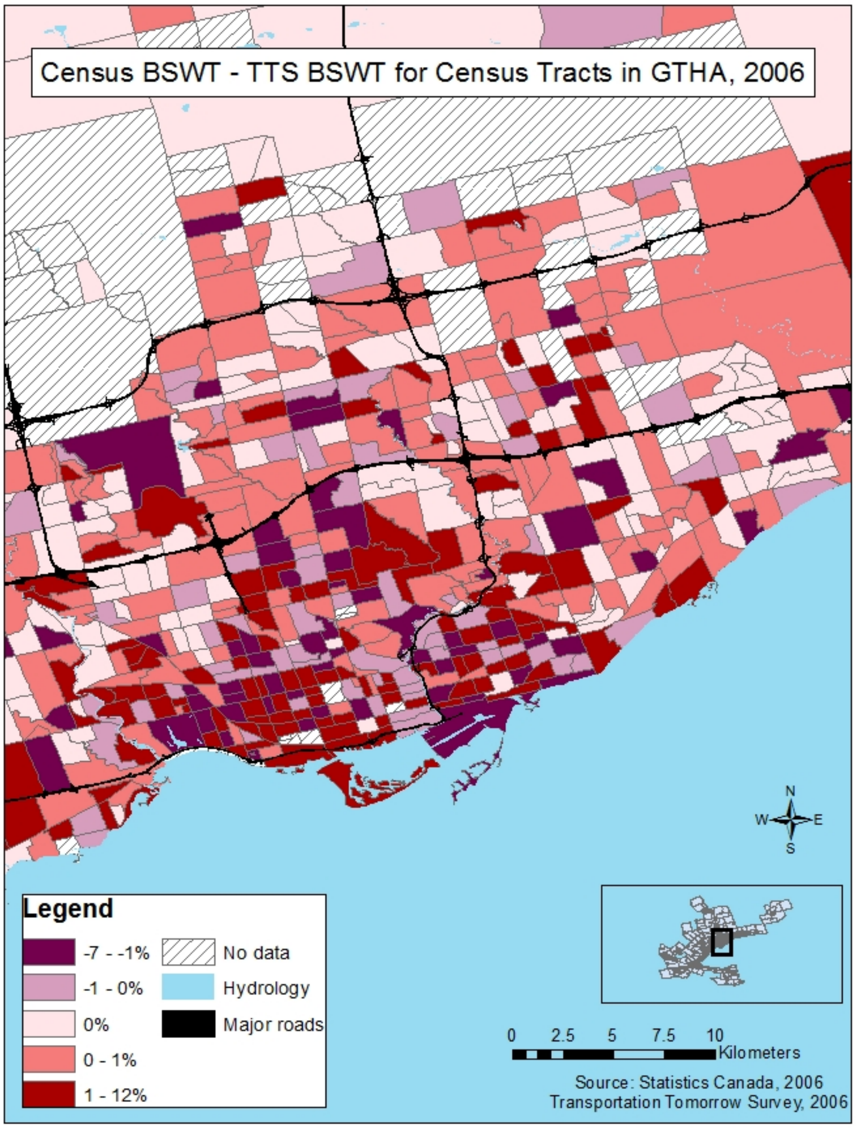
Figures 47 through 55 (Maps 3a through 6c) show the differences between the results of the Census and the TTS in various ways. Maps 3a and 3b show the difference, when the TTS BSWT is subtracted from the Census BSWT. Maps 4a and 4b show the absolute values when the TTS BSWT is subtracted from the Census BSWT. Maps 5a and 5b show the percent difference between the Census and the TTS for Census Tract BSWT. Maps 6a, 6b and 6c show the absolute percent difference between the Census and the TTS for CT BSWT. For the most part, there does not appear to be any spatial or structural pattern in the differences between the Census and the TTS. There does not appear to be a pattern for which CTs reported a higher BSWT from the Census and which CTs reported a higher BSWT from the TTS. However, for Maps 6b and 6c, there does appear to be a bit of a pattern where the downtown core is a light colour, signifying less difference between the Census and the TTS, the inner ring of Toronto suburbs is a darker colour, signifying a larger difference between the Census and the TTS, and the outer area of the GTA is generally lighter again, signifying a small difference between the Census and the TTS. The outlying municipalities of the GTHA, such as Guelph, Waterloo, Niagara, Brantford, etc. appear very dark.

Figure 47 Map 3a



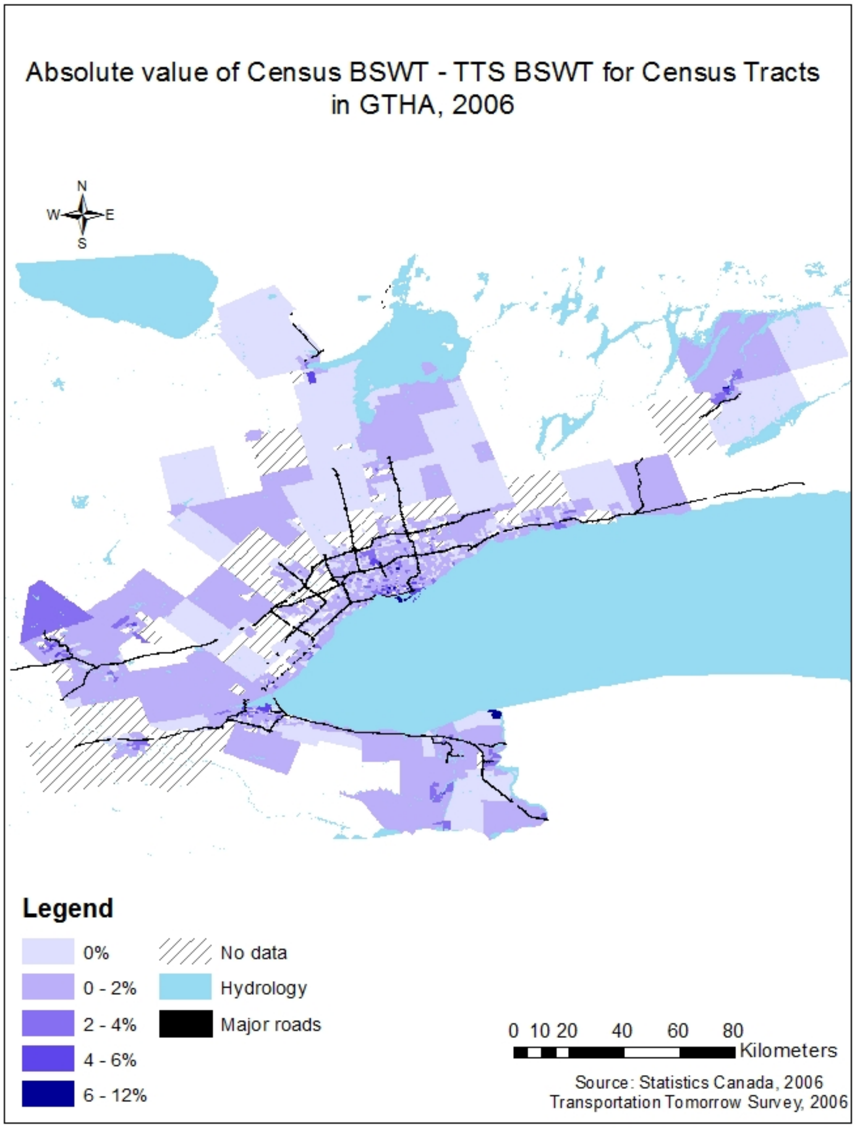
Source: Statistics Canada, 2008; Transportation Tomorrow, n.d.

Figure 48 Map 3b



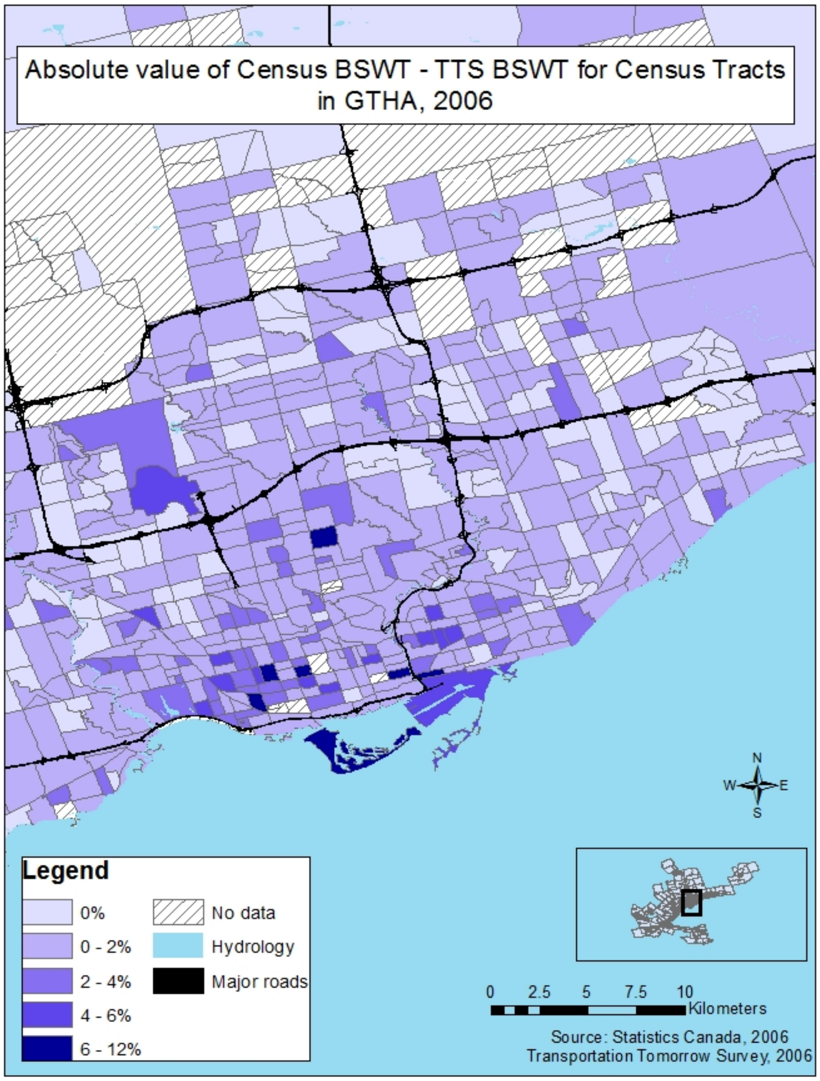
Source: Statistics Canada, 2008; Transportation Tomorrow, n.d.

Figure 49 Map 4a



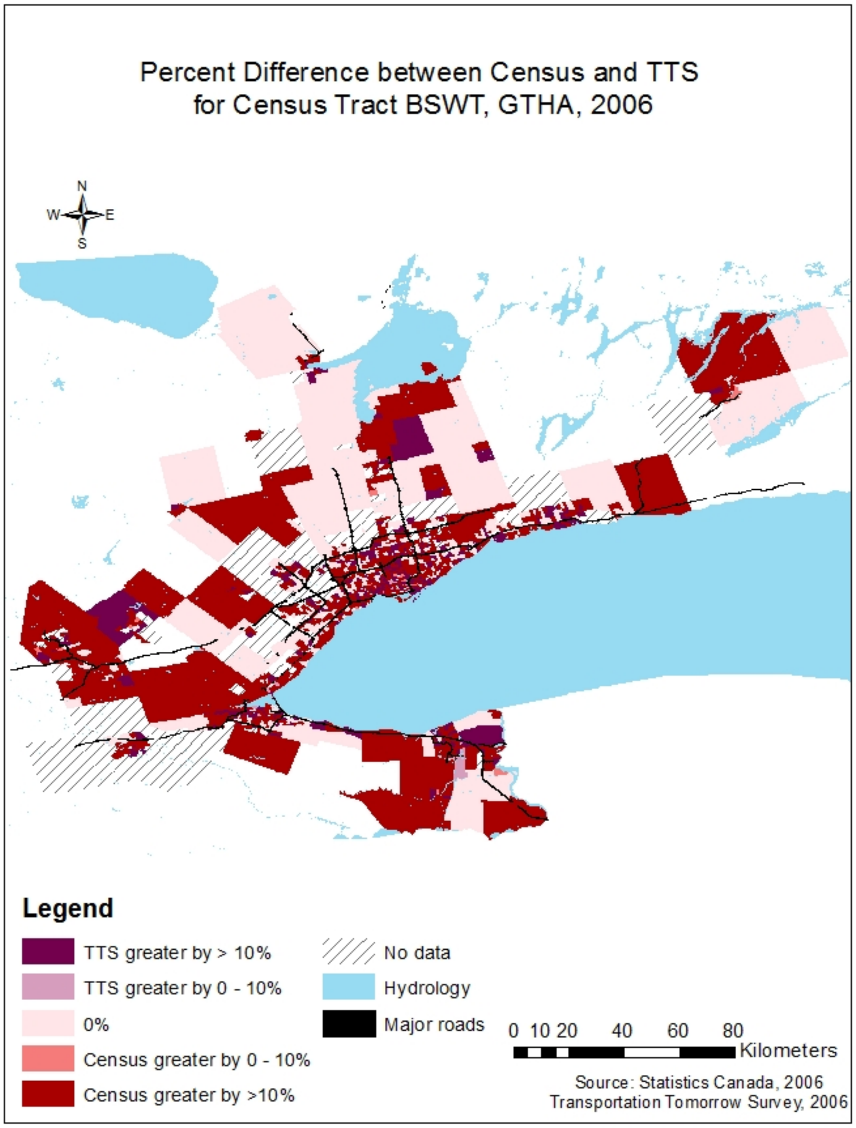
Source: Statistics Canada, 2008; Transportation Tomorrow, n.d.

Figure 50 Map 4b



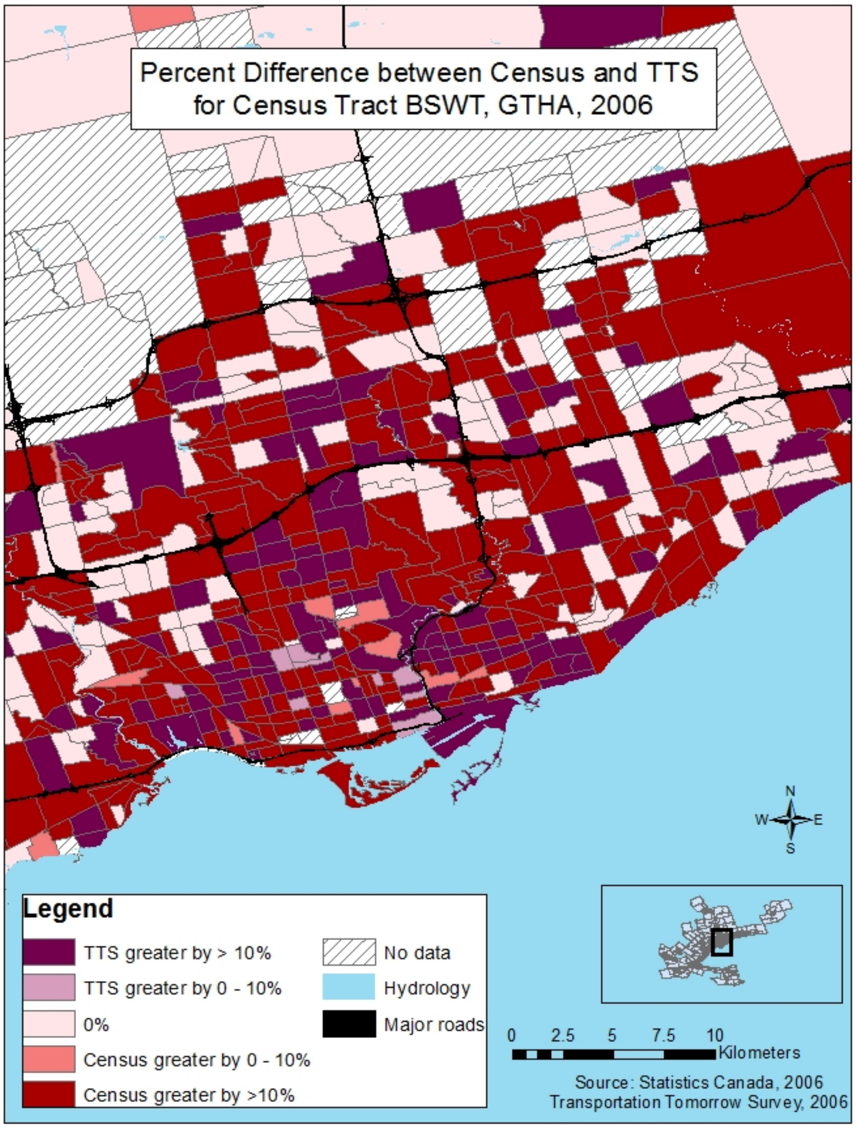
Source: Statistics Canada, 2008; Transportation Tomorrow, n.d.

Figure 51 Map 5a



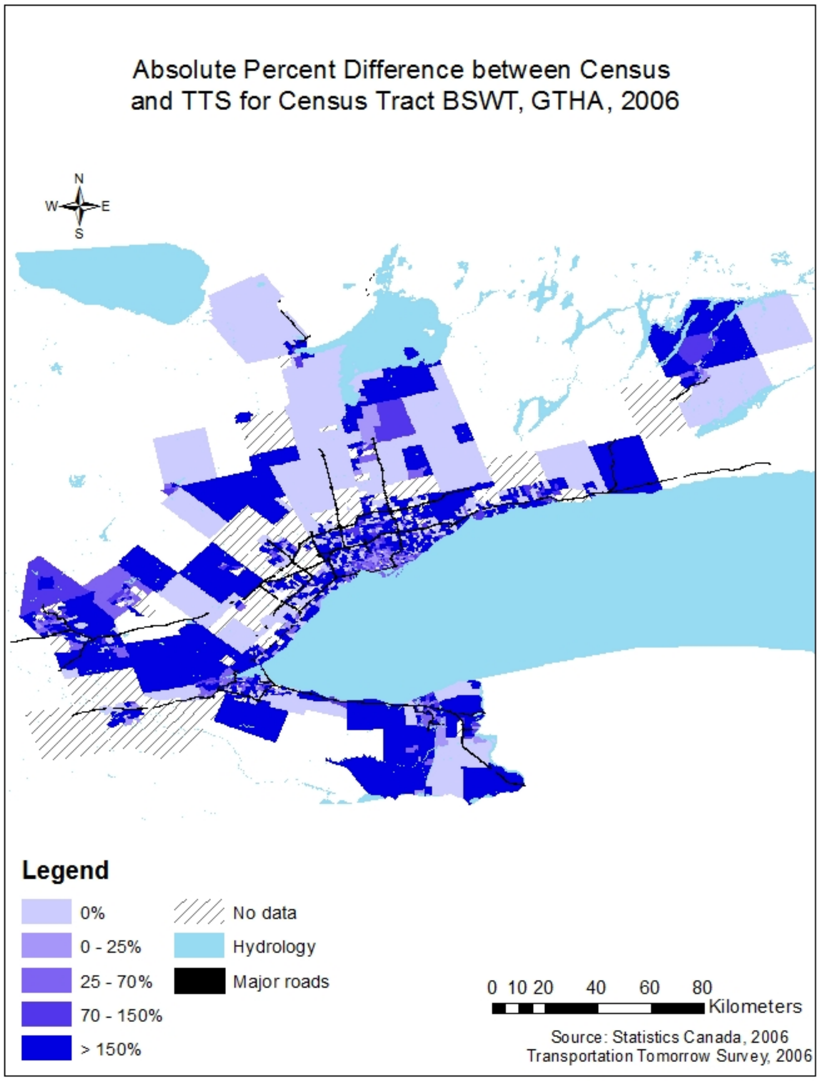
Source: Statistics Canada, 2008; Transportation Tomorrow, n.d.

Figure 52 Map 5b



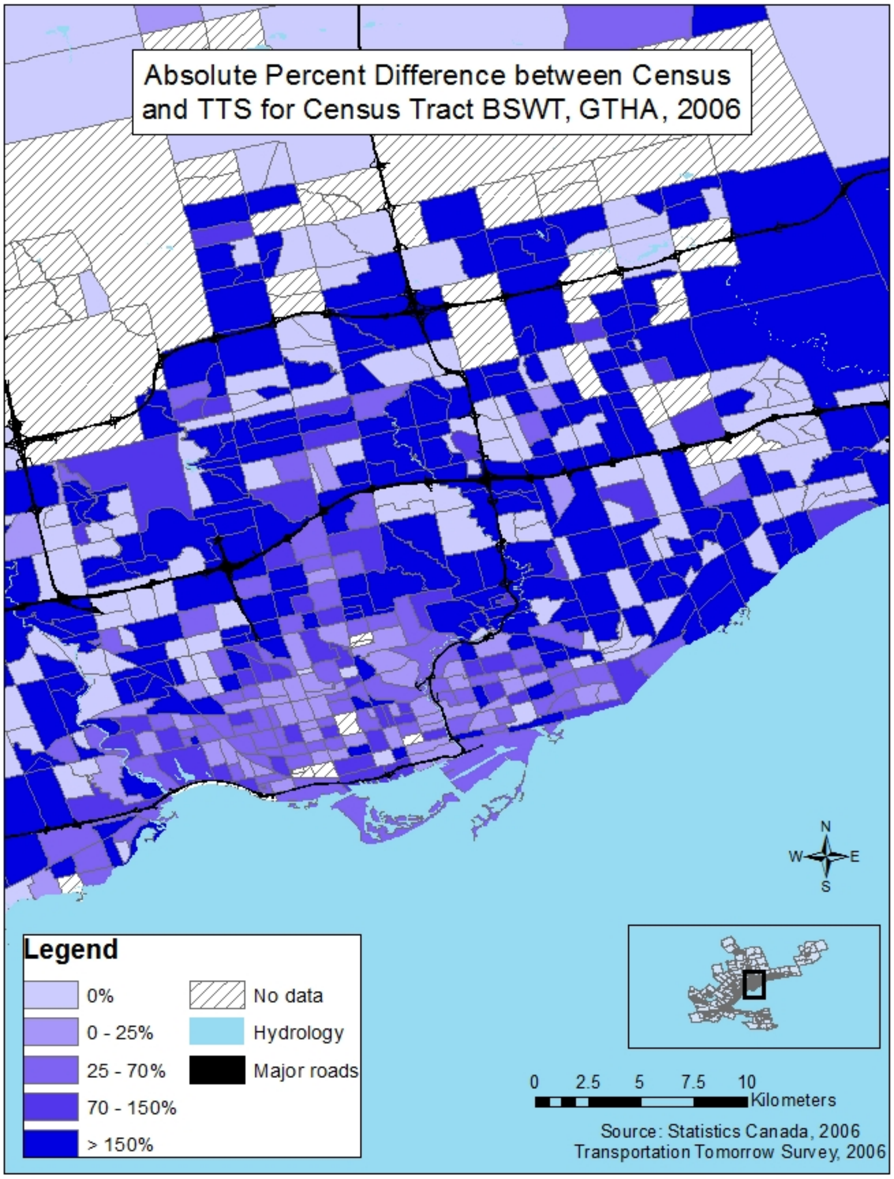
Source: Statistics Canada, 2008; Transportation Tomorrow, n.d.

Figure 53 Map 6a



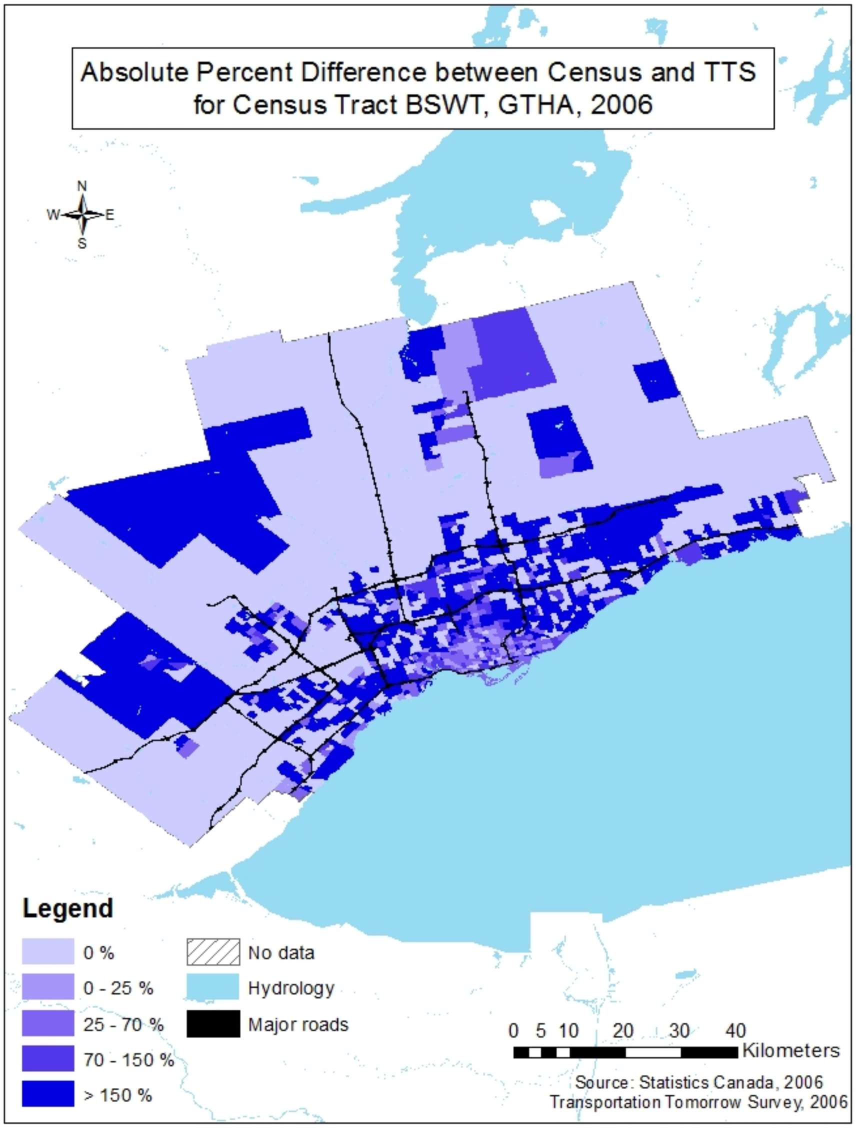
Source: Statistics Canada, 2008; Transportation Tomorrow, n.d.

Figure 54 Map 6b



Source: Statistics Canada, 2008; Transportation Tomorrow, n.d.

Figure 55 Map 6c



Source: Statistics Canada, 2008; Transportation Tomorrow, n.d.

Some thought was given to the range of BSWT that should be considered 0%, in practical terms. When anything under share of 0.1% is considered to be 0%, there are no CTs affected. However, there are 225 CTs affected if anything under a share of 0.5% is considered to be 0% for the Census, and 19 CTs affected if anything under a share of 0.5% is considered to be 0% for the TTS. When the TTS is subtracted from the Census, if any difference between -0.05 and 0.05% is considered to be 0%, 15 CTs are affected. If anything from -0.1 and 0.1% is considered to be 0%, 29 CTs are affected. If anything between -0.5 and 0.5% is considered to be 0%, there are 285 CTs affected. To enhance the ease of reading the maps, values between -0.05% and 0.05% are considered to be 0%.

In conclusion, the Census reports on average a higher percentage of people cycling to work than the TTS. There does not appear to be any spatial pattern to help predict in which CT the Census will return a higher BSWT and in which CT the TTS will return a higher BSWT. The maps do not provide much insight, however, when the percent difference is studied, a pattern does appear to emerge. These results are discussed in Section 5.4 of the thesis.

Chapter 5
Discussion

5.1 Introduction

This chapter discusses the results of the thesis. It begins with addressing the first research question by describing the general monitoring the case study cities perform, the trends and patterns found for survey and count methodology, and the evaluation of the case study cities. The second research question is addressed with a discussion of the Census and TTS comparison. The chapter concludes by tying the two research questions together.

5.2 Monitoring cycling in Canadian cities

Most of the methods mentioned in the literature are used in the cities studied. This indicates that Canadian cities are making use of the different methods available to them, although at varying levels. The section below will open by discussing Canadian cities' monitoring in a general sense.

5.2.1 General monitoring

The literature asserts that cycling and related plans must clearly state the need for monitoring and evaluation as well as outline the goals and objectives for a monitoring program. All of the cities studied have planning documents related to cycling. They have each recently published cycling plans, active transportation master plans, or transportation plans that emphasize monitoring and evaluation as key to improving cycling volumes, rates and networks. For example, an important part of Vancouver's Transportation 2040 Plan is to improve data collection, monitoring and modeling (City of Vancouver, 2012). As for Vancouver's other policy documents, monitoring to determine if targets are being achieved is mentioned as an important step in the bicycle planning process in the Downtown Transportation Plan from 2002, the Bicycle Plan from 1999 and the Transportation Plan from 1997 (City of Vancouver, 1997, 1999, 2012). Three of the four case study cities scored the maximum points for defining a clearly stated monitoring goal, with only Halifax scoring a 1 out of 2.

Although most documents state that plans and progress towards goals will be monitored, most cities do not appear to connect data collection with a systematic plan. It is generally unclear how the results of surveys and counts fit into the overall monitoring program. Many of the cycling, transportation and official plans state goals for improving cycling volumes and mode share, but few state how they will measure their success. Calgary's 2011 Cycling Strategy is one exception, as it clearly demonstrates how to track progress. It lists baseline numbers and targets as well as a data source for each indicator that will be used to measure cycling activity. The indicators and related information are displayed in Appendix P.

Although all cities mention monitoring as an essential step in the implementation of their active transportation, cycling, and official plans, some are vague about targets and how they will acquire information. An example is the *City of Toronto Bike Plan: Shifting Gears* which states that one of two Primary Goals is "to double the number of bicycle trips made in the City of Toronto, as a percentage of total trips by 2011" (City of Toronto, 2001, p. 3-1). It doesn't indicate the number or percentage of trips that are currently made by bicycle, how the goal will be measured or where the data will be obtained. Additionally, the wording of the goal is unclear. Halifax's ATP goals are also confusing. In the *Policy Recommendations* section it states the goal is to double the number of people that use active transportation in Halifax for a portion of their trips, with a focus on commuting trips. In the *Vision, Goals and Objectives* section the goal is stated to double the number of trips by active transportation modes, either for utilitarian or recreational/fitness purposes. The plan does not outline the current number of people who use active transportation or the number of trips made by active transportation modes. It does not state the target that must be reached or how it will be measured (HRM, 2006). It is important to produce clear, objective, measurable goals to track progress (Hudson et al., 2010).

One reason that Calgary has set numeric goals and outlined measurement methodology could be that their Cycling Strategy was produced in 2011, while Toronto's Bike Plan is from 2001 and Halifax's ATP is from 2006. Hopefully this means that Canadian municipalities are learning from past mistakes and defining goals more articulately as newer documents are produced. Indeed, Calgary has struggled with the implementation of its policies and plans in the past because there was "lack of clarity on how the plans should be implemented, misinterpretations around terms, processes or responsibilities, and even inability to demonstrate how progress is being achieved" (City of Calgary, 2010, p. 3).

It may be expected that smaller municipalities have less capacity to do monitoring, demonstrated in the comparison of Halifax to the bigger cities of Vancouver, Calgary and Toronto. Smaller municipalities often have difficulty with aspects of planning that do not produce short-term revenue like monitoring and evaluation. They may prioritize aspects of planning that provide substantial income like development and building permit approvals.

5.2.2 Surveys

Chapter 2 explains details about each survey type, with the inclusion of summary Tables 2 (page 36) and 5 (page 55). Chapter 4 reviewed the survey methods being used in the case study cities: general surveys, household travel surveys or travel diaries, and Census journey to work data. An example of a city using general surveys is Toronto with the 1999 and 2009 Toronto Cycling Survey and Calgary with the Pathwatch series of surveys. Examples of household travel surveys or travel diaries are the TTS in Toronto and TransLink's Trip Diaries in Vancouver. All of the cities studied use the journey to work data from the Census. Examples of this are in Halifax's bicycle plan (HRM, 2002), which can be viewed in Appendix V and in a Vancouver administrative report to the Standing Committee on Transportation and Traffic called *2008/2009 Cycling Statistics Update* (City of Vancouver, 2009), which can be seen in Figure 20. Calgary performs a civic census, which includes a question about journey to work every three years.

The most common survey used is the journey to work data from Statistics Canada's Census. This is probably because it is available online free of charge and it is conducted for all 33 CMAs in Canada. It has a large sample size and provides information about worker commutes. This is important to cities because of the social, environmental and economic benefits provided by a workforce with an efficient commute and because the commuting times of day, or peak periods, are often those with the most traffic congestion problems. If using the Census data, the municipalities don't need to use their own resources to develop and conduct a survey. The attributes listed in Tables 2 and 5 likely explain why it is well-used: the low cost, large geographic scope and availability of demographic data to examine what factors are correlated with cycling use. Municipalities seem to agree this compensates for the negatives, which are the lack of volume, route or opinion data and the small time scale. The data are best used to find out about the mode citizens use to travel to work and make comparisons across the entire country.

The second most commonly used method was general survey. Halifax, Calgary and Toronto use this method. The only evidence found of Vancouver conducting their own survey was a non-empirical opinion poll, however reference was found to the Greater Vancouver Regional District (GVRD) conducting surveys. Survey data can be expensive to collect and it is possible that Vancouver has decided that their demographics are closely matched to the rest of Canada and the GVRD and a survey of the City of Vancouver would produce similar results. Other cities have found similar results to GVRD as well, for example in terms of cyclist typology, a survey of residents in Calgary found that 22% were fearless or confident cyclists, 51% were interested cyclists and 28% were reluctant cyclists (City of Calgary, 2011), while 25% of residents are regular cyclists, 41% of residents are interested but concerned cyclists, and 34%

of residents are not interested in cycling in the GVRD (TransLink, 2011). In fact, there appears to be some parity across the country, as a *National Survey on Active Transportation* by Go for Green and the Canadian Fitness and Lifestyle Research Institute found that 66% of Canadians would like to cycle more than they presently do, while in Calgary the survey conducted in preparation for their 2011 Cycling Strategy found that 59% of Calgarians would like to cycle more than they do now (City of Calgary, 2011). The Halifax Bike Plan (HRM, 2002) uses the national survey data frequently when discussing Halifax's cycling potential. Another example of consistency in the Canadian population is the Census data, which, in practical terms, show little variation across the country. With the exclusion of Victoria, who has a BSWT of 5.65%, all other Canadian CMA fall within the range of 0.29% and 2.43% (Statistics Canada, 2009). When compared to the share of users for other modes, this is not a lot of cyclists for any city.

Of note, related to Vancouver's poll on Hornby Street, Figure 19 reports a decrease in cycling after the separated bicycle lanes were introduced. This is important because as discussed in the literature review, cities can be adverse to monitoring and evaluation due to the potential for imperfect or unimpressive results (Krizek et al., 2009). The publication of these results shows a brave and unbiased statement by the City of Vancouver. This can also be witnessed in a 2013 update to their separated bicycle lane statistics, found in Appendix H, which shows both positive and negative results.

The least commonly used method was the household travel survey or travel diary method. These surveys are only used in the case of multiple municipalities cooperating to collect data, for example with TransLink and the TTS. These surveys are probably not deployed by individual municipalities due to lack of funding and resources, as travel diary style data can be expensive to collect.

Tables 2 and 5 show that general surveys and household travel surveys have the potential for a large geographic scope and the ability to collect route, demographic and opinion data. They cannot, however, collect volume data and their time scale is small. The cost for a survey depends on the type, but is normally expensive, especially with household travel survey data. Both the general type and the household travel surveys are rich data sources that collect plenty of information about cyclists' behaviours, opinions, demographics and travel patterns. The surveys have varying methodologies; some are intercept, some are web-based and still others call people at home. Interestingly, surveys are not mentioned at all in Hudson et al.'s (2010) best practices.

It is difficult to compare how frequently the cities perform surveys, because most are not consistent. In the case of surveys, Vancouver has not performed a survey, Halifax has only performed one, Toronto has performed two that were ten years apart and Calgary has performed numerous surveys at various time intervals.

An important consideration when doing surveys is that socio-economic factors may play a role in who participates. Households with low income, little time, or difficulty communicating in English may be underrepresented. Effort should be made to ensure these households have the opportunity to be involved in the survey. Call centres should be staffed with employees who can speak common foreign languages so that residents with poor English skills can participate. Spatial distribution checks can be conducted to monitor whether citizens from all areas of the city are involved. Efforts should also be made to ensure all age groups are represented and the study's overall benefit to the city should be emphasized to participants (City of Calgary, 2002).

5.2.3 Counts

The count methods that are being used in Canadian cities vary either by methodology or by technology. The methodology types reviewed here are: cordon count; screenline count; samples of multiple locations; counts of bicycle parking stations; and bicycle registration and licensing programs. Advantages and disadvantages of these are listed in Table 3 of Chapter 2 (page 43), while general characteristics can be found in Table 5. After the methodology discussion, technology types are reviewed.

The only city that appears to do a cordon count is Toronto as detailed in Section 4.5.2.2 and illustrated in Figure 39 and Appendix U (City of Toronto, 2010). Although some reference was made to cordon counts in Vancouver, the research for this thesis did not locate a true example of a count with a defined cordon. This might be because these counts are resource intensive, as there must be a counter set up at all of the cordon's access points. The cordon count can collect volume data, acquire basic demographic data and have low cost, particularly if volunteers are used to count. The geographic scope and the time scale are typically small and there are no route or opinion data collected. They are normally used to determine how many people are travelling by bicycle to a particular attraction like a downtown or a university.

The best example of a city with a screenline count is the PSBC in Halifax, where every cyclist who crosses Cogswell Street or Quinpool Road is counted. This is possible in Halifax because the city's downtown is located on a peninsula and the majority of residents cannot access downtown except by crossing this screenline (see Appendix J). The other cities do not perform such strict screenline counts possibly because they may not have the same convenient layout and like the cordon count, it is very resource intensive to set up a counter at every screenline crossing point. Relative to other methods, screenline counts have a small geographic scope, they can collect volume data and basic demographic data, and in theory they can have low cost. They cannot collect route data or opinion data and they have a small time scale. They are mostly used to determine how many cyclists cross from one end of the city to the other, often from areas of residential neighbourhoods to primarily commercial, institutional and employment areas.

All of the cities perform counts at a sample of locations. Some examples of these are the automated counters set up at eleven different locations in Toronto or the Pathwatch counts in Calgary, which occur at anywhere between 12 and 39 stations, depending on the year. The sample at multiple locations has small geographic scope, the time scale is small and it does not collect route data or opinion data. Volume and basic demographic data can be collected and the cost is generally low, particularly if volunteers are used. As for counting the number of bicycles parked at parking stations, in Calgary, they periodically conduct counts of the municipal bike cage to estimate how many people are cycling to work. An example of a bicycle licensing or registration program is a program in Calgary that was deregulated in 1982. These types are best used to get a general sense of how many people are cycling in the city. Cites may want to collect this information before undertaking specialized projects.

The technology types reviewed by this thesis are: manual counts; manual counts with interviews; passive infrared sensors; active infrared sensors; video and computer imaging; pneumatic tubes; and inductive loop detectors. Also discussed is summarizing the results of multiple counts. Advantages and disadvantages of each technology are found in Table 4 of Chapter 2 (page 51), while their attributes are summarized in Table 5.

All cities are performing manual counts, for example in Halifax with the PSBC and in Calgary with the Pathwatch program. In Vancouver and Toronto, manual counts are used to validate their automatic technology for example on College Street in Toronto. An example of the manual count with interview is in Calgary for the Downtown Commuter Cyclist Surveys. Vancouver is an example of a city that uses passive infrared sensors. There were no examples of case study cities using active infrared sensors or computer and video imaging. Cities that use pneumatic tubes are Toronto on Jarvis Street and Vancouver on Hornby and Dunsmuir Streets. Burrard Bridge in Vancouver utilizes inductive loop detectors, as pictured in Figure 22. In their research, Hudson et al. found infrared counters are the most commonly used automated counters (Hudson et al., 2010). Conversely, this thesis found that pneumatic tubes, particularly of the EcoCounter® variety, are the most commonly used automated technology.

The most common method of counting cyclists found is manual counts. This is probably because they do not require the purchase of any equipment, advanced knowledge of technology, or the resources to develop, administer and analyze a survey. Manual counts can be performed at no cost in some cases, for example in Halifax where municipal staff, municipal councilors and engaged citizens volunteer to count. Manual counts are informative about cycling patterns in the city. Indeed some sources, for example Transport Canada, assert that manual counters are more reliable than automatic counters and this could be the reason that so many cities are using them (Transport Canada, 2011). The research by Hudson et al. (2010), which indicates that manual counts were the most commonly used method to count cyclists, is consistent with the research in this thesis, as all four case studies use manual counts. Manual counts have a small geographic scope and a small time frame. They are low cost and can collect volume data and basic demographic data. They cannot collect route or opinion data. They are useful when count data are desired for a few locations around the city, or to see general patterns, which is probably one of the reasons they are popular.

Only two cities, Vancouver and Toronto, are using automated counters. Although Vancouver is using loop detectors as well, both cities are using the EcoCounter® brand pneumatic tubes. This corresponds to the literature because Hudson et al. (2010) found EcoCounter® to be the best model of automated counter. EcoCounter® is also the brand that the NBPDP recommends. Hudson et al. (2010) found that automated counters were less commonly used than manual; only five of their eleven case studies use them. This thesis found that two of four case studies use automated devices, which is consistent with Hudson et al.'s (2010) findings that approximately half of cities are using them.

Some technologies are not being used at all. There was no evidence found of cities using active infrared sensors or computer and video imaging. These technologies may be cost-prohibitive either in general or given their disadvantages, for example with active infrared sensors, a difficulty differentiating between types of users on shared facilities, their need for both a transmitter and a receiver, their inability to determine the direction of travel, their susceptibility to extreme weather events, and the ease with which they can be subjected to tampering and vandalism (Lindsey et al., 2012). Some of the difficulties with computer and video imaging are that equipment is expensive and data processing requires significant time and labour investment.

In general, automated detection systems have a small geographic scope and a large time scale. They are best used for collecting a lot of data over a long period of time, however only for a small number of sites (as many as the municipality can afford). With the exception of the video and computer imaging equipment, the devices cannot collect data about unusual behaviour, subtle nuances, or whether cyclists are obeying the rules of the road. Vandalism or extreme weather events can interfere with the machines. They are expensive to buy ($1000 - $10 000 per machine), which probably explains why they are only used by two of four case study municipalities. The other municipalities may simply not have the funding to buy them, or may think it is not worth the expense for a localized device that does not collect route data, demographic or opinion data.

This thesis was unable to locate an example of a city synthesizing the results of multiple different types of counts. The closest example is a list of policies, plans and surveys related to cycling from Calgary's 2011 Cycling Strategy, depicted in Appendix O. This could be because it is difficult to put together data collected through different methods that are not easily comparable. An example of this comes from the literature. Some researchers have found that complete and comparable statistics from Canadian municipalities do not exist (Pucher & Buehler, 2006a) and that comparing the results of individual studies is unwise because they are so different in design, methodology and timing (Pucher & Buehler, 2006b). Alta Planning and Design states that with all the organizations across North America monitoring cycling with inconsistent approaches, it is hard to compare different cities and find patterns in the results of studies that are produced (APD & ITE PBC, 2012). With that being said, Calgary's Mobility Monitor does produce a comprehensive summary with data from different sources, complete with an explanation of the pros and cons of each. A report called *Commuter Cycling in Calgary* combines data from Downtown Cordon Count programs, the cage bicycle count, the Downtown Commuter Cyclist Survey, Calgary's civic census, and Statistics Canada (City of Calgary, 2009). Other cities may not be comparing because of the difficulties involved. Indeed, Calgary states the inherent limitations in their report.

It is also difficult to assess whether frequencies of counts are the same, because the cities are fairly sporadic with their efforts. Some cities will count yearly for period of time, then skip three years, then return to yearly counts. Others will count at inconsistent intervals, for example alternating anywhere between four, five or six years between counts. A third example of counts that are difficult to compare are cities who have been consistently counting semi-annually but this has only been ongoing for two years.

In conclusion, manual counts are used the most, probably because they are inexpensive and give a general idea of cycling levels. Since most municipalities appear to be in the beginning stages of a monitoring program, this may be all they need at this time. The high cost of surveys and automated detection systems are probably prohibiting municipalities from using them, particularly because they lack short-term monetary benefits. Manual counts also have the benefit of collecting basic demographic information about gender and other statistics.

5.2.4 GPS

There were no case study cities found using GPS to monitor their cyclists. This is probably because in the recent past, they required a lot of maintenance and were costly and awkward (Krizek et al., 2009). They also produce a specific type of information; only when a city is looking for extremely detailed information about routes, timing and speeds of cyclists is a GPS unit useful. Since most cities are only beginning monitoring programs, they may be more interested in general data about cycling patterns.

In recent years the technology has improved; they are more user-friendly and not as large. Following the insight gained from a successful study by Casello et al. (2011), GPS units may be used more frequently in cycling research. As cities collect more cycling data, the level of detail provided by the GPS unit may be appealing. They may be suitable if cities are encountering difficulties with a self-reporting bias in surveys or if counts are not providing enough origin, destination, travel time and route data.

5.2.5 Case study assessment

The literature review suggests cities are challenged in terms of monitoring cycling. This statement is largely supported by the research conducted on the four case study cities for this thesis and by the comparison to the list of best practices by Hudson et al. (2010). These best practices are shown in Table 8 in Chapter 3.

The best practices assessment summary can be found in Table 13 of Section 4.6. The highest scores received were 12/20 and 11/20, obtained by Vancouver and Toronto respectively. Halifax received the lowest score, a 3/20, and Calgary received a 9/20. The highest scoring cities only received full points for four of the best practices, while Halifax did not receive a full score for any of the items. Halifax received 0 points for seven of the items, while Vancouver received 0 points for two best practices. To see how the cities compare based on other metrics, for example kilometers of bicycle lanes per capita, please refer to Table 6 in Chapter 3.

Halifax and Calgary appear to be planning to monitor cycling in the future, but have not conducted a lot of monitoring or launched full monitoring programs thus far. Calgary received a score of 1 out of 2 for five of the items because they have future plans related to the best practice. This shows their initiative in moving towards developing a comprehensive monitoring program. Halifax is still talking about the future in more vague and undefined terms.

Toronto and Vancouver are prioritizing their cycling monitoring and investing more time and resources. For example, they have each conducted counts in many locations over the years and have used automated counters. Their cycling plans talk clearly about the amount of funding that will be allocated and what the money will be used for. Both cities advocate for and have used the NBPDP standards.

Calgary and Toronto do an excellent job of publishing the results of their counts and surveys; Vancouver has done this in the past but reports are now difficult to locate due to website restructuring. Municipal staff in Halifax will share results of their monitoring if requested, but they are not readily accessible online.

The best practice that was most commonly followed was *state the goal of the monitoring program to identify clearly why it exists*. Three cities received 2 points for this best practice and one received 1 point, for a total of 7 points distributed. This is probably because stating a goal is fairly easy in comparison to actually delivering an objective. Stating the goal does not require much capital investment, time or resources, beyond the research needed to come up with an objective, achievable and measureable goal.

Most cities have the goal written in their Bike Plan or Cycling Strategy. This is great, because without a long-term vision and strategy, it will be difficult to achieve a notable change in the number and share of people who are cycling (Tight et al., 2011). Transport Canada stresses that cities must clarify everything including objectives and indicators. Cities can only discern whether the bicycle program or facility is having the desired effect on cycling if indicators are clearly measurable. The definition of success and failure must be clear at the beginning of the study (Transport Canada, 2011). Calgary is the most advanced at this (see Appendices N and P) and the other cities still have much progress to make in stating direct metrics, baselines, targets and sources.

The two best practices: *collect as much data as possible and model efforts after existing motor vehicle counting systems* and *publish results and have them readily accessible to the public and other agencies* are the next most commonly followed, each receiving 6 points in total from the four case study municipalities. The former may score generously due to its ambiguity. It is difficult to determine how much exactly constitutes "as much as possible". Cities were given a full score if they appeared to be making a reasonable attempt at collecting data somewhat often. As far as modeling counts after existing motor vehicle, cities were given a full score if they mention that they collect vehicle volume figures at the same time as bicycle or if they mention comparing numbers of vehicles to numbers of cyclists. This is a difficult best practice to score and cities were often given the benefit of the doubt here. The best practice about publishing results probably scores highly because most municipalities simply post their reports on their website. This is not hard or expensive to do in comparison to some other best practices.

The least commonly followed best practice was: *assign a specific staff member to be in charge of monitoring projects*. This could be simply that the staff member's contact information is not available or that it is not in the responsible person's job description, even though this is one of their duties. After attempting to contact all four case study cities, Toronto, Halifax and Calgary responded with the name and phone number of a staff member to contact for information about projects related to monitoring cycling. When the Halifax staff member was reached, she was unsure of who is in charge of monitoring projects, but thought it might be her. The Calgary staff member stated that there is not a staff position responsible for the management and collection of bicycle data specifically. Recommendation #17 of the 2000 Calgary Pathway & Bikeway Plan Report and #40 of the 1996 Calgary Cycle Plan (page 90) mention hiring staff members for whom monitoring and evaluation will be a responsibility, however as of 2012, this has yet to be accomplished. The Toronto staff member did not respond to voice messages. Vancouver did not respond to the request for contact information. The reason this best practice is not commonly followed could be that municipalities are not aware they should have a staff member responsible for monitoring or they do not have available funding to hire someone for this purpose. Perhaps they feel a team effort is more effective than having one staff member responsible. Existing employees may be unable to perform monitoring or respond to inquiries because they are over-worked with other more pressing duties.

The second least commonly followed best practices were *establish a system with routine monitoring where the same locations are used yearly*; *collect data from across a metropolitan area and separate results by categories like: Downtown, Universities, Urban Core, Suburban, Rural* and *use the data to prioritize which projects will be implemented*. Each of these received 1 point, so in each case one municipality is partially following the practice or has plans to follow it in the future.

For *establish a system with routine monitoring where the same locations are used yearly*, it could be that cities do not have the funds to invest in a monitoring program with a yearly commitment. Most of the cities are monitoring somewhat sporadically and have not laid out official plans to collect data in the same locations every year. A rotating schedule of locations, as illustrated in Step 6 of Appendix C, would probably be considered appropriate in most cases. Calgary appears to be doing something that resembles this approach with their Pathwatch series, however the timing and rotation of locations is inconsistent, as noted in Section 4.4.1.6. Vancouver, in some cases, is going above and beyond annual counts: as of September 2012 the duration of time for which some locations were measured continuously with daily totals ranged from 21 months on Hornby Street to 40 months on Burrard Bridge. These are expressed as monthly totals in Appendix G. Efforts in other areas are inconsistent, for example as published in a 2007 Administrative Report and reproduced in Figure 23 (City of Vancouver, 2007).

In Calgary and Halifax, the municipal government is a single tier and is responsible for what amounts to most of the metropolitan region. In Vancouver and Toronto, the entire metropolitan area is not within their jurisdiction. For *collect data from across a metropolitan area and separate results by categories like: Downtown, Universities, Urban Core, Suburban, Rural*, only Calgary received a point. All four case study cities are mostly focusing on collecting data in their downtowns, which is normally the area with the highest rates of cycling. Since most cities are embarking on new monitoring programs it makes sense to concentrate efforts where they are likely to show good results. Hopefully with time they will expand their programs to include other areas of the city and separate results into categories so patterns can be established, as all cities are currently not counting much in areas outside the central business district. Although Vancouver and Toronto are not responsible for an entire metropolitan area, they could still monitor more different types of areas within their jurisdiction. Additionally, they could work together with their bordering municipalities to coordinate data collection efforts and compare results across the metropolitan area. Vancouver could work more with the GVRD and TransLink and Toronto could set up a counting program with collaboration between municipalities, similar to the way the TTS currently operates. A list of agencies involved in the TTS is available in Appendix R. Interestingly, trends are noticeable at times when Vancouver has monitored areas outside the downtown, as shown in Figure 23. Here, the volume of cyclists is larger as monitoring locations are closer to the downtown. Since Vancouver used different locations in different years without a systematic plan, the pattern cannot be revealed as a true relationship.

There was some mention in Vancouver of the best practice *use the data to prioritize which projects will be implemented*. It can be seen in Figure 28 that existing bicycle volumes were one of the criteria in choosing Hornby Street for the second set of separated bicycle lanes downtown. Many other factors, however, were also considered (City of Vancouver, 2010). Other cities are discussing doing this in the future (for example Halifax, Figure 29), but there are no specific plans and there is no evidence it has been done previously. As mentioned in Section 4.3.4, Halifax's scale is not precise enough to differentiate between three of the four routes and other criteria are given far greater weight. In Toronto, data appears to have limited impact on infrastructure decisions as although counts show major increases in volumes on Jarvis Street after the implementation of bicycle lanes (Figure 34), the lanes were nonetheless removed in November of 2012 (Figure 42).

5.2.6 Other best practices

Hudson et al (2010)'s framework is not the only way to evaluate a monitoring program, but it is a good starting point. After a thorough search, it was the only clear, concise list of best practices for an overall monitoring program located. Alta Planning and Design has guidelines, but they are split into two topics: recommendations for surveys and recommendations for counts. Other recommendations of best practices were listed on a more ad hoc basis, some only specific to certain technologies or methodologies. Hudson et al.'s (2010) take a broader approach. It is interesting, however, to note that Hudson et al. (2010) do not mention surveys whereas some researchers emphasize them as an important piece of the research puzzle.

5.3 Comparison of the Census and the TTS

This section will comprise the following parts: first a discussion of the advantages and disadvantages of the Census BSWT; second, a comparison of the Census and the TTS BSWT; and third, a summary of the section.

5.3.1 Advantages and disadvantages of Census BSWT

All case study cities use the Census BSWT data. There are advantages and disadvantages to this. The advantages are: it is easily accessible; it is available online free of charge; it covers a large geographic area; and cities are able to compare their cycling progress to that of their peers.

The census must be completed by law and the BSWT question is collected from 20% of the population. It focuses on an important type of trip: the commute to work. One benefit to measuring commute trips is that these trips are non-discretionary. In theory, a bicycle trip to work is one less trip by another mode. Many municipalities aspire to reduce their number of automobile trips; one way to achieve this is if people are cycling to work. Non-work trips may be discretionary and add to the total number of trips instead of reducing automobile trips. Pucher et al. (2011) use the Census data because counts and surveys initiated by individual cities do not allow for direct comparisons because of inconsistent methodologies, definitions, geographic coverage and timing.

Access to the Census data online and without a fee is a significant benefit. Canadian municipalities can have trouble obtaining resources as chronic lack of funding appears to be hindering many of them in achieving their cycling aspirations. Transport Canada occasionally provides some financing of research and education programs, however most cycling programs and infrastructure are paid for by municipalities and to a lesser extent, provinces. The federal government is not normally involved in municipal matters, particularly in the area of cycling. Most provinces contribute negligible amounts (Pucher & Buehler, 2005).

Relying on the BSWT from the Census data when evaluating cycling progress can be problematic. Firstly, it may lack validity because of the way in which the question is posed. In the Census, the question regarding commute to work is worded as follows: "How did this person usually get to work? If this person used more than one method of transportation, mark the one used for most of the travel distance" (Statistics Canada, 2006b). The respondent must choose from the following options:

- Car, truck or van – as driver
- Car, truck or van – as passenger
- Public transit (e.g., bus, streetcar, subway, light-rail transit, commuter train, ferry)
- Walked to work
- Bicycle
- Motorcycle
- Taxicab
- Other method

(Statistics Canada, 2006b), as shown in Figure 4 of Section 2.6.2.6.

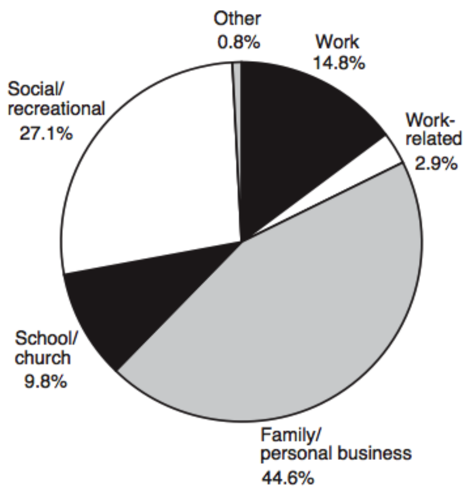
The question allows for interpretation of the term *usually* and asks only about most of the distance. It does not provide an opportunity for a mode of transportation to be counted if it is used less often than usually or for less than most of the travel distance. If people are commuting to work by bicycle five months of the year, this would be missed if they use another mode for the remainder. Asking about most of the travel distance means the time spent cycling will not be captured for those who cycle 49% or less of the distance to their workplace. Furthermore, it does not allow for seasonal variation. As the Census is taken in April, it is likely that the winter commuting mode is the one that respondents will choose. It is still worthwhile to count cyclists when they do cycle, even if they are traveling more often and further by another mode.

Secondly, the Census is not ideal for monitoring cycling because it only measures commute to work. It does not measure non-work cycling trips such as running errands, engaging in volunteer activities, journeying to school, attending appointments, commuting to a part-time or secondary job, or cycling for fitness or recreational purposes (City of Toronto, 2008). The Census report describes the commutes of the 16 million Canadians aged 15 and over who had a job in the week prior to the collection of the Census data. Of those Canadians, only 14 714 300 have the potential to commute to work by bicycle because the others either work outside the country or work from home. As the population of Canada was 31 612 897 according to the 2006 Census, only 46.55% of Canadians have the opportunity to be counted as a cyclist in the Census

(Statistics Canada, 2008). Measuring only work trips does not tell the whole story. In the US DOT NHTS, it was found that only 15% of daily trips taken by Americans are for the purpose of commuting to work. Family and personal business and social and recreational purposes both account for a greater proportion of trips, at 45% and 27%, respectively (US DOT BTS, 2003). This is illustrated in Figure 56 below.

Figure 56 Proportion of Trips by Purpose

Proportion of Trips by Purpose



SOURCE: The 2001 National Household Travel Survey, daily trip file, U.S. Department of Transportation.

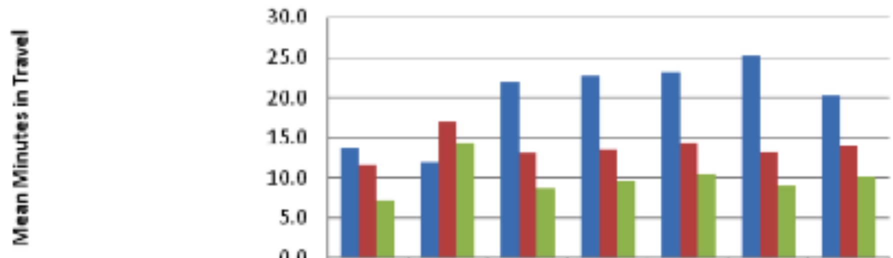
[7] Commute trips are defined as those trips made for the purpose of going to or returning from work. However, given the definition of a daily trip, those reported as commuting trips were not necessarily anchored by the respondent's home or workplace (for return commutes). Therefore, care should be taken in analyzing work trip distances, recognizing that the distance for these trips is often, but not always, the distance from home to work.

Source: US DOT BTS, 2003

An Ottawa study found that 66% of bicycle trips during the am peak hour were work trips (City of Ottawa, 2010). Since most commutes occur during peak hours (US DOT FHA, 2010), it could be hypothesized that an even smaller percentage of trips are for work outside peak hours. Appendix W shows the potential importance of non-commute trips.

Thirdly, the data are only published for residents 15 years of age and older (Statistics Canada, 2011). It has been noted in the literature that children under the age of 15 are the most likely citizens to ride a bike (Pucher, Komanoff, & Schimek, 1999), however their data are not being counted. As shown in Figure 57, Children aged 11-15 spend more time walking or biking for reasons other than exercise (i.e. travel) than any other age group (US DOT FHA, 2010) and they are a young group in need of recognition and protection.

Figure 57 Minutes of Walk and/or Bike per Day by Age

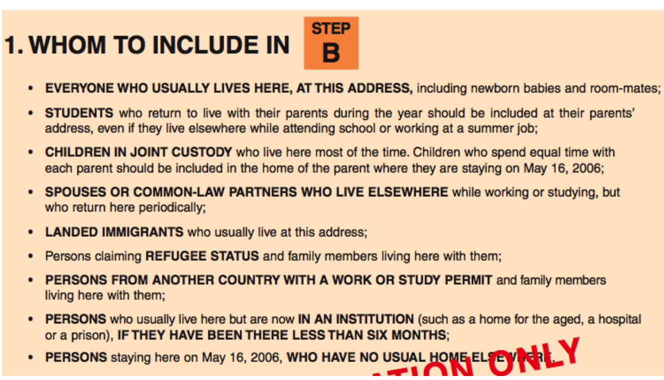


	5-10 yrs	11-15	16-20	21-35	36-65	65+	All
Walks/Bikes for Excersize	13.7	12.0	21.8	22.7	23.2	25.2	20.3
Walk/Bikes For Other Purposes	11.5	17.0	13.1	13.6	14.3	13.2	14.1
Minutes per Day Per Capita (walkers and Non)	7.2	14.4	8.6	9.6	10.5	9.0	10.0

Source: United States Department of Transportation Federal Highway Administration, 2010

Fourthly, university students, who make up a fairly large portion of many CMAs in Canada, are counted in their hometown CMA even though they may live in the CMA where their university is located for most of the year. Indeed, Statistics Canada states, “When sons or daughters study or have a summer job elsewhere but return to live with their parent(s) during the year, these sons and daughters are considered members of the census family of their parent(s)” (Statistics Canada, 2006a, p. 3), as illustrated in Figure 58.

Figure 58 Whom to include in the Census household



1. WHOM TO INCLUDE IN STEP **B**

- **EVERYONE WHO USUALLY LIVES HERE, AT THIS ADDRESS,** including newborn babies and room-mates;
- **STUDENTS** who return to live with their parents during the year should be included at their parents' address, even if they live elsewhere while attending school or working at a summer job;
- **CHILDREN IN JOINT CUSTODY** who live here most of the time. Children who spend equal time with each parent should be included in the home of the parent where they are staying on May 16, 2006;
- **SPOUSES OR COMMON-LAW PARTNERS WHO LIVE ELSEWHERE** while working or studying, but who return here periodically;
- **LANDED IMMIGRANTS** who usually live at this address;
- Persons claiming **REFUGEE STATUS** and family members living here with them;
- **PERSONS FROM ANOTHER COUNTRY WITH A WORK OR STUDY PERMIT** and family members living here with them;
- **PERSONS** who usually live here but are now **IN AN INSTITUTION** (such as a home for the aged, a hospital or a prison), **IF THEY HAVE BEEN THERE LESS THAN SIX MONTHS;**
- **PERSONS** staying here on May 16, 2006, **WHO HAVE NO USUAL HOME ELSEWHERE.**

Source: Statistics Canada, 2006a

University students are among the most likely to cycle (Dill & Carr, 2003; Heinen, van Wee, & Maat, 2010; Nelson & Allen, 1997; Twaddle & Hall, 2009), thus a large portion of cyclists in a city are not being counted or being represented in another CMA.

Fifthly, additional information is not captured by the Census. This includes information about overall volumes, routes and facilities being used, and cyclists’ opinions (Transport Canada, 2011). For example if infrastructure improvements occur in a resident’s work CT, and they begin cycling as a result, the increase in BSWT will be measured in their home CT. It is impossible to know which infrastructure motivated the increase in cycling. Causation between the infrastructure and policy changes in a CMA and a change in BSWT cannot be established or hypothesized. There are many extraneous variables that could account for a change in BSWT that are not investigated in the Census (Pucher & Buehler, 2006a). In addition, because the Census occurs only every five years it can be challenging to discern why a change in BSWT for a particular area may have occurred. It is difficult to obtain up-to-date information in a timely manner.

Finally, it is important to note that the Census normally reports data for cities according to their CMA, which is not necessarily the area for which a municipal government is responsible. For example, the Toronto CMA encompasses a much bigger area than the City of Toronto and includes many other municipalities, as far west as Milton, as far north as Georgina and as far east as Pickering (City of Toronto, 2012). An example of how this affects reported cycling mode share is in Toronto, where in 2006 the BSWT for Toronto CMA was 1%; the City of Toronto BSWT was 1.7%; and the BSWT for CT 5350059.00, which is bordered by Spadina Avenue, College Street, Harbord Street and Bathurst Street, was 17%. These figures show that Census data can hide discrepancies between different areas of a city (City of Toronto, 2008) or report figures that make a city government look unsuccessful at first glance, but are really reflective of municipalities on the outskirts.

The Census does provide valuable information for cities but they should use caution promoting themselves and informing policy with its results. Cities tend to use the Census in ways that make them look best, for example by reporting on certain neighbourhoods or districts that are successful and ignoring the others. An example of this is in Vancouver, where they report a BSWT of 4%. They emphasize that in some neighbourhoods like Kitsilano and Grandview-Woodlands, over 10% of work trips were made by bicycle (City of Vancouver, 2011). Statistics Canada reports a BWST for Vancouver CMA of 1.7% (Statistics Canada, 2008). It is recommended that cities also collect their own comprehensive data through multiple other methods to capture the full picture.

5.3.2 Comparison of Census BSWT and TTS BSWT

When the results of the Census and the TTS are examined, it is noticeable that although levels of bicycle commuting are highly variable, they are generally low, particularly in suburban areas. Not surprisingly, the CTs with high rates of cycling tend to be clustered around areas of higher population density, for example in the downtowns of the GTHA municipalities. There are other corridors with high rates, for example along the Welland Canal in Niagara Region. Presumably this is influenced by the presence of infrastructure.

Analysis described in Chapter 4 determines that there are more CTs with responses for the Census BSWT than there are for the TTS BSWT. This is probably because the Census is required to be completed by law and aims for a sample size of 20% of the population. The TTS relies on people voluntarily contributing their time and aims for a 5% sample. As a result, the TTS is more likely to miss some CTs.

The results also determine that the Census returns on average higher rates of cycling in the GTHA than the TTS. They are not, however, returning vastly different results. Descriptive statistics reveal that the Census returns a mean of 1.18% and a median of 0.59%, while the TTS returns a mean of 0.87% and a median of 0%. The mean difference when the TTS BSWT is subtracted from the Census BSWT is 0.40% and the median is 0.28%. When CTs that both report 0 are removed from the analysis, the mean of the Census BSWT minus the TTS BSWT is 0.53% and the median difference is 0.55%. This is a significant difference statistically, however in practical terms, the rates are all so low that they are a very small proportion of the population. Since the Census and the TTS both produce results around 0 – 1% for BSWT, it may not be cost-effective for municipalities to conduct their own Census-like surveys to obtain an additional data source for BSWT. It may be worthwhile if the survey is combined with other objectives, for example learning about trips for other purposes or about participants' attitudes and behaviours. Interestingly, a similar comparison can be made between a survey in Ottawa that concluded that 2% of the population commutes to work by bicycle and the Census, which reported a BSWT of 1.9%. Two different surveys reported similar results for BSWT, validating each (Pucher & Buehler, 2005).

The tendency to report percentage of cyclists is interesting, as 1% can mean many different things for the amount of people using the infrastructure. It could mean 1 person is using the facilities in a less populated CT or that there are 100 people cycling in more populated areas. The numbers would have a very different impact and would probably require different types of facilities. When looking at whether municipalities should report the change in number of people cycling as a percentage, it is important to remember that while 2% is double 1%, and 80% is double 40%, the increases have significantly different meaning. Percent difference gives a different result than merely subtracting two BSWT statistics as can be viewed in Figures 49 through 54 and in Appendix T.

The explanation for the difference in results for the two surveys is likely methodological. The Census journey to work question asks, "How did this person usually get to work" (Statistics Canada, 2006b). The TTS, however, asks about each trip each respondent took the previous day and the mode of transportation they used (Transportation Tomorrow, n.d.). Other transportation surveys about cycling have found that more people will respond that they normally cycle to a destination than will respond that they cycled when asked about a specific trip to that destination, which can be seen in Figure 19 (City of Vancouver, 2012). This may be one reason why, on average, the Census is reporting higher rates of cycling to work than the TTS. People have imperfect memories and will generally "remember" themselves doing something they perceive as good, for example cycling for its health, economic or environmental benefits, however when asked about a specific trip they recall more accurately the mode they actually used. People also remember routine events that happen over the course of an entire year differently than they remember a specific instance that they are asked to recall. This is called the halo effect (Krizek & El-Geneidy, 2005; Ryley, 2006). In addition, in a Litman (2011) study, it is noted that in the US, 2% of total trips are made by public transit, 5% of adults rely on public transit for transportation, and 12% of citizens used public transit at least once in the two months before they were interviewed. In the United Kingdom, walking comprises 2.8% of total distance travelled, 17.7% of travel time, and 24.7% of trips. If trips are only measured by total distance, walking seems inconsequential, but if total number of trips or travel time is used it is significant (Litman, 2011). This has implications for monitoring and estimating rates of cycling because it demonstrates that surveys will produce different results depending on the wording of the questions.

This argument about the wording of questions would imply that the Census is not as reliable as the TTS. The TTS, however, has a smaller sample size (TTS: 5% of population, Census: 20% of population) and is only asking about one day of the year, so occurrences like bad weather or highway closures would be more likely to affect its accuracy. Another reason the TTS may be inaccurate is that it contacts participants through a landline phone and thus mostly targets an older generation, as younger people rely more on the use of cell phones. Students, for example, are among the mostly likely populations to cycle (Dill & Carr, 2003; Heinen, van Wee, & Maat, 2010; Nelson & Allen, 1997; Twaddle & Hall, 2009) and are typically young.

Maps 3a through 6c show the differences between the results of the Census and the TTS. The areas in which the Census and TTS are most likely to be consistent are in suburban areas. In the downtowns of municipalities, the Census and TTS numbers are more variable. This is probably because in the suburbs the BSWT is most likely to be 0%, whereas in the downtowns at least some of the population cycles to work and this exact percentage will differ between the Census and TTS. In most cases where the Census and TTS report results that are close, they are both reporting a BSWT of 0%. This is the case for 333 CT. There does not appear to be a pattern as to which CT report a higher BSWT from the Census and which report a higher BSWT from the TTS.

In Map 6c, it is noticeable that in the Toronto downtown, the absolute percent difference between the Census and the TTS appears to be smaller (lighter in colour) than in Toronto's inner suburbs (darker in colour). This is likely because in most cases both surveys are reporting some number for BSWT in the downtown, whereas in the inner suburbs often at least one survey reports a BSWT of 0%. Consequently, if the other survey reports any number, there will be an extremely large difference, which is depicted on the map with dark colour. The outer ring of Toronto's suburban municipalities are mostly shown in a light colour, as in most cases both surveys report a BSWT of 0%.

It is clear that both the Census and the TTS have advantages and disadvantages. Results from both these surveys, combined with information such as volume counts and data about cycling for other trip purposes should be considered when monitoring and evaluating a city's cycling progress. The Census and TTS report statistically significant results but they are similar in a practical sense.

5.3.3 Summary

Results from the first research question identify useful methods for monitoring cycling, including manual counts, which were the most commonly used method (Section 5.2). Ideally, these methods should work together with the survey methods examined in the second research question (discussed in Section 5.3). Section 5.3 revealed that the Census and TTS produce statistically significantly different results, even though from a non-scientific view, the two reported means of 1.18% and 0.87% seem practically the same. The visual pattern of the data was similar as well with a higher percentage of the population cycling to work in areas with higher population density, for example in downtowns, and a very small proportion of people cycling to work in suburban areas. Cities may need to decide if the statistical significance is important to them, or if the results of the Census and the TTS are producing data that is similar enough that they do not need to perform their own Census-like surveys.

Transport Canada recommends that cities use several methods because Census data alone are not enough to measure cycling activity. Other methods must be used to join the pieces in the puzzle and show an accurate picture of cycling use in the city. An example of employing other methods of monitoring is in Vancouver where they have taken advantage of permanent counting stations and automated counting systems (Transport Canada, 2011).

5.4 Monitoring Recommendations

It would be useful to have national guidelines on methods to monitor cycling and national monitoring programs. Ideally municipalities would work towards and lobby for a national strategy to monitor cycling so that data collection can be consistent internally and across the country. National strategies could involve nation-wide surveys, nation-wide count days, or the opportunity for municipalities to pool data to track trends and patterns. Municipalities in Canada can use examples from the United States like the US Intermodal Surface Transportation Efficiency Act and the Transportation Equity Act for the 21st century to structure funding (Pucher & Buehler, 2006a). Municipal officials are also advised to work together with those from provincial and federal governments. The federal government could exercise leadership by bringing municipal decision-makers and transportation staff from across the country together to collaborate and learn from each other.

Governments at all levels could work together with other agencies, for example private non-profit organizations such as Vélo Quebec. Vélo Quebec receives only 10% of its revenue from the Province and municipalities in Quebec. The remainder of its funding is obtained through membership fees, events and sponsors. Vélo Quebec works closely with Quebec's Ministry of Transport to organize events like tours, conferences, races, courses and a bike-to-work week. It publishes a cycling magazine and operates a cycling café in Montreal. Vélo Quebec also conducts surveys, for example the 2000 Etat du Vélo survey which offered valuable information about the number and percentage of people cycling in Montreal and Quebec City (Pucher & Buehler, 2005). They could also look to organizations like APD, the NBPDP, LAB and the TTI.

The type of monitoring that should be performed by a municipality depends on their objective. If the municipality aims to double the percentage of people who cycle, a survey would be appropriate. If the goal is to increase the volume of trips to the downtown during peak hours, automated detectors would suffice, ideally using a cordon count methodology. If the goal is to increase the proportion of trips to downtown during peak hours, both a survey that asks about mode of transport or an automated detector that can count all modes would work.

5.5 Summary

This section talks about the methods case study cities are using to monitor their cycling, and examines in detail one method all case study cities are using: the Census BSWT. The Census is also compared to another survey used in the GTHA called the TTS. Descriptive statistics reveal that the Census returns a mean of 1.18% and a median of 0.59%, while the TTS returns a mean of 0.87% and a median of 0%. There appears to be no structural or spatial pattern in the differences between the Census and the TTS.

The triangulation of the thesis, bringing together a summary of monitoring methods used by case study cities and an in-depth analysis of the results of two surveys, highlights one discrepancy between the use of surveys and the use of counts. This is that the words used in surveys can be left open to interpretation and a self-reporting bias, whereas counts reveal only objective data. Interestingly, Hudson et al.'s (2010) best practices do not mention the use of surveys at all, perhaps because of their potential to be unreliable. The GPS units used in studies by Casello et al. (2011, 2012) provide a noteworthy mix of the characteristics of counts, which provide objective data recorded by a machine and surveys, which can provide details about cyclists' origins, destinations, routes and travel times.

This shows that cities that are looking to monitor their cycling may not need to prioritize conducting their own surveys to determine a BSWT. If this information is available from the Census and independent surveys produce similar results (if rounded to the nearest percent, both surveys report a mean of 1%), municipalities could instead focus their efforts on the other data collection methods mentioned in the literature review of this thesis.

It is interesting to note, however, that two surveys examining the same thing in the same year do conclude statistically different results. This highlights an inherent survey disadvantage: that the wording of questions has an effect on how people will respond. Analyzing journey to work data collected from a Census is not included in the list of best practices published by Hudson et al. (2010).

Decision-makers should exercise caution if using the results of the Census for informing public policy. The Census data represent only one small component of the Canadian cycling picture and it is recommended that policy be based on more comprehensive data.

Chapter 6

Conclusion

6.1 Research Questions

The Research Questions addressed in this thesis are:

1. What methods are being used to monitor cycling in Canadian cities and how do they compare to best practices?
2. How do two commonly used measures of Bicycle Share of Work Trips (BSWT), the Canadian Census and the Transportation Tomorrow Survey, compare for consistency in measuring cycling activity?

These questions are being asked to inform policy makers in Canada who wish to improve quality of life, promote health and fitness, prevent climate change, alleviate traffic congestion, decrease impermeable surfaces, reduce pollution and eliminate preventable health care spending via increasing rates of cycling. This thesis focuses on monitoring and evaluation because they are essential for the successful implementation of plans to increase levels of cycling.

The hypothesis of the first research question is that Canadian cities are using similar methods to collect data and monitor cycling. In addition, it is expected that most cities are fairly inadequate as far as monitoring their cycling and scores in comparison to best practices will be low. The hypothesis for research question 2 is that the two surveys are not producing significantly different results.

6.2 Conclusions

Most of the methods identified in the literature review to monitor cycling are being used by at least one of the case studies. All of the case study cities have bicycle plans or cycling strategies in place that emphasize a need to monitor and evaluate, however this step in the planning process is being performed inconsistently at best. Canadian cities are mostly planning future monitoring at this stage, with varying levels of specificity. Some cities mention simply that monitoring will occur, while others outline detailed plans describing the current status of cycling, future targets and sources of data.

The methods being used by Canadian cities to monitor their cycling can be categorized into the following groups: surveys and counts. The survey type that is most commonly used is the Census data, likely because it has a large geographic scope and is inexpensive. It measures what is arguably the most important type of trip: the commute to work. Although of the cities except Vancouver perform their own surveys, Calgary has the most extensive survey program and collects the most data.

The most common type of count methodology is to perform counts at various locations around the city. This is probably because it doesn't require too much coordination or planning, in some cases cities seem to just pick locations and count cyclists without involving the counting program in an overall monitoring program or system. All or some of the count locations can be repeated at regular intervals.

The most common type of count technology is the manual count. This is probably due to its low cost, particularly if volunteers are used. Using people to manually count also allows for the collection of additional data, for example about whether the cyclist is obeying traffic laws or an approximation of the cyclist's age and gender. Manual counts are performed in all of the case study cities.

Automated counters are used in two cities: Vancouver and Toronto. The reason they are not used in all cities is probably due to the initial capital cost associated with their installation. Vancouver and Toronto both use the highly recommended EcoCounter model, which has been rated as the best automated counter on the market by several sources (APD & ITE PBC, 2012; Hudson et al., 2010).

As far as the comparison to the best practice framework, Vancouver and Toronto were the two top cities, with Calgary a close third and Halifax a distant fourth. With that being said, Vancouver and Toronto still only scored 12 and 11 out of a possible 20 points. The reason the cities generally scored low is probably because they are unaware of Hudson et al.'s (2010) framework and as a result have not benefitted from its guidance. Additionally, some of the recommendations from the framework may be expensive and resource consuming. Most of the case study cities appear to be just beginning a monitoring program and are in many cases laying the groundwork for the methods they will use in the future. They have, in most cases, not yet put all their ideas into practice and most documents describe future work to be done. The most commonly followed best practice was *state the goals of the monitoring system and identify clearly why it exists.* The three least commonly followed best practices was: *assign a specific staff member to be in charge of monitoring projects*.

To address the hypothesis from the first research question, Canadian cities are using similar methods to monitor their cycling, however there is some variation in the quantity of data collected and the methods used. It is difficult to compare the frequency of monitoring, however the one thing that cities have in common is that they are inconsistent.

The hypothesis of the second research question was incorrect; the results of the second research question show that the Census and the TTS produce results for BSWT that are significantly different at a 99% confidence interval. The results of the two surveys are statistically different, however in practical terms they are not different because they are both reporting a very low BSWT. When the differences between the two surveys were mapped using GIS, spatial patterns were weak. The Census and TTS both have strengths and weaknesses, which are identified in Chapter 5. The surveys fall short of being comprehensive and often do not serve as reliable measure of cycling for the policy and infrastructure decisions planners make.

Tying the two research questions together, the Census and TTS comparison was performed to produce one way to test if the Census is a reliable way to measure BSWT. The results from the first research question revealed that all case study cities, and indeed many cities in Canada, are using the Census to measure their BSWT, which leads to the importance of testing its accuracy. The second research question revealed that the Census and the TTS are producing similar results in a practical sense and cities can probably rely on only the Census to measure their BSWT. Household travel surveys like the TTS are expensive surveys to undertake if the outcome is going to be similar to the Census. If cities need the other information produced by household travel surveys, for example for the bicycling share of trips for other purposes or for data about where people are travelling to shop, household travel surveys are worth undertaking.

Decision-makers should exercise caution if using the results of the Census for informing public policy as the Census data represent only one small component of the Canadian cycling picture. It is recommended that policy be based on more comprehensive data. There are many methods outlined in this thesis for collecting data, as well as recommendations by Alta Planning and Design, the ITE PBC, Hudson et al. and Transport Canada (APD & ITE PBC, 2012; Hudson et al., 2010; Transport Canada, 2011), and other authors. The advantages and disadvantages of Census data are many, but if they are kept in mind and the pros and cons of other monitoring methods are balanced, this thesis argues that Canadian cities will be able to view their cycling progress holistically. Although the best practices from Hudson et al. (2010)'s work mention only counts, surveys also provide important data for decision-making. Surveys provide the advantage of obtaining qualitative information and the ability to examine a specific individual's behaviour. For certain topics, for example when studying increased cycling commuting and how it relates to public health, surveys may provide more valuable information than count data.

In conclusion, Canadian cities are at the beginning stages of monitoring and evaluating their cycling. Most efforts have been limited in the past, but most cities have detailed plans for monitoring in the future.

Some cities have goals and objectives with baselines and targets specified, whereas others have vague statements without any data or numbers to back them up. There is a lot of room to improve for Canadian cities, but this thesis has unearthed a few best practices and few good examples of monitoring work as guidance.

6.3 Recommendations

The following are the recommendations gathered from the work presented in this thesis:

Cities should develop a monitoring program that produces systematic results using a variety of methods that can be compared across years and decades. Cities should not rely on only one method for monitoring their cycling. This thesis outlines many methods with advantages and disadvantages of each so that cities can create a system with balance.

It is recommended that the cities follow best practices, for example those outlined by the NBPDP, Hudson et al. (2010) and Transport Canada (APD & ITE PBC, 2012; Hudson et al., 2010; Transport Canada, 2011). Cities could develop a system where they check their methods against a list of best practices yearly, to ensure that they are staying on track. Cities should keep up to date with the methods that other municipalities and established researchers are finding to be most successful for example by subscribing to peer-reviewed journals, attending conferences, and forging links with institutions and staff at other municipalities.

Canada should develop a national cycling strategy, which includes guidelines for monitoring cycling. The case study cities appear to be mostly just beginning their monitoring programs or only monitoring on an as-needed basis and could use some guidance on how to proceed in the future. The national cycling strategy could come with funding incentives and other programs to encourage holistic and systematic monitoring and evaluation.

Cities should research and pilot different solutions and implement those that are context-specific and have proved successful for the area. Although best practices are key, cities in Canada are geographically, demographically, socially and economically diverse. An effective monitoring initiative in one community may not work well in another.

If cities are using the Census to monitor their cycling, they should be aware that there are other methods and the Census is only representing one piece of the monitoring puzzle. It is generally not recommended that cities rely on using the Census data, because of the flaws outlined in Chapter 5. Using other methods as well would triangulate results and provide a more comprehensive picture. It was found that in practical terms, the TTS produces a very similar result to the Census for BSWT and thus a municipality producing such a similar survey for the purpose of measuring BSWT is not recommended. Instead, municipalities should measure their cycling using diverse methods. The TTS is a rich source, however, and can be utilized as such if the municipality is in need of the other data it collects.

6.4 Limitations

Below are the limitations of this thesis.

A policy scan was performed to collect information from the case studies. The information from the documents collected may only represent a subset of what municipalities are doing to monitor their cycling. All attempts were made to gather as much documentation as possible. In addition, there might be a lag between the monitoring that occurs in cities and the time information is published, so all information may not be completely up to date to 2013.

Likewise, 2006 data were used from the Census and the TTS because more recent data were not available. With recent changes to the questions and methods used to collect data for the Census, data for years post-2006 may not be comparable to the data used in this study. This limits work that can be done in the future and potential for longitudinal studies.

The use of the framework from Hudson et al. (2010) is a limitation because it is only one method of assessing the monitoring programs of the case study cities. There were no other comprehensive lists of best practices found that could be used to evaluate cities. If other frameworks were used as well, cities could be more thoroughly examined and the work of other researchers could be incorporated. Hudson et al.'s (2010) framework disadvantaged cities that rely mostly on survey data collection, for example, because it did not refer to surveys as a best practice.

Spatial autocorrelations were not performed in GIS, and this makes the maps difficult to read. It is difficult to tell if there are spatial patterns without mapping them and determining through analysis if they exist. The maps were visually compared only.

6.5 Further Research

In the future, research could be performed where individuals responsible for cycling at case study municipalities are interviewed or asked to respond to a survey to find out about their methods and knowledge of best practices. This could triangulate the results of the above work.

The same study could be performed as an update in 10 years to determine if the case study cities have improved their methods and if they are obtaining more comprehensive results through their monitoring.

The Census BSWT data could be compared to BSWT data from household travel surveys or civic censuses in other cities. TransLink or the City of Calgary may be able to provide data.

A BSWT study could be performed using data from the Census and TTS from other years they were both performed to see if results are consistent with the results of this work.

References

Abraham, J. E., McMillan, S., Brownlee, A. T., & Hunt, J. D. (2002). Investigation of Cycling Sensitivities. *Transportation Research Board Annual Conference.* Washington, DC: Transportation Research Board.

Alta Planning and Design & Institute of Transportation Engineers Pedestrian and Bicycle Council. (2012). *National Bicycle and Pedestrian Documentation Project.* Retrieved April 17, 2012, from National Bicycle and Pedestrian Documentation Project: http://bikepeddocumentation.org/

Alta Planning and Design. (2011). *Best Practices in Campus Bicycle Planning and Program Development.* Retrieved February 22, 2012, from Perspectives in Planning: http://www.altaplanning.com/App_Content/files/Perspectives_Campus%20Bicycle%20Planning_ALTA.pdf

Alta Planning and Design. (2012). *National Bicycle and Pedestrian Documentation Project Summary Report.* Retrieved December 08, 2012, from National Bicycle and Pedestrian Documentation Project: http://bikepeddocumentation.org/

Banister, C. (1988). *The travel to work patterns in England & Wales for pedestrians & cyclists - The Policy Implications.* Manchester, UK: Department of Town and Country Planning, University of Manchester.

Bassett, D. R., Pucher, J., Buehler, R., Thompson, D., & Crouter, S. (2008). Walking, Cycling, and Obesity Rates in Europe, North America, and Australia. *Journal of Physical Activity and Health, 5*, 795-814.

Beckwith, D., & Hunter-Zaworski, K. (1998). Passive Pedestrian Detection at Unsignalized Crossings. *Transportation Research Record*, *1636*, 96-103.

Casello, J. & Majcherkiewicz, F. (2012). Region of Waterloo Transportation Master Plan (TMP) mode share monitoring pilot study: Revised implementation sites for technology in pilot study. Retrieved from Waterloo Public Transportation Initiative, February 14, 2013, from: http://www.civil.uwaterloo.ca/wpti/

Casello, J., Nour, A., Rewa, K., & Hill, J. (2011). An Analysis of Stated Preference and GPS Data for Bicycle Travel Forecasting. *90th Annual Meeting of the Transportation Research Board*, Washington, DC

Casello, J., Rewa, K., & Nour, A. (2012). An Analysis of Empirical Evidence of Cyclists' Route Choice and their Implications for Planning. *91st Annual Meeting of the Transportation Research Board*, Washington, DC

City of Calgary. (2000). *Calgary Pathway & Bikeway Plan Report.* Retrieved December 12, 2012, from Parks & Recreation/Transportation Department: http://www.calgary.ca/Transportation/TP/Pages/Cycling/Cycling-Route-Improvements/Pathway-and-Bikeway-Plan.aspx

City of Calgary. (2000). *1999 Travel to Work Survey.* Retrieved February 23, 2012, from City of Calgary: http://www.calgary.ca/Transportation/TP/Documents/forecasting/travel_work_survey.pdf

City of Calgary. (2002). *2001 Household Activity Survey.* Planning and Transportation Policy Forecasting Division, Calgary.

City of Calgary. (2011). *2011 Civic Census Results.* Retrieved April 21, 2012, from City of Calgary: http://www.calgary.ca/CA/city-clerks/Documents/Election-and-information-services/Civic-Census/2011_census_result_book.pdf

City of Calgary. (2012). *2012 Civic Census Results.* Retrieved December 10, 2012, from The City of Calgary: http://www.calgary.ca/CA/city-clerks/Documents/Election-and-information-services/Census2012/Final%202012%20Census%20Results%20book.pdf

City of Calgary. (2006). *Calgary Downtown Commuter Cyclist Survey Report.* Retrieved January 15, 2012, from City of Calgary: http://www.calgary.ca/Transportation/TP/Documents/transportation_solutions/downtown_cyclist_survey_2007_p1of4.pdf

City of Calgary. (2000). *Calgary Pathway & Bikeway Plan Report.* Retrieved April 5, 2012, from City of Calgary Parks & Recreation/Transportation Department: http://www.calgary.ca/Transportation/TP/Pages/Cycling/Cycling-Route-Improvements/Pathway-and-Bikeway-Plan.aspx

City of Calgary. (2009). *Calgary Transportation Plan.* Retrieved March 15, 2012, from City of Calgary: http://www.calgary.ca/Transportation/TP/Pages/Planning/Calgary-Transportation-Plan/Calgary-Transportation-Plan-(CTP).aspx

City of Calgary. (2011). *Cycling route improvements.* Retrieved June 23, 2012, from City of Calgary: http://www.calgary.ca/Transportation/TP/Pages/Cycling/Cycling-Route-Improvements/Calgary-Bike-Route-Improvements.aspx

City of Calgary. (2011). *Cycling Strategy.* Calgary: City of Calgary .

City of Calgary. (2010). *Guide to Municipal Developent Plan and the Calgary Transportation Plan.* Retrieved May 5, 2012, from City of Calgary: http://www.calgary.ca/pda/lupp/documents/publications/mdp-guide-to-mdp-ctp.pdf?noredirect=1

City of Calgary. (2012). *Mobility Monitor.* Retrieved November 4, 2012, from City of Calgary: http://www.calgary.ca/Transportation/TP/Pages/Planning/Transportation-Data/Mobility-Monitor.aspx

City of Calgary. (2009). *Mobility Monitor: Commuter Cycling in Calgary*. Retrieved January 9, 2013, from City of Calgary: http://www.calgary.ca/_layouts/cocis/DirectDownload.aspx?target=http%3A%2F%2Fwww.calgary.ca%2FTransportation%2FTP%2FDocuments%2Fdata%2F2009%2Fmobility_monitor_sept.pdf&noredirect=1&sf=1

City of Calgary. (2010). *Municipal Development Plan.* Calgary: City of Calgary.

City of Calgary. (2011). *Parks 2010 Pathway Research Comparison Summary Report.* Retrieved May 6, 2012, from City of Calgary: http://www.calgary.ca/_layouts/cocis/DirectDownload.aspx?target=http%3A%2F%2Fwww.calgary.ca%2FCSPS%2FParks%2FDocuments%2FPathways%2Fpathwatch-2010-summary-report.pdf&noredirect=1&sf=1

City of Calgary. (2004). *Pathwatch 2002: Interview Report.* Retrieved September 12, 2012, from City of Calgary: http://www.calgary.ca/CSPS/Parks/Documents/Pathways/pathwatch-interview-report.pdf

City of Calgary. (2011). *Pathway Safety Review Report 2011.* Retrieved July 8, 2012, from City of Calgary: http://www.calgary.ca/Transportation/TP/Documents/cycling/Cycling-Strategy/pathway-safety-review-report2011.pdf?noredirect=1

City of Calgary. (2005). *See for Yourself... Transportation in Calgary Dramatic Changes 1995 to 2005.* City of Calgary. Calgary: City of Calgary.

City of Calgary. (1996). *The 1996 Calgary Cycle Plan.* Retrieved December 9, 2012, from City of Calgary: http://www.calgary.ca/Transportation/TP/Pages/Cycling/Cycling-Strategy/Calgary-Cycle-Plan.aspx

City of Calgary. (2008). *Transportation Infrastructure Investment Plan 2009-2018.* Retrieved March 15, 2012, from City of Calgary Transportation: http://www.calgary.ca/_layouts/cocis/DirectDownload.aspx?target=http%3A%2F%2Fwww.calgary.ca%2FTransportation%2FTP%2FDocuments%2Fnetwork_planning%2Ftiip_brochure_aug.pdf&noredirect=1&sf=1

City of Calgary. (2006). *Transportation interactive dashboards*. Retrieved January 8, 2013, from City of Calgary: http://www.calgary.ca/Transportation/TP/Pages/Getting-Around-Calgary/Commuting/Transportation-interactive-dashboards.aspx

City of Calgary. (2004). *Urban Structure Plan: Summary of Downtown Background Information.* Retrieved May 28, 2012, from City of Calgary: http://www.calgary.ca/PDA/LUPP/Documents/Publications/downtown_urban_structure_plan.pdf?noredirect=1

City of Calgary. (2007). *Winter Pathwatch 2006-2007 Study Use Profiles: Summary Report.* Retrieved April 2, 2012, from City of Calgary Parks: http://www.calgary.ca/CSPS/Parks/Documents/Pathways/winter-pathwatch-summary.pdf?noredirect=1

City of Calgary. (2002). *Working Paper 2001 Civic Census Travel to Work Survey.* Retrieved May 5 12, 2012, from City of Calgary Planning and Transportation Policy Forecasting Division: http://www.calgary.ca/Transportation/TP/Documents/forecasting/travel_to_work_2001_survey.pdf?noredirect=1

City of Ottawa. (2010). *Cycling Activity Monitoring Tools.* Retrieved December 25, 2012, from City of Ottawa: http://www.actcanada.com/TDMConference2010Presentations/Session%2011B%20-%20Wednesday%20-%20Measured%20Success%20in%20TDM/Session%2011B%20-%20Colin%20Simpson%20and%20Zlatko%20Krstulich%20-%20Cycling%20Activity%20Monitoring%20Tools.pdf

City of Portland Bureau of Transportation. (2010). *Portland Bicycle Plan for 2030: A world-class bicycling city*. Retrieved February 24th, 2013, from City of Portland Bureau of Transportation: http://www.portlandoregon.gov/transportation/44597?a=379125

City of San Jose. (2011). *Trail Count*. Retrieved April 17, 2012, from Parks, Recreation and Neighbourhood Services: http://www.sanjoseca.gov/index.aspx?NID=595

City of Toronto. (2010, 12). *2010 Bicycle Count Report.* Retrieved December 11, 2012, from City of Toronto: http://www.toronto.ca/cycling/reports/pdf/bicycle_count_report_2010.pdf

City of Toronto. (2012). *2011 Census: Population and Dwelling Counts.* Retrieved October 9, 2012, from City of Toronto: http://www.toronto.ca/demographics/pdf/2011-census-backgrounder.pdf

City of Toronto. (2011). *Bikeway Network - 2011 Update.* Retrieved October 23, 2012, from City of Toronto: http://www.toronto.ca/legdocs/mmis/2011/pw/bgrd/backgroundfile-38906.pdf

City of Toronto. (2012). *Bikeway Network project status.* Retrieved October 23, 2012, from City of Toronto: http://www.toronto.ca/cycling/network/network-project-status.htm

City of Toronto. (2001). *City of Toronto Bike Plan: Shifting Gears.* Toronto: City of Toronto.

City of Toronto. (2010). *City of Toronto Cycling Study: Tracking Report (1999 and 2009).* Retrieved December 12, 2012, from City of Toronto Cycling: http://www.toronto.ca/cycling/reports/pdf/cycling_study_1999_and_2009.pdf

City of Toronto. (2010). *City of Toronto Cycling Study: Tracking Report (1999 and 2009).* Retrieved October 24, 2012, from City of Toronto: http://www.toronto.ca/cycling/reports/pdf/cycling_study_1999_and_2009.pdf

City of Toronto. (2012). *Counting Bike Traffic*. Retrieved October 24, 2012, from City of Toronto: http://www.toronto.ca/cycling/data/index.htm

City of Toronto. (2012). *Cycling statistics - geographic.* Retrieved October 30, 2012, from City of Toronto: http://www.toronto.ca/cycling/reports/statistics/statistics-geographic.htm

City of Toronto. (2008). *Cycling Statistics.* Retrieved December 19, 2011, from City of Toronto: http://www.toronto.ca/cycling/reports/statistics/statistics.htm

City of Toronto. (2009). *Toronto Bike Plan - New Strategic Directions.* Retrieved October 23, 2012, from City of Toronto: http://www.toronto.ca/legdocs/mmis/2009/pw/bgrd/backgroundfile-21588.pdf

City of Toronto. (2012). *Toronto Cycling Committee.* Retrieved October 30, 2012, from City of Toronto: http://www.toronto.ca/cycling/committee/index.htm

City of Toronto. (2002). *Toronto Official Plan.* Retrieved October 23, 2012, from City of Toronto: http://www.toronto.ca/planning/official_plan/pdf_chapter1-5/chapters1_5_dec2010.pdf

City of Vancouver. (2009). *2008 Pedestrian Volume and Opinion Survey - Commercial Streets.* Retrieved January 15, 2012, from Cycling in Vancouver: http://vancouver.ca/engsvcs/transport/guidingDocuments/documents/2008PedMain%20Report.pdf

City of Vancouver. (2009). *2008/2009 Cycling Statistics Update.* Retrieved January 15, 2012, from City of Vancouver: http://vancouver.ca/ctyclerk/cclerk/20090217/documents/tt1.pdf

City of Vancouver. (1999). *Bicycle Network Review.* Retrieved December 12 2012, from City of Vancouver: http://former.vancouver.ca/ctyclerk/cclerk//991102/tt1.htm

City of Vancouver. (2009). *Central Waterfront Hub Framework.* Retrieved January 15, 2012, from City of Vancouver: http://vancouver.ca/commsvcs/currentplanning/whitecaps/CoV%20HUB%20Draft%20Plan%20Low%20Resolution.pdf

City of Vancouver. (2009). *City of Vancouver Bicycle Monitoring Program.* Retrieved September 12, 2012, from Canadian Institute of Transportation Engineers Greater Vancouver Section: http://citevancouver.org/quad/presentations/CoV%20Bicycle%20Monitoring%20Program.pdf

City of Vancouver. (2011). *Cycling Statistics.* Retrieved January 15, 2012, from Cycling in Vancouver: http://vancouver.ca/engsvcs/transport/cycling/stats.htm

City of Vancouver. (2012). *Downtown Separated Bicycle Lanes Status Report, Spring 2012.* Retrieved December 12, 2012, from Standing Committee on Planning, Transportation and Environment: http://bikeroute.files.wordpress.com/2012/06/downtown_lanes_report.pdf

City of Vancouver. (2011). *Downtown Separated Bicycle Lanes Status Report, Summer 2011.* Retrieved December 12, 2012, from Cycling in Vancouver: http://former.vancouver.ca/ctyclerk/cclerk//20110728/documents/penv2-DowntownSeparatedBikeLanesStatusReportSummer2011.pdf

City of Vancouver. (2002). *Downtown Transportation Plan.* Retrieved January 20, 2012, from City of Vancouver: http://former.vancouver.ca/dtp/dtpfinalplan.htm

City of Vancouver. (2011). *Dunsmuir Street and Hornby Street separated bike lanes statistics.* Retrieved January 15, 2012, from Cycling in Vancouver: http://vancouver.ca/engsvcs/transport/cycling/separated/dunsmuir_results.htm

City of Vancouver. (2007). *Expansion of the Bicycle Count Program.* Retrieved November 27, 2012, from City of Vancouver: http://former.vancouver.ca/ctyclerk/cclerk//20070920/documents/pe4.pdf

City of Vancouver. (2012). *Geography.* Retrieved February 25, 2013, from City of Vancouver: https://vancouver.ca/green-vancouver/geography.aspx

City of Vancouver. (2010). *Hornby Separated Bike Lane.* Retrieved January 15, 2012, from City of Vancouver: http://vancouver.ca/engsvcs/transport/cycling/separated/pdf/SeparatedBikeLanes-UpdatedTechnicalBrief.pdf

City of Vancouver. (2010). *Mode Integration, Urban Design & Travel Demand.* Retrieved December 12, 2012, from Health and Community Design Lab, University of British Columbia: http://health-design.spph.ubc.ca/files/2011/07/LaClaire_Web.pdf

City of Vancouver. (2012). *New poll shows strong support for Hornby separated bike lane.* Retrieved January 15, 2012, from City of Vancouver: http://vancouver.ca/mediaroom/news/detail.htm?row=131&date=2010-09-26

City of Vancouver. (2013). *Separated bicycle lanes*. Retrieved March 6, 2013, from City of Vancouver: http://vancouver.ca/streets-transportation/separated-bicycle-lanes.aspx

City of Vancouver. (2009). *Separated bike lanes.* Retrieved January 15, 2012, from Cycling in Vancouver: http://dialogue.vancouver.ca/bikevancouver

City of Vancouver. (2011). *Summary Report: Vancouver Georgia and Dunsmuir Viaducts Study.* Retrieved December 12, 2012, from Cycling in Vancouver: http://vancouver.ca/docs/eastern-core/viaducts-study-summary.pdf

City of Vancouver. (1997). *The City of Vancouver Transportation Plan.* Retrieved December 12, 2012, from City of Vancouver: http://former.vancouver.ca/engsvcs/transport/plan/1997report/index.htm

City of Vancouver. (2012). *Transportation 2040 Plan as adopted by Vancouver City Council on October 31, 2012.* Retrieved December 20, 2012, from City of Vancouver: http://vancouver.ca/files/cov/Transportation_2040_Plan_as_adopted_by_Council.pdf

City of Vancouver. (2012). *Why Hornby Street?* Retrieved December 12, 2102, from Cycling in Vancouver: http://former.vancouver.ca/engsvcs/transport/cycling/separated/why.htm

Creswell, J. W. (2007). *Qualitative inquiry & research design: choosing among five approaches.* Thousand Oaks, CA: Sage Publications.

Creswell, J. W. (2009). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches* (Third ed.). Thousand Oaks, CA: SAGE.

Data Management Group. (2012). *Transportation Tomorrow Survey.* Retrieved October 3, 2012, from Data Management Group: http://www.dmg.utoronto.ca/transportationtomorrowsurvey/index.html

Dill, J., & Carr, T. (2003). Bicycle commuting and facilities in major US Cities: if you build them, commuters will use them. *Transportation Research Record, 1828*, 116-123.

Ecology Action Centre. (2006). *HRM Bike Plan Progress Report.* Retrieved January 22, 2013, from Halifax Regional Muncipality: http://www.halifax.ca/cycling/documents/HRMBikePlanProgressReport.pdf

Environment Canada. (2012). *National Climate Data and Information Archive.* Retrieved November 27, 2012, from Environment Canada: http://climate.weatheroffice.gc.ca/climate_normals/index_e.html?

Gerring, J. (2004). What Is a Case Study and What Is It Good for? *American Political Science Review, 98* (2), 341-354.

Ginger, N., Hong, A., Murphy, J., Rose, D., Schmiedeskamp, P., Snypp, A., Torikai, E., & Bassok, A. (2010). *Bicycle planning, best practices, and count methodology*. Retrieved February 23, 2013, from Puget Sound Regional Council: http://psrc.org/assets/5430/UDP_Bicycle_Studio_Final_20110111.pdf

Gray, M., & Bunker, J. M. (2005). Kelvin Grove Urban Village: The use of GIS in active transport planning. *27th Conference of Australian Institutes of Transport Research.* Brisbane, Australia: Queensland University of Technology.

Griswold, J. B., Medury, A., & Schneider, R. J. (2011). Pilot Models for Estimating Bicycle Intersection Volumes. *Transportation Research Record: Journal of the Transportation Research Board* (2247), 1-7.

Halifax Cycling Coalition. (2010). *The 2009 Halifax Cycling Coalition Bicycle Count.* Retrieved April 18, 2012, from Halifax Cycling Coalition: http://cyclehalifax.ca/wp-content/uploads/2012/07/2009_HCC_Bike_Count_Report.pdf

Halifax Regional Municipality. (2010). *2010 Peninsula Screenline Bicycle Count.* Halifax: Halifax Regional Municipality.

Halifax Regional Municipality. (2006). *Active Transportation Plan.* Halifax: Halifax Regional Municipality.

Halifax Regional Municipality. (2002). *Blueprint for a Bicycle Friendly HRM: Halifax Regional Municipality Bicycle Plan.* Retrieved December 5, 2012, from Halifax Regional Municipality: http://www.halifax.ca/cycling/bikeplan.html

Halifax Regional Municipality. (2011). *Community Demographics*. Retrieved September 25, 2012, from Halifax Regional Municipality: http://www.halifax.ca/community/fact1.html

Halifax Regional Municipality. (2011). *June 2011 Peninsula Screenline Bicycle Count.* Halifax: Halifax Regional Municipality.

Halifax Regional Municipality. (2002). *Naturally Green*. Retrieved March 16, 2013, from Halifax Regional Municipality: http://www.halifax.ca/environment/documents/summer_2002.pdf.

Halifax Regional Municipality. (2006). *Regional Municipal Planning Strategy.* Retrieved April 23, 2012, from Halifax Regional Municipality: http://www.halifax.ca/regionalplanning/FinalRegPlan.html

Halifax Regional Municipality. (2010). *Regional Planning*. Retrieved March 16, 2013, from Halifax Regional Municipality: http://www.halifax.ca/regionalplanning/publications/research.html.

Halifax Regional Municipality. (2009). *Trip Data Collection April 2009: Summary Report (Draft).* Halifax: Halifax Regional Municipality.

Halifax Regional Municipality. (2012). *Update to Peninsula Community Council: Stakeholder Engagement for the North-South Peninsula Bicycle Corridor.* Halifax: Halifax Regional Municipality.

Hankey, S., Lindsey, G., Wang, X., Borah, J., Hoff, K., Utecht, B., et al. (2012). Estimating use of non-motorized infrastructure: Models of bicycle and pedestrian traffic in Minneapolis, MN. *Landscape and Urban Planning, 107* (3), 307-316.

Heinen, E., van Wee, B., & Maat, K. (2010). Commuting by Bicycle: An Overview of the Literature. *Transport Reviews: A Transnational Transdisciplinary Journal, 30* (1), 59-96.

Hildebrand, D. K., Laing, J. D., & Rosenthal, H. (1977). *Analysis of Ordinal Data*. Newbury Park, CA: SAGE Publications.

Hope, D., & Yachuk, D. (1990). *Canadian Institute of Planners Community Cycling Manual: A Planning and Design Guide.* Ottawa, ON: Canadian Institute of Planners.

Hudson, J., Qu, T.-B., & Turner, S. (2010). *Forecasting Bicycle and Pedestrian Usage and Research Data Collection Equipment.* Texas Transportation Institute. College Station, TX: Texas Transportation Institute.

Jones, M. G., Ryan, S., Donlon, J., Ledbetter, L., Ragland, D. R., & Arnold, L. (2010). *Seamless Travel: Measuring Bicycle and Pedestrian Activity in San Diego County and its Relationship to Land Use, Transportation, Safety, and Facility Type.* Retrieved May 18, 2012, from Alta Planning and Design: http://www.altaplanning.com/App_Content/files/fp_docs/Caltrans-Seamless-Travel-Executive-Summary.pdf

Jupp, V. (2006). *The SAGE dictionary of social research methods.* London, UK: SAGE Publications.

Kitchin, R., & Tate, N. (2000). *Conducting Research in Human Geography: Theory, Methodology & Practice.* Harlow, England: Pearson Prentice Hall.

Kosny, M. E., Faulds, J. E., Anthony, W. D., & Chow, H. K. (1980). *The Bicycle as a mode of Urban Transportation in Metropolitan Toronto: Prepared for the Ontario Ministry of Energy under an Experience '80 Program.* Toronto, ON: Urban and Regional Planning Department, Ryerson Polytechnical Institute.

Krizek, K. J., & El-Geneidy, A. M. (2005). *A Micro-Level Analysis of Bicycle Commuting and Facility Construction Using Longitudinal Data.* Retrieved December 18, 2012, from Transportation Research at McGill: http://tram.mcgill.ca/Research/Publications/Vegas05.pdf

Krizek, K. J., & Johnson, P. J. (2006). Proximity to trails and retail: effects on urban cycling and walking. *Journal of the American Planning Association, 72*, 33-42.

Krizek, K., Handy, S., & Forsyth, A. (2009). Explaining changes in walking and bicycling behaviour: challenges for transportation research. *Environment and Planning B: Planning and Design, 36*, 725-740.

Larsen, J., & El-Geneidy, A. (2011). A travel behaviour analysis of urban cycling facilities in Montreal Canada. *Transportation Research Part D: Transport and Environment, 16* (2), 172-177.

Larsen, J., El-Geneidy, A., & Yasmin, F. (2010). Beyond the quarter mile: Re-examining travel distances by active transportation. *Canadian Journal of Urban Research: Canadian Planning and Policy (supplement), 19* (1), 70-88.

Lindsey, G., Hoff, K., Hankey, S., & Wang, X. (2012). *Understanding the Use of Non-Motorized Transportation Facilities.* University of Minnesota, Centre for Transportation Studies. Minneapolis: Intelligent Transportation Systems Institute.

Litman, T. (2011). *Measuring Transportation: Traffic, mobility and accessibility*. Retrieved February 23, 2013, from Victoria Transport Policy Institute: http://vtpi.org/measure.pdf.

McClintock, H. (2002). Chapter 1: The mainstreaming of cycling policy. In H. McClintock, *Planning for Cycling: Principles, Practice and Solutions for Urban Planners* (pp. 1-16). Cambridge, England: Woodhead Publishing.

Metropolitan Transportation Commission. (2011). *Bicycle and Pedestrian Counts.* Retrieved April 18, 2012, from Metropolitan Transportation Commission: http://www.mtc.ca.gov/planning/bicyclespedestrians/counts.htm

Metropolitan Transportation Commission. (2003). *Handbook for Bicyclist and Pedestrian Counts.* Retrieved January 15, 2012, from Metropolitan Transportation Commission: http://www.mtc.ca.gov/services/arterial_operations/downloads/ped-bike/Handbook_Summary.pdf

National Bicycle and Pedestrian Documentation Project. (2009). *Automatic Count Technologies.* Retrieved February 23, 2012, from National Bicycle and Pedestrian Documentation Project: http://bikepeddocumentation.org

National Bicycle and Pedestrian Documentation Project. (2013). *Program Forms and Materials*. Retrieved January 9, 2013, from National Bicycle and Pedestrian Documentation Project: http://bikepeddocumentation.org/downloads

Nelson, A. C., & Allen, D. (1997). If you build them, commuters will use them: Association between bicycle facilities and bicycle commuting. *Transportation Research Board* (1578), 79-83.

Nordback, K., & Janson, B. N. (2010). Automated Bicycle Counts: Lessons from Boulder Colorado. *Transportation Research Record: Journal of the Transportation Research Board* (2190), 11-18.

Ontario Ministry of Transportation. (2008). *Nomination for 2008 TAC Sustainable Urban Transportation Award: Ontario Transportation Demand Management Municipal Grant Program*. Retrieved January 10, 2013, from Transportation Association of Canada: http://www.tac-atc.ca/english/resourcecentre/readingroom/conference/conf2009/pdf/mto.pdf

Ontario Ministry of Transportation. (2012). *Cycling Strategy*. Retrieved March 11, 2013, from Ontario Ministry of Transportation: http://www.raqsa.mto.gov.on.ca/techpubs/eps.nsf/8cec129ccb70929b852572950068f16b/db68ce058968597d85257ac3005f6877/$FILE/Draft%20Cycling%20Strategy%20-%20FINAL%20CLEAN%20VERSION.pdf

Porter, C., Suhrbier, J., & Schwartz, W. (1999). Forecasting Bicycle and Pedestrian Travel - State of the Practice and Research Needs. *Transportation Research Record, 1674*, 94-101.

Province of Ontario. (2006). *Growth Plan for the Greater Golden Horseshoe.* Retrieved January 10, 2012, from Ministry of Infrastructure: https://www.placestogrow.ca/index.php?option=com_content&task=view&id=9&Itemid=14

Pucher, J., & Buehler, R. (2005). Cycling Trends & Policies in Canadian Cities. *World Transport Policy & Practice, 11* (1), 43-61.

Pucher, J., & Buehler, R. (2009). Integrating Bicycling and Public Transport in North America. *Journal of Public Transportation, 12* (3), 79-104.

Pucher, J., & Buehler, R. (2008). Making Cycling Irresistible: Lessons learned from The Netherlands, Denmark and Germany. *Transport Reviews, 28* (4), 495-528.

Pucher, J., & Buehler, R. (2006a). Sustainable Transport in Canadian Cities: Cycling trends and policies. *Berkeley Planning Journal, 19*, 97-123.

Pucher, J., & Buehler, R. (2010). Walking and Cycling for Healthy Cities. *Built Environment, 36* (4), 391-414.

Pucher, J., & Buehler, R. (2006b). Why Canadians cycle more than Americans: A comparative analysis of bicycling trends and policies. *Transport Policy, 13*, 265-279.

Pucher, J., Buehler, R., & Seinen, M. (2011). Bicycling Renaissance in North America? An Update and Re-Appraisal of Cycling Trends and Policies. *Transportation Research Part A, 45*, 451-475.

Pucher, J., Dill, J., & Handy, S. (2010). Infrastructure, programs, and policies to increase bicycling: An international review. *Preventative Medicine* (50), S106-S125.

Pucher, J., Komanoff, C., & Schimek, P. (1999). Bicycling Renaissance in North America? Recent trends and alternative policies to promote bicycling. *Transportation Research Part A, 33*, 625-654.

Richardson, A. (2006). Estimating Bicycle Usage on a National Cycle Network. *Transportation Research Record: Journal of the Transportation Research Board* (1982) .

Ryley, T. (2006). Estimating cycling demand for the journey to work or study in West Edinburgh, Scotland. *Transportation Research Record: Journal of the Transportation Research Board* (1982), 187-193.

Ryus, P., Vandehey, M., Elefteriadou, L., Dowling, R. G., & Ostrom, B. K. (2011). *Highway Capacity Manual 2010.* Retrieved January 16, 2013, from Transportation Research News: http://onlinepubs.trb.org/onlinepubs/trnews/trnews273HCM2010.pdf

Schneider, R. J., Arnold, L. S., & Ragland, D. R. (2009). A Pilot Model for Estimating Pedestrian Intersection Crossing Volumes. *Transportation Research Record: Journal of the Transportation Research Board, 2140*, 13-26.

Seasons, M. (2003a). Indicators and Core Area Planning: Applications in Canada's Mid-Sized Cities. *Planning, Practice and Research, 18* (1), 63-80.

Seasons, M. (2003b). Monitoring and Evaluation in Municipal Planning: Considering the Realities. *Journal of the American Planning Association, 69* (4), 430-440.

Stake, R. E. (1995). *The art of case study research.* Thousand Oaks, CA: SAGE.

Statistics Canada. (2006a). *Census 2006 - 2A (Short Form).* Retrieved December 19, 2011, from Statistics Canada: http://www5.statcan.gc.ca/access_acces/alternative_alternatif.action?l=eng&loc=http://www.statcan.gc.ca/imdb-bmdi/instrument/3901_Q1_V3-eng.pdf&t=Census%202006%20-%202A%20(Short%20Form)&k=5

Statistics Canada. (2006a). *Census 2006 - 2B (Long Form).* Retrieved December 19, 2011, from Statistics Canada: http://www5.statcan.gc.ca/access_acces/alternative_alternatif.action?l=eng&loc=http://www.statcan.gc.ca/imdb-bmdi/instrument/3901_Q2_V3-eng.pdf&t=Census%202006%20-%202B%20(Long%20Form)&k=5

Statistics Canada. (2008). *Commuting Patterns and Places of Work of Canadians, 2006 Census.* Retrieved December 19, 2011, from Statistics Canada: http://www12.statcan.ca/english/census06/analysis/pow/pdf/97-561-XIE2006001.pdf

Statistics Canada. (2009). *Commuting to work.* Retrieved January 15, 2012, from Statistics Canada: http://www40.statcan.gc.ca/l01/cst01/labr88a-eng.htm

Statistics Canada. (2011). *Journey to Work Reference Guide, 2006 Census.* Retrieved December 19, 2011, from Statistics Canada: http://www12.statcan.ca/census-recensement/2006/ref/rp-guides/journey-to-work-deplacement-domicile-travail-eng.cfm

Stolz, E. (2012). *National Perspectives The TRB Joint Subcommittee of Highway Traffic Monitoring: Bicycle and Pedestrian Data Subcommittee.* Retrieved March 15, 2012, from United States Department of Transportation Research and Innovative Technology Administration: https://www.transportationresearch.gov/dotrc/DDD/Shared%20Documents/Count%20data%20presentations/Stolz_NationalPerspectives_UpdateofTRBDataSubcommittee.pdf

Stopher, P., Zhang, Y., Armoogum, J., & Madre, J.-L. (2011). National Household Travel Surveys: The Case for Australia. *Australasian Transport Research Forum 2011 Proceedings* (pp. 1-13). Adelaide, Australia: Australasian Transport Research Forum.

Texas A & M Transportation Institute. (2012). *About TTI.* Retrieved November 27, 2012, from Texas Transportation Institute: http://tti.tamu.edu/about/

Texas Transportation Institute & Cambridge Systematics Incorporated. (2004). *Monitoring Urban Freeways in 2003: Current Conditions and Trends from Archived Operations Data.* Retrieved March 30, 2012, from Federal Highway Administration United States Department of Transportation: http://tti.tamu.edu/documents/FHWA-HOP-05-018.pdf

Tight, M., Timms, P., Banister, D., Bowmaker, J., Copas, J., Day, A., et al. (2011). Visions for a walking and cycling focussed urban transport system. *Journal of Transport Geography, 19* (6), 1580-1589.

TransLink. (2011). *Cycling for Everyone: A Regional Cycling Strategy for Metro Vancouver.* Retrieved December 12, 2012, from TransLink: http://www.translink.ca/~/media/Documents/cycling/regional_cycling_strategy/Cycling%20for%20Everyone.ashx

Transport Canada. (2011). *Measuring the Impacts of Bicycle Infrastructure Through Monitoring and Evaluation.* Retrieved December 9, 2012, from Case Studies in Sustainable Transportation: http://www.tc.gc.ca/media/documents/programs/cs91e.pdf

Transport Canada. (2010). *Urban Bicycle Planning*. Retrieved December 19, 2011, from Transport Canada: http://www.tc.gc.ca/eng/programs/environment-utsp-casestudy-cs77ebikeplanning-1177.htm

Transportation Association of Canada. (1994). A Primer on Transportation Investment and Economic Development. Retrieved April 10, 2013, from http://www.tac-atc.ca/english/resourcecentre/readingroom/pdf/econo.pdf

Transportation Tomorrow. (n.d.). *Questions being asked?* Retrieved October 23, 2012, from Transportation Tomorrow: http://www.transportationtomorrow.on.ca/faqs.html

Transportation Tomorrow. (n.d.). *Survey Questions.* Retrieved December 11, 2012, from Transportation Tomorrow: http://www.transportationtomorrow.on.ca/questions.html

Transportation Tomorrow. (n.d.). *Welcome to the Transportation Tomorrow Survey!* Retrieved December 11, 2012, from Transportation Tomorrow: http://www.transportationtomorrow.on.ca/

Transporte Ativo & Institute for Transportation and Development Policy. (2010). *Photographic Bicycle Counts.* Retrieved July 6, 2012, from Transporte Ativo: http://www.ta.org.br/contagens/Photographic_bicycle_counts.pdf

Twaddle, H., & Hall, F. (2009). *2009 University of Calgary Commuter Cyclist Survey Report.* Retrieved December 12, 2012, from City of Calgary: http://www.calgary.ca/Transportation/TP/Documents/cycling/2009_uofc_commuter_cyclist_surv_rep.pdf

United States Department of Transportation Bureau of Transportation Statistics. (2000). *Bicycle and Pedestrian Data: Sources, Needs, & Gaps.* Retrieved December 31, 2012, from United States Department of Transportation: http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/bicycle_and_pedestrian_data/entire.pdf

United States Department of Transportation Bureau of Transportation Statistics. (2003). *Research and Innovative Technology Administration Bureau of Transportation Statistics.* Retrieved December 8, 2012, from Highlights of the 2001 National Household Travel Survey: http://www.bts.gov/publications/highlights_of_the_2001_national_household_travel_survey/

United States Department of Transportation Federal Highway Administration. (1999). *Guidebook on Methods to Estimate Non-Motorized Travel.* Retrieved December 31, 2012, from United States Department of Transportation Federal Highway Administration: http://safety.fhwa.dot.gov/ped_bike/docs/guidebook1.pdf

United States Department of Transportation Federal Highway Administration. (2010). *Publications.* Retrieved December 8, 2012, from National Household Travel Survey: http://nhts.ornl.gov/briefs/ActiveTravel.pdf

Wen, H., Hu, Z., & Sun, J. (2010). Road Traffic Performance Monitoring in Beijing. *6th Advanced Forum on Transportation of China (AFTC 2010)* (pp. 19-24). Beijing: The Institution of Engineering and Technology.

Wilke, A., Lieswyn, J., & Taylor, S. (2012). *Cycle counting programme in Hamilton.* Retrieved July 6, 2012, from 2Walk&Cycle Conference, Hastings: http://www.hardingconsultants.co.nz/2walkandcycle/downloads/L10_Wilke__Axel___Poster.pdf

Winters, M., & Teschke, K. (2010). Route preferences among adults in the near market for bicycling: Findings of the Cycling in the Cities Study. *American Journal of Health Promotion, 45* (1), 40-47.

Winters, M., Davidson, G., Kao, D., & Teschke, K. (2011). Motivations and deterrents of bicycling: comparing influences on decisions to ride. *Transportation, 38*, 153-168.

Appendix A

National Bicycle and Pedestrian Documentation Project Summary Report: Vancouver

Summary Report

National Bicycle and Pedestrian Documentation Project

Location: Ontario Street and 11th Avenue East (Local Street Bikeway)
Jurisdiction: Vancouver, BC
Count Period: January 7, 2010 - December 31, 2011

Thank you for submitting Eco-counter data for inclusion in the National Bicycle and Pedestrian Documentation (NBPD) project database. This report provides a summary of the automatic bicycle and pedestrian counter data submitted from the location above and helps answer the following questions:

- **How many people are using the facility?** The table of summary statistics provides metrics of annual, monthly, daily and hourly activity.
- **When are people using the facility?** The report identifies activity levels by month of year, day of the week, and hour of the day as well as peak travel periods.
- **What purpose are people using the facility?** Relative activity levels and usage patterns between weekend and weekdays provide insight into trip purpose (i.e., recreational vs. utilitarian trips).

Table 1 below provides summary statistics for the facility and time period described above. As indicated in the table, over 113,000 people used the local street bikeway between January and December of 2010. This translates to an average of over 9,400 users per month and over 2,100 users per week. Daily activity is slightly higher on the weekend (334 users/day) as compared to the weekday (310 users/day). The peak hour of activity was 5:00PM during the week and 11:00 AM on weekends. The highest activity was recorded in July and the lowest was in January.

Table 1 – Summary Statistics

Metric	Number of bicyclists
Total Activity	
Annual total	113,541
Averages	
Average Monthly Activity	9,462
Average Weekly Activity	2,183
Average Weekday Activity	310
Average Weekend Activity	334
Average Weekday Peak Hour Volume	41
Average Weekend Peak Hour Volume	42
Peak Periods	
Weekday Peak Hour	5:00 PM
Weekend Peak Hour	11:00 AM
Month with Highest Activity	July
Month with Lowest Activity	January
Weekday Peak Hour Volume (Peak Month)	64
Weekend Peak Hour Volume (Peak Month)	49

When is the Facility Used?

Activity by Month

As indicated in Figure 1 below, activity levels increased steadily through the spring, hitting their highest levels in the summer months of July and August. Activity levels then decline through the fall, with December and January being the lowest activity months.

Figure 1 – Facility Usage by Month

Table 2 – Number of Users by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4,238	6,613	7,505	9,619	11,989	12,437	16,013	14,425	10,928	9,197	6,088	4,489

Activity by Day

As indicated in Figure 2 below, activity along the facility is slightly more prominent on weekends. However, the facility also experiences regular activity through the week. Mondays and Fridays tend to experience lighter use as compared with the middle of the week.

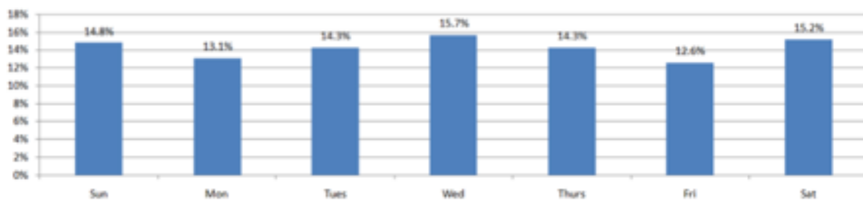


Figure 2 – Facility Usage by Day

Activity by Time of Day

Figure 3 shows the percentage of counted bicycles at different times of day. Overall, activity peaks slightly in the morning and more prominently in the afternoon, with 5:00 PM being the hour with this highest activity. The following sections shows the difference in travel patterns between weekends and weekdays

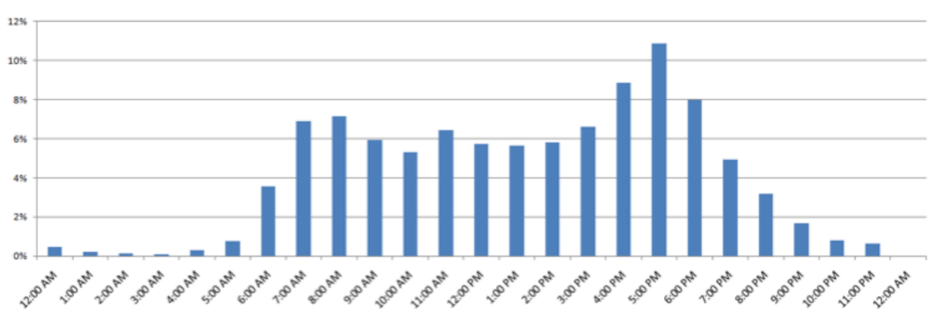


Figure 3 – Facility Usage by Time of Day

Weekend and Weekday Activity

Activity levels by time of day are displayed for weekend and weekday activity in Figure 4 and Figure 5 below. The weekday volumes show clear peak periods during the morning and evening commute hours, indicating a significant amount of utilitarian trip making. Weekend trips, by contrast, suggest more recreational travel, with travel increasing throughout the morning and continuing throughout the afternoon.

Figure 4 – Facility Usage by Time of Day (Weekday)

Figure 5 – Facility Usage by Time of Day (Weekend)

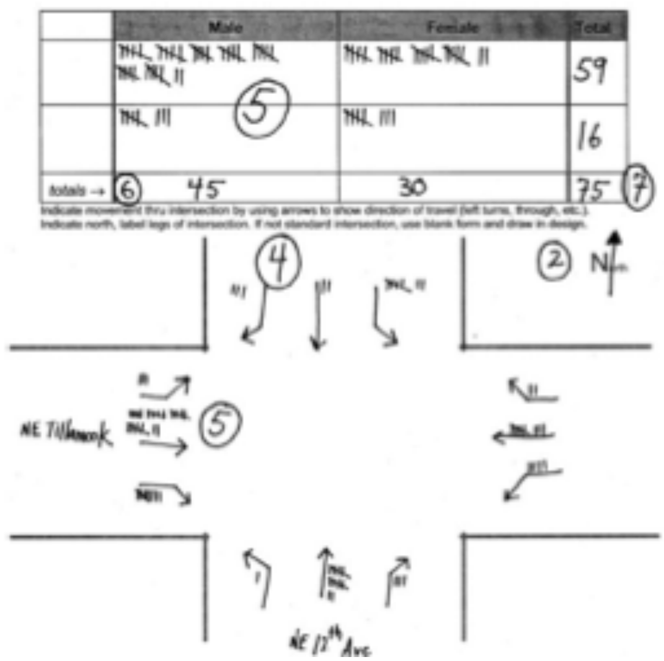
Additional Information

For additional information about the National Bicycle and Pedestrian Documentation Project, please visit www.bikepeddocumentation.org. For questions about this summary report, please email info@bikepeddocumentation.org.

Transportation | Recreation | Innovation

Source: (Alta Planning and Design, 2012)

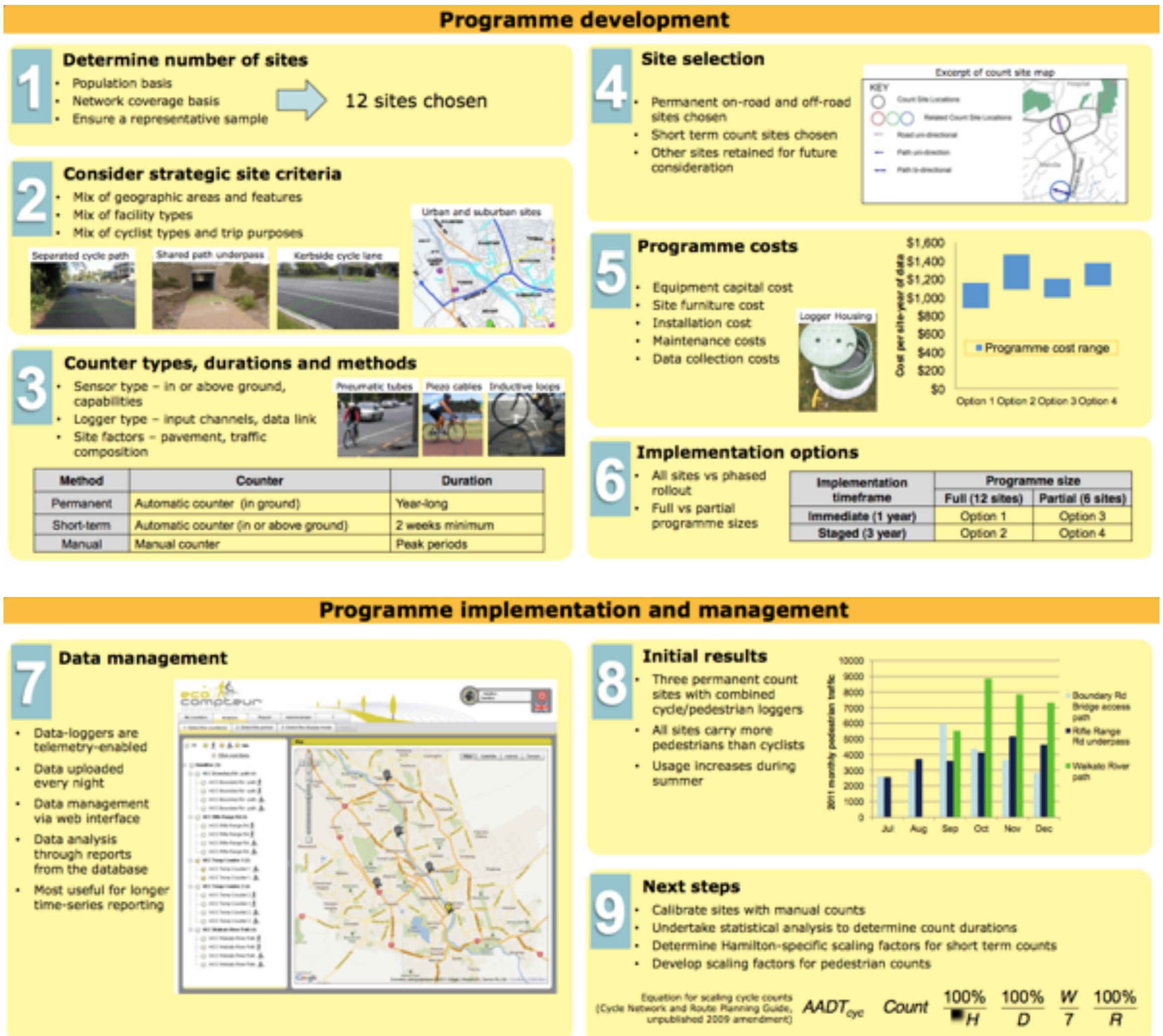
Appendix B
Example of a form used in a manual bike count by the Department of Transportation in Portland, Oregon, USA



Source: **(Transporte Ativo & ITDP, 2010)**

Appendix C

Steps to decide among monitoring options



Source: **(Wilke et al., 2012)**

Appendix D

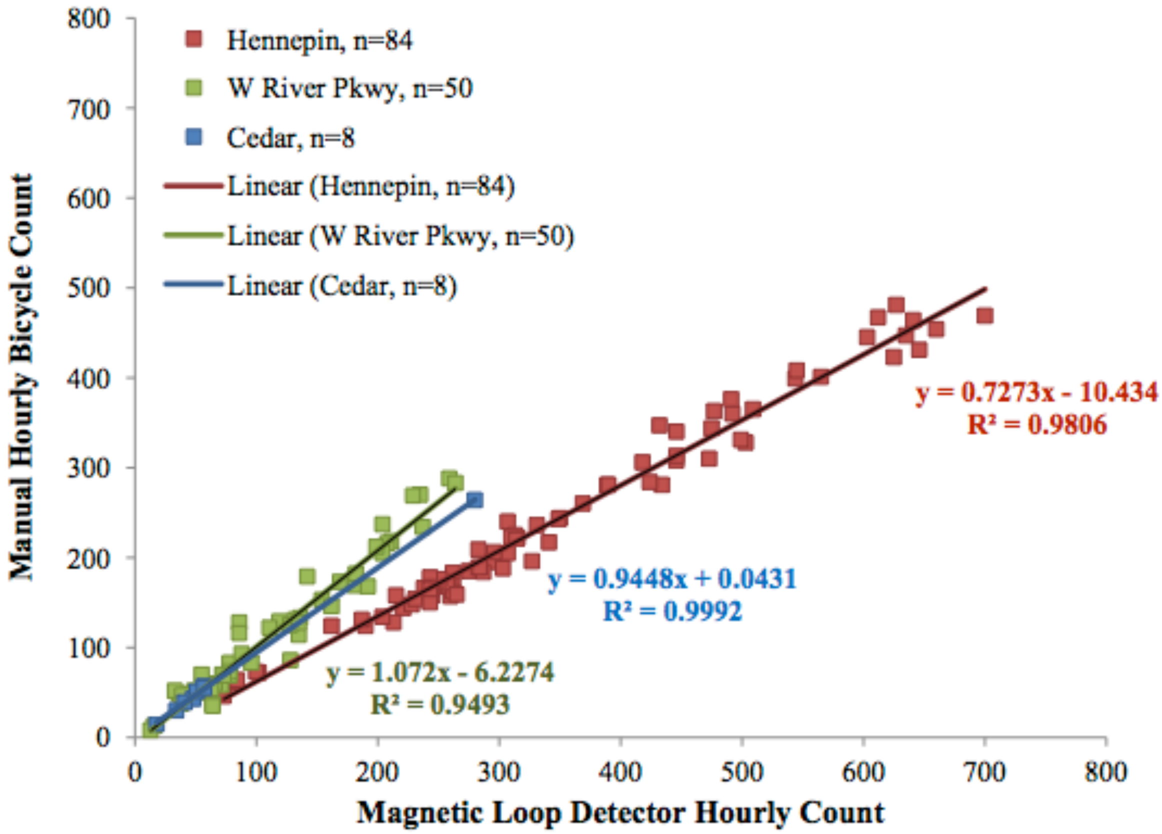
Automated Count Technologies

Technology	How it Works	Differentiate between bikes and peds?	Where can it be used?	Can it be moved to other locations?	Other Considerations	Technology Cost
Passive infrared	Detects a change in thermal contrast	No	Sidewalk, path	Easily		$,2000-3,000
Active infrared	Detects an obstruction in the beam	Yes	Sidewalk, path	Easily		$800-$7,000
Video imaging	Analyzes pixel changes	Unknown	Intended for indoor use	Yes	Difficult detection outdoors, no bike/ped application yet	$1,200-$8,000
Video playback	Video analyzed by a person	Yes	Anywhere	Yes	Difficult detection at night and bad weather. Considerable staff time	$7,000
Piezometric Tube	Senses pressure on tube	No	Path, on-street	Easily	Bicycles only. Potential tripping hazard	$1,600
Piezometric Pad	Senses pressure	No	Sidewalk, path	No		$2,000-3,000
In-pavement magnetic loop detectors	Senses magnetic field change as metal passes	No	Path, on-street	No	Requires cutting into pavement or into ground to install	$2,000-3,000

Source: **(NBPDP, 2009)**

Appendix E

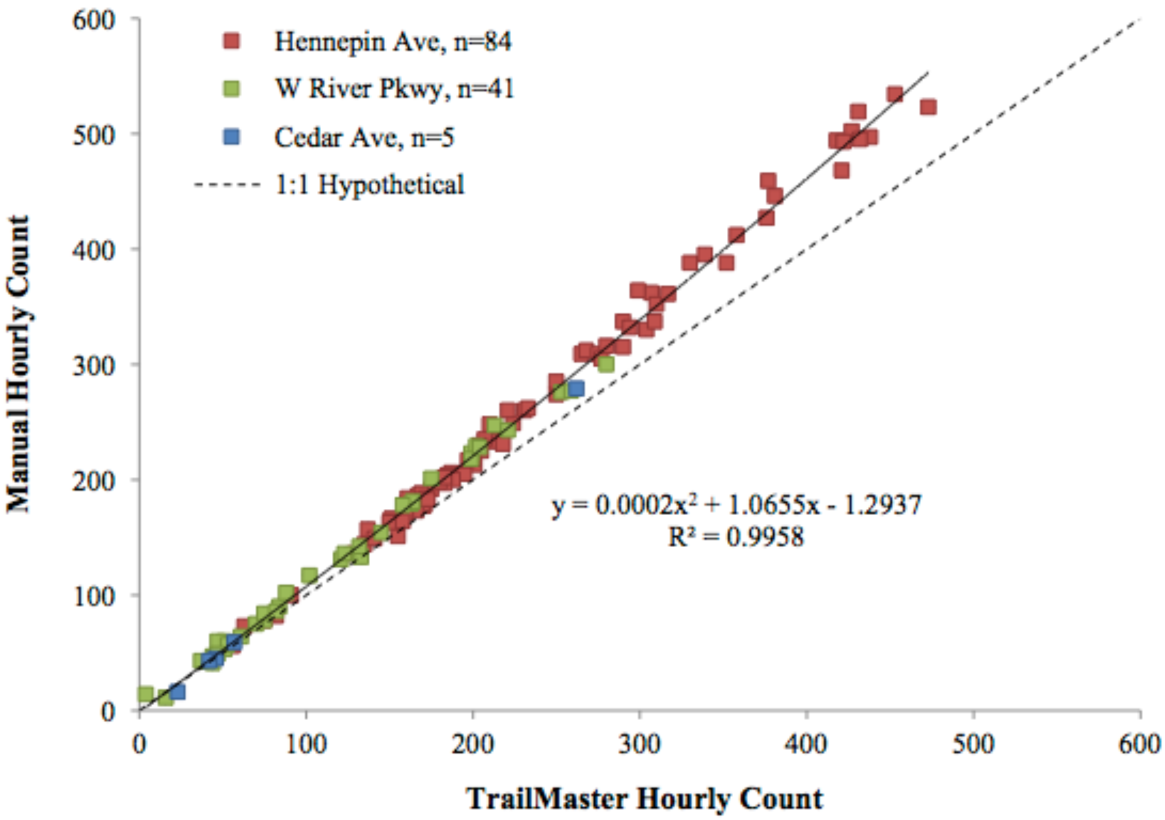
Scatter plot of manual counts vs. magnetic loop detector counts



Source: Lindsey et al., 2012

Appendix F

Scatter plot of manual counts vs. TrailMaster™ infrared counts



Source: Lindsey et al., 2012

Appendix G

Vancouver Monthly Totals

	Total Monthly Bike Trips				Mid-Week Daily Bicycle Trips (Average of all Tuesdays, Wednesdays, Thursdays)			
	Burrard Bridge	Hornby Street	Dunsmuir Street	Dunsmuir Viaduct	Burrard Bridge	Hornby Street	Dunsmuir Street	DunsmuirViaduct
09-Aug	130,000							
09-Sep	107,000							
09-Oct	70,000							
09-Nov	43,000							
09-Dec	34,000							
10-Jan	46,000							
10-Feb	71,000							
10-Mar	68,000			14,000				600
10-Apr	77,000			15,000				600
10-May	103,000			20,000				800
10-Jun	117,000			34,000	4,200			1,600
10-Jul	162,000		46,000	43,000	6,000		1,900	1,800
10-Aug	139,000		48,000	44,000	5,000		1,900	1,800
10-Sep	100,000		37,000	39,000	4,000		1,600	1,700
10-Oct	80,000		35,000	35,000	3,000		1,400	1,500
10-Nov	45,000		24,000	25,000	1,800		1,000	1,000
10-Dec	36,000		21,000	20,000	1,300		800	800
11-Jan	41,000	14,000	23,000	21,000	1,500	700	900	900
11-Feb	42,000	19,000	24,000	22,000	1,800	900	1,100	1,000
11-Mar	55,000	23,000	30,000	28,000	1,900	900	1,100	1,100
11-Apr	74,000	27,000	35,000	32,000	2,500	1,200	1,500	1,300
11-May	98,000	34,000	43,000	38,000	3,500	1,400	1,700	1,500
11-Jun	129,000	45,000	58,000	50,000	4,300	1,700	2,200	1,900
11-Jul	153,000	48,000	60,000	52,000	4,800	1,800	2,300	2,000
11-Aug	165,000	54,000	68,000	57,000	5,600	2,100	2,600	2,200
11-Sep	122,000	45,000	59,000	44,000	4,200	1,800	2,400	1,800
11-Oct	79,000	34,000	44,000	24,000	2,800	1,400	1,800	1,000
11-Nov	52,000	20,000	33,000	23,000	2,100	900	1,400	1,000
11-Dec	39,000	19,000	22,000	22,000	1,400	800	900	900
12-Jan	34,000	17,000	24,000	20,000	1,400	700	1,000	800
12-Feb	48,000	20,000	25,000	26,000	1,800	800	1,100	1,000
12-Mar	51,000	22,000	30,000	26,000	1,800	900	1,300	1,100
12-Apr	74,000	28,000	33,000	33,000	2,200	1,100	1,300	1,300
12-May	108,000	41,000	48,000	44,000	3,400	1,600	1,700	1,800
12-Jun	108,000	40,000	50,000	42,000	3,800	1,600	1,900	1,800
12-Jul	155,000	53,000	57,000	54,000	5,500	2,000	2,300	2,200
12-Aug	157,000	54,000	58,000	54,000	5,000	2,100	2,000	2,000
12-Sep	126,000	49,000	53,000	51,000	4,700	2,100	2,000	2,200

Source: City of Vancouver, 2013

Appendix H
Separated Bicycle Lane Statistics

Nine months (January to September)

Bike lane	Jan 2011 – Sept 2011	Jan 2012 – Sept 2012	Difference
Burrard Bridge	879 000	861 000	-2%
Hornby Street	309 000	324 000	+5%
Dunsmuir Street	400 000	378 000	-6%
Dunsmuir Viaduct	344 000	350 000	+2%

Note. The Hornby Street separated bike lane opened in January 2011.

Source: City of Vancouver, 2013

One year (October to September)

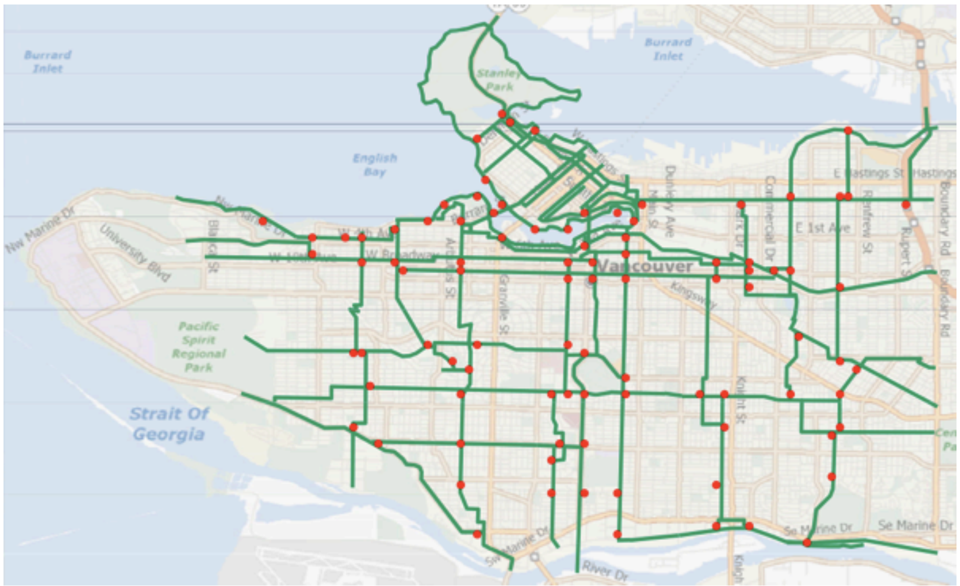
Bike lane	Oct 2010 – Sept 2011	Oct 2011 – Sept 2012	Difference
Burrard Bridge	1 040 000	1 031 000	-1%
Dunsmuir Street	480 000	477 000	-1%
Dunsmuir Viaduct	424 000	419 000	-1%

Source: City of Vancouver, 2013

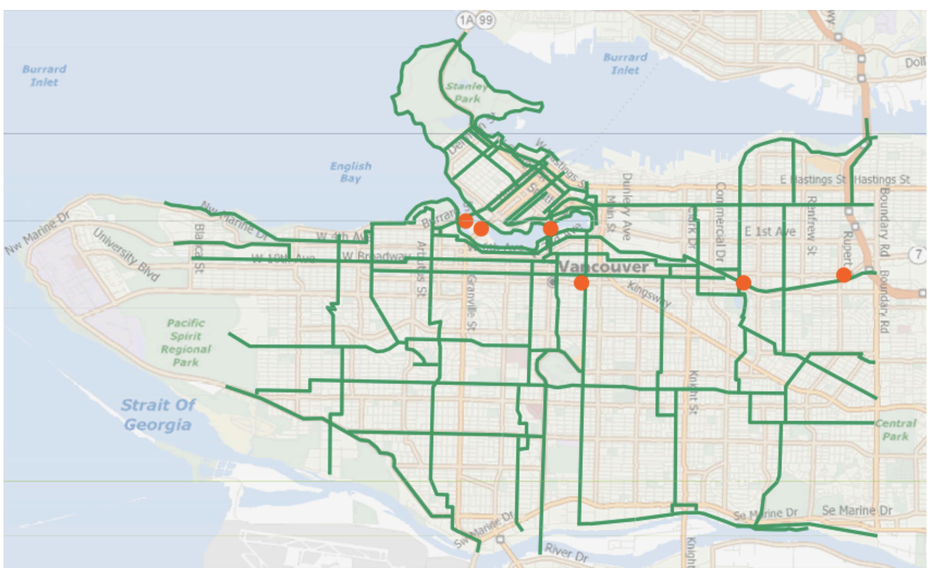
Appendix I

Count Locations in Vancouver

Manual Count Locations



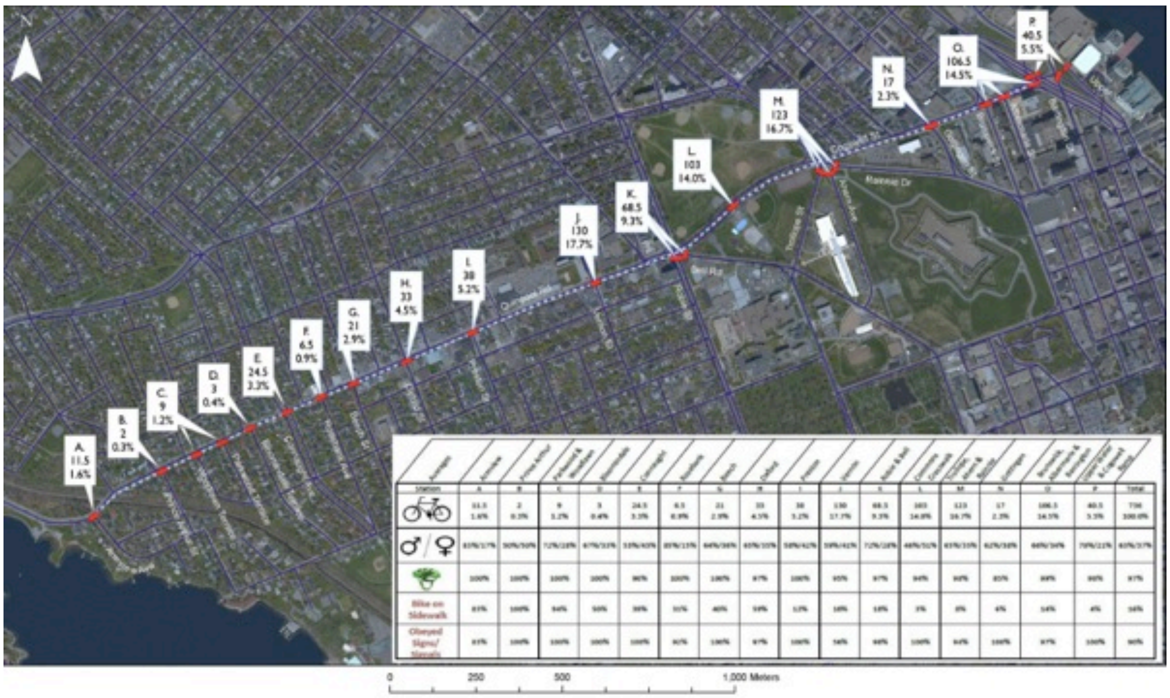
Permanent Count Locations



Source: (City of Vancouver, 2009)

Appendix J

Number of Bicycles Crossing Peninsula Screenline in Halifax (Average am/pm Peaks)



Source: (HRM, 2010)

Appendix K

Halifax's Peninsula Screenline Bicycle Count Instructions

WHO TO COUNT

This is a screenline count. Imagine a 'magic line' which runs down the southern curb of Quinpool and Cogswell Streets. Every time a cyclist crosses that line, they are counted. We are **not** counting cyclists travelling on the screenline itself as that would mean double counting or more, as there are multiple counting stations along the screenline. So, in a nutshell:

- if a bike turns on to or off of Quinpool/ Cogswell to/from the north at your station or travels past you without turning, that bike **DOES NOT** get counted.

- if the bike crosses or turns onto Quinpool/Cogswell from the south or comes along Quinpool/Cogswell and turns south, that bike **DOES** get counted.

WHEN / WHERE

The count will be held on #INSERT DATE#. Arrive at your station 15 minutes before your count time. Count in 15 minute increments from 7-9 and 4-6.

WHAT TO BRING

Supplies needed include:

- watch or other time-keeping device;
- clipboard/ pencil.

Dress appropriately for the weather conditions. Bring water to drink, a snack, and hat/ sunscreen if sunny.

RAIN DATE

The count will be called off by 4:30 pm the day before if forecast details call for rain. Rain date is #INSERT DATE#.

CONTACT INFO

Return forms to:

David MacIsaac
Strategic Transportation Planning, Eric Spicer Building
PO Box 1749
Halifax, NS B3J 3A5

For more information or questions contact:
David MacIsaac (cell): (phone): 490-1665 (email): macisad@halifax.ca

Source: **(HRM, 2010)**

Appendix L

Halifax's Bicycle Count Form

Location: ____________________ Date: ____________ NAME: ____________
Weather: ____________________ Temperature: ________
Posted Speed Limit: 50KM **Time from:** ________ **to:** ____________

Observations	- 15 min	- 30 min	- 45 min	- 60 min	Total
Total numbers of cyclists observed					
Cycle on sidewalk					
Cycle in crosswalk					
Other Illegal moves running or 'jumping' red light/ stop sign; wrong way on one way street; riding side by side; ignoring turn restrictions; jumping curbs; turning from the wrong lane					
No bell					
No helmet					
Gender Male					
Gender Female					
Age – Child/Youth (<18 years old)	Riding own bike				
	Bike seat/Trailer/Tandem				
Age – Adult (18 – 60 years old)					
Age – Senior (60+ years old)					
Comments					

*riding on the road when a bike lane is present is legal, and so is 'taking the lane' if there is a reason to do so - but please note if you see this in the comment line above.
*count tandems with two cyclists as two; count children in bike trailers or on 'tag along' bikes as cyclists in the top line, but note them in the 'own bike' or 'trailer' line.
*helmets not fastened, helmets which are not proper bike helmets, etc. count as 'no helmets'
*bells may be hard to see, but we've been asked to try and observe this this year.
* you can also note if you see any hazards or near collisions. e.g potholes, left cross, right hook.

Source: (HRM, 2010)

Appendix M

Route Selection Evaluation Criteria in Halifax Regional Municipality

FACTOR	EVALUATION CRITERIA	ROUTE ASSESSMENT	
		Route A	Route B
Risk Assessment	♦ Are there numerous mid-block or railway track crossings? ♦ Is there a high volume of automobiles, trucks and transit vehicles? ♦ Is there sufficient right-of-way width to accommodate trail connections? ♦ Does the route provide a safe crossing of major barriers? ♦ Are there poor sight-lines? ♦ What is the posted speed limit of the route, if applicable? ♦ Can the route accommodate the preferred facility type?	◕	◑
Connectivity/ Access	♦ Does the route provide a vital connection to existing routes and trails? ♦ Does the route provide direct access to major destinations and connect major nodes throughout the town? ♦ Does the route connect to municipal networks, supporting services and facilities?	◕	◔
Convenience	♦ Does the route include adequate traffic control devices to cross intersecting roads? ♦ Are mid-block crossings possible where demand warrants? ♦ Is the route part of the "Spine" network? ♦ Does the route provide a direct path to the destination?	◕	◔
Attractiveness	♦ Does the route provide access to HRM's scenic routes, vistas and destinations? ♦ Is the route highly visible? ♦ Does the route provide diversity of experience?	●	◑
Cost	♦ Is the route the most cost-effective solution? ♦ Is there the ability to reduce costs by combining route development with existing road works?	◑	◕
Route Alignment	♦ Is the location suitable with respect to adjoining land uses and environmental considerations? ♦ Can existing barriers be overcome? ♦ Is the road right-of-way width sufficient to accommodate cycling facilities or does the roadway require widening?	◕	◔
	DECISION	◕ Route Recommended	◔ Route Not Recommended

Poor	Adequate	Good	Very Good	Excellent
○	◔	◑	◕	●

Source: (HRM, 2006)

Appendix N

Core Indicators for Land Use and Mobility from Calgary's MDP

#	Core Indicators	Metric	Baseline	60-year Target
1	Urban Expansion	Per cent of population growth accommodated within developed area (2005 boundary area)	In 2005, the developed area of the city was losing 5% of population to greenfield area.	50%
2	Density	People per hectare	In 2005, Calgary had a population density of 20 people per hectare.	27
		Jobs per hectare	In 2005, Calgary had employment density of 11 jobs per hectare.	18
3	Population / Jobs Balance	Population/Jobs East/West ratio	In 2005, the population/ jobs East/ West ratio was 2.7.	1.7
		Population/Jobs North/South ratio	In 2005, the population/ jobs North/ South ratio was 1.9.	1.7
4	Mix Land use	Land Use Diversity Index	In 2008, land use mix diversity index was 0.53.	0.7
5	Residential Mix	Residential Diversity Index	In 2008, residential diversity index was 0.19.	0.4
6	Road and Street Infrastructure	Roads to Streets ratio	0.72 (42% Roads and 58% Streets)	0.57 (36%Roads and 64% Streets)
7	Accessibility to Primary Transit Network	Per cent of population within 400m of Primary Transit Network	LRT is the only transit service approaching Primary Transit levels of service in Calgary today.	45%
		Per cent of jobs within 400m of Primary Transit Network	LRT is the only transit service approaching Primary Transit levels of service in Calgary today.	67%
8	Transit Service	Annual transit service hours per capita	Currently, 2.2 transit service hours are provided for each resident in Calgary annually.	3.7
9	Goods Access	Per cent of intermodal and warehousing facilities within 1600m (actual) of Primary Goods Movement Network	Currently, 73% of intermodal and warehousing facilities are located within 1600m of Primary Goods Movement Network.	95%
10	Transportation Mode Split	Walking and Cycling Mode Split (all purpose trips, 24 hours, city-wide)	In 2005, walk and bike trips contributed to 14% of all trips made.	20% - 25%
		Transit Mode Split (all purpose trips, 24 hours, city-wide)	In 2005, 9% of all trips were made by transit.	15% - 20%
		Auto Mode Split (all purpose trips, 24 hours, city-wide)	In 2005, 77% of all trips were made by car.	65% - 55%
11	Accessibility to Daily Needs	Per cent of population within Major and Community Activity Centres, and 600m of Urban and Neighbourhood Corridors	In 2006, 18% of all population was located within Major and Community Activity Centres, and 600m of Urban and Neighbourhood Corridors.	30%
12	Watershed Health	Per cent of impervious surface	In 1998, 32% of land cover was impervious (made up of roadways, parking and buildings).	10% - 20%

Note: This figure is also in the CTP.

Source: (City of Calgary, 2010, p. 5-10)

Appendix O

Past policies, plans and surveys from Calgary

1958 to present – CBD Cordon Count	• This is a survey of all trips, including cycling trips, entering or leaving the CBD on weekdays over a 16-hour period.
1996 – Calgary Cycle Plan	• The Cycle Plan contained 45 recommendations of which 85 per cent are complete or in progress.
2000 – Downtown Commuter Cyclist Survey	• This was the first comprehensive survey of cyclists entering downtown Calgary, weekdays between 6:30 a.m. and 9 a.m. • The survey had a 58 per cent response rate and the results provide the baseline data for future surveys and trends with respect to downtown cyclists.
2001 – Pathway and Bikeway Plan	• The plan developed the principles for an integrated multi-use pathway and on-street bikeway network, including a detailed city-wide implementation plan map, and engaged over 60 stakeholder groups. • The plan contained 27 recommendations of which 89 per cent are complete or in progress.
2001 – Wide curb lane standard adopted on major roads	• Calgary's first change in street standards to provide space for on-street cycling.
2003 – Bicycle Parking Handbook	• Calgary's first guideline on bicycle parking type, placement and quantity for property development.
2005 – Traffic Calming Policy	• The policy includes a variety of tools to help make community streets more comfortable for cyclists through decreasing vehicle speed and volumes.
2006 – Downtown Commuter Cyclist Survey	• This was a follow-up to the 2000 survey and informed The City if any cycling data was changing with respect to cyclist route preferences, behaviours and demographics.
2007 – CBD Bicycle Parking Inventory	• This was the first time that The City surveyed private building owners in the CBD on the type and number of bicycle parking facilities they had.
2008 – Bicycle Policy	• The policy re-affirmed cycling as a meaningful, non-motorized choice of transportation and established broad, city-wide policies that provide direction and guidance on how to plan, design, build, operate and maintain a city where cycling is a meaningful form of transportation for social and economic activities.
2008 – Bicycle Parking into Land Use Bylaw 1P2007	• The Land Use Bylaw was updated to include bicycle parking requirements for new developments.
2009 – University of Calgary Commuter Cyclist Survey	• An online survey, co-sponsored by The City of Calgary and the University of Calgary, gathered information about commute characteristics and barriers to cycling from 1,100 cyclists and potential cyclists, capturing over 85 per cent of the estimated number of students and staff who cycle to campus.
2009 - Calgary Transportation Plan	• Identifies walking and cycling as the most sustainable forms of travel. • Identifies the principles and alignment for the Primary Cycling Network (PCN), which connects Major Activity Centres and will provide high quality service for cycling. • States that cycling will be "accommodated with high standards" on most new street types (arterial, urban boulevard, neighbourhood boulevard and parkway). • Sets a target for city-wide walking and cycling trips to increase from 14 per cent today to 20-25 per cent in 60 years.
2010 - Centre City Mobility Plan	• Identifies the bicycle network in the Centre City.

Source: (City of Calgary, 2011, p. 19)

Appendix P

Calgary's Cycling Indicators

Indicator	#	Metric	Unit	Baseline (2009 unless otherwise noted)	2020 Target	Source
Cycling Activity	1	Home to work mode split (24 hours, city-wide)	%	1.4% (2006)	2%	Civic census transportation survey
	2	Cycling mode split (all purpose trips, 24 hours, city-wide)	%	0.8% (2001)	1.5%	Calgary and Region Travel Survey (formerly Household Activity Survey)
	3	Percentage of female cyclists (all-purpose trips, 24 hours, city-wide)	%	29% (2001)	40%	Calgary and Region Travel Survey (formerly Household Activity Survey)
	4	Centre City cycling mode split (AM peak, inbound only)	%	1.9% (2010)	4%	Annual CBD cordon counts
	5	Major Activity Centre cycling volumes	# / 16 hrs	To be established		Major Activity Centre cordon counts
	6	Average increase in cyclist volumes observed after a route improvement	%	To be established		Bicycle volume counts
	7	Number of cycling trips using the bike share system per year.	#	0	200,000	Bike share system operator
Cycling Infrastructure	8	Length of future primary cycling network built (as per 2009 CTP)	km	68	100	Future TransNet GIS layer
	9	Length of primary cycling network completely implemented including snow clearing (as per 2009 CTP)	km	8	38	Roads Maintenance & Future TransNet GIS layer
	10	Percentage of population and jobs within 800 metres of cycling network	%	To be established		Pathway and bikeway GIS layers
	11	a) Total length of cycling network	km	1,067	1500	Pathway and bikeway GIS layers
		b) Regional pathways	km	712	900	Pathway GIS layer
		c) On-street bikeways	km			Bikeway GIS layer
		• Signed routes/bicycle boulevards		328	370	
		• Shared lanes		15	20	
		• Bicycle lanes		12	180	
		• Cycle tracks		0	30	
		Total on-street bikeways		355	600	
	12	Length of on-street cycling network with high level of snow and ice control service	km	0	60	Roads Maintenance & bikeway GIS layer
Safety	13	Collisions involving a cyclist on public streets	# crashes / 1,000 home to work cyclists	18.4	16	Calgary Police Service, civic census transportation survey
	14	Cyclist injuries due to collision	# injuries / 1,000 home to work cyclists	11.2	10	Calgary Police Service, civic census transportation survey
	15	Cyclist fatalities due to collision	#	0	0	Calgary Police Service
Citizen Satisfaction	16	Satisfaction with the on-street cycling network	% satisfied and very satisfied	To be established		Citizen Satisfaction Survey
	17	Perceived safety in traffic	% agreement	21% (2010)	40%	Telephone Survey or other surveys
	18	Perceived coverage of bikeway network	% agreement	47% (2010)	60%	Telephone Survey or other surveys
	19	Perceived satisfaction with amount of bike parking	% satisfied and very satisfied	46% (2010)	60%	Telephone Survey or other surveys

Source: (City of Calgary, 2011, p. 64)

Appendix Q

Actions for data collection and reporting

	Cycling Strategy actions	2012 to 2014	2015 +	Capital Costs	Operating Costs	Potential Partnerships
C42	Investigate best practices and technology for cycling data collection, purchase automated counting stations and install them in strategic locations.	—		✓		
C43	Investigate the inclusion of a question regarding on-street bikeways in the Citizen Satisfaction Survey to update and report on indicator 16 in Table 8-1.	—			✓	
C44	Investigate conducting periodic telephone surveys to update and report on indicators 17, 18 and 19 in Table 8-1.	→	→		✓	
C45	Investigate improvements to bicycle collision reporting format and procedures with the Calgary Police Service and the Government of Alberta.	—				
C46	Report to Council, Administration and the public on all performance measures prior to each business planning cycle, beginning with the 2015-2017 business planning cycle.	—				
C47	Report yearly to Council on the status of actions identified in the Cycling Strategy.	→	→			

Source: (City of Calgary, 2011, p. 65)

Appendix R
Agencies Involved in the Transportation Tomorrow Survey

Cities

Barrie
Brantford
Guelph
Hamilton
Kawartha Lakes
Orillia
Peterborough

Counties

Brant
Dufferin
Peterborough
Simcoe
Wellington

Towns

Orangeville

Transportation Agencies

Metrolinx
Toronto Transit Commission

Ministries

Ministry of Transportation Ontario

Regional Municipalities

Durham
Halton
Niagara
Peel
Waterloo
York

Source: (Transportation Tomorrow, n.d.)

Appendix S

Sample Questions from the Transportation Tomorrow Survey

A. About your household
- Type of building (house or apartment);
- Number of people; and
- Number of vehicles available for personal use.

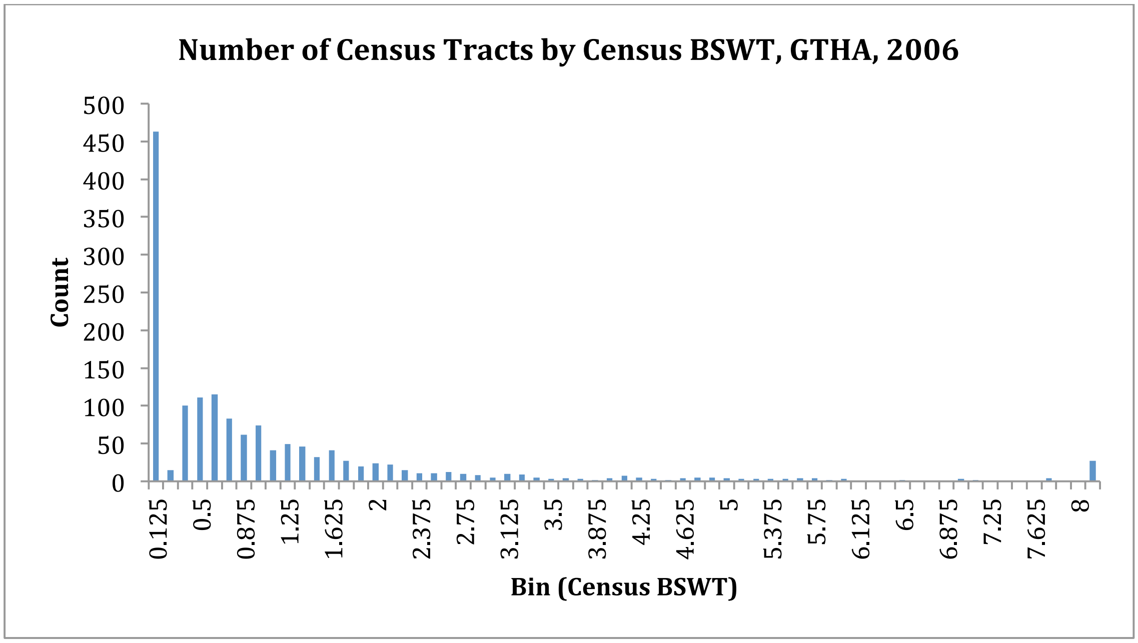
B. About each person
- Their age;
- Do they have a driver's license?; and
- Where do they work or go to school (street address).

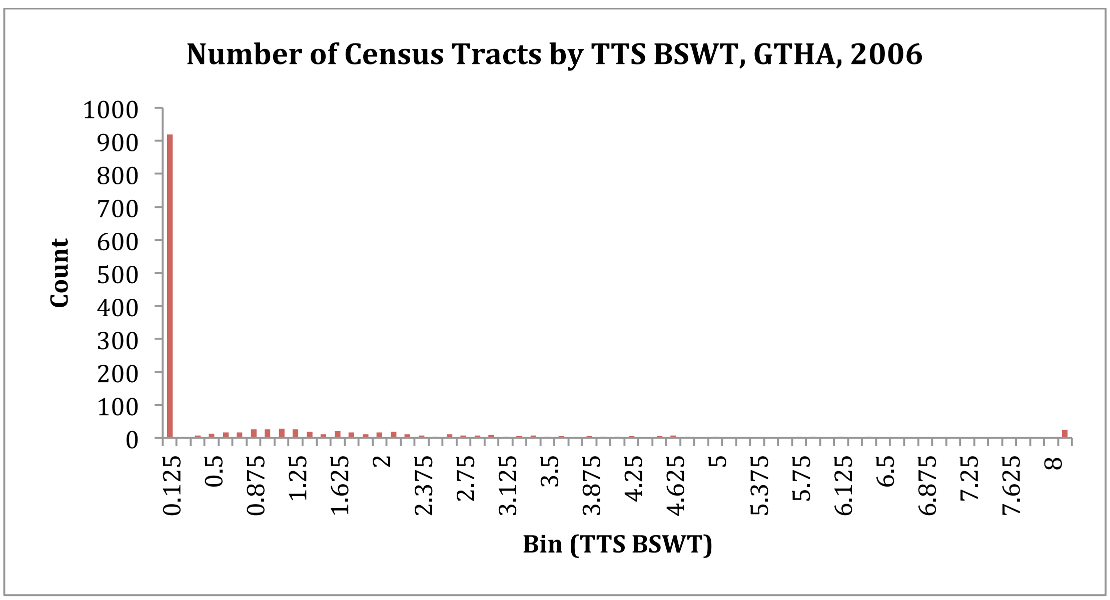
C. About each trip made by each person the previous day
- From where, to where (street address preferred or otherwise building name);
- Reason for making the trip (e.g. shopping);
- Start time of the trip; and
- Type of transportation (bus, car, bicycle, etc.).

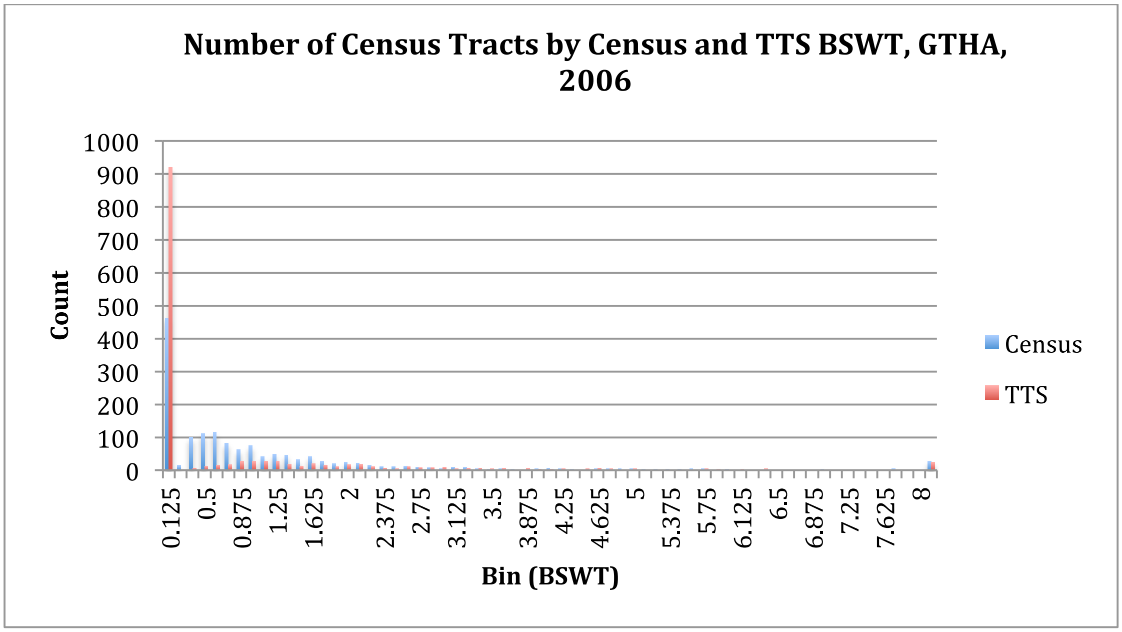
Source: (Transportation Tomorrow, n.d.)

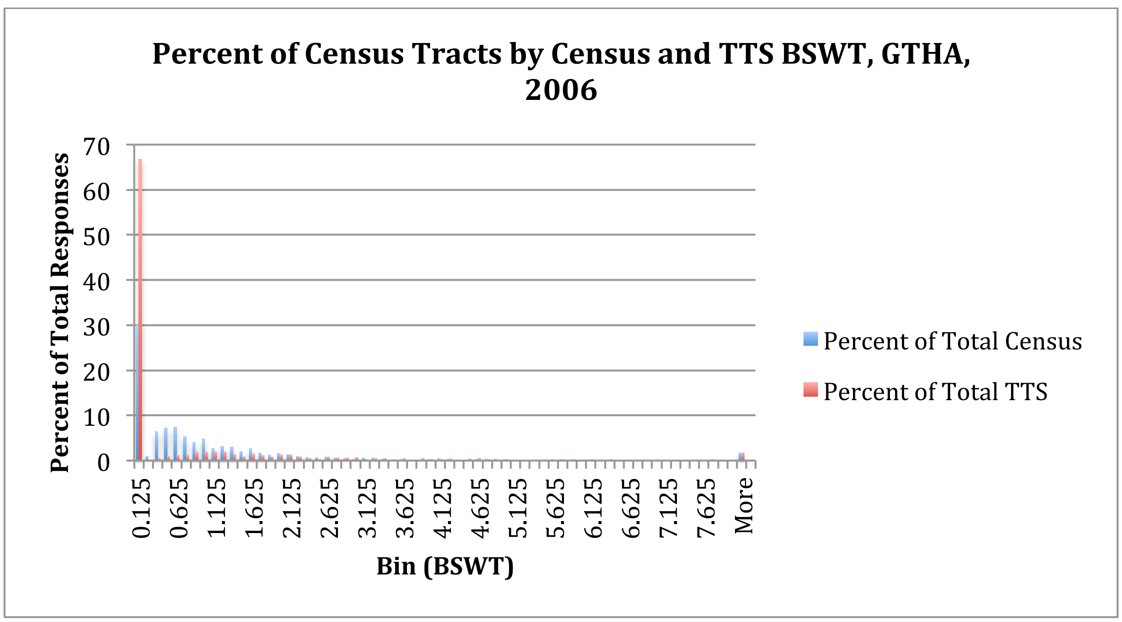
Appendix T

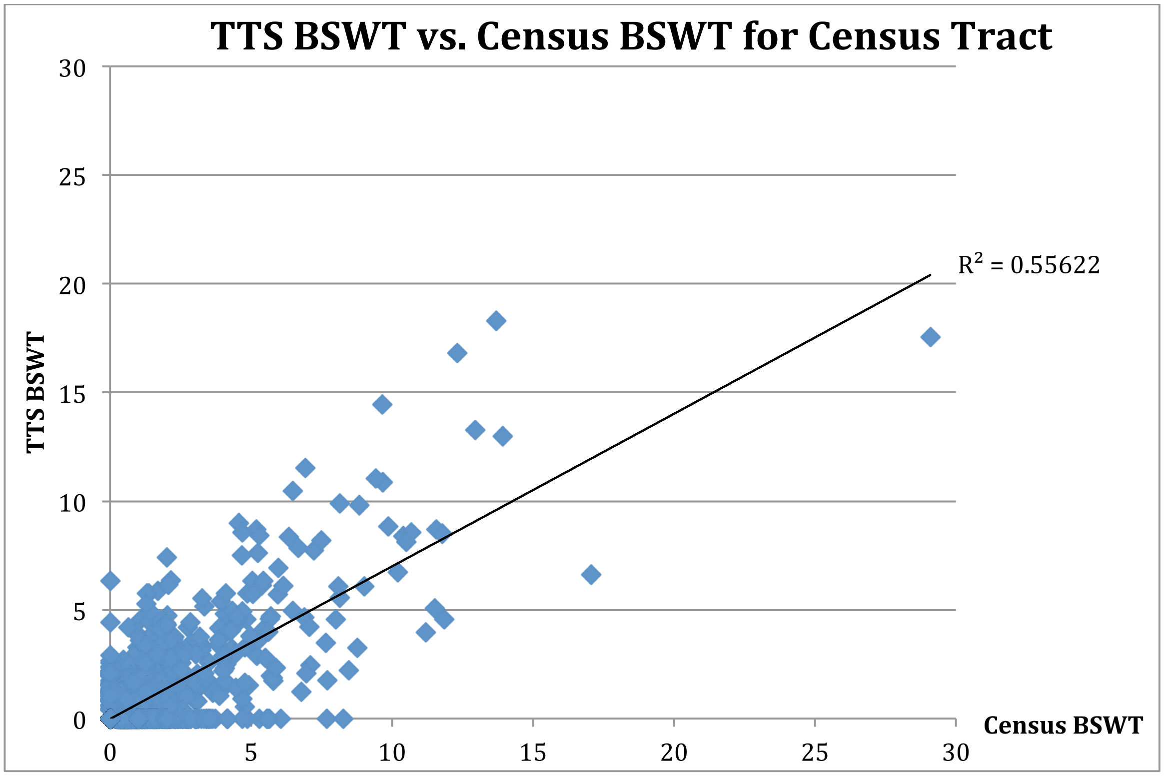
Graphic Results

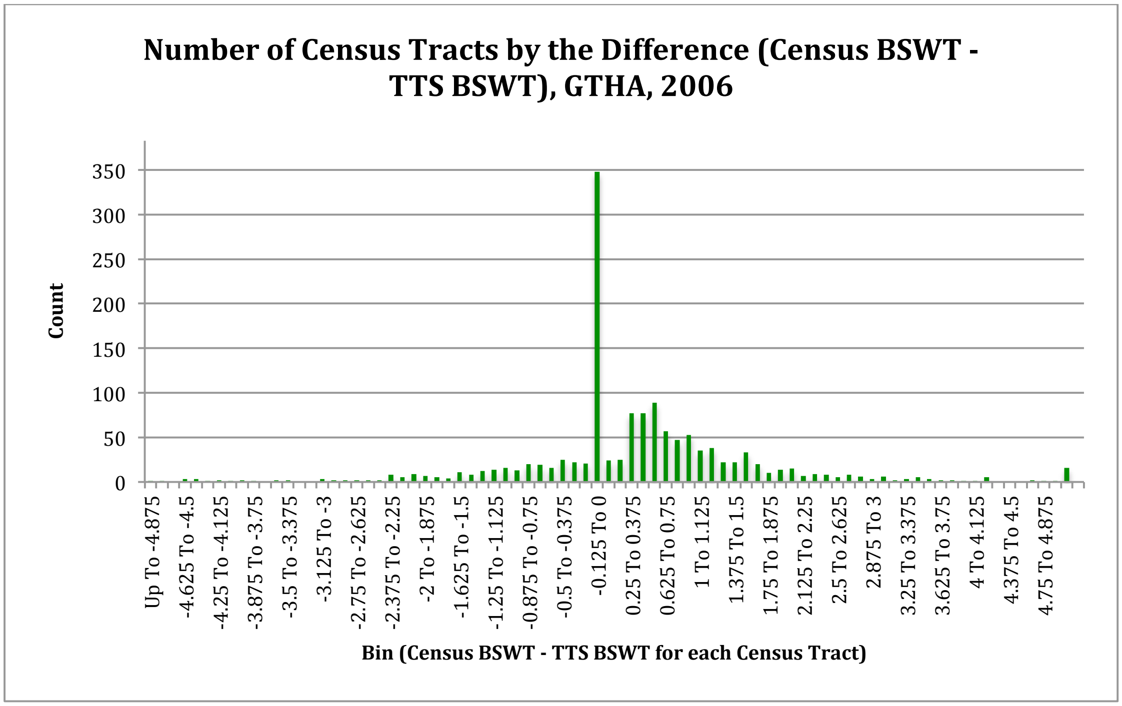


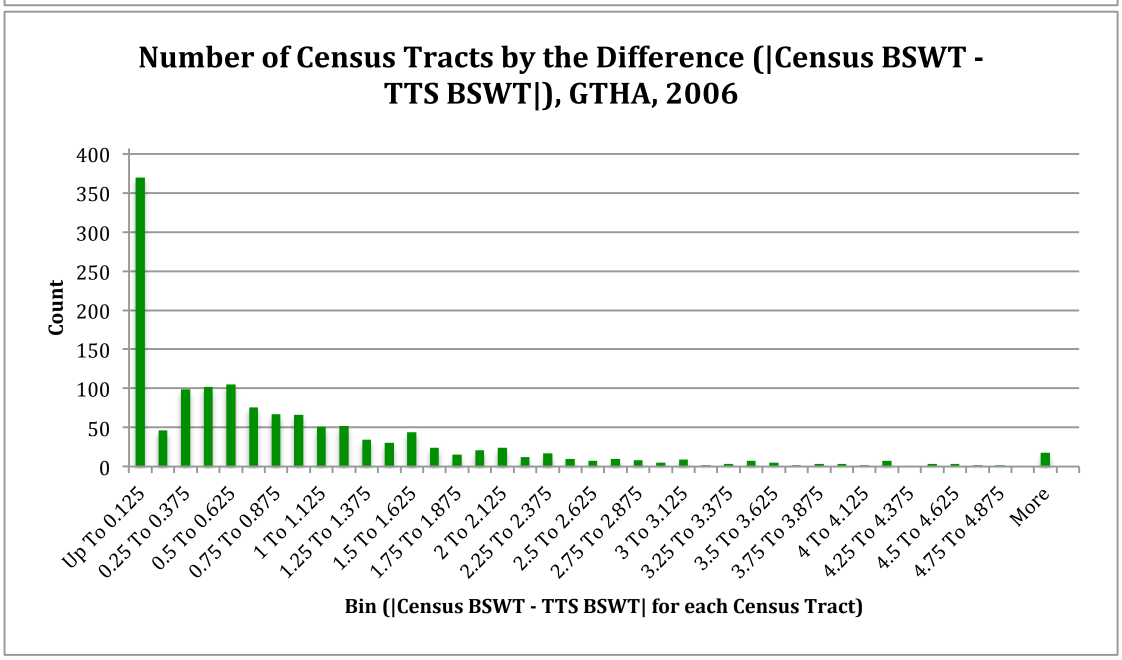


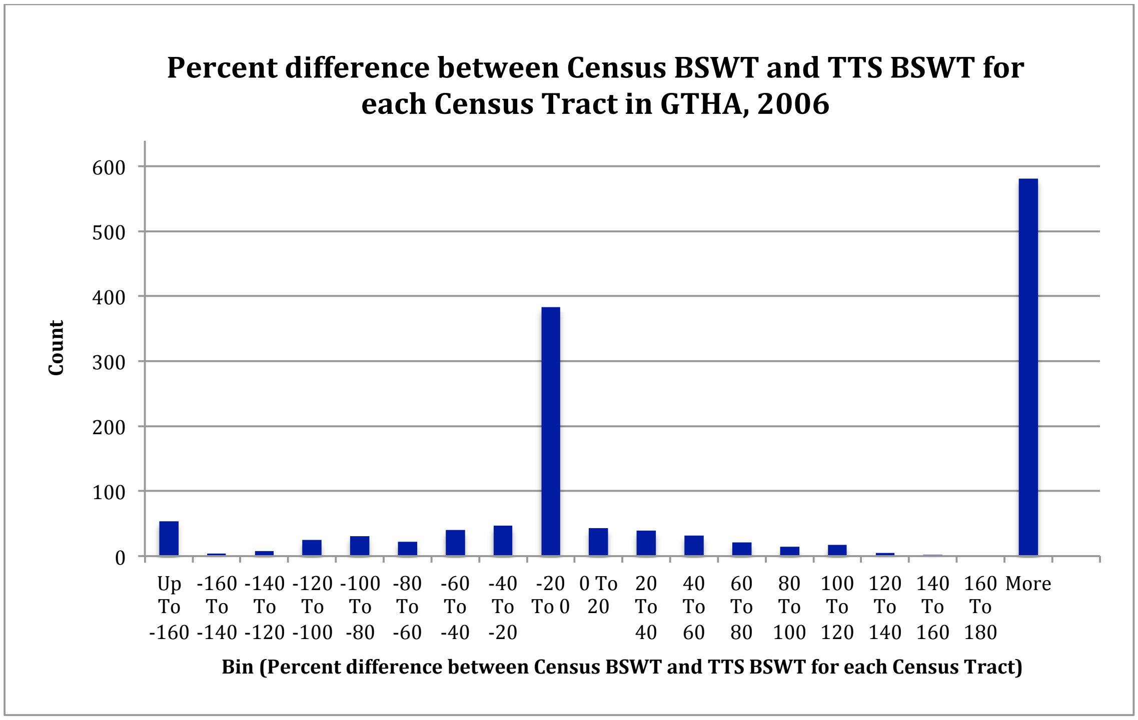

Number of Census Tracts by Census and TTS BSWT, GTHA, 2006
Count
1000
900
800
700
600
500
400
300
200
100
0
0.125
0.5
0.875
1.25
1.625
2
2.375
2.75
3.125
3.5
3.875
4.25
4.625
5
5.375
5.75
6.125
6.5
6.875
7.25
7.625
8
Bin (BSWT)
Census
TTS

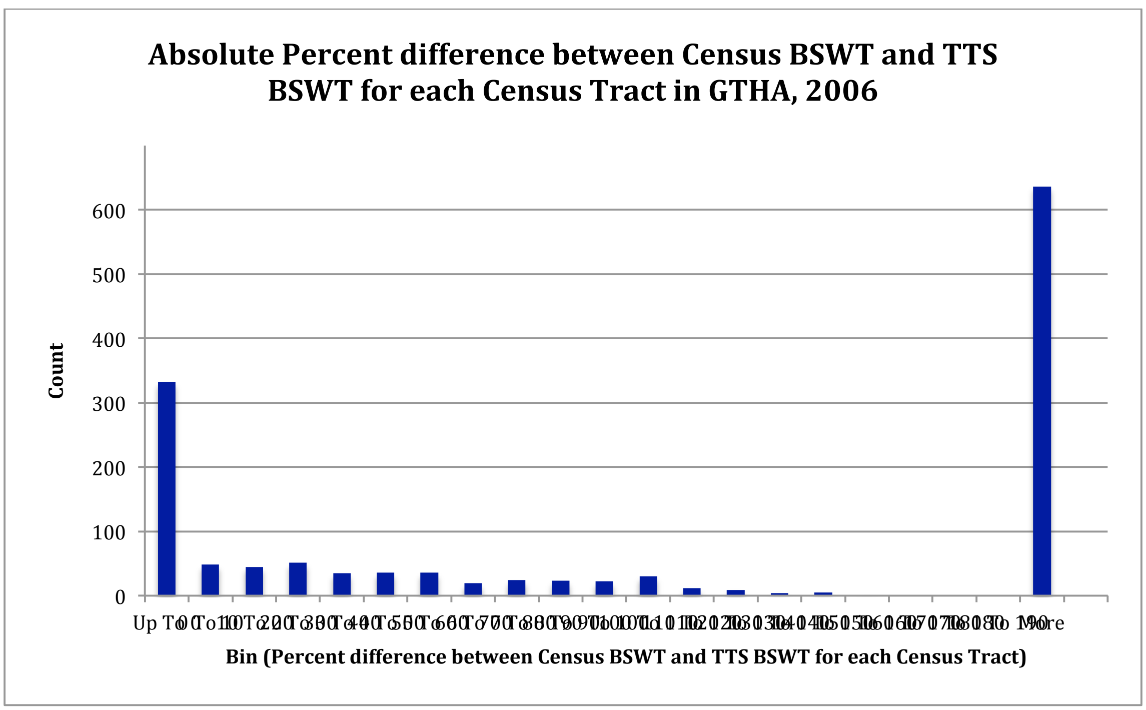

Percent of Census Tracts by Census and TTS BSWT, GTHA, 2006
Percent of Total Responses
70
60
50
40
30
20
10
0
0.125
0.625
1.125
1.625
2.125
2.625
3.125
3.625
4.125
4.625
5.125
5.625
6.125
6.625
7.125
7.625
More
Bin (BSWT)
Percent of Total Census
Percent of Total TTS


TTS BSWT vs. Census BSWT for Census Tract
TTS BSWT
Census BSWT
R^2 = 0.55622
0
5
10
15
20
25
30
0
5
10
15
20
25
30


Number of Census Tracts by the Difference (Census BSWT - TTS BSWT), GTHA, 2006
Count
Bin (Census BSWT - TTS BSWT for each Census Tract)


Number of Census Tracts by the Difference (|Census BSWT - TTS BSWT|), GTHA, 2006
Count
Bin (|Census BSWT - TTS BSWT| for each Census Tract)


Percent difference between Census BSWT and TTS BSWT for each Census Tract in GTHA, 2006
Count
600
500
400
300
200
100
0
Up To -160
-160 To -140
-140 To -120
-120 To -100
-100 To -80
-80 To -60
-60 To -40
-40 To -20
-20 To 0
0 To 20
20 To 40
40 To 60
60 To 80
80 To 100
100 To 120
120 To 140
140 To 160
160 To 180
More
Bin (Percent difference between Census BSWT and TTS BSWT for each Census Tract)


Absolute Percent difference between Census BSWT and TTS BSWT for each Census Tract in GTHA, 2006
Count
600
500
400
300
200
100
0
Bin (Percent difference between Census BSWT and TTS BSWT for each Census Tract)

Appendix U

Bicycle Counting Locations for Cordon Count in Toronto

Source (City of Toronto, 2010, p. 5)

Appendix V

Use of Census Journey to Work data in Blueprint for a Bicycle Friendly HRM: Halifax Regional Municipality Bicycle Plan

Census Area	% Cycle Commuters
Halifax Peninsula	2.95%
Eastern Passage/Cow Bay	1.08%
Dartmouth	0.94%
Eastern Shore East	0.75%
Halifax Mainland	0.61%
Eastern Shore West	0.58%
Timberlea/Lakeside/Beechville	0.56%
Cole Harbour./Westphal	0.55%
St. Margaret's Bay	0.55%
Lake Echo/Porters Lake:	0.29%
Hammonds Plains/Upper Sackville/ Beaver Bank	0.27%
Shubenacadie Lakes	0.18%
Sackville	0.16%
Bedford	0.14%
All other Plan Areas	0.00%.
Average for all HRM	0.95%

Source: (HRM, 2002)

Appendix W

Example of potential importance of non-commute trips

Comparing Modes

Consider the daily travel of somebody who commutes by car but walks and bikes for errands, as summarized in Table 5. A *traffic* perspective, which only counts motor vehicle travel, classifies her as an auto-commuter and measures her car mileage. A *mobility* perspective also counts walking and cycling trips, but since driving represents 87% of person-miles, considers nonmotorized modes of little importance. However, an *access* perspective indicates that driving represents just 50% of her travel time and only 20% of her trips, suggesting a more important role for alternative modes.

Table 5 **Example of Daily Person Trips**

Purpose	Mode	Distance (miles)	Time (minutes)
To work	Drive	15	30
From parking to office.	Walk	0.2	4
To restaurant for lunch.	Walk	0.5	10
From restaurant after lunch.	Walk	0.5	10
From office to parking.	Walk	0.2	4
To home.	Drive	15	30
To commercial center.	Bike	1	6
Errands (travel between shops)	Walk	0.5	10
Home from shopping center.	Bike	1	6
Walk dog.	Walk	0.5	10
Drive	*2 trips (20%)*	*30.0 (87%)*	*60 (50%)*
Walk	*6 trips (60%)*	*2.4 (7%)*	*48 (40%)*
Bike	*2 trips (20%)*	*2.0 (6%)*	*12 (10%)*
Totals	***10 trips (100%)***	***34.4 (100%)***	***120 (100%)***

(Assumes Drive = 30 mph, Walk = 3 mph, Bike = 10 mph. Values in parentheses indicate percentage of total travel.)

Source: Litman, 2011