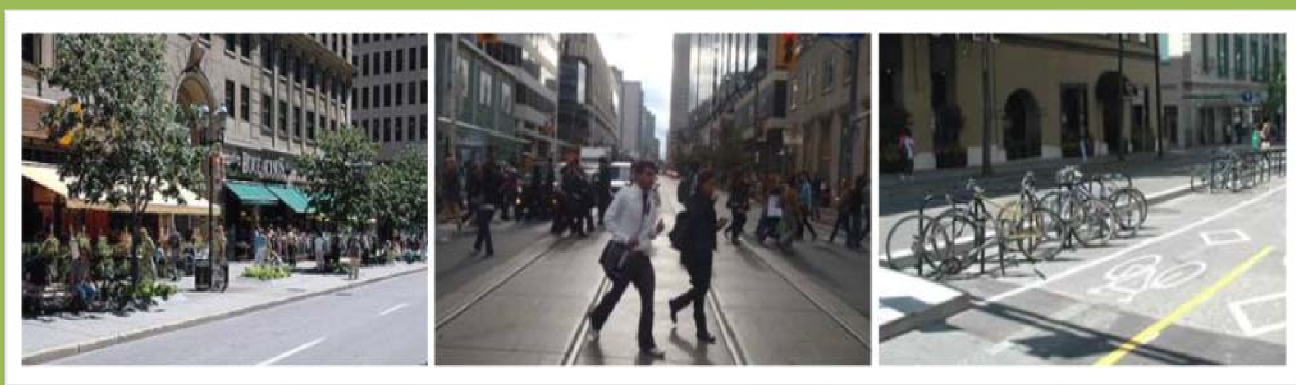
Benchmarking Active Transportation in Canadian Cities



Clean Air Partnership

Researchers and Authors

Kevin Behan, Researcher, Clean Air Partnership

Nancy Smith Lea, Director, Toronto Coalition for Active Transportation, Clean Air Partnership

Cover Photo Credits:

Montreal: Dylan Passmore
Toronto: Carrie Armstrong
Vancouver: City of Vancouver

Support has been provided by the Vital Toronto Fund at the Toronto Community Foundation. CAP would also like to thank Daniel Egan, Charles O'Hara and Michelle St-Amour for their help in reviewing the report and Jana Neumann for her input on the survey development.

For more information, contact:

Clean Air Partnership
75 Elizabeth Street,
Toronto, Ontario,
M5G 1P4, Canada
416-392-6672
cap@cleanairpartnership.org

This publication may be downloaded at www.cleanairpartnership.org

Clean Air Partnership (CAP) is a registered charity that works in partnership to promote and coordinate actions to improve local air quality and reduce greenhouse gases for healthy communities. Our applied research on municipal policies strives to broaden and improve access to public policy debate on air pollution and climate change issues. Our social marketing programs focus on energy conservation activities that motivate individuals, government, schools, utilities, businesses and communities to take action to clean the air.

The Toronto Coalition for Active Transportation (TCAT) was formed in 2006 to give a unified voice to the many groups working for a better cycling and pedestrian environment in Toronto. TCAT has worked closely with CAP since its inception and became a project of CAP in 2008. TCAT guides the active transportation programming at CAP and has expanded its activities to other communities in Ontario.

Table of Contents

List of Figures

Executive Summary

The effect of the built environment on motorized transportation is well understood, but considerably less attention has been paid to its impacts on active transportation (Cervero and Duncan, 2003). A key omission has been a credible assessment of the indicators against which planners can assess the benefits of active transportation interventions. The United Nations Commission on Sustainable Development (2001) notes the vital role that indicators can play in assisting planning and decision making through measuring progress towards stated goals, identifying deficient areas and by providing units of measurement through which we can quantify complex social and physical information.

As active transportation grows in popularity, planners require accurate data to measure this growth and to assess the impacts of transportation policies, programs and infrastructure changes. Who is walking and cycling to work and what are the conditions that would encourage more people to do so? What are the factors that *dis*courage active transportation? How do trends and conditions change over time?

This report has two distinct parts. The first consists of an extensive review of active transportation indicators employed in both academic and governmental studies. Over 50 papers were reviewed resulting in a list of 78 unique active transportation indicators. 39 of these indicators were reviewed in this research study and grouped into five categories: Infrastructure, Safety, Travel Behaviour, Demography and Geography. These indicators were then employed in the second part of the report in order to complete a comparative analysis of active transportation in eight selected cities. The indicators are used to provide a snapshot of two time periods – 2007 and 2010.

The report concludes with a section that compares the success of active transportation in Toronto with other Canadian, American and European cities. In doing so we aim to recognize the success of existing initiatives, while highlighting areas where increased efforts may be required.

Among the study’s findings:

- Cities with more kilometres of bicycle facilities also have a higher AT mode share, as do those cities with a higher *density* of bike lanes
- In cities with high mode shares, the percentage of cyclists and pedestrians injured and killed is lower than in cities with low mode shares, thus confirming the “safety in numbers” theory

- The two cities with the lowest active transportation mode shares (Chicago and Calgary) are also the two cities with the highest private automobile shares
- Cities in jurisdictions with low gas taxes tend to have low active transportation levels and higher private automobile mode shares
- Cities with shorter commuting distances are more likely to have higher rates of active transportation. Vancouver with the highest AT share in the North American study cities has the lowest median commuting distance of 5 km.
- Both population and population density influence active transportation and public transit use
- In North America, pedestrian trips are more likely to be made by women, while cycling mode share is predominantly male
- Vienna and Berlin, with the two highest levels of active transportation of all study cities, have the lowest annual sunshine
- Toronto's automobile mode share of 56% is dramatically lower than the lowest of its Greater Toronto Area neighbours, at 81%
- An examination of the effect of an aging population in Toronto reveals the highest increases in both walking and cycling are in the 55-64 age category

This comparative analysis allows us to "benchmark" where Toronto is relative to other cities. Benchmarking is an important exercise because it allows us to gauge where we are against where we can be. Such exercises allow us to identify our weaknesses, while simultaneously identifying areas where we have achieved successes. Benchmarking provides an opportunity to see what other cities are doing and identify best practices as well as areas to avoid.

Although active transportation mode shares in Toronto are still quite low, they are improving. Toronto's investment in active transportation is relatively low when compared to those European cities with very high active transportation mode shares. Still, we have witnessed improvements in mode shares and levels of infrastructure. With continuing improvement and increased investment in the future, we have the potential to create a vibrant, liveable, moving city, with greater levels of active transportation, cleaner air and healthier citizens.

1. Introduction

1.1 Context

Researchers have long highlighted the importance of using objective measures to help interpret the relationships between the physical environment and physical activity (Saelens et al, 2003; Sallis et al, 2004; Owen et al, 2004). While the effect of the built environment on motorized transportation is well understood, considerably less attention has been paid to its impacts on active transportation (Cervero and Duncan, 2003). Curran (2005) further observes that while many studies examine active transportation from public health or recreational perspectives, far fewer have looked at the utilitarian aspects of active transportation, noting "the built environment impacts active transportation differently than leisure time physical activity".

The United Nations Commission on Sustainable Development (2001) notes the vital role that indicators can play in assisting planning and decision making through measuring progress towards stated goals, identifying deficient areas and by providing units of measurement through which we can quantify complex social and physical information.

A number of countries have attempted to benchmark active transportation on a national level. England, Scotland and the Netherlands have completed comprehensive benchmarking studies. The Bicycle Policy Audit (BYPAD) is a European audit instrument that can be implemented in towns, cities & agglomerations and regions. BYPAD has already been carried out by over 100 cities, towns and 18 regions in 21 countries (BYPAD, 2009). Velo Mondial have completed a multi-national benchmarking program which examined national cycling policies in the Czech Republic, England, Finland, Scotland and the Netherlands. The Urban Transport Benchmarking Initiative is another multinational study, which uses benchmarking to compare European Union cities around a variety of transport themes (Thunderhead Alliance, 2007).

The United States has engaged in several benchmarking projects over the past decade, including the League of American Bicyclists *Bicycle Friendly Community Program*, the U.S. Department of Transportation's *National Bicycle and Walking Study*, the National Bicycle & Pedestrian Documentation Project co-sponsored by Alta Planning and the Institute of Transportation Engineers as well as a variety of smaller-scale, local initiatives. In 2009, the U.S. Department of Transportation International Technology Scanning Program completed an international scan on pedestrian and bicyclist safety and mobility in 10 cities across 5 countries. The Alliance for Biking & Walking (formerly Thunderhead Alliance) has published two benchmarking reports, the first in 2007 and a second in 2010, providing comprehensive walking and cycling data for all 50 states and 50 of the most populated cities.

In Canada, the Transportation Association of Canada is currently undergoing a comprehensive study to document active transportation successes and challenges across Canada. Other notable active transportation data collection projects include Statistics Canada's "journey to work" census data and central Ontario's *Transportation Tomorrow* Survey. Both of these have provided valuable walking and cycling trends over time but of the two, only Statistics Canada has reported the two modes separately, which is important for understanding the unique differences of each. Unfortunately, in June 2010, Statistics Canada discontinued its mandatory long census form which is how the "journey to work" data was collected.

This report has two distinct parts: the first is a review of active transportation indicators employed in both academic and governmental studies and the second is a comparative analysis of active transportation indicators in 8 selected cities.

In our review of active transportation literature, we examined over 50 papers. Many of these papers addressed the components of active transportation collectively, while others examined walking, cycling (and sometimes public transportation) individually. From the reviewed literature, 19 papers were selected for closer scrutiny and inclusion in this study. These papers employed over 70 indicators which we have grouped into five categories; Infrastructure, Safety, Travel Behaviour, Demography and Geography. The geographic range of this study shall focus on a number of cities in Canada, the United States and Europe. In comparing the success of active transportation in Toronto with other Canadian, American and European cities, we aim to recognize the success of existing initiatives, while highlighting areas where increased efforts may be required.

1.2 Study Limitations

During the course of this study, several limitations were noted.

1. Language. This is the most obvious challenge when making international comparisons. English was not the first language for our contacts in three of our study cities.

2. As many previous studies have documented (most notably in Thunderhead's Benchmarking report), access to reliable active transportation data is limited and inconsistent. Each study city had a slightly different approach regarding what data it collects, how publicly accessible it is, and what terminology is used to describe cycling- and walking-specific infrastructure. For example:

- while attempts have been made to set out standards (e.g. in the American Association of State Highway and Transportation Officials *Guide for Development* *of Bicycle Facilities)* for bike routes, bike trails, and bike lanes these standards are not typically mandated in law or applied consistently

- in some cities accident statistics are compiled by the police, others by hospitals, while others rely on national or federal data. What constitutes an "injured" cyclist varies depending upon who collects the data.

- different countries classify "violent crime" differently (e.g. Canada includes a wider range of crimes in this category than does the U.S.)

3. As noted in the introduction, different agencies often combine walking and cycling data at the reporting stage, and sometime even at the data collection stage. This makes it difficult to understand and track the inherent characteristics of each.

4. Despite repeated attempts, we were unable to get the survey completed in the following cities: Calgary, Vienna and New York. For the other cities, it was difficult to find "one" person who could complete our survey. Due to the size of the study cities, active transportation data resides in many different divisions and departments, and sometimes within outside agencies.

5. To ensure harmonization of data and consistency in data sources, it was necessary to examine cities based on their political boundaries. The key reason for this is that data collected by municipalities is generally within political boundaries only, not the entire urban area. The inclusion of cities based on political boundaries is worth noting when comparing among cities. For example, we examine four Canadian cities, Toronto, Montreal, Calgary and Vancouver. While Toronto, Montreal and Calgary are of a similar size, the City of Vancouver is considerably smaller, with many neighbouring cities comprising the greater Vancouver urban area.

2. Indicators

In the process of benchmarking active transportation (AT), the selection of accurate and robust indicators is considered imperative. Canby (2003) recommends the development of a set of performance and accountability outcomes/indicators that would be included in an inventory of the availability and condition of active transportation infrastructure. Leslie (2006) reinforces this point with specific reference to pedestrian infrastructure, stating; “In order for local governments to progressively make their communities more walkable, it is important that they use appropriate tools to evaluate and monitor the walkability status of their local area” (Leslie et al, 2006).

While many AT indicators are common to both walking and cycling, since each mode has its own distinctive characteristics and infrastructure some indicators are specific to only one or the other mode. Pedestrian trips by their nature are quite different to cycling trips, with shorter trip times and distances, often as part of a multimodal trip chain involving transit or private vehicles at either end, and thus have a unique indicator set. This study uses indicators mutual to both modes as well as those indicators that are unique to each.

2.1 Infrastructure

As is the case for motorized transportation, the provision of adequate infrastructure is essential for AT in order to move people safely and efficiently. Basset et al (2008) note that extensive, safe, and convenient facilities for walking and cycling are omnipresent in cities with high levels of active transportation. Similarly, Cervero and Duncan (2003) found that the absence of bicycle/pedestrian friendly designs at either the origin or the destination had an extremely strong statistical relationship with mode choice, where the automobile was almost universal in such circumstances.

The main infrastructure attributes included by Thunderhead Alliance (2007) in their comprehensive benchmarking study of active transportation in American cities were “miles of existing and planned facilities including sidewalks, on-street striped bike lanes, multi-use paths, and signed bike routes” and the number of existing bicycle racks and spaces per rack.

Figure 2.1 A Montreal Bike Lane
(Photo Credit: Tapesonthefloor)

2.1.1 Pedestrian Infrastructure Attributes

Cervero and Duncan (2003) note that built environment factors had a stronger influence on cycling than walking. This is, in part, due to the fact that cyclists' safety is more directly affected by poor infrastructure. They also observe that balanced, mixed use environs with retail services significantly induce walking.

Figure 2.2 Montreal- McGill College Avenue
(Photo Credit: Dylan Passmore)

For aesthetic purposes and comfort, pedestrian-scale lighting, benches and shade trees should be dominant in corridors that have large numbers of pedestrians (Dixon, 1996).

Two important factors closely influence the efficiency with which pedestrians can move in an urban area, the level of connectivity, and the wait time to cross at intersections. In her development of pedestrian level of service measures, Dixon (1996) uses a measure of less than 22 driveways/sidestreets per 1.61km as acceptable. Driveways and sidestreets present possible points of hazard for both pedestrians and cyclists. At an access point, pedestrians and cyclists must scan the intersection for possible hazards before proceeding. The greater the number of access points, the greater the potential for conflicts between cyclists/ pedestrians and other modes.

Minimizing pedestrian signal delays is also key to a pedestrian friendly environment. Research by Kaiser (1994) demonstrates how pedestrians' impatience and potential to take risks increases after 30 seconds of delay. Restrictions on car use such as car-free zones, prohibitions of through traffic and traffic calming in residential neighbourhoods are common features of cities with high levels of active transportation (Basset et al, 2008). Pedestrianized areas imply the imposition of complete vehicular restrictions, generally in the urban centre. This practice could be considered a more radical approach, but has been when implemented in both European and North American cities.

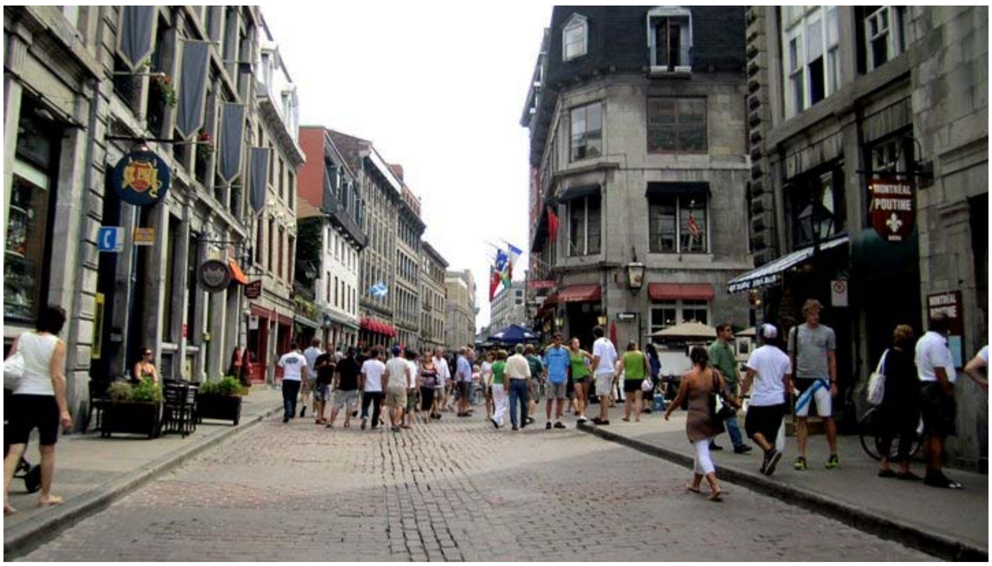


Figure 2.3 Old Montreal
(Photo Credit: Caribb)

Many studies employ Geographic Information Systems (GIS) to quantify pedestrian infrastructure attributes. In GIS-based studies, four attributes are typically used in the creation of a 'walkability' index. These are dwelling density, street connectivity, land use mix and net retail area (Leslie et al 2006).

2.1.2 Cycling Infrastructure Attributes

Cycling-specific infrastructure is important for encouraging bicycle use. "Supplying an infrastructure which offers cyclists a quick, comfortable and safe link during every journey, is an essential precondition for a successful cycling policy' (CROW, 1993). The 1998 Go for Green/Environics study reported that 70% of Canadians would bike to work if there were dedicated bike lanes that would result in a travel time less than 30 minutes (or approximately 7.5km). **Bike lanes and paths have been consistently correlated by multiple researchers with higher rates of bicycle use** (Cervero and Duncan, 2003, Dill and Carr, 2003). To highlight the importance of bicycle facilities, several studies found that bicyclists will actually take a longer route to use bicycle lanes or paths (Shafizadeh and Niemeier, 1997, Krizek et al, 2007).

Pucher et al (1999) note that every European country where cycling has a mode share greater than 10%, separate cycling facilities (and traffic-calmed neighborhood streets) are integral parts of the bike route system. Thunderhead Alliance (2007) found that not only do the raw numbers of cycling facilities affect levels of cycling, but the density of these facilities is key. **Cities with more miles of cycling facilities per square mile generally have higher levels of cycling.** However, on-street facilities must be maintained to ensure consistent use. Over time, these facilities, just like standard roadways, require maintenance. Cracking, patching, weathering, potholes, rough road edge, rough railroad crossings and standing water have been identified by Dixon (1996) as possible maintenance issues that may result in lower levels of cycling. The same author also notes that the existence of any on-street parking discourages bicycle use and creates very real safety concerns for bicyclists. The provision of bicycling facilities is not simply about moving cyclists in an efficient manner, but also in a way that is safer for the cyclist and minimizes the risk of collisions.

Bicycle parking facilities are also important in encouraging a shift towards active transportation. Good parking facilities can reduce the risk of theft and protect bikes from weather elements while concurrently increasing the importance and status of the bicycle, stimulating numbers of cyclists (Guit, 1993). Bicycle parking facilities must be easy to use, conveniently located and most importantly, prevent bicycle theft. Facilities that are not well understood are rarely used (Zuks, 2002). If bicycles are going to be locked for longer periods of time, the requirement for shelter and supervision of the facility is more pronounced.

Figure 2.4 Innovative Bike Lanes
(Photo Credit: S. Anam)

Figure 2.5 Bike Lockers, City of Toronto
(Photo Credit: Tyson Williams)

2.1.3 Transit Integration

Well-developed public transit systems with bike parking facilities, are standard features within cities with high levels of active transportation (Basset et al, 2008). Other ways of integrating transit and bicycles are by permitting bicycles on public transit vehicles. In Toronto bike racks are being installed on the front of all TTC buses and bicycles are permitted on the subway outside of rush hour periods. Some cities designate a special area for bikes inside of subways and streetcars equipped with a bike rack. Transit integration is of particular importance for cyclists where greater commuting distances are necessary.

Figure 2.6 Bicycle Racks on TTC
(Photo Credit: C. Moffat)

The International Technology Scanning Program (2009) observe that "close integration of bicycling and walking considerations with public transit (including intercity rail) make longer intermodal commutes by bike practical as well as safer and more convenient". The Team recommends several integration strategies, including a variety of bike parking solutions at stations, covered outdoor parking, secured indoor parking, policies that permit bikes on trains and buses, even during peak times, and bike rental or sharing programs located in or very near train or bus stations.

Figure 2.7 BIXI Bikes
(Photo Credit: C. Gittings)

2.1.4 Speed Limits/Differentials

Canby (2003) provides planning and design recommendations for municipalities to create successful communities. The author observes that approaches to design must be mindful of active transportation modes, noting "design speeds can be adjusted to recognize the shared right of way among different users, and traffic calming techniques can reduce vehicle speeds and accidents, making the system work better for all users". In general, **low speed limits were observed in cities with high levels of active transportation** by Basset et al (2008).

Figure 2.8 Pedestrians Crossing Street with Reduced Speed
(Photo Credit: C. Zegeer, PBIC image library)

In London (UK), studies have shown that pedestrians will tolerate high levels of nearby road traffic. For pedestrians, the presence of the traffic itself is not necessarily a deterrent to mobility (Stonor et al, 2002). Landis et al (2001) present contradictory evidence, stating that the frequency of vehicles passing pedestrians was a significant factor in the perception of safety, whereas vehicular frequency increases, the pedestrians' feeling of safety decreases. While the effect of traffic volume on pedestrian comfort might be contentious, speed certainly is not. The relationship between vehicular speed and the safety of pedestrians has been well researched. Dixon (1996) observes that "**high-speed traffic greatly decreases the comfort of pedestrians and can be a major deterrent to pedestrian trips**. Posted speed limits of 56 kph create operating speeds at the maximum tolerable level of pedestrian comfort." Jacobsen et al (2000) have also proved an inverse relationship between pedestrian safety and high traffic speeds.

Restraining the speed of automobiles is also considered 'very important' to the safety of cyclists (European Cyclists' Federation, 1998). **The safe integration of bicycle traffic with motor traffic requires a low speed of traffic flow, which is beneficial to both the *actual* and *perceived* safety of cyclists** (Zuks, 2002). A myriad of methods are available to reduce speeds. Zuks (2002) notes that "Speed reductions can be achieved by means of physical traffic calming measures or through the implementation of lower speed limits or both". The speed differential is what is key here. Speed differential can be calculated by comparing the average bicycle speed (24 kph) with the posted speed (Dixon, 1996). In an ideal scenario, this differential should be as close to zero as possible.

2.1.5 Average Expenditure On Bicycle and Pedestrian Improvements/ Policy

The International Technology Scanning Program (2009) note that higher rates of political support from elected officials, government staff, and the general public is a key factor behind the success of active transportation in Northern European countries. In Canada, the Federal Government plays no role in cycling policies, and has provided minimal funding through programs such as Moving On Sustainable Transportation (MOST). The Federal Government has an extremely limited role in urban transport in general, including public transport (Pucher and Buehler, 2005). Provincial involvement in active transportation varies in Canada. Quebec "has been deeply involved in a range of programs to promote cycling, increase its safety, coordinate local efforts, and fund infrastructure improvements" (Pucher and Buehler, 2005), where Ontario has an extremely limited presence in this area. In B.C., the provincial government has a 'modest' spending program for cycling infrastructure as well as a Cycling Advisory Committee to aid local efforts. The situation in the United States is not that different. Thunderhead Alliance (2007) report that in the US, states spend just 1.54% of their federal transportation dollars on bicycle and pedestrian projects. They recorded over 50 federal funding programs that contributed to bicycle and pedestrian projects over a three year period, but noted that most of these programs received relatively small amounts.

Figure 2.9 Henderson Bridge Bike Lane
(Photo Credit: K. Gradinger, Greater City: Providence)

More often than not, local governments are forced to take the initiative and fund their own active transportation programs. Leslie et al (2006) note that local government has "a crucial role to play in encouraging the creation of liveable active neighbourhoods that promote health and wellbeing". **Local government has a profound effect on walkability because of the planning decisions they make that affect urban design and also through their role in community leadership** (Steele & Caperchione, 2005).

In the Dutch context, policy at the national level has played an important role in the development of an active transportation culture. In response to the oil crisis of 1975, the Dutch Ministry of Transport and Public Works implemented the National Bicycle Tracks Grant Act, which provided funding for the construction of urban and rural bicycle facilities. Municipalities could receive a subsidy of 80% of the construction costs of new bicycle tracks with priority given to dense traffic areas. The Act also imposed uniform design standards to give coherence and standardization to the 'cause' of bicycling. In the Netherlands, bicycle policy addresses five key areas with a view to improving cyclist safety and increasing its mode share. These policies include the improvement of bicycle infrastructure; the creation of good connections with public transport; fostering of road safety; prevention of bicycle theft; and promotion of bicycle usage (CROW, 1993). These policies are often implemented with complimentary policies aimed at restricting car use and increasing the relative cost of this mode.

Rietveld and Daniel (2004) measure policy efforts in a number of different ways. They count the number of plans made by the city and consider the effects on the municipal budget caused by bicycle-friendly policies. The authors also looked at the quality of the bicycle network and bicycle racks, and also appraise incentives awarded by the municipality to its employees to use a bicycle. Thunderhead Alliance (2007) use the level of fulltime equivalent (FTE) governmental staff dedicated to active transportation programs as an indicator of commitment to active transportation. Their report found that State Departments of Transportation employ an average of 0.3 FTE staff per million people. Cities were found to have higher rates, with an average of 2.8 FTE staff per million people. The same researchers also found positive correlations between advocacy capacity and levels of active transportation, but noted difficulties in calculating this metric.

2.2 Safety

There are two principle safety concerns for pedestrians and cyclists. The first set of concerns is related to personal safety that could be jeopardized by crime. The second set of safety concerns arise as a result of traffic safety, primarily due to the fact that non-motorized and motorized modes often share the same infrastructure. Traffic safety is a more pressing concern for both pedestrians and cyclists than for motor vehicle occupants. Pucher and Dijkstra (2003) found that in the United States, pedestrians and cyclists suffer 2-3 times more accidents that car drivers (per 100 million trips). Jacobsen (2003) recognizes that policies that aim to increase levels of walking and bicycling are an effective route to improving the safety of people walking and bicycling, thus recognizing the ‘safety in numbers’ theory. This theory holds strong across international boundaries where consistently, we see overall levels of injury and fatality fall as numbers of cyclists and pedestrians increase. Thunderhead Alliance (2007) compared data on bicycle and pedestrian fatalities to active transportation mode share and found a positive correlation between levels of biking and walking and safety. Cities with the highest raw numbers of walking and cycling also had the lowest per capita fatality rates for pedestrians and cyclists.

Figure 2.10 Separated Cycling Facilities
(Photo Credit: City of Vancouver)

Guaranteeing the safety of cyclists is a necessary prerequisite for promoting cycling as a daily mode of transport (Dekoster and Schollaert, 1999). The Canadian Go for Green/Environics survey (1998) found that 53% of respondents felt traffic safety was a barrier to active transportation, especially to cycling. Similar trends have been found in the United States, where in a study of over 1,739 bicycle trips in the city of Portland, Oregon, respondents were asked to rank the importance of various factors behind the choice of bicycle route. Minimizing distance was found to be the most important factor with a score of 3.60 (out of a maximum of 5) (Dill, 2009). The second most important factor was avoiding streets with a lot of vehicular traffic, with a score almost identical to that of reducing trip time of 3.57. Riding in a bike lane was found to be the third most important factor, at 2.95.

Substandard infrastructure exacerbates the preexisting safety concerns of pedestrians and cyclists. Inadequate sidewalks and bicycle paths, dangerous intersections and crosswalks and poor lighting were found by Zeeger (1993) to contribute to high fatality rates among cyclists and pedestrians. This is reaffirmed by Landis et al (2001) who note that the factors that *significantly* affect pedestrian safety are:

- presence of a sidewalk
- lateral separation from motor vehicle traffic
- barriers and buffers between pedestrians and motor vehicle traffic
- motor vehicle volume and composition
- effects of motor vehicle traffic speed, and

- driveway frequency and access volume

Using regression analysis, Landis et al (2001) show that "a safe, separate place to walk alongside the roadway is fundamental in pedestrians' sense of safety and comfort in the roadway environment". As the degree of lateral separation between the sidewalk and the roadway increases, as does the pedestrian's sense of safety. In a study of Toronto residents (City of Toronto, 2008), the amount and quality of sidewalks was found to be the number one reason why Torontonians think their neighbourhood is walkable.

Figure 2.11 Carrall Street, Vancouver
(Photo Credit: City of Vancouver)

2.2.1 Accidents/Injuries/Deaths per Capita

The rate of injury to people walking and bicycling does not correlate linearly with the numbers of pedestrians and cyclists. Jacobsen (2003) demonstrates that the number of motor vehicle collisions involving cyclists and pedestrians increases at roughly 0.4 power of the number of people walking or bicycling. So a community doubling its walking can expect a 32% increase in injuries (where $2^{0.4} = 1.32$). This is proven in the Canadian context in the Province of Quebec, where from 1987 to 2000, the total number of bicycles increased by a factor greater than 100%, with the number of 'regular' cyclists increasing by 50%. Concurrently, cycling fatalities fell by 42%, serious injuries fell by 56%, and minor injuries fell by 38% (Pucher and Buehler, 2005).

However, **the rate of injury between cyclists, pedestrians and the occupants of motor vehicles is drastically misaligned.** Globally, a greater number of pedestrians and cyclists are killed by cars than car occupants (Nantulya and Reich, 2002). In the year

2001 in the United States, pedestrians were 23 times more likely to get killed than car occupants per kilometer travelled (Pucher and Dijkstra, 2003). **Consistently, researchers have found that traffic regulations and enforcement policies that favour pedestrians and cyclists over motorists are positively correlated with active transportation rates** (Basset et al, 2008).

2.2.2 Level of Crime/Assault

Although many studies associate higher levels of crime with lower levels of recreational physical activity, Curran (2005) observes that there is less evidence that personal safety has an effect on utilitarian active transportation. What may have a greater effect is the risk of theft or vandalism of a person's bicycle, especially in larger urban areas. This can mean potential bicyclists are reluctant to cycle or will cycle using a cheaper bicycle that is less comfortable and might result in fewer kilometres traveled as a result (Rietveld and Daniel, 2004).

2.2.3 Presence of Education/Advocacy Programs

Canby (2003) recommends the creation of a strong education and advocacy program noting it is a key challenge in achieving transportation reform. The author recognizes that paramount to the establishment of a climate for change is the engagement of all citizens in examining the choices for the future of their communities. In their scan of Northern European cities, the International Technology Scanning Program (2009) noted that many of the study cities had widespread traffic safety education programs for all children that start at an early age and can continue into the teen years. Closed courses that simulate real life traffic situations can be used to teach young children to ride safely in traffic. The researchers recommend the institutionalization of multifaceted ongoing traffic safety education starting at an early age including knowledge and skill-based learning delivered by a variety of agencies and organizations. The US Department of Transportation recognizes that increases in levels of active transportation will only come about with the combined efforts of governments, other agencies and advocacy groups (USDOT, 1999)

Zuks (2002) confirms this, noting that bicycle education is important and should include the aspects of bicycle handling, road sense, route selection and road rules. Thunderhead Alliance (2007) also point out that education is a potential factor contributing to active transportation (Thunderhead Alliance, 2007). Educational courses are delivered by a variety of agents, including advocacy organizations, government agencies and private companies. Thunderhead Alliance (2007) noted great difficulty in attempting to quantify levels of cycling education due to the variety of organizational structures and data collection methods. Additionally, many organizations are volunteer run or staffed on a part-time basis.

The International Technology Scanning Program (2009) notes that many policies, practices and designs currently used in Europe are not easily transferred internationally. However, the researchers placed educational and encouragement programs in the ‘easily transferable’ category, noting they could be quickly implemented without a thorough policy analysis or evaluation.

2.2.4 Traffic Regulations and Enforcement

Since the mid-1970s, Dutch and German governments have introduced extensive auto-free zones that cover large swaths of urban centres. There are also a large number of "bicycle streets" in these countries, where cyclists have right-of-way over the entire roadway, cars are permitted, but cyclists control the speed of flow. Pucher and Dijkstra (2003) observe that the most significant safety impact of traffic calming is reduced motor vehicle speed, crucial not only to the motorist's ability to avoid hitting pedestrians and bicyclists, but also to the survival of non-motorists in a crash. Studies have found that the risk of pedestrian death from a motor vehicle collision rises from 5% at 32kmh to 45% at 48kmh and 85% at 64kmh (STPP, 1997).

Many European governments have imposed rigorous traffic calming measures where speeds are reduced by law and also through physical restrictions including raised intersections and crosswalks, traffic circles, road narrowing, speed bumps, and artificial dead ends created by midblock street closures (Pucher and Dijkstra, 2000). Moreover, no European countries allow traffic to turn on red lights, as is commonplace in Canada and the United States (Pucher and Dijkstra, 2003). It is important to note that the aforementioned traffic calming measures are not isolated, but area-wide, thus forcing through traffic onto arterial routes. In addition to this, trucks are generally prohibited from entering residential areas, with access to other metropolitan areas only at designated times.

Figure 2.12 Coloured Bike Lanes Come to Tempe
(Photo Credit, D. Newton, la.streetsblog.org)

In bicycle-friendly countries such as the Netherlands and Germany, we see far more stringent traffic enforcement for all road users, motorists, cyclists and pedestrians. In any collision between a motorist and a non-motorist, the motorist is always found to be partially at fault. Should the non-motorist be elderly or a child, then the motorist is generally found to be completely at fault. **Motorists are expected to "anticipate unsafe walking and cycling."** (Pucher and Dijkstra, 2003)

2.3 Travel Behaviour

2.3.1 AT Mode Shares

The active transportation mode share simply tells us the share of people using active transportation modes. The mode share is the number of trips or, more commonly, the percentage of trips by a given mode.

2.3.2 Vehicle Ownership

Using US car ownership data from the 2000 Census and Journey to Work data from the 2005 American Community Survey, Thunderhead Alliance (2007) found that residents of cities with higher rates of cycling and walking own fewer cars. The researchers note that they could not determine whether not owning a car causes someone to bike or walk or vice versa, but nonetheless, car ownership is a valid indicator of active transportation levels in an urban area. While the statistical relationship is robust, the causal relationship may not be.

2.3.3 Average Trip Time/ Distance

The average trip time (in minutes) is ultimately a function of distance. Many empirical studies have proven the negative relationship between distance and active transportation mode choices (Cervero and Duncan, 2003). Curran (2003) states that **“reducing trip distance is an absolute requirement to facilitate increased active transportation levels.**” In a US study of over 1,739 bicycle trips in the City of Portland, Oregon, minimizing distance was found to be the most important factor behind the choice of route (Dill, 2009). In two separate surveys of Toronto residents (City of Toronto, 2010), distance was cited as the single largest deterrent to cycling to work. The National Active Transportation Survey (1998) found that 82% of Canadians would prefer to use active transportation to get to work, but citied time and distance as the major barriers to this mode (Go For Green / Environics, 1998)

Cervero and Duncan confirm this, and found that as average trip lengths increase, the probability of walking or cycling decreases. This logical conclusion is applicable even at short trip distances, where the researchers observed automobile mode shares of 60.7% even for trips less than 1 mile (where walking captured 34.3% of trips at this distance). Interestingly, for bicycle trips above 5 miles versus bicycle trips less than 5 miles, the mode shares were nearly identical at 1.5%, implying that for cyclists, distance is not as important a factor as it is for pedestrians. The effect of time / distance varies between active transportation modes. Time is a greater barrier for walking than for cycling, given the average ‘moderate’ walking speed is 5km/h compared to a 15km/h ‘moderate’ cycling pace (FWHA, 1994).

Travel time over the same distance also varies between municipalities due to variation in spatial structure. The adequacy of cycling infrastructure, the directness of the route and the wait time at crossings all affect the travel time (Rietveld and Daniel, 2004). In Canada for the year 2001, bicycling accounted for only 1.2% of work trips (Pucher and Buehler, 2005). As over 25% of urban work trips are less than 3.2km long (Pucher and Buehler, 2005), there is great untapped potential for bicycles to occupy a far greater mode share in urban Canada.

2.3.4 Cost of Car Use

Pucher et al (1999) observe that the cost, speed, and convenience of alternative modes have a crucial impact on modal choice. By making motorized modes too attractive and attainable, active transportation mode shares suffer. "For walking and cycling to flourish, action to restrain motorized traffic must be comprehensive in manner and scale", (Tolley, 1997). Actions to restrain motorized traffic can include higher parking and congestion pricing and in general, higher costs of vehicle ownership, as observed in northern European nations by The International Technology Scanning Program (2009).

Pucher et al (1999) has noted that European countries have a long-term commitment to enhance the safety, speed, and convenience of bicycling while making driving more difficult and expensive. Basset et al (2008) validate this research, noting that the higher costs of owning and operating motorized vehicles contribute to higher levels of active transportation in urban areas. The European and North American driving environments are quite dissimilar. **Compared to North America, Europeans pay dramatically higher taxes on gasoline and new cars.** There is no abundance of no-cost or low-cost parking like there is in North America. This contributes to the "irresistible" perception of driving in North American cities and in turn, discourages active transportation (Pucher and Dijkstra, 2003). While several 'carrot' approaches are available to promote active transportation, concurrent 'stick' approaches aimed at reducing motorized transportation are also necessary. "Given the detrimental effects of motorized traffic on the cycling environment it is logical that a policy aimed at promoting bicycle usage be accompanied by a policy of automobile restraint" (Zuks, 2002).

2.4 Demography

2.4.1 Income

In the United States context, cycling is inversely correlated with income. The mode share of cyclists in households earning less than US$15,000 is three times higher than in households earning more than $80,000. This is not only due to the cost of automobile ownership being an exclusionary factor, but also due to the fact that in North America, lower-income households tend to be more concentrated in city centres, where the urban form in general is more akin to bicycling and walking (Pucher et al, 1999). As incomes rise, car use becomes more attainable, so the potential to travel by car increases (Pucher et al, 1999). Interestingly, incomes are lower in Canada than the U.S. and approximately three times more Canadians cycle than Americans (Pucher et al, 1999). However according to a City of Toronto study (2010), a greater percentage of Toronto's utilitarian cyclists (30%) than non-cyclists (14%) have a household income over $100K. As well countries such as Denmark, Germany and the Netherlands that have made cycling attractive and easy have not witnessed decreases in their cycling populations as incomes have increased over the past 20 years.

The Thunderhead Alliance 2007 Benchmarking Report notes that pedestrian mode shares differ among income classes, with lower income categories having the highest numbers of pedestrians, however, they note that this does not hold true for all cities and in places like New York City where the distribution of pedestrians is basically equal among all income categories.

2.4.2 Population Density

Density is clearly a factor that affects levels of active transportation, as is the overall population size of an urban area. In 1999, Pucher et al noted that they were unaware of any city on the planet with a population greater than 2 million where bike use exceeded 10% of trips. North America has many cities with populations over 2 million while Europe has considerably fewer, and tends to have smaller, denser cities, where active transportation can flourish with greater ease (Pucher et al, 1999). Thunderhead Alliance (2007) found residential density to be positively strongly correlated with levels of active transportation, where denser cities have considerably higher rates. Many other studies employ measures of population or residential density and generally find that densities at the point of trip origin are high in cities that have high levels of active transportation. Mixed land use, and a balance of residences, jobs and retail opportunities were found to significantly influence the choice to cycle at the point of origin by Cervero and Duncan, (2003). Interestingly, **built environments were shown to have a stronger impact on walking and bicycling at the point of origin (generally a residence) as opposed to the point of destination** (Cervero and Duncan, 2003).

2.4.3 Gender

Numerous research studies have consistently found that women are less likely to bicycle than men (Plaut, 2005, Dill & Voros, 2007). In fact, this relationship is so strong that some researchers believe that gender is the most important indicator of all. “If you want to know if an urban environment supports cycling, you can forget about all the detailed ‘bikeability indexes’—just measure the proportion of cyclists who are female.” (Garrard, 2009) Possible explanations for this include that women are more concerned about safety, especially as a result of vehicular traffic (Garrard et al, 2008). Gender is also considered to influence mode choice when women contemplate the social risks of travelling by bicycle at night (Rietveld, 2004) In a sample of 727 utilitarian bicycle commuters, Dill and Carr (2003) observed marked differences between cyclists and other commuters, where 82 percent of the bicycle commuters were men, compared to 54 percent of all commuters, respectively. Thunderhead Alliance (2007) found that in the US, men make up 78% of all bike commuters. For pedestrian trips, they found significantly less difference in the male to female sex ratio.

2.5 Geography

2.5.1 Topography

Cervero and Duncan (2003) found that while the slope affects levels of both walking and cycling, it exerts a far greater effect on walking, where as slope increases, the level of walking falls. Stonor et al (2002) confirm this, noting that analysis suggests that the gradient of a footway can significantly affect pedestrian flows. The effect of topography on levels of cycling is inconsistent.

2.5.2 Rainfall

Rainfall was found to be a major deterrent to walking by Cervero and Duncan (2003). Thunderhead Alliance (2007) argue against this, noting that rainfall has at best a minimal effect on levels of active transportation. Dill and Carr (2003) concur, in the context of cycling, the authors surveyed utilitarian cycling in 35 US cities and found that three of the top six cities had over 100 days of rain per year, demonstrating that **rainfall is not a significant deterrent to bicycle commuting**. Pucher et al (1999) agree, hypothesizing that the effect of climate on cycling may be exaggerated, noting that in Northern Europe, where there are mostly cloudy days and frequent rain and drizzle, cycling levels are far higher than in the drier, sunnier and warmer regions of Southern Europe.

2.5.3 Temperature

The relationship between average temperature and levels of cycling is not completely clear. In the Canadian provincial context, the Yukon has the highest level of bike-to-work cycling trips at 2% (tied with British Columbia). Far behind this is Ontario (1.0%) and Quebec (1.2%) (Pucher and Buehler, 2005). On a municipal scale, Montreal, which is markedly colder than Toronto, shows remarkably higher levels of cycling, with 1.3% versus 0.8%. Another interesting statistic is regarding the level of ridership between Vancouver, BC and Ottawa/Hull, ON/PQ, where both areas are tied at 1.9%, even taking Ottawa’s harsher winter into account (Pucher and Buehler, 2005).

Evidence shows that temperature only has a moderate effect on pedestrian flows. Comparative analysis has shown very little difference between summer and winter pedestrian flows (Stonor et al 2002). The effect of rain on pedestrian flows in London, UK is described by Stonor et al (2002) as only ‘moderate’.

2.5.4 Land Use Mix

Land use mix is the degree of variability in land uses located in close proximity to each other. Land use mix has an intrinsic relationship with distance, where a high degree of mixing implies decreased distances between different uses. Frank et al (2003) recommend that the most robust indicators of land use should not focus purely on the total commercial floor space in the study area, but rather, on the absolute numbers of different land uses in the community.

Cervero and Duncan (2003) estimate discrete choice models to determine the individual attributes behind active transportation. They observe the only significant built environment variable (at the 5% probability level) was land-use diversity at the point of origin for the trip (which was generally a residential location). The aforementioned authors note that well connected streets, small city blocks, mixed land uses and close proximity to retail activities induce non-motorized transport. In an extensive literature review of active transportation studies, Curran (2003) notes that in nearly all the studies examined, density and land use mix are positively correlated with active transportation trips, where both density and land use mix are ultimately indicators of “access”. **Deficiencies in access have been consistently cited as the number one barrier to active transportation**. Leslie et al (2006) note that the choice to walk for the purposes of transport is largely influenced by the way land is used. This hypothesis is reiterated by Frank (2004), observing “where there is high density and a mixture of different land uses, walking for transport becomes more practical, as destinations are closer together in a more compact environment. The more compact and intermixed an urban environment is, the shorter the distances between destinations. Walking, relative to other modes of travel becomes less probable, as distances between origins and destinations increase”. The International Technology Scanning Program (2009) notes that overall urban and land use policy, street planning and design are key factors behind the success of active transportation in Northern European countries. A mixed land use results in a diverse urban fabric with shorter distances of travel between various activities (Newman and Kenworthy, 1999). Such a scenario is desirable in encouraging high rates of active transportation.

3 Methods

From our review of indicators in active transportation literature, we compiled an initial list of 167 indicators, of which 78 were unique. This list went through several iterations of refinement resulting in a total of 39 indicators used in this research [see list below on pp. 27-28]. In deciding on appropriate indicators, we employed those methodologies used by many researchers identified in our literature review, notably, Curran (2005) and Thunderhead Alliance (2007). Certain indicators were removed if they were not found to have correlations with active transportation based on available empirical evidence. Other indicators were removed because the data collection effort to ascertain the levels of these indicators in our study cities would have been beyond the scope and budget for this research. Again, certain indicators were tailored to individuals as opposed to cities. Where this was the case, the indicator in question was removed from this study. If an indicator was incapable of providing meaningful comparison between cities, it was also removed.

For indicator evaluation, we also employed the principles proposed by Wood (2005). Wood recommends that indicators have policy relevance, that is, persons interpreting the indicators must understand the connection between the indicator and critical decisions and policies. Simplicity is another criterion, the indicator must be easily understood by diverse audiences. The validity of the indicator is also considered imperative, the indicator must clearly and accurately describe the variable under examination. Finally, indicators must use quality data that is readily available. An indicator without a data source cannot be estimated.

3.1 Data Collection

As previously noted, quality data is essential for any indicator to have real value. To attain quality data, we employed a two-pronged approach to data collection. The first source of data was through literature sources and examining recent government documentation regarding the quantification of our selected indicators. For Canadian cities, much of the information was available through the 2006 census, including data on mode shares, populations, gender etc. For American cities, Berlin and Vienna, census data was also used to obtain this information, as well as information from State Departments of Transportation. Information regarding safety, crime and injury statistics was obtained from relevant municipal police departments. Meteorological data was obtained from the Weather Network while data regarding taxation policies were obtained from a variety of sources.

Data that was not obtained through literature reviews was gathered using an online survey sent to selected persons employed by municipal governments in our study cities. We used Survey Monkey software to deliver the survey, which consisted primarily of closed-ended questions to minimize ambiguity and provide harmonized results for all cities. The survey was developed in consultation with staff from the City of Toronto's Cycling Infrastructures and Programs Unit of the Transportation Services Division to ensure relevance and applicability. Between February and August 2010, we sent the survey to transportation staff in each of the eight study cities, with the exception of Montreal. For that city the survey was sent to the Research Director of Velo Quebec, a provincial organization.

3.2 Selected Cities

The cities that selected for this research were:

1. Toronto, Ontario, Canada
2. Montreal, Quebec, Canada
3. Calgary, Alberta, Canada
4. Vancouver, British Columbia, Canada
5. Chicago, Illinois, USA
6. New York, New York, USA
7. Vienna, Austria
8. Berlin, Germany

Several criteria were applied to determine what cities would be included in this study. All of the cities are of a high standard of living in nations with comparable gross domestic product and high levels of auto ownership. All study cities are located at similar latitudes in the northern hemisphere. For this reason, the study cities share many meteorological similarities, with warm summers and relatively cold winters. Four of the cities have populations under 2 million (Calgary, Vancouver, Montreal and Vienna) while four have populations greater than 2 million (Toronto, Chicago, New York and Berlin). The eight selected cities span four countries, Canada, USA, Germany and Austria. The largest city in each of these countries has been included as well as smaller cities in the case of the USA and Canada. The area of the study cities ranges from

115km^2 (Vancouver) to 892km^2 (Berlin) with a mean area of 568km^2. Population densities range from 1,360 persons/km^2 in Calgary to 10,588 persons/km^2 in New York with a mean of 4735 persons/km^2.

3.3 Selected Indicators

Based on our extensive literature review, we chose indicators that previous studies had noted as relevant based on their findings. We then identified the availability of data for these indicators. Indicators that were both relevant and available were included in our final list of indicators. Table 3.1 below tabulates the papers covered in our literature review and the indicators they employed. A complete list of all indicators included in this research is then provided in Table 3.2.

Indicator Type	Bassett et al. (2008)	Butterworth et al (2006)	Canby (2003)	Cervero & Duncan (2003)	Curran (2005)	Curran et al (2006)	Dill (2009)	Dill & Carr (2003)	Dixon (1996)	Emery(2003)	Gallin (2001)	Jacobsen (2003)	Kelly et al (2003)	Landis et al (2001)	Pucher & Buehler (2005)	Pucher & Dijkstra (2003)	Pucher et al (1999)	Rietveld (2004)	Stonor et al ()	**Total occurrences of this indicator**
Infrastructure	0	0	1	2	3	6	7	0	1	5	5	6	0	1	2	1	2	1	3	46
Safety	0	2	0	1	0	0	0	2	1	0	0	2	0	0	2	3	2	0	0	15
Travel Behaviour	3	7	0	5	4	1	0	3	1	2	0	0	3	0	2	2	4	0	2	39
Demography	0	2	5	3	2	0	0	0	1	0	0	0	0	1	1	4	6	3	2	30
Geography	0	1	3	0	0	0	0	0	0	0	0	0	1	0	0	4	2	0	1	12
Land Use	0	0	2	1	6	0	0	0	0	0	0	0	0	2	0	0	0	0	0	11
Other	1	1	0	0	0	0	0	0	2	0	0	0	2	0	2	2	2	1	1	14
	Both Walking and Cycling									**Walking only**					**Cycling only**					**167**

Table 3.1 Indicators examined in our literature review

Indicator Type	**Specific Indicator**	**Metric**
Infrastructure	1. Total length of on-street cycling facilities 2. On-Street Cycling Facilities (separated) 3. On-Street Cycling Facilities (not separated) 4. Signed bicycle routes 5. Multiuse paths 6. Policies regarding inclusion of bicycle lanes 7. Shared lane markings 8. Bike boulevards 9. Woonerf/living streets 10. Colored bicycle lanes 11. Bicycle traffic lights 12. Covered Bicycle Parking Facilities 13. Uncovered Bicycle Parking Facilities 14. Pedestrianized Zones 15. Pedestrian Sidewalks 16. Bicycles permitted on Streetcars? 17. Bicycles permitted on Subways? 18. Bicycles permitted on Buses? 19. Bicycles permitted on Commuter Rail? 20. Bikes permitted on these modes at all time	km km km km km yes/no yes/no yes/no yes/no yes/no yes/no capacity capacity km km Yes/no Yes/no Yes/no Yes/no Yes/no
Safety	21. AT Injuries 22. AT Fatalities 23. Violent Crime Rates	% % Crimes/1,000 people
Travel Behaviour	24. Cycling Mode Share (Work Trips) 25. Walking Mode Share (Work Trips) 26. Combined AT mode share (Work Trips) 27. Other Mode Shares (Work Trips) 28. Median Commuting Distance 29. % work trips <5km in length 30. Level of taxation on new vehicles 31. Level of taxation on petrol	% % % % Km % % %
Demography	32. Population (total) 33. Population Density 34. Gender	# Persons/km^2 %m/f
Geography	35. Annual precipitation 36. Hours of Sunshine per year 37. Mean Summer Temperature 38. Mean Winter Temperature 39. Mean Annual Temperature	Mm/year Hours/year °c °c °c

Table 3.2 39 Indicators included in this research

4 Comparative Analysis of Active Transportation in Canadian and World Cities

4.1 Infrastructure

To gauge levels of active transportation in our study cities, an online survey was developed. This survey was sent to our eight study cities. Five cities completed the survey: Montreal, Toronto, Vancouver, Chicago and Berlin. The complete survey is attached as an appendix. Surveys were completed in early 2010.

4.1.1 Total Length of Bicycle Facilities

The first question sought to gauge levels of cycling infrastructure in our study cities. Berlin (as of Jun 15, 2010) had the greatest level of infrastructure with 1300km of facilities. Chicago (as of Jun 10, 2010) and Montreal (as of Sep 2, 2010) followed with 637 and 531km respectively, while Toronto (as of Feb 25, 2010) and Vancouver (as of Jul 14, 2010) had 515 and 416km respectively. Figure 4.1 displays the total length of bicycle facilities in our study cities (km) plotted against mode share (%). **As shown, there seems to be a pattern emerging – those cities with more kilometres of bicycle facilities also tend to have a higher AT mode share.** This becomes even more evident when we examine the total length of bicycle facility density by study city (Figure 4.3). It should be noted that when estimating the total length of facilities, the City of Berlin counts only one side of the street, while Toronto, Montreal, Vancouver and Chicago count both sides. This could result in a slight discrepancy in estimating total facility lengths.

4.1.2 Bicycle Facility Types

A further question asked cities to specify the breakdown of these cycling facilities into their respective facility types. This closed-ended question specified four facility types;

- Multi-use paths
- Signed bicycle routes
- On-street bicycle lanes NOT physically separated from motorized traffic
- On-street bicycle lanes physically separated from motorized traffic

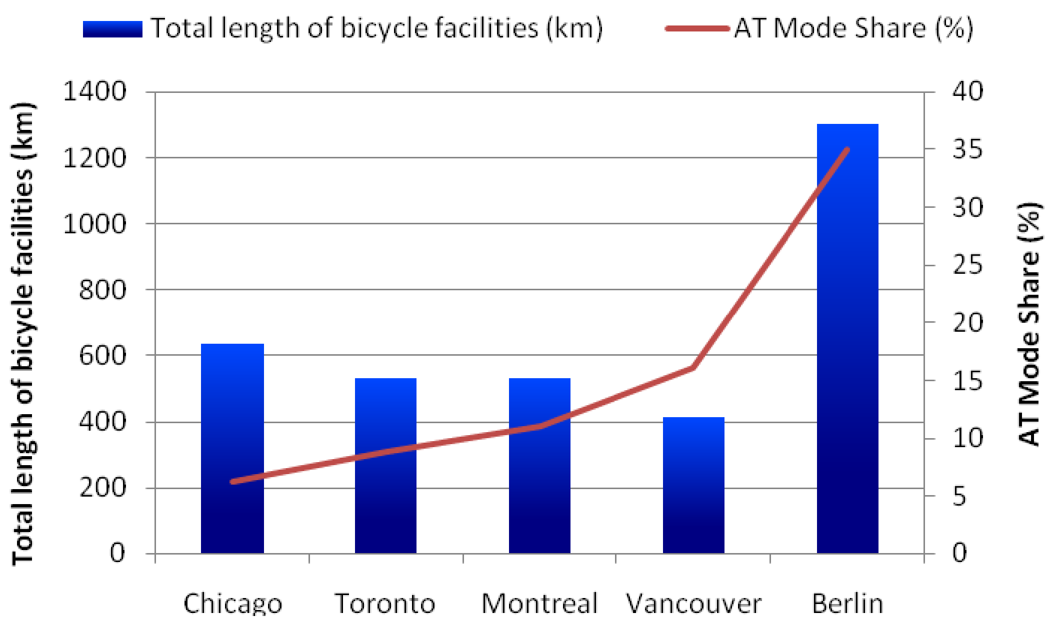


Figure 4.1 Total length of bicycle facilities by study city, 2010

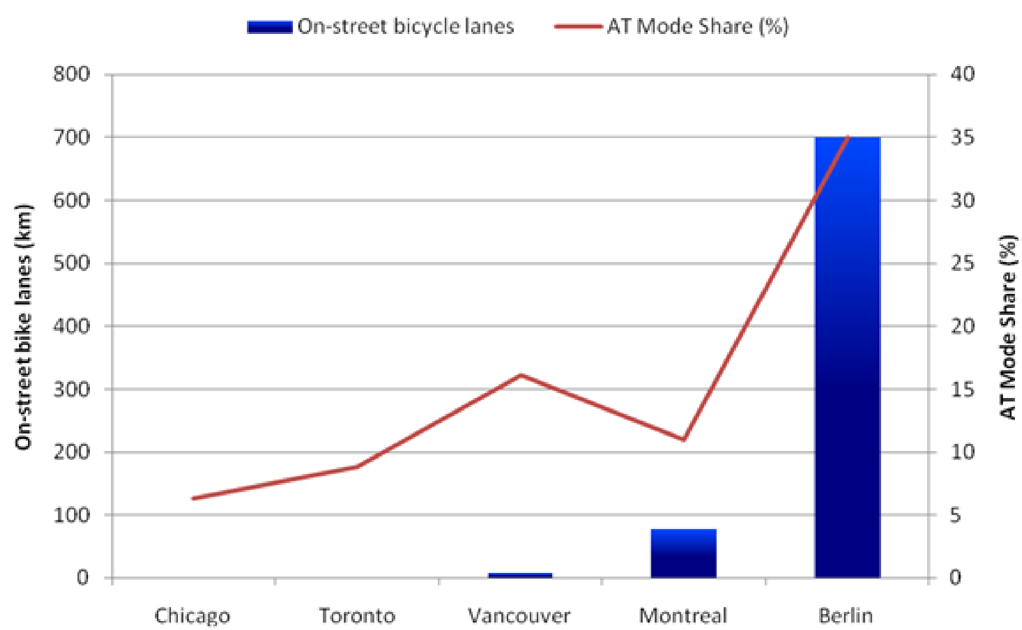


Figure 4.2 Total length of on-street bicycle lanes by mode share and study city

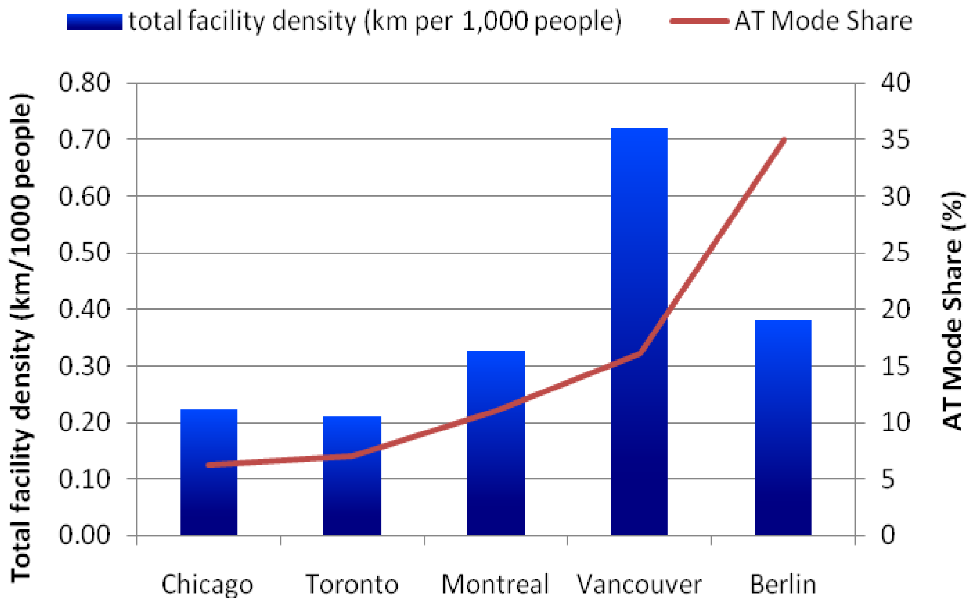


Figure 4.3 *Total Facility Density by Mode Share and Study City*

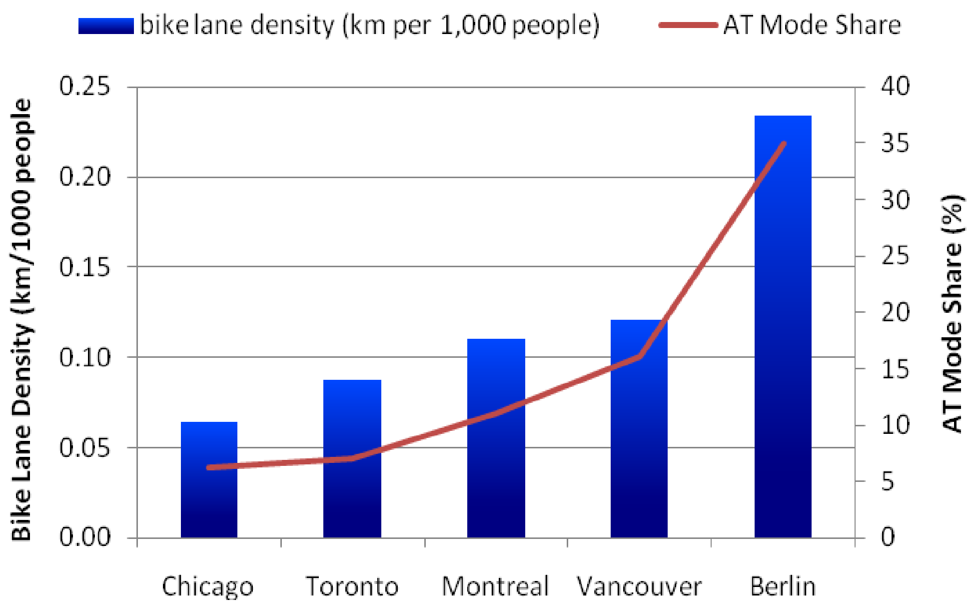


Figure 4.4 *Bike Lane Density by Mode Share and Study City*

Physically separated bikes lanes provide a buffer zone intended to increase both the perceived and actual safety of cyclists. They are especially suitable for arterial roads that carry high volumes of high-speed motorized traffic. Berlin led the way with on-street bicycle lanes physically separate from motorized traffic with 700km, followed by Montreal with 78km. Vancouver had 7km of this facility type while Toronto and Chicago have none.

Regarding on street bicycle lanes not physically separated from motorized traffic by a barrier, Toronto has the highest amount of these facilities, with 219 km, followed by Chicago with 183km and Montreal with 107km. Berlin had 100km of these facilities, while Vancouver had 63km. When we examine signed bicycle routes, we see the City of Chicago leads the way with 386km, followed by Vancouver with 278km, then Berlin with 200km, Toronto with 138km and Montreal with 96km.

Figure 4.2 depicts the length of on street bicycle lanes (both physically separated and not separated) against mode share. Not only does the *amount* of bike lanes seem to make an impact on mode share, but the *density* of bike lanes do as well. **Figure 4.4 presents a depiction of this data, where we plot on-street bike lane density by study city against mode share revealing a strong correlation between the two.**

The final bicycle facility examined is multi-use paths. Berlin and Montreal had the greatest number of multi-use paths with 300km and 250km respectively. Toronto had 168km of multi-use paths while both Vancouver and Chicago had 68km. A complete breakdown of all facility types can be seen in Figure 4.5.

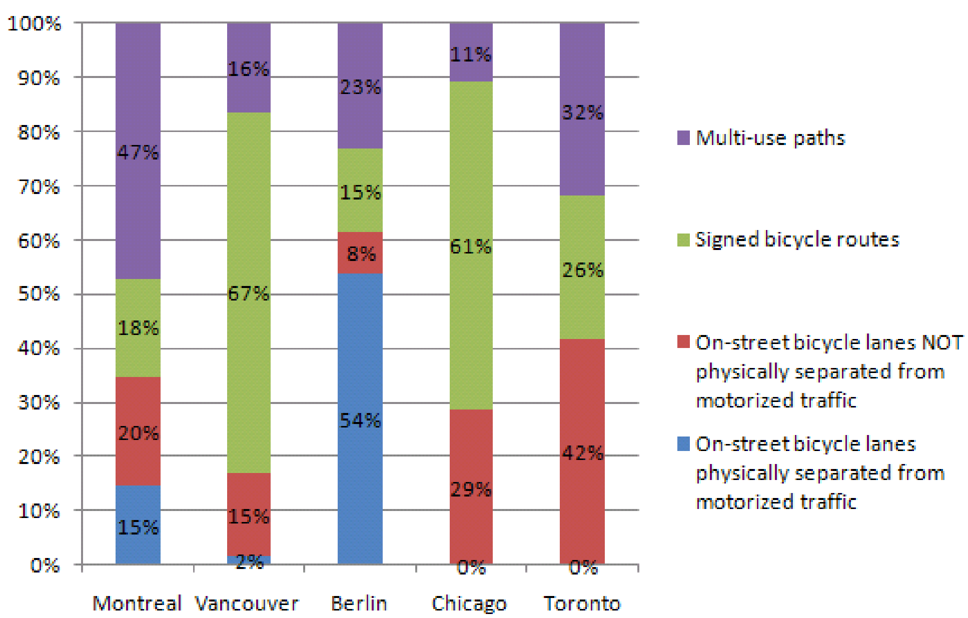


Figure 4.5 Bicycle facility types by study city, 2010

4.1.3 Policies Regarding the Street Conditions that warrant Bike Lanes

Of all the cities asked if they have policies outlining street conditions that warrant bike lanes, only Berlin responded affirmatively. A second part to this question asked what characteristics influenced this decision. Berlin noted that this decision was influenced by the posted speed limit and motorized traffic volume. Of the two the most important condition warranting bike lanes is if traffic volume exceeds 10,000 cars per day.

4.1.4 Innovative Bicycle Facilities

When examining innovative bicycle facilities in our study cities, we found a mixture of responses. The innovative facilities we looked at included shared lane markings, bicycle boulevards, woonerf/living streets, coloured bicycle lanes and bicycle traffic lights. The results are presented in table 4.1.1 below. All cities use shared lane markings. Only Montreal and Vancouver are experimenting with bicycle boulevards. Berlin was the only city that had experimented with woonerf/living streets. Berlin, Chicago and Toronto have used coloured bike lanes, while all cities but Chicago have used bicycle traffic lights.

Facility Type	Montreal	Vancouver	Berlin	Chicago	Toronto
Shared Lane Markings	Yes	Yes	Yes	Yes	Yes
Bicycle Boulevards	Yes	Yes	No	No	No
Woonerf / Living Streets	No	No	Yes	No	No
Coloured Bicycle Lanes	No	No	Yes	Yes	No
Bicycle Traffic Lights	Yes	Yes	Yes	No	Yes

Table 4.1 Innovative bicycle facilities by study city, 2010

4.1.5 Bike Parking

All cities were asked to estimate the levels of public bicycle parking. The cities of Vancouver and Berlin were unable to answer as they do not keep an inventory of bike parking spots. Results for the cities of Montreal, Chicago and Toronto are presented in Figure 4.6, where Toronto had 32,000 spots, Montreal had 15,335 and Chicago had 12,000. A second part of this question asked what proportion of these parking spots are in long term bike stations. Only Toronto responded to this question, with a total of 332 spots.

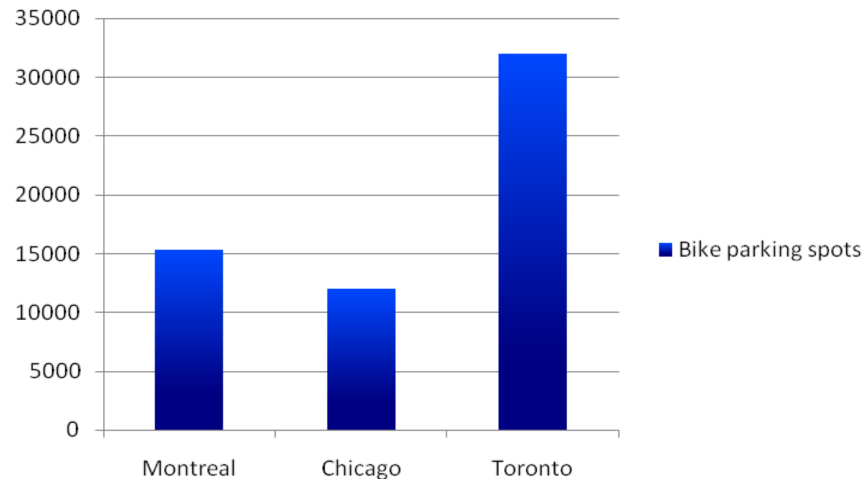


Figure 4.6 Bicycle parking spaces by study city, 2010

4.1.1 Transit Integration

As previously discussed, well-developed public transit systems with bike parking facilities are standard features in cities with high levels of active transportation. Because of this, we endeavoured to ascertain the level of transit integration with active transportation in our study cities. All cities in our survey allow bikes on subways and commuter rail. All cities that have streetcar lines (Toronto and Berlin) also allow bikes on streetcars. The cities of Toronto, Vancouver and Chicago allow bikes on busses while Montreal and Berlin do not. Table 4.2 displays this information in a tabular format.

An additional question asked if bikes were allowed on these transit modes at all times including rush hours (Table 4.3). The Cities of Toronto and Montreal do not allow bikes inside any transit vehicles during peak hours. However 92% of Toronto's TTC bus routes are equipped with bike racks on buses. The City of Vancouver allows bikes on all modes at all times. The City of Berlin allows bikes on subways, street cars and commuter rail at all times, but does not allow bikes on buses at anytime. The City of Chicago allows bikes on buses during rush hour, but not on the subway or commuter rail.

Transit Type	**Montreal**	**Vancouver**	**Berlin**	**Chicago**	**Toronto**
Subway	Yes	N/A	Yes	Yes	Yes
Streetcar/Tram	N/A	N/A	Yes	N/A	Yes
Bus	No	Yes	No	Yes	Yes
Commuter Rail	Yes	Yes	Yes	Yes	Yes

Table 4.2 Are bicycles allowed on these transit vehicles? (2010)

Transit Type	Montreal	Vancouver	Berlin	Chicago	Toronto
Subway	No	N/A	Yes	No	No
Streetcar/Tram	N/A	N/A	Yes	N/A	No
Bus	No	Yes	No	Yes	No
Commuter Rail	No	Yes	Yes	No	No

Table 4.3 Integration of bikes on transit during rush hours, 2010

4.2 Safety

As noted in our literature review, guaranteeing the safety of cyclists is a necessary prerequisite for promoting cycling as a daily mode of transport. The Canadian Go for Green/Environics survey (1998) found that 53% of respondents felt traffic safety was a barrier to AT. We examined the relationship between AT mode shares and accidents involving vehicles and pedestrians and cyclists. **Our findings show that in cities with high mode shares, the percentage of cyclists and pedestrians injured and killed is lower than in cities with low mode shares.** These findings reinforce the 'safety in numbers' theory. In ascertaining the percentage of pedestrians and cyclists killed or injured, we took the raw mode share numbers of each, and the raw numbers of injuries and fatalities, and calculated the percentage injured and killed. So, these figures represent the percentage injured and killed of those using active transportation modes, not the percentage relative to the population or any other metric. Figure 4.7 illustrates the percentage of pedestrians and cyclists injured, while figure 4.8 presents fatality data.

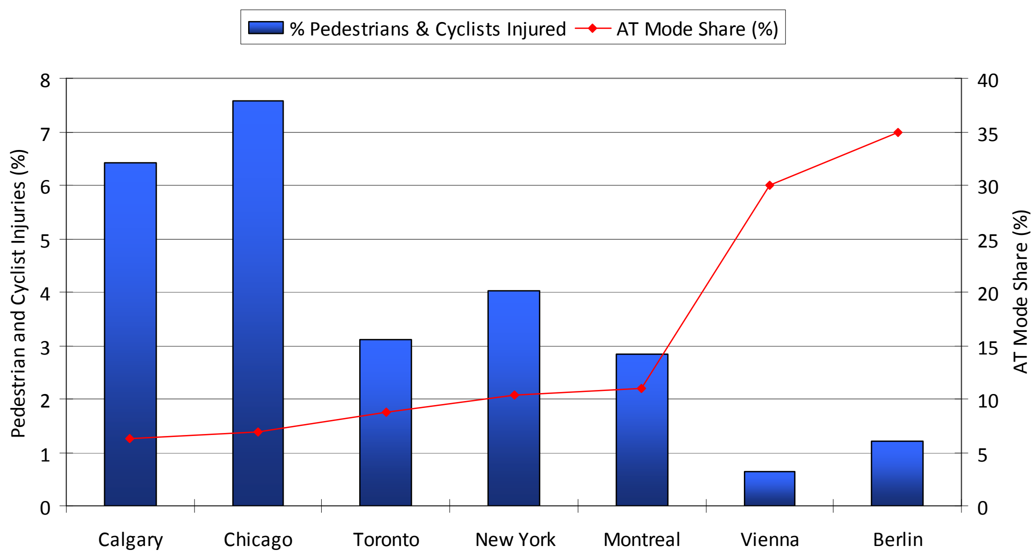


Figure 4.7 % of AT users Injured by study city, 2007

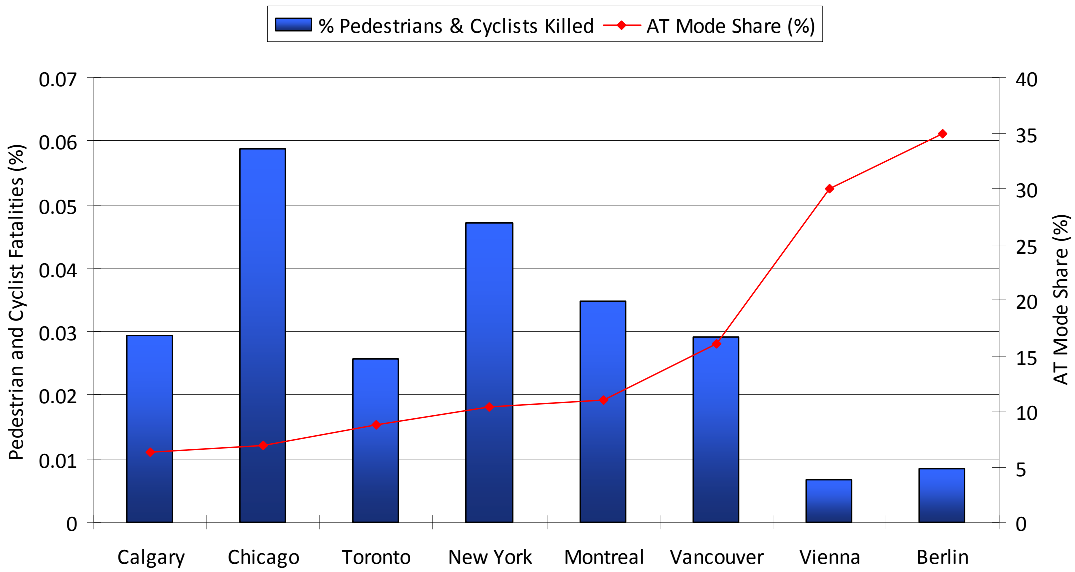


Figure 4.8 % of AT user fatalities by study city, 2007

As previously discussed in 2.2, there are two sets of safety concerns for pedestrians and cyclists, safety concerns that arise as a result of traffic safety, and safety concerns related to personal safety (acts of violence). To examine the effect of personal safety on active transportation, we examined violent crime rates in our study cities. Definitions of 'violent crime' vary between nations. Because of this, this comparison is only within our Canadian cities. **Our research did not prove the relationship between violent crime and active transportation.** As Figure 4.9 displays, in the Canadian context, AT rates actually increased in tandem with violent crime rates, where Vancouver has the highest violent crime rate and also the highest rate of AT, and Calgary has the lowest crime rate and the lowest AT share. Obviously, the presence of violent crime does not encourage AT. If we had mode share and crime rate information on a finer scale, such as a census tract level, it's possible that these results might be quite different (i.e. tracts with high crime rates could have lower AT rates.) However the amalgamation of crime and transportation data on a municipal level does not capture this variance.

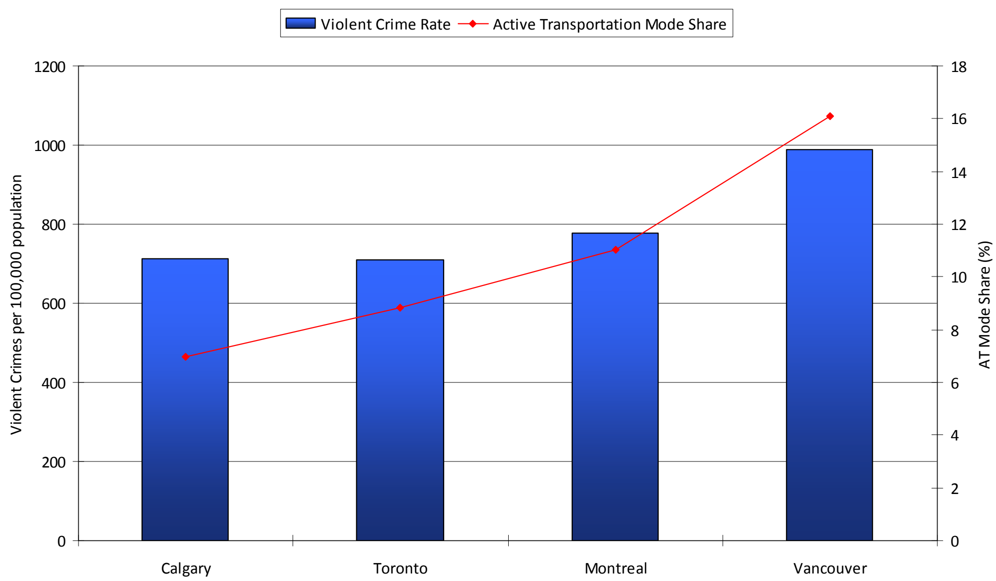


Figure 4.9 Violent crime and AT rates in Canadian cities, 2007

4.3 Travel Behaviour

Figure 4.10 presents the overall AT mode share in our study cities. In all cities, this is the mode share for work trips only. As we can see from figure 4.10, Chicago has the lowest AT mode share of all study cities at 6.3%, followed by Calgary at 7%. Toronto, New York and Montreal have AT mode shares of 8.8%, 10.3% and 11% respectively. Vancouver has the highest AT mode share of any of the North American cities in this study at 16.1%. However the size of the city unit needs to be kept in mind when comparing mode shares. In Vancouver, only the central city, more compact and dense, is being counted whereas Toronto and Montreal numbers comprise a much larger area and include suburban neighbourhoods. Vienna has an impressive share of 30%, while Berlin has the highest mode share of all study cities at 35%.

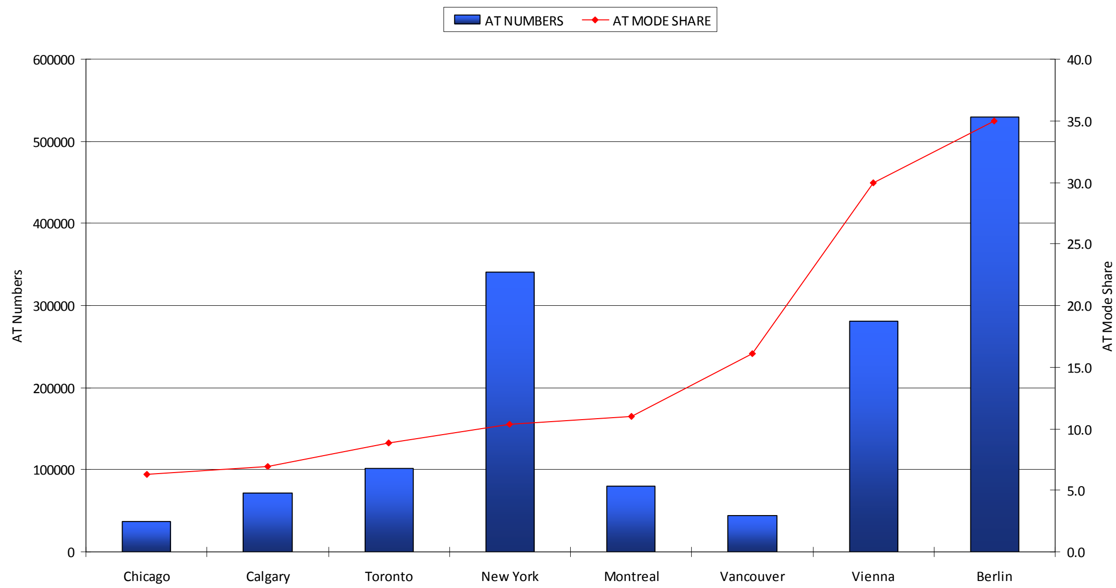


Figure 4.10 Active transportation raw numbers and mode share by study city, 2007

Figure 4.10 presents data for both pedestrians and cyclists combined. Many agencies treat these modes as one and gather data around them collectively. However, this is problematic given the very different characteristics of these modes. If we are to promote AT in our cities, we must have a better understanding of the behaviours and numbers of cyclists and pedestrians, not simply AT in general. Cyclists and pedestrians have specific infrastructure requirements unique to their modes. In Canada, although these modes are often presented in tandem, Statistics Canada has until recently collected information around them independent of each other. Figures 4.11 and 4.12 examine the cycling and pedestrian mode shares in Canadian cities. This disaggregated information was not available for other study cities. Both modes follow identical trends, where Calgary has the lowest numbers, followed by Toronto and Montreal, with Vancouver attaining the highest mode shares. Although Vancouver has the highest cycling mode share of any Canadian city, this share is still only 3.56%. Again, the size of the city unit needs to be taken into consideration when evaluating cycling mode share. In larger cities like Toronto, many census districts have a mode share in excess of 4% or even much higher. For example, according to cycling statistics compiled by the City of Toronto, the bicycle mode share for the census tract located at College St. and Bathurst St. is 17% (City of Toronto, 2008).

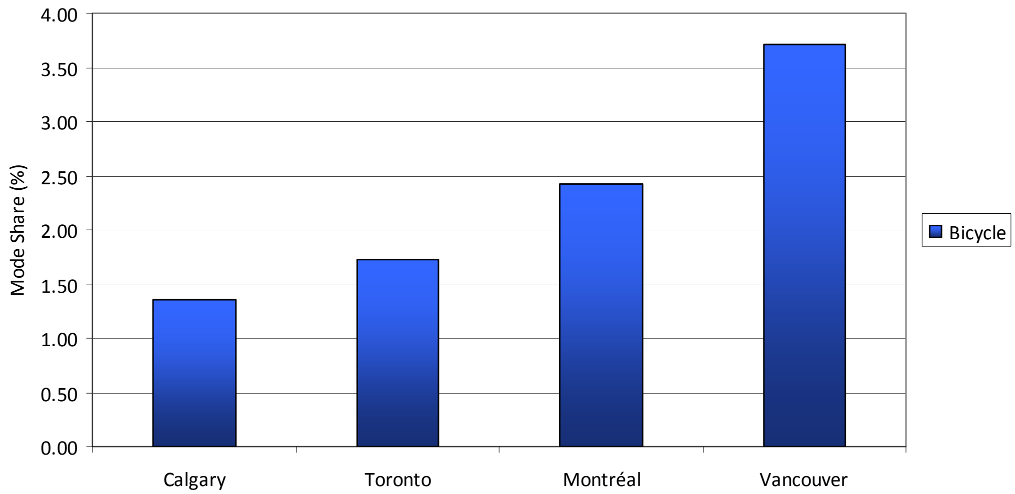


Figure 4.11 Cycling mode shares in Canadian cities, 2007

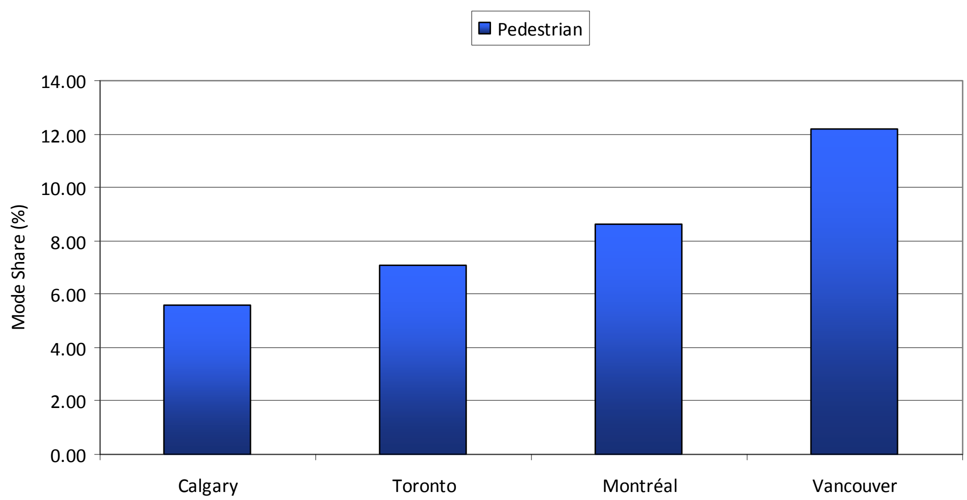


Figure 4.12 Pedestrian mode shares in Canadian cities, 2007

Figure 4.13 presents a complete modal breakdown for all study cities. It is noteworthy that the two cities with the lowest active transportation shares (Chicago and Calgary) are also the two cities with the highest private automobile shares. The public transit share for New York City stands out in its magnitude, where we see 56.8% of all trips in that city are by transit. Because of the dominance of transit in this city, coupled with not insignificant levels of AT (10.3%), New York has the lowest private automobile share of any city we studied (32.1%).Vienna and Berlin show the most equal distribution across modes, with both cities having approximately one third of their mode share by AT, one third by private automobile and one third by transit. Calgary stands out as being the most dominated by the private automobile, with a staggering share of 75.2%.

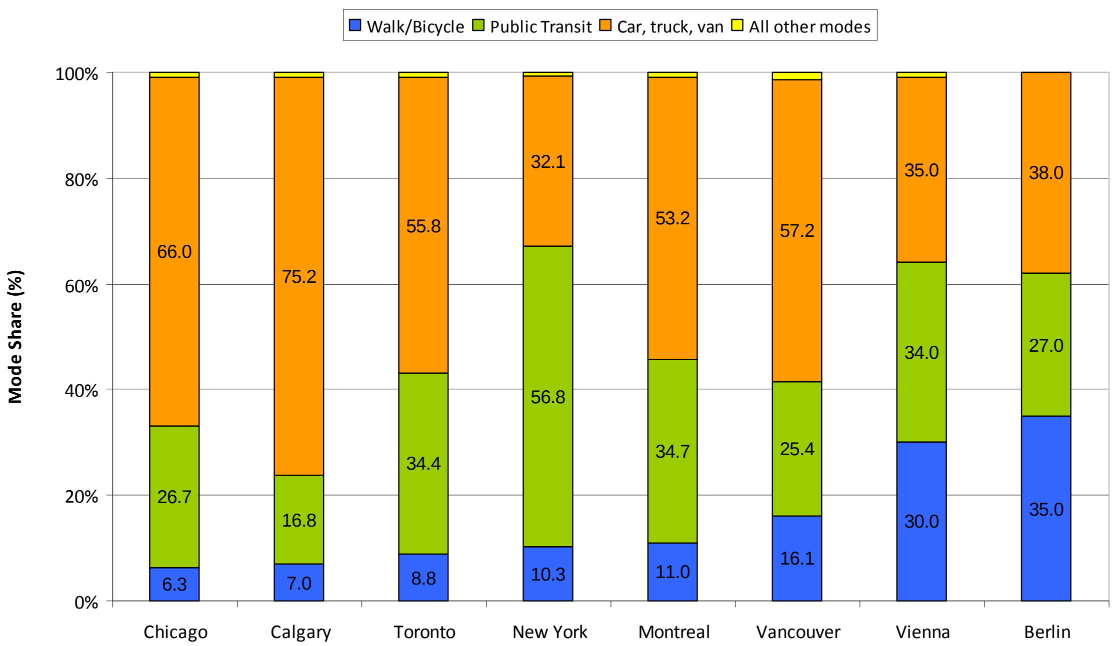


Figure 4.13 Complete modal breakdown for all study cities, 2007

Another travel behaviour indicator we examined was the level of taxation on gasoline. Pucher et al (1999) had argued that the cost, speed, and convenience of alternative modes have a crucial impact on modal choice. Imperative in increasing AT mode shares are a combination of 'carrot and stick' approaches, where taxation is a 'stick' approach. Figure 4.14 examines gasoline taxation and the relative AT mode shares in our study cities. Taxation on gasoline was chosen as an indicator above the actual price of gasoline. The reason for this is because in North America, the price of gasoline can change on a daily basis. In Europe, it is held constant for several months at a time. However, taxation on gasoline tends to hold constant for at least one year at a time, and often for longer. As we can see in figure 4.14, there is a robust relationship between these two indicators. Cities with low gas taxes tend to have low AT levels. Figure 4.15 presents the converse to this, where we model taxation on gasoline against private automobile mode shares.

We can see that those cities with lower taxation levels have higher private automobile mode shares. New York City presents an anomaly here. Even with low taxation on gasoline, New York has relatively high AT mode shares and low private automobile shares. We hypothesize that this is due to the attractiveness of public transportation with high speed, good geographical coverage and an excellent level of service, coupled with the high costs of parking in that city and the high rates of congestion. In the New York context, even low rates of tax on gasoline are not enough to encourage commuters to drive to work.

Cities with shorter commuting distances are more likely to have higher rates of active transportation. In our study, information around commuting distances was available only for the Canadian cities in the study. Even with this smaller number of cities, this theory was strong. Calgary, with the lowest AT rate, had the longest median commuting distance at 7.9 km, followed by Toronto at 7.5 km. Montreal, with the second highest rate of AT among the Canadian cities had a median commute of 5.8 km. **Vancouver, with the highest AT share, has the lowest median commuting distance at 5 km**. This information is graphically depicted in Figure 4.16.

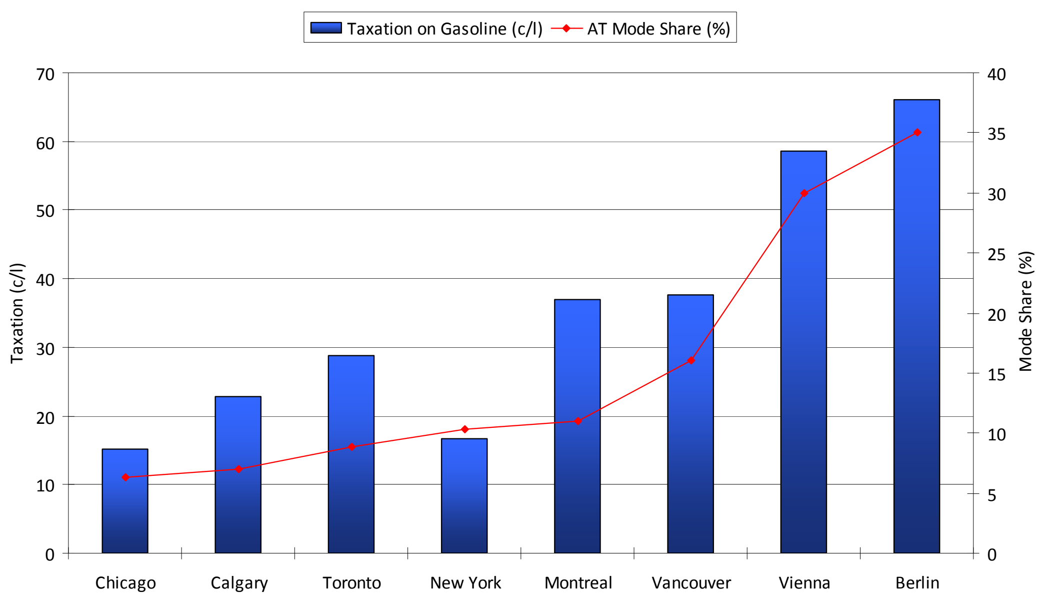


Figure 4.14 AT mode shares and taxation on gasoline, 2007

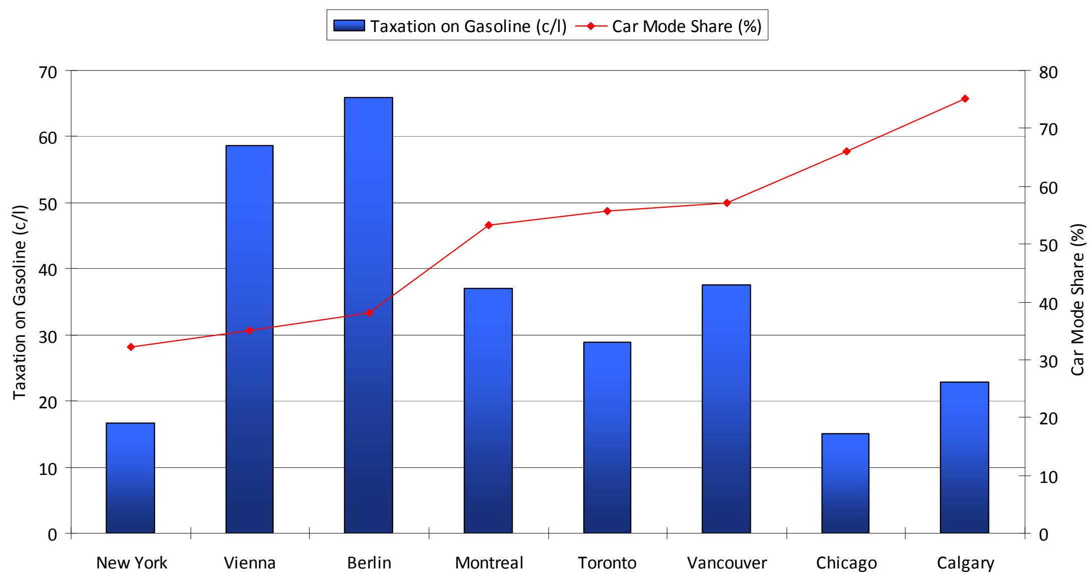


Figure 4.15 Private automobile mode shares and taxation on gasoline, 2007

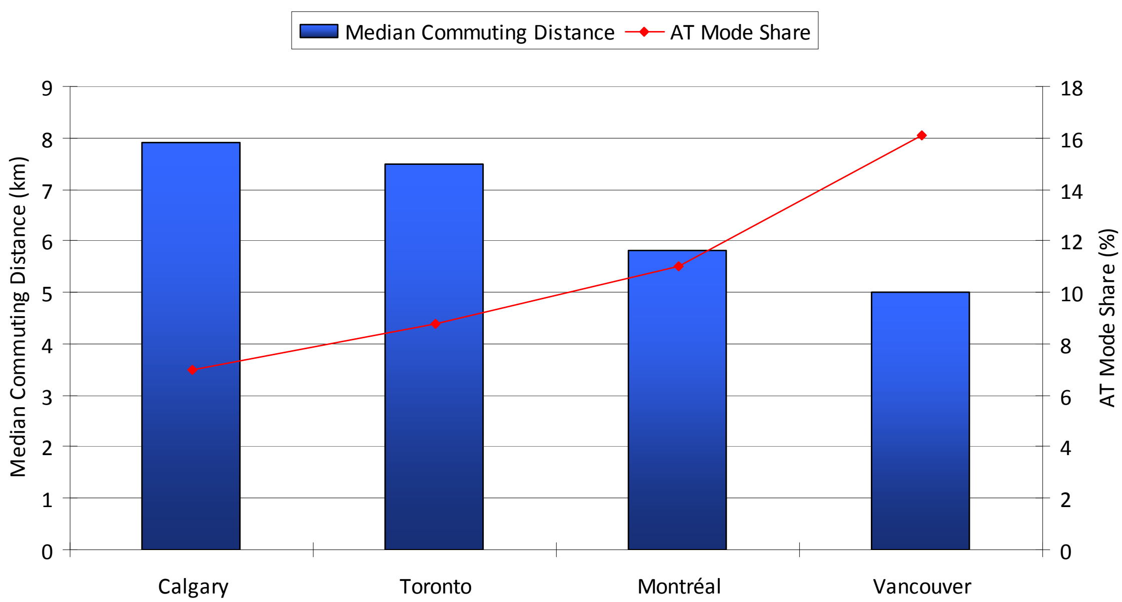


Figure 4.16 Median commuting distance in Canadian cities, 2007

We followed this analysis with an examination of the percentage of work trips within a 5 km commuting radius. The results follow a similar trend to that of median commuting distance. 31.2% of work trips made by Calgary residents are less than 5 km in distance. In Toronto and Montreal, 34% and 42.6% of work trips are under 5km, while in Vancouver, 49.7% of trips are under this threshold. This information is presented in Figure 4.17.

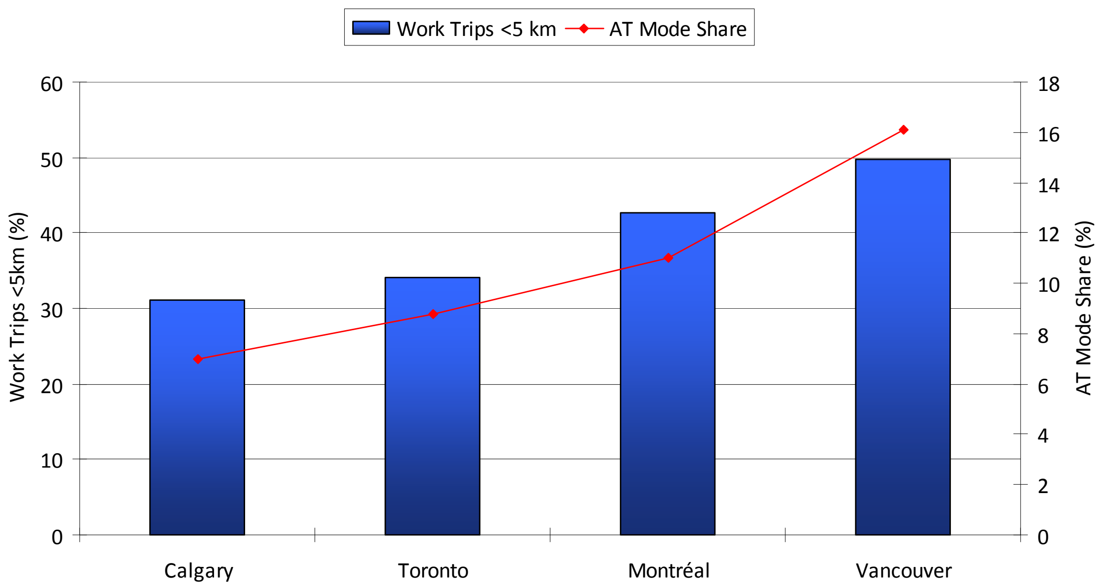


Figure 4.17 Percentage of work trips less than 5 km in length in Canadian cities, 2007

4.4 Population and Population Density

Our review of the literature revealed that both overall population and population density influence the propensity for AT in cities. Figure 4.18 shows the total population in our study cities plotted against their AT rate. As is evident from this graph, in our study there was no clear relationship between overall population and AT rates. All cities in our study have populations in excess of 500,000 and as high as 8 million. We postulate that once a certain minimum threshold is reached, (which exists somewhere well below 500,000) that there is no distinct trend that can be identified between population and AT rates and if we were to compare AT rates between cities of 10-20,000 population against cities over 100,000, then perhaps the population theory would be more robust. The research also informs us that very large cities (>2m) are highly unlikely to have cycling rates above 10%. This holds true in our analysis. Figure 4.19 presents AT mode plotted against population density. The results are very similar to those of absolute population numbers and follow no distinct trend. Cities such as Montreal, Toronto, Berlin and Vienna are all of a similar population density, yet have very different AT rates. Interestingly, if we only focus on Canadian cities, there is a clear trend between population density and AT rates (see Figure 4.20). However, given the results from our international cities around this metric, we would hesitate to draw firm conclusions around this outcome. Given the big jump in AT in Berlin and Vienna can we not postulate that another variable is again cycling infrastructure?

Building on our analyses around population density, we examined the mode shares of transit and private automobile. These results were considerably more conclusive. Figure 4.21 plots population density against the mode share for public transit and reveals a more linear relationship, where **as density grows, so does the mode share for public transit**. The city with the highest density, New York City, also has the highest transit mode share, while Calgary, with the lowest density also has the lowest transit mode share. This reflects the ability for transit systems to operate more efficiently in high density environments. Sprawling cities are considerably harder to serve by transit due to their lower population densities. The converse to this is presented in figure 4.22 where we plot private automobile mode shares against population density. Here, we see Calgary has, by far, the highest car mode share where New York has the lowest.

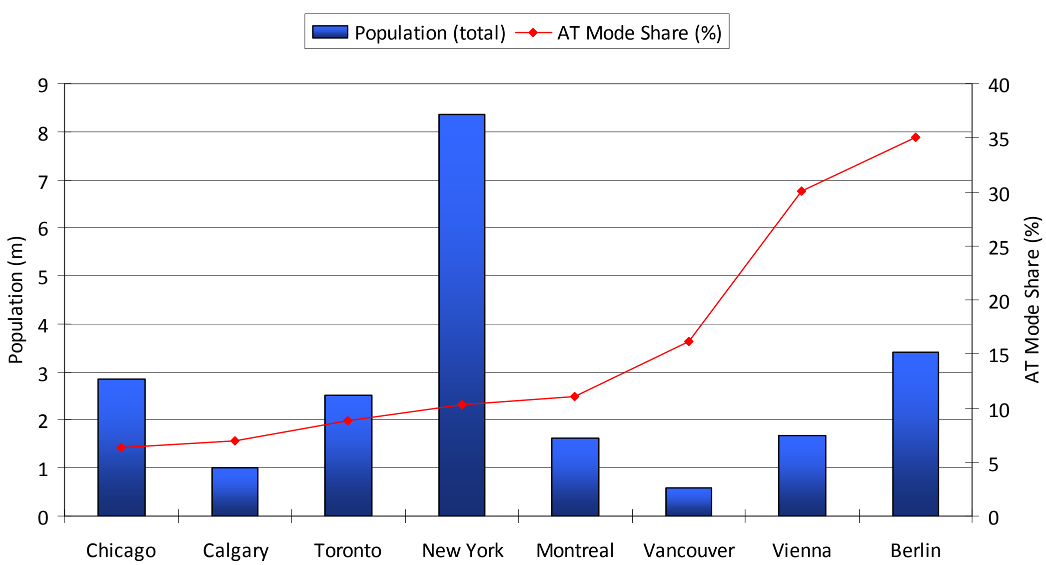


Figure 4.18 AT mode share by total population, 2007

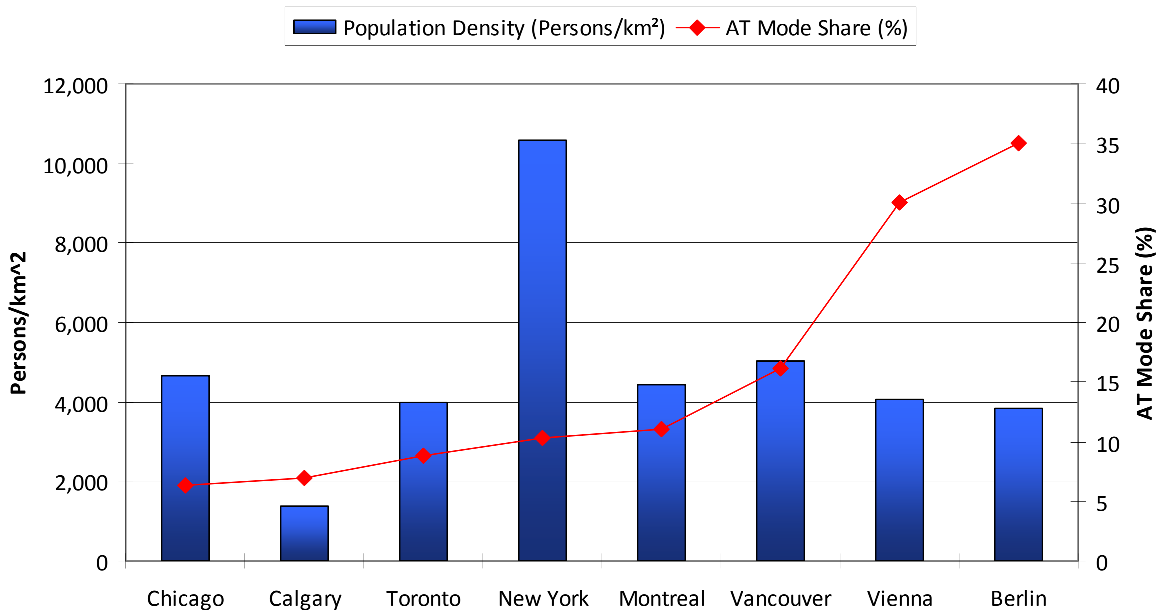


Figure 4.19 AT mode share by population density, 2007

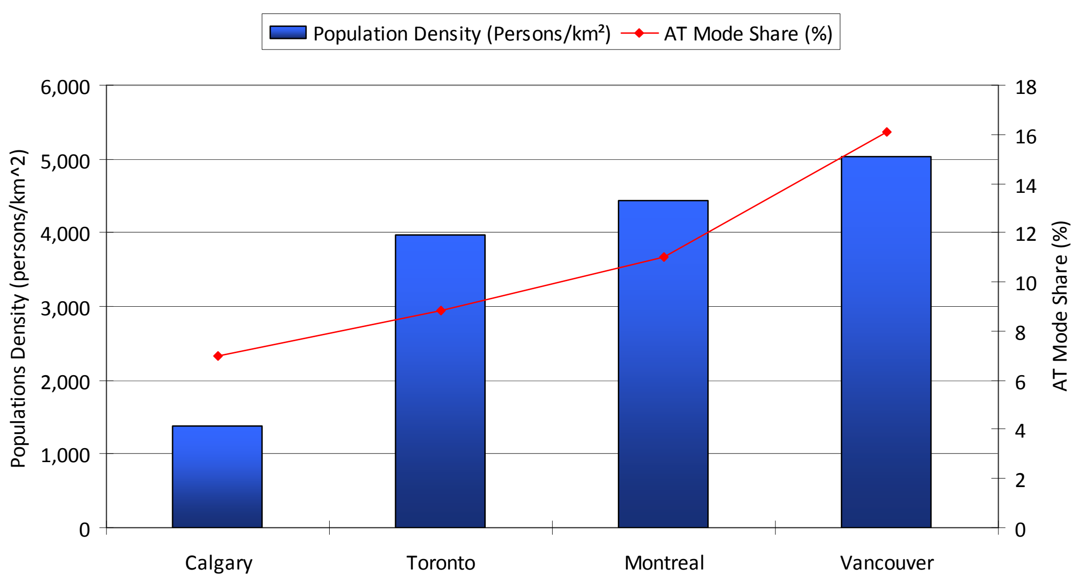


Figure 4.20 AT mode share by population density (Canadian cities only), 2007

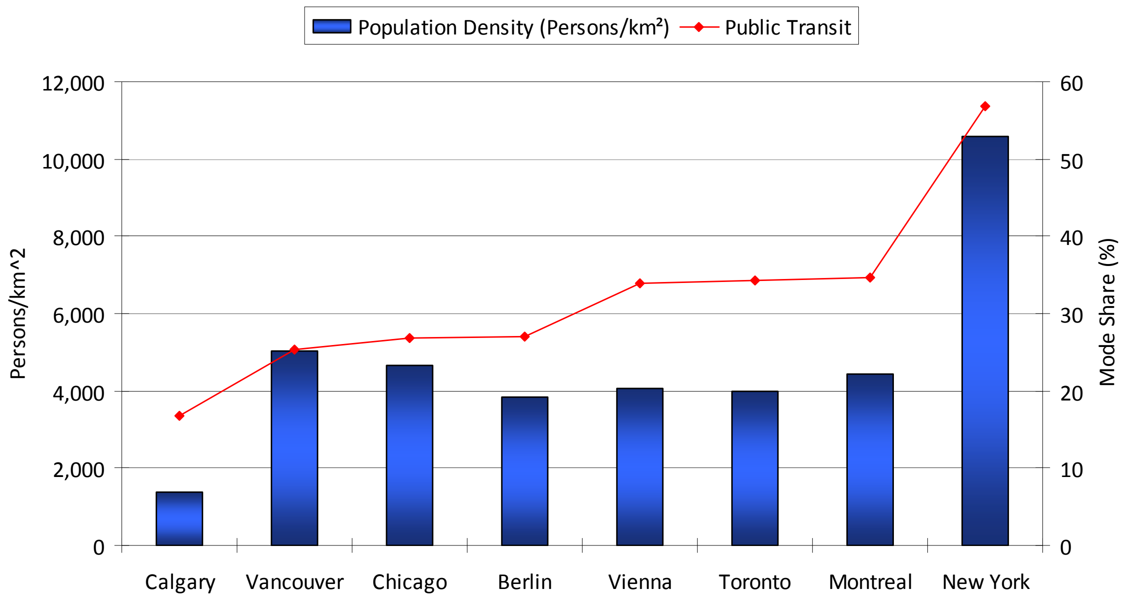


Figure 4.21 Transit mode share by population density, 2007

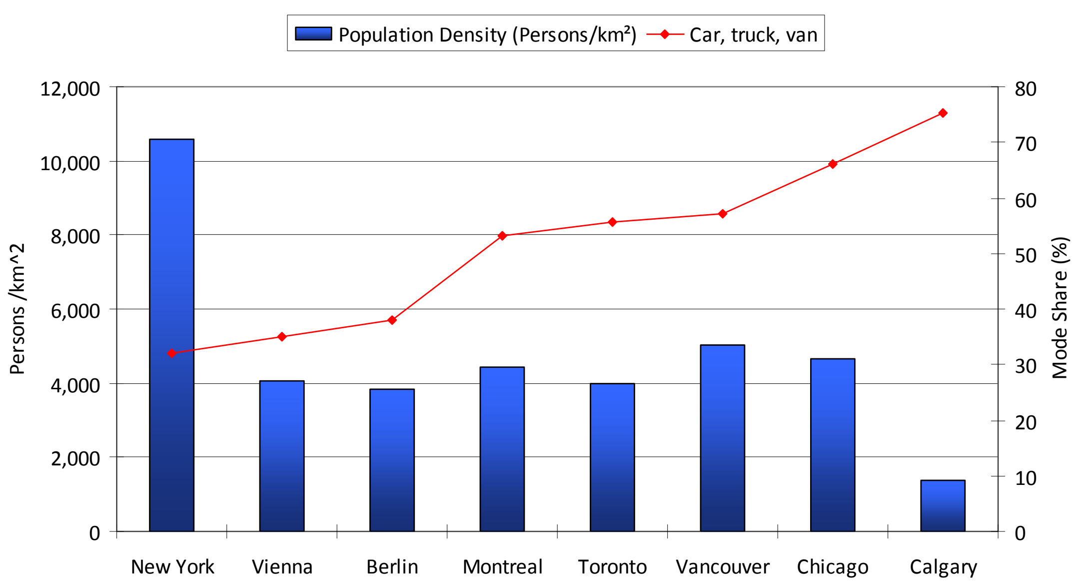


Figure 4.22 Private automobile mode share by population density, 2007

When we examine gender and AT modes combined, we see that overall, the female to male split hovers around 50:50. This is evident in Figure 4.23. Information on AT modes and gender was only available for Canadian cities in the study. However, on closer examination, when we separate AT into walking and cycling, we see that there are great disparities between the sexes. As displayed in Figure 4.24, where we look at pedestrian trips, **in all cities the majority of pedestrian trips are made by females.** In Toronto this is most pronounced, where 56.2% of pedestrian trips are by females, followed by 54.8%, 53.9% and 53.7% in Montreal, Vancouver and Calgary respectively. Whilst these differences are not vast, an examination of cycling trends between the sexes reveals a far more polarized situation. **As is evident in Figure 4.25, cycling as a mode choice in North American cities is predominantly male.** In Calgary, 77.9% of all cycle trips to work are by males. In Montreal, this figure is 64.9%, with 63.5% in Toronto and 62.2% in Vancouver. As we have seen from our injury data, Calgarians are more likely to be injured than any other Canadians in our study. Calgary also has the greatest male-female disparity around cycling. It is worth noting that in European cities with high cycling mode shares (above 20%), there is no visible disparity between males and females.

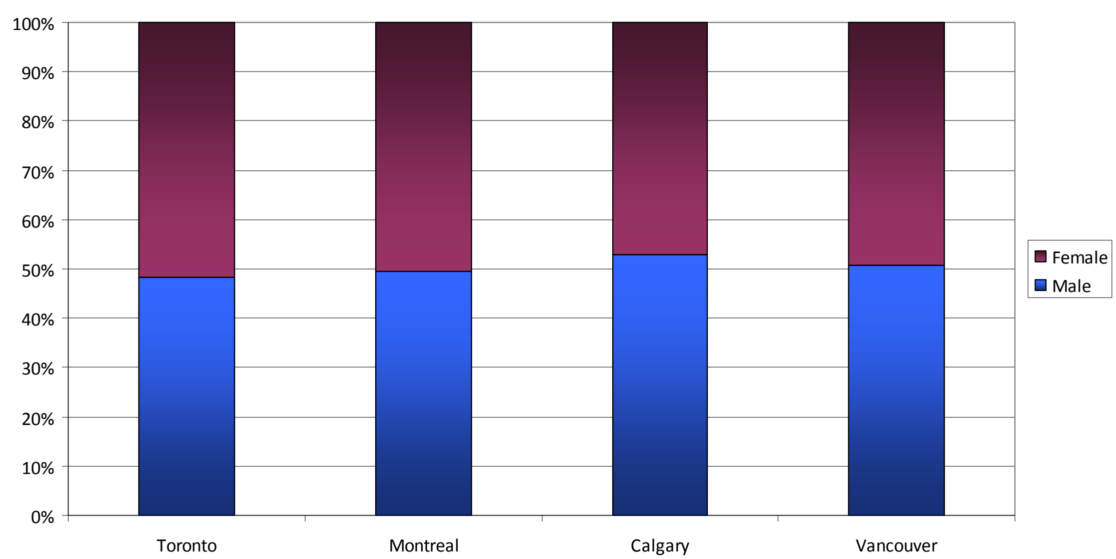


Figure 4.23 AT modes combined by gender (Canadian cities only), 2007

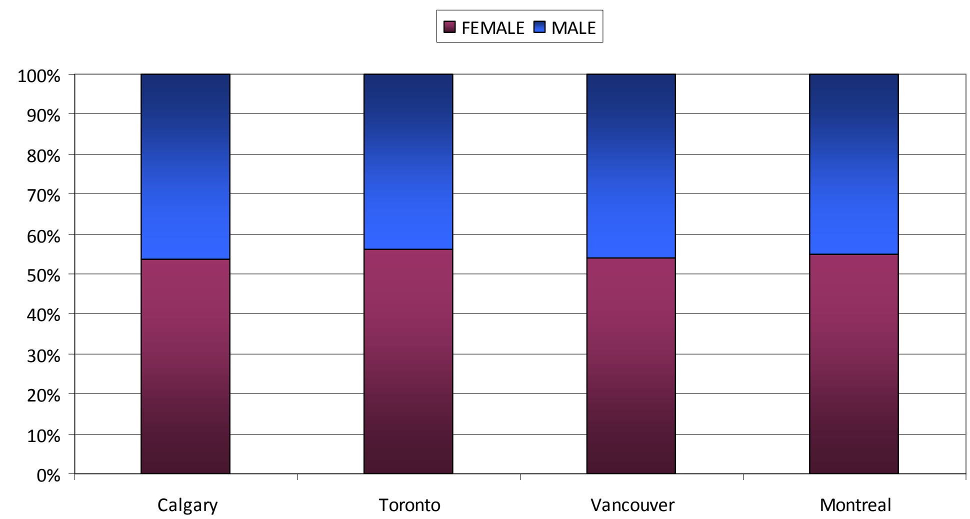


Figure 4.24 Walk to work by gender in Canadian cities, 2007

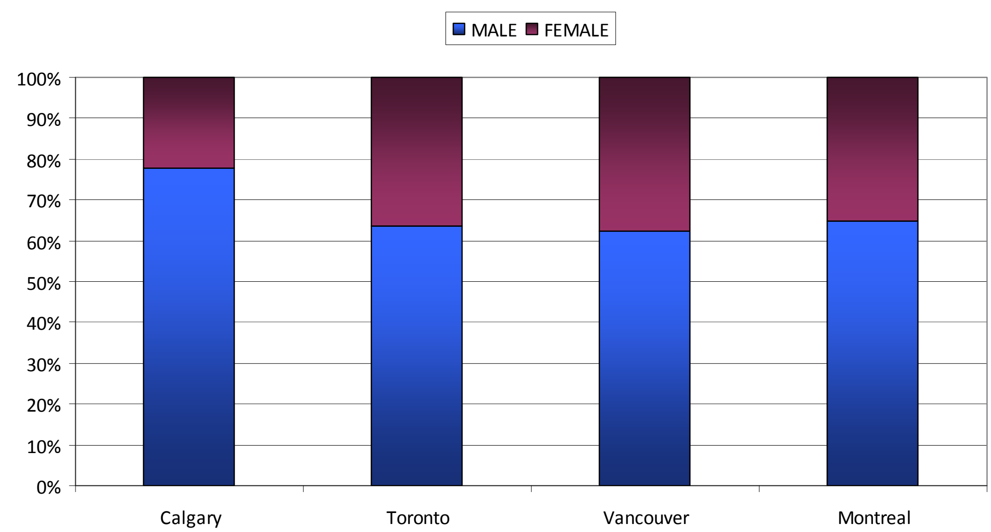


Figure 4.25 Cycle to work by gender in Canadian cities, 2007

4.5 Weather and Climate

Based on our literature review, our *a priori* expectations around meteorological indicators were that there would be no significant correlations. This proved to be the case. When we examine annual precipitation (Figure 4.26) we see no meaningful results. Vancouver for example, the Canadian city with the highest mode share, also has the highest precipitation. An examination of annual hours of sunshine reveals similar results, where **Vienna and Berlin, with the two highest levels of AT of all study cities, have the lowest annual sunshine** (Figure 4.27). Average summer temperatures also proved inconclusive, although it should be noted that the range in summer temperature between all cities was only 6°c (Figure 4.28). Winter temperatures, obviously of a different magnitude, also presented a similar variance, but still no discernable trends exist in the data. In the Canadian context, Vancouver is the warmest city through the winter months, and has the highest mode share. However, Montreal, which is markedly colder than Toronto, has an AT mode share that is significantly higher than that of Toronto (see Figure 4.29). Combining summer and winter temperatures and examining the mean annual temperature proved similarly inconclusive for all study cities (see Figure 4.30). All of our analyses around meteorology and AT proved our expectation that the effect is, at best, minimal.

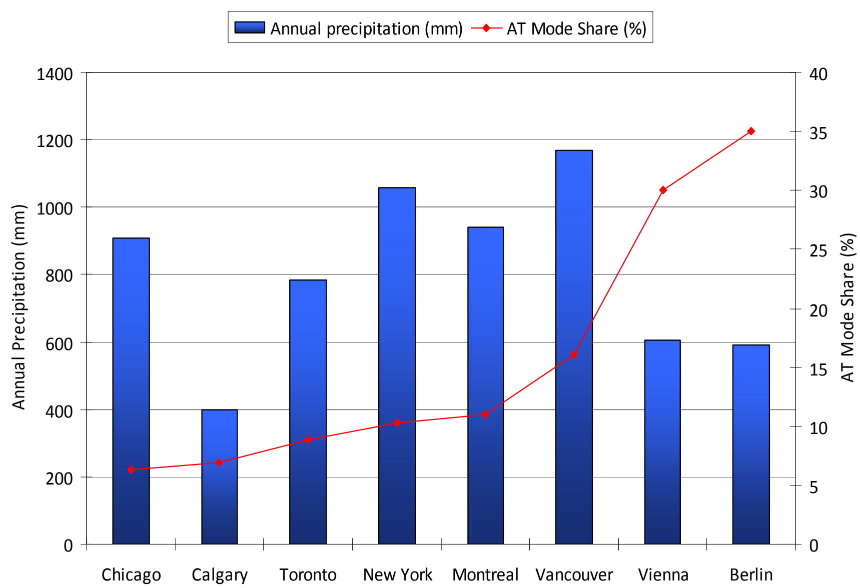


Figure 4.26 Annual precipitation by study city, 2007

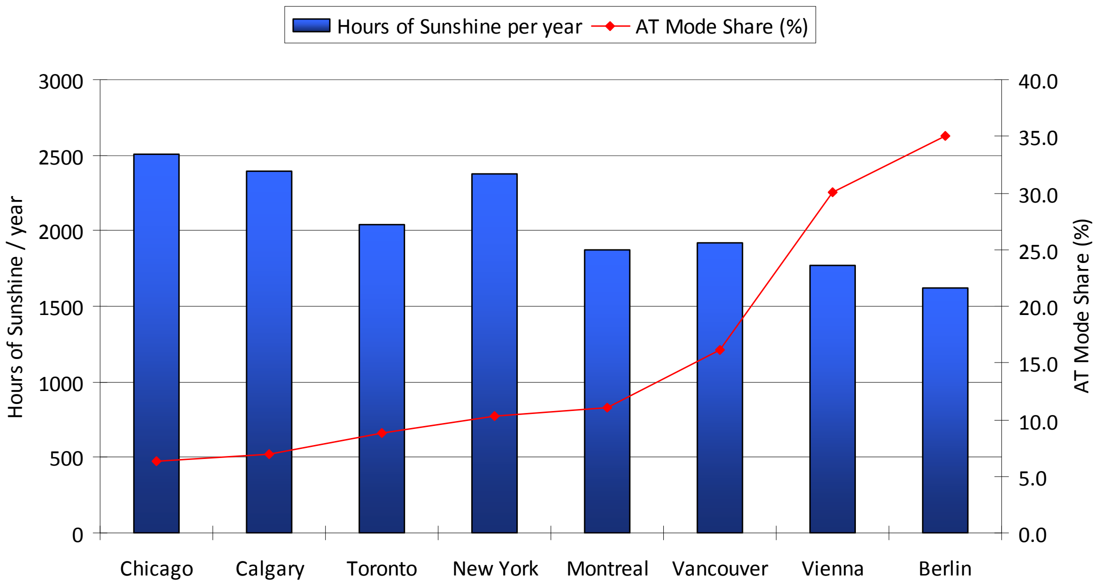


Figure 4.27 Annual hours of sunshine by study city, 2007

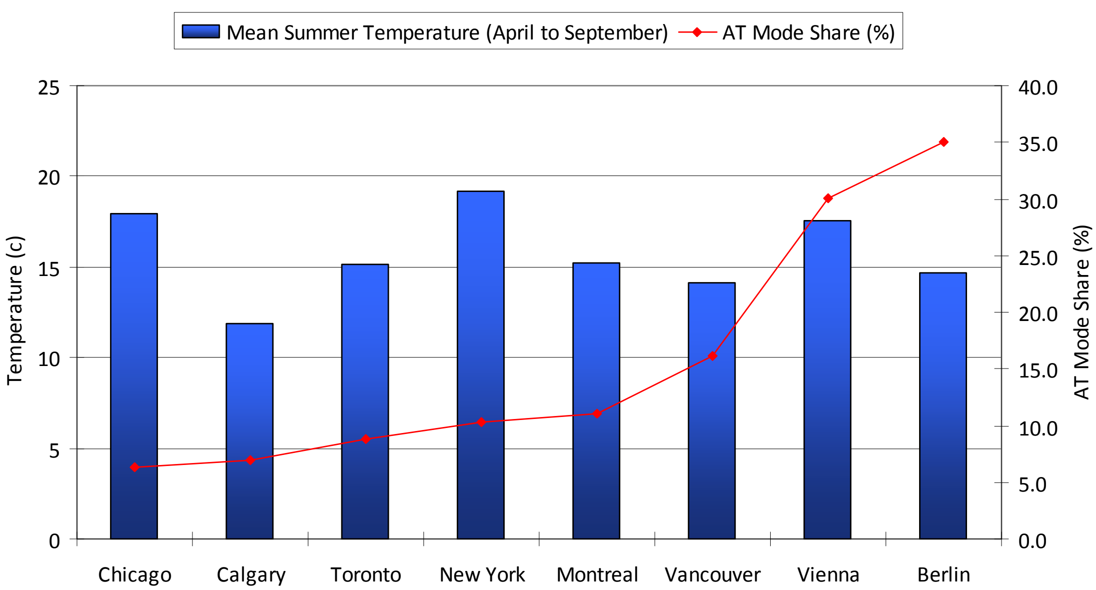


Figure 4.28 Mean summer temperature by study city, 2007

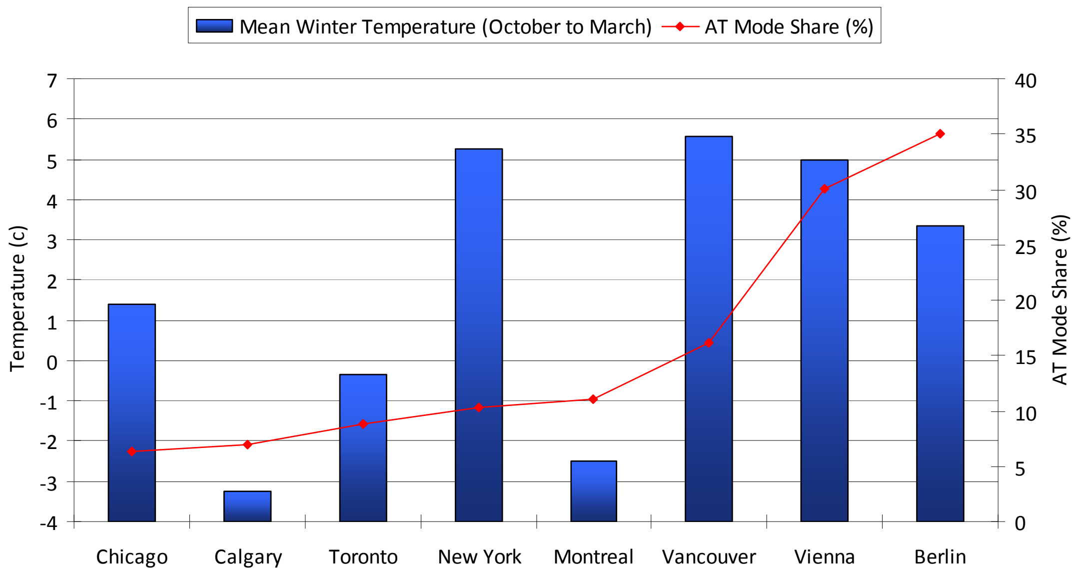


Figure 4.29 Mean winter temperature by study city, 2007

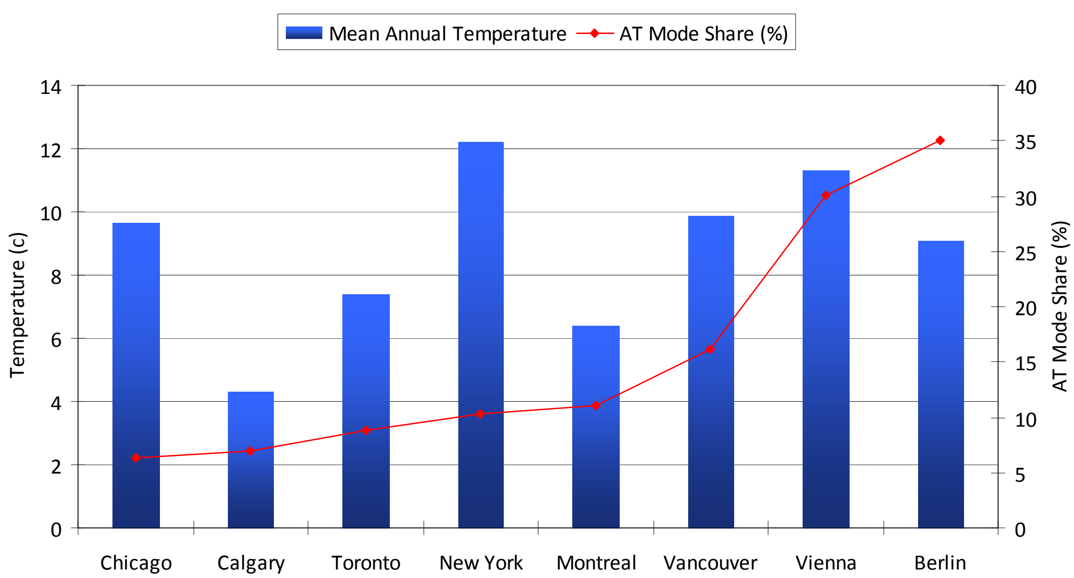


Figure 4.30 Mean annual temperature by study city, 2007

5 Current Status of Active Transportation in Toronto

5.1 Comparing Toronto against Neighbouring Municipalities

When comparing Toronto to its surrounding municipalities, we see the unique position the city occupies relative to its neighbours across all aspects of transportation. When we examine private automobile mode shares, we see Toronto's is considerably lower than all neighbouring municipalities. **Toronto's automobile mode share of 55.8% is dramatically lower than the lowest of its neighbours, at 80.6%** (see Figure 5.1). When we compare among public transit mode shares, Toronto has the highest in the Greater Toronto Area (GTA), and is over twice the magnitude of the second highest. **Toronto's transit mode share is 34.4%, the second highest is Mississauga, at 15.8%.** Figure 5.2 presents this information graphically. Similarly, Toronto's active transportation mode shares are impressive when compared against other GTA municipalities (see Figure 5.3). This statement should be qualified by noting the extremely low levels of AT in the surrounding areas. Toronto's neighbouring municipalities are dominated by low density sprawling suburbs that are difficult to service with transit and AT infrastructure.

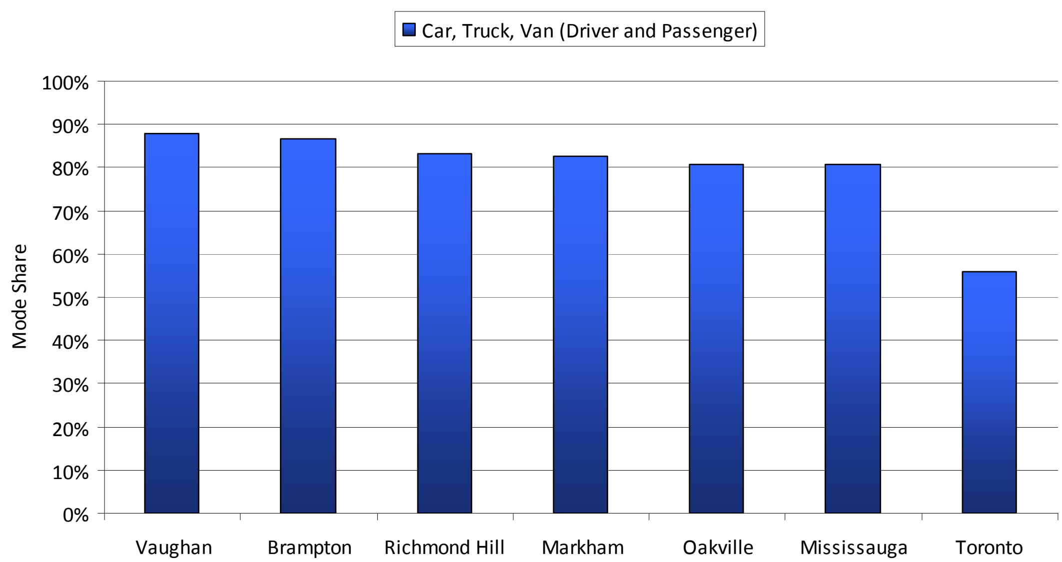


Figure 5.1 Mode to work by private automobile – GTA municipalities, 2007

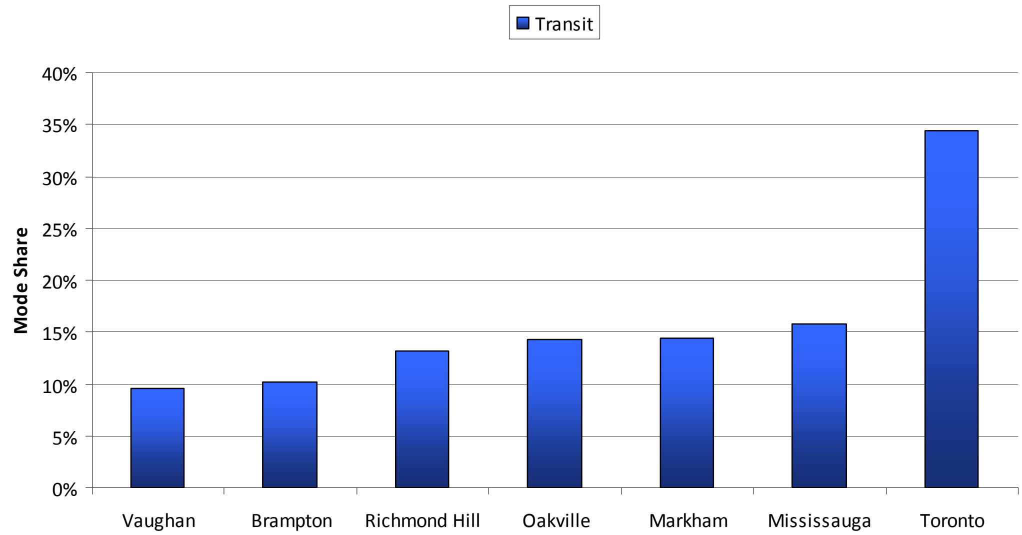


Figure 5.2 Mode to work by transit – GTA municipalities, 2007

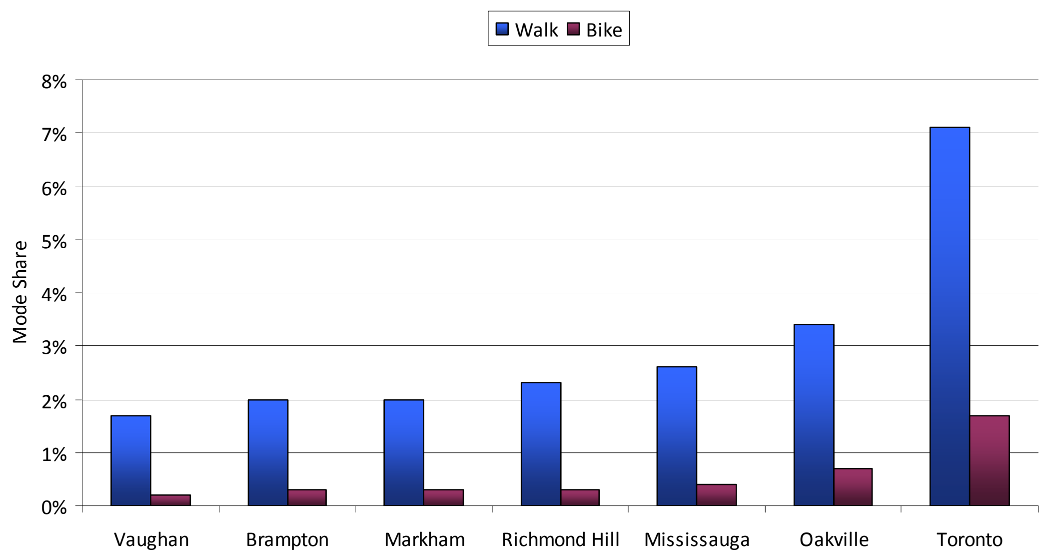


Figure 5.3 Mode to work using active transportation – GTA municipalities, 2007

5.2 Changes in the Transportation Choices of Torontonian's, 2001-2006

This section examines the changes between 2001 and 2006 in the transportation choices of Torontonians, using Statistics Canada's "journey to work" census data. The highest rate of change for any mode was with cyclists, where we see an increase of 32.6% (see Figure 5.4). Obviously, this increase is from a low baseline, but nonetheless presents some positive results that could be built on moving forward. Increases in the pedestrian mode of 11.4% are also positive and encouraging. However, when we examine actual numbers, the 13.5% increase in private automobile as the mode to work represents 233,548 people. This increase includes both drivers and passengers, although the actual increase in drivers was 5.6% compared to an increase of 29.5% as passengers. This larger increase in passengers may point to a greater level of carpooling and less of an increase in single occupancy vehicles. The actual increase in public transit numbers between 2001 and 2006 was 10,269 while for pedestrians and cyclists these increases were 13,181 and 8,050 respectively. The total increase for transit riders, pedestrians and cyclists combined was 31,501. This figure is relatively low compared to the 233,548 individuals who represented the growth in use of private automobiles to get to work. Although there have been impressive gains in AT modes, the automobile is clearly still dominant in Toronto's transportation portfolio.

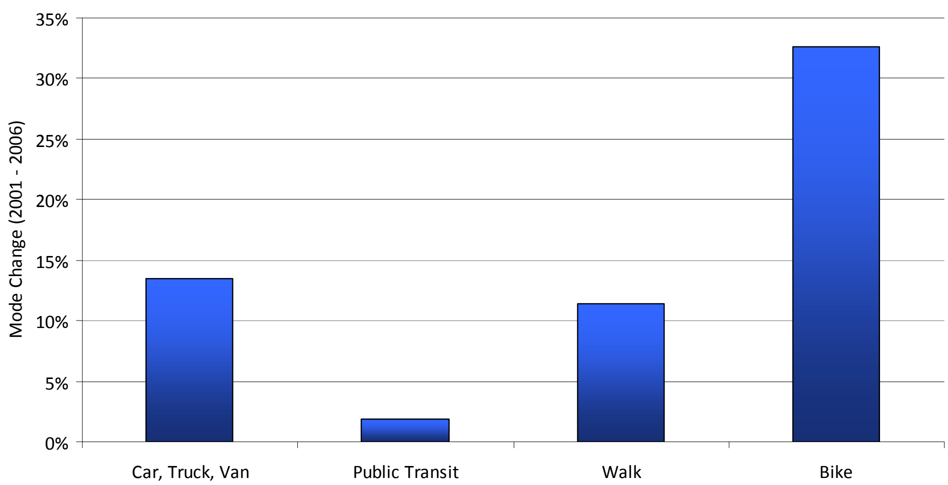


Figure 5.4 Change in mode to work, Toronto, 2001 – 2006

Interestingly, when we examine changes in AT between the sexes in Toronto between 2001 and 2006, we see greater increases for males walking to work compared to females, and greater increases for females cycling to work against males. Our literature review suggests that as numbers of males and females cycling reach parity, that this is a healthy indicator for the success of cycling in a city. Although the actual numbers of males and females cycling are not near parity in Toronto, at least the rate of change is (see Figure 5.5).

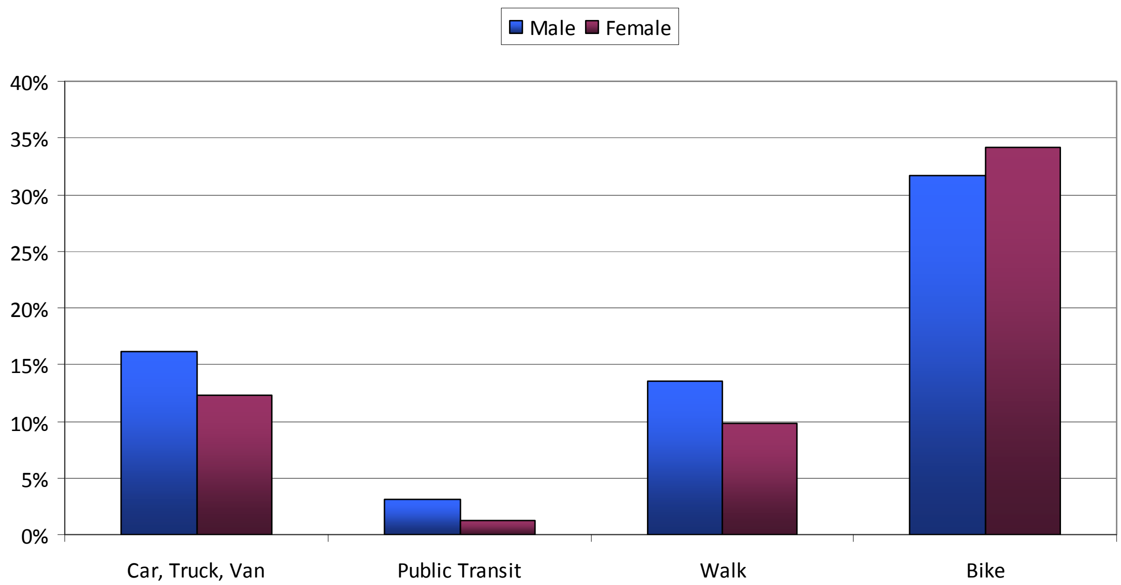


Figure 5.5 Change in mode to work, Toronto, 2001 – 2006 by sex

By examining the change in AT modes by age category, we discovered an interesting trend. As we know, Toronto, and Canada in general, has an aging population. As Canada's baby-boomers are now in the 45-65 age category, and with sub-replacement fertility rates, this aging population will uniquely influence transportation planning decisions. Other Canadian studies have noted that this group is heavily dependent on the automobile (Maoh et al, 2009). However, **on examination of the effect of an aging population in Toronto, we see that residents are cycling and walking in impressive numbers.** As Figure 5.6 displays**, the highest increases in both walking and cycling were in the 55-64 age category.** This group showed increases of 109.6% in their level of cycling and 31.7% in their level of walking. Gains in the level of cycling were especially prominent in 45-54 year olds (69.3%), 55-64 year olds (109.6%) and over 65s (55.0%). Increases in the levels of pedestrian work trips were also evident in these groups, but were of magnitudes not unlike those of younger cohorts.

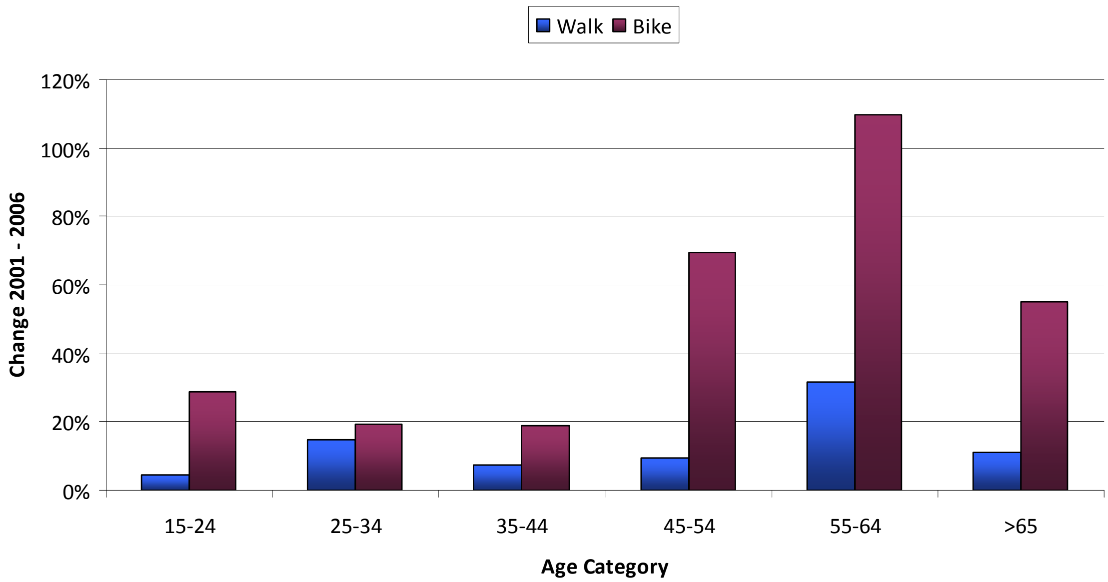


Figure 5.6 Changes in active transportation modes, 2001 -2006, by age category

6 Recommendations

In this section we identify next steps, both in terms of future research, as well as suggestions for improving active transportation data collection in Canada.

1. **There is a need for active transportation benchmarking at the national level**. Our benchmarking study was limited by the number of cities that we could include, and that responded to the survey. There is a pressing need for a more systematic study of Canadian cities, conducted at fixed intervals to measure longitudinal patterns of change in active transportation. In order to be robust, a rigorous methodology is required and should be developed with input from a team of active transportation experts including academics, transportation planners and engineers, and NGOs.

   The Alliance for Biking and Walking (formerly Thunderhead Alliance) has set an excellent precedent in the U.S. with its ongoing benchmarking project. Recognizing the lack of available data to measure progress of bicycling and walking, the Alliance's Benchmarking Project, launched in 2003, collects, analyzes and publishes a comprehensive nationwide report every two years. There is nothing comparable in Canada yet but an in-progress project sponsored by the Transportation Association of Canada (TAC) holds promise. Launched in 2008, the study "Active Transportation: Making it Work in Canadian Communities" will research, identify and understand active transportation successes and challenges in Canadian communities. IBI Group was commissioned to do the work and their findings and recommendations are expected this year.

2. **More reliable data is needed.** As noted in the study limitation section, access to reliable active transportation data is limited, inconsistent, and varies from city to city. A national initiative to collect the data in a consistent way is required. In the absence of this there are steps that individual cities can take to make their data more uniform and accessible. The National Bicycle & Pedestrian Documentation (NBPD) Program, initiated and led by Alta Planning and Design and co-sponsored by the Institute of Transportation Engineers (ITE), is a nationwide U.S. effort to provide consistent and ongoing data collection on pedestrian and bicycle trip generation. Canadian cities are encouraged to participate and some are already doing so (e.g. Victoria and Toronto). This is especially critical for Canadian cities since the Census "Journey to Work" data is scheduled to be discontinued. Collecting this basic usage data is the bare minimum required to benchmark active transportation.

3. **Missing data needs to be collected.** The most important active transportation benchmarking data is also the most difficult to come by, namely the length and type of pedestrian and cycling facilities installed and the dollar amounts invested. While most municipalities do keep track in some manner, there is a real need for a standardization of the terminology used (e.g. the term "bike route" is ill defined) and the way in which data is collected (e.g. counting on one or both sides of the street). The good news is that data for some of the important indicators that impact on active transportation are already collected, albeit inconsistently, on a regular basis (e.g. weather, density, income, car ownership, and traffic injuries). Some municipalities additionally collect attitudinal data on residents' habits and opinions regarding active transportation (i.e. City of Toronto's 1999 and 2009 Cycling Study and 2008 Walking Habits and Attitudes Report). It would be useful if this type of data was collected in municipalities across the country at regular intervals. Programming efforts (i.e. cycling skills training and promotional efforts) should also be tracked and evaluated.

4. **More research required on active transportation indicators.** The indicators themselves need further refinement in order to determine which are the most applicable, for individual municipalities as well as in the national context, while other indicators may need to be explored in more depth. While some indicators show general trends, they also point to the potential of a more complex reality that it would be useful to understand. For example, there is a relationship between cycling and walking mode shares and the amount of active transportation infrastructure provided, but it's unclear what type of infrastructure has the greatest effect. It would also be useful to explore the indicators in a more fine-grained way by studying the central cities separately from the suburban areas.

5. **Beyond tracking, assessing effectiveness**. Most benchmarking efforts merely track the existence of various indicators. A critical next step is assessing the effectiveness of the various programs and facilities that are being employed. This is especially important since active transportation is a relatively new field of study and interventions impact a vulnerable population (pedestrians and cyclists) so it is deserving of the benefit of rigorous testing to evaluate what works well and what needs to be improved. The impact of key interventions should be analyzed on a regular basis, before and after they are introduced.

7 Conclusion

Benchmarking is an important exercise in that it allows us to gauge where we are against where we can be. Such exercises allow us to identify our weaknesses, while simultaneously identifying areas where we have achieved successes. Benchmarking provides an opportunity to see what other cities are doing and identify best practices as well as areas to avoid. This report has only scratched the surface of active transportation benchmarking. While it was the intention of this research to examine all relevant indicators (as identified in our literature review), in the process of doing this work it became evident that due to inconsistent data holdings and inconsistent municipal approaches to managing active transportation, such a task would require considerably greater human and monetary resources. A project of this scope is a bold endeavour, especially for a smaller NGO. Were it not for the foresight and generosity of the Toronto Community Foundation, it is arguable that such a Canadian-focused project would not be possible.

Despite the small sample size and study limitations, the findings largely mirror those found in larger benchmarking studies. As in previous studies, we found that those cities with more kilometres of bicycle facilities also tend to have a higher cycling mode shares. Cities with greater transit integration, where bicycles are permitted on transit vehicles during rush hours also have higher active transportation mode shares. Our findings show that in cities with high mode shares, the percentage of cyclists and pedestrians injured and killed is lower than in cities with low mode shares, reflecting the 'strength in numbers theory'. Our research did not prove the relationship between violent crime and active transportation – safety as a result of crime is far less of a deterrent to active transportation than the threat of injury to a pedestrian or cyclist from a motor vehicle.

As was the case in previous research, our study found that weather is not as great a deterrent to active transportation as is generally conceived. Vancouver, the wettest of our Canadian study cities had the highest active transportation mode shares of any Canadian city. Vienna and Berlin, with the two highest levels of active transportation of all study cities, have the lowest annual sunshine.

Commuting distance was also found to influence active transportation rates, where we found that cities with shorter commuting distances are more likely to have higher rates of active transportation. Vancouver, with the highest active transportation mode share of any Canadian city, has the lowest median commuting distance at 5 km. Local policies also have an effect, where we found that those cities with lower fuel taxation levels have higher private automobile mode shares. As is the case in most cities with relatively low active transportation rates (compared to Northern European cities), we found that for all Canadian cities, walking tends to be dominated by females where cycling has a higher number of males.

The final focus in our research looked at the City of Toronto specifically and compared Toronto with neighbouring municipalities. Toronto's automobile mode share of 55.8% is dramatically lower than the lowest of its neighbours, at 80.6%. Toronto's transit mode share (34.4%) is the highest in the region, where the next highest is 15.8%. Toronto has made investments in active transportation over the past decade. Although active transportation mode shares are still quite low, they are improving. It can be argued that this improvement is as a result of investment in these modes by the municipality and the dedication of local NGOs. There has been a 32.6% increase in bike to work trips in Toronto between 2001 and 2006, where there was only a 13.5% increase in the number of people travelling to work by private automobile. In the same period, we witnessed greater increases in the number of female cyclists, where parity between the sexes can be seen as an important step in creating a healthy state of active transportation. Interestingly, when we examined the age structure of cyclists and pedestrians in Toronto, the highest increases in both walking and cycling were in the 55-64 age category.

Toronto's investment in active transportation is relatively low when compared to those European cities with very high active transportation mode shares. Still, we have witnessed improvements in mode shares and levels of infrastructure. With continuing improvement and increased investment in the future, we have the potential to create a vibrant, liveable, moving city, with greater levels of active transportation, cleaner air and healthier citizens.

8 Appendix Survey as sent to study cities

Toronto Coalition for Active Transportation Infrastructure Survey

The Toronto Coalition for Active Transportation (TCAT), a project of the Clean Air Partnership, gives a unified voice to the many groups working for a better cycling and pedestrian environment in Toronto, Canada. TCAT works to create a better city for cycling and walking by conducting research, developing policy, and creating opportunities for knowledge sharing.

Currently, we are conducting a research project benchmarking active transportation in 8 international cities. We would very much appreciate your input by completing this survey which seeks to estimate levels of active transportation infrastructure.

Few studies have attempted to benchmark international cities of a comparable size and density. In doing this, we hope that the results will be of interest to all participating cities. In addition, your participation in this exercise will contribute to active transportation research and promotion. All participants will be mailed a complete report once finished.

If you are unable to answer all questions in the survey, please submit what you can, and if possible, suggest alternative contacts who might be better able to respond. Space has been provided at the end of the survey to do so.

1a. What City are you responding on behalf of?

______

1b. When estimating distances for bicycle infrastructure, what metric do you employ?

	Please check the appropriate option
Kilometres	☐
Metres	☐
Miles	☐
Feet	☐

1c. What is the total length of bicycle facilities in your city? (including on-street bicycle lanes physically separated from motorized traffic by a barrier, on-street bicycle lanes designated with painted lines, signed bicycle routes and multi-use paths)

______

1d. Of the total on-street bicycle facilities indicated in 1c, please provide the length for each of the following types.

On-street bicycle lanes physically separated from motorized traffic by a barrier (e.g. bollards, curbs)	______
On-street bicycle lanes NOT physically separated from motorized traffic by a barrier (e.g. designated by painted lines)	______
Signed bicycle routes	______
Multi-use paths	______

1e. Do you have a policy outlining which street conditions warrant bicycle lanes?

◯ Yes

◯ No

1f. If yes, which characteristics influence this decision?

	Yes	No
Posted speed limit	◯	◯
Motorized traffic volume	◯	◯
Number of lanes of traffic	◯	◯

Other (please specify)

1g. When estimating these distances, do you measure bicycle facilities length for each direction of travel (both sides of the street) or by street segment (one side only)?

◯ One side only

◯ Both sides

2. Does your City use any of the following innovative bicycle facilities?

	Yes	No
Shared Lane Markings	◯	◯
Bicycle Boulevards	◯	◯
Woonerf / Living Streets	◯	◯
Coloured Bicycle Lanes	◯	◯
Bicycle Traffic Lights	◯	◯

3a. Please estimate the total number of bicycle parking spaces for use by the public in your city (the total number of bikes that can be locked up at any given time).

3b. Of the total bicycle parking available indicated in 3a, please estimate the number of spaces that are long-term (e.g bike stations).

4a. Are bicycles allowed on the following transit vehicles?

	Yes	No
Subway	◯	◯
Streetcar/Tram	◯	◯
Bus	◯	◯
Commuter Rail	◯	◯

4b. If yes, are there times when bikes are not allowed (for example, during rush hour)?

	Allowed at all times	Not allowed at all times
Subway	◯	◯
Streetcar/Tram	◯	◯
Bus	◯	◯
Commuter Rail	◯	◯

4c. Please estimate the percentage of local transit with dedicated space for bicycles (e.g., racks on buses, areas reserved for bicycles inside trains, 0 indicates absence)

Subway

Streetcar/Tram

Bus

Commuter Rail

5a. Please estimate the total length of sidewalks in your city.

5b. Please estimate the total length of pedestrian streets in your city (with permanent or partial vehicle restrictions, 0 indicates absence)

5c. When estimating these distances, do you measure length for each direction of travel (both sides of the street) or by street segment (one side only)?

◯ One side only

◯ Both sides

6. When estimating distances for pedestrian infrastructure, what metric do you employ?

	Please check the appropriate option
Kilometres	☐
Metres	☐
Miles	☐
Feet	☐

7a. Does your city have a default speed limit that applies everywhere unless otherwise specified? What is this limit?

- ◯ Yes
- ◯ No

7b. If yes, what is this limit?

7c. Does your city have a specified speed limit that applies to residential areas?

7d. Are the speed limits indicated in 6a and 6b in miles per hour or kilometres per hour?

- ◯ Miles per hour
- ◯ Kilometres per hour

If there are questions you are unable to answer, but feel you have contacts who may be able to provide this information, please list the details below and we will contact the relevant parties.

9 References

Anam, S. (Photographer). (2010). *Old Montreal* [Photograph], Retrieved July 13, 2010, from: http://www.facebook.com/album.php?id=504444266&aid=183773&s=180&hash=994c1e1391309e416659d2689dc99c89#!/photo.php?pid=4294346&id=504444266

Bassett Jr., D.R., Pucher, J., Buehler, R., Thompson, D.L., Crouter, S.E. (2008) Walking, cycling, and obesity rates in Europe, North America and Australia. *Journal of Physical Activity and Health* Volume 5, Issue 6, November 2008, Pages 795-814

Butterworth et al (2006) Measuring the walkability of local communities using Geographic Information Systems data. Paper presented at Walk21-VII, "The Next Steps", The 7th International Conference on Walking and Liveable Communities, October 23-25 2006, Melbourne, Australia.

BYPAD (2009) BYPAD Facts. Available at http://www.bypad.org/cms_site.phtml?id=676&sprache=en Accessed 06/08/09.

Canby (2003) Creating Successful Communities – Making it Happen! Institute of Transportation Engineers. *ITE Journal*; Jul 2003; 73, 7; ABI/INFORM Global pg. 26

Caribb. (Photographer). (2006). *Montreal- McGill College Avenue* [Photograph], Retrieved July 13, 2010, from: http://www.flickr.com/photos/caribb/84014017/

Carrall Street [Photograph]. (2010). Retrieved July 13, 2010, from: http://olympichostcity.vancouver.ca/mediaroom/feature-stories/carrall-street.htm

Cervero R, Duncan M. Walking, bicycling, and urban landscapes: evidence from the San Francisco Bay Area. Am J Public Health. 2003;93:1478–83.

City of Toronto (2004) Cycling Website for City of Toronto. Accessible at: http://www.city.toronto.on.ca/cycling/index.htm

City of Toronto (2005) Cycling Injuries and Fatalities. Toronto, Canada: Office of Bicycling Programs.

City of Toronto (2008) Cycling Statistics. Toronto, Canada: City of Toronto. Accessible at: http://www.toronto.ca/cycling/reports/statistics/statistics.htm

City of Toronto (2001) 2000-2001 Toronto Bike Plan: Shifting Gears. Toronto, Canada: City of Toronto. Accessible at: http://www.city.toronto.on.ca/cycling/bikeplan/index.htm

City of Toronto (2010) Cycling Study Tracking Report (1999 and 2009). Toronto, Canada: City of Toronto. Accessible at: http://www.toronto.ca/cycling/reports/pdf/cycling_study_1999_and_2009.pdf

City of Toronto (2008) Walking Habits and Attitudes Report. Toronto, Canada: City of Toronto. Accessible at: http://www.toronto.ca/transportation/walking/pdf/walking_study_report.pdf

City's Transportation Plan Working During the Games [Photograph]. (2010). Retrieved July 13, 2010, from: http://olympichostcity.vancouver.ca/mediaroom/feature-stories/city-transportation-plan-working-during-games.htm

CROW (1993) Quicker by bicycle: Policy manual for a bicycle-friendly infrastructure. In, Michels, T. (ed) (1993) Cycling in the city, pedalling in the polder: Recent developments in policy and research for bicycle facilities in the Netherlands, CROW, the Netherlands, 25-52.

Curran et al (2006) Indicators for Community Action: Built Environment and Community Health *Journal of Rural and Community Development* 2 (2006) 59-74

Curran, A (2006) Taking the pulse of active transportation: Measuring the built environment for healthy communities 2006 *Plan Canada* 46 (2), pp. 32-34

Cradock et al (2009) Factors Associated with Federal Transportation Funding for Local Pedestrian and Bicycle Programming and Facilities. *Journal of Public Health Policy* (2009) 30, S38–S72.

Dekoster, J. and Schollaert, U. (1999) *Cycling: the way ahead for towns and cities.* European Communities, Belgium.

Dill J. and Carr T. (2003) Bicycle commuting and facilities in major U.S. cities: if you build them, commuters will use them. Transp Res Rec. 2003;1828:116–23.

Dill, J. and Voros, K. (2007) Factors affecting bicycling demand: initial survey findings from the Portland, Oregon, region. Transportation Research Record;2031:9–17.

Dill, J. (2009) Bicycling for Transportation and Health: The Role of Infrastructure. *Journal of Public Health Policy* (2009) 30, S95–S110.

Dixon L.B. (1996) Bicycle and pedestrian level-of-service performance measures and standards for congestion management systems. Transport Res Rec 1538. 1996:1–9.

Emery, J., Crump, C., Bors, P. (2003) Reliability and validity of two instruments designed to assess the walking and bicycling suitability of sidewalks and roads. *American Journal of Health Promotion*, Volume 18, Issue 1, September 2003, Pages 38-46

European Cyclists' Federation. (1998) *Position Paper: Cycling in Urban Areas* (Online), Available World Wide Web: URL: www.ecf.com

Federal Highway Administration (1999) National Bicycling and Walking Study Five Year Status Report by the U.S. Department of Transportation. Washington, DC: Federal Highway Administration; 1999.

Federal Highway Administration (1994) The FWHA National Bicycling and Walking Study case study No.1: Reasons why bicycling and walking are and are not being used more extensively as travel modes. Washington DC: Federal Highway Administration.

Federal Highway Administration International Scanning Team (2009) International Scan Summary Report on Pedestrian and Bicyclist Safety and Mobility. Available at:

http://drusilla.hsrc.unc.edu/cms/downloads/Pedestrian%20Bicycle%20Scan%20Summary%20Report.pdf Accessed August 6, 2009.

Frank, L.D., Engelke, P. and Schmid, T. (2003) Health and Community Design: How Urban Form Impacts Physical Activity. Washington DC: Island Press.

Frank LD. (2004) Economic determinants of urban form. Resulting trade-offs between active and sedentary forms of travel. *American Journal of Preventive Medicine, 27(3S)*, 146-153.

Gallin, N. (2001) Quantifying Pedestrian Friendliness – Guidelines for Assessing Pedestrian Level of Service. Presented at Australia: walking the 21st Century. http://www.dpi.wa.gov.au/mediaFiles/walking_21centconf01apaper_gallin.pdf

Garrard J., Rose G., Lo S.K. (2008) Promoting transportation cycling for women: the role of bicycle infrastructure. Prev. Med. 46:55–9.

Garrard, J., 2009. Scientific American http://www.scientificamerican.com/article.cfm?id=getting-more-bicyclists-on-the-road

Gittingsc. (Photographer). (2010). *BIXI* [Photograph], Retrieved July 13, 2010, from: http://www.flickr.com/photos/gittingsc/4607187203/

Go for Green/Environics (1998) 1998 National Survey on Active Transportation Summary Report. Ottawa, Ontario, Go for Green.

Gradinger, K. (Photographer). (2009). *Henderson Bridge Bike Lane* [Photograph], Retrieved July 13, 2010, from: http://www.gcpvd.org/2009/10/23/henderson-bridge-bike-lane/

Greenberg M, Lane R, Zupan J, Renne J. (2005) Physical activity and use of suburban train stations: an exploratory analysis. *J Public Transp.* 2005;8:89–116.

Guit, A. (1993) Facilities for bicycle parking. In, Michels, T. (ed) (1993) Cycling in the city, pedalling in the polder: Recent developments in policy and research for bicycle facilities in the Netherlands, CROW, the Netherlands, 177-194.

Jacobsen, P., Anderson, C., Winn, D., Moffat, J., Agran, P. and Sarkar, S. (2000) Child Pedestrian Injuries on Residential Streets: Implications for Traffic Engineering. Institute of Transportation Engineers Journal *2/2000 vol. 70, no. 2.*

Jacobsen, P. (2003) Safety in numbers: more walkers and bicyclists, safer walking and bicycling, *Injury Prevention,* 9, pp. 205–209.

Kaiser, S.H. (1994) Urban Intersections that Work: a New Definition for Level of Service. In *Transportation Research Record 1438*, TRB, National Research Council, Washington, D.C., 1994.

Kelly C.E., Tight M.R., Page, M.W. and Hodgson F.C. (2007) Techniques for Assessing the Walkability of the Pedestrian Environment. Institute for Transport Studies, University of Leeds, Leeds, LS2 9JT, UK.

Krizek KJ, El-Geneidy A, Thompson K. (2007) A detailed analysis of how an urban trail system affects cyclists' travel. Transportation;34: 611–24.

Landis BW, Vattikuti VR, Ottenberg RM, Mc-Leod DS, Guttenplan M. (2001) Modeling the Roadside Walking Environment: A Pedestrian Level of Service. Washington, DC: Transportation Research Board; 2001. TRB Paper 01-0511.

Leden L. (2002) Pedestrian risk decrease with pedestrian flow. A case study based on data from signalised intersections in Hamilton, Ontario. Accid Anal Prev 2002;34:457–64.

Maoh, H., Kanaroglou, P., Scott, D., Páez, A. and Newbold, B. (2009) IMPACT: An Integrated GIS-Based Model for Simulating the Consequences of Demographic Changes and Population Ageing on Transportation. *Computers, Environment and Urban Systems*. 33 (3): 200-210

Millward, H. (2008) Evolution of Population Densities: Five Canadian Cities, 1971–2001 *Urban Geography*, 2008, 29, 7, pp. 616–638

Moffat, C. (Writer). (2010). *Bicycle Racks on TTC* [Photograph], Retrieved July 13, 2010, from: http://bicyclemechanic.blogspot.com/2010/05/bicycle-racks-on-ttc.html

Moudon, A.V. and Lee, C. (2003) Walking and Bicycling: An Evaluation of Environmental Audit Instruments. *Am J Health Promot* 2003;18[1]:21–37.

Nantulya V.M., Reich M.R. (2002) The neglected epidemic: road traffic injuries in developing countries. *BMJ* 2002;324:1139X41.

Newman, P. and Kenworthy, J. (1999) *Sustainability and Cities: Overcoming automobile dependence* Island Press. Washington, DC.

Newton, D. (Photographer). (2008). *Colored Bike Lanes Come to Tempe* [Photograph], Retrieved July 13, 2010, from: http://la.streetsblog.org/2008/03/25/colored-bike-lanes-come-to-tempe/

Nicoll, G. and Zimring, C. (2009) Effect of Innovative Building Design on Physical Activity. *Journal of Public Health Policy* 2009, 30, S111–S123

NYPB. (Photographer). (2006). *Sensible Bike Lanes* [Photograph], Retrieved July 13, 2010, from: http://www.flickr.com/photos/10978356@N00/208482768/

Owen N, Humpel N, Leslie E, Bauman A, & Sallis JF. (2004) Understanding environmental influences on walking: review and research agenda. *American Journal of Preventive Medicine, 27*(1), 67-76.

Passmore, D. (Photographer). (2008). *Streets for All Modes* [Photograph], Retrieved July 13, 2010, from: http://www.flickr.com/photos/dylanpassmore/2639703024/

Plaut P.O. (2005) Non-motorized commuting in the U.S. Transportation Research D – Transport and Environment;10:347–56.

Pucher, J., Komanoff, C., and Schimek, P. (1999) Bicycling renaissance in North America? Recent trends and alternative policies to promote bicycling, *Transportation Research A,* 33(7/8), pp. 625–654.

Pucher, J. and Dijksira, L. (2000) "Making Walking and Cycling Safer: Lessons From Europe," *Transportation Quarterly* 54 (2000): 25-50

Pucher, J. and Dijkstra, L. (2003) Promoting Safe Walking and Cycling to Improve Public Healtti: Lessons From The Netherlands and Germany. *American Journal of Public Health* September 2003. Vol 93, No, 9

Pucher, J. and Buehler, R. (2005) Cycling Trends and Policies in Canadian Cities. *World Transport Policy and Practice*, 2005, volume 11, issue 1

Ramierez et al (2006) Indicators of Activity-Friendly Communities - An Evidence-Based Consensus Process *Am J Prev Med* 2006;31(6)

Rietveld, P. and Daniel, V. (2004) Determinants of bicycle use: do municipal policies matter? *Transportation Research A,* 38, pp. 531–550.

Rundle, A, Neckerman, K.M., Freeman, L., Lovasi, G.S., Purciel, M., Quinn, J., Richards, C., Sircar, N. and Weiss, C. (2009) Neighborhood food environment and walkability predict obesity in New York City *Environmental Health Perspectives.* 117.3 (March 2009): 442(6)

Saelens B, Sallis J, Black J, Chen D. (2003) Neighborhood-based differences in physical activity: an environment scale evaluation. *Am J Public Health*. 2003;93:1552–1558.

Saelens BE, Sallis JF, & Frank LD. (2003). Environmental correlates of walking and cycling: Findings from the transportation, urban design, and planning literatures. *Annals of Behavioral Medicine, 25*(2), 80-91.

Sallis JF, Frank LD, Saelens BE, & Kraft MK. (2004) Active transportation and physical activity: opportunities for collaboration on transportation and public health. *Transportation Research Part A, 38*, 249-268.

Schlossberg, Marc A and Nathaniel Brown. (2004) “Comparing Transit Oriented Developments Based on Walkability Indicators”. *Transportation Research Record*: Journal of the Transportation Research Board, No. 1887, pp. 34-42

Schlossberg, Marc, Asha Weinstein and Katja Irvin (2007) An Assessment of GIS-Enabled Walkability Audits URISA Journal. Vol. 19, No. 2, pp. 5-11

Shafizadeh K. and Niemeier D. (1997) Bicycle journey-to-work: travel behavior characteristics and spatial analysis. Transp Res Rec.;1578:84–90

Smith et al (2008) Walkability and Body Mass Index; Density, Design, and New Diversity Measures *American Journal of Preventive Medicine*, Volume 35, Number 3

Statistics Canada (2007) *Where Canadians Work and How They Get There* (Ottawa: Statistics Canada).

Stonor et al (2002) Towards a walkability index. Presentation to the 3rd Walk 21 Conference, 9th - 10th May, Donostia-San Sebastian, Spain (2002)

Surface Transport Policy Project (1997) *Mean Streets: Pedestrian Safety and Reform of the Nation's Transportation Law* (Washington, DC: Surface Transportation Policy Project, 1997) Table 4, p, 4.

Tapesonthefloor. (Photographer). (2010*) A Montreal Bike Lane* [Photograph], Retrieved July 13, 2010, from:http://www.flickr.com/photos/tapesonthefloor/4619383886/

Tolley, R. (1997) Obstacles to walking and cycling. In, Tolley, R, (ed) (1990) *The greening of urban transport: Planning for walking and cycling in Western cities*, 2nd Ed, John Wiley and Sons, Chichester, Chapter 1, 3-20.

Thunderhead Alliance (2007) *Bicycling and Walking in the US: Benchmarking Report, 2007* (Prescott, AZ: Thunderhead Alliance).

Tysonwilliams.com. (Photographer). (2007). *Bike Parking* [Photograph], Retrieved July 13, 2010, from: http://www.flickr.com/photos/tysonwilliams/341899759/

USDOT (1999) National Bicycling and Walking Study, Five Year Status Report. U.S. Department of Transportation, Washington, DC. April 22, 1999

Victoria Transport Policy Institute (2008) Evaluating Nonmotorized Transport; Techniques for Measuring Walking and Cycling Activity and Conditions http://www.vtpi.org/tdm/tdm63.htm Accessed 21st May, 2009.

Walk 21 (2009) Measuring Walking http://walk21.com/evolving/measuringwalking.asp Accessed 21st May, 2009.

Walkinfo (2004) http://www.walkinginfo.org/walkingchecklist.htm

Zegeer, C. (Photographer). (2008). *PBIC image library* [Photograph], Retrieved June 28th, 2010, from: http://www.pedbikeimages.org/pubdetail.cfm?picid=232

Zegeer, C.V. (1993) "Designing for Pedestrians". In The Traffic Safety Toolbox: A Primer on Traffic Safety. Washington DC: Institute for Transportation Engineers.

Zuks, R (2002) The Stimulation of Bicycle Usage in European Cities, http://www.istp.murdoch.edu.au/ISTP/casestudies/Euro_Field_Trip/eft2002-ch-10.pdf Accessed, June 24th, 2009