Abstract

The low level of physical activity in Canadian cities has encouraged planners/engineers to investigate the fundamentals of forming livable communities characterized by more active and healthier lifestyles. A major factor that hinders promoting healthier communities is our auto-oriented developments. Another factor appears to be a lack of integrated, system-based approaches to community planning and Active Transportation (AT) infrastructure design that provides a safe environment for AT users. Therefore, the objectives of this research were to 1) identify the barriers communities face when trying to promote healthy communities, 2) review Canadian practices for encouraging a more active lifestyle and healthy living, and 3) recommend a tool for planners to assess developments in terms of health and safety.

Thirty-six one-hour interviews were conducted to collect publicly available data from key stakeholders in randomly selected cities to identify challenges for promoting AT. In addition, the functional ability of the Healthy Development Index (HDI) was examined by conducting a “beta test” case study on nine developments in major urban centers. Moreover, the effectiveness of the Fused Grid (FG) community design was evaluated using the HDI and Sustainable Transport Safety principles.

Based on the interviews with stakeholders, it was found that discontinuity of the AT infrastructure system, caused mainly by a lack of available AT funding, is a main barrier to AT use in the majority of cases. It was also found that low density and uncontrolled land development are other main barriers. Conventionally, the focus is more concentrated on providing AT infrastructure within new developments; rather, the focus should also be on integrating the development within the existing larger community, and to enhance high density and good land-use. While the HDI has a comprehensive set of measures that capture most of these factors, the functional ability evaluation identified several drawbacks including: 1) the data collection process to perform the HDI analysis is a difficult and time consuming process for older, existing communities and 2) there is a gap in both the literature and the index on the relationship between intersection density (a vehicle connectivity metric) and, the safety of pedestrians/cyclists and the connectivity of pedestrian/cyclists off-road paths. Moreover, the effectiveness evaluation of the FG community illustrated how it can be a successful model for building sustainably healthy and safer communities.
Preface

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Table of Contents

Abstract .................................................................................................................................................. ii
Preface .................................................................................................................................................... iii
Table of Contents .................................................................................................................................... iv
List of Tables .......................................................................................................................................... vi
List of Figures .......................................................................................................................................... vii
Glossary .................................................................................................................................................. viii
Acknowledgements ............................................................................................................................. x

<table>
<thead>
<tr>
<th>Chapter 1</th>
<th>Introduction ...................................................................................................................................... 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Problem Statement and Motivation ............................................................................................... 1</td>
</tr>
<tr>
<td>1.2</td>
<td>Research Objectives ..................................................................................................................... 3</td>
</tr>
<tr>
<td>1.3</td>
<td>Thesis Structure ............................................................................................................................ 4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter 2</th>
<th>Literature Review .......................................................................................................................... 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Outline .......................................................................................................................................... 5</td>
</tr>
<tr>
<td>2.2</td>
<td>Challenges and Barriers for Active Transportation .......................................................................... 5</td>
</tr>
<tr>
<td>2.3</td>
<td>Why AT Infrastructure? .................................................................................................................. 8</td>
</tr>
<tr>
<td>2.4</td>
<td>HDI Theory ..................................................................................................................................... 10</td>
</tr>
<tr>
<td>2.4.1</td>
<td>HDI .............................................................................................................................................. 11</td>
</tr>
<tr>
<td>2.4.2</td>
<td>Tools similar to HDI ...................................................................................................................... 12</td>
</tr>
<tr>
<td>2.4.3</td>
<td>Review of Literature related to HDI Criteria .................................................................................. 16</td>
</tr>
<tr>
<td>2.5</td>
<td>Dutch Sustainable Transport Safety Principles ............................................................................... 21</td>
</tr>
<tr>
<td>2.6</td>
<td>Fused Grid Neighborhood Design .................................................................................................. 23</td>
</tr>
<tr>
<td>2.7</td>
<td>Survey Design ............................................................................................................................... 25</td>
</tr>
<tr>
<td>2.8</td>
<td>Summary ......................................................................................................................................... 26</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter 3</th>
<th>Methodology .................................................................................................................................. 29</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Outline ......................................................................................................................................... 29</td>
</tr>
<tr>
<td>3.2</td>
<td>Cross-Canada CLASP Study ............................................................................................................ 29</td>
</tr>
<tr>
<td>3.2.1</td>
<td>Survey Design ............................................................................................................................... 29</td>
</tr>
<tr>
<td>3.2.2</td>
<td>Response ......................................................................................................................................... 30</td>
</tr>
<tr>
<td>3.3</td>
<td>Review of the Healthy Development Index .................................................................................... 33</td>
</tr>
</tbody>
</table>
Chapter 4 Results and Discussion ................................................................................. 36
  4.1 Outline .................................................................................................................. 36
  4.2 The CLASP AT Study for Canadian Communities .............................................. 36
    4.2.1 Barriers for AT Infrastructure ........................................................................ 36
    4.2.2 AT Infrastructure ............................................................................................ 42
  4.3 A Review of the HDI Tool: Improving its application to Land-use and Transportation Projects ........................................................................................................... 68
    4.3.1 HDI Case Studies – Project Evaluations ....................................................... 68
    4.3.2 The Value of the HDI Evaluation Tool .......................................................... 87
  4.4 I-THRIVe Tool ....................................................................................................... 93
    4.4.1 Application of CLASP, HDI & STS Principles to the FG Neighborhood: A More Sustainable Community Design ................................................................. 96
  4.5 Summary ................................................................................................................ 102

Chapter 5 Conclusions & Recommendations ............................................................... 104
  5.1 Conclusions ........................................................................................................... 104
  5.2 Recommendations ................................................................................................ 105
  5.3 Limitations and Future Research .......................................................................... 107

Bibliography .................................................................................................................. 108

Appendices ..................................................................................................................... 120
  Appendix A: Surveys Questions ............................................................................... 120
  Appendix B Surveyed Cities ....................................................................................... 134
  Appendix C AT Infrastructure Inventory .................................................................... 135
  Appendix D HDI Criteria Scoring ............................................................................. 138
  Appendix E Other Indices Measures ........................................................................ 145
  Appendix F HDI Evaluation Summary ...................................................................... 149
List of Tables

Table 2.1. The housing indicators in the INDEX ................................................................. 15
Table 2.2. Smart Transportation Guidebook's connectivity indicators .................................. 18
Table 3.1. Participating Cities ............................................................................................... 31
Table 4.1. Cycling Infrastructure in the surveyed communities ............................................. 43
Table 4.2. Equipment to facilitate AT on public transit ......................................................... 55
Table 4.3. Design standards ................................................................................................ 57
Table 4.4. Snow removal policies ........................................................................................ 62
Table 4.5. Data Sources for HDI Project Evaluations ............................................................ 68
Table 4.6. HDI Scoring Summary ......................................................................................... 86
Table 4.7. Lane width guidelines according to TAC .............................................................. 91
Table 5.1. Surveyed cities .................................................................................................... 134
Table C-1. AT Infrastructure Inventory ............................................................................... 135
Table D-1. HDI Criteria Scoring ......................................................................................... 138
Table E-1. INDEX travel elements indicators ..................................................................... 146
Table E-2. Galster (2001) Sprawl Index .............................................................................. 147
Table F-1. Difference in results between the buffer and the network dataset methods ....... 160
List of Figures

- Figure 3.1. Location of participating cities .................................................. 32
- Figure 4.1. Perceptions of barriers faced for AT ........................................... 37
- Figure 4.2. Perceptions of AT in surveyed communities ................................ 37
- Figure 4.3. Cyclists’ classification ................................................................. 39
- Figure 4.4. Cities planning priority ............................................................... 41
- Figure 4.5. Perceptions of Bike lanes ............................................................ 44
- Figure 4.6. Bike lane ...................................................................................... 45
- Figure 4.7. Salisbury Road after ................................................................. 46
- Figure 4.8. Salisbury Road before ............................................................... 46
- Figure 4.9. Perceptions of Cycle track (aka separated bike lane) .............. 48
- Figure 4.10. Colored Bike Lane ................................................................. 49
- Figure 4.11. Bike box (Kelowna, BC) .......................................................... 50
- Figure 4.12. Elephant's feet .......................................................................... 51
- Figure 4.13. Bicycle slide ............................................................................ 55
- Figure 4.14. Cycling facilities snow removal policies .................................. 61
- Figure 4.15. Neighborhood services around the community of Rutherford Street North and Centre Street North .................................................. 71
- Figure 4.16. Communities around Franklin Street and Ellis Street projects ........................................... 73
- Figure 4.17: Map of the community around Hadden Park Pathway ............ 74
- Figure 4.18. The community around Finch Hydro trail ................................ 76
- Figure 4.19. Collingwood Village map (Neighborhood services) .............. 78
- Figure 4.20. Garrison Woods map (Neighborhood services) .................... 80
- Figure 4.21. Planned phases of Saddlestone Development ....................... 83
- Figure 4.22. Planned phases of Sage Creek development ......................... 85
- Figure 4.23. The typical four quadrant FG community under evaluation (Sun and Lovegrove 2013) ......................................................................................... 97
- Figure 4.24. Hierarchy of Roads in the Fused Grid Network (Grammenos et al. 2008) .. 100
Glossary

Bike Lane “A portion of the roadway that has been designated by striping, signage, and pavement markings for the preferential or exclusive use of bicyclists” (NACTO, 2014).

Bike box A treatment used at the signalized intersection to give cyclists priority and allows them to go ahead of waiting traffic, giving them a head start when the signal turns green.

Bicycle Boulevard A low speed and traffic volume street that gives cyclists the priority over motorists by using pavement markings, signs, and calming measures (NACTO, 2014).

Buffered Bike Lane Traditional bike lane that is buffered by two solid white lines from the vehicle or parking lane.

Colored bike lane “Colored pavement within a bicycle lane increases the visibility of the facility, identifies potential areas of conflict, and reinforces priority to bicyclists in conflict areas” (NACTO, 2014).

Cycle tracks A dedicated bicycle facility that is physically separated from the road, and which may be on or off (but alongside) the road.

Diversers A treatment that allows cyclists and restricts motorized traffic from entering a street (Harris et al., 2013).

Elephant’s feet Paint markings applied at crosswalks that indicate the cyclists’ path to allow them to cross more safely.

Multi-use paths Paved or unpaved path that is designated for all modes of AT (cycling, walking, skateboarding, etc.) that is either alongside or away from streets (Harris et al., 2013).

Paved shoulder A paved part of the street that is adjacent to the vehicle travel lane, which is used to accommodate cyclists and pedestrians, provide a recovery area for vehicles, and provide space for emergency parking (FHWA, 2007).

Roundabout A circular junction in which approaching vehicles have to yield to traffic already circulating around a central island.

Shared lane (Sharrows) A lane in which bicycles share the road with vehicles with road markings that indicate the appropriate position of cyclists along the travel lane (NACTO, 2014).
<table>
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<tr>
<th>Term</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Signed bike route</td>
<td>Similar to shared lane, except that “bike route” signs, are used instead of road marking to indicate that cyclists share the road with vehicles.</td>
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<tr>
<td>Variable Message Sign</td>
<td>A digital traffic sign used to give road users different live information, depending on its purpose, such as traffic congestion.</td>
</tr>
</tbody>
</table>
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To my dear parents
Chapter 1 Introduction

1.1 Problem Statement and Motivation

Numerous global and Canadian efforts are aiming to develop more sustainable communities and active lifestyles through building walkable and bikeable communities, for several reasons. First, the increasing obesity rate has led the national and local health authorities to promote more active lifestyles and transportation options. Almost 60 percent of Canadian adults and 26 percent of children are considered overweight or obese (Transport Canada, 2011). Additionally, the Healthy Canada by Design Coalition Linking Action and Science for Prevention Initiative (CLASP) is looking to prevent chronic diseases in order to improve Canadians’ health. The high burden of chronic diseases was estimated to cost the Canadian government $6.8 billion in direct and indirect costs in 2009 (Janssen, 2012). Second, the United Nations World Health Organization (WHO) and Canadian road authorities have declared 2010 to 2020 the decade of road safety, as road collisions are one of the leading causes of death worldwide, accountable for approximately 1.24 million deaths every year (World Health Organization, 2013). Furthermore, WHO research showed that 95 percent of injuries are a result of driver errors has led to calls for reduced use of private automobiles and increased use of walking, biking and public transit. Third, over 250 municipalities have committed to reduce Greenhouse Gas (GHG) emissions by joining Partners for Climate Protection program. Transportation is a rapidly growing source of GHG emissions accountable for 24 percent of the total released emissions (Environment Canada 2012). All these benefits (health, environment, social) are not just theoretical benefits; instead, they have been well researched and demonstrated in many built communities around the world (Grammenos and Lovegrove, 2015).

The first factor that is driving planning for Active Transportation (AT) is its correlation with health. Physical inactivity has massive health-related consequences (VanBlarcom and Janmaat, 2013). Both walking and cycling contribute to reducing obesity and chronic diseases (Pucher and Buehler, 2010); cycling also substantially reduces the risk of cancer, cardiovascular diseases and obesity-related diseases among adults and seniors (Oja et al.,
Similarly, a study of commuting by AT modes found that it has a negative correlation with obesity, triglyceride levels, and higher blood pressure; in other words, walking and bicycling to work are associated with favourable health outcomes (Gordon-Larsen et al., 2009). Moreover, AT has a multiplicity of environmental advantages including decreasing greenhouse gas emissions and energy consumption. The extent to which these factors affect the environment depends on the total length of fossil-fuel-using trips that are substituted with AT modes (Martens, 2004).

Another factor driving planning is the correlation between AT and safety. It has been demonstrated that increasing the number of AT users has a great influence on AT users’ safety; “Safer cycling encourages more cycling, and more cycling encourages greater safety” (Pucher et al., 2011). Pucher and Buechler (2005) states that the increase in the number of cyclists in Canadian cities was associated with a drop in the number of fatalities. For example, the number of cyclists in Quebec increased by 50 percent between 1987 and 2000; yet, the number of cyclist fatalities dropped by 42 percent during the same period. The benefit of increasing the number of AT extends to road safety as well. One study suggested that there is a relationship between cyclist infrastructure and road safety as it found that increasing cycling infrastructure reduces collisions (Wei et al., 2011). Furthermore, the characteristics of the route also affect the safety of AT users. Harris et al. (2013) found that roundabouts, depending on their design, can be associated with risk on cyclists, and that intersections of local streets are much safer for cyclists than intersections of major streets; however, at intersections that warrant traffic controls, roundabouts in general are safer for pedestrians and cyclists than traffic signals (Elvik, 2003). Also, the same research found that vehicle speed less than 30 km/h reduce the risk of injuries significantly. For AT facilities, the research found that cycle tracks and local streets with diverters have very low risk, where multi-use paths and sidewalks are associated with high risk. This suggests that engineers should design/plan for separation of all road users: pedestrian, cyclists, and motorists (Reynolds et al., 2009; Wegman et al, 2008).

The third factor driving planning is the environmental benefits of increasing AT use, including decreasing GHG emissions, reducing energy consumption, and preserving green
space (Transport Canada, 2011). Vehicles are the predominant mode of transportation in Canadian cities. In 2011, around 78 percent of the total daily trips in the nation were travelled by vehicles; surprisingly, 32 percent of these trip distances are less than 5 km, the average cyclable trip distance (Statistics Canada, 2011). In a typical inner city vehicle trip, 90 percent of the emissions are released in the first 1.6 km. This suggests that switching short trips to AT would have a substantial effect on reducing air pollution (Transport Canada, 2011). The extent to which these factors affect the environment depends on the total length of fossil-fuel-using trips that are substituted with AT modes (Martens, 2004).

However, while some communities have achieved success in increased walking and bicycling, many have also seen counter-productive results. Why have some communities succeeded and others failed in promoting safe use of roads and pathways by pedestrians and bicyclists? What are the challenges facing community planners and engineers in changing how our communities are designed? Also, how can these challenges be successfully planned for and overcome for the benefit of AT?

1.2 Research Objectives

This research investigates the professional engineer’s role in promoting more cycling and walking, to discover why some communities have succeeded in increasing the use of AT while others have failed. It also explores the challenges facing community planners and engineers in changing how the communities are designed. This research focuses mainly on two correlated perspectives of healthy communities: community design and AT infrastructure. Community design makes walking/cycling more appealing for people by reducing trip distances to destinations. However, increasing the number of AT users without careful planning of the type of infrastructure, including its level of separation needed for each context, will have severe effects on AT users’ safety.

The objectives of the research presented in this thesis include:
1. Review attitudes on how governments, land developers, and the public are embracing healthier communities.
2. Identify the challenges that communities are facing when trying to encourage AT, and identify practices and policies that could overcome these challenges.

3. Document case studies, both successful projects and those that encountered opposition, relating to the creation of innovative street designs.

4. Evaluate the sustainability of the Fused Grid Neighborhood Design using the Healthy Development Index and Sustainable Transport Safety Principles.

1.3 Thesis Structure

This thesis is divided into five chapters. Chapter One introduces the topic via background information, motivation, objectives, and thesis outline. Chapter Two reviews associated literature, including previous work to identify challenges and barriers for AT, STS, HDI, etc., and the effect of AT infrastructure and community planning on promoting AT. Informed by the literature review, Chapter Three describes the methodology used to achieve each of the objectives, as well as the data collected for analysis. Chapter Four presents and discusses the results. Finally, chapter Five presents conclusions, makes recommendations, presents the limitations of the current work, and suggests future research work.
Chapter 2  Literature Review

2.1  Outline

The purpose of this literature review is to describe previous research on elements that have been associated with AT. Section 2.2 describes challenges and barriers that cities usually face in promoting cycling and walking. Section 2.3 describes how different AT infrastructure have different effects on promoting AT. In addition, it describes some factors that have to be taken into consideration when designing AT infrastructure. Section 2.4 describes how community design and characteristics encourage AT. In addition, it reviews literature related to the HDI and reviews other healthy and sustainable development tools similar to the HDI and the criteria of the HDI. Section 2.5 discusses the Dutch Sustainable Transport Safety Principles. Section 2.6 describes the concept of the Fused Grid neighborhood design. Finally, section 2.7 describes the process of collecting public data for research.

In an initial scan of the HDI tool and literature, a concern was raised about the use of a street connectivity measure and its scoring. The HDI uses a simple intersection count to establish the general network characteristics (e.g. grid, cul-de-sac, curvilinear, or fused grid) in order to establish the navigability of neighborhoods. As presented in the HDI, higher intersection counts translated to greater road connectivity and were rewarded with higher HDI scores. However, such a measure focuses only on road-road intersections, which have been shown to be associated with decreased safety and health, due to its auto-centric nature. Alternatively, a more balanced focus on walkway and bikeway connectivity — whether on or off-road — would be a more accurate metric. This connectivity issue was then given a high priority as part of all literature reviews, including a review of how other tools similar to the HDI considered connectivity.

2.2  Challenges and Barriers for Active Transportation

Five main barriers were found in the literature pertaining to AT. These barriers are the lack of funding, sprawl, lack of transit-AT integration, topography, and weather. Recognizing
these barriers is a critical step to develop an action plan for encouraging AT. Each of these barriers is discussed below.

One of the main barriers facing Canadian communities is the lack of funding. Active transportation modes need more financial and political support from the federal, provincial, and local governments. The inadequate funds provided for AT limits planners and engineers from implementing new infrastructure, or even maintaining existing infrastructure. For example, one of the main barriers municipal staff are facing in the greater Toronto and Hamilton regions is the lack of funding provided for AT projects (The Clean Air Partnership, 2008). As the federal government has no recurring funding to support AT facilities across Canada, communities must rely mainly on their local governments (Pucher et al., 2011).

Other barriers common in Canadian cities are the low density and dispersed land-use. These barriers minimize the efficiency of AT by stretching the lengths of trips, and the cost of installing and maintaining the infrastructure in the first place (The Clean Air Partnership, 2008; Pucher and Buehler, 2007). Some literature, as cited by Meyer and Miller (2001), reported -0.1, -0.24, and -0.4 elasticity for trip distance with residential density, and -0.5 and -0.9 elasticity for land-use mix (i.e. a 10 percent increase in land-use mix results in 5% reduction in trip distances). High density and mixed land-use were found to be statistically significant in increasing non-motorized travel rates (Cervero and Kockelman 1997). In addition, a study found that increasing the residential density by 1.5 units/acre is linked with a 12 percent decrease in the likelihood of commuting to work by car (Chatman 2003). This distance barrier for AT users can be somewhat overcome if the transit systems are well integrated with AT programs. For example, a survey conducted by the Clean Air Partnership (2008) in Greater Toronto, Hamilton, and beyond in Ontario reported that public transit can actually be a barrier for AT because of: 1) the low level of transit service, and 2) lack of integration between walking and biking facilities. However, cycling and public transport more often complement each other, as cycling can increase the catchment area of public transit facilities. On the other hand, public transit facilities that support AT (e.g. bike lockers, bike racks on buses, bike space on LRT trains) do significantly increase the amount of cycling that takes place (Pucher et al., 2011). Moreover, the integration of biking and public
transport—known as bike and ride—minimizes total trip time (Martens, 2007). Bike and ride has also been found to be a competitive alternative to cars. Although data have shown that having a car has a significant negative effect on selecting bike and ride, at the same time, availability of a car does not eliminate using the other less expensive options (Martens, 2004).

Topography variance is another factor that affects AT in some Canadian cities. Rietveld and Daniel (2004) found that topography has a significant relationship with cycling, with the presence of hills associated with a decrease in cycling by as much as 74 percent. Clare (2011) suggested that topography variance, among other variables, might explain the different levels of cycling between Waterloo, ON and Halifax, NS.

Finally, all efforts to install AT infrastructure and increase AT use might be useless if the cold weather in Canada has a great negative impact on cycling. There has been an ongoing debate regarding the effect of cold weather on cycling and walking. Levels of cycling in Canada are generally three times higher than in the USA, which means the cold weather in Canada has not appeared to negatively impact the mode split of cyclists (Pucher and Buehler, 2007). For example, cyclists account for 2.6 percent of the total commuters in the Yukon, one of the coldest areas in Canada (Pucher et al., 2011). These findings suggest that cold weather does not seem to be a significant barrier for cycling. A study conducted in Stockholm, Sweden to examine cycling in winter found that only a few participants replied that cold weather prevented them from cycling in winter (Eriksson et al., 2011). Further, the bicycling freeways in Copenhagen, Denmark are well known and used so heavily in the winter that the government places top priority on plowing them during winter snowfalls (Capital Region of Denmark, 2014). On the other hand, others have found that cold weather will diminish AT use. For example, a study of Halifax shows that there is a direct relationship between higher average temperatures and walking, and an inverse relationship with precipitation (Clark et al., 2013). These relationships indicate that promoting walking in communities where the average annual temperature is very cold and often rainy might be difficult.
In summary, the literature revealed five main barriers for encouraging AT in Canadian Communities including: 1) the lack of funding, 2) sprawl, 3) lack of transit AT integration, 4) topography, and 5) weather. These barriers could be overcome if a clear understanding was present of how different AT infrastructure and community design affected walking and cycling. There are several clues in research today as discussed in sections 2.3 and 2.4 below, which will help to identify remaining knowledge gap to be addressed.

### 2.3 Why AT Infrastructure?

AT infrastructure is an important factor in encouraging people to be more physically active as research has shown that the amount and type of AT infrastructure is strongly correlated with physical activity (Sallis et al., 2004). This section discusses how different AT infrastructure has different effects on encouraging AT. In addition, it discusses how these effects vary among different communities depending on cultural and physiological factors. Each of these topics is discussed below.

The main requirement of the physical environment is a continuous AT infrastructure network, with no gaps in the system (Heinen et al., 2010). Additionally, there is a need for convenient End-of-Trip Facilities (EOTFs) for cyclists, such as providing safe parking areas (Arvidson, 2012). The relationship between the type of the infrastructure and the volume of users has been investigated by many researchers; cyclists will ride on a road with better AT infrastructure rather than using the shortest route. Cyclists also generally prefer using off-street paths and lower-volume roads (Winters et al. 2010). This finding was supported by El-Geneidy and Larsen (2011), who also found that cyclists would even ride farther (versus driving) if it was on an off-street facility, as compared to a delineated on-street lane. Additionally, the research found that the availability of cycling facilities within 400 m of the home and destination increases the probability of using the facility by 129 percent (Geneidy and Larsen, 2011). Cyclists who prefer using trails are willing to extend their travel distance by 67 percent in order to use a trail as part of their trip (Krizek et al., 2007). In contrast, a study in Guelph, ON found that the majority of cyclists prefer using on-road facilities rather than using off-road paths (Aultman-Hall et al., 1997)—this may have been a local cultural
effect related to the relatively low-volume roads and high university student demographics typical in the Guelph community population. The classification of the road where the AT facility is located also influences AT use, as well as driver attitudes. Audirac (2008) showed that drivers would be annoyed the most to share the road with cyclists on an arterial road (83 percent), followed by highways (80 percent), and finally local collectors (58 percent).

Geller (2006) created four categories to classify cyclists based on the level of comfort when biking on different AT facilities, namely: 1) strong and fearless; 2) enthused and confident; 3) interested but concerned; and 4) no way, no how. In Geller’s research, interviewees were asked to estimate the percentage of each type of cyclists in their community. For this purpose, the four types were identified for the interviewees in the following ways:

- 1 to 2 percent of residents - Strong and fearless: will ride regardless of road condition.
- 2 to 10 percent of residents - Enthused and confident: are comfortable riding on road with automobiles, but prefer to improve facilities.
- 10 to 40 percent of residents - Interested but concerned: Like to ride, but afraid to do so unless safe routes provided.
- 20 – 40 percent of residents - No way, no how

Another important factor for consideration when planning AT infrastructure is the gender-based factors that affect cycling use, with women in Canada accounting for 47.9 percent of the labor force in 2009 (Statistics Canada, 2011). Women have been shown to prefer routes that are separated from road traffic like off-road paths and sidewalks (Garrard et al., 2008). This preference can be explained by the higher sensitivity of women toward safety, regardless of their experience level, when compared on average to the sensitivity of men toward safety (Emond et al., 2009).

In summary, different AT infrastructure have different effects on cycling depending on the type of the infrastructure (on or off-road), the level of separation (motorist, cyclist, and pedestrian), and the classification/AT-friendliness of roads. These effects might vary from one community to another depending on cultural, demographic, and/or physiological factors.
related to each community’s population. It is important to note that all of these infrastructure influences on AT use are in turn influenced, if not determined, by community development patterns (Saelens et al., 2008).

2.4 HDI Theory

Transportation planning focused mainly on automobile movement (mobility), suburban development, and the rapid growth of highways since the mid-twentieth century, has led to huge expansions in road network infrastructure. Moreover, it has created auto-dependent, sprawling cities with low density development patterns, reducing the attractiveness of sustainable transport, and discouraging physical activity (Grammenos et al. 2008).

Community development patterns were originally motivated by the pursuit of public health, when cities were suffering from infectious disease and sanitation (Perdue et al., 2003). In the 1920s, it was well established that de-concentration and segregation of land-uses would improve public health and safety (Perdue et al., 2003); thus, zoning by-laws were introduced such as separating different land-uses and stating building heights and setbacks (Perdue et al., 2003). However, new research suggests that there is a relationship between urban planning and physical activity (Jognson and Marko, 2008; Frank et al., 2008; Knox, 2003). Several factors were found to affect an individual’s physical activity, including land-use mix, housing density, street connectivity and design, and transport infrastructure (Gebel et al., 2005). Similarly, Sallis et al. (2006) stated that low density and disconnected street networks are associated with more driving, hence, less physical activity. Moreover, Ewing et al. (2006) found that regional accessibility, high population density, land-use mix and streetscape design have several benefits for public health. This has encouraged some municipalities and developers to undertake efforts to promote greater AT use through improved community design. One of these efforts is the Healthy Development Index (HDI) developed by public health and community planning experts in the Peel Region of Ontario, Canada. Literature about the HDI and other similar tools are examined in the next section.
2.4.1 HDI

In 2009, the Region of Peel, ON in partnership with the researchers from the McMaster University and the Centre for Research on Inner City Health at St. Michael’s Hospital developed an evidence-based tool used to assess the health impacts of developments in the Region. The Healthy Development Index highlights seven elements in the built environment that are associated with walkability: density, service proximity, land-use mix, street connectivity, road network and sidewalk characteristics, aesthetics and human scale and parking. Each criterion is further broken down into quantifiable measures. After points are scored, individual criterion scores are summed to give a final Healthy Development Index measure for the development, similar to the way LEED\(^1\) scores are given for new buildings, for comparison with other developments and desirable ranges. The weighting of each element depends on the influence it has on walkability, which was determined based on research and consultation with stakeholders.

After identifying the main elements, the HDI tool was developed based on a procedure consisting of four steps: 1) strength of evidence analysis; 2) stakeholder consultation; 3) policy gap analysis; and, 4) Geographic Information System (GIS)-based validation analysis in order to achieve the maximum feasibility and applicability.

The region of Peel conducted a strength-of-evidence analysis to determine the amount and quality of the studies in literature for each element. The analysis was based on calculation methods, sample size, controlling the parameters, and the statistical significance of the results for each study. After that, consultations with stakeholders on different levels were conducted including Peel regional planners, Peel municipal planners, and private planning and consulting firms. Through the consultation process, several topics were discussed, such as the applicability of each measure, the feasibility of the targets, and implementation barriers. A gap analysis was then completed to compare the HDI index measures with the municipal, regional, and provincial policies related to development and designing guidelines. The results

\(^1\) Stands for “Leadership in Energy & Environmental Design”, which is a green building certification program
were used to better understand barriers to HDI implementation that exist in current policies and zoning bylaws. Finally, validation analyses were performed in the three Ontario communities of Port Credit, Mississauga; Downtown Brampton, and Bolton, Caledon. In addition, the HDI was tested on five existing and proposed communities within the region to assess the practicality and appropriateness of the HDI elements (Gladki Planning Associates, 2011), which lead to further refinement of the HDI into the Health Background Study Framework (HBSF) in 2011.

Having been launched for community planning use, the HDI (aka HBSF) includes a user guide and terms of reference that explains why the element is important from a health perspective, and that offers various ways to meet the measures. It is used as an implementation tool to integrate the principal elements of healthy communities identified in the HDI with planning policies and cities’ by-laws. The tool also has qualitative standards to allow developers to justify their project’s design, rather than just having solid quantitative measures with two possible results: approved or rejected. This also gives planners and city staff flexibility in evaluating proposed developments based on the scale and the context of each project. The region of Peel is currently using the HDI tool to comment on and identify development applications that have potential impacts on health. On those identified applications, regional staff negotiate with the developer in order to improve its health promoting potential. In addition, Peel is currently developing a quick checklist tool based on the tool with quantitative metrics, for use by staff and developers at the pre-consultation stage.

2.4.2 Tools similar to HDI

To establish the comprehensiveness of the HDI and to identify relevant sustainability metrics that might improve the tool, a literature review was conducted on its criteria and on other tools similar to the HDI. While there are no tools that overlap with the HDI, there are two that do some of the things that HDI is proposed to do, including: 1) the Sustainable
Community Index; and, 2) the INDEX PlanBuilder Planning Support system. Each is reviewed below.

2.4.2.1 Sustainable Community Index (SCI)

This tool was developed by the San Francisco Department of Public Health to provide a set of measures on how livable, equitable and prosperous a city is. It consists of seven main elements including environment, transportation, community cohesion, public realm, education, housing, and health systems. Most of the measures used in the SCI are designed to evaluate existing neighborhoods and cities, which differs from the intended purpose of the HDI. Moreover, the SCI measures require extensive data from the field, much of which would not exist for planned Greenfield developments. However, some insights were gained from its transportation and education criteria.

The transportation element provides a measure to evaluate transit proximity using 1) a public transit score (PTS) and 2) proximity to streets with high transit service. The first indicator is calculated as the summation of the Intersection-Route Score (IRS) for each residential intersection (Intersections located within 100m of residential parcels) within the subject area being analyzed, as shown in equation 1 - Appendix E (San Francisco Department of Public Health, 2012). The advantage of this method is adding transit frequency to the metric, since higher frequency makes transit more convenient for the users.

The education element is interesting as it has two main objectives: 1) Provision of affordable and high quality child care and, 2) provision of accessible and high quality educational facilities. Affordable and accessible local services are presumed to attract more patronage by local residents, thus reducing longer trips by auto, and promoting local community social interactions and healthy transport modes.

2.4.2.2 INDEX PlanBuilder Planning Support system

INDEX (Criterion Planners Engineers, 2011) is a set of interactive pre-programmed, automated GIS planning support tools that measure various traits of existing communities to identify their design advantages and disadvantages. In this sense, INDEX is very similar to
the HDI, because it is used to develop and visualize alternative scenarios and rank them according to their expected performance in terms of predefined achievement goals. However, INDEX can also be used to monitor the implementation of the selected scenario plan, and is equipped with 90 different indicators that address different planning aspects related to demographics, land use, housing, employment, recreation, environment, travel, and climate change.

For example, for land use mix, INDEX evaluates the diversity of a land use mix using an equation (equation2 - Appendix E) that gives score expressed on a scale between 0 (not diverse) and 1 (very diverse). This requires the user to define a two-dimensional grid of cells to calculate the ratio of dissimilar land uses to the total number of land uses. This diversity consideration would influence local versus longer distance trip making habits, both associated with healthy outcomes.

A second element in INDEX worth noting is its housing element which provides the ability to review developments in three categories: density, proximity, and water management, as shown in Table 2.1.
This wide variety of metrics used by INDEX to measure different kinds of densities in communities is of significant value as it facilitates a broader, multi-faceted view of community sprawl compared to simply calculating one number. For example, communities with moderate density and less sprawl in the development have been shown to still promote a significant amount of physical activity (Rashad, 2009). Moreover, the proximity measures in this housing criterion are similar to those used in the HDI, except that INDEX enhances it by taking into consideration transit proximity to employment.
A third element in INDEX that is worth considering for the HDI is the travel element, which uses a variety of indicators to evaluate street connectivity. Examples of connectivity metrics from the INDEX tool include internal street connectivity, external street connectivity, street segment length, street network density, intersection density, street network extent, and street route directness (check appendix E).

It is important to note that INDEX does NOT consider off-road AT connectivity, only auto centric measures. However, this larger variety of measures to evaluate connectivity – external versus internal - gives planners and engineers a broader understanding of the situation. It also allows them to control the level of connectivity for each category as needed. Providing connectivity throughout cities and from the community to city streets is important. At the same time, making walking and cycling more convenient than using cars encourages residents to be more physically active.

2.4.3 Review of Literature related to HDI Criteria

In addition to searching for HDI-like tools, a review of the actual HDI tool was conducted, including the rationale behind its metrics. In particular, the literature investigated metrics used to assess criteria such as sprawl and street connectivity, and what the literature revealed for each of these criteria.

Most of the literature regarding sprawl indices evaluates large urban areas. One of these is the Sprawl index that was developed in 2012 by Smart Growth America, which evaluates community sprawl using four factors: development density, land use mix, activity centering, and street accessibility, as follows:

- High residential and employment densities in the central area with steep density gradient, so that jobs are close to home, and the resident-to-jobs ratio approaches 1.
- Having a variety of job sectors present enhances this effect, and facilitates high proximity to amenities.
- Lower than average block length and size (less than 2.6 ha each) promotes walkability and connectivity.
Galster et al. (2001) evaluated the sprawl of 13 urban areas using six indicators including density, concentration, clustering, centrality, nuclearity, and proximity. The metrics for these measures are shown in Appendix E.

Both sprawl indexes (Smart Growth America and Galster) assumed equal weights for all the factors used in each index. In addition, they assumed the community’s average value was the value for that community’s sprawl index, where sprawl index values above the average were more compact, and values below the average were more sprawled. Thus, these two indexes would not be applicable to the HDI. Nonetheless, they provide a clear understanding of the factors affecting sprawl and the metrics used to evaluate it.

For street connectivity, the New Jersey Department of Transportation’s Smart Transportation Guidebook classifies connectivity into three categories: Internal Connectivity, External Connectivity, and Pedestrian Route Directness (PRD) as shown in Table 2.2 (New Jersey DOT):
Table 2.2. Smart Transportation Guidebook’s connectivity indicators

<table>
<thead>
<tr>
<th>Type</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Connectivity</td>
<td>Beta Index: The number of street links over the number of nodes or Intersections per square mile</td>
</tr>
<tr>
<td>External Connectivity</td>
<td>All neighborhoods in the community should be connected to the larger street system at least every ¼ mile.</td>
</tr>
<tr>
<td>Pedestrian Route Directness</td>
<td>The ability of pedestrians to follow paths in line with common desire lines between origin and destination in the subject community.</td>
</tr>
</tbody>
</table>

Of note is the PRD measure, which hints at AT connectivity, although it does not address a similar measure for bicycles. However, it does suggest that consideration of more than just road connectivity is needed in the HDI to be comprehensive.

Summarizing the literature to this point, there is no other tool similar to HDI. However, the available tools suggest that there may be gaps in the HDI that need further investigation or reconsideration, including metrics to evaluate sprawl in developments and to evaluate off-street (i.e. AT) connectivity. Although it appears that intersection counts have been used in studies to establish an understanding of the built environment, the safety impacts of increased intersection density have not been the focus of such studies. The relationship between intersection density and connectivity is discussed in the next section.

2.4.3.1 Intersection Density and Connectivity

Intersection density is defined as the number of intersections per unit area (km² or hectare). Connectivity refers to the directness and density of connections in a path or road network. Higher connectivity is associated with shorter travel distances and increased route options.
Intersection density has been commonly associated with street connectivity; connectivity increases as intersection density increases. However, there has been ongoing debate regarding whether higher intersection density is associated with higher collision rates. If this correlation is true, then how can planners and engineers increase the safety of neighborhoods while maintaining high connectivity? Before discussing this topic, it is essential to differentiate between providing connectivity through cities (mainly serving a mobility function for longer trips by motorized vehicles), versus providing connectivity into, out of, and across neighborhoods (mainly serving short distance local trips by residents that would promote walking and biking). It is important to provide connectivity and access for cars to use arterial roads travelling city-wide/regionally to other neighborhoods. These arterial trips occur at higher speeds, over longer distances, and in higher volumes, with heavy vehicles (buses, trucks) as well. An efficient arterial grid network (i.e. high arterial connectivity), with proper intersection control provides the necessary capacity to prevent through trips from shortcutting through neighborhoods. Thus, neighborhood road networks can focus on local access for vehicles (i.e. accessibility, not mobility), and connectivity for active transport (i.e. an off-road grid network for walking and biking), such that it is quicker to walk/bike across the neighborhood than it is to drive across it. This low vehicle connectivity (while maintaining emergency and utility vehicular access) paired with high AT connectivity in neighborhoods is the key to promoting AT use and healthier, more active living lifestyles. Frank and Hawkins (2007) found that increasing relative AT connectivity for pedestrians by 10 percent is correlated with a 23 percent decrease in vehicle miles traveled.

Moreover, several factors can affect the safety of a road network including intersection density, types of intersections, signalization, and Vehicle Kilometers Traveled (VKT) (Lovegrove, 2007; Lovegrove and Sayed, 2006). Regarding intersection density, there are many studies done on this. The most comprehensive engineering studies were done by Lovegrove and Sayed (2006, 2007) among others (Hadayeghi et al, 2003; Ladron de Geuvera et al, 2004), who used Generalized Linear Interactive Modelling (GLIM) regression modeling and statistical analyses to show that increased intersection density is associated with increased collisions across North American cities.
While many associate increased connectivity with reduced safety, contradictory studies exist. Marshall and Garrick (2011) found that increased street connectivity and network intersection density were associated with increased safety. However, they could not explain these preliminary results, and commented that the effects of vehicles speeds on the results had not been accounted for. No mention was made regarding whether off-road AT networks were included in their connectivity analysis. The key difference between these two groups of studies would appear to be the confounding factors of speed, and off-road AT networks. No research was found during this review that studied the safety impacts of increased off-road AT network connectivity. Ewing and Dumbaugh (2009) showed similar contradictory results, but with some hints as to why. They noted that the travel patterns in these communities included a lower percentage of people who chose to drive to work. Essentially, the researchers admitted that they did not control their samples for VKT in their methodology, which would lead to a bias in their results, relative to other studies. They did try to consider traffic speeds, and found that neighborhoods with lower speeds were also associated with decreased crashes, a finding consistent with other researchers (Gladhill and Monsere, 2012). Most importantly, more recent research has found that more than one variable must be considered, as all are inter-related and systematically related in a neighborhood-wide safety analysis; hence, a community-based macro-level collision prediction modelling approach as used in the engineering studies (see Sun and Lovegrove, 2013; Lovegrove, 2007) would be a fairer evaluation of safety impacts of connectivity. So while there were several studies that related increased intersection density (i.e. connectivity) and improved safety, there were questions raised by the researchers themselves about their study methodology because of the seemingly contradictory results, such that they cannot be relied upon. The bulk of research evidence suggests increased connectivity is associated with decreased road safety. Most recently, Sun and Lovegrove (2013) analyzed different street network patterns, and found that irregular, low-connectivity street network patterns, such as, warped parallel (compounded by curvilinear streets in long, narrow blocks, T intersections and L corners) and loops-and-lollipops (characterized by the presence of loops and cul-de-sacs) were associated with increased safety for vehicle-vehicle and vehicle-pedestrian crashes. For the loops-and-lollipops pattern, curves require more caution and, therefore, generate more attention and reduced speed. The more regular, grid pattern was found to be less safe than
these curvilinear streets and cul-de-sac given its straight runs. Moreover, a new street network design named the Fused Grid pattern has been found among the most safe road network patterns, and allows for a highly connected off-road AT network while preventing shortcutting opportunities and high through speeds. The results showed that the fused grid development pattern was up to 60 percent safer than developments built using the traditional grid and cul-de-sac patterns (Sun and Lovegrove, 2013).

In summary, it would appear that the predominance of research supports the conclusion that, while high arterial/highway connectivity across a region is required for efficient mobility, high connectivity in a neighborhood is associated with decreased vehicular and AT safety. Moreover, increased AT connectivity via off-road paths is associated with increased biking and walking. However, while health benefits have been quantified, more research is needed to quantify and predict the safety benefits of increased off-road AT network connectivity. Until further research, the best that can be currently concluded is that no contradictory evidence exists against promoting AT network continuity and AT connectivity, for sake of improved community health and safety.

### 2.5 Dutch Sustainable Transport Safety Principles

In an effort to reduce the number of road causalities in the Netherlands, the Dutch National Government, in support of research findings from their Road Safety Research Institute (SWOV), launched a sustainable safety vision in the early 1990s with three main principles: functionality, predictability, and homogeneity (Wegman et al, 2008). These principles aimed to minimize the fundamental risk factors such as speed, mass, and vulnerability along risk-increasing factors such as lack of driving experience and distraction (SWOV, 2012a). Implementing these principles has successfully led to a decrease in the number of causalities in the Netherlands, which encouraged the Dutch government to continue with and update its vision that aims to prevent collisions, or at least reduce their severity if they do occur. To take into the account the user’s responsibilities in preventing collisions, two new principles were introduced in the updated vision: forgivingness, and state awareness (Wegman et al, 2008). Applying the STS principles for the past 20 years resulted in reducing the number of
road collisions in the Netherlands by 70 percent, representing an over 3.6 to 1 benefit to cost return on infrastructure investments (Wegman et al, 2012), while at the same time increasing pedestrian and bicycling volumes in its communities. A review of how each of these five principles is implemented follows, to ascertain how it can be applied to AT planning and infrastructure in Canada.

The Functionality principle means that a road network system needs to provide strict hierarchy, with each road serving a single purpose only as the following (SWOV, 2010a):

- Through road: provides high vehicular mobility between destinations (arterial roads).
- Access road: provides high accessibility to users’ final destinations (local roads)
- Distributor road: distribute traffic from through roads to access roads (collector roads)

The Homogeneity Principle goal is to minimize the risk of road injuries by reducing road users’ variations in speed, mass, and direction (SWOV, 2010a). Thus, different transportation modes (i.e. auto-driving and cycling) should be separated where traffic speed is high; otherwise, the traffic speed should be decreased to reduce the severity of a collision if it does occur.

The Predictability principle aims to reduce human errors by creating a predictable road environment for each road type in terms of expected speed, acceptable maneuvers, and type of road users (SWOV, 2012b). Distinguishable road characteristics can be the type of road surface, edge marking, and parking availability (SWOV, 2012b). These characteristics will inform all road users of the expected driving behavior.

Recognizing the fact that 96 percent of all crashes are due to human error and that drivers will eventually continue to make errors, the Forgivingness principle aims to reduce the consequences of human error by providing a forgiving road environment (SWOV, 2010b). A forgiving road as defined by Bekiaris et al. (2011) is “a road that is designed and built in such a way as to interfere with or block the development of driving errors and to avoid or mitigate negative consequences of driving errors, allowing the driver to regain control and either stop or return to the travel lane without injury or damage”. Examples of measures that
can be implemented to create a forgiving road environment are wide shoulders, medians, and variable message signs (SWOV, 2010b; Bekiaris et al., 2011).

The State Awareness principle refers to the road users’ perception of a driving task (i.e. yielding at intersection) compared to their capabilities (i.e. driving skills) to handle the task. Thus, task demand need to be minimized as much as possible to account for different users’ capability levels (SWOV, 2010c). For example, roundabouts and T-intersections can be used to reduce potential collision conflicts and to remove dangerous traffic conflict configurations such as left turn tasks.

2.6 Fused Grid Neighborhood Design

The Fused Grid (FG) model was developed recently by a land-use planner at the Canada Mortgage and Housing Corporation (CMHC) to create a subdivision layout that combines the best characteristics of the loops, cul-de-sac, and grid patterns (Grammenos et al, 2008; Sun and Lovegrove, 2013). The name ‘Fused Grid’ is derived from the FG design process, whereby it fuses the best aspects of through mobility, local accessibility, restorative green spaces, and built environment, all built from a modular 80 metre, walkable, modular grid pattern (Grammenos et al. 2008). A typical FG plan consists of four 16 hectare quadrants with perimeter roads to provide traffic mobility with the following spacing: minor collectors at 400 m, major collectors at 800 m, and arterials at 1600 m. All major intersections in the FG are controlled by roundabouts, except for intersections connecting local roads to perimeter roads, which are controlled via three-way intersections.

Initial field experiments in several planned communities using the Fused Grid design show promise, because by definition it includes designing for increased AT connectivity via an off-road grid, thereby reducing private auto travel and VKT; and, hence, improving safety (Grammenos and Grant, 2008). FG consists of a combined connectivity and easy orientation from the common street grid. In addition, it combined the efficiency, safety and tranquility from the more recent suburban cul-de-sac and Loop Street. All this is achieved by a ‘fusion’ of four grids: (1) A continuous vehicular major arterial/collector grid for district and regional
connectivity; (2) A discontinuous vehicular road grid for local traffic to allow for access but preclude shortcutting; (3) A continuous AT on/off-road grid of paths that allow convenient walking/biking across the neighborhood in less than 5 minutes without requiring road crossings; and, (4) A continuous green grid of restorative spaces dispersed throughout, such that all residents can walk to a street corner park, or to the central neighborhood park space in less than a minute (Sun and Lovegrove, 2013). In addition to the health benefits, the high proximity to green spaces and services in the FG communities would cause higher home prices, which means; 1) higher revenue for developers, 2) higher resale price for residents, and 3) higher tax revenues for community.

In addition, several findings in the literature suggest that the FG model can improve neighborhoods sustainability, in several ways. First, several sustainability-related benefits have been linked to a community using Fused Grid design, including: optimized land-use for streets and infrastructure, increased safety and tranquility and social interaction, reduced impermeable area, improved arterial traffic flow, increased walking, and decreased auto use, especially short auto trips [Sun and Lovegrove, 2013; Frank et al., 2010; Grammenos and Grant, 2008]. Moreover, 30% of street space that would normally be used in a traditional grid network is reclaimed and used in the FG for additional development and off-road AT networks, which means less capital/servicing costs and more buildable area. Second, higher rates of walking were found to occur when a pathway is relatively more direct to a nearby retail or recreational destination than in a neighborhood with low pedestrian connectivity. Built environment, walk/bike path density and mixed land-use also are strongly correlated with distance and time traveled by foot/cycling. Third, research done by land-use planners and public health researchers (Frank et al, 2010) showed that the Fused Grid community design has very low road connectivity and high AT path connectivity. All the benefits listed above are based on a theoretical model of the FG neighborhood design; however, most of the FG aspects are already implemented in different communities across the Netherlands and the Denmark, in which they demonstrated positive outcomes on public health and safety. This indicates that the FG benefits are not just theoretical, but are also realized.
2.7 Survey Design

Surveys are a very common approach for collecting data for research. Surveys allow the researcher to explore and investigate a topic of interest by collecting information in an organized manner. Surveys can be quantitative, qualitative, or both. The main difference between quantitative and qualitative research is that the latter type does not give estimates for frequencies or means; instead, it describes the variety and diversity of responses on a topic (Jansen, 2010). Thus, the sample size must be sufficient to assure the representation of the variety of responses in a population (Mason, 2010). As opposed to quantitative research, there is no precise technique to determine sample size for qualitative research. Marshall et al. (2013) suggests that qualitative research should include 15-30 interviews; Creswell (2013) suggests a minimum sample size of 20-30. Generally, the concept of saturation is used to determine the sample size, which is the point at which collecting new data does not add any value to the research (Mason, 2010).

There are many different methods of conducting survey research including semi-structured interviewing. This method gives the interviewer/researcher the ability to interact with the interviewee to clarify answers, emphasize certain topic, or even share knowledge and information (Brinkmann, 2013). Semi-structured interviews should generally be based on a questionnaire. This is because wording a question differently might lead to different meanings, which in turn will affect the research reliability and validity (Denzin 1989 as cited in Barriball and While 1994).

In general, survey questions can be classified into two categories; direct (facts) and attitudinal (opinions and beliefs) questions. Direct Questions can be asked in different formats, such as open-ended and closed-ended. Research has shown that responses for a question differ according to the question formatting type (Bradburn and Sudman, 1979 as cited in Guppy and Gray, 2008).

The open-ended question provides respondents with the ability to state the answers with their own wording. These questions are generally challenging to analyze as responses may vary
greatly; nonetheless, appropriate use of these questions could lead to better findings (Gillham, 2007). Open-ended question could produce useless results, thus, it is more suitable for interview type surveys as the interviewer would have the chance to clarify the answer by a follow-up question (Guppy and Gray, 2008).

For the closed-ended questions, participants are provided with a limited list of answers to select from. Closed-ended questions are usually used when the answers are predictable and can be presented in a brief set of possibilities (Gillham, 2007). In addition, it is important to make sure that the selected answers for the question are mutually exclusive (Guppy and Gray, 2008). Closed-ended questions have many advantages including requiring relatively short time, easy to process, and helpful for testing hypothesis (Oppenheim, 1992).

The other type of survey questions is attitudinal, which aims to assess the interviewees’ opinion and attitude on a topic, thus, they are very sensitive to the wording of the question (Richardson et al., 1995). A common technique for attitudinal questioning is to give a statement and ask the interviewee what they think about it, whether they support it or not (Guppy and Gray, 2008). Several scales are used to rate attitudinal statements including Likert and interval category scales (Richardson et al., 1995). For the Likert scale, several attitudinal statements are presented with an answer consisting of five different categories representing different polarities; strongly agree, agree, neutral, disagree, and strongly disagree (Richardson et al., 1995). The other type is the interval category scale which is very similar to the Likert scale as it provides two polarities with a set of numbers between them to indicate how much a respondent lean toward one of them.

2.8 Summary

While Canadian cities are looking forward to building walkable and bikable communities, five main barriers for encouraging AT were identified in the literature: 1) lack of funding, 2) sprawl, 3) lack of transit AT integration, 4) topography, and 5) weather. The insufficient funds for AT projects hinder community planners and engineers from implementing new, and maintaining existing, AT infrastructure. Another important barrier to encouraging AT is
the lack of integration between AT efforts and public transit. This barrier is important as transit can support AT overcoming demographic and geographic barriers such as sprawl and topography variance.

AT infrastructure is a key element for encouraging physical activity. However, the literature shows a wide range of findings on how each specific AT infrastructure affects physical activity. Moreover, these effects are different from one community to another depending on cultural factors, physiological factors, and most importantly, urban planning and community design aspects. Current research suggests a significant relationship between urban planning (i.e. density, land use mix, and connectivity) and physical activity. Thus, different municipalities are undertaking efforts to create more livable and healthier communities through improving urban planning community design. An example of such efforts is the HDI tool developed by the region of Peel. The literature to date shows that there is no other tool similar to the HDI; however, it suggests that there is a gap in the HDI related to the metric used to evaluate street connectivity (intersection density). Evidence in the literature support that high intersection density (high connectivity) in a neighbourhood has negative effects on vehicular and AT safety and that increased AT connectivity is associated with increased walking.

The STS principles were developed by civil engineers and researchers at the Dutch Road Safety Research Institute (SWOV), and it specifies five principles: functionality, predictability, homogeneity, forgivingness, and state awareness. Applying the STS principles in the Netherland over the last 20 years resulted in a more than 70 percent declined in road crashes.

The Fused Grid is a new community design, developed by the CMHC, which seeks to balance the needs of walking, biking, and driving. It was to create a more sustainable and livable community, by fusing the best aspects of accessibility, mobility, and green spaces in a human scale pattern.
Surveys have been used widely as a reliable source of data for research purposes. They can be classified into qualitative or quantitative surveys. While there are many techniques of estimating the sample size for quantitative research, there is no precise technique for estimating sample size for qualitative research. Survey questions can be direct (i.e. open-ended, closed ended) or attitudinal (i.e. Likert, interval category scales).
Chapter 3  Methodology

3.1 Outline

This chapter consists of three main sections. Section 3.2 describes the methods used to collect public data from municipal staff across Canada. In section 3.3, the approach used to evaluate the HDI is described including the communities selected to perform the beta test. Finally, Section 3.4 describes the approach used to evaluate the Fused Grid case study.

3.2 Cross-Canada CLASP Study

3.2.1 Survey Design

Three questionnaires were designed for each level of stakeholders: government, advocacy groups, and land-developers. The general public was not interviewed in this study for three main reasons: 1) time constraints, 2) limited budget, and 3) the client (CLASP) wanted the focus of the study to be on publicly available data. Thus, the research team decided to interview advocates as a reasonable surrogate for the general public. For government representatives, the interview questions were divided into five sections. The first section contained general information on the community status of AT, such as the type of facilities implemented in the community and the policies and standards the community is using for designing facilities. The second section was about a community's profile, such as the percentage of AT users, accidents statistics, and the classification of cyclists. The third section was regarding public attitudes toward AT in general and AT infrastructures\(^1\). The fourth section documented AT infrastructure case studies, how it helped promote AT in the community, the public perception regarding the infrastructure, and whether it was successful or not in overcoming AT barriers\(^2\). The fifth section discussed future projects, available policies for AT, and what can be done better to encourage AT in the communities in question.

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\(^1\) Questions 3.10-3.18 were adopted from online survey conducted on June 22-25, 2013 by Insights West Research Company.

\(^2\) The evaluation was mainly based on answers from each city; however, in few cases (10% of case studies), the evaluation was based on the international and national literature review conducted in this research.
Similarly, the interview questions for advocacy groups were divided into five sections, but with less technical questions and more focus on the barriers that are facing the communities. The survey questions for developers were very brief consisting of one section. They focused on capturing the value of AT infrastructure and other supportive elements to the housing market, and what is the developers’ perspective/experience of such inclusion if requested by government. The questions are listed in Appendix A.

All interviews were conducted by UBC researchers by telephone. No surveys were sent out except for one (Montreal), which was sent for translation purposes. Interview responses were entered directly into an Excel database using web-based entry forms; interview summaries were sent to each respondent for verification, and internal consistency of each respondent answers were checked to increase the reliability of the study; all contradictory answers were omitted from the study. As a supplement to interview answers, most respondents provided additional reference maps and documents. All data collected from the literature review and interviews was already publicly available data, and has been preserved on secure UBC servers.

### 3.2.2 Response

The cities of interest were randomly chosen based on a previous research on the safety of Vulnerable Road Users (VRU) by Lovegrove and Barrs (2012). In the previous study, all Canadian cities above 5000 population (687 cities according to 2006 census data) were sorted in each province and territory. Then, 300 cities were randomly selected by picking every third city from the list; the number of selected cities in each province/territory varied based on provincial/territorial to national population ratio. Once the 300 cities were identified, a website scan of these cities was performed to check which cities have AT programs and infrastructure. Based on the cities’ website scan, the top five to ten cities in each province/territory were identified as candidates for the study with an aim to achieve at least three cities (small, medium and large) in each province, and at least one city in each territory.
Seventy-three email invitations were sent to possible interview candidates (including government officials, developers, and advocates) in 45 cities. Final response rates to interview requests fell short of that initial goal but a representative sample (concept of saturation) was nonetheless obtained from all major geographic regions and stakeholder levels. In total, 25 government officials, five developers, and representatives from six advocacy groups were interviewed from eight provinces and one territory. The response rate was approximately 50 percent, as shown in Table 3.1 and Figure 3.1.

Table 3.1. Participating Cities

<table>
<thead>
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<th>Region</th>
<th>Cities</th>
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<tr>
<td>Western Provinces</td>
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<td>Alberta, British Columbia</td>
<td>Calgary, Edmonton, Red Deer, Canmore, Kelowna, Kimberley, Whistler, TransLink (Greater Vancouver), Chilliwack</td>
</tr>
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<td>Prairie Provinces:</td>
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<tr>
<td>Manitoba, Saskatchewan</td>
<td>Pinawa, Manitoba Provincial Government, Regina</td>
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<td>Central Canada:</td>
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<td>Halifax, Cape Breton, Moncton, Fredericton</td>
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<td>Nova Scotia, New Brunswick</td>
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<tr>
<td>Territories:</td>
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<tr>
<td>Northwest, Yukon, Nunavut</td>
<td>Whitehorse</td>
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</table>
Figure 3.1. Location of participating cities
3.3  Review of the Healthy Development Index

During the initial surveys and data collection, a knowledge gap was identified regarding how cities are encouraging more walking and biking. We found that all cities were focused mainly on simply installing more AT infrastructure to encourage healthier communities, and less on what the literature had identified as key system factors for encouraging AT use, such as neighborhood layout and land-use. After discussing this data gap with the CLASP project manager, researchers at the UBC Sustainable Transportation Safety (STS) research lab were given an additional task, to review and criticize the (HDI) as a tool, specifically to assess how well it would be able to encourage more AT-friendly land-use and transportation developments, including its: 1) comprehensiveness; 2) practical usability; 3) effectiveness, and 4) outstanding gaps that needed to be addressed for the HDI to achieve its objectives. Subsequently, a methodology was proposed that involved: 1) an in-depth review of the HDI tool; 2) a review of the literature identified by the Region of Peel on which the HDI was based; and, 3) application of the HDI on nine new or proposed development projects across Canada.

The nine assigned projects were pursued, including e-mail and phone requests to planners and engineers in each community. These projects were classified into two types: 1) new (greenfield) developments; and, 2) existing communities near active transport corridors. For the first type (new developments), five communities were selected to understand how the index works, such as the level of effort needed to review developments, data requirements, and practical value of results. These communities were selected by the project manager as examples of developments that support AT and healthy living, at least based on a qualitative professional evaluation of these communities. Thus, the HDI was used as a science-based evaluation tool to assess how truly these communities are supporting healthy living. The second type (existing communities around AT projects) was selected to understand the effectiveness of the tool when applying it to communities near AT Projects, and whether modification is needed to be applicable to evaluate AT projects. The AT projects were selected to have a diverse mix of densities and land-uses to emphasize the importance of
having connectivity throughout the network and that not every segment of AT infrastructure should be in a mixed-use, high density development.

During the data collection process, the researcher assessed the HDI based on how easy it was to collect the required data for each metric and for each type of development as well. After collecting the required data, the HDI was applied on each of the nine communities to obtain the final HDI score for each one. This helped observing the trends in Canadian communities as well as in cities bylaws and standards in terms how they support healthy living lifestyle. Moreover, the practical usability of applying each metric was assessed during this stage according to the following criteria: 1) the easiness of performing the analysis required for each metric and the possibility to automate the process via ArcGIS and 2) observing how the metrics interact with each other and if there are redundant metrics that could be combined.

ArcMap (ESRI) was used as much as possible (depending on data availability) to perform the analysis using automated means to save effort and time, while reducing errors. When it was not possible to use it, manual methods were used to apply the index, such as calculating residential density based on counting the number of dwelling units from Google Map aerial photos.

### 3.4 Fused Grid Case Study

This case study assesses the health and safety impact potential of the Fused Grid neighborhood from a civil engineering perspective using two sustainability-oriented frameworks: the Peel Healthy Development Index and the Dutch Sustainable Transport Safety principles. The evaluation was performed assuming a theoretical four quadrant fused grid neighborhood. Each quadrant has an area of 16 hectares (160,000 m²), with dimensions of roughly 400 m × 400 m, bounded by calmed collector roads, and one-way arterial couplets. All local roads in the community have a maximum width of 5 m with 15 km/h posted speed. In addition, collector and arterial roads will have a maximum width of 3.2 m with a maximum posted speed of 50 km/hr. Fused grid contains high (or low) density, service amenities within a 5 minute walk of all housing, land-use mixes in modular layouts, high on-
road (vehicular) and off-road (AT) connectivity. All these features are achievable due to 0.64 hectare block sizes, safe AT and road networks, controllable parking maximums and locations as well as a network of restorative green spaces connected at a human scale.

For the land use design evaluation, the HDI tool was applied on the fused grid neighborhood as described in the above section. Since the case study evaluates hypothetical neighborhood (not yet built), several assumptions were made to assess the theoretical strengths of the Fused Grid neighborhood design. While for the transportation design evaluation, a detailed assessment was performed to review how well the FG community design supports each of the five STS principles.
Chapter 4  Results and Discussion

4.1  Outline

Based on the 36 interviews conducted and the evaluation process of the HDI, findings are categorized into three main sections. Section 4.2 discusses the barriers and challenges reported in the surveyed communities. In addition, it discusses different AT infrastructure that has been implemented in Canadian cities and how they were successful in increasing the number of AT users. Section 4.3 discusses how development can play a role in encouraging AT and evaluate a state of the art tool to assess new and existing developments. Finally, section 4.4 presents a comprehensive tool that combines the HDI, modified according to the recommended revisions discussed in section 4.3, and the STS principles.

4.2  The CLASP AT Study for Canadian Communities

4.2.1  Barriers for AT Infrastructure

One of the main objectives of this research was to investigate the barriers and challenges that different Canadian communities face when trying to promote AT, especially in communities where AT has never been built. As shown in Figure 4.1 Error! Reference source not found., the majority of the interviewees reported that people in their communities are facing barriers to increase their ability to ride a bike and walk. Additionally, almost 50 percent of the surveyed communities reported that people do not consider walking or cycling to be as important as driving as shown in Figure 4.2. The responses for the two questions shown in Figure 4.2 were broken out according to surveyed cities size to check the hypothesis that there is no trend/difference in level of barriers based on cities size; the result shows that there is no significant relationship between AT barriers and cities size. This research found that there are four major barriers to AT. In order of importance, these barriers are: 1) AT infrastructure discontinuity, 2) length of trips, 3) social and cultural perceptions, and 4) lack of funds.
Fifty-seven percent of the communities reported barriers related to AT infrastructure; discontinuity is the main AT infrastructure barrier in these cities. For instance, the city of...
Chilliwack has a network of 180 km of bike lanes, but needs 100 km of gaps filled to make it continuous. Only three communities reported that this barrier is affecting pedestrians, whereas the majority mentioned that it is related to cycling infrastructure. In some communities, the gap in the AT system is caused by the lack of AT infrastructure. In this case, the users can use AT facilities on part of their trips, but in order to reach their destinations they also have to share the road with vehicles. This barrier was more significant in cities with high-volume traffic roads. Two other barriers that people reported facing are related to infrastructure discontinuity; they are: 1) keeping the infrastructure clear from snow in winter, and 2) maintaining the surface of the infrastructure (e.g. paved versus gravel roads).

The second most-cited barrier by cities is related to low density and land-use mix. Density and segregated land-use development increase walking and bicycling distances between origins and destinations in and/or between developments, especially single-use developments, where only one use is allowed in the development area (e.g. either residential or commercial, not both). This increases travel distance beyond what is considered to be an attractive cycling or walking distance, which is generally accepted to be 1 to 2 km (10-20 min) for pedestrian and 3 to 5 km (10-20 min) for cyclists. In addition, high density (a minimum of 30 units/ha) supports providing convenient public services, retail services, and transit system in a neighborhood (Grammenos and Lovegrove, 2015). Four cities noted low density as a barrier including the city of Canmore which reported that the low density in the city caused an increase in the average trip distance making it very expensive to provide adequate infrastructure for AT, and extremely challenging to encourage users to walk/bike those long distances. In addition, two cities mentioned land-use mix as a barrier (e.g. Edmonton). Both of these barriers can be attributed to the way the city has grown. For instance, Halifax Pensinsula, which is classified as a dense and mixed use area, has high rates of AT use. However, the other parts of the city, which have segregation of land-uses and low densities, have low rates of AT use.

Third in importance, and reported by three cities, was the mental barriers faced by the communities. Mental barriers could be caused by social or cultural perceptions of cycling
(e.g. staff from Whitehorse felt that their citizens were just not into cycling due to car-dominant culture). Besides social factors, there are also safety factors that affect AT, that can be caused by aggressive behavior of drivers toward cyclists, lack of training and/or experience, or both. For example, the city of Thunder Bay reported that people perception of safety is a barrier for cycling. Understanding and predicting the behavior of AT users and what makes them feel comfortable and safe is critical to the planning and design of AT infrastructure.

Most of the communities had not previously done any studies to understand their cyclists’ behavior, so the percentages obtained for this section of this thesis were approximated based on the interviewees’ best guesses, where possible. More than 85 percent of the communities classified cyclists as "interested but concerned." Surprisingly, some of these communities admitted to implementing cycling infrastructure targeted at the more self-assured cyclists, such as the "enthused and confident" cyclists. Mr. Darren Charters, traffic engineer for the City of Fredericton, said that if he would change anything in AT infrastructure it would be, “working more closely with the public on AT infrastructure planning; cities need to address what the public demands, not what engineers want”. Figure 4.3 shows responses for two cities on cyclists’ classification.

![Figure 4.3. Cyclists’ classification](image)
Finally, only two municipalities reported that lack of funds is a barrier (Kimberley and Whistler). Most of the communities fund AT infrastructure locally. Additionally, only four municipalities consider walking and cycling a priority (Calgary, Canmore, Kelowna, and Guelph), which plays a role in the limitation of local funds. Little to no budget for AT infrastructure may also explain why most of the cities/towns interviewed are not choosing active modes of transportation. Only seven communities get funding for AT programs and infrastructure from provincial and/or federal governments. It seems that senior levels of government, as well as local governments, have not made AT a priority.

The seven communities that are using funds from senior governments were asked to provide more details. Three communities are using the Gas Tax Fund (GTF) from the federal government. The GTF has been provided to local governments to help build public infrastructure that will have positive impacts on the environment (e.g. transit, AT). The Infrastructure Stimulus Fund (ISF) is another federal program that was launched in 2009 after the world economic crisis to enhance the Canadian economy. In any case, two municipalities across the sample are using these funds to support AT infrastructure. In contrast, in the United States, the federal government allocates funds for AT projects, the fund amount of which increased from 1.6 percent to 2.1 percent from 2006 to 2009 from all federal funding programs (Milne and Melin, 2014). However, the projects should be identified in the Statewide Transportation Improvement Program (STIP) to be eligible for the federal fund, which is a list of transportation projects a state intends to fund over at least a four years period.

Other challenges facing AT are:
- Weather (as stated by two cities)
- Lack of road rules education with regard to cyclists (one city).

To overcome these barriers in community development patterns would require more explicit consideration of AT modes in community planning processes. Ms. Sharla Cote, project manager for the City of Regina, in Saskatchewan, Canada, notes that “if there is no priority
given, it will always stay least priority”. In some communities, interviewees noted that residents demand municipalities to be more AT oriented (e.g. from residents and tourists in Toronto); in other cities, the city councilors and the mayor take leadership roles in having AT infrastructure installed to encourage growth in public demand for AT use (e.g. in Vancouver and Calgary).

Interviewees were asked how they prioritize different modes of transportation during community planning. Figure 4.4 shows city planning priority for each mode. Out of 21 communities, only four reported that pedestrians and cyclists are the first priority. Some communities still do not have a clear policy to prioritize AT planning, and they are hoping to establish this priority by introducing a new civic transportation master plan. A third group, which does not have a clear AT priority, makes pedestrians and cyclists a priority at particular locations if a specific project is part of the city’s AT plan, but otherwise maintains equal priority for all modes of transportation.

![Figure 4.4. Cities planning priority](image)

Engineers and planners need to review planning strategies and priorities within their communities in an attempt to improve the walking and cycling experience. Two of the interviewed cities (Kelowna and Canmore), that consider AT as a first priority, could achieve increases in walking and cycling. For example, the city of Kelowna achieved a 3 percent shift in transport modes from driving to AT in years between 2007 and 2013. Most of the cities
reported successful AT projects that increased AT use at the project location; however, 82% of the surveyed communities noticed a decrease in total AT use in the period between 2006 and 2011 (Statistics Canada, 2006; Statistics Canada, 2011). This suggests that further investigation is needed to determine how cities’ master plans and prioritizing AT planning affect AT use.

4.2.2 AT Infrastructure

4.2.2.1 Facilities

AT infrastructure used to promote cycling and walking are many and varied across Canada, but little is known about which is most effective, and about how much local context impacts effectiveness. These facilities may also vary in the level of safety – real and perceived – offered to users. The interviewed cities were asked to speak to these issues regarding their inventory of AT infrastructure. Some inventories could not be obtained during the interview and others were retrieved from the cities’ websites later; a few others remain unknown. Table 4.1 contains a summary of AT infrastructure in the surveyed communities with facilities ranked based on how common they are in Canadian cities. The table shows that large cities are more likely to have a wide combination of different cycling infrastructure/treatments. Many factors could explain the variety of AT infrastructure in large cities including 1) staff commitment and available time for staff to work on AT infrastructure, 2) capital investments, and 3) complex variety of contexts that exists within the same city such as built environment characteristics (ex. high and low density) and traffic conditions (i.e. speed, volume). Appendix C contains a summary of AT infrastructure quantities in the surveyed communities. (Please note that an empty cell in Table 4.1 and Appendix C does not necessarily mean that a city does not have the facility, only that it was not publicly available or that the surveyed community failed to report it during the interview).
Table 4.1. Cycling Infrastructure in the surveyed communities

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<th>Bus bike racks</th>
<th>Bike racks</th>
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<th>bike lockers</th>
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Although there is a debate on whether on-road or off-road facilities attract more cyclists, bike lanes are the most common on-road facility component of community cycling networks, and most often provide connectivity to the users’ final destinations. Most of the community interviewees noted that bike lanes are used most because they are simplest to install on new and/or existing roads, maximize opportunities for people to be physically active, and improve safety of environments for both cyclists and motorists, as shown in Figure 4.5.

![Figure 4.5. Perceptions of Bike lanes](image)

Bike lanes are usually right next to the vehicle lane, but sometimes they are buffered from the vehicle lane. The cost of building a bike lane is between $20,000 and $150,000 per km, depending if widening is required for the project (Transport Canada, 2011). The city of Thunder Bay reported that bike lanes have reduced cyclists’ collisions by 70 percent each time the city installs a bike lane. Also, Edmonton staff found a 14 percent increase in cycling because the city is implementing bike lanes. Some cities have policies to encourage expanding the bike lane networks in their communities. For example, the city of Guelph has a policy that bike lanes must be installed on any reconstructed or resurfaced arterial road.
Similarly, the city of Chilliwack spends $240,000 annually through to 2022 to build new bike lanes.

![Bike lane](image)

**Figure 4.6. Bike lane**

Some communities provide space for bike facilities by shifting part of the road right of way from traffic lane and reconfiguring the street design (road diet). This also has positive effects on the road users’ safety (drivers, cyclists, and pedestrian) as it helps reinforcing and reducing traffic speed. An example of one such successful project was found in Moncton, New Brunswick. Salisbury Road (5 km), Shediak Road (6 km), and Killam Drive (6 km) all pass through residential areas in Moncton. The design of the streets (a wide arterial standard), as well as the low volumes of traffic on these streets, was encouraging drivers to exceed the speed limits. As part of the AT plan, the City completed three road diet projects to reduce speeds—projects that had never been tried before in Moncton. The cross-section of Salisbury and Shediak Roads was originally a four-lane road, but after reconfiguring the design, the roads now have only two lanes (i.e. one each way) with a common central left turn lane, and one bike lane on each side. The increase in the number of cyclists as a result of this project is impressive, increasing from 10 cyclists per day to almost 150 cyclists per day. Equally important to note, the project provides safety for pedestrians by having a dedicated buffer for them. However, such projects need extensive public consultation to address the public
concerns and educate the public regarding the potential benefits of road diet project, especially if the project is implemented for the first time in the city.

For instance, the city of Red Deer conducted a road diet pilot project that consisted of 13 km of bike lanes and 5 km of bike routes. After the project's completion a debate in the city followed: was it the right time to implement AT facilities in the city? Residents were not consulted and caught off-guard by the bike lane project; they complained that there were not enough cyclists on the road to use the new infrastructure. Residents also were worried that the project would increase congestion, and that it would waste tax payers’ money. Though the number of cyclists at least doubled during weekdays after implementing the project, the city removed some of the bike lanes, kept other parts, and converted a few into bike routes (shared travel lane for both cyclists and motorists) due to the public concerns and feedback.

Another on-road facility reported in the interviewed cities is a cycle track, which is a bike lane facility that is physically separated from the road, and which may be on or off (but alongside) the road. Reported in five cities only, a cycle track is not as common as bike lanes, though surveyed communities acknowledge the fact that cycle tracks would increase the comfort and safety for cyclists as shown in Figure 4.9. In some European cities that are known to have a high mode share for cycling like Copenhagen, cycle tracks are the main components of the cycling network. It combines the advantages of bike lanes as it provides more street connectivity for cyclists, and perceived safety of off-road paths as it is physically separated and buffered from road vehicular traffic via curbs and lateral separation distance.
The city of Calgary introduced its first cycle track on 7th Street in 2013, and saw the number of cycling trips on that segment increase dramatically, from 270 trips per weekday before to 1,160 trips per weekday after installation. Cycle tracks were also approved to be built in downtown Toronto in response to a cycling study in 2009. Their study stated that separating cyclists from vehicular traffic would improve cycling significantly, keeping in mind that its design would significantly impact user perceptions of safety and comfort. Guelph built a 1 km long cycle track along a busy arterial road after observing a high number of its cyclists on the adjacent pedestrian-only sidewalk. To meet their context, the cycle track was not designed to be laterally separated from the road, as buses needed to have access across the cycle track to stop at bus stops; hence, it was vertically separated and raised from the road (mountable curb). The city got feedback from cyclists that this design is not much safer than a regular bike lane and that they prefer to be separated horizontally from traffic. So the city is looking for designing buffered bike lanes as extensions occur to the same road that have the cycle track to compare the cyclists’ perception of safety and comfort level on both types of facilities. Other on-road facilities implemented in the interviewed cities are paved shoulders (similar to bike lanes but located in the emergency parking lane), bicycle boulevards (low speed and traffic volume streets that give cyclists the priority over motorists by using pavement markings, signs, and calming measures), shared lanes (lanes in which bicycles share the road with vehicles with road markings that indicate the appropriate position of cyclists along the travel lane), and signed bike routes (similar to shared lane, except that “bike route” signs, are used instead of road marking to indicate that cyclists share the road with vehicles).
Some communities reported bicycle on-road infrastructure, such as colored bike lanes, elephant’s feet, bike boxes, volume counters, pedestrian and cyclists actuated crossing signal buttons, and bike signals. Installing a colored bike lane in a busy mixed-mode intersection reduces the number of collisions significantly (Jensen, 2008). The city of Kelowna started implementing coloured bike lanes in 2010 at a cost of $80 to $120 per m sq., with an expected life of five years (City of Kelowna, 2014). The city did a public survey to evaluate the installation of coloured bike lanes and 69 percent of cyclist respondents felt safer after its implementation, while 59 percent of cyclists and 66 percent of motorists thought that motorists were paying more attention to cyclists as a result (City of Kelowna, 2014).
A concept used in Copenhagen to help make cycling efficient, is a coordination scheme of traffic signals that provides a ‘green wave’ for cyclists (Pucher and Buehler, 2007). When cyclists ride at a given speed (e.g. 15 km/h) along this system of coordinated signals, they get green lights all along the route. The city also complemented this treatment with speed radar signs so cyclists would be aware of their speeds. This concept, favoring cyclists over drivers, helps the city make cycling the fastest mode of transport in the city, which is a key element in cycling in Copenhagen. The full potential of this treatment is more likely to be achieved in a large neighborhood (i.e. Downtown Vancouver) with a route (i.e. bike lane, cycle track) that passes through many intersections. For instance, the city of Copenhagen implemented the green waves in a response for congestion problems in several main bikeways (Pucher and Buehler, 2007). The initial results show that this treatment decreased bike trip time by 10 percent.

A bike box is a treatment used at the signalized intersection to give cyclists priority. It allows the cyclists to go ahead of waiting traffic, giving them a head start when the signal turns green. While the literature shows a variety of findings related to the behavior of cyclists and motorists at intersections (Pucher et al., 2010), future research is needed to quantify the impact of bike boxes on cyclists’ safety as most of the research examined perceived safety among cyclists rather than actual safety outcomes. Nonetheless, several studies found that the
majority of cyclists could successfully position themselves in front of motorists, which suggests safety improvements for cyclists by making them more visible to motorists and by reducing conflicts (Allen et al., 2005; Loskorn et al., 2013). Groningen, Netherlands uses advanced green signals for cyclists so they can go through the intersection ahead of vehicles in order to be visible for motorists (Pucher and Buehler, 2007).

Figure 4.11. Bike box (Kelowna, BC)

Cities like Vancouver, Guelph, Canmore, Fredericton, Kelowna, and others are already using another treatment to enhance the safety of cyclists at intersections called elephant’s feet, also known as cross bikes. Shown in Figure 4.12 below, elephant’s feet are paint markings applied at crosswalks to allow cyclists to cross more safely, as regulations in some Canadian cities do not allow cyclists to cross the street in a pedestrian crosswalk. Elephant’s feet can be shared with pedestrian or used exclusively for cyclists. Signage may be used to notify motorists that cyclists are expected to cross the road. Additionally, traffic light signals can be used to indicate when it is safe for cyclists to cross the street.
Another unique treatment used to make intersections safer for cyclists are Variable Messages Signs (VMS) for cyclists, used where there are high volumes of turning trucks. To reduce the number of collisions between cyclists and right-turning vehicles, the city of Aarhus, Denmark has introduced VMS to protect cyclists. These signs light up to alert cyclists when there is a vehicle in the right-turn lane. At the desired intersection, two VMS were installed, one at the beginning of the right turn lane and the other at the intersection stop line. Additionally, a passive sign was installed 100 m before the right-turn lane. On-pavement truck warning stencils are also used in Copenhagen where bikeways cross driveways with high volumes of vehicle traffic. The initial evaluation of the treatment, using video to record cyclists’ actions, is promising as many cyclists changed their behavior (shoulder check) and become more aware of the potential conflict with motorists. In addition, the city is conducting a before-and-after analysis of accidents (Madsen, 2011). However, several quality checks need to be done to make sure that the VMS is functioning accurately for all right-turn maneuvering possibilities; otherwise, it will give a false sense of safety for the cyclists.
Volume counters are used to monitor the number of cyclists in some cities—like Ottawa, Montreal, and Vancouver—in order to assess the success of the cities’ AT promotion plan, and to plan new improvements (Transport Canada, 2011). Some volume counters, like the ones used in Montreal, can distinguish between cyclists and pedestrians, but others, like the ones used in Whitehorse, cannot (Lovegrove and Barrs 2012). However, since implementing monitoring programs could be very expensive (Davis and Wicklatz, 2001), future research is needed to estimate the feasibility of these programs.

Some of the interviewed city staff noted that their on-road facilities (i.e. bike lanes and shared shoulder) are acknowledged to be for cyclists who have a moderately high level of confidence and cycling skills, leaving out novice and concerned cyclists. However, these same staff also admit that these two (novice and concerned cyclist) groups represent the majority of cyclists in Canada, and prefer off-road cycling facilities, like multi-use trails, because it gives them a greater sense of safety. Their dilemma is that often there is not enough space to provide separated facilities along all cycling corridors, but that they do try to build off-road, multi-use trails where possible.

One should be careful when comparing multi-use trails in different communities; a multi-use trail can serve many purposes according to its location and surface material. For example, a multi-use trail with a gravel surface may attract mountain bikers and horses, but might not attract as many commuters as a paved surface trail, which in turn would attract fewer mountain bikers and horses. Additionally, the AT connectivity or network continuity of the trail via on- or off-road AT infrastructure plays a major role in determining whether it will be used for transportation or recreational purposes, and by more timid or more experienced cyclists. This relates to the weakest link concept discussed by Mekuria et al. in their research on bicycle level of stress (Mekuria, Furth, and Nixon 2012).

Most of the interviewed cities provide bike-parking facilities, the most common form of which is the bike rack; some cities encourage installing bike racks by subsidizing them. For example, the city of Kelowna covers 50 percent of bike rack purchases and installation costs for businesses and organizations attracting the public. Bike lockers are another common type
of bike parking facility. They are usually intended for longer and/or recurring use because they provide more security compared to bike racks. The city of Toronto offers bicycle parking stations in different locations throughout the city in the form of secure, indoor bicycle parking facilities that provide long-term parking options for up to two working days. Most of these facilities in Toronto are close to public transit. Similarly, Calgary provides seven Park 'N' Bike sites, where people can park their vehicles while they bike to the downtown area using pathways along the river. These sites are located five to eight km from the city’s downtown, and have access from the main streets in the city.

4.2.2.2 Integrating AT with Public Transit

Having a transit system that facilitates cycling and walking adds value for AT modes. The integration between public transit and AT can be accomplished in many ways, like providing bus-mounted bike racks, bike parking at bus and train terminals, and easily accessible transit facilities. Interviewed cities were asked how the transit system ties-in with the AT efforts. More than 90 percent of the surveyed communities reported that the transit system in their communities supports AT.

Allowing cyclists to bring their bikes on transit gives more options for cyclists in cases where they cannot finish their trip due to bad weather, a flat tire, or any number of other reasons. It also helps overcome demographic and geographic barriers, such as low density and mountainous areas. Most of the interviewed cities have buses equipped with bike racks; the cities of Kelowna, Vancouver, and Guelph have bike racks installed on their full fleet of buses. The common bus bike rack used in the majority of the interviewed cities has the capacity for two bikes. However, a three bike capacity is also possible, like the racks used in Moncton. Allowing bikes inside the buses has the same advantages as bike racks, although it might not be as convenient for other transit users. Thirty percent of the surveyed communities allow bike on board except for peak hours. For example, in Calgary, bikes are allowed on their Light Rail Trains (LRT) Train from 9 am to 3 pm and after 6 pm on weekdays, with no restrictions on weekends and holidays.
Additionally, providing bike parking (typically bike lockers) at transit facilities enables cyclists to leave their bikes secure until they finish their trip. Commuters who are not permitted to take their bikes on board transit while riding during rush hours, will still have the option to bike to the transit facility, keep their bike there, and then collect it on the way home at the end of the day. Advertising could support bike parking by covering the cost of installation and maintenance for items like bike racks and bike lockers. This option is not limited to transit facilities only; it can also support bike parking in public and private spaces where suitable.

Surveyed communities feedback suggested that giving AT users easy access to public transit facilities made a significant impact to improving integration between the two modes. Four communities reported that there is a lack of interconnectivity between the two modes with instances such as not having sidewalks on bus routes or bicycle facilities not connecting to transit terminals. Additionally, providing easy access to subway stations is important. Currently, the Société de transport de Montréal (STM) is assessing the use of bicycle slides up and down staircases at some of their metro stations; bicycle slides allow cyclists to access stations without having to carry their bikes.

*Courtesy: Société de transport de Montréal (STM)*
Figure 4.13. Bicycle slide

The city of Whitehorse implemented bicycle slides when they did a road diet for 4th Avenue, providing two-way bike lanes. To make the staircase that connects to the Airport Trail easier for cyclists, the City of Whitehorse installed bicycle slides for cyclists to continue their trip between bike lanes on the 4th Avenue corridor and the Airport Trail.

A noteworthy program is a pilot project conducted in Seattle, Washington. The Highway 520 Evergreen Floating Bridge does not have bicycling infrastructure across the bridge; the project provides free lifts for pedestrians, joggers, and cyclists (and their bikes) between either ends of the bridge using out-of-service buses. There is no fixed schedule for the service, but it runs frequently to minimize wait times and maximize convenience for AT commuters.

Table 4.2 summarizes the public transit facilities available in the interviewed cities that facilitate AT:

<table>
<thead>
<tr>
<th>City</th>
<th>Facilities</th>
<th>Notes</th>
</tr>
</thead>
</table>
| Calgary      | • Bus bike racks (three routes).  
• Bikes are allowed on CTrain during holiday and non-peak hours during weekdays.  
• Bike lockers at most CTrain stations (142 bike lockers) | The City is planning to have bike racks on most of the routes.         |
| Red Deer     | • Bus bike racks                                                             | Frequency of service is a barrier                                     |
| Canmore      | • Bus bike racks (three bike capacity)  
• Bikes are allowed on board | Planning to install bike trailer for buses in 2014.                    |
| Edmonton     | • Bus Bike Racks(11 routes)  
• Bike racks (12 LRT facilities).  
• Bikes are allowed on board except for peak hours. | They are designing new LRT, which will be urban style LRT. It will require people to walk or bike to reach the stations. |
<p>| Kimberley    | • Bus bike racks.                                                            |                                                                      |</p>
<table>
<thead>
<tr>
<th>Location</th>
<th>Bus bike racks</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whistler</td>
<td>Bus bike racks</td>
<td>Bike racks are installed on buses in mid-April, and removed in early November.</td>
</tr>
<tr>
<td>Kelowna</td>
<td>Bus bike racks</td>
<td>Need to improve bike connectivity at older bus stops, those in outlying areas.</td>
</tr>
<tr>
<td>Moncton</td>
<td>Bus bike racks</td>
<td></td>
</tr>
<tr>
<td>Cape Breton</td>
<td>Bus bike racks</td>
<td>Some have capacity for three bikes, and many capacity for two bikes.</td>
</tr>
<tr>
<td>Fredericton</td>
<td>Bus Bike racks</td>
<td>Frequency and routing of service is a barrier.</td>
</tr>
<tr>
<td>Halifax</td>
<td>Bus bike racks (80 percent of the fleet)</td>
<td>They are working toward 100 percent within five years. The major barrier is the lack of sidewalks on both sides of the roads on the bike routes, as well as poor bicycle facilities connecting to the terminals.</td>
</tr>
<tr>
<td>Thunder Bay</td>
<td>Bus bike racks</td>
<td>The transit system is currently building new bus shelters that will have bike racks. Additionally, there will be a new transit hub, which will have bike lockers.</td>
</tr>
<tr>
<td>Niagara falls</td>
<td>Bus Bike racks</td>
<td></td>
</tr>
<tr>
<td>Toronto</td>
<td>Bus Bike racks</td>
<td>Working with Toronto Transit Commission (TTC) to have parking facilities in the subway stations. Funding is a barrier.</td>
</tr>
<tr>
<td>Ottawa</td>
<td>Bus Bike racks (540 buses, 58 percent of the fleet). Bikes are allowed on the O-Train during designated time periods. Bike storage facilities at rapid transit stations.</td>
<td>Bus bike racks are available six months of the year.</td>
</tr>
<tr>
<td>Guelph</td>
<td>Bus bike racks</td>
<td>There are some locations where there is no biking or walking connection.</td>
</tr>
</tbody>
</table>
Montreal
- Bus bike racks (eight routes)
- Bikes are allowed on board during designated times.

Société de transport de Montréal is testing bicycle slides in some metro stations.

Regina
- Bus bike racks

Whitehorse
- Bus bike racks

Bikes are allow on board transit vehicles if the outside racks are full

Chilliwack
- Bus Bike racks

### 4.2.2.3 Design Standards

The surveyed communities reported using many design standards and guidelines to design the AT infrastructure in their communities as shown in Table 4.3.

<table>
<thead>
<tr>
<th>Standard/Manual</th>
<th>Cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAC</td>
<td>Calgary, Canmore, Cape Breton, Chilliwack, Edmonton, Fredericton, Guelph, Halifax, Kelowna, Moncton, Niagara Falls, Ottawa, Red Deer, Regina, Thunder Bay, Translink (Greater Vancouver).</td>
</tr>
<tr>
<td>NACTO</td>
<td>Calgary, Canmore, Edmonton, Regina, Thunder Bay, Toronto</td>
</tr>
<tr>
<td>Vélo Québec</td>
<td>Moncton, Montreal, Regina, Thunder Bay</td>
</tr>
<tr>
<td>AASHTO</td>
<td>Calgary, Cape Breton, Toronto</td>
</tr>
<tr>
<td>Ontario Traffic Manual</td>
<td>Guelph, Ottawa, Thunder Bay</td>
</tr>
</tbody>
</table>

The following is a description of these standards and guidelines available across Canada.

**TAC**

The most popular transport infrastructure design guidelines used by these communities are produced by the Transportation Association of Canada (TAC) \(^1\). TAC has different

\(^1\) www.tac-atc.ca
documents that refer in part to AT infrastructure design guidelines, including the *Geometric Design Guide for Canadian Roads* (TAC, 1999), *Bikeway Traffic Control Guidelines for Canada*, BTCGC (TAC, 2012), *Traffic Signal Guidelines for Bicycles* (TAC, 2014), and *Manual of Uniform Traffic Control Devices for Canada* (TAC, 2014). The GDGCR document provides guidelines for different geometry design aspects, such as alignments, cross section, and intersection design. The BTCGC has suggestions for the proper practices for traffic control devices, such as signs and pavement markings, as well as illustrated diagrams for them. The TSGB helps engineers to design and install exclusive traffic signals for bikes at intersections.

**Velo Quebec**
Planning and Design for Pedestrians and Cyclists (PDPC)¹ is a technical guide developed by Velo Quebec (Vélo Québec, 2010). The first version of the guidelines was published in 1990, and the most recent version was released in 2010. The PDPC outlines best practices for designing and maintaining pedestrian and cyclist infrastructure, as well as guidelines on integrating AT with transit and snow removal.

**NACTO Urban Bikeway Design Guide**
The Urban Bikeway Design Guide (UBDG)² by the National Association of City Transportation Officials (NACTO) is part of the Cities for Cycling initiative to develop the best bicycle practices in urban American communities; it is in direct contrast to the American Association of State Highway and Transportation Officials (AASHTO) design guidelines, which focus on highways and rural areas (NACTO, 2014). The NACTO guide provides three levels for each treatment—required, recommended, and optional—to distinguish between the core elements in each treatment, that add more value to each one.

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¹ www.velo.qc.ca
² www.nacto.org
AASHTO
The American Association of State Highway and Transportation Officials (AASHTO)\(^1\) has two documents that guide the planning and designing of AT facilities, including the *Guide for the Development of Bicycle Facilities* (AASHTO, 2012) and the *Guide for the Planning, Design, and Operation of Pedestrian Facilities* (AASHTO, 2004). In addition to guiding the design of different bicycle facilities and treatments, the former document provides guidance on road diets (lane reductions) and on choosing the appropriate type of infrastructure needed based on the road characteristics.

USDOT Manual on Uniform Traffic Control Devices (MUTCD)

Bicycle Facility Design Guidelines (TransLink)
Bicycle Facility Design Guidelines were created by the Greater Vancouver Transportation Authority (TransLink) for the planning, design, and maintenance of bicycle facilities throughout the Metro Vancouver regional bicycle network. The guidelines are designed to maximize safety, improve efficiency, and ensure that an acceptable level of service is provided. The plan includes guidelines for on-street facilities, multi-use pathways, crossings, end-of-trip facilities, signs and pavement marketing, as well as maintenance.

Provincial and local standards and guidelines
Some cities reported using provincial and local documents such as the Ontario Traffic Manual Book, their respective Ministry of Transportation design standards, the Ottawa Design Guidelines, and other provincial standards in BC, Ontario Quebec, and Nova Scotia.

\(^1\) www.transportation.org
4.2.2.4 Facilities Winter Maintenance

As discussed earlier in the literature review, many studies suggest that cold weather might not be a significant barrier for AT but temperature is not the only factor that affects AT during winter in Canada. An important factor that influences winter use of AT is the condition of the facilities during winter. The snowfall in most geographical areas in Canada poses a challenge to keep AT infrastructures usable in winter. The Canadian cities that were interviewed reported different practices regarding snow removal.

Ten cities reported that there are policies in place to clear snow from bike routes, four of these clear both on-road and off-road facilities, five clear only the on-road facilities, and one city reported policies for off-road facilities only as shown in Figure 4.14. However, because roads are not always cleared well from edge to edge, most Canadian cities are not currently well-suited to the needs of winter cyclists. Six of these communities have policies stating that snow should be removed from bike lanes and shared lanes according to the priority of the street where the facility is located. For example, Edmonton prioritizes roads as per the following:

- **Priority 1** (plowed within 36 hours)
  - Central business districts, arterial roads, freeways, and bus ways
- **Priority 2** (plowed within 48 hours)
  - Collectors and bus routes
- **Priority 3** (plowed within 5 days)
  - Local and industrial roadways
In other cities, there are no bike lane snow removal policies. The snow is plowed off of the general purpose lanes and onto the bike lanes as snow storage, which renders them unusable and a barrier to safe cycling. In some communities, lack of funding is the reason behind not maintaining AT facilities, where in other communities lack of demand results in municipalities failing to plow the snow. This is the case for Whistler, where most cyclists convert to cross country skiing in the winter. On the other hand, other cities, like Whitehorse, who do not yet have winter maintenance policies are still interested in encouraging winter biking. In fact, Whitehorse is already starting to study how to accommodate bike lanes during the winter months by completing a pilot project in the downtown core. Similarly, the city of Edmonton is implementing a winter maintenance pilot project on a bike route along 106 Street. This project will help the City to assess the maintenance of three types of bicycle facilities, including bike lanes, buffered bike lanes, and shared-use lanes.

Sidewalks receive better service than bike lanes and shared lanes in most communities. In Thunder Bay, the City clears the snow from all sidewalks and hires a private company to plow the snow from trails. Similarly, in Kimberley, trail machines for sidewalks are sent out at the same time as road snowplows. In some communities, snow plowing for sidewalks is prioritized according to the location of the facility. To illustrate this, the Halifax municipality sets the sidewalks alongside its main arterials and in its hilly capital district as a first priority.
(within 12 hours after the snow stops), and removing snow from intersections and bus tops as the last priority (within 48 hours). In other cities, snow is cleared from only some of the sidewalks. For instance, Moncton clears snow from 50 percent of its sidewalks because of a lack of dedicated budget. Finally, it is common in all Canadian cities that occupants of adjoining properties are responsible for clearing sidewalks. Table 4.4 contains a summary of the snow removal policies in the surveyed communities.

**Table 4.4. Snow removal policies**

<table>
<thead>
<tr>
<th>City</th>
<th>Policy</th>
</tr>
</thead>
</table>
| Calgary   | • Bike lanes located on a road that receives priority 1 will be cleared with the road within 24 hours. Other on-street type facilities are considered priority 2 and are cleared within 48 hours.  
• Occupants of adjoining properties are responsible for clearing sidewalks within 24 hours. In certain situations the city clears the sidewalks, such as if the owner can’t be identified.  
• City clears 300 km of pathways within 24 hours.                                                                                         |
| Chilliwack| • City staff clears snow next to its properties.                                                                                                                                                         
• Occupants of adjoining properties are responsible for clearing sidewalks.                                                                 |
| Edmonton  | • Bike routes are cleared according to the priority of the street where they are located  
• Shared use paths and sidewalks are cleared after 48 h of the snowfall                                                                   |
| Canmore   | • Occupants of adjoining properties are responsible for clearing sidewalks.                                                                                                                               |
| Cape Breton| • Designated sidewalks will be cleared.                                                                                                                                                                  
• Bike lanes are cleared according to the priority of the street where they are located.                                                  |
| Fredericton| • City clears all sidewalks.                                                                                                                                                                             |
| Guelph    | • City clears all sidewalks  
• Bike lanes are cleared according to the priority of the street where they are located.                                                                                                           |
| Halifax   | • Bike lanes are cleared according to the priority of the street where they are located.  
• Sidewalks are cleared according to the location of the facility  
• Pathway will be cleared 36 hours after snow fall                                                                                       |
<table>
<thead>
<tr>
<th>City</th>
<th>Details</th>
</tr>
</thead>
</table>
| Kelowna      | - Occupants of adjoining properties are responsible for clearing sidewalks, and the city is responsible for clearing sidewalks fronting its properties.  
- Multi use pathways are a priority for the city |
| Kimberley    | - Occupants of adjoining properties are responsible for clearing sidewalks within 72 hours. |
| Moncton      | - City clears 50 percent of the sidewalks                                 |
| Montreal     | - Sidewalks are Priority 1  
- Bike paths are Priority 3, off street facilities are not maintained |
| Niagara Falls| - Sidewalks are cleared in designated areas when snow exceeds eight cm   |
| Ottawa       | - Bike lanes are cleared according to the priority of the street where they are located.  
- Sidewalks and pathways based on classification |
| Red Deer     | - Bike lanes are cleared according to the priority of the street where they are located.  
- Occupants of adjoining properties are responsible for clearing sidewalks  
- City clears 95 km of sidewalks. |
| Regina       | - Occupants of adjoining properties are responsible for clearing sidewalks in some locations, such as downtown area. |
| Toronto      | - Some cycling facilities depend on the road type and others on the type of the cycling facility.  
- Occupants of adjoining properties are responsible for clearing sidewalks in some locations such as core area. |
| Thunder Bay  | - City clears all the sidewalks                                           |
| Whistler     | - Bike lanes are last priority for snow removal                          |
| Whitehorse   | - Occupants of adjoining properties are responsible for clearing sidewalks.  
- The city is responsible for clearing sidewalks fronting its properties. |

Improving winter maintenance for AT facilities in Canadian cities requires prioritizing it in the first place. Some cities in Canada have already taken this step, but they are still facing problems. Winter and other maintenance costs should be integrated with the budget planning
and design phases of AT facilities to ensure a sustainable infrastructure. Feedback from interviewees suggests that providing long, continuous, and homogeneous cycling facilities would make the snow removal process easier (Vaismaa, 2014). Additionally, providing enough space for snow storage is necessary to keep bike lanes open all year. Suggestions on how to accommodate winter cycling include (Cebe, 2014):

- Store snow between roadways and buffered bike lanes
- Complete removal by truck
- Place snow into the tree strip between curb and sidewalk if available
- Design separated or off-road facilities that have enough width to accommodate small snow plows
- Allow cyclists to use sidewalks in winter
- Ban on-road parking in winter if applicable, to be snow storage space

To summarize, bike lanes and multi-use trails are the most common AT facilities in Canadian cities, regardless of the risk tolerance and experience level of the AT users in those cities. Meanwhile, cycling tracks have not been used widely in Canadian cities despite research showing their ability to increase a sense of safety and the connectivity of an AT system. In addition, maintaining AT infrastructure during winter is a challenge for the surveyed communities; the condition of AT facilities in winter is not well-suited to the needs of cyclists. Moreover, 100 percent of the surveyed communities are making efforts to improve the connectivity between AT and public transit

### 4.2.2.5 Incorporating AT Infrastructure into New Developments

In addition to addressing AT infrastructure, municipalities across Canada have started partnering with land developers in an effort to change to more sustainable built environments that support more active lifestyles. Many municipalities have introduced new zoning bylaws that require developers to provide a minimum level of AT infrastructure. Seventy percent of the cities surveyed adopted zoning bylaws that concentrate on establishing the minimum requirements for bicycle parking facilities. Twenty-four percent of those interviewed have comprehensive policies for the developers to include AT infrastructures other than bicycle
parking facilities, such as sidewalks and pathways. Only one community does not yet have any policies in place for developers related to AT, rather decisions are made on a case by case basis as each new development is built to decide if AT elements are needed. For example, if the new development is part of the City of Guelph’s official plan, the city will include AT elements as a requirement in the development application. In the case of one new subdivision development, the city of Guelph required that the developers create an AT connection for pedestrians and cyclists, instead of a road connection between the development and the adjacent subdivision. This was done because the City wanted to encourage access by foot to a school in the adjacent community.

In addition to other types of planning, an important element of AT infrastructure is bicycle parking or other end-of-trip facilities (EOTF). Seventy percent of the interviewed cities have zoning bylaw policies specifying the rate of bicycle parking facilities required for each development. Generally, the types of parking facilities are classified into two categories: the first category is long-term parking facilities, such as bike stations and bike lockers; the second category refers to short-term parking facilities, such as bike racks. The City of Calgary provides a document called the Bicycle Parking Handbook to guide developers on how to design and plan a proper parking facility. In a few communities—like Toronto, Edmonton, and Ottawa—the zoning bylaws have regulations for providing other EOTF for cyclists, such as showers, change rooms, and covered parking. In Toronto, showers and change rooms are compulsory if a long-term bicycle parking facility is required for a non-residential building. In Edmonton, non-residential buildings in the downtown area that have more than 5000 m sq. of floor area should provide showers, change rooms, and covered and secured parking. The City of Ottawa offers to reduce the number of car parking required by the city bylaw for a development, if the developer provides showers, change rooms, or any other EOTF.

While it is more common to require EOTF, some cities require developers to provide either bicycle and pedestrian pathways, or funding for them. In Halifax, the Municipal Design Guidelines specify that developments next to collector and arterial roads should have either bike lanes and sidewalks, or a bike lane on one side and a multi-use path on the other side.
depending on what is suitable for each case. Similarly, Edmonton’s Construction Design Manual requires developers to align paths with arterial roadways in utility right-of-ways; sidewalks are required on both sides of the roads. Developers in Kelowna must provide AT facilities, including on-site and perimeter circulation plans, that offer convenient access and connectivity for pedestrians, cyclists, and transit users. Several cities—Halifax, Kelowna, Ottawa—collect development cost charges (DCC) from developers, in addition to road infrastructure components, for AT infrastructure elements. There is always a debate between the city and the developers to determine the required amount of money, and to ensure that it is spent in their development.

According to interviews, developers are embracing the trend toward more active and less car-centric communities. For example, in cities like Edmonton, Fredericton, Ottawa, and Kelowna, the developers interviewed noted that people are demanding these inclusions; therefore, they are not opposed to government bylaws for AT elements. However, AT has not yet become a major attraction for homebuyers. Financial factors like the cost of land still drive developments; it is important that a business case be made to support investments in AT infrastructure construction and maintenance. Sometimes, there is a pushback from the developers when the government required cost of AT elements is perceived to be too high. Most developers are still looking for a successful example of a development that has introduced AT elements with a reasonable return on investment (ROI) to convince them to change the design of their developments. To remain solvent, developers must achieve reasonable ROI; the resulting resistance to change from current methods is expected, unless the same ROI is possible. It may not be fair, at this point, to claim that the lack of public demand for AT is responsible, just as it may be unfair to blame the developers. Most interviewees stated that governments should take the lead on partnering with developers to integrate AT within their developments by offering developers incentives like exemptions from certain city bylaws, and/or land swaps for AT corridors, similar to what Ottawa is doing to create EOTF.

Creating regulations to encourage developers to provide AT infrastructure in their developments is not enough. Providing AT infrastructure does not necessarily mean that
there will be an active community; designing neighborhood layouts that provide the most 
direct pedestrian and cyclist routes plays a major role in determining the efficiency and 
usefulness of the infrastructure provided in these communities. Tom Young, an Associate at 
Stantec Consulting, said, “The infrastructure is there, but the reasons to walk or cycle aren’t 
there.” He noted several reasons why walking and bicycling do not increase, mainly related 
to land-use mix, including:

- Homes without stores and services nearby (i.e. not walkable or bikeable).
- Neighborhoods beyond a reasonable distance from, or without a convenient AT route to, 
  employment.

Some communities have recognized the importance of the built environment, and they are 
making an effort to create more livable and healthier communities. One of these efforts is the 
Healthy Development Index developed by the region of Peel. Peel has been using the HDI as 
a reference tool in evaluating all proposed developments, with an aim to promote healthier 
community lifestyles. The HDI highlights seven elements in the built environment that are 
associated with walkability: density, service proximity, land-use mix, street connectivity, 
road network and sidewalk characteristics, aesthetics and human scale and parking. Each 
element is further broken down into quantifiable measures.

As part of the Innovative Street Case Study project undertaken by CITE and funded by the 
Healthy Canada by Design CLASP Initiative, the UBC STS research lab was asked to 
validate the HDI to bring it closer to adoption. The validation process includes a “beta test” 
implementation, and assessment of any remaining details that may cause erroneous outputs 
from the assessment.
4.3  A Review of the HDI Tool: Improving its application to Land-use and Transportation Projects

4.3.1  HDI Case Studies – Project Evaluations

To establish the functional ability of the index, the HDI was applied on nine communities. These communities can be classified into two categories: 1) Retro-fitting AT Projects into existing communities; and, 2) Construction of new ‘Greenfield’ developments. The initial test was slated to look at only three Greenfield developments, but in order to have a more representative sample and to test the application of the tool to developments near AT projects, six more communities were added. The methodology for AT-related project evaluations recognized that the HDI tool was meant to assess an entire development, and not to assess just its transportation component. Therefore, the HDI was applied to evaluate the communities around the AT projects.

The results have been summarized in the next section. The full set of data required to perform all the analysis in the index couldn’t be gathered for all tested communities because of time limitations and because some of the data were not publicly available, which precluded applying some of the criteria. For four of the communities, some of the data was gathered from the city’s GIS Open Catalog, and the remainder obtained from Google maps analysis. The data for the rest of the developments were purely dependent on Google maps as shown in Table 4.5.

<table>
<thead>
<tr>
<th>Data Sources</th>
<th>Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>City GIS Data &amp;</td>
<td>Collingwood Village, Vancouver</td>
</tr>
<tr>
<td>Google Maps Only</td>
<td>Finch hydro corridor Trail, Toronto</td>
</tr>
<tr>
<td>City GIS Data &amp;</td>
<td>Garrison Woods, Calgary</td>
</tr>
<tr>
<td>Google Maps Only</td>
<td>Hadden Park Pathway, Vancouver, BC</td>
</tr>
<tr>
<td>Google Maps Only</td>
<td>Saddlestone, Calgary, Alberta</td>
</tr>
<tr>
<td>City GIS Data &amp;</td>
<td>The Bikeway projects, Cambridge, Ontario</td>
</tr>
<tr>
<td>Google Maps Only</td>
<td>Rutherford Road North and Centre Street North, Brampton, Ontario</td>
</tr>
<tr>
<td>Google Maps Only</td>
<td>Sage Creek, Winnipeg, Manitoba</td>
</tr>
<tr>
<td>Google Maps Only</td>
<td>Village de la Gare, Mont-Saint-Hilaire, Quebec</td>
</tr>
</tbody>
</table>
The availability of GIS shape files allowed data analysis to be performed more effectively and efficiently. If the HDI tool was meant to be used primarily by municipal staff it should be relatively convenient to apply as most municipalities have at least started database conversions onto GIS platforms. On the other hand, where using the tool in the absence of access to GIS data, it was cumbersome and labor intensive. Overall, the tool seemed overwhelmingly difficult for new users, mainly due to the myriad data sources and metrics required. Once familiarity with its metrics grew however, the HDI tool’s value became clearer and the effort required fell. Finally, it should be noted that while the HDI scores for each of the 9 communities are tabulated in this report, it would be unfair to compare them as they span widely different community contexts across Canada. The most effective comparisons, in our opinion, would be to compile HDI scores from projects within the same community or region. Until a large HDI database of evaluations is available, comparison of HDI scores should be done with caution. If nothing else, HDI allows for relative comparisons in the same community, and provides important clues on ways to improve the ‘health-promoting’ aspects of developments. A brief description for each of the nine communities and a summary of the evaluation is presented below and summarized in Table 4.6; the detailed analysis is presented in Appendix F.

**AT Corridors**

**Brampton, Ontario**

**Rutherford Street North and Centre Street North traffic Calming**

Centre Street North and Rutherford Street north are residential collector roads in the city of Brampton, Ontario. When the city reviewed the traffic data on these streets, they found that 85th percentile of the speed was about 89 km/h, when the speed limit is 40 km/hr. The cause of this has been shown to be that motorists are using this thoroughfare to avoid using other busier road in the city, which is adding extra volume as well. To restore the intended purpose of this street in order to increase the safety of the neighborhood, the city decided to conduct traffic calming along the corridor.
The community around the project as shown in Figure 4.15 is 88.3 Hectare of residential area with three main housing types. Those types include detached, semi-detached, and townhouse. It has medium density of 21 units/ha, with little mixed land usage. Services are limited to a few public parks, retail stores, and childcare centers. The community has a variety of block sizes from small and large, which affects connectivity. The impact of large blocks at several locations in the community has been reduced by having cut-through paths for AT users.

Both traffic-calming proposals put forth by the city for these roadways have been rejected by the residents, so the city is not planning to implement any changes to the roadways at this time.

Summary

The overall HDI score is 20, based on the four of seven criteria for which data was available to measure. Land zoning was the main drawback of the neighborhood to achieve high in the HDI. Most of the lots in the neighborhood are classified as low residential areas which limits the density and number of neighborhood retail services.
Figure 4.15. Neighborhood services around the community of Rutherford Street North and Centre Street North
City of Cambridge, Ontario - Bikeway Projects

In the spring of 2008, the city of Cambridge, Ontario approved a 20 year master plan to improve the existing cycling network and to update the city policies related to cycling such as funding and maintenance. As part of the master plan, the city adopted an implementation plan for proposed projects in the city that consists of three phases: 1) Short Term phase (2008 -2012) at which 55 km of bike way projects were built; 2) a Medium Term phase (2013-2017) which intends to build 43 km of bikeway routes; and finally 3) a Long Term phase (2018 – 2028) that intends to build another 14 km bikeways for a total of 112 km of bikeways costing $2.49 million. In addition, the city’s policies were changed in order to achieve four different initiatives related to this master plan. These initiatives are the creation of a bicycle-friendly community, the new bikeway network, promoting cycling related practices, and cycling-supportive programs. Therefore, land-use policies were changed in order to require developers to provide end of trip facilities as well as integrating cycling with transit. In 2013, the city implemented four bikeway projects

- Paved shoulder at Bishop Street between Franklin Blvd and Werlich Drive.
- Paved shoulder at Bishop Street between Can-Amera Parkway and Franklin Boulevard
- Shared-use lane at Ellis Road Hespeler Optimist Park and Cooper Street.
- Multi-use Trail at Franklin Blvd between Jamieson Parkway and Winston Blvd (the HDI tool was also applied at the other section of the Multi-use Path that was completed in 2012 between Winston Blvd and Johnston Ave).

Summary
The overall HDI score for these neighborhoods is 21 based on five of the seven criteria for which data was available. Difficulties were encountered in determining the catchment area to be analyzed as the two projects serve a large community. In addition, the community does not meet the street connectivity criteria, but as opposed to the community around Rutherford Street North, it does not provide AT cut-throughs to provide high connectivity for AT users.
Figure 4.16. Communities around Franklin Street and Ellis Street projects
**Hadden Park Bike path, Vancouver, British Columbia**

A $2.2 million project has been proposed for Hadden Park in Vancouver BC that would have created a 3.5 m wide bike lane separating cyclists from pedestrians through Hadden and Kitsilano Beach Parks. However, it was postponed in February of 2014. It was opposed by various groups who did not want any changes to the park structures and also cited safety and cost concerns. The lack of public consultation was raised as a concern as well. After hearings, in late 2013 and early 2014, the project has officially been cancelled.

**Summary**

Hadden Park achieves an overall HDI score of 33, based on 4 of 7 criteria for which data could be found. In addition, none of the three communities analyzed so far could achieve the minimum net residential dwelling density. This suggests that health was not considered as a primary factor when designing neighborhoods in Canadian cities.

![Figure 4.17: Map of the community around Hadden Park Pathway](image-url)
Finch Hydro Corridor Trail, Toronto, Ontario

In 2009, Toronto got funding to build a preliminary series of trail projects along the Finch Hydro Corridor. This corridor has several potential trail sections that could create a new bicycle network up to 30 km in length. This network would also connect with Toronto’s existing bike network in a mixed land use space toward the Northern area of the trail; however, there is a 3km section between Kenneth Avenue and Pineway Boulevard that is currently owned by Ontario Hydro.

A segment of the network between Dufferin and Younge Street is already built and is about 3.5 meters wide and 7 km long with a connection to the recently built 3 km bikeway inside G. Ross Lord Park. Another 3.5m wide section about to finish construction runs 3km between Willowdale Avenue and Pineway Boulevard. The project started in July, 2013 and it is supposed to finish in 31st July, 2014. There is also another project for a trail between York Gate Boulevard to Driftwood Park. The projects are slated to include benches, bike parking spaces, garbage receptacles, landscaping, light fixtures and crossing signals for major arterial roads.

Summary
Overall, this project achieves a HDI score of 32 out 63, based on 4 of 7 criteria for which data was available. The community around Finch hydro trail could improve its score by providing more high density and mixed land use zones as most of the community is classified as low density residential zone, which could improve both the density and proximity to services elements score.
Figure 4.18. The community around Finch Hydro trail
**Development**

**Collingwood Village, Vancouver, British Columbia**
(Canada Mortgage and Housing Corporation, 2009)

Collingwood Village is the largest master planned community in British Columbia, with a gross residential density of 239 uph (units per hectare). Occupying what was originally industrial land, it is a mixed land use development built in two phases and is composed of a residential area with 2,700 units (1,917 condominiums and 783 rental) within 16 buildings (11 condominiums and 5 rentals) including four-story townhouses with mid and high-rise apartment buildings (units goes from 34 m² to 123 m²). It also includes a non-residential area of 6,500 m² including a grocery store, drug store, a 200 pupil elementary school, a 930 m² community centre, a 650 m² daycare, small scale-retail and a neighborhood policing center. (Canada Mortgage and Housing Corporation, 2009)

The housing complex is composed of three building types: up to four townhouses and garden apartments, six-story apartment buildings, and high-rise towers up to 26 stories. The 11 condominiums buildings have a total of 2,173 parking stalls (1.35/unit in phase 1 and 1.04/unit in phase 2) and all on-site parking is underground. Bicycle parking is also available for all building offering a total of 2,048 spaces provided both at up and below grade. The community centre and the commercial buildings provide changing rooms and showers for its users.

The Joyce-Collingwood SkyTrain station is the eighth stop on the Expo Line from Downtown Vancouver and is close to this community (25-700 m). It was found that the SkyTrain line is used by 56 percent of Collingwood Village’s inhabitants. The streets have lots of trees and pedestrian bulges to reduce travel distances, which also create a pleasant environment for walking and cycling.
Figure 4.19. Collingwood Village map (Neighborhood services)
Summary
Overall HDI evaluation score is 44, based on 4 of 7 criteria for which data were found. It seems that some HDI criteria are not appropriate to be applied to small developments, in terms of developed area, such as Collingwood. One of these criteria is the variety of housing types’ requirement. Also, while AT connectivity is very good and health-promoting, the stricter HDI street connectivity/intersection density criteria gave it a zero, which is a bit misleading regarding the health-promoting traits of this development.

Garrison Woods, Calgary, Alberta
(Canada Mortgage and Housing Corporation, 2004)

Garrison Woods was developed by Canada Lands Company in a former Canadian Forces Base (CFB) of 65 hectares plus 6 hectares of established uses. Today it has a gross residential density of 25 units per hectare and it is a mixed land use area compounded by residential space with 1,600 units with townhouses, single-detached houses, apartments, refurbished single and semi-detached military housing units and single family infill among the refurbished units. The community also features apartments above retail outlets, coach houses above garages and residences. Non-residential space includes 6,500 m² of retail space, two private schools, a museum, a twin hockey arena and 8 percent of its total space in parks and common open space.

The parking facilities are different for each unit. Single, semi-detached houses and townhouses have two-stall garages and each apartment unit has 1.5 parking stalls Most of its inhabitants live within a five-minute walk to a bus stop and a 10-minute walk from a large grocery story. This community is also within close proximity with Calgary’s downtown area which was one of the factors behind the strong growth of this neighborhood.
Summary
The Overall HDI for Garrison Woods is 43 or 63 based on 4 of 7 criteria for which data was available. Garrison Woods illustrates a successful example on how communities can be redesigned to support healthier life style; it has high density, high proximity to services, and high street connectivity with paths through green spaces to enhance AT.
**Village de la Gare, Mont-Saint-Hilaire, Montreal, Quebec**

The Village de la Gare project was started in 2002 and took about 10 years to complete. It is considered the first master planned and transit oriented community in Quebec with a gross residential density of 30 uph (units per hectare) for multi-family housing and 20 uph for single-family units.

It is compounded by a residential area of 1000 units, including single-family detached homes, duplexes, townhouses and multi-units buildings with up to three stories, and a non-residential area with commercial uses, community facilities, a primary school and nearly 15 percent of its total area for parks and open spaces including bicycle routes and pedestrian pathways.

The Mont Saint-Hilaire Railroad Station is within between 200-750 meters of the community and is used by around 44 percent of its inhabitants. In 2004, from the 5,900 riders a day, 600 were from Village de la Gare and this number is increasing years over year. A bus line linking this neighborhood to the train station was also implemented encouraging transit usage further.

For parking, there are 1.5 spaces for each unit, which is lower than the standards for the Mont Saint-Hilaire region. Around the train station, the commercial areas are not required to offer parking spaces, but the station provides a 444 space parking lot with room for 1000 spaces total in the future. Also, there are two bike racks with 15 bicycle spots next to the station.

**Summary**

Overall HDI is 11 out 63 based on 4 of 7 criteria for which data was found. Village de la Gare seems to be pure residential development that is not well served by retail and public services. In addition, the Loops & Lolly-pop street pattern of the neighborhood provide a low vehicular and AT connectivity.
Saddlestone, Calgary, Alberta

Saddlestone is an environmentally friendly community located in Calgary that is currently under construction. The total area is about 64.5 hectares with just over 1000 units. The community will also contain a public school, a commercial area, parks, and other public area.

Summary
The Saddlestone overall HDI is 16, based on 4 of 7 measured criteria. Saddlestone could have achieved higher results for proximity to services if it had more food markets serving the community and transit stops. In addition, the community needs to include more high density-mixed use buildings to achieve higher score in the density and land use mix elements. The information about this community was difficult to find as the project is still under development.
Figure 4.21. Planned phases of Saddlestone Development
Sage Creek, Winnipeg, Manitoba

Sage Creek is a master planned community located in Winnipeg, Manitoba. It’s a multiple phase project intended to create a “unique Winnipeg suburban community” through a walkable environment along trails and pathways where people can meet neighbors at the local stores. It occupies over 420 hectares but has a low gross residential density of about 19.8 units per hectare.

This neighborhood is composed of a residential area with apartments, townhouses and fashioned single residences. In order to accommodate social and economic diversity, it has over 5000 units as well as non-residential space including a village centre, a dental centre, an animal centre, an insurance broker, a fire station, a bank, public schools, a trail system connecting the various neighborhoods, lots of stores, dinning and ample parking. Over 6 percent of the land is dedicated for outdoor public spaces.

Sage Creek is also a transit-oriented neighborhood, and therefore, is served by two bus lines. The first one is route 96, a connecting route, going from St. Vital Centre to Patterson Loop traversing the south city as well as route 50 going from Sage Creek to the University of Winnipeg passing by downtown area.

Summary
Overall HDI = 20 based on 4 of 7 criteria measured. Sage Creek could not meet the minimum requirements for proximity to services, though it has lots of retail and public services. This suggests that choosing a more centric location that provides easy accessibility for all the community is important to achieve a higher HDI score and promote healthy AT activity.
Figure 4.22. Planned phases of Sage Creek development
## Table 4.6. HDI Scoring Summary

<table>
<thead>
<tr>
<th></th>
<th>Total HDI Score</th>
<th>Density</th>
<th>Service Proximity</th>
<th>Land-Use Mix</th>
<th>Street Connectivity</th>
<th>Road Network &amp; Sidewalk Characteristics</th>
<th>Parking</th>
<th>Aesthetic &amp; Human Scale</th>
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<tbody>
<tr>
<td>Maximum possible score</td>
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<td>19%</td>
<td>13.5%</td>
<td>5%</td>
<td>22%</td>
<td>16%</td>
<td>13.5%</td>
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### AT Projects (%)

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<th>Project</th>
<th>Density</th>
<th>Service Proximity</th>
<th>Land-Use Mix</th>
<th>Street Connectivity</th>
<th>Road Network &amp; Sidewalk Characteristics</th>
<th>Parking</th>
<th>Aesthetic &amp; Human Scale</th>
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<td>Finch Hydro Trail</td>
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### Development Projects (%)

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<th>Service Proximity</th>
<th>Land-Use Mix</th>
<th>Street Connectivity</th>
<th>Road Network &amp; Sidewalk Characteristics</th>
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<th>Aesthetic &amp; Human Scale</th>
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</table>

Of 9 projects evaluated, the highest scored only 24%, or 44/63 when the three criteria that could not be evaluated were taken into account. This suggests, in keeping with the motivation behind development of the HDI tool, that most communities in Canada are not considering health during their land-use and transportation planning. Moreover, due to time limitations, data could not be acquired to perform complete HDI evaluations on any of the projects. However, the exercise did allow for a functional evaluation of most of the HDI itself, in keeping with assigned objectives. It also provided opportunities to identify common deficiencies in current development plans in Canada, for example in these nine cases, the common deficiencies related to 1) low density, 2) large block size, 3) low vehicular and AT.
connectivity with Cul-de-sac or Loops & Lolly-pop street patterns, and 4) segregation of land-use.

4.3.2 The Value of the HDI Evaluation Tool
Discussion of the results follows in order of: data collection and availability, the individual HDI criteria, and applying the HDI for AT projects.

The availability and ease of collecting the data required to perform the analysis of the index depends on the type of the community, as well as on the type of development being evaluated. Finding data for recently developed or proposed Greenfield projects would be an easier process than an older or established development. This is because most of the data would be available in the documents that developers need to submit to municipalities during the modern development proposal process. Staff from the Transit Oriented Development and Special Projects Office of Land Servicing & Housing in the City of Calgary advised that “It depends on the point of time you’re gathering it, you can get it now, but you will go after the raw data for all the development permits” (Hackman, 2014). Similarly, it is difficult to collect data for infill developments. The structures in infill developments are not planned or built at the same time or within a short period of time, so the data collection can be hard for not only the researchers but also the municipalities. A city planner for the City of Ottawa said “In terms of difficulty, it depends on how robust a municipality’s information system is. The most difficult is residential by unit type, since not many municipalities will have this information readily available. At the end of the day this will not be an easy request to respond for the typical municipality, especially in mature/urban areas” (Fu, 2014). As such, three of the HDI criteria – Road Network and Sidewalk Characteristics, Parking, and Aesthetics & Human Scale criteria – could not be completed for any of the developments (except Parking criteria was evaluated for Saddlestone because Calgary had the data available), due to lack of detailed data available within the several month time frame of this

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1 Hackman, Linda (2014) “Personal Communication”, Transit Oriented Development and Special Projects Office, Land Servicing & Housing, City of Calgary, AB.
2 Fu, Royce (2014) “Personal Communication”, City Planner, Research and Forecasting, City of Ottawa, ON.
study. As GIS use and techniques become more prevalent, this barrier should be reduced to a more reasonable level of effort. However, these three missed criteria represent some of the highest HDI values totaling 95 points or almost 50 percent of the total 185 HDI score. This casts doubt on the immediate practical value of the HDI. Some thought should be given to reducing the number of criteria to be evaluated, thereby reducing data requirements, and enhancing its practical applicability, especially as many of the criteria overlap with each other. For example, higher net residential density will require less large lot detached houses and a variety of housing types. It also encourages developers to build more mixed-use buildings instead of just commercial buildings to achieve the service proximity prerequisite.

Regarding the index criteria themselves, the first criterion of the HDI, density, requires a minimum net residential dwelling density of 35 residential units / hectare and a minimum average floor area ratio (FAR) of 0.7. Out of the seven communities, only three of them could meet the minimum net residential dwelling density. Nevertheless, the value specified in the index does seem to be theoretically reasonable. That was clear in Garrison Woods development which achieves the density prerequisite even though the most dense housing type in the site is a four-story apartment, with 40 percent of development being single-family houses. The developments that couldn’t meet the prerequisite consisted mainly of single family houses. The second density prerequisite, the FAR ratio couldn’t be analyzed because of lack of data and time, although again it seems to be theoretically sound.

The second criterion in the HDI, proximity to a variety of services, transit, and employment, has three prerequisites as shown in Appendix D. The third prerequisite could not be verified due to the lack of required data. Six of nine communities met the first two prerequisites. We observed that achieving the density prerequisite greatly contributes to service proximity, as dense, compact areas would require fewer neighborhood services to serve a large number of residential units. Therefore perhaps these two criteria (Density and Service Proximity) could be combined into one criterion. Moreover, the measurements required to perform service proximity analysis are labor intensive and based on walkable distance networks via designated walking infrastructure (i.e. sidewalks, multi-use paths). Using straight-line distances would affect the analysis significantly. Unfortunately, due to the lack of time and
resources, this could be completed for only two communities. The locations of commercial and mixed-use buildings play a major role in achieving these element prerequisites. For example, Sage Creek, which offers commercial and mixed-use lands with a variety of existing and proposed retail services, couldn’t achieve these prerequisites. This is because the community centre, which includes all of the commercial and mixed use buildings, is located on one (North) side of the development and is not central. This caused the rest of the community, which consists mainly of single-family houses spread over a large area of land, to have no services in a walkable distance despite its relatively dense and mixed land-use.

The fourth criterion in the HDI is street connectivity. The HDI evaluates street connectivity as a function of intersection density and block size. Only two of the seven communities could achieve the prerequisite for connectivity. It seems that these prerequisites are quite strict, as they require all the blocks to meet the 1.5 ha block area requirement (except for blocks with large park areas). This ignores the location of the block, and if it is located at the edge of the development. This means it might not have an effect on the connectivity. It also ignores the cut-throughs that some communities provide in large blocks to increase the connectivity for walking and cycling (i.e. AT connectivity). In addition, it does not consider the effectiveness of any off-road pathway systems that some communities provide to enhance AT connectivity. Perhaps this is their motivation on the 1.5 hectare block size, which facilitates shorter walking distances; however, our review of literature and the project evaluations suggests this criterion needs to be reconsidered, with removal of the block size minimum and insertion of an AT connectivity criterion. This does not mean removal of sidewalks and bikeways from roads, rather, adding more AT pathways in quieter off-road locations in order to give AT users more choice and connectivity. This will enable AT users to travel in and around the neighborhood more conveniently than driving, thus increasing attractiveness of AT versus unhealthy driving. For example, AT directness was used to evaluate the connectivity of Sage Creek development which couldn’t meet the street connectivity prerequisites. The community got a reasonable PRD ratio of 1.35 because it provides a system of trails connected with the on-road pedestrian network. Dill (2003) has shown that planning communities that strive to maximize such a measure may be one of the most effective strategies to encourage bikeable and walkable communities.
The fifth criterion in the HDI, Road Network and Sidewalk Characteristics, requires a maximum through lane width of 3.2 m for all the streets within the community. The HDI requires it as a traffic calming measure to reduce vehicular speed promoting a safer walking and cycling environment. However, the safety effects of lane width are still not well known in North America. We realize that the HDI is meant to align with the emerging Complete Streets design philosophy that ensures safe and convenient travel for all ages and modes of transportation. Most of the Complete Street guidelines recommend narrowing travel lane width, except where wider lane is needed such as in industrial areas. This has been driven by studies suggesting that narrow lanes encourage reducing travel speed, which in return reduce the severity of vehicle collisions involving vulnerable road users (City of Edmonton, 2013; New Jersey Department of Transportation, & Pennsylvania Department of Transportation, 2008). However, other research have found that there is no difference in terms of safety between 3.0 m lanes and 3.6 m lanes. (Potts et al., 2007; Midwest Research Institute, 2006 as cited in LaPlante and Mccann, 2011). Many European local roads follow a lane narrowing guideline as well. Therefore, we would recommend caution on this criterion, as the findings of the most recent Canadian study were inconsistent on whether lane narrowing is positively or negatively related to the number collisions (Manuel et al., 2014). Moreover, the maximum lane width specified in the HDI might contradict many long-standing municipal road standards that consider other factors when determining street width such as the context for the area as well as recommended engineering guidelines offered from the Transportation Association of Canada (TAC) Geometric Design Guide for Canadian Roads shown in Table 4.7 (Transportation Association of Canada, 1999). While these documents (i.e. TAC, AASHTO, Complete Streets policies, etc.) are just guidelines, not manuals, it will still take time for the traffic engineering profession to sort out how to address the narrowing of lanes in each community context. Therefore perhaps some transition phase and/or wording needs to be included in the HDI regarding this criterion.
Table 4.7. Lane width guidelines according to TAC

<table>
<thead>
<tr>
<th>Road Classification</th>
<th>Desired Lane Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector - Residential</td>
<td>3.5-3.7 m</td>
</tr>
<tr>
<td>Collector - Commercial/Industrial</td>
<td>3.7 m</td>
</tr>
<tr>
<td>Local - Residential</td>
<td>3.0-3.7 m</td>
</tr>
<tr>
<td>Local - Commercial/Industrial</td>
<td>3.5-3.7 m</td>
</tr>
</tbody>
</table>

In addition, the time at which a community was developed affects the road network characteristics. For example, in 1998, when Garrison Wood was developed, the city of Calgary didn’t have Complete Street requirements and cyclists were intended to use travel lane with vehicles. Additionally, this prerequisite might not be applicable for infill development where the street network already exists. It is equally important to note that there are few developments being constructed that design roads for a max speed of 15 km/h, unbundle parking across an entire development, incorporate traffic calming initially, and other similar measures. Therefore, a method needs to be developed to account for projects that must be retrofitted into existing communities, and direction given to community planners on whether or not to apply the HDI, or if so, how.

We encountered difficulties due to inability to acquire data for existing communities into which AT projects were being proposed. The HDI as designed is an easy tool to use when evaluating new, isolated, stand-alone projects where data is much simpler in both availability and context. In existing communities, municipal databases often are out of date, and/or electronic data sets (i.e. GIS) may not even be available in sufficient detail to perform the required data extraction and HDI evaluations. This is because one AT project can connect more than one community, each varying in their characteristics (i.e. density, housing types, which makes it tricky to determine the weight that should be given for each of these communities. It is also difficult to determine the catchment area of an AT Project that should be analyzed for each community, which depends on the type of facility (multi-use paths, bike lanes, paved shoulders). In this report, a 400m buffer was used as a catchment area for AT.
Projects serving large communities. In addition, use HDI with caution when evaluating AT projects proposed in low density, poor land-use mix communities, as the motivation may have larger ramifications, for example, to provide AT network continuity, and/or for connections to popular destinations.

Moreover, the strict prerequisites required by the HDI hide some of the advantages for the evaluated communities. For example, the high proximity to public transit including commuter train station available in the Village de La Gare development didn’t positively affect the community’s score in the index. This is because the development does not meet the prerequisites of proximity to a variety of services and employment (less than 75 percent of residential units are within walkable distance of neighborhood 5 public and 7 retail services). Additionally, the HDI index treats all developments that fail certain prerequisites the same even though dramatic differences may exist. For instance, both, the community around the multi-use trail in the Franklin Street and Saddlestone developments got scores of zero for street connectivity when the former had an average intersection density of 32 intersections/km² and the latter an average of 74 intersections/km². We were pleased to see that some of these concerns were addressed in the most recent HBSF report and its revisions to the HDI, as it provides flexibility with the minimum standards depending on each project scale and context. However, more refinements are recommended including missing measures to evaluate the safety of transportation networks in Canadian communities. Thus it is recommended to integrate the HDI tool with a safety evaluation framework such as the STS principles.

Another concern observed relates to the actual scoring of the HDI. While it is prudent to rate and rank projects according to a scoring system, one possible way to improve the appeal, comprehension, and practical applicability of the HDI might be to re-work the maximum HDI score to be out of 100. This way, projects closer to the ‘ideal’ and promoting healthy communities would be rated closer to 100 or 100 percent. With the current maximum score of 185, a project scoring 90 or 100 might be misperceived as very good whereas it is only around 50 percent of what an ideal healthy project should be. Therefore, we’d suggest revising the HDI scoring to be in percentage, not out of 185.
Our last observation relates this scoring issue in general, and the low scores that the reviewed projects received. It was surprising that what were thought to be handpicked progressive ‘health-promoting’ projects scored very low at less than 50 percent. While we conclude that this may be indicative of the current state of healthy design expertise in Canada, more research should be done to identify whether there are in fact any Canadian (or international) projects that would rate as 100 percent. An immediate theoretical model that could be referenced is the Fused Grid neighborhood development design, which has been deemed as a healthy design by health, psychology, planning, and engineering researchers alike (Frank et al, 2010). Section 4.4.1 presents a newly developed tool, The Interactive Sustainable Transport Safety / Healthy Development Index Valuation Tool (I-THRIVe), and uses it to assess the fused grid neighborhood design in order to demonstrate the theoretical strengths of the FG and how it would rate what researchers consider a sustainable community development pattern.

4.4 I-THRIVe Tool

The I-THRIVe Tool has been developed to help community planners and engineers in two parts, the first part from the original HDI tool developed by Peel region, and the second part from the Dutch SRS principles. The theoretical foundations of both parts have been relied on heavily, but modified slightly for use to develop this Tool. The I-THRIVe provides a user friendly interface that allows planners and developers to input the project under consideration’s values for each of the tool’s metrics and then sees the results easily and instantaneously; Excel Visual Basic Macros were utilized to automate the analysis.

The HDI focuses mainly on encouraging people to be more physically active; however, increasing the number of AT users without careful planning of transportation infrastructure will have severe effects for AT users’ safety. These effects can be addressed by using the Dutch STS principles, which evaluate the safety of a transportation infrastructure system. Hence, it is suggested that a combination of the two frameworks, the HDI and STS, will
create a holistic approach to evaluate communities’ land-use and transportation infrastructure designs. Thus, a balance will be provided between the need for a healthy, active lifestyle and the safety of VRUs.

The I-THRIVE consists of 12 elements including 1) density, 2) service proximity, 3) land-use mix, 4) street connectivity, 5) road network and sidewalk characteristics, 6) parking, 7) aesthetics and Human Scale, 8) functionality, 9) predictability, 10) homogeneity, 11) forgivingness, and 12) state awareness. The first seven elements are the built environment criteria, while the other five elements are the road safety criteria.

For the built environment criteria, all the criteria were adopted from the HDI tool except for street connectivity criteria. As discussed earlier, street connectivity metrics in the HDI need to be refined to account for AT network connectivity. Thus, it is suggested that the HDI takes route directness into consideration to account for off-road walkways/bikeway connectivity as well. Increasing pedestrian network connectivity relative to vehicles is associated with increased walking; thus, the AT to vehicle route directness ratio should be less than one (the lower the route directness value, the better the connectivity).

For the five road safety criteria, the metrics were selected to support creating a safe road environment by utilizing the Dutch STS principles. The first criterion is functionality, which aims to create clear road classifications according to their traffic functions. Thus, street layout should be designed to serve one function only, such as providing access for local roads and providing high mobility for arterial roads. The first metric for this criterion is functional classification, which targets reducing the number of grey roads in a neighborhood. The second criterion is access management on collector roads. Much research evidence suggests that increasing the number of access points per km in a road has a negative effect on road safety (Elvik and Vaa, 2004; Papayannoulis et al., 1999). Thus, access points should be optimized to improve road safety and traffic flow while maintaining acceptable level of accessibility according to the road classification.
The second criterion, predictability, aims to develop recognizable road environment by including distinguishable characteristics (e.g. road surface and edge marking) for each road category; thus, the road user will be able to predict the speed, acceptable maneuvers, and type of road users. The selected distinguishable characteristics need to be used consistently in a neighborhood. Road design should have at least one distinguishable characteristic; however, more characteristics, if practical, will help to create a more recognizable environment for road users.

The next criterion is homogeneity. The main objective of this criterion is to separate road users that have high variance in speed, mass, and direction. For example, cyclists should be separated from high speed vehicles and heavy traffic volume streets. If separating cyclists and motorists is not possible (i.e. limited right of way), then the speed need to be reduced to minimize the VRUs injury risk. To achieve a high score on this criterion, an appropriate level of separation should be applied for each road in a neighborhood according to the streets’ volume and speed. Some European countries and Canadian cities have established criteria to determine street layout requirements (ex. Ottawa, Sweden, Netherlands, New Zealand, and Australia). It should be noted that the requirements provided in this tool are minimum, and a community can still score points by providing a greater level of separation.

The forgivingness criterion aims to provide a road environment that minimizes the negative consequences of driver errors. A community can achieve a high score on this criterion by including at least one forgiving road design measure for all collector and arterial roads. Forgiving road design measures include, but are not limited to, rumble strips, medians, and wide shoulders. Although road calming measures usually can be considered as forgiving road environment characteristics, they are not considered toward getting points for this criteria to avoid overlap with road network and sidewalk characteristics criteria.

The last criterion is state awareness. The objective of this criterion is to encourage the inclusion of intersection design that reduces drivers’ task demand, such as 3-way intersections, and roundabouts. The bulk of research evidence suggests that roundabouts and 3-way intersections provide safer environment for all road users (Elvik, 2003; Lovegrove and
Sayed, 2006; Tanner, 1953; Grammenos et al., 2008). Moreover, several measures can be implemented to reduce cyclist’s task demand as discussed in section 4.2.2, including bike boxes, elephant’s feets, colored bike lanes, and bike signals.

4.4.1 Application of CLASP, HDI & STS Principles to the FG Neighborhood: A More Sustainable Community Design

4.4.1.1 Healthy Development Index Evaluation

This section evaluates a theoretical four quadrant Fused Grid (FG) neighborhood using the HDI to demonstrate how the FG model would score in an HDI evaluation, assuming that the HDI tool was refined as recommended above. Each quadrant has an area of 16 hectares, with dimensions of roughly 400 m x 400 m, bounded by calmed collector roads, and one-way arterial couplets. The Fused grid contains high (or low) density, service amenities within a 5 minute walk of all housing, mixed land-use in modular layouts, high on-road (vehicular) and off-road (AT) connectivity. All these features are achievable due to 0.64 hectare block sizes, safe AT and road networks, controllable parking maximums and locations as well as a network of restorative green spaces connected at a human scale.

4.4.1.1.1 Density

The average density assumed in this analysis was 85 units/ha, higher near the perimeter arterial roads to provide a higher proximity to neighborhood public and retail services. The fused grid street network design has low road connectivity at the local level through having cul-de-sacs with AT cut-throughs. Thus, it can maintain traffic on local roads as low as 14% of the total traffic in the neighborhood (IBI Group, 2007).

In regard to the Floor Area Ratio (FAR), the mix land-use zones in the arterial corridor, that have high residential and employment density, ensure that the FG neighborhood will have the HDI recommended FAR value of 2.5.
4.4.1.2 Connectivity

One of the key elements that make the FG community very unique is its high AT connectivity compared to vehicle connectivity via an off-road grid and calmed local roads. The AT to vehicle route directness ratio for a fused grid community can range from 0.61 to 1.0, with an average of 0.89 (Frank and Hawkens, 2007). For the evaluated fused grid community, the route directness ratio was found to be 0.83.

4.4.1.3 Proximity to Services

Each fused grid quadrant is bounded by calmed collector roads, and one-way arterial couplets with mix land-use zones surround each neighborhood (four quadrants). Hence, residents have a five minute walk access to many amenities, services, and green spaces. Regarding proximity to transit, buses can easily serve the neighborhood through major collector streets due to the high residential and employment density. For the proximity to employments, the HDI encourage developers to build near activity centers for several reasons including avoiding negative sprawl effects on AT. Thus, hypothetically, the FG neighborhood provides a 30 minute transit service to activity centers.

Figure 4.23. The typical four quadrant FG community under evaluation (Sun and Lovegrove 2013)
4.4.1.1.4  Land-use mix

More than 8 percent of the FG neighborhood are green spaces for recreational purposes and AT off-road pathway network. Moreover, the FG neighborhood provides multiple neighborhood and retail services and a variety of housing types that makes it relatively easy for the FG to complete the heterogeneity of land-use maximum credits including the following features:

- At least 60 percent of commercial buildings include a ground floor pedestrian use.
- 100 percent of mixed-use buildings and at least 50 percent of multifamily residential buildings include ground floor retail, live/work spaces, and/or residential dwellings.

4.4.1.1.5  Road Network and Sidewalk Characteristics

The FG network design and features give AT users the first priority within the neighborhood with AT cut-throughs, and off-street pedestrians and cyclist paths. Furthermore, the design includes many traffic calming measures, such as roundabout, three-way intersection, and raised cross walks on major collectors to reduce the severity of collisions. In addition, all local roads have a posted speed of 15 km/hr.

Moreover, the FG neighborhood includes sidewalks wider than 2.5 m, buffer strips, and side parking on major collector and arterial roads. For cyclists, facilities are provided according to the road classification that suits the road speed and volume as follow:

- Local roads with low speed and traffic will be designed to be pedestrian/cyclists priority streets.
- Minor collectors with moderate speed and traffic have a colored bike lane.
- Major collectors and arterials with moderate speed and high traffic have separated bike lanes.
In addition, pedestrian level street lighting (solar and/or wind powered if possible) is provided on both sides of all roads, as well as low-level pathway lighting for personal security.

4.4.1.1.6 Parking

Although the fused grid design does not specify parking guidelines, the HDI parking criteria would easily be accommodated in a fused grid community. Thus, it was assumed that the assessed fused grid community would adhere to these criteria as the following:

- All multifamily units would have unbundled parking.
- Driveways for loading/unloading in residential and commercial areas have a maximum width of 3 m with long term residential parking accessed via rear alleys.
- Shared parking would be provided in multi-use zones.
- Metered parking would be enforced in all multi use zones, with the price of all parking increasing with the length of the stay.
- All on-road parking in each neighborhood would be restricted to a 2-hour maximum.

4.4.1.1.7 Aesthetics and Human Scale

Similar to the parking element, the Aesthetics and Human Scale criteria can also be easily embraced in the FG design. The buildings within the FG neighborhood by definition are architected to attain a minimum average building height to street width ratio of 1:1. Moreover, commercial buildings provide a nice human scale with the following characteristics:

- No setbacks from property lines, which allows for convenient walk-in access,
- Clear glass on more than 60 percent of their facades, giving a more inclusive look and feel to walkers,
- No blank walls longer than 40 percent, or 15m, of the facade facing the sidewalk.
- Trees planted every 10m on street sidewalks abutting the facade.

4.4.1.1.8 HDI Evaluation Summary

The previous section illustrated the theoretical health-promoting strength of the FG design by assessing it using the HDI, with a resultant maximum HDI score. The next section utilizes the Dutch Sustainable Transport Safety principles to illustrate the safety aspects of the FG design.
4.4.1.2 Sustainable Transport Safety Principles:

The FG model also appears to fully follow the five principles espoused in the Dutch sustainable transport safety (STS) philosophy – functionality, predictability, homogeneity, forgiveness, and user state awareness - which were created to maximize community safety, as summarized below. Although STS ‘scores’ like the HDI tool per se have not been given, what follows describes how the FG model would achieve a maximum STS score if such were given.

4.4.1.2.1 Functionality

The FG model follows a strict hierarchy street network system in which each road fulfils a single function only, as shown in Figure 4.25. Uninterrupted Traffic flow functions are provided at the regional level through arterial roads. Local roads only provide accessibility to final destinations within neighborhoods. Major and minor collector roads distribute traffic between local and arterial roads.

![Figure 4.24. Hierarchy of Roads in the Fused Grid Network (Grammenos et al. 2008)](image)

4.4.1.2.2 Predictability

The FG model provides consistent street designs for each road class (arterial, collector, or local) that create distinguishable road characteristics. Thus, road users can easily predict the road class, speed, and availability of other types of road uses (i.e. cyclists). For instance,
local roads in FG are narrow, two-way, with lower speed limits. However, arterial roads are wider, one-way, with separated bike lanes. In addition, most of the intersections in the FG community are either controlled by roundabouts or T-intersections, which reduce conflict points compared to four-way intersections.

4.4.1.2.3 Homogeneity
The FG community offers continuous grid networks of dedicated paths in the central green spaces, that provide access to daily destinations, such as shops, homes, work, to separate the Vulnerable Road Users (VRUs) from the road traffic. Since motorists and VRUs are sharing the same space on local roads, the posted speed is reduced to a minimum, 15 km/h, to reduce the severity of injuries. In addition, two treatments are used to reduce the number of collisions on arterial roads where the traffic speed is high. First, sidewalks and separated bike lanes are provided to separate different road users. Second, one-way couplets are used to separate the two directions of travel, which does not only reduce the number of vehicle crashes, but also reduces the injury risk for VRUs (Research Triangle Institute, 1976).

4.4.1.2.4 Forgivingness
The FG design provides many forgiving surrounding features to reduce collisions, injury risk, and the risk of death. One of these features is T-intersections, which have been associated with increasing safety for motorists and pedestrian (Sun and Lovegrove, 2013). Another feature is the FG self-enforcing layout that reduces private auto travel and VKT, hence, improving safety. The third feature to limit the physical consequences of driver errors is providing relatively low speed limits at all roads; 15 km/h on local roads and 50 km/h on arterial roads.

4.4.1.2.5 User State Awareness
The FG achieves the user state awareness principle by maintaining the task demand at a lower level than most of the road users’ capabilities. For instance, the FG relies on T-intersections, roundabouts, off-road paths, and one-way couplets to reduce traffic conflict points between all the road users.
4.4.1.2.6  STS Evaluation Summary

The STS Principles were used to show how the FG design would meet the requirements of a sustainably safe road system. The evaluation illustrated how the FG design minimizes conflicts between different road user types, and reduces speeds in potential conflict locations, such that risks of collisions and severe injuries are minimized.

4.5 Summary

Based on 36 interviews with civic officials, developers, and advocates in communities across Canada, section 4.2 identified the challenges and barriers that community planners and engineers face when attempting to encourage AT use. One of the main barriers was the discontinuity of the AT infrastructure system, which was found in the majority of the interviewed cities. Another main challenge for Canadian cities was maintaining AT facilities during winter; the condition of AT facilities in winter is not well-suited to the needs of cyclists. Other major barriers reported by the interviewed cities were length of trips, social and cultural perceptions of cycling, and lack of funds.

Additionally, this section discussed the different AT infrastructure that have been implemented in Canadian cities. Bike lanes and multi-use trails have been implemented broadly across Canada, but findings from interviews and literature suggested that they may not be the preferred AT infrastructure for all Canadian communities, as people in each community based their preferences for AT infrastructure types on risk tolerance and experience level. Moreover, Cycle tracks have not been used widely in Canadian cities; but, cities that implemented cycle tracks reported promising results regarding their ability to significantly encourage AT use.

The next section 4.3 presented the results of field experiment testing of the HDI using real development project data from nine communities across Canada. ArcGIS 10.1 software was used if possible (i.e. if open source data were available) to perform more efficient and
accurate analysis. Out of nine developments evaluated, the highest score obtained was only 44 out of a possible 63, because data were available for 4 of 7 criteria. These low scores indicate that the majority of Canadian communities do not consider health during their transportation and land-use planning. In addition, the evaluation gave the opportunity to detect common deficiencies including low density, large block size, and low vehicular and AT connectivity. Moreover, several drawbacks have been identified including 1) HDI analysis is difficult and time consuming, especially for existing communities, 2) street connectivity metrics do not consider the cut-throughs that some communities provide in large blocks to increase the connectivity for walking and cycling, and 3) the maximum lane width specified in the HDI might contradict many long-standing municipal road standards; a transition phase is needed regarding this criterion in the HDI.

Finally, section 4.4 presented the I-THRIVe tool, which assesses developments in terms of health and safety; it combines the HDI and STS principles with a new rating system. This section also presented a case study that evaluated the FG community design using the I-THRIVe. While there are some concerns regarding increase AT use due to a negative perception of AT safety, the evaluation of the FG model demonstrated that promoting AT use with less driving is possible while reducing the injury risks for both motorists and pedestrians.
Chapter 5 Conclusions & Recommendations

5.1 Conclusions

In view of the well-researched benefits of AT related to health safety and sustainability, a research project was conducted to investigate successful strategies to increase AT uses in Canadian communities. All surveyed communities have recognized the advantages of AT, but not all have been successful in encouraging increased AT use. Based on the results obtained in this research, several conclusions have been drawn regarding AT Infrastructure:

- The most common barrier in Canadian cities to increasing further AT growth is network discontinuity. Lessor but still significant barriers include sprawling communities, and lack of land-use mix with walkable home-work-school-shopping trip distances.
- Some cities have plans to improve AT networks, whereas others do not have the funding or policies in place to make the necessary progress. Surprisingly, only 25% of Canadian communities place a priority on walk/biking in their community planning, operations, and/or funding.
- It is important to note that cold weather was not cited as a barrier for AT, rather failure to keep the facilities clear from snow in winter discourages people to bike or walk.
- Conducting studies to understand community resident profiles, behaviors, and attitudes toward AT is needed to maximize ROI by implementing the appropriate infrastructure in each context. Some interviewed cities mentioned that their community demanded more on-road facilities (e.g., bike lanes); however, others requested off-road facilities (pathways). This suggested that what might be most effective in one city would not be appropriate for another city in terms of encouraging more AT—careful, individual analysis is required.
- Improving integration between transit and AT is important to overcome low density and barriers related to land-use in most Canadian cities. It is equally important for public transit to be seen as a complement to AT; improving transit Level of Service (LOS) (e.g., coverage, frequency) should also be considered in concert with other AT infrastructure and system improvements.
• The most common deficiencies in developments/communities to promote more AT use and healthy lifestyle are 1) low density, 2) large block size, 3) low vehicular and AT connectivity with Cul-de-sac or Loops & Lolly-pop street patterns, and 4) segregation of land-use.

5.2 Recommendations

Recommendations arising from these conclusions include:
• In regards for community design, future endeavors should include introducing new policies in zoning bylaws that require developers to provide a minimum level of AT infrastructure, and to build high-density and mixed land-use developments that play key factors in promoting AT.
• The Healthy Development Index (HDI) is recommended as a state of the art Canadian tool to assess developments, and help local governments design built environments that encourage healthier lifestyle. However, there are improvements needed to the HDI facilitate its widespread adoption.
• In its present form, HDI is a data-hungry tool such that data collection is a difficult and time-consuming process, even for municipal staff in the existing communities. However, data collection and HDI evaluation is easiest for new isolated Greenfield projects in the newest parts of communities. Thus, simplifying it by reducing the number of criteria or by simplifying the specificity of each criterion is recommended.
• There is a gap in the literature of the HDI describing the relationship between intersection density, which is usually road connectivity metric, and the safety of pedestrians and bicyclists. This suggests further investigation is needed on how to provide high vehicular connectivity for mobility outside and around the neighborhood, while maintaining safety for vulnerable AT road/off-road users within and across the neighborhood. HDI does not consider the effectiveness of any off-road pathway systems that some communities provide to enhance connectivity for pedestrians and bicyclists. Thus, we would suggest simply redefining the metric from that of measuring only vehicles and on-road connectivity, to that of measuring pedestrians/bicyclists and off-road walkways/bikeway connectivity as these are the true avenues of AT.
Performing the analysis required by the HDI would be much easier using Geographic Information System (GIS) programs. In addition, the possibilities of automating the analysis in these programs will significantly shorten the time of the analysis. Unfortunately, few municipalities (even larger and better equipped municipalities) have access to the GIS software and expertise required to perform this level of analysis or to acquire the necessary data.

Caution should be exercised when using HDI as a decision-making tool for AT projects, as several aspects need to be considered when evaluating AT projects (e.g. providing network continuity and access to different land-uses, connectivity for the city-wide AT network, etc.). But nonetheless, with some modification, it could be used for AT projects, by example, adding in more STS principle-related criteria.

Based on the evaluated communities across Canada, it seems that most communities are not promoting health during their land-use and transportation planning. Thus, more research is needed across Canada to identify whether any such ‘healthy ideal’ projects exist. The only community design found to promote healthy lifestyles was the Fused Grid neighborhood development pattern; however, it needs more research based on fully built out communities that have adopted it in Canada. This research showed how the FG model would rate highly using an HDI and STS evaluation tool, and thus it should be emulated and referenced in transitioning from current practices to state of the art practices in both safety- and health-promoting land-use and transportation planning across Canada.
5.3 Limitations and Future Research

This section presents some limitations and recommendations for future research that have been identified during this research as follows:

- Given the limited time and that some of the data were not publicly available, the full set of data required to perform all the analysis in the HDI could not be gathered for all the nine communities. Thus, three of the HDI criteria – Road Network and Sidewalk Characteristics, Parking, and Aesthetics & Human Scale criteria – could not be completed for most of the developments.

- This research reviewed several aspects of the HDI including 1) Its comprehensiveness; 2) Its practical usability; and 3) Its effectiveness, but it didn’t compare the results of the HDI tool score against readily known information of the public health in the evaluated communities. Thus, it is recommended that a cross-sectional study needs to be done on selected communities where information on public health is available. Once selected, the Healthy Development Index would be applied to these communities and the output would be assessed against the information requested from the appropriate cities health and planning departments.

- Combining the HDI evaluation tool with the STS principles would strengthen it as a more comprehensive tool that can look at both land-use and transportation projects. This study presented a proposed combination of the two tools; however, more research is needed to determine the practicality of the I-THRIVE tool, and to evaluate the effectiveness of the proposed criteria in promoting safe AT use.
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Appendices

Appendix A: Surveys Questions

A.1 Survey questions for the Government

Section 1: General Information

1.1) Interviewee:

1.2) Name of organization:

1.3) The type of organization?

☐ Federal
☐ Provincial
☐ Regional
☐ Municipal/City
☐ First Nations
☐ Non-Government Organization

1.4) Province/Territory:

☐ Alberta
☐ British Columbia
☐ Manitoba
☐ New Brunswick
☐ Newfoundland and Labrador
☐ Northwest Territories
☐ Nova Scotia
☐ Nunavut Territory
☐ Ontario
☐ Prince Edward Island
☐ Quebec
☐ Saskatchewan
☐ Yukon Territory

1.5) Does your community have priorities in planning for different means of transportation?
1.5.1) If you yes, can you please rank them? (1 being the highest priority)

___ Automobile
___ Car Share
___ Carpool
___ Trucks
___ Transit
___ Bike
___ Pedestrians
___ other, please specify: ____________________

1.6) Can you please quantify the infrastructure that have been implemented to encourage AT in the community

___ Bike lanes
___ Bike racks
___ Bike lockers
___ Bus bike racks
___ Overpass
___ Sidewalks
___ Greenways
___ Paths
___ Elephants feet
___ other (please specify)

1.7) How does the community prioritize the snow removal? Please rank the following use 1 for the highest priority, and NA if not cleared.

___ Single Occupancy Vehicle (SOV) lanes
___ High Occupancy Vehicle (HOV) lanes
___ Emergency Vehicle Routes
___ Bike paths
___ Sidewalks
___ other, please specify: ____________________

1.8) Please list the Standards and Guidelines used by your community. (ie TAC, MUTCD, CITE)

7.1) Cycling Facility Design:

7.1.1) Urban: ____________
7.1.2) Rural: ____________

7.2) Walking Facility Design:

7.2.1) Urban: ____________
7.2.2) Rural: ____________

1.9) What year did your community start using these manual(s)?

8.1) Cycling: ____________
8.2) Walking: ____________
Section 2: Community Profile

2.1) Percentage of males using active transportation in each age group (Sum=100):
   Children (15-24) : ___
   Youth (25-64) : ___
   Adults (25-64) : ___
   Seniors (over 64) : ___

2.2) Percentage of females using active transportation in each age group (Sum=100):
   Children (15-24) : ___
   Youth (25-64) : ___
   Adults (25-64) : ___
   Seniors (over 64) : ___

What is the number of accidents/incidents (most recent two years)?

2.3) (Year : ______)
   Cyclist: ______________
   Pedestrian: ____________
   Inline Skater: __________
   Skateboarder: __________
   Disabled (scooter, wheelchair, etc): __________
   Vehicles: ____________

2.4) (Year : ______)
   Cyclist: ______________
   Pedestrian: ____________
   Inline Skater: __________
   Skateboarder: __________
   Disabled (scooter, wheelchair, etc): __________
   Vehicles: ____________

2.5) What is the percentage of each type of cyclist?

2.5.1) Based on Risk tolerance:
   _____: Strong and fearless (will ride regardless of road condition)
   _____: Enthused and confident (are comfortable riding on road with automobiles, but prefer to improve facilities)
   _____: Interested but concerned (Like to ride, but afraid to do)
   _____: No way, no how (not going to ride a bicycle)

2.5.2) Based on skill level:
   _____: Beginner (infrequent or new to cycling in the community)
   _____: Novice (starting to ride more)
   _____: Intermediate (semi-regular)
2.6) Purpose of the trips (percentage):

<table>
<thead>
<tr>
<th></th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utilitarian</td>
<td>_______</td>
<td>_______</td>
</tr>
<tr>
<td>Recreational</td>
<td>_______</td>
<td>_______</td>
</tr>
<tr>
<td>Touring</td>
<td>_______</td>
<td>_______</td>
</tr>
</tbody>
</table>

2.7) Does your transit system tie in well with the active transportation efforts (Bus bike rack, etc.)?
   2.7.1) What are the current problems?
   2.7.2) What can be done to make it better?

2.8) Does the provincial/federal government in the area support active transportation infrastructure along highways and between municipalities?
   2.8.1) If yes, please briefly describe those initiatives.

2.9) List name(s) of active advocacy groups and land developers in the city and their activities:

2.9.1)
   - advocacy groups
   - land developers
   Name: _________________________________
   Activities: ____________________________
   Level of involvement ____________________

2.9.2)
   - advocacy groups
   - land developers
   Name: _________________________________
   Activities: ____________________________
   Level of involvement ____________________

2.9.3)
   - advocacy groups
   - land developers
   Name: _________________________________
   Activities: ____________________________
   Level of involvement ____________________

Section 3: Public Attitudes in General in Your Community towards AT

Now we want to find out in general the general attitudes in your community towards AT. Please let me know your sense of how much an average resident would agree or disagree with each of the following statements:

3.1) People in my community WANT to get out more to do more biking and/or walking
   □□□Strongly Agree □□Agree □□Neutral □□Disagree □□□Strongly Disagree

3.2) People in my community NEED to get out more to do more biking and/or walking
3.3) People in my community face MANY barriers to getting out more to do more biking and/or walking.
3.4) People in my community face NO barriers to getting out more to do more biking and/or walking.
3.5) People in my community Consider biking and/or walking as a good mode as driving for Work trips.
3.6) People in my community Consider biking and/or walking as an important mode as driving for Work trips.
3.7) People in my community will Bike/Walk even if other mode of transport are available.
3.8) People in my community feel comfortable when they Bike or Walk.
3.9) People in my community feel safe when they Bike or Walk.
3.10) Having a separated bike lane increases safety and comfort for cyclists
3.11) Bike lanes provide more opportunities for people to be physically active
3.12) Bike lanes are safer for cyclists and motorists
3.13) Bike lanes have made parking more difficult
3.14) Bike lanes have hurt local businesses
3.15) Bike lanes have reduced pollution
3.16) Bike lanes have added value to urban development

☐ Strongly Agree  ☐ Agree  ☐ Neutral  ☐ Disagree  ☐ Strongly Disagree

3.17) Bike lanes are a good use of taxpayers’ money

☐ Strongly Agree  ☐ Agree  ☐ Neutral  ☐ Disagree  ☐ Strongly Disagree

3.18) Bike lanes have increased tourism

☐ Strongly Agree  ☐ Agree  ☐ Neutral  ☐ Disagree  ☐ Strongly Disagree

3.19) On what is your answer based (check all that apply):

☐ Anecdotal evidence
☐ Public surveys
☐ Letters from the public
☐ News coverage
☐ Personal opinion of the interviewee
☐ Other, please specify: __________

Section 4: New AT Infrastructure Case

4.1) Name of Project ________________________

4.2) General description of the project – what new AT infrastructure was built?

4.3) Can you please provide us with any material related to the project? (e.g. project sheets, site plan drawings and photos).

4.4) Where did the idea to introduce this new AT infrastructure come from? Or where did you hear about it?

☐ Conference
☐ Journal reading
☐ Colleague
☐ On-line searching web
☐ Email list serve
☐ News cast, new paper, news media
☐ Hiring new people with new ideas
☐ Going to school/workshop
☐ Webinar
☐ Other, please specify: __________

4.5) Were new infrastructure targeted to a specific AT mode?

☐ walking
☐ cycling
☐ Both
4.5.1) If you selected cycling, please specify which unofficial type of cyclists:
   - Strong and fearless
   - Enthused and confident
   - Interested but concerned
   - No way, no how

4.5.2) Skill level of the cyclists:
   - Beginner
   - Novice
   - Intermediate
   - Experienced

4.6) How long did it take to implement, from the first idea, to the finished project? What were the major project milestones? What year did the project go into service? __________

4.7) Was there any push-back or “lack of support” from any organization, community, etc. to this project? If so, please briefly describe the issues and how they were resolved?
   4.7.1) If there was a lack of support, did it impact the schedule of the project, the final design of the project, or result in the project being scaled back, etc. Please explain:

4.8) Was this project integrated as part of a larger project that was constructed at the same time, or was it a standalone project (for instance, a bike corridor might have been built as part of a new highway corridor)?

4.9) Please indicate the scope of the project (kilometers of bike lane and number of facilities such as bike boxes) What are the percentages of AT users in the community before and after implementing the new project? (Approximations are acceptable). Or just more, less, same?

4.10) Before:
   - Cyclist: ______
   - Pedestrian: ______
   - Inline Skater: ______
   - Skateboarder: ______
   - Disabled: ______
4.11) After:

Cyclist: ______
Pedestrian: ______
Inline Skater: ______
Skateboarder: ______
Disabled: ______

What is the number of accidents/incidents before and after implementing project?

2.12) Before Cyclist: __________________
Pedestrian: __________________
Inline Skater: __________________
Skateboarder: __________________
Disabled (scooter, wheelchair, etc): __________________
Vehicles: __________________

2.13) Before Cyclist: __________________
Pedestrian: __________________
Inline Skater: __________________
Skateboarder: __________________
Disabled (scooter, wheelchair, etc): __________________
Vehicles: __________________

4.14) How is the project(s) funded?
4.15) Is there a maintenance program in place for the project's infrastructure?
4.16) What is/was the Annual cost of operation/maintenance?

4.17) What is the public perception regarding this project?

4.17.1) Comfort Level:
          Cyclist: uncomfortable □ 1 □ 2 □ 3 □ 4 □ 5 comfortable
          Pedestrian: uncomfortable □ 1 □ 2 □ 3 □ 4 □ 5 comfortable
          Inline Skater: uncomfortable □ 1 □ 2 □ 3 □ 4 □ 5 comfortable
          Skateboarder: uncomfortable □ 1 □ 2 □ 3 □ 4 □ 5 comfortable
          Disabled (scooter, wheelchair, etc): uncomfortable □ 1 □ 2 □ 3 □ 4 □ 5 comfortable

4.17.2) Safety:
          Cyclist: Unsafe □ 1 □ 2 □ 3 □ 4 □ 5 safe
          Pedestrian: Unsafe □ 1 □ 2 □ 3 □ 4 □ 5 safe
          Inline Skater: Unsafe □ 1 □ 2 □ 3 □ 4 □ 5 safe
          Skateboarder: Unsafe □ 1 □ 2 □ 3 □ 4 □ 5 safe
Disabled (scooter, wheelchair, etc): Unsafe □ 1 □ 2 □ 3 □ 4 □ 5 safe

4.17.3) Satisfaction:
  Cyclist: Bad □ 1 □ 2 □ 3 □ 4 □ 5 Good
  Pedestrian: Bad □ 1 □ 2 □ 3 □ 4 □ 5 Good
  Inline Skater: Bad □ 1 □ 2 □ 3 □ 4 □ 5 Good
  Skateboarder: Bad □ 1 □ 2 □ 3 □ 4 □ 5 Good
  Disabled (scooter, wheelchair, etc): Bad □ 1 □ 2 □ 3 □ 4 □ 5 Good

4.17.4) Self educating:
  Cyclist: Simple □ 1 □ 2 □ 3 □ 4 □ 5 Complex
  Pedestrian: Simple □ 1 □ 2 □ 3 □ 4 □ 5 Complex
  Inline Skater: Simple □ 1 □ 2 □ 3 □ 4 □ 5 Complex
  Skateboarder: Simple □ 1 □ 2 □ 3 □ 4 □ 5 Complex
  Disabled (scooter, wheelchair, etc): Simple □ 1 □ 2 □ 3 □ 4 □ 5 Complex

4.17.5) Pleasant:
  Cyclist: unpleasant □ 1 □ 2 □ 3 □ 4 □ 5 pleasant
  Pedestrian: unpleasant □ 1 □ 2 □ 3 □ 4 □ 5 pleasant
  Inline Skater: unpleasant □ 1 □ 2 □ 3 □ 4 □ 5 pleasant
  Skateboarder: unpleasant □ 1 □ 2 □ 3 □ 4 □ 5 pleasant
  Disabled (scooter, wheelchair, etc): unpleasant □ 1 □ 2 □ 3 □ 4 □ 5 pleasant

4.18) On what is your answer based (check all that apply):

☐ Anecdotal evidence
☐ Public surveys
☐ Letters from the public
☐ News coverage
☐ Personal opinion of the interviewee (i.e. their gut feel, don’t really know for sure)
☐ Other, please specify: __________

Section 5: Final Remarks

5.1) Are there any future projects that will be implemented to encourage the AT use?
5.2) What policies does the city have related to Active Transportation (If any, kindly send a copy of the policies)
5.3) Overall, how would you assess your system of AT infrastructural – a success, a moderate success, etc. What would you do differently next time, or what advice would you give to others implementing projects similar to this one?
5.4) Based on your experience, would you do anything differently in AT infrastructure to encourage AT use?
5.5) Is the inclusion of AT and other elements of walkability (such as fused grid layouts, higher density) high on
the list of elements to incorporate into new development projects for developers, or driven by government?

5.5.1) If driven by government, are they optional?
☐ ☐ Yes
☐ ☐ No

5.5.2) How is this handled? (Do they comply or challenge request)

5.6) Does altering the design to incorporate them create delay or cause other problems?

5.7) Are governments starting to pass on more of the costs of development to the industry, such as servicing?

5.8) Do you see such elements becoming more common in the industry, or are they a fad?

5.9) Is the public demanding such elements?

A.2  Survey Questions for Developers

Interview questions for land-developers

1) Interviewee:
2) Company name:

3) Province/Territory:
- Alberta
- British Columbia
- Manitoba
- New Brunswick
- Newfoundland and Labrador
- Northwest Territories
- Nova Scotia
- Nunavut Territory
- Ontario
- Prince Edward Island
- Quebec
- Saskatchewan
- Yukon Territory

4) City:

5) What drives the projects in your area please check the boxes that apply?
- Availability of land and market demand
- Nearby existing Transit
- Nearby Green space
- Nearby Bike paths
- Nearby a Shopping Centre
- Density
- Others please specify

6) What is the government’s attitude towards AT infrastructure when a new project is implemented?
7) Does the availability of AT infrastructure attract more homebuyers in the area?
8) In terms of community AT infrastructure what is the main appeal for the homeowners/homebuyers?
9) How does the AT infrastructure drive the market value in the area?
10) Is the inclusion of AT and other elements of walkability (such as fused grid layouts, higher density) high on the list of elements to incorporate into new development projects, or an afterthought?
11) Are the inclusions of these elements driven by government reviews?

11.1) Are the inclusions optional by the government?
11.2) How is this handled? (Comply or challenge it as per the government request)

12) Does inclusion of these elements ever prove problematic, such as reducing the number of units, increasing costs, etc.?

13) Does altering the design to incorporate them create delay or cause other problems?

14) Are governments starting to pass on more of the costs of development to the industry, such as servicing?

15) Do you see such elements becoming more common in the industry, or are they a fad?

16) Is the public demanding such elements, or are they being included only to satisfy requirements from government review agencies?

17) Is there a demand for alternatives to single family homes such as townhomes, apartments, or mixed use developments?

A.3 Survey Questions for the Advocacy groups

Section 1: General Information

1.1) Interviewee:

1.2) Name of Advocacy group:

1.3) Province/Territory:

☐ Alberta
☐ British Columbia
☐ Manitoba
☐ New Brunswick
☐ Newfoundland and Labrador
☐ Northwest Territories
☐ Nova Scotia
☐ Nunavut Territory
☐ Ontario
☐ Prince Edward Island
☐ Quebec
☐ Saskatchewan
☐ Yukon Territory

1.4) City: ________________________________

1.5) For how long have you been advocating Active transportation in the community?

1.6) How many members in the group?

Section 2: Community Profile

2.1) Percentage of males using active transportation in each age group (Sum=100):
   - Children (0-14) : ___
   - Youth (15-24) : ___
   - Adults (25-64) : ___
   - Seniors (over 64) : ___

2.2) Percentage of females using active transportation in each age group (sum=100):
   - Children (0-14) : ___
   - Youth (15-24) : ___
   - Adults (25-64) : ___
   - Seniors (over 64) : ___

2.5) What is the percentage of each type of cyclist?

2.5.1) Based on Risk tolerance:
   - ___: Strong and fearless (will ride regardless of road condition)
   - ___: Enthused and confident (are comfortable riding on road with automobiles, but prefer to improve facilities)
   - ___: Interested but concerned  (Like to ride, but afraid to do)
   - ___: No way, no how (not going to ride a bicycle)

2.5.2) Based on skill level:
   - ___: Beginner (infrequent or new to cycling in the community)
   - ___: Novice (starting to ride more)
   - ___: Intermediate (semi-regular)
   - ___: Experienced (regular rider)

2.5.3) Do you have any document or statistics that support your numbers?
   - ☐ Yes
   - ☐ No

   If yes can you provide us with a copy?

2.6) Does your transit system tie-in well with the active transportation efforts (Bus bike rack, etc.)?

   2.6.1) What are the current problems?
   2.6.2) What can be done to make it better?

Section 3: Public Attitudes in General in Your Community towards AT
Check section 3 in the government survey questions

Section 4: Barriers and support

4.1) Please list the main barriers that the community is/was facing about AT.
4.2) Were any of these barriers addressed?
4.3) How did you address these barriers?
4.4) What is the process for prioritizing the barriers and why?
4.5) How much impact does the advocacy group have in the implementation of AT infrastructure in the city/Jurisdictions?
4.6) What sort of support do you get from citizens, government?

Section 5: Final Remarks

5.1) Are there any future projects that will be implemented to encourage the AT use?
5.2) Overall, how would you assess your system of AT infrastructure – a success, a moderate success, etc. What would you do differently next time, or what advice would you give to others implementing projects similar to this one?
5.3) How would you compare Canada’s AT infrastructure with other countries that have similar climate?
5.4) Based on your experience, would you do anything differently in AT infrastructure to encourage AT use?
## Appendix B Surveyed Cities

### Table 5.1. Surveyed cities

<table>
<thead>
<tr>
<th>City</th>
<th>Government</th>
<th>Land-Developers</th>
<th>Advocacy Groups</th>
</tr>
</thead>
<tbody>
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<td>Canmore</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Calgary</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Cape Breton</td>
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<td>✔</td>
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<td></td>
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<tr>
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<td>✔</td>
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</tr>
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</tr>
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<tr>
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<td></td>
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</tr>
<tr>
<td>Winnipeg</td>
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</tr>
</tbody>
</table>
## Appendix C  AT Infrastructure Inventory

### Table C-155.2. AT Infrastructure Inventory

<table>
<thead>
<tr>
<th>City</th>
<th>Bike Lanes</th>
<th>Sidewalk</th>
<th>Path</th>
<th>Bike locker</th>
<th>Bike rack</th>
<th>Other</th>
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</thead>
<tbody>
<tr>
<td>Chilliwack</td>
<td>160 km</td>
<td>320 km</td>
<td>469 km</td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Montreal</td>
<td>648 km</td>
<td>350 km</td>
<td></td>
<td></td>
<td>4848</td>
<td>Bicycle slides</td>
</tr>
<tr>
<td>Guelph</td>
<td>101 km</td>
<td>678 km</td>
<td>58</td>
<td>45</td>
<td>3000</td>
<td>1 km cycle track, 2.5 km of paved shoulder</td>
</tr>
<tr>
<td>Halifax</td>
<td>107 km</td>
<td>850 km</td>
<td>134 km</td>
<td>34</td>
<td>300</td>
<td>14 km paved shoulder, 6 overpass</td>
</tr>
<tr>
<td>Edmonton</td>
<td>37 km</td>
<td>Over 300</td>
<td></td>
<td></td>
<td></td>
<td>20 km of bicycle boulevard, 15 km of shared use lanes, over 475 km of river valley revain trail, and 100 km signed on road bike routes</td>
</tr>
<tr>
<td>Canmore</td>
<td>80 km</td>
<td>6</td>
<td>76</td>
<td></td>
<td></td>
<td>10 elephant’s feet</td>
</tr>
<tr>
<td>Ottawa</td>
<td>161 km</td>
<td>2175 km</td>
<td>1027 km</td>
<td></td>
<td></td>
<td>167 km paved shoulder</td>
</tr>
<tr>
<td>Cape Breton</td>
<td>7 km</td>
<td>300 km</td>
<td>8 km</td>
<td></td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>City</td>
<td>Distance to Kelowna</td>
<td>Distance to Calgary</td>
<td>Distance to Red Deer</td>
<td>Distance to Kimberley</td>
<td>Distance to Whistler</td>
<td>Other</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------</td>
<td>---------------------</td>
<td>----------------------</td>
<td>----------------------</td>
<td>---------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Kelowna</td>
<td>295 km</td>
<td>400 km</td>
<td>42 km</td>
<td>34 km</td>
<td>360 km</td>
<td>5 km Greenways, 1 overpass, 10 elephant’s feet</td>
</tr>
<tr>
<td>Calgary</td>
<td>26 km</td>
<td>760 km</td>
<td>122 km</td>
<td>800 km</td>
<td></td>
<td>345 signed route, 14 km shared lane, 1.2 km cycle track, and 2000 parking spots in the city.</td>
</tr>
<tr>
<td>Red Deer</td>
<td>12.5 km</td>
<td>100 km</td>
<td></td>
<td></td>
<td></td>
<td>4 km of on street bike routes</td>
</tr>
<tr>
<td>Kimberley</td>
<td>26.8 km</td>
<td>46.2 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whistler</td>
<td></td>
<td>500 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pinawa</td>
<td></td>
<td>28 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moncton</td>
<td>431 km</td>
<td>70 km</td>
<td></td>
<td></td>
<td></td>
<td>120 km Bike routes</td>
</tr>
<tr>
<td>Fredericton</td>
<td>45 km</td>
<td>80 km</td>
<td></td>
<td></td>
<td></td>
<td>39 km of bike routes</td>
</tr>
<tr>
<td>Thunder Bay</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Niagara Falls</td>
<td>12.4 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>46.9 km of paved shoulder, 1.1 km of signed routes, 22.5 km Niagara circle route (Niagara river parkway)</td>
</tr>
<tr>
<td>Toronto</td>
<td>209 km</td>
<td>7100 km</td>
<td>326 km</td>
<td>226 km</td>
<td></td>
<td>15.1 of cycle tracks, 26.2 km of shared lanes, 6.1 km of contra-flow bike lanes, 302 km signed routes, 297 km of multi-use trails, 30,000 parking spots, and 16</td>
</tr>
<tr>
<td></td>
<td>Regina</td>
<td>Whitehorse</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>---------</td>
<td>------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td>1072 km</td>
<td>66 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>34.6 km</td>
<td>104 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td></td>
<td>850 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Appendix D HDI Criteria Scoring

### Table D-15.3. HDI Criteria Scoring

<table>
<thead>
<tr>
<th>Standard</th>
<th>Scoring (Maximum score can exceed 10 for most criteria)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Density</strong></td>
<td></td>
<td><strong>Max possible = 20</strong></td>
</tr>
<tr>
<td>a- Min. residential dwelling density</td>
<td>Part a: 35-44 residential uph (1 credit) 45-64 residential uph (4 credits) 65-84 residential uph (7 credits) 85+ residential uph(10 credits)</td>
<td>Part a: Public ROW is excluded from the area calculation)</td>
</tr>
<tr>
<td>b- Min. Avg Floor Area Ratio (FAR) for (non-residential , mixed-use, multifamily)</td>
<td>Part b: FAR = 0.70-0.80 (1 credit) FAR = 0.81-0.95 (2 credits) FAR = 0.96-1.25 (4 credits) FAR = 1.26-1.75 (6 credits) FAR = 1.76-2.5 (8 credits) FAR &gt; 2.5 (10 credits)</td>
<td>Part b: Area excluding parking facilities and public right of way. Pre-requisite ratio of FAR, which is 0.7, should be achieved by each building not average.</td>
</tr>
<tr>
<td><strong>2. Service Proximity</strong></td>
<td></td>
<td><strong>Max possible = 35</strong></td>
</tr>
<tr>
<td>a- Proximity to a variety of services</td>
<td>Part a: Proximity to Services  • ≥ 75 % of residential units within ≤ 800m of ≥ 13 (1 credit)  • ≥ 75 % of residential units within ≤ 800m of ≥ 16 neighbourhood services* (3 credits)  • ≥ 75 % of residential units within ≤ 800m of ≥ 20 neighbourhood services,* including at least 3 food markets,** and at least 1 park ≥ 1/3 hectare (10 credits)  • 100 % of residential units within ≤ 800m of ≥ 20 neighbourhood services,* including at least 3 food</td>
<td>Prerequisite: 50 % of the number of residential dwelling units as full and part time job must be located within &lt;= 800 m of centre of</td>
</tr>
</tbody>
</table>
Part a: Heterogeneity of LU mix
- ≥ 5% of total community land is outdoor public space (3 points)
- Community provides ≥ 4 new services* to an existing neighbourhood (within a 1 km radius of the community centre) (3 points)
- There is a mix of 3 housing types*, 6 different services*, a public school, and a park ≥ 0.4/ha within 800m of the community centre (5 points)

Max possible = 25
Part b: Heterogeneity of Building mix
• ≥ 60% of commercial buildings include a ground floor pedestrian use along ≥ 60% of their street façades (4 points)
• 100% of mixed-use buildings include ground floor retail, live/work spaces, or residential dwellings along ≥ 60% of their street façade (4 points)
• ≥ 50% of multifamily residential buildings have a pedestrian use on the ground floor (4 points)

Part c: Mixed housing types
• ≤ 30% of housing is large lot detached homes (3 points)
• As above and the community includes ≥ 3 housing types, with none making up less than 20% of the total residential units (5 points)

| 4. Street connectivity | • 75-114 intersections/km² (1 point) | Max possible = 10
| (Intersection density) | • 115-149 intersections/km² (5 points) | Prerequisites:
| | • 150+ intersections/km² (10 points) | Min average int’n density = 75 int’ns / km²
| | | Each block size <= 1.5 hectares (excl parks) |

| 5. Road network and sidewalk characteristics | Part a: Traffic Calming | Max possible = 40
| a- Traffic calming | • 4-6 traffic calming measures*/hectare (1 credit) | Pre-requisites:
| b- Traffic speed and | • 7-10 traffic calming measures*/hectare (3 credits) | Providing at least four traffic calming measures
| | • 11-13 traffic calming measures*/hectare (5 credits) | At least 10% of
| | • 14+ traffic calming measures*/hectare (7 credits) | Each transect must have
| | • 1 or more pedestrian-priority streets/hectare (add 3 points) | ≥ 35% of
| | | pedestrian traffic

140
Part b: Speed Control / Pedestrian Priority
- 10-19% of local roads are ≤ 15km/h with ped-priority (1)
- 20-29% of local roads are ≤ 15km/h (3 credits)
- 30-39% of local roads are ≤ 15km/h (6 credits)
- ≥ 40% of local roads are ≤ 15km/h (10 credits)

Part c: Sidewalks and buffer strips
- Avg sidewalk width ≥ 2.5m on all mixed-use streets (1)
- Buffer strips, curbside parking all roads > 30km/h (3 cr)
- Buffer strips with physical barriers all roads ≥ 50km/h (5)

Part d: Cycle friendly design
- dedicated raised bike lanes, extension of SW (5 credits)
- bicycle-priority streets (cars must yield to cyclists; speed ≤ 30km/h) (5 credits)
- streets that are one-way for cars; two-way for cyclists; speed ≤ 30km/h (2 credits)
- cul-de-sacs with bicycle cut-throughs (2 credits)
- advance green lights for cyclists (1 credit)
- off-street pedestrian and cyclist shortcuts (2 credits)
- right-hand turn short cuts for cycles (1 credit)
- 1 bicycle rack per ten car parking spots (includes on- and off-street spots) (3 credits)

Part e: Lighting
- All mixed-use streets have an average luminance of 10 lux, with a minimum of 5 lux (3 credits)
- Provide ≤ 4.6m tall street lamps spaced no more than
30m apart on both sides of 80% of mixed-use streets (3 credits)
  • Provide ≤ 4.6m tall aesthetically-pleasing (artistically-designed) lamp posts on both sides of 100% of mixed-use ‘core’ streets (2 credits).

<table>
<thead>
<tr>
<th>6. Parking</th>
<th>Part a: Unbundled &amp; Shared parking (Max 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a-</td>
<td>Unbundled and shared parking</td>
</tr>
<tr>
<td>b-</td>
<td>Parking price and difficulty</td>
</tr>
<tr>
<td>c-</td>
<td>Parking location and alleys</td>
</tr>
<tr>
<td></td>
<td>• Provide unbundled parking for 50% of multifamily dwellings (1 credit)</td>
</tr>
<tr>
<td></td>
<td>• Provide unbundled parking for 75% (5 credits)</td>
</tr>
<tr>
<td></td>
<td>• Provide unbundled parking for 100% (7 credits)</td>
</tr>
<tr>
<td></td>
<td>• Allow shared parking so that parking spaces can count towards the requirements of two separate uses, such as a civic building and a restaurant, or a place of worship and an office building (3 credits).</td>
</tr>
<tr>
<td>Part b: Parking price and restrictions (Max 10 credits)</td>
<td>• Charge the market rate* for off- and on-street parking for all mixed-use and retail streets (4 credits)</td>
</tr>
<tr>
<td></td>
<td>• Designated ‘Parking Meter Zones’ - parking revenues go back to the zone for ped-friendly and aesthetic imp’s, such as public art, paving, street furniture, lighting, trees, cleaning, and painting/maintenance (3 credits)</td>
</tr>
<tr>
<td></td>
<td>• Variable parking pricing, so that costs increase with the length of stay, or limit length of stay to ≤ 2 h (2 credits)</td>
</tr>
<tr>
<td></td>
<td>• Max 2-hour on-street parking, or resident-only parking on all streets within 200m of a mixed-use centre (2 credits)</td>
</tr>
<tr>
<td></td>
<td>• Require employers to cash-out non-driving employees when employee parking is free (2 credits)</td>
</tr>
<tr>
<td>Part c: Parking location and alleys (max 10)</td>
<td>Max possible = 30 It is recommended to set maximum parking requirements rather than a minimum.</td>
</tr>
</tbody>
</table>
• All residential driveways* are ≤ 3m wide (2 credits)
• ≥ 70% of residential dwellings have either no parking or access their parking via rear alleys or lanes and have no parking in their front setbacks (4 credits)
• All parking placed at rear or side of buildings (4 credits)
• ≥ 90% of residential lot parking no in front (4 credits)
• On-street parking on both sides of ≥ 70% of new streets, excluding ‘woonerfs’ (2 credits)

<table>
<thead>
<tr>
<th>7. Aesthetics and human scale</th>
<th>Part a: Building height to street width ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>a- Building height to street width ratio</td>
<td>• Avg building height to street-width ratio 1:3 - 1:2.1 (1 credit)</td>
</tr>
<tr>
<td>b- Setbacks and street walls</td>
<td>• Avg height to street-width ratio 1:2 - 1:1.1 (3 credits)</td>
</tr>
<tr>
<td>c- Tree placement and characteristics</td>
<td>• Average height to street-width ratio 1:1 - 3:1 (7 credits)</td>
</tr>
<tr>
<td>d- Outdoor open spaces</td>
<td>Part b: Setbacks and street walls (Max 8 credits)</td>
</tr>
<tr>
<td></td>
<td>• ≥ 80% of commercial struct’s flush to SW/street (3 credits)</td>
</tr>
<tr>
<td></td>
<td>• ≥ 80% of commercial lots that face public space* have clear glass on ≥ 60% of façades, 1-2.4m above grade (3 cr)</td>
</tr>
<tr>
<td></td>
<td>• ≥ 80% of commercial lots do not have blank walls (no doors or windows) longer than 40%, or 15m, of a façade facing a sidewalk, front street, or plaza (2 credits)</td>
</tr>
<tr>
<td></td>
<td>Part c: Tree placement and characteristics (Max 10 credits)</td>
</tr>
<tr>
<td></td>
<td>• ≥ 75% of new and existing residential streets in a community have ≥ 1 tree for every 10m of lot frontage on both sides of the street (4 credits)</td>
</tr>
</tbody>
</table>

Max possible = 25
Prerequisite: Setting requirement for maximum allowable setbacks (e.g. detached residential buildings <=7.6 m)
>=80% of commercial buildings are flush to the sidewalk, having clear glass on 60% of their facades, and limiting black walls
| • \( \geq 75 \% \) of new and existing mixed-use streets have \( \geq 1 \) tree for every 10m of lot frontage, both sides of street (4 credits) |
| • \( \geq 75 \% \) of streets with a speed limit of \( \geq 50 \text{km/h} \) have \( \geq 1 \) tree for every 10m of lot frontage on both sides of the street, trees placed between the sidewalk & road (4 credits) |

Part d: Outdoor open spaces (Max 0 credit)

• Communities give \( \geq 5 \% \) of land to public outdoor spaces, such as parks and plazas (0 credits)
Appendix E  Other Indices Measures

\[ IRS = F \times DS \]  \hspace{1cm} \text{Equation (1)}

Where:

\( F = \) frequency of transit

\( DS = \) 

\[ \begin{cases} 
1, & \text{if the distance between the intersection and the route stop} < 0.25 \text{ mile} \\
0.9, & \text{if the distance between} 0.25 - 0.49 \text{ mile} \\
0.75, & \text{if the distance between} 0.5 - 1.0 \text{ mile} 
\end{cases} \]

\[ M_i = \frac{\sum_{i=1}^{n} (D_i + \sum_{a=1}^{n} D_a)}{\sum_{i=1}^{n} (U_i + \sum_{a=1}^{n} U_a)} \]  \hspace{1cm} \text{Equation (2)}

Where:

- \( M_i = \) Use Mix at cell “i”.
- \( U_i = \) Uses at cell “i”
- \( U_a = \) Uses at adjacent cell “a”
- \( D_i = \) Uses at cell “i” dissimilar to any uses at the same cell
- \( D_a = \) Uses at adjacent cell a dissimilar to uses at cell “i”
Table E-1. INDEX travel elements indicators

<table>
<thead>
<tr>
<th>Indicator name</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Internal Street Connectivity</strong></td>
<td>$\frac{I}{C+I}$ Where ${I = \text{number of intersections} }$</td>
</tr>
<tr>
<td>recommended: 0.7-0.9</td>
<td>${C = \text{number of cul de sacs} }$</td>
</tr>
<tr>
<td><strong>External Street Connectivity</strong></td>
<td>Average distance between ingress/ egress roads of the community</td>
</tr>
<tr>
<td>(Recommended: &lt;500 ft.)</td>
<td></td>
</tr>
<tr>
<td><strong>Street Segment Length</strong></td>
<td>$\frac{\sum L_s}{N}$ Where ${L_s = \text{length of one street segment} }$</td>
</tr>
<tr>
<td></td>
<td>${C = \text{number of segments} }$</td>
</tr>
<tr>
<td><strong>Street Network Density</strong></td>
<td>Total street segments length per area</td>
</tr>
<tr>
<td>(15-40 mi/mi²)</td>
<td></td>
</tr>
<tr>
<td><strong>Intersection Density</strong></td>
<td>Number of intersections per area</td>
</tr>
<tr>
<td>(200-400 intersection/mi²)</td>
<td></td>
</tr>
<tr>
<td><strong>Street Network Extent</strong></td>
<td>Total street segments length per 1000 residents</td>
</tr>
<tr>
<td><strong>Street Route Directness</strong></td>
<td>$\frac{\sum_p \frac{Dnp}{D_{ip}} \times (R_p \times E_p)}{\sum_p (R_p \times E_p)}$</td>
</tr>
<tr>
<td>(recommended: &lt;1.5)</td>
<td>Where:</td>
</tr>
<tr>
<td></td>
<td>$D_{np} = \text{actual distance on the street network from the reference}$</td>
</tr>
<tr>
<td></td>
<td>$D_{ip} = \text{Linear Distance from the reference to the selected node}$</td>
</tr>
<tr>
<td></td>
<td>$R_p = \text{Number of the Residents for the parcel}$</td>
</tr>
<tr>
<td></td>
<td>$E_p = \text{Number of employees for the parcel}$</td>
</tr>
</tbody>
</table>
### Table 55.5. Galster (2001) Sprawl Index

<table>
<thead>
<tr>
<th>Indicator name</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Density</strong></td>
<td>Number of residential dwelling units or number of jobs per square for each one square mile grid</td>
</tr>
<tr>
<td><strong>Concentration:</strong> The degree to which urban area is evenly developed (low concentration pattern is more sprawl-like)</td>
<td>Percentage of high density grids of all grids in the Urban Area (high density grid is two or more standard deviation above the mean)</td>
</tr>
<tr>
<td><strong>Clustering:</strong> The degree to which developments are evenly distributed within each grid.</td>
<td>$CLUS(i)u = \frac{\sum_{m=1}^{M} \sqrt{\left(\sum_{s=1}^{S} [D(i)s - D(i)m]^2 / 4\right)}}{\sum_{m=1}^{M} (D(i)m / M)}$</td>
</tr>
<tr>
<td><strong>Centrality:</strong> The degree to which residential units and jobs are close to the central business district (Low values, indicate more sprawl-like).</td>
<td>$\text{CBDDIST} = \frac{T(i)u \times (\sqrt{A})}{\sum_{m=1}^{M} T(k,m) \times T(i)m}$ $\text{CEN}(j)u = \frac{\sum_{h=1}^{H} [T(j)h - 1][Ah]}{\sum_{h=1}^{H} [T(j)h][Ah - 1]}$</td>
</tr>
</tbody>
</table>
| **Nuclearity:** The degree to which an urban area is characterized by a Mononuclear pattern. | 1. Locate the highest density grid (nucleus 1).  
2. Add to it the adjacent grid within one standard deviation density, as well as the nodes adjacent to the added nodes to nucleus c.  
3. Recalculate the density for nucleus 1.  
4. Add the grids that are within one standard deviation within one standard deviation, but not adjacent to nucleus 1, to form new nuclei, n.  
Degree of polynuclearism = Total number of nuclei  
Degree of mononuclearity = $\frac{T(i)c}{T(i)c + \sum_{n=1}^{N} T(i)n}$ |
| **Proximity** | • The average distance between randomly chosen grids of different land-use.  
• The average distance between randomly chosen grids of the same land-use. |
| **Parameters:** | |
i = Same type of land-use
j = Different type of land-use
u = largest grid scale
m = medium grid scale

$T(i)u$ = the total number of observations (population) of land-use i in Urban Area u.
$T(i)m$ = the total number of observations (population) of land-use i in land area m

A = Total developable land area.

$D(i)m$ = the density of land-use i over the developable area in m

$D(i)s$ = the density of land-use i over the developable area in s

$F[k,m]$ = the distance between the centroids of grid k and grid m.
Appendix F HDI Evaluation Summary

AT Corridors

Brampton, Ontario
Rutherford Street North and Centre Street North traffic Calming

Density
The community around the project does not meet the minimum residential density prerequisite, with a density of 31 dwellings/ha. This may be because most of the lots in the study area are low residential areas (single detached dwelling), while the rest of the residential lots are classified as medium density.
The credits earned for this element is 0.

Service Proximity
The community around Rutherford Street North and Centre Street North traffic calming project exceeds the prerequisite requirements of proximity to a variety of public and retail services. A hundred percent of the residential units are located within 800m buffer of public services, and 96 percent of the units are within 800m buffer of retail services. This community received three credits in proximity to a variety of services measure, and ten credits in proximity to transit since 95 percent of the residential units are within 400m of suitable transit stop.
The credits earned for this element = 13

Land-use Mix
Almost 9 percent of the total community land is outdoor public spaces. In addition, the community provides three housing types (detached, semi-detached and town houses). The community has two commercial with pedestrian access along their facades.
The credits earned for this element = 7

Street Connectivity
This community does not meet the requirements of intersection density and block size as it scores 55 intersections/km² and 80 percent of the blocks are larger than 1.5 ha. This might be because the cul-de-sacs street patterns implemented in the community. Some of the large blocks do however include pedestrian walkways which help reducing the impact of large blocks.

The credits earned for this element = 0

Summary
The overall HDI score is 20, based on the four of seven criteria for which data was available to measure. Land zoning was the main drawback of the neighborhood to achieve high in the HDI. Most of the lots in the neighborhood are classified as low residential areas which limits the density and number of neighborhood retail services.

City of Cambridge, Ontario - Bikeway Projects

Density
The net developable area for this community is 81.225 hectares for the community around the Franklin street project (Part A) and 38.465 hectares for the community around the Ellis street project (Part B). In project Part A, the total number of units is 1106. Therefore, the net residential dwelling density for Part A is 13.616 units/ha while Part B has 466 units, and a net residential dwelling density of 12.1 units/hectare. Neither of these achieves the prerequisite minimum density.

The credits earned for this element = 0

Service Proximity
The community around the Ellis Street Project does not meet the prerequisite requirement of proximity to a variety of services as less than 75 percent of the residential units are within 800m of retail services. The Franklin Street community is served by many public services including parks and childcare. A hundred percent of the residential units are within 800m of
public services. In addition, almost 100 percent of the residential units are within 400m of public transit stop.
The credits earned for this element = 0

The community around Franklin Street meets the prerequisite of proximity to variety of services and it gets 1 credit as ≥ 75 percent of residential units within 800m of at least 13 neighborhood services. In addition, it gets 10 credits as 100 percent of the residential units are within 400m of a suitable transit stop.
The credits earned for this element = 11

Land-use Mix
In these communities, more than 5 percent of the total area is outdoor public space. Approximately 70 percent of commercial buildings include ground floor pedestrian use along over 60 percent of their street façades. Over half of the housing includes large lot attached houses. For Part A, there are 3 types of housing (detached house, townhouse and apartment), but apartments make up over 20 percent. For Part B, only one type of housing (detached houses) is present.
The credits earned for this element = 10

Street Connectivity
The average number of intersections for Parts A and B are 31.5 and 45.6 intersections /km² respectively. The numbers are less than the minimum average intersection density of 75 intersections/km². For both Parts A and B, min block size exceeds 1.5 hectares which does not meet the prerequisite of intersection density or block size.
The credits earned for this element = 0

Aesthetics and Human Scale
Most of the residential structures in the community have 7.6m building setbacks or greater. Therefore, it does meet the prerequisite for this element. However, no data was available to evaluate this metric.
The credits earned for this element = NA due to lack of data
Summary
The overall HDI score for these neighborhoods is 21 based on five of the seven criteria for which data was available. Difficulties were encountered in determining the catchment area to be analyzed as the two projects serve a large community. In addition, the community does not meet the street connectivity criteria, but as opposed to the community around Rutherford Street North, it does not provide AT cut-throughs to provide high connectivity for AT users.

Hadden Park Bike path, Vancouver, British Columbia

Density
The community around the proposed Hadden Park Bike Path just falls short of the minimum density requirement, with an average density of 34 units/ha.
The credits earned for this element = 0

Service Proximity
The community around the trail in Hadden Park meets and exceeds the prerequisite of proximity to variety of services. The community is served by at least 25 neighborhood services including at least 8 food services. Also, 94 percent of community is within 800 m of a suitable transit stop.
The credits earned for this element = 25

Land-use Mix
Twelve percent of the community land is outdoor public area. The community also has a variety of services including a hospital, childcare, a school, restaurants, a museum, and a post office. It consists of at least three housing types (single family, detached, and apartments).
The credits earned for this element = 3 credits

Street Connectivity
The community around Hadden Park meets and exceeds the prerequisite requirement of street connectivity. The average intersection density in the community is 123 intersections/
km². In addition, all of the blocks in the community are less than 1.5 ha, except for Tatlow Park which has trails through it to enhance AT.
The credits earned for this element = 5

Summary
Hadden Park achieves an overall HDI score of 33, based on 4 of 7 criteria for which data could be found. In addition, none of the three communities analyzed so far could achieve the minimum net residential dwelling density. This suggests that health was not considered as a primary factor when designing neighborhoods in Canadian cities.

Finch Hydro Corridor Trail, Toronto, Ontario

Density
The total area of the Finch bike path development is approximately 108 hectares and total number of units is 5739. The net residential dwelling density is approximately 53 units/hectare.
The credits earned for this element = 5

Land-use Mix
Over 10 percent of the land is outdoor service. Most of commercial and mixed use buildings within the community include a ground floor pedestrian access along > 60 percent of their street façades.
The credits earned for this element = 11

Proximity to services
The community around the trail in Finch Hydro Corridor Trail meets and exceeds the prerequisite of proximity to variety of services. More than 80 percent of the residential units in the community are within at least 16 retail and public services. In addition more than 75 percent of the units are within 400 m of bus stops.
The credits earned for this element = 13
Street Connectivity
The average intersection density of this development is about 85.2 intersections/km², which meets the first part of the prerequisite for street connectivity. However, the single block size can exceed 1.5 hectares in some area. Therefore, the development does not achieve any credit in this section.

The credits earned for this element = 0

Summary
Overall, this project achieves a HDI score of 32 out 63, based on 4 of 7 criteria for which data was available. The community around Finch hydro trail could improve its score by providing more high density and mixed land-use zones as most of the community is classified as low density residential zone, which could improve both the density and proximity to services elements score.

Development

Collingwood Village, Vancouver, British Columbia
(Canada Mortgage and Housing Corporation, 2009)

Density
Collingwood village exceeds the prerequisite requirement of minimum density. It consists of 2700 units within 16 buildings on 11.3 hectare, with gross residential density of 239 units/ha. This is because the high-rise apartment buildings up to 26 stories.

The credits earned for this element = 10

Service Proximity
Collingwood village exceeds the prerequisite requirement of proximity to a variety of services. It has many amenities including a neighborhood house, community policing, and daycares. One hundred percent of the community is within an 800m buffer of public services and retail stores. This includes at least 3 food markets and a park as specified in the index. But even with these impressive statistics, it appears that it hasn’t been completely successful in encouraging less driving and more walking as 6 percent of the residents surveyed reported
less driving than before, with none reporting more walking than before (Canada Mortgage and Housing Corporation, 2009). In addition, all the residential dwelling units in the community are within 400 m of a suitable bus stop.
The credits earned for this element = 25.

Land-use Mix
Almost 25 percent of the community land is used as outdoor public spaces. The development provides 2 housing types; townhouse and apartments. Also it provides a variety services such as grocery store, drug store, Community Centre, public school, policing centre, and day care.
The credits earned for this element = 9.

Street Connectivity
Collingwood village meets the minimum average intersection density, but it does not meet the maximum single block size prerequisite. The average intersections density in the community is 124 intersections/km², where the blocks sizes at Collingwood Village vary from small blocks to large blocks, 28 percent of the blocks in the community exceeds 1.5 ha. This might affect the connectivity for cars, but the cut-throughs in the blocks help reduce the effects on AT movements. So while there is good AT connectivity, the street connectivity by virtue of excessively large block size is rated at zero.
The credits earned for this element = 0

Summary
Overall HDI evaluation score is 44, based on 4 of 7 criteria for which data were found. It seems that some HDI criteria are not appropriate to be applied to small developments, in terms of developed area, such as Collingwood. One of these criteria is the variety of housing types’ requirement. Also, while AT connectivity is very good and health-promoting, the stricter HDI street connectivity/intersection density criteria gave it a zero, which is a bit misleading regarding the health-promoting traits of this development.
Garrison Woods, Calgary, Alberta
(Canada Mortgage and Housing Corporation, 2004)

Density
Garrison Woods consists of 1600 units over approximately 42 hectare of developable land, with a net residential density of 38 units/ha. Garrison wood was one of the most densified communities when it was developed in 1998; the average gross density in the surrounding communities at that time was 10-15 units/ha compared to 25units/hectare in Garrison wood. This encouraged the surrounding communities to increase their density using infill houses. The credits earned for this element = 10.

Service Proximity
Garrison Woods meets and exceeds the prerequisite of proximity to a variety of services. Eighty-three percent of the residential dwellings are within an 800m buffer of 5 public services, and 100 percent of retail services. In total, 100 percent if residential dwelling units is within 800 m buffer of 20 neighborhood services including 3 food markets and park. Also, 100 percent of the residential units are within 400 m of suitable bus stop. The Garrison Woods development also returns the life to a historical shopping street. The 33 Avenue (Marder loop) was a historic shopping street that served the military base and the surrounding communities. When the military decided to close the base and move to Edmonton, many shops went out of business on that street. As Garrison Woods was developed, the retail opportunities returned to the area allowing Garrison Woods to extend the shopping street, adding more retail stories. The credits earned for this element = 25.

Land-use Mix
Almost 7 percent of the community land are outdoor public services. These areas are well distributed throughout the community so almost all of the residential dwellings are within walking distance of an outdoor public space. The development includes different housing types such as detached houses, semidetached, townhouses, apartments, and couch houses (laneway housing and second dwellings on a single lot above a garage). Almost 40 percent of these houses are single family, where the rest are multi-family. Four hundred of these houses
were military housing units which have been relocated and refurbished to meet new density targets. The community provides different services such extended care, childcare, and public school.

The credits earned for this element = 3

Street Connectivity
Garrison Woods meets and exceeds the prerequisite of average intersection density with an average of 137 intersections/km². Modified grid street pattern was used to eliminate non-residential traffic, slow down traffic, and to enhance AT by providing paths throughout the green public areas as 20 percent of the intersections are between multi-use paths and roads. Also on-street parking was used as a calming measure for vehicles. Garrison Woods also meets the prerequisite of minimum block size, as all the blocks in the community have area less than 1.5 ha.

The credits earned for this element = 5.

Summary
The Overall HDI for Garrison Woods is 43 or 63 based on 4 of 7 criteria for which data was available. Garrison Woods illustrates a successful example on how communities can be redesigned to support healthier life style; it has high density, high proximity to services, and high street connectivity with paths through green spaces to enhance AT.

Village de la Gare, Mont-Saint-Hilaire, Montreal, Quebec

Density
The density of the Village de la Gare is approximately 25 units/hectare. It does not meet the prerequisite of minimum 35 unit/hectare.

The credits earned for this element = 0.

Service Proximity
The Village de la Gare development does not meet the minimum prerequisites requirement for proximity to a variety of services.
The credits earned for this element = 0

**Land-use Mix**
Nearly 15 percent of the land area includes parks and public open space. All the mixed-use buildings have ground floor retail, live/work spaces, or residential dwellings along over 60 percent of their street façade. Most of the houses are large lot detached homes.
The credits earned for this element = 11

**Street Connectivity**
The Village de la Gare have block sizes that exceeds 2 hectare, therefore, it does not earn any credits from this section.
The credits earned for this element = 0

**Summary**
Overall HDI is 11 out 63 based on 4 of 7 criteria for which data was found. Village de la Gare seems to be pure residential development that is not well served by retail and public services. In addition, the Loops & Lolly-pop street pattern of the neighborhood provide a low vehicular and AT connectivity.

**Saddlestone, Calgary, Alberta**

**Density**
The Saddlestone development does not meet the meet the minimum density prerequisite. The total developable area is 35.25 hectares. With 1001 units, the net residential dwelling density is 28 units/ha. This is because most of the housing type is single family housing with few multi-family houses.
The credits earned for this element = 0.

**Service Proximity**
Saddlestone meets the requirement of the prerequisite of proximity to a variety of services. A hundred percent of the community is within 800 m of 5 public services and 7 retail
services. It gets 3 points for proximity to a variety of services as 75 percent of residential units are within 800m of the 16 neighborhood services. In addition, more than 80 percent of residential units are within 800m of a transit stop.

The credits earned for this element = 13.

Land-use Mix
The outdoor public space in Saddlestone is around 6 hectares which is over 5 percent of total community land.

The credits earned for this element = 3.

Street Connectivity
Saddlestone barely failed the minimum average intersection density with an average of 74 intersections/km². It should be noted that it satisfied the maximum single block size of 1.5 ha.

The credits earned for this element = 0.

Summary
The Saddlestone overall HDI is 16, based on 4 of 7 measured criteria. Saddlestone could have achieved higher results for proximity to services if it had more food markets serving the community and transit stops. In addition, the community needs to include more high density-mixed use buildings to achieve higher score in the density and land-use mix elements. The information about this community was difficult to find as the project is still under development.

Sage Creek, Winnipeg, Manitoba

Density
Sage Creek does not meet the minimum density prerequisite with a density of only 17 units/ha. The total planned developable area so far is 91 ha with an approximate 1527 residential dwelling units.

The credits earned for this element = 0.
Service Proximity
For Sage Creek, two type of analysis were conducted for the proximity of services. Both a buffer analysis and network analysis for the pedestrian walkways were completed. Though the street network data was available for Sage Creek to evaluate the service proximity based on the shortest walking path, the buffer analysis was conducted as well to be consistent with the other projects. Sage Creek fails the prerequisite for the proximity of services using both methods because the majority of services are concentrated in the village centre, which is located at the edge of the development. This still can be overcome by developing more mixed-use land in the unplanned area. The following table show the results obtained from the analysis.

Table F-1. Difference in results between the buffer and the network dataset methods

<table>
<thead>
<tr>
<th></th>
<th>Buffer</th>
<th>Network Dataset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of units within 800m of 5 neighborhood public services</td>
<td>18 %</td>
<td>0 %</td>
</tr>
<tr>
<td>Percentage of units within 800m of 7 neighborhood retail services</td>
<td>38 %</td>
<td>21 %</td>
</tr>
</tbody>
</table>

It should be noted that the development has not been completed yet. Many services and retail shops are expected to be added to the community.
The credits earned for this element = 0.

Land-use Mix
Over 6 percent of the land is reserved for outdoor public space which meets the first target of heterogeneity of land-use mix. There are attached, detached and multifamily housing units within the community with over 6 services, 2 public schools and parks within 800m of community centre. It satisfies the third target of heterogeneity of land-use mix. Most of the multifamily residential buildings have commercial service or public service on the ground floor. Only a small amount of housing is large lot detached homes. Each type of housing makes up over 20 percent of the total residential units.
The credits earned for this element = 20.
Street Connectivity

Sage Creek does not meet the prerequisite for the street connectivity with an average 35 intersection/km². However, it should be noted that the community is designed to provide more connectivity for AT users rather than motorized users through providing a system of trails in the community. The credits earned for this element = 0.

Summary

Overall HDI = 20 based on 4 of 7 criteria measured. Sage Creek could not meet the minimum requirements for proximity to services, though it has lots of retail and public services. This suggests that choosing a more centric location that provides easy accessibility for all the community is important to achieve a higher HDI score and promote healthy AT activity.