BC Sprawl Report

Walkability and Health

2009

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Contents

List of Tables and Figures

Tables

Figures

Executive Summary

Introduction

This report is the third in Smart Growth BC's Sprawl Report series and focuses on how the physical design of neighbourhoods affects walking and biking in BC's communities, and whether this has any impact on individual health. Smart growth is about creating more compact, complete, walkable communities that encourage and facilitate walking and more physically active and healthy lifestyles. By raising awareness of the health implications of our land use decisions and promoting smart growth planning principles and practices, Smart Growth BC hopes to assist municipalities, developers and health organizations to build communities that are more walkable and less automobile dependent, therefore promoting healthy living.

It has been acknowledged that physical inactivity is an important contributor to the prevalence of overweight and obesity in Canada. Creating more walkable, less automobile dependent communities through land use planning policies can contribute to decreasing the incidence of obese and overweight Canadians and British Columbians (HSFC, 2007, PHSA, 2007). Given that the lack of physical activity has been shown to be a leading risk factor attributed to a number of health problems such as heart attacks, strokes, hypertension and diabetes, increasing the rate of active transportation has also potential to lead to broader public health benefits.

Many health professionals now acknowledge that urban planning policies have important effects on physical activity patterns and ensuing population health outcomes (e.g., Bray et al., 2005). Some experts in the field also believe that the greatest contribution to physical activity levels among sedentary individuals will have to come from modest intensity activities such as walking and bicycling (e.g., Frank et al., 2003).

Urban planning practices can significantly influence the factors that contribute to peoples' decision to walk or bicycle. For example, when everyday destinations such as grocery stores, post offices and daycares are placed near or within residential areas, people are encouraged to adopt active transportation options (walking or wheeling), rather than drive or be driven. Higher densities can provide the local market needed to support shops and services in the neighbourhood, and to build ridership for better quality transit (which in turn encourages walking to and from transit stops). Likewise, when streets are designed to reduce traffic speeds and make routes pleasant for pedestrians and bicyclists (e.g., shorter blocks, sidewalks, and a grid street pattern instead of crescents and dead-ends), many people will adopt active forms of transport. Together, these and other design features can contribute to the "walkability" of a neighbourhood.

A review of the scientific literature reveals a statistically significant relationship between physical environment variables and the incidence of walking (e.g., Handy, 1996; Handy et al., 2004; Cervero and Radisch, 1996; and Craig et al. 2002). In particular, land use mix, residential and employment density at trip origins and destinations, the attractiveness of streetscapes, and street connectivity were commonly found to have a positive influence on people's walking rate.

Several studies reviewed showed that Body Mass Index BMI and obesity were positively associated with sprawling communities characterized by low densities and homogenous land uses (Saelens et al., 2003b; Lopez, 2004; Frank et al., 2004). There is also evidence that the built environment has an impact on the incidence of hypertension (Ewing et al., 2003). There is much evidence in the medical literature that physical activity in general and walking in particular can reduce the incidence of diabetes, but there is little evidence directly linking urban form to the incidence of diabetes in resident populations. Most of the literature cited in the review was carried out in the US. While land use and travel patterns in Canadian cities are comparable to those of US communities, more empirical research is needed in Canada to corroborate the US findings. The present study is a contribution to meeting this need.

Methodology

This empirical part of the report explores the relationship between urban form, walking and health outcomes in neighbourhoods across BC. A major source of data was the Health and Wellness Survey conducted in the spring of 2006 by the BC Provincial Health Services Authority (PHSA, 2007).[1] The survey was designed to collect data and gather information on the behavioural determinants of health (e.g., exercise levels, dietary habits, tobacco and alcohol use) at the local or community level. Data was collected through telephone interviews from adult residents (one per household) in 26 Local Health Authorities or communities across the province. We obtained individual records from this database, sorted by census dissemination area (DA), which is the smallest geographic unit used for census reporting.

Our study units were defined as neighbourhoods rather than whole municipalities in order to allow us to look at relatively homogenous urban forms and reduce the complexity of the data gathering task. We chose 16 neighbourhoods from 16 different municipalities covered in the PHSA study. Of the 10,485 individuals who responded to the PHSA survey, 2,731 are in our 16 sample neighbourhoods.

Table 1 lists the municipalities and the summary statistics of their study neighbourhood, including the municipal population, neighbourhood population, and the neighbourhood area.

1 Individual names, addresses and postal codes were not included in order to protect the confidentiality of the respondents.

Table 1: Study municipalities and neighbourhood descriptions

	Municipality	Municipal Pop 2006	Neighbourhood Pop 2006	Neighbourhood Area (sq km)
A	Creston	4,944	1,715	1.44
B	Fernie	4,217	780	3.22
C	Fort Nelson	4,514	1,200	1.22
D	Golden	3,811	970	0.96
E	Hope	6,185	1,385	2.20
F	Invermere	3,002	705	1.79
G	Mackenzie	4,539	1,325	0.97
H	New Westminster	58,549	2,520	0.73
I	Port Hardy	3,822	2,010	1.28
J	Port Moody	27,512	2,905	1.73
K	Prince Rupert	12,815	2,845	1.72
L	Richmond	174,461	6,370	1.55
M	Smithers	5,217	495	0.75
N	Tofino	1,655	605	2.40
O	Valemount	1,018	260	0.79
P	Vancouver	578,041	10,280	1.30

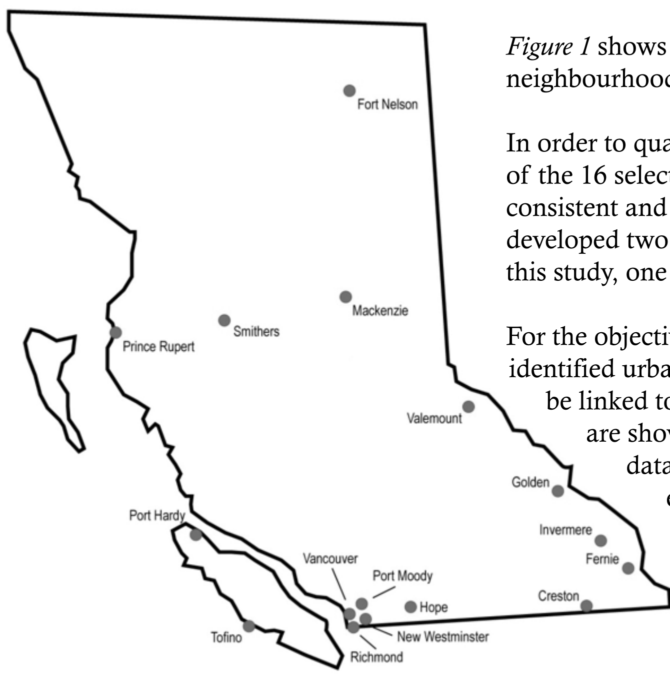

Figure 1: Location of Municipalities

Figure 1 shows the relative location of the neighbourhoods included in the study

In order to quantify the walkability of each of the 16 selected neighbourhoods using a consistent and comprehensive framework, we developed two walkability indices for use in this study, one objective and one subjective.

For the objective walkability index, we identified urban form variables thought to be linked to walking incidence. These are shown in *Table 2*, along with the data sources and a definition for each variable. Data sources included aerial photos, the 2006 Canadian census, and GIS maps from third party providers such as DMTI Spatial Incorporated.

Table 2: Variables in the objective walkability index

	Variable	Data Source	Definition
1	Net population density	2006 census and GIS maps	Number of people living in the neighbourhood per sq km of residential land
2	Street connectivity	GIS maps	Percent of intersections that have three or more streets intersecting
3	Intersection density	GIS maps	Number of intersections per sq km
4	Land use mix index	GIS maps	An index that reflects diversity of land types, varies between 0 (homogenous) and 1 (balanced mix)
5	Access to parks and green space	GIS maps	Straight line distance to the closest major green space from the neighbourhood centroid, in metres
6	Housing mix index	2006 census	An index that reflects diversity of housing types, varies between 0 (homogenous) and 1 (balanced mix)
7	Sidewalks	aerial photos	Percentage of streets with no sidewalks
8	Setbacks	aerial photos	Average distance from curb to front of house, in metres
9	Street widths	aerial photos	Average width of streets from curb to curb, in metres
10	Block lengths	GIS maps	Average block length, in metres

The data for the subjective walkability index were drawn entirely from the PHSA survey responses. The PHSA survey included a set of questions on the respondent's assessment of the neighbourhood environment, BMI and health indicators, as well as socio-demographic questions such as gender, age and income. We used the questions on the neighbourhood environment to create a subjective walkability index. Responses to those questions from individuals in each neighbourhood were used to score each neighbourhood. *Table 3* presents a list of variables used in creating the subjective index.

Table 3: Variables in the subjective walkability index

	Variable
1	Prevalent housing type
2	Shops, stores, markets are within walking distance
3	Home is within a 10-15 minutes walk to a transit stop
4	Sidewalks on most of the streets in the neighbourhood
5	Facilities to bicycle in or near the neighbourhood
6	Neighbourhood has several free or low cost recreation facilities
7	Crime rate in the neighbourhood makes it unsafe to walk at night
8	Traffic on the streets makes it difficult or unpleasant to walk
9	Many people being physically active can be seen in the neighbourhood
10	Many interesting things to look at while walking in the neighbourhood

This report seeks to determine the influence of urban form (the independent variable) on walking and health outcomes (the dependent variables). In addition to the questions it contained on urban form (which we used to create the subjective walkability index), the PHSA survey also collected information on walking activity and health. In terms of walking, the survey asked respondents to estimate the number of days they had walked for more than 10 minutes over the last seven days. In terms of health, respondents were asked for their weight and height (from which we calculate Body Mass Index) and whether they had hypertension or diabetes.

A series of regression models were estimated to determine the impact of neighbourhood urban form on walking and health. The walkability indices for each neighbourhood were included as independent variables, whereas dependent variables were walking levels, BMI, diabetes, and hypertension. The analysis controlled for some other factors that could influence walking and health outcomes, such as income, age and gender.

Finally, case studies were carried out in three municipalities drawn from the 16 included in the empirical part of this study: the City of Vancouver, the City of Port Moody and the District of Invermere.

Table 4: Summary of correlation analysis

	Subjective index	Objective index	Walking	BMI	Hypertension	Diabetes
Subjective index		+/99%	+/99%	-/99%	not sig	not sig
Objective index	+/99%		+/99%	-/99%	-/95%	not sig

+ = positive correlation - = negative correlation
99% = correlation significant at 99% confidence level
95% = correlation significant at 95% confidence level
not sig = correlation not significant

While the correlation analysis reveals that walkability is statistically associated with more walking, lower BMI, and lower hypertension, it does not allow us to conclude that walkability has a causal influence on these outcomes. Some other factor or set of factors may explain why people who live in more walkable neighbourhoods tend to walk more, have lower BMIs and lower levels of hypertension. In order to control for or eliminate the effect of these variables on the observed correlations, we undertook a regression analysis.

In our regression models, the walkability indices for each neighbourhood were included as independent variables, whereas dependent variables were walking levels, BMI, diabetes, and hypertension. The analysis controlled for several factors that could influence walking and health outcomes, i.e., income, age and gender.

The regression analysis confirmed the relationship between the walkability indices and walking, even when controlling for gender differences, age, and income. The relationships were statistically significant, allowing us to conclude that urban form, as measured through our walkability indices, is correlated with changes in walking behaviour in the 16 sample neighbourhoods. In short, people living in more walkable neighbourhoods, regardless of age, income or gender, are more likely to walk for at least 10 minutes on a daily basis than those living in less walkable neighbourhoods.

The statistical analysis also indicates a relationship between urban form and the incidence of obesity in the 16 study neighbourhoods. Thus, even when controlling for age, income, and gender, we can conclude that an increase in walkability correlates with a decline (albeit small) in the odds of being obese or overweight. These findings are consistent with those in the wider literature.

Similarly, we found that the odds of suffering from hypertension decline with an increase in the **objective** walkability index, all else being equal. However, the empirical models did not reveal a statistically significant correlation between the **subjective** walkability index and the odds of suffering from hypertension. Also insignificant is the correlation between diabetes and the two walkability indices, suggesting that diabetes may not have a direct correlation with the walkability of a neighbourhood. *Table 5* summarizes the findings from the regression analysis.

Table 5: Summary of regression analysis

	Walking	BMI	Hypertension	Diabetes
Income	not sig	+/ 95%	-/95%	-/95%
Age	-/99%	+/ 99%	+/99%	+/99%
Female	not sig	-/ 99%	not sig	not sig
Subjective index	+/99%	-/ 99%	not sig	not sig
Objective index	+/99%	-/ 99%	-/ 99%	not sig

+ = positive correlation
- = negative correlation
99% = correlation significant at 99% confidence level
95% = correlation significant at 95% confidence level
not sig = correlation not significant

Case Studies

The empirical analysis provided evidence of a connection among walkability, walking behaviour, obesity, and hypertension. In this section, we examine walkability in specific community contexts. Three case studies are presented on municipalities drawn from the 16 whose neighbourhoods were included in the statistical analysis, reported above: the City of Vancouver, the City of Port Moody and the District of Invermere. These communities were chosen based on our desire to include a mix of urban, suburban and small town locations. Each case study includes general information on the municipality, a synopsis of active transportation policies, a review of urban form policies, and a synopsis of future plans that might affect walkability in the community.

The City of Vancouver

The City of Vancouver, BC's most populous municipality, has consistently enacted policies supporting active transportation. Some policies, including the 1997 Transportation Plan, the 1999 Bicycle Plan, the 2002 Downtown Transportation Plan, and the 2005 City Greenways Plan, support the development of a range of pedestrian and bicycle facilities across the city. Other policies, including the 1991 Central Area Plan, the 1995 CityPlan, and more recently the EcoDensity framework, aim to support the development of an urban form that is more conducive to the use of active modes of transportation.

Vancouver has had the most success in promoting walking and, to a lesser extent, cycling in and around its downtown area. This success can at least partly be attributed to the Central Area Plan, which underpinned the development of high density, mixed residential developments with its so-called "Living First" policies. There has been less success in encouraging active transportation elsewhere in the municipality. Though there has been considerable investment in pedestrian and cycling facilities across the city, the key CityPlan goal of creating amenity-rich, pedestrian-oriented neighbourhood centres has not yet been achieved.

Evidence of progress

- Successful redevelopment downtown and in surrounding areas, achieving high densities and considerable mix of uses.
- 7% decrease in automobile trips to downtown between 1993 and 2004, despite significant residential and employment growth, with mode share shifting towards transit and active modes; around 30% of trips to and within downtown Vancouver are made by walking, exceeding 1997 Transportation Plan target mode share of 18% for walking and cycling combined.
- Average distance driven by Vancouver-registered passenger vehicles decreased 30% between 1993 and 2002.
- Mixed-use, high-density development achieved around certain SkyTrain stations.
- Secondary suites by-law enacted in 2004.
- Large number of traffic calming and sidewalk improvement projects carried out in neighbourhoods across the city; almost 95% of all streets now have sidewalks; large number of push-button pedestrian crossings installed.

Where work is needed

- Outside downtown, progress on intensification has been limited.
- Despite numerous traffic calming and pedestrian improvement projects, urban form in

low density areas remains largely automobile-oriented.

- Policy goal of creating a "city of neighbourhoods" has still not been achieved.
- 19 Neighbourhood Centres have been identified through participative community planning, but only two are beginning to be implemented; the remaining 17 have yet to be planned.
- Planned greenway system is only roughly one-third complete.
- 1997 Transportation Plan benchmarks for mode share of walking and cycling to be achieved by 2021 are too modest, having already been surpassed for the most part.

Port Moody

Port Moody, a suburb of Vancouver, has a fairly extensive network of on- and off-street pedestrian and cycling facilities, yet the automobile remains the overwhelmingly dominant mode of transportation. The City of Port Moody's 2000 Official Community Plan (OCP) and 2005 Master Transportation Plan both contain policies that directly and indirectly support active modes of transportation, through infrastructure investment as well as through the creation of an urban environment that is more conducive to walking and cycling. Both of these policy documents are consistent with Metro Vancouver's regional policies with respect to land use and transportation.

Evidence of progress

- High-density, mixed use development achieved at Inlet Centre.
- The majority of new development is multi-family.
- The City's development permit guidelines include strong directives for the design of pedestrian facilities and street fronts.
- Secondary suites allowed in certain areas since 2004.
- Pedestrian and cyclist connections across CP railway implemented.
- Numerous traffic calming projects executed.
- Increasing pedestrian activity in Moody Centre.

Where work is needed

- Mode share of walking and cycling is below regional average.
- The role of active transportation is not clearly defined; no specific goals have been set in terms of mode share of walking and cycling.
- Little progress on the OCP goal of creating "village-like" environment in existing neighbourhoods.
- No policies with respect to location of public facilities to maximize pedestrian and cycling access.
- No program encouraging bicycle use for trips to work.
- No local greenways plan and no connections planned to the regional greenways network.

Invermere

Invermere is a small town in the Columbia Valley of southeastern B.C., not far from the Alberta border. Increasing numbers of second homeowners and tourists are bringing increased traffic to the town. Preserving the cachet of this growing town is a high priority for Council and residents alike. The 2006 Official Community Plan (OCP) and 2008 Environmental Agenda demonstrate the municipal government's understanding of urban growth issues, and make explicit reference to the connections between urban form, active transportation and positive health and environmental outcomes.

Evidence of progress

- Smart growth and active transportation are recognized as important issues.
- New pedestrian and cyclist facilities added, with private and public resources.
- Municipal policies address the challenges and opportunities of more compact and walkable development.
- OCP emphasizes the role of a pedestrian-friendly downtown, including residential and mixed-use infill development.
- Increased density and dwelling-type diversity.
- Secondary suites allowed.

Where work is needed

- Limited policy development and follow-through.
- Limited data collection and use of quantitative indicators.
- Urgent water-supply issues have consumed most financial and administrative resources in recent years.
- Second-home boom is increasing traffic, and new and reconfigured roadways may pose challenges to pedestrians and cyclists.
- Key policies on site planning and urban form are limited to downtown; more general growth and planning controls are needed.
- Parkland and park/greenways planning efforts are lagging behind goals.

Conclusions

This study reveals that urban form could be significantly associated with some forms of physical activity and with some health outcomes. After controlling for demographic variables (income, age and gender), the neighbourhood walkability indices showed statistically significant associations with walking, BMI and hypertension. Those living in walkable neighbourhoods were likely to walk more, weigh less, and have a lower odds of hypertension than those living in less walkable neighbourhoods.

The effects observed in this study provide added support for the hypothesis that urban form affects health and health-related behaviors. The consistency of findings with those generally found in previous research on associations between health outcomes and covariates, such as gender, age, and income, provides some assurance that our observations on health and urban form also have validity.

The implications of this and similar research for urban planning are significant; municipal and provincial governments should carefully consider the health implications of decisions affecting neighbourhood design and take the necessary steps to ensure that more compact, complete communities are promoted over sprawling, homogenous urban landscapes. Although our research does not allow us to pinpoint the urban design features that are of greatest relevance to health outcomes, the literature reviewed in this report suggests that land use mix, residential and employment density at trip origins and destinations, the attractiveness of streetscapes, and street connectivity are among the most important features to be promoted in new developments and major redevelopments.

The research findings also hold some significance for public health professionals. If urban form can have significant (positive or negative) influences on health and health-related behaviors, health practitioners can improve public health by advocating for more compact development patterns and complete communities. To do so, public health advocates (e.g., public health officials, health promotion workers, recreation professionals, educators and others) should be more directly involved in planning exercises, such as preparing a community plan, designing major new real-estate development projects, transportation planning, recreation planning, green space/environmental planning, and so on.

The case studies reveal that municipal governments are increasingly committed to promoting an environment that is conducive to walking and biking. Local authorities are taking steps to improve pedestrian and bike facilities (including pedestrian paths, bike lanes, and bike parking), calm traffic on pedestrian corridors, and afford more attention to the attractiveness and walkability of streetscapes, including street fronts, sidewalks and landscaping. In some cases, municipalities are adopting separate biking and walking plans in order to provide an integrated long-term vision for active transportation.

Moreover, the case studies show that smart growth policies are being increasingly adopted to guide municipal planning and development decisions. Intensification is proceeding, especially through minimally disruptive strategies such as secondary suites legalization and increased multifamily development in new communities. Densities are rising in redevelopment projects, central areas and in strategic locations located near transit. There is also evidence of a move towards an increased mix of land uses in strategic locations, such as around transit stations and in central areas. Planning documents reflect a recognition that urban villages that are walkable and bikable are desirable.

While progress is clearly being made, there are several fronts on which the case studies reveal the need for more work. Not all municipalities have included specific goals (e.g., modal shares) to promote active transportation in their community or transportation plans. These municipalities lack measures to gauge the effectiveness of interventions related to facilitating active transportation. There is also a need to ensure that all municipalities have developed comprehensive active transportation plans, including capital investments, programs and targets.

From a land use planning point of view, there is a need to develop specific land use objectives and implementation/monitoring frameworks for ensuring that municipalities move towards smart growth goals. The reshaping of existing neighbourhoods to be more pedestrian-friendly in terms of density, mix of uses, etc. has been slow to materialize. While streetscapes are being increasing attended to, regulations on maximum setbacks and orderly street fronts are still not universal. Greater efforts are also needed to ensure that government services (e.g., social, health, recreational services and libraries) are to be located in accessible locations such as neighbourhood centres. Finally, integrated greenway strategies are needed in order to connect green areas and provide a network of bike and pedestrian paths throughout the jurisdiction.

Stemming sprawl and building more compact, complete and walkable communities is a policy recommendation that is very much in line with recommendations emerging from other studies in public health. Most importantly, more compact communities are seen as one important way to achieve lower levels of regional air pollution and associated health impacts (Bray et al, 2005). Beyond public health, research in other disciplines is also pointing towards more compact cities as an important policy lever for achieving a range of benefits, from improved regional ecological health and a lower ecological footprint to reduced energy use and greenhouse gas emissions. Together, these studies are presenting a formidable argument that managing growth more responsibly and building communities that are walkable, bikable and livable is the key to the sustainability and health of our communities.

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1. Introduction

Photo: Smart Growth BC

This report is the third in Smart Growth BC's Sprawl Report series. It focuses on how the physical design of neighbourhoods affects walking and biking in BC's communities, and whether this has any impact on individual health. Smart growth is about creating more compact, complete, walkable communities that encourage and facilitate walking and more physically active and healthy lifestyles. By raising awareness of the health implications of our land use decisions and promoting smart growth planning principles and practices, Smart Growth BC hopes to assist municipalities, developers and health organizations to create communities that make "healthy choices the easy choices."

The theme of this report was inspired by the growing recognition that the design of our communities is contributing to the increasing incidence of overweight and obesity in Canada. Between 1979 and 2003, the proportion of the adult population that was obese[2] grew from 14% to 23%, while the proportion of overweight[3] Canadians increased from 35% to 36%. In British Columbia, 40% of adults are overweight while 19% are obese (Tjepkema, 2005). Over half the population is above a healthy weight.

It has been acknowledged that physical inactivity is an important contributor to the prevalence of overweight and obesity in Canada. Although British Columbians are the most physically active in the country, only 57 percent of the provincial population engages in recommended levels of daily physical activity (Statistics Canada, 2005). Across Canada, more than half the population over the age of 12 is not physically active and the majority of

2 A person is considered obese when their Body Mass Index (BMI) is equal to or greater than 30. Body mass index is defined as the individual's body weight divided by the square of their height.

3 A person is considered overweight when their BMI is from 25 to 29.9.

children do not engage in physical activity levels needed for healthy growth and development (HSFC, 2007). Public health agencies are now recommending that Canadians engage in a minimum of 30 minutes per day of moderate forms of physical activity such as walking and bicycling as a means to generate long-term health benefits.

Walking and bicycling make up only 12 percent of all trips made to the store, work or school across Canada. Although this rate fares better than that in the United States (where it is only 7 percent), it is much lower than in countries such as the Netherlands and Denmark, where active transportation makes up 46 and 41 percent of the modal share respectively (HSFC, 2007). However, there is evidence that Canadians desire more opportunities for active transportation. In a 1998 survey of 1,500 adults across Canada, eight in ten respondents stated that they would like to walk more than they already do while 2 in 3 respondents would like to bicycle more (Go for Green, 1998). Seventy percent of survey participants also indicated that they would bicycle to work if dedicated bike lanes took them to their place of employment in less than 30 minutes (ibid).

Creating more walkable, less automobile–dependent communities through land use planning policies can contribute to decreasing the incidence of obese and overweight Canadians and British Columbians (HSFC, 2007, PHSA, 2007). Given that the lack of physical activity has been shown to be a leading risk factor attributed to a number of health problems such as heart attacks, strokes, hypertension and diabetes, increasing the rate of active transportation could also result in broader public health benefits. Evidence shows that regular, moderately intense physical activity "helps maintain normal muscle strength and joint structure and function, lowers high blood pressure, relieves depression and anxiety, lowers obesity levels, and is necessary for normal skeletal development during childhood." (Frank et al., 2003). Moreover, physical inactivity plays a significant role in the development of chronic diseases such as coronary heart disease, colon cancer and diabetes, and therefore premature mortality (ibid).

Many health professionals now acknowledge that urban planning policies have important effects on physical activity patterns and ensuing population health outcomes (HSFC, 2007, Bray et al. 2005, PHSA, 2007). Some experts in the field also believe that the greatest contribution to physical activity levels among sedentary individuals will have to come from modest intensity activities such as walking and bicycling (e.g., Frank et al., 2003). They point out that, compared to strenuous exercise programs, moderate exercise such as walking can be performed by beginners, is more easily integrated into a person's daily schedule, and has a higher adherence rate. These advantages make moderate exercise more likely to be adopted and maintained over the long term compared to other types of exercise. Moreover, walking has almost no barriers to participation (e.g., low physical activity threshold, no equipment/ facilities needed, no other participants required) and both walking and biking can be practiced as a recreation activity or for utilitarian purposes such as walking to work, school, or shopping.

2. Urban Planning and Walkability

Urban planning practices can significantly influence the factors that contribute to people's decision to walk or cycle. For example, by placing everyday destinations (e.g., grocery stores, post offices, and daycares) near or within residential areas, people are encouraged to get around through active transportation means, rather than drive or be driven. Higher densities can provide the local market needed to support shops and services in the neighbourhood and built ridership for better quality transit (which in turn encourages walking and wheeling to and from transit stops). Likewise, when streets are designed to reduce traffic speeds and make routes pleasant for pedestrian and bicyclists (e.g., shorter blocks, sidewalks, and a grid street pattern instead of crescents and dead-ends), many people will adopt active forms of transport. Together, these and other design features can contribute to the "walkability" of a neighbourhood.

In contrast to the large amount of research done on the relationship between physical activity and health, research exploring the role of the built environment on walking and physical activity levels is relatively limited, but growing rapidly (TRB, 2005). This review provides a summary of the literature that has been published on the links between the built environment, walking, physical activity levels and related health indicators.

2.1 Literature review

Several studies have shown that urban form can have an impact on the choices people make as to their mode of transport ("modal choice"). Most of the studies on urban form and travel patterns have proceeded by comparing different types of neighbourhoods to see if those that we usually think of as more walkable do in fact encourage walking.

Handy (1996) compared four communities in the San Francisco Bay area — two "traditional" and two "modern" neighbourhoods — in order to determine the links between urban form and travel patterns for shopping purposes. "Traditional" neighbourhoods were characterized by grid street patterns and commercial activity spread throughout the residential area, while "modern" neighbourhoods had curvilinear street networks (i.e., crescents and dead-ends) and commercial activity along arterial streets on the outskirts of the neighbourhood. Urban form characteristics (e.g., street patterns, location and distribution of commercial uses relative to residential areas, sidewalk width, and street tree sizes) were measured in each case study community. Measures of density for all four case study neighbourhoods were within the range of typical suburban areas and were not used to determine if a community was "traditional" or "modern". The author stressed the importance of controlling for socioeconomic variables (e.g., average income, age, and ethnicity) given that "individual and household characteristics are a primary determinant of travel behaviour." Results of this study show that higher accessibility, as determined by shorter distances as well as qualitative urban design factors, is associated with higher levels of walking trips to shopping destinations. Walking trips to commercial areas in "traditional" neighbourhoods ranged from 4.8 to 5.7 walks per month compared to 1.0 to 2.8 walks per month in the "modern" neighbourhoods.

In another study of eight residential neighbourhoods in Northern California, Handy et al. (2004) investigated the relationship between neighbourhood design and travel behaviour for both work and non-work purposes. Using a household survey, the authors collected data on travel behaviour, perceived neighbourhood characteristics, preferences for neighbourhood characteristics, travel preferences, and socio-demographic characteristics. The eight sample neighbourhoods were divided into two separate groups, "traditional" and "suburban." The four "traditional" neighbourhoods were characterized by higher densities, greater mix of land uses, better pedestrian infrastructure, and higher levels of transit service compared to the four "suburban" neighbourhoods selected for the study. The study revealed that traditional neighbourhood residents were found to walk to the store more than twice as much as suburban neighbourhood residents. The authors concluded that the built environment had a causal effect on walking behaviour, even after accounting for socioeconomic characteristics and resident attitudes and preferences. The distance between potential destinations was found to play a major role in walking incidence.

Cervero and Radisch (1996) explored the differences in modal choice between two different neighbourhoods in the San Francisco Bay Area. Based on physical environment features of the two communities, one was characterized as pedestrian–oriented and the other automobile–oriented. The pedestrian–oriented neighbourhood had a much higher housing density, and more blocks and intersections per square mile. It had a grid street pattern and relatively high land use mix compared to the automobile–oriented community which had a more conventional suburban design with curvilinear streets, large-lot tract housing and an auto-oriented retail strip. For non-work trips (e.g., shopping, personal business, recreation and medical appointments), residents of the pedestrian oriented neighbourhood were found to be around five times as likely to travel by foot or bicycle than residents in the other community. The largest difference was found to be travel for shopping purposes; non-auto travel accounted for 19 percent of the modal share in the pedestrian–oriented neighbourhood compared to only 2 percent in the automobile–oriented neighbourhood. The difference in non-auto travel for work trips between the two neighbourhoods was not found to be significant.

New urbanism is a planning movement that advocates for more walkable neighbourhoods, a mix of incomes, and traditional architectural designs. Dill (2004) tested the claim that such neighbourhoods encourages residents to walk or bicycle more by comparing a new urbanist neighbourhood to two control suburban neighbourhoods in the Portland, Oregon region. The new urbanist community was characterized by a diversity of retail and service establishments within a quarter mile from most residences and a variety of residential unit types (i.e., townhomes, rowhouses, duplexes and single detached). The two sample suburban communities had only single detached housing and no shops or services within either development. Surveys asking about travel behaviour and attitudes were delivered to residents of each neighbourhood. The study showed that walking represented 30 percent of all trips made by new urbanist community residents while it represented only 9 percent of total trips in suburban neighbourhoods. Residents in the new urbanist development stated that they made on average 6.6 walking trips per week compared to 1.7 trips per week for residents of suburban neighbourhoods. Some residents of the new urbanist development asserted that they were looking for a place that enabled them to walk and bicycle more before moving into their current homes, indicating that the results could at least in part be explained as the result of pre-existing attitudes.

In one of the few Canadian studies on this topic, Craig et al. (2002) found that a number of neighbourhood characteristics were associated with walking to work. The study combined data for 27 neighbourhoods in Ontario, Quebec and Alberta with diverse urban form, social class, and economic characteristics. A neighbourhood observational study was used to create an environmental score for each community based on 18 neighbourhood characteristics (e.g., number of destinations, variety of destinations, availability and quality of walking facilities, visual aesthetics, transportation systems, pedestrian safety and route connectedness). Income, university education, poverty and degree of urbanization were used as control variables. The 1996 Canadian Census provided walking to work incidence for each community. The researchers found that environmental scores were positively associated with the percentage of people who walked to work, which ranged between two percent and over 40 percent of the total population. A one-point increase in the environmental score (which had a 10-point scale) was associated with a 25 percentage point increase in walking to work.

The studies mentioned so far have focused on the link between urban form and walking as a mode choice. Other studies look at the link between urban form and overall levels of physical activity. For example, Rodriguez et al. (2006) compared activity levels of residents in a new urbanist neighbourhood to those of people living in conventional suburban developments in central North Carolina. A travel diary and a household survey were used to collect data on levels and location (i.e., at home, outside the home but in the neighbourhood, outside the neighbourhood) of moderate and vigorous physical activity. The study found that levels of physical activity between neighbourhood types were not statistically different. However, statistically significant differences in the location and type of physical activity existed between neighbourhood types. Households in the new urbanist community spent about one hour more per day being physical active in their neighbourhood than residents in conventional suburbs. The total number of walking and bicycling trips among residents in the new urbanist community was twice as high as that for suburban households. Finally, new urbanist neighbourhood residents spent around 42 more minutes per week walking and bicycling than their counterparts in the suburban communities.

Other researchers have looked for linkages among urban form, physical activity, body weight and other health outcomes. For example, Saelens et al. (2003b) used the concept of neighbourhood walkability to compare the physical activity and weight of residents in two neighbourhoods in San Diego, California. The high-walkability neighbourhood was characterized by high residential density, mixed land uses, grid-like street pattern and few cul-de-sacs, whereas the low-walkability neighbourhood was made up of mostly single-family homes with only a small commercial area on the periphery, longer block lengths, curvilinear street patterns and more cul-de-sacs. The authors found that residents living in the high-walkability neighbourhood engaged in roughly 52 more minutes of moderate-intensity physical activity per week compared to study participants in the low-walkability neighbourhood. Vigorous-intensity physical activity levels did not differ significantly between high- and low-walkability neighbourhood residents. The largest difference in walking rates between the two neighbourhoods was found to be walking for errands. There was no observed difference between communities regarding walking for exercise or leisure. The results also revealed that the high-walkability neighbourhood residents had lower overall BMI and that 60% of residents in the low-walkability neighbourhood were overweight compared to 35% in the high-walkability neighbourhood.

Ewing et al. (2003) examined the relationship between urban sprawl, health, and health-related behaviors in 448 counties and 83 metropolitan areas in the US. The authors developed a metropolitan sprawl index (a combination of 22 land use and street network factors) and looked for linkages between the index and levels of physical activity, obesity, BMI, hypertension, diabetes, and coronary heart disease incidences. After controlling for demographic and behavioral covariates (e.g., gender, age, race/ethnicity, education, smoking and diet), results showed that the number of minutes walked, obesity, BMI and hypertension varied with the sprawl index at statistically significant levels. Residents of counties with high sprawl indexes were more likely to walk less during leisure time, weigh more, and have greater prevalence of hypertension than residents of counties with smaller sprawl indexes.

A similar study conducted by Lopez (2004) looked at the association between urban sprawl and the risk for being overweight or obese among US adults. Based on data contained in the 2000 US census, an urban sprawl index was developed for 330 metropolitan areas across the US based on residential densities. The study revealed that for every 1-point increase in the sprawl index, there is a 0.2% increase in the risk of being overweight and a 0.5% increase in the risk of being obese.

Frank et al. (2004) also examined the relationship between community design and obesity. For this study, data on BMI, minutes spent in a car, kilometers walked, age, income, educational attainment, and gender were obtained from a travel survey of over 10,000 participants in the Atlanta, Georgia region. Physical environment variables included land use mix, net residential density, and street connectivity within a 1-kilometer network distance of each participant's place of residence. After adjusting for socio-demographic covariates (e.g., age, income, educational attainment, and gender), the study revealed that land use mix had the strongest association with obesity, followed by time spent in a car and kilometers walked. For each quartile increase in land use mix, the chance of being obese decreased by 12.2%, while it decreased by 4.8% for every additional kilometer walked. The impact of residential density and street connectivity was not explored separately as these factors were found to vary with (i.e., to mirror) the land use mix variable.

These types of studies – called "cross-sectional" because they look at the behaviour of a cross-section of residents at a particular time — have been criticized as non-conclusive because they do not take into account what is called the "self-selection bias" (Eid et al, 2007). It is possible, critics argue, that the observed link between urban form characteristics and walking behaviour reflects the fact that individuals who prefer to lead a physically active lifestyle choose to reside in walkable neighbourhoods, thereby accounting for higher levels of active transportation typically observed in such communities. In order to eliminate this as a possible explanation for the observed relationships, we need to turn to studies that compare people's urban travel behaviour before and after they move from one neighbourhood type to another — so called "longitudinal" studies.

In one of the few such studies, Handy and Mokhtarian (2005) measured changes in travel behaviour among residents who had recently moved to eight neighbourhoods in Northern California (four traditional and four suburban). In order to test for self-selection bias, the authors controlled for personal attitudes and preferences while measuring changes in the built environment and accompanying changes in travel behaviour. Although evidence did show that individual preferences and attitudes influence walking incidence, the built environment was found to have the greatest effect on changes in walking. The most important variable explaining differences in walking behaviour was found to be subjectively reported neighbourhood attractiveness (i.e., more walking was associated with attractive appearance, high level of upkeep, variety of housing styles, and street trees). The availability of alternatives to automobile use (i.e., sidewalks, transit services), better safety (i.e., low crime rate, low level of traffic, good street lighting) and more sociability among neighbours were other variables that increased walking. Lastly, the authors also found that, all else being equal, increased accessibility through a mix of land uses was the most important variable associated with decreased levels of automobile use.

Another way to explore the self-selection issue is to ask people what type of neighbourhood they prefer to live in and then see if this affects the actual walking more than their built environment. Frank et al. (2007) used a travel and neighbourhood preference survey done in Atlanta to control for neighborhood preference and isolate the effect of the built environment on walking and obesity. They found that a significant proportion of the population were ''mismatched'' and do not live in their preferred neighborhood type. Individuals who preferred and lived in a walkable neighborhood walked most (33.9%). Individuals who preferred and lived in car–dependent neighborhoods walked the least (3.3%). Individuals who did not prefer a walkable environment walked little and showed no change in obesity prevalence regardless of where they lived. About half as many participants who prefer and live in walkable environments were obese (11.7%) as participants who prefer car–dependent environments (21.6%). These findings suggest that creating walkable environments may result in higher levels of physical activity and in slightly lower obesity prevalence for those preferring walkability.

2.2 Summary

The literature review reveals that neither urban planning nor public health research has a long history of examining the built environment's effect on walking and physical activity. However research on the topic is quickly growing in quantity and scope with new research findings continually emerging. Most of the literature cited in the review was carried out in the US. More Canadian empirical research is needed to corroborate the US findings. The present study is a contribution to meeting this need.

In defining the research model, many studies controlled for socioeconomic variables (e.g., income, automobile ownership, age, gender, race/ethnicity, employment status). Physical environment indicators most commonly employed in the literature were population and employment density, land use mix, and urban design features such as street connectivity, pedestrian facilities, accessibility of open spaces and aesthetic attributes. The use of walkability indices to incorporate several built environment features is also a popular technique in the research reviewed. Although most studies used objective measures of the physical environment, a few also employed subjective indicators (e.g., accessibility, safety and attractiveness).

The literature reviewed revealed a statistically significant relationship between the physical environment variables and the incidence of walking. In particular, land use mix, residential and employment density at trip origins and destinations, the attractiveness of streetscapes, and street connectivity were commonly found to have a positive influence on people's walking rate. Several of the studies reviewed showed that BMI and obesity were positively associated with sprawling communities characterized by low densities and homogenous land uses. There is also evidence that the built environment has an impact on the incidence of hypertension. There is much evidence in the medical literature that physical activity in general and walking in particular can reduce the incidence of diabetes, but there is little evidence directly linking urban form to the incidence of diabetes in resident populations.

The influence of the built environment on walking and physical exercise appeared to be strongest for utilitarian trip purposes, especially shopping, errands and entertainment purposes. The influence is weaker on recreational walking, implying that residents in less walkable neighbourhoods walk for recreational purposes but engage in less utilitarian walking within their neighbourhoods. The studies reviewed showed that the influence of the built environment on walking, physical activity and health was usually a significant but not always a dominant factor in explaining BMI and health outcomes.

3. Methodology

This empirical part of the study explores the relationship between urban form, walking and health outcomes in municipalities across BC. To carry out this study, we used many of the same methods described in the literature review: we collected data on the physical environment of selected neighbourhoods, the levels of walking activity and health outcomes, and ran regression models to determine the influence of urban form on walking and health indicators. This section offers an overview of the research methodology. For more details, please *see Appendix A*.

3.1 Selecting study neighbourhoods

A major source of data for this study was the Health and Wellness Survey conducted in the spring of 2006 by the BC Provincial Health Services Authority (PHSA, 2007).[4] The survey was designed to collect data and gather information on the behavioural determinants of health (e.g., exercise levels, dietary habits, tobacco and alcohol use) at the local or community level. Data was collected through telephone interviews from adult residents (one per household) in 26 Local Health Authorities or communities across the province. We obtained individual records from this database, sorted by census dissemination area (DA),[5] the smallest geographic unit used for census reporting.

Our study units were defined as neighbourhoods rather than whole municipalities in order to allow us to look at relatively homogenous urban forms and reduce the complexity of the data gathering task. We chose 16 neighbourhoods from 16 different municipalities covered in the PHSA study. Although our goal was to identify neighbourhoods of a similar size, this was not possible given that neighbourhoods had to be assembled from DAs, which vary widely in size.[6] Thus, the neighbourhoods chosen vary from about .7 sq. kms. to just over 3 sq. kms. The neighbourhoods chosen also reflect our desire to maximize the number of PHSA survey responses per 1000 population and to achieve a mix of small town, suburban and urban areas.[7] Of the 10,485 individuals who responded to the PHSA survey, 2,731 are in our 16 sample neighbourhoods. Appendix B presents maps showing the location of each neighbourhood within its municipal context.

Table 6 lists the municipalities and presents some summary statistics of the study neighbourhoods, including the municipal population, the number of responses to the PHSA survey from the neighbourhood, neighbourhood population, the number of responses per 1000 neighbourhood population, the neighbourhood area and the number of Dissemination Areas (DAs) in each neighbourhood.

Figure 2 shows the relative location of the municipalities included in the study.

4 The survey report is available at: www.phsa.ca/NR/rdonlyres/76D687CF-6596-46FE-AA9A-A536D61FB038/ 23375/PHSAreportBCHWSdescripreportFINAL1.pdf
5 Individual names, addresses and postal codes were not included in order to protect the confidentiality of the respondents.
6 DAs located in dense cities tend to be very small (e.g., a single apartment building) while those in rural areas can range up to hundreds or even thousands of square kilometres. Likewise, DA populations also varied widely, from several thousand in dense areas to a few dozen in rural areas.
7 As a result, the selected neighbourhoods are not necessarily representative of the community as a whole.

Table 6: Study municipalities and neighbourhood description

	Municipality	Population 2006	N'hood Responses	N'hood Population 2006	Responses per 1000 Population	N'hood Area (sq km)	DAs in N'hood
A	Creston	4,944	180	1715	104	1.44	2
B	Fernie	4,217	119	780	152	3.22	1
C	Fort Nelson	4,514	388	1200	323	1.22	1
D	Golden	3,811	43	970	44	0.96	1
E	Hope	6,185	187	1385	135	2.20	2
F	Invermere	3,002	82	705	116	1.79	1
G	Mackenzie	4,539	392	1325	295	0.97	1
H	New Westminister	58,549	35	2520	13	0.73	2
I	Port Hardy	3,822	268	2010	133	1.28	2
J	Port Moody	27,512	36	2905	12	1.73	3
K	Prince Rupert	12,815	85	2845	29	1.72	3
L	Richmond	174,461	76	6370	11	1.55	10
M	Smithers	5,217	345	495	696	0.75	1
N	Tofino	1,655	143	605	236	2.40	1
O	Valemount	1,018	213	260	819	0.79	1
P	Vancouver	578,041	139	10280	12	1.30	19

3.2 The indices of walkability

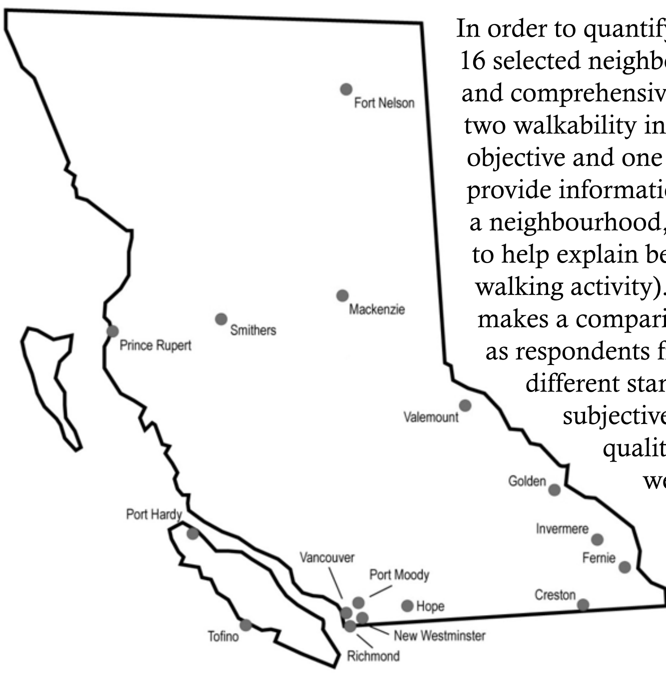

Figure 2: *Location of Municipalities*

In order to quantify the walkability of each of the 16 selected neighbourhoods using a consistent and comprehensive framework, we developed two walkability indices for use in this study, one objective and one subjective. Subjective indicators provide information on how residents experience a neighbourhood, and are therefore important to help explain behavioural outcomes (such as walking activity). However, this type of indicator makes a comparison of neighbourhoods difficult, as respondents from different areas may have different standards in mind when answering subjective questions about neighbourhood qualities. In order to address this issue, we also developed a set of objective indicators of the walkability of the neighbourhood, based on measurable variables. Our objective index is derived from quantitative metrics, while the subjective index is estimated from the PHSA survey where individuals responded to a variety of questions related to urban form and walkability.

For the objective walkability index, we identified urban form variables thought to be linked to walking incidence, focusing on variables for which province-wide data were available from a single source. Variables that would require local data sources (such as distance to transit stops) were not included in the index in order to minimize inconsistencies in data collection methods and cost. Data sources included aerial photos, the 2006 Canadian census, and GIS maps from third party providers such as DMTI Spatial Incorporated. Variables chosen for inclusion in the study are shown in *Table 7*, along with the data sources and a definition for each variable. For details on the derivation of the land use mix index and the housing mix index, please see Appendix A.

Table 7: Variables in objective walkability index

	Variable	Data Source	Definition
1	Net population density	2006 census and GIS maps	Number of people living in the neighbourhood per sq km of residential land
2	Street connectivity	GIS maps	Percent of intersections that have three or more streets intersecting
3	Intersection density	GIS maps	Number of intersections per sq km
4	Land use mix index	GIS maps	An index that reflects diversity of land types, varies between 0 (homogenous) and 1 (balanced mix)
5	Access to parks and green space	GIS maps	Straight line distance to the closest major green space from the neighbourhood centroid, in metres
6	Housing mix index	2006 census	An index that reflects diversity of housing types, varies between 0 (homogenous) and 1 (balanced mix)
7	Sidewalks	aerial photos	Percentage of streets with no sidewalks
8	Setbacks	aerial photos	Average distance from curb to front of house, in metres
9	Street widths	aerial photos	Average width of streets from curb to curb, in metres
10	Block lengths	GIS maps	Average block length, in metres

The data for the subjective walkability index were drawn entirely from the PHSA survey responses. The PHSA survey included a set of questions on the respondent's assessment of the neighbourhood environment, BMI and health indicators, as well as socio-demographic questions such as gender, age and income. We used the questions on the neighbourhood environment to create a subjective walkability index, and responses to those questions from individuals in each neighbourhood were used to score each neighbourhood.

Table 8 presents a list of variables used in creating the subjective index. The first variable (housing type) allowed respondents to choose among several housing types: single detached, apartments, etc. The remaining variables captured the individual's perception of their neighbourhood by asking respondents to choose an option on a scale from "strongly disagree" to "strongly agree" (a Likert scale).

Table 8: Variables in subjective walkability index

	Variable
1	Prevalent housing type
2	Shops, stores, markets are within walking distance
3	Home is within a 10-15 minute walk to a transit stop
4	Sidewalks on most of the streets in the neighbourhood
5	Facilities to bicycle in or near the neighbourhood
6	Neighbourhood has several free or low–cost recreation facilities
7	Crime rate in the neighbourhood makes it unsafe to walk at night
8	Traffic on the streets makes it difficult or unpleasant to walk
9	Many people being physically active can be seen in the neighbourhood
10	Many interesting things to look at while walking in the neighbourhood

3.3 Dependent variables

This report seeks to determine the influence of urban form (the independent variable) on walking and health outcomes (the dependent variables). In addition to the questions it contained on urban form (which we used to create the subjective walkability index), the PHSA survey also collected information on walking activity and health. In terms of walking, the survey asked respondents to estimate the number of days they had walked for more than 10 minutes over the last seven days. In terms of health, respondents were asked for their weight and height (from which we calculate Body Mass Index) and whether they had hypertension or diabetes.

3.4 Statistical analysis

A series of regression models were estimated to determine the impact of neighbourhood urban form on walking and health. The walkability indices for each neighbourhood were included as independent variables, whereas dependent variables were walking levels, BMI, diabetes, and hypertension. The analysis controlled for some other factors that could influence walking and health outcomes, such as income, age and gender.

3.5 Case studies

Finally, case studies were carried out in three municipalities drawn from the 16 included in the empirical part of this study: the City of Vancouver, the City of Port Moody and the District of Invermere. These communities were chosen based on our desire to include a mix of urban, suburban and small town locations and a diversity of scores on the walkability index. The case studies explore policies, plans and investments that together shape the walkability of the community, providing a cross-section of current practices in BC.

4. Empirical Results

This section provides an overview of the empirical part of the study. The discussion begins with a presentation of the two walkability indices (objective and subjective) we developed for this report. The indices are then used to explore correlations between walkability and health/activity outcomes across the 16 study neighbourhoods. Finally, we report results from regression models that explore the relationship between walkability indices and health/activity outcomes in greater depth. This section omits technical details of the statistical procedures and results. These can be found in *the Appendix*.

4.1 Dependent and control variables

In order to carry out the statistical analysis, we must first characterize the respondents according to several key factors, including dependent and control variables. The tables below show the breakdown of the respondents for each of these variables. The difference in the total number of respondents in the various tables results from the fact that not all respondents answered all questions. Therefore, each table compiles results from valid responses only.

The dependent variables are the incidence of obesity, hypertension and diabetes. *Table 9* offers the average BMI values for the three categories, namely, normal weight, overweight, and obese. The figures show that 38% of respondents were overweight and an additional 20% were obese.

Table 9: Occurrence of obesity among respondents

Categories	BMI	Freq.	Percent
Normal weight	22.6	1101	42
Overweight	27.1	976	38
Obese	34.2	517	20
Total	**26.6**	**2,594***	**100**

* missing 137 responses

Table 10 shows the occurrence of hypertension and diabetes among respondents. Only 6% of respondents in the sample reported suffering from diabetes. The incidence of hypertension was higher at 20.1% amongst respondents.

Table 10: Occurrence of hypertension and diabetes among respondents

	Diabetes		Hypertension	
	Freq.	Percent	Freq.	Percent
No	2,562	94	2,173	80
Yes	165	6	547	20
Total	**2,727***	**100**	**2,720‡**	**100**

* missing 4 responses ‡ missing 11 responses

The three control variables used in our analysis are age, income, and gender. The age variable was broken down into ranges such that each age range contains about the same number of respondents. The breakdown of age categories is presented in *Table 11*.

Table 11: Breakdown by age into four categories

Age range (years)	Frequency	Percent
18-36	705	27
37-46	613	23
47-57	675	26
58-98	640	24
Total	**2,633***	**100**

* missing 98 responses

The breakdown by income is presented in *Table 12*. The largest number of respondents fell within the middle income range of $50,000-$79,000, although significant numbers were found at the two extreme income ranges.

Table 12: Breakdown by income

Income Categories	Frequency	Percent
Less than $29k	441	21
Between $30k and $49k	415	20
Between $50k and $79k	575	27
Between $80k and $99k	253	12
Over $100k	434	20
Total	**2,118***	**100**

* missing 613 responses

Finally, *Table 13* shows the gender breakdown of the respondents. It shows that 52% of respondents were women in our sample.

Table 13: Breakdown by gender

Gender	Frequency	Percent
Male	1,304	48
Female	1,427	52
Total	**2,731***	**100**

* no records missing responses

4.2 Correlation analysis

This section presents a summary of the correlation analysis between the two walkability indices and measures of walking and physical well-being (Body Mass Index, hypertension, and diabetes). A correlation analysis can tell us whether variables are statistically linked, i.e., whether a change in one variable is likely to be accompanied by a change in another variable. A positive correlation means that the two variables rise or fall together, whereas a negative correlation means that as one rises, the other falls, or vice versa. Not all correlations are statistically significant, however. A correlation may arise due to a real world link between the two variables, or it may reflect pure chance in the choice of our samples. A correlation at the 99% significance level means that we are very confident that the observed relationship is a real one; there is only a one percent likelihood that the correlation is due to chance.

Table 14 presents a summary of our findings in terms of the relationships among the variables and the statistical significance of the relationships.

The key points are as follows:

- The two walkability indices, i.e., subjective and objective, are positively correlated with each other, with a significance at the 99% confidence level. This means that as one goes up, the other is likely to rise too.

- Both subjective and objective indices are correlated positively with walking, implying that a more walkable neighbourhood is correlated with higher walking amongst the residents. The correlation between walking and the two indices is statistically significant at the 99% level.

- Both indices show a negative correlation with BMI. The statistically significant correlations at the 99% level allow us to conclude that as a neighbourhood becomes more walkable, it is likely to have a lower incidence of obesity amongst its residents.

- The subjective index of walkability is negatively correlated with the incidence of hypertension and diabetes. However, the strength of this correlation is not statistically significant at the 95% level, so we cannot draw any real conclusions from this observation.

- The objective index of walkability is also negatively correlated with hypertension and diabetes, i.e., as the index rises, the likelihood of these health problems tends to fall. The correlation with hypertension is statistically significant at the 95% confidence level, while it is not significant for diabetes.

- The incidence of diabetes and hypertension are found to be positively correlated with a significance at the 99% confidence level. In other words, people with one of these conditions are likely to have the other one.

Table 14: Summary of correlation analysis

	Subjective index	Objective index	Walking	BMI	Hypertension	Diabetes
Subjective index		+/99%	+/99%	-/99%	not sig	not sig
Objective index	+/99%		+/99%	-/99%	-/95%	not sig

+ = positive correlation
- = negative correlation
99% = correlation significant at 99% confidence level
95% = correlation significant at 95% confidence level
not sig = correlation not significant

4.3 Regression analysis

While the correlation analysis reveals that walkability is statistically associated with more walking, lower BMI, and lower hypertension, it does not allow us to conclude that walkability has a causal influence on these outcomes. Some other factor or set of factors may explain why people who live in more walkable neighbourhoods tend to walk more, have lower BMIs and lower levels of hypertension. In order to control for or eliminate the effect of these variables on the observed correlations, we undertook a regression analysis.

In our regression models, the walkability indices for each neighbourhood were included as independent variables, whereas dependent variables were walking levels, BMI, diabetes, and hypertension. The analysis controlled for several factors that could influence walking and health outcomes, i.e., income, age and gender.

First, we explored the relationship between walking behaviour and the walkability indices. The survey respondents reported the number of days in a week they walked for a certain time period. The results suggest that the odds of walking increase with an increase in objective as well as subjective walkability indices, all else being equal. No relationship was found between income and the number of days walked, nor was any statistical difference found between women and men for this correlation. However, we did find that the incidence of walking declined with age.

Next we examined the relationship between walkability and BMI. The regression analysis suggests that the odds of being overweight or obese increase with age. For instance, the odds of an individual in the second age group (37-46) being obese or overweight are 26% higher than an individual in the first age group (18-36). The analysis also suggests that the odds of being obese or overweight increase with income. The odds of being obese are higher for mid-income earners than for low or high-income earners. Lastly, it suggests that women are 25% less likely to be obese or overweight than men, all else being equal.

The results show that the chances of being obese or overweight decline with an increase in either the objective or subjective walkability index. Although the overall effect is not large, these results are statistically significant at the 99% level. Thus, even when one controls for age, income, and gender, an increase in walkability correlates with a decline (albeit small) in the odds of being obese or overweight.

Turning our attention to the linkages between the walkability indices and hypertension, we begin by recalling that almost 20% of respondents in the sample reported suffering from hypertension. The regression analysis reveals a very strong correlation between age and hypertension, i.e., the odds of suffering from hypertension are considerably higher for older individuals than the youngest cohort in the sample. There is a weak correlation, which is statistically insignificant for two income categories and marginally significant for the other two income categories, suggesting that hypertension is lower amongst high-income individuals, all else being equal. The results also suggest that men and women are likely to have the same odds for hypertension when we control for other variables. The model suggests that the odds of suffering from hypertension decline with an increase in the objective walkability index, all else being equal. However, the model did not discover a statistically significant correlation between the subjective walkability index and the odds of suffering from hypertension.

Finally, we looked at the connection between diabetes and the walkability indices. Only 6% of respondents reported suffering from diabetes in our sample. We found that the odds of suffering from diabetes increased significantly with age and declined with an increase in income. No difference between men and women was detected in terms of the probability of individuals suffering from diabetes. Also insignificant is the correlation between diabetes and the two walkability indices, suggesting that diabetes may not have a direct correlation with the walkability of a neighbourhood.

Table 15 summarizes the findings from the regression analysis.

Table 15: Summary of regression analysis

	Walking	BMI	Hypertension	Diabetes
Income	not sig	+/ 95%	-/95%	-/95%
Age	-/99%	+/ 99%	+/99%	+/99%
Female	not sig	-/ 99%	not sig	not sig
Subjective index	+/99%	-/ 99%	not sig	not sig
Objective index	+/99%	-/ 99%	-/ 99%	not sig

+ = positive correlation
- = negative correlation
99% = correlation significant at 99% confidence level
95% = correlation significant at 95% confidence level
not sig = correlation not significant

4.4 Summary

The correlation analysis revealed that both the subjective and objective indices were positively correlated with walking activity and negatively correlated with BMI in our sample of 16 neighbourhoods. The objective index of walkability was negatively correlated with hypertension. Neither of the indices was significantly correlated with diabetes.

The regression analysis confirmed the relationship between the walkability indices and walking, even when controlling for gender differences, age, and income. The relationships were statistically significant, allowing us to conclude that urban form, as measured through our walkability indices, is correlated with changes in walking behaviour in the 16 sample neighbourhoods. In short, people living in more walkable neighbourhoods, regardless of age, income or gender, are more likely to walk for at least 10 minutes on a daily basis than those living in less walkable neighbourhoods.

This relationship was evident, in spite of the fact that the PHSA survey did not distinguish among different trip purposes; instead, respondents were directed to count walking for all purposes, including "at work and at home, walking to travel from place to place, and any other walking that you did solely for recreation, sport, exercise or leisure." As noted in the literature review presented in Section 2, total walking is less affected by urban form than is walking for utilitarian purposes. Thus, we suspect that if the PHSA survey had asked respondents to report walking for different purposes, we might have been able to detect a stronger relationship between our walkability indices and walking for utilitarian purposes.

The statistical analysis also indicates a relationship between urban form and the incidence of obesity in the 16 study neighbourhoods. Thus, even when controlling for age, income, and gender, we can conclude that an increase in walkability correlates with a decline (albeit small) in the odds of being obese or overweight. These findings are consistent with those in the wider literature.

Similarly, we found that the odds of suffering from hypertension decline with an increase in the objective walkability index, all else being equal. However, the empirical models did not reveal a statistically significant correlation between the subjective walkability index and the odds of suffering from hypertension. Also insignificant is the correlation between diabetes and the two walkability indices, suggesting that diabetes may not have a direct correlation with the walkability of a neighbourhood.

In general, the two indices of urban form returned similar results (except for the statistical significance of the relationship between the subjective index and hypertension). This finding suggests that there is a connection between the walkability indices devised by researchers and residents' perception of the walkability of a neighbourhood. The positive correlation between the two indices also validates the methodology used by the research team to devise the objective index, since the index was able to capture independently what was revealed by the residents of the 16 neighbourhoods through the subjective index. The strong positive correlation between the two indices confirms that an abstract metric of urban form, i.e., walkability, when viewed through the objective lenses of a researcher or through the perceptive eyes of a neighbourhood dweller, appears similar.

5. Case Studies

The empirical analysis presented in the last section provided evidence of a connection between walkability, walking behaviour, obesity, and hypertension. In this section, we examine walkability in specific community contexts. Three case studies are presented on municipalities drawn from the 16 included in the statistical analysis reported above: the City of Vancouver, the City of Port Moody and the District of Invermere. These communities were chosen based on our desire to include a mix of urban, suburban and small town locations. Each case study includes general information on the municipality, a synopsis of active transportation policies, a review of urban form policies, and a synopsis of future plans that might affect walkability in the community.

5.1 The City of Vancouver

5.1.1 Summary

The City of Vancouver, BC's most populous municipality, has consistently enacted policies supporting active transportation. Some policies, including the 1997 Transportation Plan, the 1999 Bicycle Plan, the 2002 Downtown Transportation Plan, and the 2005 City Greenways Plan support the development of a range of pedestrian and bicycle facilities across the city. Other policies, including the 1991 Central Area Plan, the 1995 CityPlan, and more recently the EcoDensity framework, aim to support the development of an urban form that is more conducive to the use of active modes of transportation.

Vancouver has had the most success in promoting walking and, to a lesser extent, cycling in and around its downtown area. This success can at least partly be attributed to the Central Area Plan, which underpinned the development of high density, mixed residential developments with its so-called "Living First" policies. There has been less success in encouraging active transportation elsewhere in the municipality. Though there has been considerable investment in pedestrian and cycling facilities across the city, the key CityPlan goal of creating amenity-rich, pedestrian-oriented neighbourhood centres has not yet been achieved.

Evidence of progress

- The City experienced successful redevelopment downtown and in surrounding areas, achieving high densities and considerable mix of uses.
- Despite significant residential and employment growth, the City achieved a 7% decrease in automobile trips to downtown between 1993 and 2004, with mode share shifting towards transit and active modes.
- Around 30% of trips to and within downtown are made by walking, exceeding the 1997 Transportation Plan's target mode share of 18% for walking and cycling combined.

- Between 1993 and 2002, Vancouver-registered passenger vehicles decreased their average travel distance by 30%.
- The City achieved mixed-use, high-density development around certain SkyTrain stations.
- In 2004, the City enacted a secondary suites by-law.
- Neighbourhoods across the City have carried out a large number of traffic calming and sidewalk improvement projects; almost 95% of all Vancouver streets now have sidewalks, and a large number of push-button pedestrian crossings have been installed.

Where work is needed

- Outside of the downtown core, the City has made limited progress on intensification.
- Despite numerous traffic calming and pedestrian improvement projects, the urban form in low density areas remains largely automobile-oriented.
- Vancouver has still not achieved its policy goal of creating a "city of neighbourhoods." Through participative community planning, the City identified 19 "Neighbourhood Centres." Of these, only two are beginning to be implemented; the remaining 17 have yet to be planned.
- The planned greenway system is only roughly one-third complete.
- The 1997 Transportation Plan's benchmarks for mode share of walking and cycling to be achieved by 2021 are too modest, having already been surpassed for the most part.

5.1.2 General Information

The City of Vancouver is the largest municipality in British Columbia and the nucleus of the Metro Vancouver region.

The densest and most mixed land uses are found on the Downtown Peninsula. Mid- and high-rise buildings set on a rectilinear grid prevail here. Areas surrounding False Creek, directly south and east of downtown, are also very dense and mixed, with low to mid-rise forms prevailing. Much of the remainder of the City is dominated by low-density, low-rise urban form and limited spatial overlap of land uses, the main exception being areas around rapid transit (SkyTrain) stations, in which mixed use mid- and high-rise development has been encouraged.

Vancouver's 2006 census population was 578,041. This represents a 5.9% increase over the 2001 census population.

At present, 19% of dwellings in Vancouver are single detached; 22% are ground-oriented multi-family types, including townhouses, duplexes, and mobile homes; and the remaining 59% are either low- or high-rise apartments.

A unique feature of the City of Vancouver's arterial road network is the absence of limited access highways crossing its territory. Vancouver is served by a full range of public transit services, including bus, light rail (SkyTrain), and ferry (SeaBus) services operated by TransLink, the regional transportation authority. There is also a commuter train service, the West Coast Express, linking Vancouver to its northeastern suburbs.

Vancouver's 2006 census mode share for trips to work was 52% by automobile as driver, 6% by automobile as passenger, 25% by transit, and 16% by foot or bike. The last figure is well above the CMA average of 8%. Furthermore, 60% of all bicycle trips in the region are made within the city limits (TransLink, 2008).

5.1.3 Active Transportation

Planning policies and strategies

The 1995 CityPlan established a vision of Vancouver as a city of neighbourhoods in which transit, walking, and cycling are the prioritized modes of transportation. The plan proposes improving facilities for pedestrians and cyclists as well as creating an urban form that is more supportive of active transportation modes (City of Vancouver, 1995 a).

Numerous local neighbourhood plans, called Community Visions, have been developed for residential neighbourhoods across the city. As directed by CityPlan, the focus of Community Visions will be establishing neighbourhood centres and improving the pedestrian environment (City of Vancouver, 2007 a).

CityPlan's emphasis on transit and active transportation was reinforced by the 1997 Transportation Plan, whose policies aim to achieve the following:

- Better sharing of the road network: more space allocated to pedestrians and cyclists, improved comfort and safety for both.
- Calmer traffic on neighbourhood streets: reducing speed limits to 40 km/h, implementing various physical traffic calming measures.
- Better transportation balance downtown: bike lanes on downtown streets, improved pedestrian environment (pedestrian shortcuts, awnings, wider sidewalks, more lighting, more seating).

The 2002 Downtown Transportation Plan addresses movement within the Downtown Peninsula itself, and also between downtown and other parts of the city and metropolitan region. The Pedestrian Plan section makes 19 policy recommendations, including creating pedestrian connector routes and greenways and the improvement of existing pedestrian facilities, such as: wider sidewalks; wider awnings and canopies for better weather protection; more corner bulges; mid-block crossings; better laneway crossings; and others. The Bicycle Plan makes seven policy recommendations, including the implementation of a 25 km bicycle network (composed of on-street bicycle lanes and greenways) that covers the entire downtown area (City of Vancouver, 2002).

At the regional level, the 1996 Livable Region Strategic Plan directs the region and member municipalities to "enhance and/or retrofit local streets and infrastructure to favour transit, bicycle and pedestrian uses" (GVRD, 1996). The plan also has a number of policies for the creation of more compact and complete communities.

Also at the regional level, TransLink's (2008) long term transportation plan, Transport 2040, contains a number of policies that explicitly address active transportation, including:

Policy 1.2 directs the region to provide "significant" support for walking and cycling, such as: (a) supporting the expansion of cycling networks both at the regional and municipal levels; (b) improving integration of cycling and transit; (c) improving pedestrian facilities to destination along and within the region's Frequent Transit Network; and (d) upgrading access to key transit stations and facilities.

Policy 1.4 directs the region to develop TravelSmart, a program to assist people in making sustainable travel choices, including trip reduction and increased use of transit, ride-sharing, walking and cycling.

Policy 3.1 directs the region to make transit walking and cycling appealing by ensuring that they are safe, attractive, and easy to use.

The document also acknowledges the importance of land use planning for creating an urban form that is conducive to transit use, walking and cycling.

Pedestrian infrastructure

95% of all streets in Vancouver have at least one sidewalk and the vast majority has double sidewalks.

On local streets, residents can initiate sidewalk improvements through a Neighbourhood Improvement Program.

Many street crossings in Vancouver allow pedestrians to influence the timing of traffic lights.

The City has initiated a street beautification initiative called Blooming Boulevards, under which local residents are involved in planting and landscaping the boulevards on their streets.

The City has a network of 71 walking trails totaling 118 km in length. There are an additional 31 trails (37 km) in Pacific Spirit Regional Park, adjacent to the City's western boundary. The length of pedestrian paths is growing along with the expansion of the City and regional greenway networks.

Bicycle infrastructure

Vancouver's bicycle network began developing in the late 1980s with the adoption of the Vancouver Comprehensive Bicycle Plan (1988) and construction of the BC Parkway and Seaside recreational routes.

In 1992, the City approved the Bicycle Network Study, which recommended the creation of on-street bicycle routes on quiet, residential streets running parallel to major arterials.

The current Bicycle Plan was approved in 1999. The plan aims to increase cycling in Vancouver through "four fundamental Es" - engineering, education, enforcement, and encouragement. In terms of infrastructure, the plan calls for completing the routes envisioned in the 1992 Bicycle Network Study (which were around 60% complete in 1999) and ultimately creating a grid of bicycle routes across the territory, in which parallel routes would be no more than 1 km apart. The plan also called for developing a citywide network of greenways (City of Vancouver, 1999 a; City of Vancouver, 2007; TransLink, 2008).

Since 1999, the bicycle route network has grown at a slower pace than over the previous decade, expanding from 133 km in 1999 to 178 km in 2007. Nevertheless, in 2007, eleven new route segments were approved by council and expected to increase the total network length to 241 km (City of Vancouver, 2007 b). With the construction of these bicycle routes, all points within the City's territory, except areas in the south-east corner, will be within 1 km of a bicycle route.

There are dedicated bicycle lockers in two City-owned parkades, and supervised bicycle racks in two other parkades. The City does not have data on the number of bicycle racks, either on public or private property.

The City's Parking By-law (City of Vancouver, 2008a) requires most multi-family residential uses to provide a certain amount of off-street bicycle parking space. There are also bicycle parking requirements for most retail, service, office, cultural and recreational uses, as well as for certain institutional uses, namely for schools and health care facilities.

The Vancouver Building By-law stipulates that buildings with four or more required bicycle parking spaces must provide one pair of end-of-trip facilities, i.e., showers. An additional pair of facilities is required for roughly every 30 additional required bicycle parking spaces (City of Vancouver, 1995 b).

In practice, the City has been using street road and utility maintenance projects as opportunities for inserting new, on-street bicycle facilities or making roads more bicycle-friendly, despite the absence of an official requirement (City of Vancouver, 2007 b).

Most SkyTrain stations in the City (except in the downtown) have numerous unsupervised bicycle racks and several secure bicycle lockers. Bicycles are allowed on all modes of public transportation services operated by TransLink, including buses, light rail (SkyTrain), and ferry (SeaBus), at no additional cost. The West Coast Express also allows bicycles on board with the payment of a modest $1/day or $15/month fee.

Traffic

Numerous neighbourhood traffic calming projects have been undertaken since the early 1990's, the majority of which have been resident-initiated under Neighbourhood Improvement Programs (City of Vancouver, 1999 b). Projects have included measures such as traffic circles, speed humps, corner bulges, partial diverters, diagonal diverters, right-in-right-out diverters, signs, street closures, and street narrowing.

The 1997 Transportation Plan states that traffic calming projects should be prioritized in areas subjected to the greatest traffic impacts. The plan also proposed that a number of secondary arterial roads be reclassified as "Neighbourhood Collectors", which will be modified to increase safety, calm traffic, and improve livability (City of Vancouver, 2005 a).

The City has asked the provincial Ministry of Transportation to amend the BC Motor Vehicle Act to allow local authorities to reduce speed limits on residential streets from 50 km/h to 40 km/h (City of Vancouver, 2008 b).

Implementation

Mode share targets, to be achieved by 2021, are set out in the 1997 Transportation Plan. The mode share of the automobile is set to decrease by shifting most trips to transit. Shares for walking and cycling are set to increase only slightly above 1992 levels.

In 2006, the City prepared a 10-year progress report on the Transportation Plan. It was found that in terms of the mode share of walking and cycling, most of the targets for 2021 have already been met or exceeded (City of Vancouver, 2006).

5.1.4 Urban Form

Mix of uses and housing types

The 1991 Central Area Plan established "Living First" policies for Vancouver's Downtown Peninsula. Through intensive redevelopment over the 1990s, a series of new residential neighbourhoods have been established. The planning approach was to create complete, integrated neighbourhoods with a full array of infrastructure and services within walkable distances (Beasley, 2000).

Outside the downtown district, the 1995 CityPlan encourages a focus on the diversification of land uses in and around designated Neighbourhood Centres. To date, 19 such Neighbourhood Centres have been approved in Community Vision plans across the city. Two such centres, Kingsway & Knight and Norquay Village, are presently being implemented as pilot projects.

Generally, Community Visions have directed local commercial development to designated Neighbourhood Centres and other established shopping areas. Otherwise, new local shopping facilities have not been allowed within low-density residential areas.

Following directions set by the CityPlan, most Community Visions have made provisions for increasing the variety of housing options within existing neighbourhoods.

Street fronts

Street-side, at-grade parking is not allowed and has been actively eliminated in the downtown core. In most neighbourhood shopping areas, the City cannot eliminate existing street-side at-grade parking due to grandfathering rights. Whenever development does occur in such areas, automobile–oriented site designs - i.e., front side parking - is strongly discouraged.

Strict urban design guidelines have been applied to development on the Downtown Peninsula, seeking to create an attractive street-level environment while allowing for very high levels of density. Many high-rise residential towers are set on a pedestal composed of narrow, two or three story ground-related “maisonnettes” set close to the sidewalk. The remaining floors – the high–rise portion of the development – is set further back from the street, and thus partly obscured by the ground level maisonnettes.

In the rest of Vancouver, design guidelines that emphasize pedestrian friendliness have been established for Neighbourhood Centres through Community Visions. In general, the intention is for Neighbourhood Centres to be highly pedestrian- and cyclist-friendly.

Density and intensification

The City of Vancouver is bound by regional growth management policies laid out in the 1996 Livable Region Strategic Plan (Metro Vancouver, 1996). Key policies include protecting the region’s designated Green Zone, building complete communities, and creating overall a more compact metropolitan region.

Even though it predates the regional growth management plan, Vancouver’s 1995 CityPlan is consistent with the region’s growth management goals. The plan calls for increasing the variety of housing options in the City by creating new medium– and high–density housing.

Under the new EcoDensity initiative, the City of Vancouver aims to increase its population density while reducing pressure for outward growth on the urban periphery. The EcoDensity Charter presents carefully planned densification as a means of achieving greater ecological sustainability while fostering greater livability and affordability (City of Vancouver, 2008 d).

In 2004, Vancouver’s City Council approved amendments to the Zoning and Development By-law that have made it possible for any single-detached house anywhere in the City to have a legal secondary suite, provided it meets certain standards (City of Vancouver, 2005 b).

Beyond the major intensification projects undertaken in and around the Downtown Peninsula in the 1990s, the City has also implemented intensification projects around major transit (ie., SkyTrain stations) and is currently focusing on implementing intensification plans in designated Neighbourhood Centres. The City is also in the process of planning for intensification around stations on the new Canada Line light rail service.

In October 2008, Vancouver’s City Council approved a set of policy recommendations on the implementation of laneway housing in single family areas. Laneway housing is supported by the EcoDensity initiative (City of Vancouver, 2008 c).

Green space and greenways

Vancouver has approximately 200 parks covering 1,302 hectares, or 11.4% of the City's area (ACV, 2007).

The Vancouver Parks and Recreation Board's policy is to maintain a "neighbourhood park" ratio of 1.1 hectares per 1,000 residents, largely through land dedications from developers (Vancouver Park Board, 2006).

The City's greenway network plan envisions a network of 16 major greenways, with a total length of 140 km. Bicycle routes within greenways interconnect with and complement the on-street bicycle route network.

The Greenway Program also supports smaller, Neighbourhood Greenways. There are currently 11 such greenways across the City.

The City was the first municipality in BC to accept the provincial government's "20 by 2010 Challenge" (to increase levels of physical activity in the province 20% by 2010), launching the Active Communities Vancouver program in 2006. The program is overseen by the Vancouver Parks and Recreation Board and includes initiatives that incent residents to walk and cycle for recreational and utilitarian purposes (City of Vancouver, 2007 c).

Accessibility

The CityPlan emphasizes the creation of "accessible, community-based services". Social, health, and recreational services and libraries are to be "located in neighbourhood centres where they are easy to get to".

The Downtown Transportation Plan states that "the provision of additional transportation choices will help increase accessibility and promote an economically competitive downtown". However, the plan does not explicitly state that accessibility should be prioritized over mobility.

Implementation

As directed by CityPlan, all neighbourhoods across Vancouver have approved Community Visions, many of which have identified an area to be developed as a Neighbourhood Centre. To date, only two of 19 Neighbourhood Centres have been fully planned and are beginning to be implemented. The remaining 17 still need to be planned.

About one-third of the planned city greenway network has been implemented. Another one-third is presently being planned or under construction.

5.1.5 Future plans

Council recently gave City staff the go-ahead for preparing zoning amendments to enable the creation of laneway housing in single family zones. The amendments could be approved as early as late 2009.

The Planning Department wishes to accelerate the development of Neighbourhood Centres and has committed to plan them and begin implementation at a rate of two per year.

The City intends to continue implementing the EcoDensity Charter. Council approved a set of initial actions with respect to EcoDensity in June 2008 (see City of Vancouver, 2008 d). One of the more global planned initiatives is an update of the CityPlan to bring it more in line with the EcoDensity Charter.

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5.2 Port Moody

5.2.1 Summary

Port Moody, a suburb of Vancouver, has a fairly extensive network of on- and off-street pedestrian and cycling facilities, and yet the automobile remains the overwhelmingly dominant mode of transportation. The City of Port Moody's 2000 Official Community Plan (OCP) and 2005 Master Transportation Plan both contain policies that directly and indirectly support active modes of transportation, through infrastructure investment as well as through the creation of an urban environment that is more conducive to walking and cycling. Both of these policy documents are consistent with Metro Vancouver's regional policies with respect to land use and transportation.

Evidence of progress

- The City achieved high-density, mixed use development at Inlet Centre.
- The majority of new development is multi-family.
- The City's development permit guidelines include strong directives for the design of pedestrian facilities and street fronts.
- Since 2004, the City has allowed secondary suites in certain areas.
- The City planned and built pedestrian and cyclist connections across the CP railway, and has executed numerous traffic calming projects.
- There is increasing pedestrian activity in Moody Centre.

Where work is needed

- The City's mode share of walking and cycling is below the regional average.
- The role of active transportation is not clearly defined in the City's planning documents. For example, no specific goals have been set in terms of mode share of walking and cycling.
- The City has made little progress on the Official Community Plan's goal of creating "village-like" environments in existing neighbourhoods.
- The City has no policies encouraging the location of public facilities to maximize pedestrian and cycling access, nor does it have a program promoting bicycle use for trips to work.
- The City lacks a local greenways plan and connections to the regional greenways network.

5.2.2 General Information

Port Moody is a relatively small but rapidly growing suburb of Vancouver, in the north-eastern portion of the Metro Vancouver region.

Port Moody has older, denser, and more mixed urban form based on a rectilinear street grid in the southern part of its territory. The densest development is focused around the Inlet Centre, in the south-eastern part of the city. The eastern and northern periphery of the City is dominated by low-density residential development on a curvilinear, cul-de-sac street network. Heavy industrial uses and port facilities are located on the south shore of the Burrard Inlet, near the city's western border.

The 2006 census population was 27,512 people, a 15% increase over the 2001 population.

At present, 38% of dwellings in Port Moody are single-family detached; 37% are ground-oriented multi-family types, including townhouses, duplexes, and mobile homes; and the remaining 25% are either low- or high-rise apartments.

Port Moody is connected to the regional arterial network via the Barnet Highway (7A). The City is served by the heavy rail West Coast Express commuter train and frequent service bus lines, which connect it with the region's SkyTrain light rail rapid transit system.

The distribution of mode shares for trips to work is 74% by automobile as driver, 8% by automobile as passenger, 14% by transit, and 4% walking and cycling. The regional average mode share for walking and cycling is 8%.

5.2.3 Active Transportation

Planning policies and strategies

The City of Port Moody's 2000 OCP lays down general policies with regards to transportation, including a statement that the City will endeavour to "reduce the use of the private automobile and the congestion and pollution which accompanies it" (City of Port Moody, 2000).

The transportation chapter (10) of the OCP provides more specific policies, including:

- The City will address the mobility needs of residents through a number of means, including sidewalks, walking and hiking trails, as well as commuter and recreational bicycle paths.

- The City will support efforts to reduce automobile use by supporting the development of "non-automobile and alternative transportation systems".

- The City will update its Transportation Plan to cover a range of modes of transportation, including among others walking and commuter and recreational cycling.

- The City will create pedestrian connections between adjacent mixed use developments.

The City's 2004 Master Transportation Plan proposes a number of specific improvements to pedestrian and cycling facilities. For pedestrians, the plan proposes the widening and extension of some existing sidewalks, the construction of new sidewalks in selected locations, and new crosswalks at specific intersections. For bicycles, the plan proposes the widening of curb lanes on certain roads, the construction of a few off-road routes to interconnect existing bicycle facilities, and a number of improvements to signage. For both active modes, the plan proposes the construction of a new passage and the improvement of existing passages over the CP rail line that runs east-west across the City (City of Port Moody, 2004 a).

Policies found in the 1996 Livable Region Strategic Plan and TransLink's Transport 2040 plan (outlined in the Vancouver case study) also apply to Port Moody.

Pedestrian infrastructure

Arterials and collectors in Port Moody have double sidewalks and local streets have single sidewalks, while cul-de-sacs have either a single or no sidewalk (most new developments provide a single sidewalk on cul-de-sacs).

Designated street crossings are only installed around school sites and in places where they are warranted by the levels of pedestrian activity.

The total length of the pedestrian network is approximately 90 km - 48 km of roads with sidewalks plus 42 km of off-street pedestrian paths.

The City requires a land dedication for parks, which can in principle serve to augment the pedestrian path or trail network.

Bicycle infrastructure

There are 44 km of on-street bicycle paths in Port Moody and 17 km of off-street paths. There are currently no planned extensions to the official bicycle route system. Rather, the City is currently in the process of standardizing on-street existing bicycle lanes by introducing consistent signage and street markings, as directed by the Master Transportation Plan.

The City does not have data on the number of bicycle racks. A planner reported anecdotally that there is "a large number of racks throughout the city, in all shapes and sizes."

As a general practice, the City requires that bicycle parking facilities be incorporated in new office and other commercial developments as well as multi-family developments.

There is no formal policy directing the City to create bicycle lanes through new road or road improvement projects. Nevertheless, in practice, the engineering department has consistently been adding bicycle facilities and generally making roads more bicycle-friendly through recent road projects.

There are numerous standard bicycle racks and eight secure bike lockers at the Port Moody West Coast Express station (West Coast Express, undated). Bicycles can be carried on most TransLink buses at no additional cost and on all West Coast Express trains for a modest fee of $1/day or $15/month.

Traffic

The Neighbourhood Traffic Calming Policy, approved in 2001, establishes the procedures by which local residents can request traffic calming measures on their street.

Traffic calming measures have consisted mainly in the addition of curb extensions and traffic circles. The City has generally not resorted to road narrowing and lane reductions.

Implementation

Port Moody's Transportation Plan supports the development of pedestrian and cycling infrastructure, but does not include any specific goals in terms of mode share for either. As such, there are no measures currently employed to gauge the effectiveness of interventions related to facilitating active transportation.

A Transportation Action Plan (City of Port Moody, 2005) lists a number of specific actions that are to be taken to implement the Master Transportation Plan. Several actions are listed under the rubric of promoting walking and cycling. Most of the listed actions have since begun to be implemented but few are as of yet complete.

There is one staff person in the Engineering Department who oversees pedestrian and cycling networks.

5.2.4 Urban Form

Mix of uses and housing types

The OCP states that the City will "encourage and create pedestrian-oriented neighbourhoods, which provide the necessary and appropriate amenities".

The housing chapter of the OCP lists a number of criteria for which residential development or redevelopment, including infill, are to be evaluated. These include creating "the physical attributes of a village-like community" and "neighbourhoods that are… pedestrian and bicycle oriented".

In the land use chapter of the OCP, it is stated that in commercial areas, mixed use development incorporating a residential component shall generally be encouraged.

The Development Permit Area Guidelines for residential neighbourhoods include guidelines for small-scale commercial uses within residential areas (City of Port Moody, 1996).

Street fronts

Port Moody's Development Permit Area Guidelines require that all buildings, regardless of their use, should be located at or near the front property line and that required parking, if located at grade, is to be located at the rear of the site. The guidelines also state that surface parking is not to be placed between the building and the front property line where a pedestrian environment is intended (City of Port Moody, undated).

Among the Development Permit Area Guidelines, there are a number of requirements that are intended to help create interesting street fronts and a quality pedestrian-oriented environment. The guidelines specify materials, colours, fenestration, and the articulation of individual building fronts with the aim of promoting visual diversity and maintaining a human scale.

Density and intensification

Intensification through infill and redevelopment is encouraged by the OCP. The plan proposes secondary suites, redevelopment of sites in existing neighbourhoods, and encouraging commercial developments to include significant residential components as modes of residential intensification.

Since 2004, secondary suites have been allowed in Port Moody, provided they meet building code requirements and design guidelines specified by the City (City of Port Moody, 2004 b).

The OCP does not explicitly commit the City to increasing population density. Rather, the plan states that the City is to create a variety of housing forms, including higher density forms. The land use chapter of the OCP establishes the spatial distribution of different forms and densities of housing. Most of the land slated for development in the OCP, such as the Inlet Centre area, is to include higher density development.

Port Moody is bound by regional growth management policies laid out in the 1996 Livable Region Strategic Plan (Metro Vancouver, 1996). Key policies include protecting the region's designated Green Zone, building complete communities, and creating overall a more compact metropolitan region. Port Moody's OCP is consistent with the region's growth management goals.

Green space and greenways

The total area of parks and green spaces is 1,028 hectares, or 40% of Port Moody's total landmass - the highest share in Metro Vancouver.

Port Moody's minimum standards for public open space are as follows: 2.4 hectares per 1,000 residents (ha/1,000) of city parks, 0.8 ha/1,000 of community parks, 1.2 ha/1,000 of neighbourhood parks, 0 to 0.2 ha/1,000 of mini parks, and 4.0 ha/1,000 for natural open spaces. Exact requirements are negotiated between the City and developers at the subdivision stage.

There are no urban form guidelines that put green or open space at the centre of new development.

The City does not have its own greenways plan. The Metro Vancouver regional greenways plan does not include any greenways in Port Moody.

The City does have a Parks and Recreation Master Plan, last updated in 2003. The plan lays down general directives for parks and recreational infrastructure and recommits the City to upholding its 1993 Bike and Trail Plan. It does not provide any further directives as to the disposition of bicycle paths and trails across the City.

General policies regarding the citywide bicycle path and trail system are included in the OCP. In particular, the plan states that the citywide trail system will include only those routes that "show a viable connection between off-road and on-street paths" (City of Port Moody, 2000).

Accessibility

There are no specific policies regarding the location of public facilities or the desired mix of land uses around them. In practice, however, major facilities have been placed near dense, mixed-use development, such as Newport Village for example.

There are numerous references in the current OCP to creating "village-like" centres in different neighbourhoods and encouraging the development of complete communities, i.e., communities with a range of services.

Implementation

In terms of land use and urban form, the OCP lays down a set of broad policy goals. However, the goals are not specified in terms of any exact measures, and there is no timetable for attainment of any of the stated goals.

Despite the absence of concrete objectives, progress has been made in many areas. Notably, the City has been successful in increasing the mix of land uses, especially around Moody Centre and the Inlet Centre. There is also progress in terms of intensification. Notably, a secondary suites program, as proposed in the OCP, has been launched. However, there has so far been little progress in making existing, low-density neighbourhoods more village-like and more amenable to walking and cycling.

5.2.5 Future plans

The City is presently in the process of reviewing and updating its OCP. Discussion papers and a draft document include proposals such as creating laneway housing in single-family areas, ensuring the optimal use of Port Moody's limited land base by supporting higher densities of development at appropriate location, improving site design standards, and encouraging the establishment of locally-serving commercial uses within existing neighbourhoods (City of Port Moody, 2007 and 2008).

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5.3 Invermere

5.3.1 Summary

Invermere is a small town in the Columbia Valley of southeastern B.C., not far from the Alberta border. Increasing numbers of second homeowners and tourists are bringing increased traffic to the town. Preserving the cachet of this growing town is a high priority for Council and residents alike. The 2006 Official Community Plan (OCP) and 2008 Environmental Agenda demonstrate the municipal government's understanding of urban growth issues, and make explicit reference to the connections between urban form, active transportation and positive health and environmental outcomes.

Evidence of progress

- The District recognizes smart growth and active transportation as important issues.
- The District has built new pedestrian and cyclist facilities using private and public resources.
- The District's municipal policies address the challenges and opportunities of more compact and walkable development.
- The District's Official Community Plan emphasizes the role of a pedestrian-friendly downtown, including residential and mixed-use infill development.

- The District is seeing increased density and dwelling-type diversity.
- The District allows secondary suites.

Where work is needed

- The District demonstrates limited policy development and follow-through, as well as limited data collection and use of quantitative indicators.
- In recent years, a series of urgent water-supply issues have consumed most of the District's financial and administrative resources.
- The "second-home boom" is increasing traffic and resulting in new and reconfigured roadways, which may pose challenges to pedestrians and cyclists.
- The District's key policies on site planning and urban form are limited to downtown, thereby creating a need for more general growth and planning controls.
- The District's parkland and park/greenways planning efforts are lagging behind its goals.

5.3.2 General Information

Most of the town is laid out on an irregular grid, with some more curvilinear streets in newer areas. Virtually all of the built-up area of the District falls within a 1.5-km radius of the downtown commercial strip on 7th Avenue.

72% of all dwellings are single detached houses, 15% are ground-oriented multi-family types, including townhouses, duplexes, and mobile homes; and the remaining 12% are either low- or high-rise apartments.

Invermere's 2006 population was 3,002, a 5.0% increase from 2001.

BC Highways 93 and 95 connect the area to the Trans-Canada highway that runs between Calgary and Kamloops further north. Columbia Valley transit service started up only this year, and there is very infrequent service on the two routes linking Invermere with nearby towns.

79% of work commutes in Invermere were by car in 2006, while public transit accounted for 1% and walking/biking had 19% modal share.

5.3.3 Active Transportation

Planning policies and strategies

The 2006 OCP includes “a functional pedestrian transportation system that encourages an alternative to using motor vehicles” among its objectives for building a complete community. Alternative transportation is the focus of the OCP’s transportation policies, including adjusting road construction standards for pedestrian, cyclist, traffic-calming and aesthetic purposes; studying the impact of new development on bicycle and pedestrian circulation; and supporting alternative transportation in general. The downtown policies in the OCP include commitments to focus on streetscape and beautification efforts in improving downtown conditions.

The District’s 2008 Environmental Agenda includes some active transportation policy development priorities, to be undertaken in the coming years. A Cycling and Pedestrian Plan is to be developed by Spring 2010, “to encourage a non-motorized community and promote a healthy and active lifestyle”. The Agenda also calls for new development density targets to be set taking active lifestyles into account.

In July 2008, the District received a grant from the Union of British Columbia Municipalities (UBCM) to develop an Active Transportation Network Plan, which will evaluate existing pedestrian and bicycle routes and guide additions to the system.

Pedestrian infrastructure

All new development is required to improve the road frontage, including sidewalks or pathways.

The District has not been able to dedicate much of its own resources to building new sidewalks in recent years, but has successfully negotiated with developers to add to the pedestrian network.

The District is carrying out enhancements to the downtown streetscape to improve the pedestrian experience, including a set of raised crosswalks.

Invermere’s single bus route loops around the village core with stops at the supermarket, the hospital, and the main shopping area downtown. Most housing and retail businesses in the town are within a kilometre of the bus route.

In January 2008, the District received a grant from the UBCM to implement an “anti-idling, walking school bus” program, which is an active-transportation effort to reduce vehicle idling and support parents who collaborate in walking their children to school en masse.

Bicycle infrastructure

Invermere currently has 12 kilometres of bike routes overall. The municipality has added 2 kilometres of bike lanes, while developers have provided a further 10 kilometres of cycling pathways and lanes.

The District has placed several bike racks downtown, and has successfully encouraged developers to include them in their projects.

Bike lane requirements have been negotiated with developers as part of servicing requirements. This may become more formal through changes to subdivision and servicing bylaws.

Traffic

A traffic policy is among the goals listed in the 2008 Environmental Action Plan, and will come before Council soon.

A 2006 traffic study anticipated increasing congestion problems due to new residential construction. The study concluded that adding lanes for through traffic on existing streets would "detract from the small-town character of Invermere," and that reconfigured intersections with new turn lanes and traffic signals would provide sufficient capacity increases.

A traffic safety study that explores and encourages pedestrian-friendly traffic calming measures, street geometries, and streetscapes has been drafted and is under review prior to approval.

The District is working to reduce the width of streets in new developments from the current standard width of nine metres, through negotiations with developers.

Longer-distance transportation options are largely confined to the car, and easy highway access from Calgary is a major part of Invermere's appeal as a second-home market.

Implementation

The District has not directly dedicated funding to bike lanes, but Public Works has been able to mark out some cycle lanes with funds and resources from its existing budget and activities.

No District staff members are currently assigned exclusively to transportation planning. Upper-level transportation plans and priorities are set by Council, and the District Chief Administrative Officer, along with the Public Works administrative and technical staff (two people) are assisting these efforts. Outside consultants provide technical and engineering analyses to support these plans and make recommendations.

The District has not engaged in extensive quantitative benchmarking or monitoring for its transportation outcomes. Proposed policies for pathways and overall transportation have not been fully developed. The assessment of many transportation-related policy efforts has been informal and qualitative.

5.3.4 Urban Form

Mix of uses and housing types

Invermere's residential zoning categories prohibit commercial uses other than home-based businesses, and there are very few commercially zoned sites outside of the 7th Street, 13th Avenue and Laurier Street (the downtown and "gateway") commercial areas. The OCP supports mixed-use development downtown.

Resort zones, which are dedicated to medium- and high-density housing, hotel and recreational facilities, allow various commercial services to be integrated with resort/residential projects. Easy access to downtown services and a seasonal population in new developments has generally limited the market for neighbourhood commercial.

The older housing stock in Invermere is predominantly single detached. More recent development has been heavily skewed towards multi-family housing, with the construction of new tourist and second-home developments, but a lack of new entry-level or rental housing has elicited concern from local residents. Medium- and high-density residential development of various kinds is permitted in a range of residential zones. The OCP calls for a "well balanced mixture of housing types, tenure options and prices" and for "entry level and rental accommodations within existing and future residential areas".

Street fronts

The downtown concept plan in the OCP requires continuous street frontage flush with the existing building line, retail along the ground floor, and landscaped parking areas at the rear of the building. Special development permits enforce these requirements in the Downtown Permit Area, which forms the primary retail centre in the District.

Minimum setbacks from the front parcel line are set in the zoning bylaw. There are no maximum setbacks except for some types of "cluster development" that require setbacks between 3.0 and 4.5m.

New multi-family complexes, while they include green spaces and pedestrian facilities, tend to focus inward and lack an orientation to the public street.

The OCP includes design guidelines for development permit areas such as downtown. The guidelines emphasize natural materials, gabled roofs, articulated building volumes, and other features that echo traditional "mountain" styling. They discourage or forbid excess windows, blank walls, and other unattractive or conventional elements of typical commercial buildings.

Density and intensification

Secondary suites have been permitted on all single-family parcels since the zoning code was revised in 2002. Residential and mixed-use development is encouraged, and the OCP highlights priority infill areas in and around the downtown.

The compact size of Invermere has put most new residential development within a kilometre of the town's retail and commercial core. Many new multi-unit properties are very close to downtown services, but are used as second homes and generate relatively little retail or pedestrian activity. Limited neighbourhood commercial space is planned for some new residential projects.

The District adopted a Growth Management Policy in 2006. It sets conditions on extensions of the municipal boundary, including infrastructure capacity, protection of Lake Windermere and other natural features, and an "identifiable need" for expanded residential land.

The District's 2008 Environmental Agenda includes growth-related policy development priorities slated for implementation in the coming years, including the creation of an Urban Containment Boundary to limit sprawl, and density targets based on infrastructure capacity and potential for active transportation.

Green space and greenways

Only roughly 10% of the total land in Invermere is park space, well short of the District's 25% target. The District is making ongoing efforts to secure a significant tract of provincially owned land, in the southeastern part of the District, for park space.

Municipal officials have been successful in negotiating with developers to obtain a dedicated 30% of the land area of new developments to be used as parkland. The District's revised development charge bylaw includes charges for community-wide parks.

There are no urban form guidelines that put green or open space at the centre of new development; however the preferences of second-home buyers have led most developers to emphasize landscaping and recreational access in their site designs.

A Greenways Strategy to ensure continuity of parkland and recreational trails through new private developments was planned in 2005 and 2006, only to be dropped due to staff changes.

Accessibility

The OCP includes detailed concept and site plans for new community facilities to be integrated into the downtown commercial area. Two underused sites are slated for redevelopment, one as a community center and school district offices, the other as a new library and plaza. An undeveloped portion of downtown's Pot Hole Park will be reconfigured into a natural amphitheatre and skating rink.

Implementation

Objectives and measurements on relevant initiatives from 2006-2008 District annual reports:

- Greenways Strategy: Not developed
- Downtown revitalization: Plan to be adopted Sept 2008
- Development charge review: Charges revised in 2007
- Transportation Plan: Traffic studies adopted, works underway
- Study of a "new tax model for sprawl": Not completed
- Parking strategy/downtown parking plan: Not completed
- Parks and Pathways Master Plan: Not funded.

5.3.5 Future plans

The 2006 traffic study recommends the construction of a new roadway, the Westside Parkway, to create a new north-south corridor linking the Castle Rock and Pineridge Mountain developments with the provincial highways that connect to the Trans-Canada.

With the support of developers and municipalities, the Columbia River Greenways Alliance is working on completing trails linking Invermere to Radium Hot Springs and points north, and to Fairmont Hot Springs and Canal Flats to the south.

5.3.6 Sources

Interviews

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Documents

NB: District of Invermere documents are housed on the District's web site, which does not provide direct URLs. Specific documents are listed in the left-hand navigation column of the web site linked to below.

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6. Conclusions

This study reveals that urban form can be significantly associated with some forms of physical activity and with some health outcomes. After controlling for demographic variables (income, age and gender), the neighbourhood walkability indices showed statistically significant associations with walking, BMI and hypertension. Those living in walkable neighbourhoods were likely to walk more, weigh less, and have a lower odds of hypertension than those living in less walkable neighbourhoods.

The effects observed in this study provide added support for the hypothesis that urban form affects health and health-related behaviors. The consistency of findings with those generally found in previous research on associations between health outcomes and covariates, such as gender, age, and income, provides some assurance that our observations on health and urban form also have validity.

The implications of this and similar research for urban planning are significant; municipal and provincial governments should carefully consider the health implications of decisions affecting neighbourhood design and take the necessary steps to ensure that more compact, complete communities are promoted over sprawling, homogenous urban landscapes. Although our research does not allow us to pinpoint the urban design features that are of greatest relevance to health outcomes, the literature reviewed in Section 2 of this report suggests that land use mix, residential and employment density at trip origins and destinations, the attractiveness of streetscapes, and street connectivity are among the most important features to be promoted in new developments and major redevelopments.

The research findings also hold some significance for public health professionals. If urban form can have significant (positive or negative) influences on health and health-related behaviors, health practitioners can improve public health by advocating for more compact development patterns and complete communities. To do so, public health advocates (e.g., public health officials, health promotion workers, recreation professionals, educators and others) should be more directly involved in planning exercises, such as preparing a community plan, designing major new real-estate development projects, transportation planning, recreation planning, green space/environmental planning, and so on.

The case studies reveal that municipal governments are increasingly committed to promoting an environment that is conducive to walking and biking. Local authorities are taking steps to improve pedestrian and bike facilities (including pedestrian paths, bike lanes, and bike parking), calm traffic on pedestrian corridors, and afford more attention to the attractiveness and walkability of streetscapes, including street fronts, sidewalks and landscaping. In some cases, municipalities are adopting separate biking and walking plans in order to provide an integrated long-term vision for active transportation.

Moreover, the case studies show that smart growth policies are being increasingly adopted to guide municipal planning and development decisions. Intensification is proceeding, especially through minimally disruptive strategies such as secondary suites legalization and increased multifamily development in new communities. Densities are rising in redevelopment projects, central areas and in strategic locations located near transit. There is also evidence of a move towards an increased mix of land uses in strategic locations, such as around transit stations and in central areas. Planning documents reflect a recognition that urban villages that are walkable and bikable are desirable.

While progress is clearly being made, there are several fronts on which the case studies reveal the need for more work. Not all municipalities have included specific goals (e.g., modal shares) to promote active transportation in their community or transportation plans. These municipalities lack measures to gauge the effectiveness of interventions related to facilitating active transportation. There is also a need to ensure that all municipalities have developed comprehensive active transportation plans, including capital investments, programs and targets.

From a land use planning point of view, there is a need to develop specific land use objectives and implementation/monitoring frameworks for ensuring that municipalities move towards smart growth goals. The reshaping of existing neighbourhoods to be more pedestrian-friendly in terms of density, mix of uses, etc. has been slow to materialize. While streetscapes are being increasing attended to, regulations on maximum setbacks and orderly street fronts are still not universal. Greater efforts are also needed to ensure that government services (e.g., social, health, and recreational services and libraries) are to be located in accessible locations such as neighbourhood centres. Finally, integrated greenway strategies are needed in order to connect green areas and provide a network of bike and pedestrian paths throughout the jurisdiction.

Stemming sprawl and building more compact, complete and walkable communities is a policy recommendation that is very much in line with recommendations emerging from other studies in public health. Most importantly, more compact communities are seen as one important way to achieve lower levels of regional air pollution and associated health impacts (Bray et al, 2005). Beyond public health, research in other disciplines is also pointing towards more compact cities as an important policy lever for achieving a range of benefits, from improved regional ecological health and a lower ecological footprint to reduced energy use and greenhouse gas emissions. Together, these studies are presenting a formidable argument that managing growth more responsibly and building communities that are walkable, bikable and livable is the key to the sustainability and health of our communities.

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Appendix A:
Details on Methods and Results

This section provides further details of the empirical part of the study, including methods and results.

Walkability indices

As mentioned in the main report, we developed two walkability indices for use in this study: an objective index derived from measures of the form of the neighbourhood and a subjective index estimated from the PHSA survey where individuals responded to a variety of questions related to urban form and walkability.

Two of the variables used in the objective index, namely the land use mix and housing mix indices, require some explanation as to how they were derived. The land use mix index was developed using an entropy formulation. Such a formulation is often used to depict concentration or dispersion of an underlying phenomenon. Mathematically, it is expressed as follows:

$$\text{Entropy} = \{-\sum_{\text{k}}[(p_i)(1\text{n } p_i)]/(1\text{n}k)$$

Where p_i presents the proportion of land use type i in a Census Tract, $\ln(p_i)$ presents the natural log of p_i. k_i is the number of land uses categories within a Census Tract. The index varies between 0 and 1, where 0 suggests complete homogeneity and 1 represents a balanced mix of land uses.

Similarly, the housing index was also developed using the entropy formulation. For housing index, p_i presents the proportion of housing of a particular type (e.g., single family detached) in a Census Tract, and k is the total number of housing types.

To create the objective index from the variables measured, we first determined the "direction" of each variable, depending on whether a high score is considered more walkable than a low score. For example, higher density neighbourhoods are thought to be more walkable than low-density ones, so those neighbourhoods with higher scores on this variable were considered better from a walkability point of view. The neighbourhood with the best score was assigned a value of 100 and other neighbourhoods received scores from 0 to 100 as a direct ratio of the variable value in that neighbourhood compared to the variable value in the highest scoring neighbourhood. For example, if neighbourhood A had the highest density score at 80 units per hectare, then this would be assigned a normalized value of 100, and another neighbourhood with a density of 40 units per hectare would be assigned a score of 50. Normalizing the variables in this way allows us to add disparate measures together to obtain a single index value. The index value for each neighbourhood is the average of the normalized scores on the

10 urban form variables for that neighbourhood. The variables were weighted the same in the index in order to avoid introducing any systematic bias into the analysis.

In order to develop the subjective index, we relied on a multivariate technique called Factor Analysis to collapse the 10 subjective variables into one composite variable to reflect each individual's assessment of the walkability of their neighbourhood.[8] The new index was normalized with an average value of zero and a standard deviation of one. We rescaled this index to match the mean and standard deviation of the objective walkability index.The following table presents the summary statistics of the objective and subjective walkability indices.

Table 16: Summary statistics of the two walkability indices

	Observations[10]	Mean	Std. Dev.	Min	Max
Objective index	2731	56.48	9.87	48.71	89.58
Subjective index	2431	56.48	9.87	32.49	7.94

The above table confirms that the average and standard deviation of the two indices remains the same, however the minimum and maximum values are different. Another difference between the two indices is that the objective index has the same value for all observations (individuals in our sample) within the same neighbourhood, while the subjective index returns a unique value for each individual in the data set.

Table 17 shows the minimum and maximum values of variables used in the objective index.

Table 17: Minimum and maximum values

Variable	Minimum	Maximum
DA Pop Density (Net) persons per sq km	558	13584
Housing mix index	0.44	0.70
Average block length (metres)	103	148
Average set back in metres	5.58	14.45
No sidewalk	6%	100%
Intersections per sq km	14	119
Street connectivity (% Link 3 or more)	32%	84%
Land use mix index	0.28	0.89
Distance to open space and parks (meters)	251	800
Street width in meters	6	12

8 Factor Analysis is a technique often used to develop measures that are abstract in nature, such as happiness, but that could be gauged from proxies, which are then aggregated into one composite index.

Correlation analysis

A correlation analysis was carried out to reveal relationships between the two indices and measures of walking and physical well-being, such as Body Mass Index (BMI), hypertension, and diabetes. *Table 18* presents correlation statistics as well as the measures of statistical significance for these variables.

Table 18: Summary of correlation analysis

Variables	Subjective	Objective	Walking	BMI	Hyper	Diabetes
Subjective	1.0000					
Objective	0.2556 0.0000	1.0000				
Walking	0.0840 0.0001	0.0550 0.0061	1.0000			
BMI	-0.0884 0.0000	-0.0676 0.0005	-0.0576 0.0049	1.0000		
Hypertension	-0.0272 0.1808	-0.0425 0.0266	-0.0298 0.1381	0.2088 0.0000	1.0000	
Diabetes	-0.0357 0.0783	-0.0256 0.1812	-0.0267 0.1839	0.2251 0.0000	0.2393 0.0000	1.0000

Econometric models of walkability and health/activity outcomes

A series of regression models were estimated to determine the impact of neighbourhood urban form on walking and health. The walkability indices for each neighbourhood were included as independent variables, whereas dependent variables were walking levels, Body Mass Index (BMI), diabetes, and hypertension. The analysis controlled for some other factors that could influence walking and health outcomes, such as income, age and gender.

Walking and walkability indices

The three models reported in this section explore the relationship between walking and the walkability indices. The survey respondents reported the number of days in a week they walked for a certain time period. The results from the ordered probit models are presented in *Table 19*.

10 The number of observations for the two indices differ because the subjective index is estimated for those respondents who have provided valid answers for the variables included in the index; respondents with incomplete records were excluded.

Table 19: Ordered probit models showing relationship between walking and walkability

Variable	A	B	C
daywalking			
agecat==2	0.84*	0.83*	0.83*
agecat==3	0.80**	0.79**	0.81**
agecat==4	0.79*	0.79**	0.79**
inccat==1	0.92	0.91	0.97
inccat==2	0.89	0.90	0.91
inccat==3	0.85	0.87	0.87
inccat==4	0.92	0.95	0.96
women	1.03	1.04	1.04
objective index		1.01**	
subjective index			1.01***
cut 1			
Constant	0.13***	0.22***	0.27***
cut 2			
Constant	0.22***	0.38***	0.46***
cut 3			
Constant	0.32***	0.56**	0.68*
cut 4			
Constant	0.40***	0.70	0.85
cut 5			
Constant	0.55***	0.96	1.16
cut 6			
Constant	0.62***	1.09	1.32
Statistics			
N	1881	1881	1703

legend: * p<0.05; ** p<0.01; *** p<0.001

Model	Obs	11(null)	11(model)	df	AIC	BIC
A	1987	-2103.965	-2566.059	14	5160.118	5237.671
B	1987	-2103.965	-2560.147	15	5150.295	5233.388
C	1797	-1901.008	-2310.655	15	4651.31	4732.912

Obesity and walkability indices

Table 20 presents results from the ordered probit model. There are three models reported in the table. The first model labelled A does not include the walkability indices as explanatory variables. The second model labelled B includes the objective walkability index as an explanatory variable and the third model labelled C includes the subjective walkability index as an explanatory variable. Results reported in Table 4 are odds ratios, which are exponentials of the estimated coefficients. Also reported in the table are statistics for fit of the three models.

Table 20: Ordered probit models showing relationship between obesity and walkability

Variable	A	B	C
bmicat			
agecat==2	1.26**	1.27***	1.31***
agecat==3	1.46***	1.48***	1.51***
agecat==4	1.60***	1.61***	1.60***
inccat==1	1.01	1.02	0.95
inccat==2	1.24**	1.21*	1.19*
inccat==3	1.31**	1.27*	1.29*
inccat==4	1.20*	1.16	1.11
women	0.75***	0.75***	0.74***
objective index		0.99***	
subjective index			0.99***
cut 1			
Constant	1.03	0.54***	0.56**
cut 2			
Constant	3.00***	1.59**	1.66**
Statistics			
N	1987	1987	1797

legend: * p<0.05; ** p<0.01; *** p<0.001

Model	Obs	11(null)	11(model)	df	AIC	BIC
A	1881	-2574.263	-2054.947	10	4129.894	4185.838
B	1881	-2574.263	-2046.061	11	4114.122	4175.66
C	1703	-2329.048	-1843.092	11	3708.183	3768.616

Hypertension and walkability indices

We have estimated logit models to capture the relationship between walkability and hypertension in our sample. Logit models are used when the dependant variable is dichotomous and not ordinal as was the case previously. The results from the logit model are presented in *Table 21*.

Table 21: Logit model showing relationship between hypertension and walkability

Variable	A	B	C
agecat==2	1.998**	2.037**	0.538**
agecat==3	5.954***	6.056***	6.153***
agecat==4	16.581***	17.055***	16.824***
inccat==1	0.632*	0.655*	0.538**
inccat==2	0.711	0.705*	0.733
inccat==3	0.891	0.862	0.864
inccat==4	0.607*	0.589**	0.599*
women	0.873	0.855	0.842
objective index		0.979**	
subjective index			1.004
Constant	0.070***	0.233**	0.057***
N	2062	2062	1859

legend: * p<0.05; ** p<0.01; *** p<0.001

Model	Obs	11(null)	11(model)	df	AIC	BIC
A	1881	-2574.263	-2054.947	10	4129.894	4185.838
B	1881	-2574.263	-2046.061	11	4114.122	4175.66
C	1703	-2329.048	-1843.092	11	3708.183	3768.616

Diabetes and walkability indices

We also estimated logit models to capture the relationship between diabetes and the walkability indices, while controlling for age, income, and gender. The results are presented in *Table 22*.

Table 22: Logit model showing relationship between diabetes and walkability

Variable	A	B	C
agecat==2	1.665	1.691	1.829
agecat==3	4.985***	5.023***	5.159***
agecat==4	7.572***	7.634***	6.583***
inccat==1	0.629	0.652	0.560*
inccat==2	0.377***	0.374***	0.391**
inccat==3	0.433*	0.419*	0.463*
inccat==4	0.345***	0.334***	0.366**
women	0.852	0.836	0.813
objective index		0.979	
subjective index			0.988
Constant	0.034***	0.113**	0.072***
N	2064	2064	1861

legend: * p<0.05; ** p<0.01; *** p<0.001

Model	Obs	11(null)	11(model)	df	AIC	BIC
A	2064	-468.9011	-422.9868	9	863.9736	914.6652
B	2064	-468.9011	-421.2794	10	862.5588	918.8828
C	1861	-406.6578	-371.7431	10	763.4863	818.7749

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