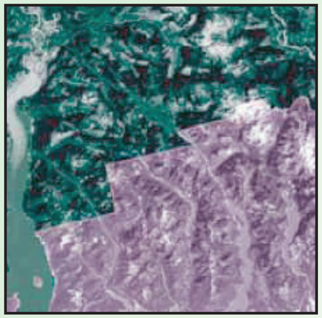
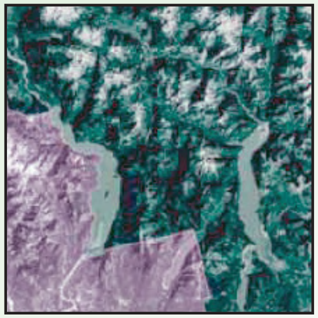

Promoting Physical Activity *through* Healthy Community Design

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Cover satellite image coutersy of Metro Vancouver.

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Executive Summary

The prevalence of overweight and obesity has reached global epidemic proportions. There are currently over 1 billion overweight or obese adults throughout the world. This epidemic is particularly evident in North America, where nearly two thirds of all American adults and nearly half of all Canadian adults are either overweight or obese. Even more alarming is the dramatic rise in overweight and obesity levels over the past few decades — since the early 1970s, overweight and obesity levels have risen by nearly 40% in the United States and by nearly 20% in Canada.

These trends are particularly worrisome primarily because of their public health implications. Overweight and in particular, obese people are more likely to suffer from a variety of serious health conditions — such as diabetes, cardiovascular disease, hypertension, stroke, and certain types of cancer — which increase the risk of premature mortality. The number of deaths attributable to overweight and obesity has almost doubled in Canada over the past fifteen years. Obesity is now the second leading cause of death in North America, second only to smoking. As a result, the costs of overweight and obesity on our health care systems are staggering. Obesity alone accounts for nearly 12% of all private health care spending in the United States, or $36.5 billion annually — an increase from just 2%, or $3.6 billion, in 1987.

There are many causes for this epidemic. One of the most common and preventable causes of obesity and overweight is physical inactivity. Physical activity is an important factor to consider because of its potential health benefits. The U.S. Surgeon General recommends that significant health benefits can accrue from engaging in at least 30 minutes of moderate physical activity (such as walking or bicycling) at least five days each week. However, most North Americans do not meet these minimum guidelines.

The level of physical activity that people engage in is influenced by many complex and interrelated factors. One such factor that has been receiving increasing attention in recent years is the built environment. Over the last several years, a growing body of research has emerged that has consistently shown that there is a significant relationship between the built environment, physical activity patterns, and public health outcomes. In particular, this research has shown that residents of typical urban communities (characterized by medium- to high densities, a variety of land uses, and a well-connected street network) walk and bicycle more and are less likely to be obese than residents of sprawling, suburban communities (characterized by lower densities, segregated land uses and poorly connected street networks). These findings show that where population densities are higher there is the ability to support increased amounts of street level retail, and other destinations – as well as public transport and other services. Research shows that proximity between where people live, work and play, and where there is a well connected street network results in more walking for daily needs.

However, nearly all of the studies to date have been conducted in the United States. Few such studies have been conducted in the Canadian context. This project addresses this gap in the literature by conducting one of the first comprehensive Canadian studies of the relationship between physical activity and objective measures of the built environment. In particular, this project examines the relationship between self-reported physical activity patterns and objectively measured urban form characteristics in southwestern British Columbia. Based on the findings, this project presents the implications of this relationship for land use policy and transportation investment in the Metro Vancouver and Greater Victoria regions.

To analyze this relationship, a Geographic Information System (GIS) was used to spatially integrate detailed parcel-level land use and transportation network data for the Metro Vancouver and Greater Victoria regions with physical activity data from the Physical Activity Monitor Survey conducted by the Canadian Fitness and LifeStyle Research Institute (CFLRI). Participants in the Metro Vancouver and Greater Victoria regions were asked to describe their physical activity patterns over the previous 7-day period. The data combines physical activity for all purposes: work, transport and leisure. The survey also included height and weight to create Body Mass

Index (BMI). Physical activity and BMI were then correlated with neighborhood design factors (mixed use, residential density, street connectivity (route directness), and retail site design) measured within a 1 kilometer distance from each respondent's home. Additional information on the presence of grocery stores and parks was included.

A variety of statistical analyses were conducted that adjusted for socio- demographic factors including analysis of variance (ANOVA) and more detailed logistic regressions to examine the statistical relationship between BMI, physical activity patterns, and urban form characteristics, while controlling for demographic variables. In total, 620 participants with complete data were used in the analysis. In general, the population of southwestern British Columbia is very active. More than half of all survey participants (54%) indicated that they walked every day over the previous week, whereas only 9% of respondents indicated that they did not walk at all. The average time walking was about 371 minutes per week (about 53 minutes per day); the average time engaged in moderate activity for an average of about 163 minutes of per week (about 23 minutes per day). Nearly two-thirds (62%) met the recommended weekly physical activity recommendation by walking alone and three-quarters (75%) by a combination of walking and moderate activity. This might appear higher than one would expect, however the recommendations were based primarily on studies of leisure-time physical activity whereas we measured all daily physical activity, including work, commuting, chores and leisure. Across the region there was no statistically significant trend in physical activity patterns between urban, suburban and rural areas.

Despite being generally active, much of the population was overweight. Nearly half (47%) of study participants were overweight (Body Mass Index (BMI) ≥25) and 15% were obese (BMI ≥ 30), with older respondents and males more likely to have high BMI. BMI patterns did vary geographically, with those in suburban and rural municipalities significantly more likely to be overweight than their rural counterparts: in the urban core only 35% of individuals were overweight; this was as high as 62% in the rural areas.

Which factors might account for this geographical distribution of BMI? The analysis revealed that certain aspects of the physical environment within a kilometer of one's residence were significantly associated with a lower likelihood to be overweight, over and above demographic factors. The following findings were most significant:

- Residents living in the most walkable areas of each region (ie the top quartile of walkability) were half as likely to be overweight than those in the least walkable buffers;
- Residents living in the most connected areas – or in the highest quartile of intersection density were half as likely to be overweight as those living in the lowest quartile;
- Residents living in buffers with the highest quartile of retail floor space ratio (where retail is set up against the street) were half as likely to be overweight as those living in the lowest quartile (where retail is set behind surface parking lots);
- Each additional grocery store within about a kilometer distance was associated with an 11% reduction in the likelihood of being overweight.

Similarly, particular land uses were associated with getting sufficient activity from walking. We found that the self reported physical activity data created the inability to adequately separate out walking for specific purposes (to get somewhere) or for leisure. Therefore, our utilitarian measures of walkability (residential density, intersection density, land use mix, or the ratio of retail floor space ratio) were not significantly associated with overall walking once we adjusted for demographic characteristics. However, key findings on physical activity were:

- Living in a buffer with at least one grocery store was associated with a nearly 1.5 times the likelihood of getting sufficient physical activity, as compared to living in an area with no grocery store in the buffer;
- The presence of either small or large neighbourhood retail land use was associated with an increased likelihood of getting sufficient physical activity (90% significance level).

These findings have significant implications in terms of land use policy as it relates to public health in the Metro Vancouver and Greater Victoria regions. In particular, the analysis found that the likelihood of being overweight decreased significantly in areas with higher walkability, higher intersection density, a higher ratio of retail floor area, or in areas with more grocery stores within about a kilometer road network distance. Although there are clearly other factors that influence obesity and physical activity patterns, this project presents a strong public health based argument in favour of developing walkable neighbourhoods, and suggests that land use policies should promote density, pedestrian-friendly design, and the availability of healthy food choices and neighbourhood retail in order to improve the health status of people in their neighbourhoods.

CHAPTER ONE
Introduction

BACKGROUND

With more than 1 billion adults throughout the world exceeding guidelines for acceptable weight levels,[1] the prevalence of overweight and obesity has emerged as a global epidemic. In North America in particular, there has been an alarming increase in recent decades in the number of people that are overweight or obese. In the United States, nearly two out of every three adults are currently either overweight or obese, compared to less than half of the American adult population in the late 1970s.[2]

These figures are more moderate but still significant in Canada, where nearly half the adult population is currently overweight or obese – an increase of 18% since the early 1970s.[3] This trend of rising levels of overweight and obesity is particularly worrisome because of its public health implications. People who are overweight or obese are much more likely to suffer from a variety of serious health conditions – such as diabetes, cardiovascular disease, hypertension, stroke, and certain types of cancer – that increase the risk of premature mortality. This has become such a concern in recent years that the increasing prevalence of overweight and obesity is now considered a public health crisis. In fact, the Heart and Stroke Foundation of Canada recently stated that "the increasing number of overweight and obese Canadians now poses one of the greatest threats ever to public health in this country" and warns that "fat is the new tobacco."[4]

There are many possible reasons for the increasing levels of overweight and obesity, such as poor diet, smoking, and inadequate levels of physical inactivity. Physical inactivity is often regarded as one of the most common and preventable causes of overweight and obesity. The majority of North Americans do not meet the minimum guidelines for physical activity as recommended by the United States Surgeon General. In fact, at least 60% of the American adult population does not meet these minimum physical activity guidelines,[5] while nearly half the Canadian adult population is physically inactive.[6]

As a major factor influencing the likelihood of becoming overweight and obese, physical inactivity poses significant health risks. In addition, physical inactivity places significant costs on the health care system. The direct and indirect cost of physical inactivity in Canada are estimated to be more than $5 billion annually.[7] To date, most efforts to increase physical activity levels have focused on modifying individual behaviour through interventions such as personal exercise programs. However, these interventions have had limited success, in part because the amount of physical activity that people engage in is influenced by many complex and interrelated factors, such as socio-economic status, ethnicity, the natural environment and climate, and the amount of time spent watching television, browsing the internet, or driving. One factor that can have a particular influence on physical activity levels is the built environment. The way communities are designed can have a significant effect on how much physical activity individuals engage in, by making it either easier or more difficult for people to engage in certain types of physical activity (such as walking and bicycling) in their neighbourhood. For example, people are likely to walk or bicycle more in areas that have a well-connected grid street network, medium- to high-densities and a mixture of land uses (see **Figure 1-1**) than they are in low density, sprawling environments with segregated land uses and a high number of dead-end streets (see **Figure 1-2**). The reason for this pattern is simple – where densities are higher, there are more destinations in a given area; where there is a mixture of land uses, there is a greater diversity of destinations in an area (such as homes, workplaces, stores, restaurants, services, or parks); and where there is a well-connected street network, distances are shorter than in areas with a poorly-connected street network, thereby making it easier to walk or bicycle to these destinations. When present, these three factors – density, land use mix, and street connectivity – work together to encourage walking and bicycling. However, when these three factors are absent, significant environmental barriers are put in place that make it less likely that people will walk or bicycle in their neighbourhood.

PROBLEM STATEMENT, RESEARCH QUESTIONS, AND HYPOTHESIS

In the past several years, a growing body of research has emerged that suggests there is indeed a statistically significant relationship between the built environment, physical activity patterns, and public health outcomes (see **Figure 1-3**). In particular, this research suggests that several features of the built environment, ranging from transportation infrastructure and land use patterns to micro-scale urban design elements, have a significant impact on physical activity patterns and overweight and obesity levels. In addition, many empirical studies have been conducted to examine which specific built environment variables have the most significant relationships with physical activity levels. However, nearly all of these studies have been conducted in the United States.

To date, a limited amount of research has been conducted to explore the relationship between the built environment and physical activity patterns in the Canadian context. This project aims to address this gap in the literature by conducting one of the first comprehensive analyses of such a relationship in the Canadian context, using southwestern British Columbia as a case study. Southwestern British Columbia is defined for this project as incorporating the Metro Vancouver region (including the lower Fraser Valley municipalities of Abbotsford, Chilliwack and Mission) and the Greater Victoria region (see **Figure 1-4**). Southwestern British Columbia is the most urbanized and populated portion of the province, as it is home to nealy 2.9 million people, or approximately 64% of the province's population. More specifically, there are over 2.6 million residents in the Metro Vancouver region and over 360,000 residents in Greater Victoria. Southwestern British Columbia was selected as a case study for this project because of a variety of natural and historic factors, particularly evident in the Metro Vancouver region, that make it distinct in North America (see Chapter Two). For example, although both the Metro Vancouver and Greater Victoria regions are home to much of the same type of sprawling, suburban development typical of most North American regions, these regions are distinct in North America because of various natural and historic features that have constrained the geographic extent of this suburban sprawl. In Metro Vancouver in particular, this has allowed for the creation of many compact, mixed-use and relatively dense communities spread throughout the region. In fact, more than six out of every ten residents of the Metro Vancouver region and a third of Greater Victoria residents live in compact communities — ranking these regions first and second in the Pacific Northwest, respectively, in terms of compact growth.[8] Because of its distinct development patterns, and because southwestern British Columbia is

Figure 1-1

Walkable environments. Characteristics include mixed land uses, medium densities, and a grid street network. Also notice the minimal building setbacks and continuous sidewalks.

Figure 1-2

Less walkable environments. Characteristics include segregated land uses, low densities, and disconnected street networks. Also notice the large building setbacks and lack of sidewalks on the top picture.

one of the most physically active and healthy areas in North America, this area serves as a useful case study to assess whether the relationship between physical activity and the built environment is similar to or different than that found in previous studies. Drawing on a wide range of literature from the fields of urban planning, environmental psychology and public health, and based on a comprehensive analysis of existing land use, transportation network, and physical activity data, this project will examine the relationship between self-reported physical activity patterns and objectively measured urban form characteristics in southwestern British Columbia. In particular, this project will explore the following questions:

1. What is the spatial distribution of walkable and unwalkable environments in southwestern British Columbia?
2. What is the spatial distribution of physical activity patterns in southwestern British Columbia?
3. Which built environment variables have the most significant relationships with physical activity patterns in southwestern British Columbia, after controlling for demographic variables?
4. What are the possible implications of these findings in terms of transportation investment and land use policy as they relate to public health in the Metro Vancouver and Greater Victoria regions?

Based on the findings from previous studies, while being cognizant of the unique context of southwestern British Columbia, it is hypothesized that a relationship between the built environment and physical activity patterns indeed exists in the region. However, it is likely that this relationship will be more moderate than that found in many American cities, as a result of the many of the unique characteristics of the region previously mentioned and elaborated upon in Chapter Two. In addition, contrary to most research in American regions that shows that residents of most suburban environments engage in less physical activity and are more likely to be obese than their urban counterparts, it is hypothesized that there will be a distinct and unusual pattern in southwestern British Columbia, with residents of some suburban municipalities exhibiting physical activity patterns more typical of urban environments. In particular, it is hypothesized that residents of the suburban municipalities of North Vancouver

(City and District), West Vancouver and Richmond in Metro Vancouver, as well as the inner suburban municipalities in Greater Victoria, will exhibit physical activity levels more typical of urban environments. In contrast, it is hypothesized that residents of the suburban municipalities located south of the Fraser River and east of Vancouver in the Metro Vancouver region, as well as the outer suburban municipalities in Greater Victoria, will exhibit physical activity levels more typical of suburban environments. This hypothesis of a dichotomy of physical activity levels among suburban municipalities is based on the differing characteristics of these municipalities, such as land use patterns, topography, and demographics, that will be elaborated upon in Chapter Two.

PROJECT OUTLINE

This project contains six chapters. A brief outline of each subsequent chapter is provided below:

Chapter Two outlines the context of southwestern British Columbia in order to explain, at least in part, why its residents are among the healthiest and most physically active in North America. The chapter first outlines several socio-demographic characteristics of the region, such as size, population trends, and patterns of development. The chapter then presents several characteristics that are unique to each of the Metro Vancouver and Greater Victoria regions, and which make southwestern British Columbia an informative case study within which the relationship between the built environment, physical activity patterns, and overweight and obesity levels can be explored.

Chapter Three provides a review of relevant literature to examine the relationship between the built environment and physical activity patterns. This chapter begins by examining the rising levels of overweight and obesity throughout North America and argues that this trend can be partly explained by insufficient levels of physical activity. This chapter then presents findings of several empirical studies to demonstrate that the built environment does have an effect on physical activity patterns. The chapter then outlines and refutes an argument against the findings of such a relationship, and concludes by outlining a theoretical framework within which the analysis for this project will be carried out.

Chapter Four outlines the methods of data collection and analysis that were used for this project. The analysis for this project was conducted by integrating land use, transportation network, and physical activity data for southwestern British Columbia. This chapter first describes the data collection methods and the attributes of each of the datasets used for this

Figure 1-3

Conceptual model. The built environment (land use patterns, transportation systems, and urban design features) is one of many factors that influences physical activity patterns, which in turn affects public health outcomes.

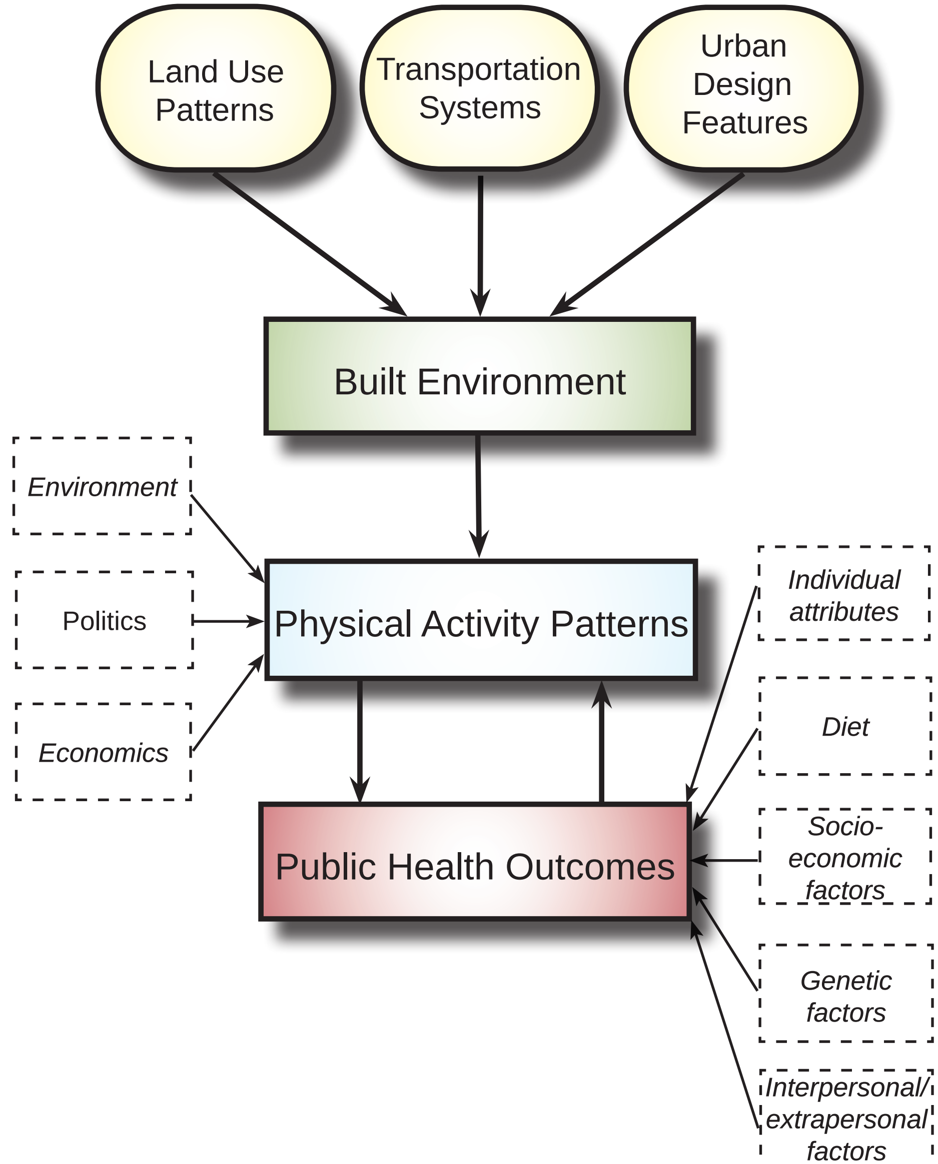


Figure 1-4

Study area and its context. The Metro Vancouver and Greater Victoria regions and their context within the Georgia Basin in the Pacific Northwest.

Source: Setton, 2005.

project. The chapter then discusses the methods used to analyzed this data for this project.

Chapter Five presents the results of the analyses. This chapter will begin by presenting the characteristics off the survey sample, and will then present descriptive statistics that outline general land use and transportation characteristics as well as physical activity levels. Finally, this chapter will present inferential statistics, which will outline the relationship between the land use and transportation data and the physical activity data.

Chapter Six will provide conclusions and recommendations for southwestern British Columbia, by informing how land use policy and transportation investment decisions impact critical aspects of public health in the Metro Vancouver and Greater Victoria regions.

CHAPTER TWO

Regional Context

"Vancouverites are an uncommonly vigorous and healthy bunch... More than any North American city, Vancouver has intentionally merged public health with city planning. The goal is not just to promote recreation (there are plenty of bike trails and tennis courts), but to design physical activity into the daily routine, to build a city so compelling that people will leave their cars at home, strap on a backpack and take up walking as their primary mode of travel."
The Star Tribune, July 31, 2005

"Vancouver has emerged as the poster child of urbanism in North America. In recent years, through a series of locally grown strategies, Vancouver has consciously willed itself into becoming a model of contemporary city-making…something curious, perhaps even miraculous, is happening here."
Lance Berelowitz. Dream City. Page 1.

Southwestern British Columbia was selected as a case study for this project because it is a unique region that consists of several distinct historic, natural and built environment characteristics that influence the physical activity patterns of the residents in unique ways. The Metro Vancouver and Greater Victoria regions as defined for this project encompass 37 municipalities and one electoral district (see **Box 2-1**). These two metropolitan regions share many distinctions. Both regions are relatively young, have compact forms of development and have mild climates. Both regions are also renowned for their livability, as seen from Metro Vancouver's global reputation as one of the world's most livable cities[9] as well as the City of Victoria's vision to become the most livable city in Canada.[10] As a result of these, and many other factors the Metro Vancouver and Greater Victoria regions are home to some of the most healthy and physically active residents in North America. In fact, with the coming of the 2010 Winter Olympics, the Provincial government has stated its desire to make British Columbia the most physically fit jurisdiction to ever host a Winter Olympic games. As British Columbia's Premier Gordon Campbell once proclaimed: "We are going to have the healthiest, most physically active people in North America, the most physically fit jurisdiction ever to host a winter Olympics, right here in 2010 in British Columbia."[11]

This chapter will first provide a brief overview of some general characteristics of southwestern British Columbia, by outlining socio-demographic profiles for the

BOX 2-1: MUNICIPALITIES IN THE REGION

Metro Vancouver Region *(member municipalities of Metro Vancouver, or the Fraser Valley Regional District where noted)*

- City of Abbotsford (FVRD)
- Village of Anmore
- Village of Belcarra
- Island Municipality of Bowen Island
- City of Burnaby
- City of Chilliwack (FVRD)
- City of Coquitlam
- District of Delta
- City of Langley
- Township of Langley
- Village of Lions Bay
- District of Maple Ridge
- District of Mission (FVRD)
- City of New Westminster
- City of North Vancouver
- District of North Vancouver
- District Pitt Meadows
- City of Port Coquitlam
- City of Port Moody
- City of Richmond
- City of Surrey
- City of Vancouver
- District of West Vancouver
- City of White Rock
- Electoral Area A (University Endowment Lands)

Excluded: *Electoral Area A (Other)*

Greater Victoria Region *(member municipalities of the Capital Regional District)*

- District of Central Saanich
- City of Colwood
- Township of Esquimalt
- District of Highlands
- District of Langford
- District of Metchosin
- District of North Saanich
- District of Oak Bay
- District of Saanich
- Town of Sidney
- District of Sooke
- City of Victoria
- Town of View Royal

Excluded: *Saltspring Island Electoral Area, Southern Gulf Islands Electoral Area, Juan de Fuca Electoral Area*

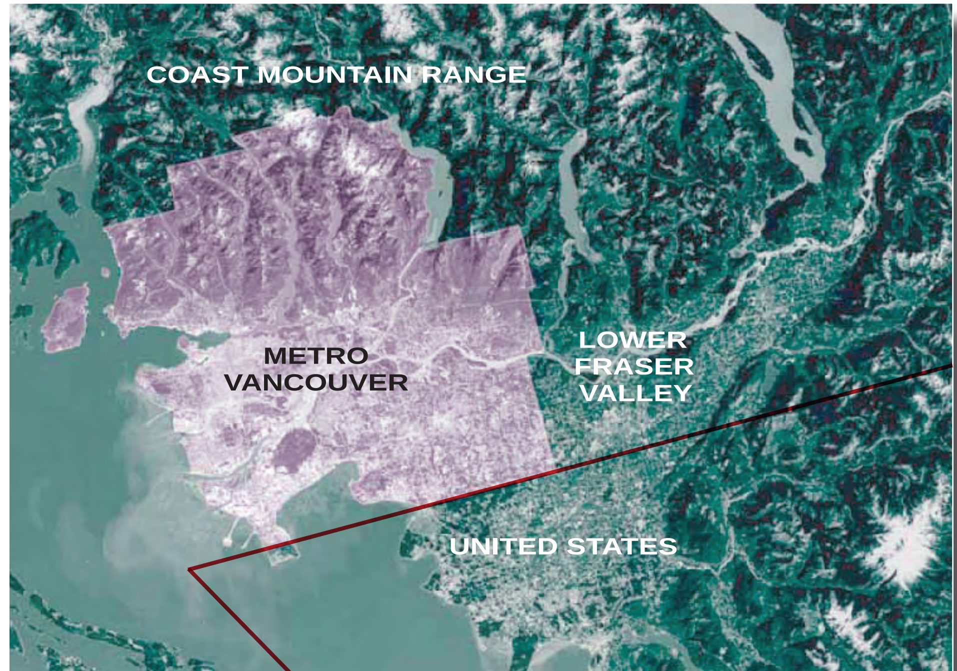
Metro Vancouver and Greater Victoria regions and by providing a concise overview of the area's development context. This chapter will then outline some unique features of the region that combine to make this a particularly physically active region, and therefore a unique and relevant region to examine as a case study for this project.

REGIONAL OVERVIEW

Situated on the west coast of North America immediately north of the Canada-United States border, southwestern British Columbia encompasses an area of 4,176 km^2. The area defined for this project is made up of 37 municipalities and one electoral area in the Metro Vancouver region (including three municipalities of the lower Fraser Valley) as well as the Greater Victoria region (see **Box 2-1**). This area is the most populated portion of British Columbia, as about 66% of the province's population lives in Southwestern British Columbia. In addition, 9 of the province's 11 largest cities are located in this area. Despite the large population base, however, there is a large variation in the types of environments that exist in southwestern British Columbia, ranging from highly urbanized environments to suburban locales and rural areas. The regional boundaries were defined as such for this project so as to allow statistically significant comparisons of physical activity patterns among these different environments.

Figure 2-1

Metro Vancouver and lower Fraser Valley and its context.



Source: Adapted from Metro Vancouver, 1996. Page 4.

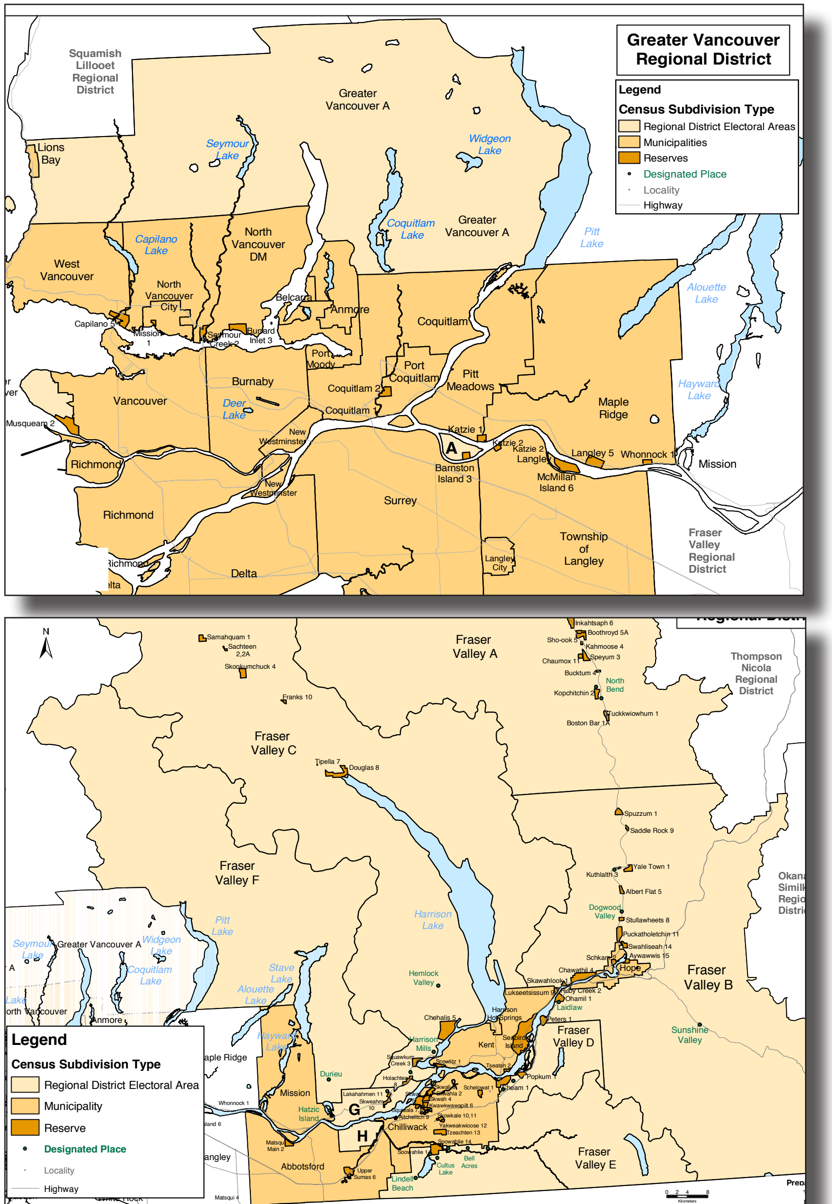
BOX 2-2: DEFINING METRO VANCOUVER

Throughout this project. the term **Metro Vancouver** will be used to refer only to the 21 municipalities and one electoral area that are officially members of the Regional District.

The term **Metro Vancouver region** will be used throughout this project to refer to the 21 member municipalities of Metro Vancouver as well as the City of Abbotsford, City of Chilliwack, and District of Mission which are situated in the lower Fraser Valley and are members of the Fraser Valley Regional District (FVRD).

Figure 2-2

Metro Vancouver and Fraser Valley Regional District (FVRD).



Source: BC Stats, 2003.

Metro Vancouver Socio-Demographic Profile

As shown in **Figure 2-1** and **Figure 2-2**, the Metro Vancouver region as defined for this project consists of 21 member municipalities and one electoral area of Metro Vancouver, and three member municipalities of the Fraser Valley Regional District (FVRD). The three Fraser Valley municipalities (City of Abbotsford, City of Chilliwack and District of Mission) were included in this definition to ensure a sufficient number of suburban and rural environments were incorporated in the analysis.

The Metro Vancouver region is spread over a vast area, with a total land base of 3,722 km^2 (of which 2,879 km^2 is located in Metro Vancouver and 843 km^2 is located in the three lower Fraser Valley municipalities).[12] However, due to several constraints, such as the Coast Mountain Range as well as areas that are protected from urban development (such as parks, watersheds, and land within the provincially designated Agricultural Land Reserve), the amount of land suitable for urban development is much smaller — the total developable land area in Metro Vancouver is estimated to be about 1,441 km^2.[13]

Metro Vancouver is a fast-growing region; its population has grown from about 580,000 in 1951 to nearly 2.3 million today and is projected to grow to over 3.3 million by 2036 (see **Figure 2-4**).[14] With about 578,000 residents in 2006, the City of Vancouver itself is home to about 25% of the Metro Vancouver region's population, despite only encompassing about 3% of Metro Vancouver's land base with a land area of 115 km^2.[15] Metro Vancouver is also ethnically diverse, with a particularly large Asian influence. In 2001, about 36% of the region's population (almost 740,000 people) was born in another country. Of these first generation immigrants to the region, over 60% were born in Asian countries, while over 25% were born in European countries (see **Figure 2-5**).[16] Metro Vancouver is also home to a relatively young population, with nearly two thirds of its population (64%) being 44 years of age or younger (including 32% who are between 25 and 44 years of age). In contrast, 24% of the population is between 45 and 64 years of age, and 12% of the population is 65 years or older (see **Figure 2-6**).[17] Metro Vancouver is also highly educated, with 39% of its population having received credentials from college or university.[18]

Greater Victoria Socio-Demographic Profile

The Greater Victoria region is located within the Capital Regional District on the southern tip of Vancouver Island. This region, which consists of 13 municipalities, is much smaller than the Metro Vancouver region, with a land base of 2,341 km^2 (see **Figure 2-3**). However, the majority of that land base is located in unincorporated Electoral Areas.

The amount of land in incorporated municipalities in Greater Victoria is only 454 km^2.[19] While Greater Victoria has a much smaller population than Greater Vancouver, it is also a fast growing region. The population of the Capital Regional District has grown from about 121,500 people in 1951 to nearly 364,000 today, and is projected to grow to about 460,000 residents by 2036 (see **Figure 2-4**).[20] The City of Victoria itself has a particularly small land area of less than 20 km^2, or just 4% of the Greater Victoria region, although it is home to about 78,000 residents, or about 24% of Greater Victoria's residents.[21] As such, the City of Victoria and the City of Vancouver are similar in that these two urban centers are each home to about a quarter of their respective region's populations, despite encompassing a very small proportion of their regional land bases.

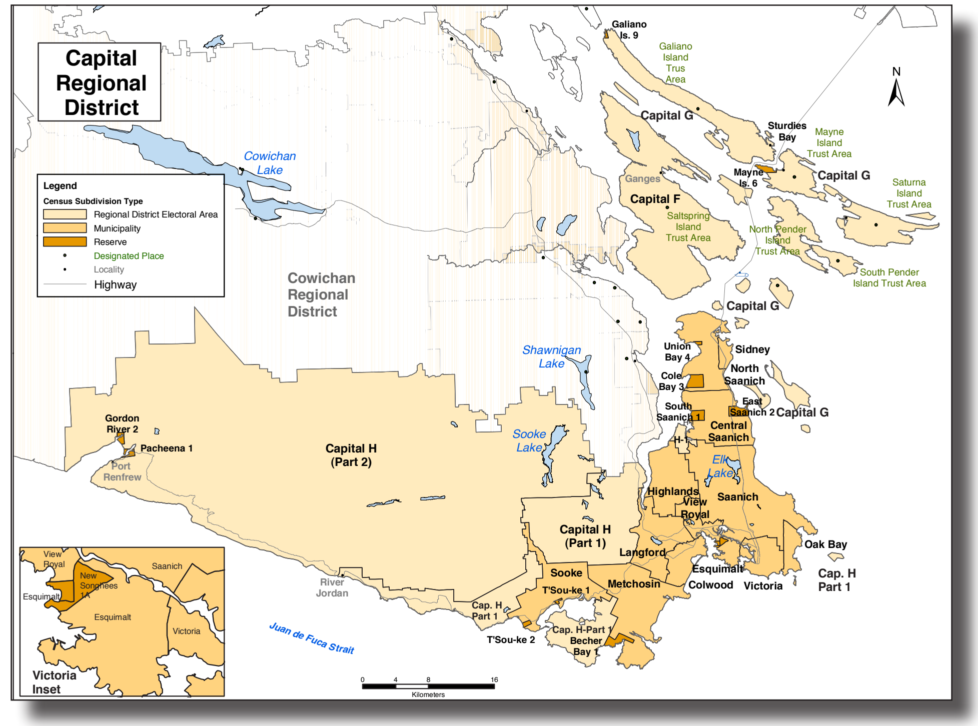
The ethnic make-up of the Greater Victoria region is significantly different than that of the Metro Vancouver region, both in the size of the immigrant population and the patterns of immigration. Immigrants make up about 19% of the region's population, or about 61,000 people. In addition, there is a less significant Asian influence in the Greater Victoria region (see **Figure 2-5**), as the majority of immigrants (59%) were born in Europe, while just 22% were born in Asia.[22] The Greater Victoria region is home to an older population than the Metro Vancouver region (see **Figure 2-6**), with 44% of the population being 45 years of age or older (including 18% of the population that is over 65 years of age). In contrast, only 27% of the region's population is between 25- 44 and about 13% is between 15-24 years of age.[23] The region is also highly educated, with about 40% of the region's population having received credentials from college or university.[24]

Regional Development Context

The Metro Vancouver and Greater Victoria regions are both relatively young in global terms. Although First Nations peoples have inhabited southwestern British Columbia for centuries, European explorers did not first 'discover' the area until the late 18th century, and it would take until the mid- to late-19th century before any municipalities in the area were formally incorporated. The first European urban developments in the Metro Vancouver region were in the cities of Vancouver, New Westminster, and North Vancouver, while the first developments in the Greater Victoria region were concentrated in today's urban core of the City of Victoria. These four municipalities are now the most densely populated areas of their respective regions. Over the course of the 20th century, both regions grew rapidly, in parallel with the rise and fall of the streetcar and the emergence of the automobile. As will be seen later in

Figure 2-3

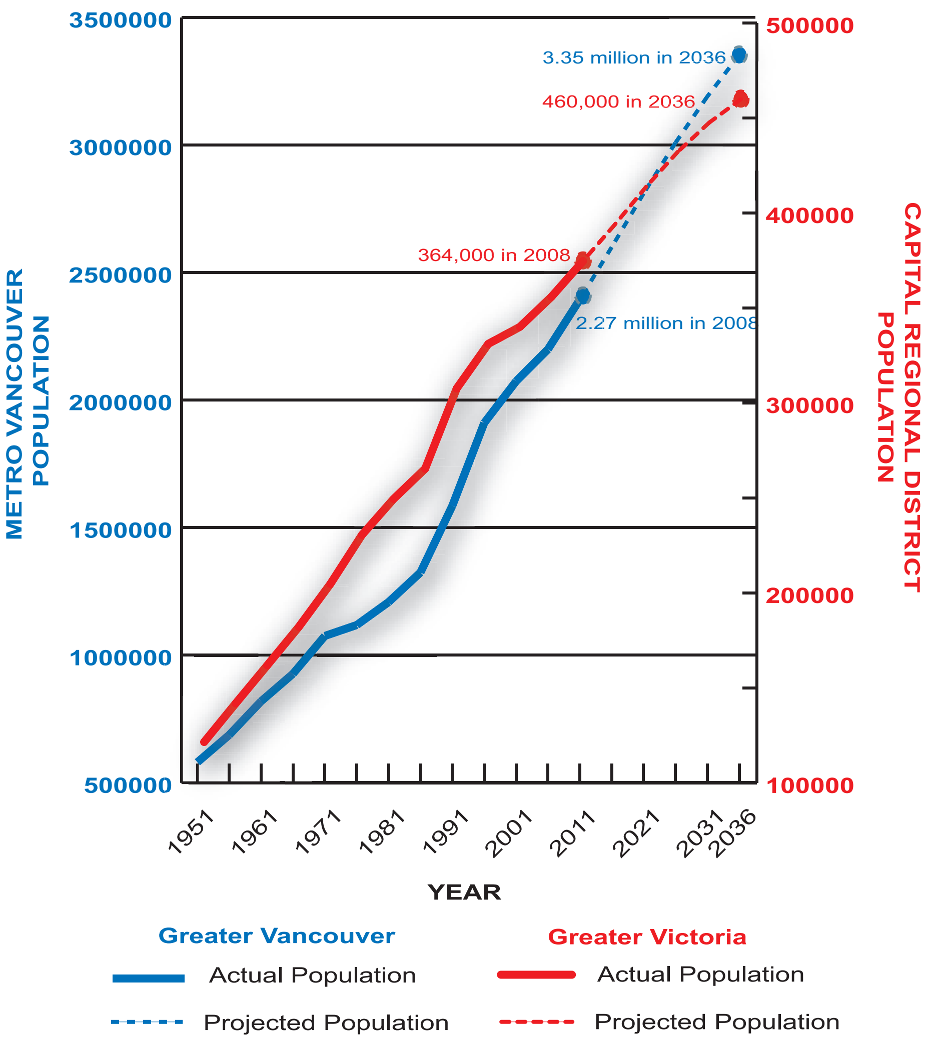
Capital Regional District (Greater Victoria).



Source: BC Stats, 2003.

Figure 2-4

Metro Vancouver and Greater Victoria population trends, 1951-2036.



Source: BC Stats, 2009a, 2004, 2001a, 2001b, and 1988.

this chapter, this had a profound impact on the resulting urban form of both regions.

In Metro Vancouver in particular, which experienced much of its growth during the autmobile era, development has, until fairly recently, been primarily in the form of relatively low density sprawl, interspersed with pockets of higher density that were largely unconnected by effective transportation services. This resulted in large distances between where people lived and worked, and a significant regional reliance on the automobile. However, in the past several decades this trend has changed, as density and levels of land use mix have increased not only in Vancouver's downtown core, but also in several regional and municipal town centres. For example, multiple-family dwellings currently account for more than 50% of the regional housing stock, compared to just 25% in 1966 (see **Figure 2-7**).[25] However, despite this increase in density throughout Metro Vancouver, the region is still heavily reliant on the automobile. In their relatively short development histories, a range of urban, suburban, and rural environments have emerged throughout both the Metro Vancouver and Greater Victoria regions. While both regions have relatively high densities with overall population densities of 690 people/km^2 in Metro Vancouver and 449 people/km^2 in Greater Victoria — they both exhibit a wide range of environments, as can be seen by comparing densities throughout each region (see **Figure 2-8** and **Figure 2-9**):

- Urban core municipalities. These are the earliest settlements and, correspondingly, the most densely populated municipalities of their respective regions. These include the cities of Vancouver (4,759 people/km^2), North Vancouver (3,707 km^2) and New Westminster (3,548 people/km^2) in the Metro Vancouver region, and the City of Victoria (3,767 km^2).
- Mature suburban municipalities. These municipalities began to develop in the late 19th and early 20th centuries as the urban core municipalities began to expand outward with the emergence of the streetcar. Examples include the municipalities of Burnaby (2,153 people/km^2) in Metro Vancouver, and Esquimalt (2,291 people/km^2), Sidney (2,169 people/km^2) and Oak Bay (1,714 people/km^2) in Greater Victoria.
- Developing suburban municipalities. These municipalities experienced much of their growth after the emergence of the automobile and, as such, have relatively low densities and generally sprawling patterns development. Examples include the municipalities of Surrey (1,096 people/km^2), Port Coquitlam (1,780 people/km^2), Coquitlam (928 people/km^2) and Richmond (1,277 people/km^2) in Metro Vancouver, and Saanich (1002 people/km^2) in Greater

Victoria.

• Exurban municipalities. These municipalities have the lowest densities, are often located on the fringes of their respective regions, and have preserved a rural character. Examples include the municipalities of Delta (528 people/km^2), Abbotsford (321 people/km^2), Chilliwack (244 people/ km^2) and Mission (139 people/km^2) in the Metro Vancouver region, and Central Saanich (371 people/ km^2), Sooke (179 people/km^2), Metchosin (68 people/km^2) and Highlands (44 people/km^2) in the Greater Victoria region. However, despite these trends, it should be emphasized that many of the most densely populated environments in each region are found in suburban or rural locations, such the Cities of North Vancouver, New Westminster, Langley (2,313 people/km^2) and White Rock (3,456 people/km^2). In contrast, some of the least dense municipalities are located relatively close to the core of their respective regions, such as the Districts of North Vancouver (513 people/km^2) and West Vancouver (474 people/km^2).[26]

UNIQUE CHARACTERISTICS

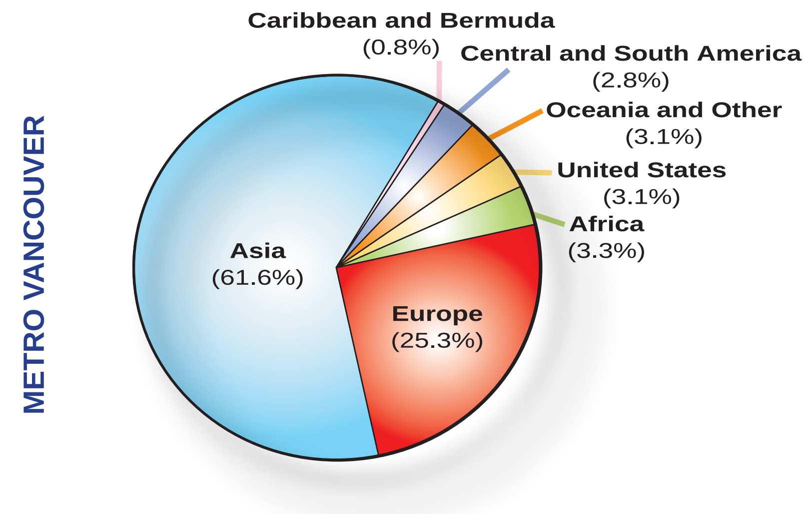
With this brief overview of some general characteristics of the Metro Vancouver and Victoria regions in mind, it is also important to describe several of the distinct historic, natural and built environment characteristics that influence the physical activity levels of its residents in interesting ways.

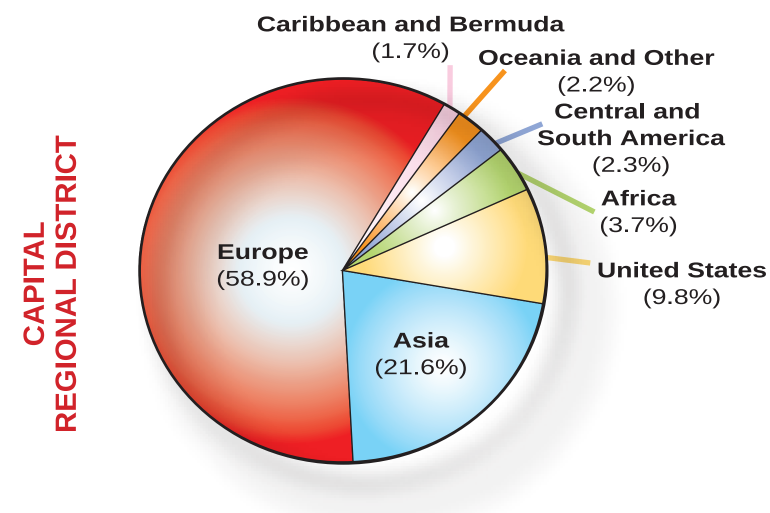
Geographic constraints and compact regions

Both the Metro Vancouver and Greater Victoria regions are situated in restrictive natural settings. In the Metro Vancouver region, development is geographically constrained in every cardinal direction: by the steep slopes of the Coast Mountain Range to the north, the Strait of Georgia to the west, the United States border to the south, and the protected, fertile agricultural farmlands of the Fraser Valley to the east (see **Figure 2-1** and **Figure 2-2**). Development in the Greater Victoria region is also constrained in most directions by geographic features, as the region is bordered to the south by Strait of Juan de Fuca, to the east by the Strait of Georgia and to the north by the coastline of the Saanich Peninsula (see **Figure 2-3**). This has resulted in the development of a particularly compact region, where most growth is focused in the City

Figure 2-5

Metro Vancouver and Greater Victoria immigrant populations, 2001.

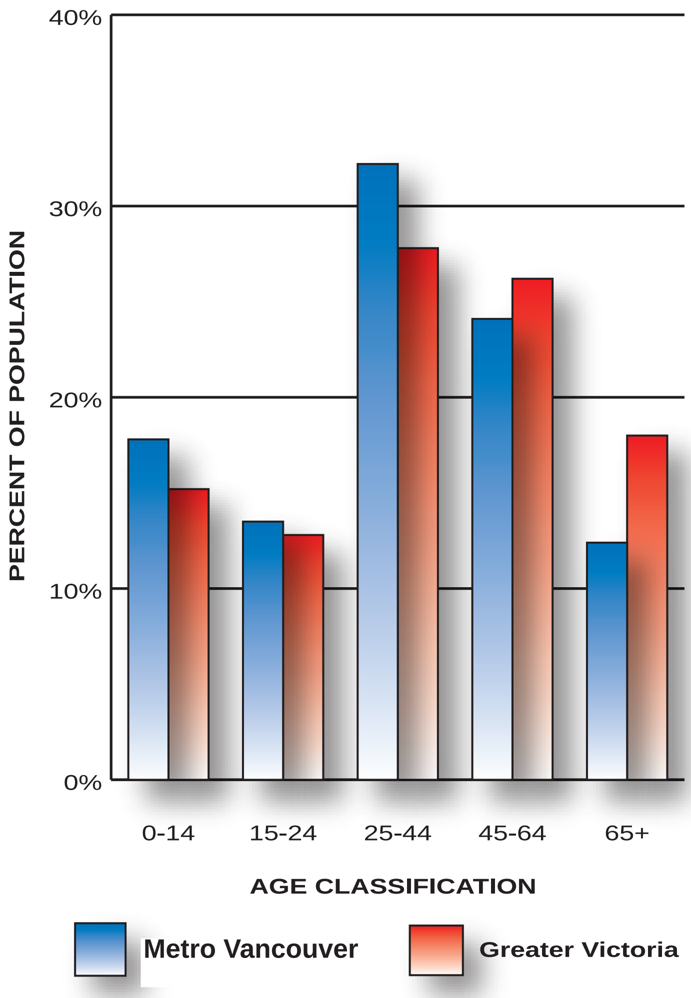




Note: Based on immigrants' country of birth.
Source: Statistics Canada, 2005.

Figure 2-6

Metro Vancouver and Greater Victoria age classifications, 2001.



Source: BC Stats, 2005b, 2005c, 2005d, 2001d and 2001e.

of Victoria and the core municipalities of Oak Bay, Saanich, Esquimalt, and Colwood.

These geographic features have combined to act as an urban containment boundary that defines the edges of both regions. In Metro Vancouver in particular, these features "have played a significant role in limiting the size and direction of urban sprawl, and the rate of densification…There is only so much flat land available for urbanization, let alone for large-scale industrial manufacturing. As a result, the urban form is more concentrated than the typical North American conglomeration."[27]

Largely as a result of these geographic constraints, both the Metro Vancouver and Greater Victoria regions have much smaller land bases than most other North American regions. Because both regions are relatively compact, they also have significantly higher population densities than found in most other North American regions, particularly when compared to other regions in western Canada and the western United States (see **Table 2-1**).

Topography

The Metro Vancouver region is home to a dramatic topography, with elevations in the region ranging from below sea level to around 1500 metres (4,900 feet) in the Coast Mountain Range. Between these extremes, which define many of the edges of the region, there are also several significant topographical features that have influenced the urban form within these edges: "In Vancouver, topography has always been a shaper of the city's urban form as well as a socio-economic indicator. The high ground has always been sought out by the social elite, and cursory study of a topographic map reveals a direct correlation between contour levels and real estate values…What the topographic impulse has meant is that some of the most dramatic natural landscapes have been directly targeted for urban development."[28] Several areas with relatively steep slopes have been the focus of development in the Vancouver region, including the heights of Spanish Banks, Shaughnessy Heights, Quilchena Ridge and Fairview Slopes in Vancouver, as well as virtually all of West and North Vancouver and much of Port Moody and Coquitlam. Development in these sloping areas is particularly interesting for this project due to the influence of topographical variations on physical activity patterns, although this relationship often exists in counter-intuitive ways. For example, Vancouver's North Shore is home to some of the steepest slopes in the region, yet is also home to the most physically active population in the Metro Vancouver region.[29] Topography plays a less significant influence in the Greater Victoria region, which has a comparatively flat topography. As a result, it is unlikely that topography significantly influences physical activity patterns among Greater Victoria residents.

Mild climate

Southwestern British Columbia is renowned for having the mildest climate in Canada. Greater Victoria and Metro Vancouver are the warmest regions in Canada during the winter, with winter temperatures rarely falling below 0°C. For example, the average daily temperature in January ranges from 3°C to 7°C in Victoria and 0.5°C to 6°C in Vancouver. In contrast, summer temperatures rarely exceed 30°C, and the average daily temperature in July ranges from 11°C to 20°C in Victoria, and from 13°C to 22°C in Vancouver. Southwestern British Columbia is home to significant amounts of precipitation, particularly in the winter months. For example, the average monthly rainfall in Vancouver ranges from 154mm in January to 40mm in July. Despite this rainfall, Vancouver only has an average of 166 days with measurable precipitation per year, although it also has an average of 289 days with measurable sunshine per year. Victoria experiences significantly less rainfall than Vancouver, with average monthly rainfall ranging from 94mm in January to just 14mm in July.30 Due to the mild temperatures, snow is rare in both Metro Vancouver and Greater Victoria. As a result of this mild climate, southern British Columbia presents the most favourable climate in Canada for encouraging physical activity on a year-round basis.

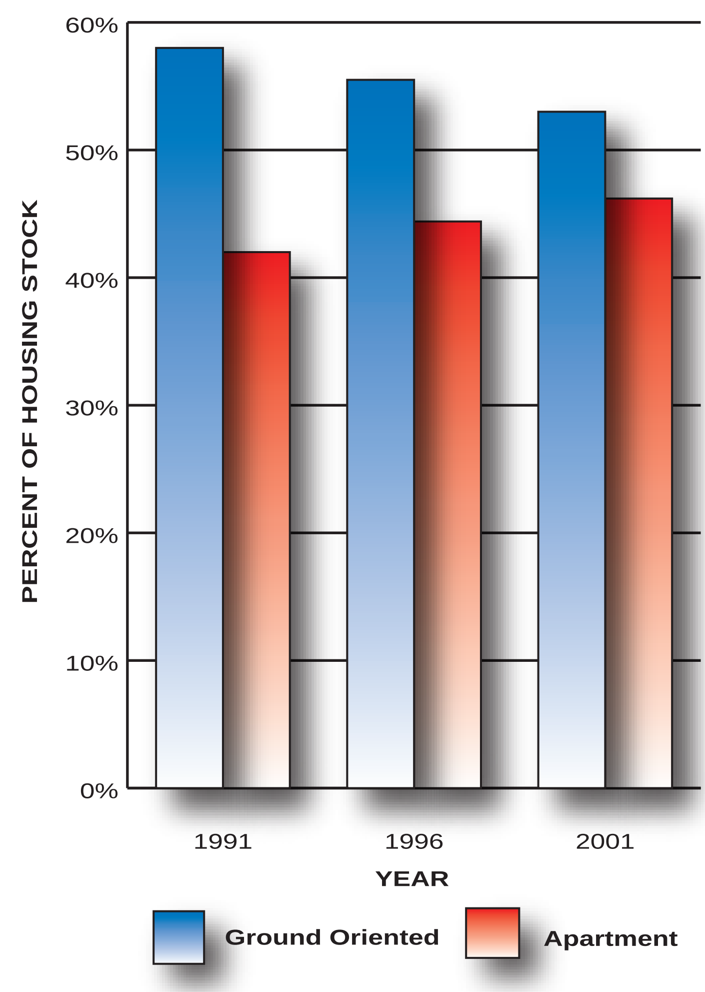
Streetcar era vs automobile era development

Both Metro Vancouver and Greater Victoria are very young, as none of the municipalities in these regions were incorporated until the late 19th or early 20th centuries – the City of New Westminster was the first to incorporate in 1860, followed by Victoria in 1862, Maple Ridge in 1874; Surrey, Delta, and Richmond in 1879; Vancouver in 1886; Coquitlam and the District of North Vancouver in 1891; and Burnaby in 1892.[31] In fact, in the Greater Victoria region, many municipalities were not even incorporated until the late 20th century. For example, Colwood was incorporated in 1985, View Royal in 1988, Langford in 1992 and Highlands in 1993. The fact that the region is very young, at least in global terms, has had a profound influence on the resulting urban form of the region.

Unlike many cities in Europe or Eastern North America – which were founded at a time when the dominant form of transportation was by foot and which therefore had their central cores developed at a pedestrian-scale – the Metro Vancouver and Greater Victoria regions were founded at roughly the same time as the invention of the electric streetcar. In fact, the first streetcar line in the region opened in February 1890 in the City of Victoria, and was followed four months later in the City of Vancouver (only four years after the City of Vancouver's incorporation). The streetcar network was relatively limited in the Greater Victoria region, as the network

Figure 2-7

Metro Vancouver regional housing mix, 1991-2001.



Note: Ground Oriented includes all dwelling units except apartments
Source: GVRD, 2001.

Table 2-1

Population, area, and density of select North American regions.

Region	Population*	Area (Km²)	Population Density (people/ km²)
New York-Northern New Jersey-Long Island CMSA	18,087,251	20,192	895.8
Toronto CMA	5,113,149	5,904	866,1
Montreal CMA	3,635,571	4,258	853.6
Vancouver CMA	2,116,581	2,879	735.6
Chicago-Gary-Lake County CMSA	8,065,633	14,553	554.2
Boston-Lawrence-Salem CMSA	4,171,643	8,043	518.7
Victoria CMA	330,088	695	474.7
Philadelphia-Wilmington-Trenton CMSA	5,899,345	13,845	426.1
San Francisco-Oakland-San Jose CMSA	6,253,311	19,084	327.7
San Diego MSA	2,498,016	10.890	229.4
Quebec City CMA	715,515	3,276	218.4
Calgary CMA	1,079,310	5,107	211.3
Ottawa-Gatineau CMA	1,130,761	5,716	197.5
Seattle-Tacoma CMSA	2,559,164	15,259	167.7
Los Angeles-Anaheim-Riverside CMSA	14,531,529	87,971	165.2
Winnipeg CMA	694,668	5,303	131.0
Portland-Vancouver CMSA	1,477,895	11,321	130.6
Sacramento MSA	1,481,102	13,195	112.3
Edmonton CMA	1,034,945	9,417	109.9

Red indicates Canadian regions, defined as Census Metropolitan Area (CMA)
Blue indicates American regions, defined as Consolidated Metropolitan Statistical Area (CMSA) or Metropolitan Statistical Area (MSA)
* = Population of American regions based on 1990 U.S. Census; Population of Canadian regions based on 2006 Canadian Census. Source: Statistics Canada, 2009 and U.S. Census Bureau, 1996.

only grew to about 9km of track spread throughout the city's core.[32] In the City of Vancouver, however, the streetcar network expanded rapidly over the next several decades. The fact that the early growth of both Metro Vancouver and Greater Victoria occurred in parallel with the expansion of the streetcar had a profound influence on the shape of both regions. For example, In Vancouver "many of these new routes preceded urban development and in some cases were even cut through virgin forest… Vancouver's suburban residential development largely followed the streetcar lines, with local shops and services opening along the key routes."[33] In both regions, the emergence of the streetcar led to the creation of typical 'streetcar suburbs' with: "a continuous corridor whose backbone was the road carrying the trolley tracks (usually lined with stores and other local commercial facilities), from which gridded residential streets fanned out for several blocks on both sides of the tracks."[34] This urban form – characteristic of much of the development in the cities of Vancouver, Victoria, New Westminster and North Vancouver – remains largely intact today.

The remaining suburbs (located to the south and east in Metro Vancouver, and to the north and west in Greater Victoria) did not begin to develop significantly until after World War II, when the automobile was becoming the dominant mode of transportation. With the coming of the automobile, these newly developing suburbs were built at an entirely different scale, which led to a sprawling form development throughout much of the suburban areas of the region. These developments, which are typical of most North American suburban areas, are characterized by having low densities, segregated land uses, and hierarchical, disconnected street networks designed for the automobile and not the pedestrian.

The region is therefore home to a dichotomous development pattern: the urban grid street network in the City of Vancouver, City of Victoria, and a few suburban municipalities; and a sprawling development pattern with a hierarchical street network prevalent throughout most of the suburban municipalities. This dichotomous development pattern is particularly important for this project, because it allows for comparison between significantly different development patterns.

Limited number of highways

Throughout the United States, the post-World War II period saw a rapid and dramatic expansion of highways as a result of the 1956 Interstate Highway Act, which was the impetus for the development of a comprehensive national freeway system throughout the United States. This Act had a profound influence on American cities, as these freeways were not only interregional (connecting urban regions to each other), but also intraregional (connecting the various areas within an urban region). Freeway construction made tracts of land far from urban centres more accessible and more affordable to the general population, and was the main force for sprawling, suburban development. In fact, "these new freeways would soon reshape every corner of urban America as the new suburbs they engendered represented nothing less than the turning inside out of the historic metropolitan city."[35] However, while American urban regions began to change dramatically in the last half of the 20th century, in Canadian cities "this did not occur at nearly the same rate or to nearly the same extent"[36] because of much more limited investment in freeways. As a result, "residents of more compact Canadian cities use their cars 20 to 40 percent less than their American counterparts. There are options to the car. This is not because Canadian cities become denser since WWII, it is because American cities became less dense…(In Canada) the vast majority of new development occurring at the rural metropolitan interface is, by American standards, high density."[37] The difference in density levels between Canadian and American cities is highlighted in **Table 2-1**.

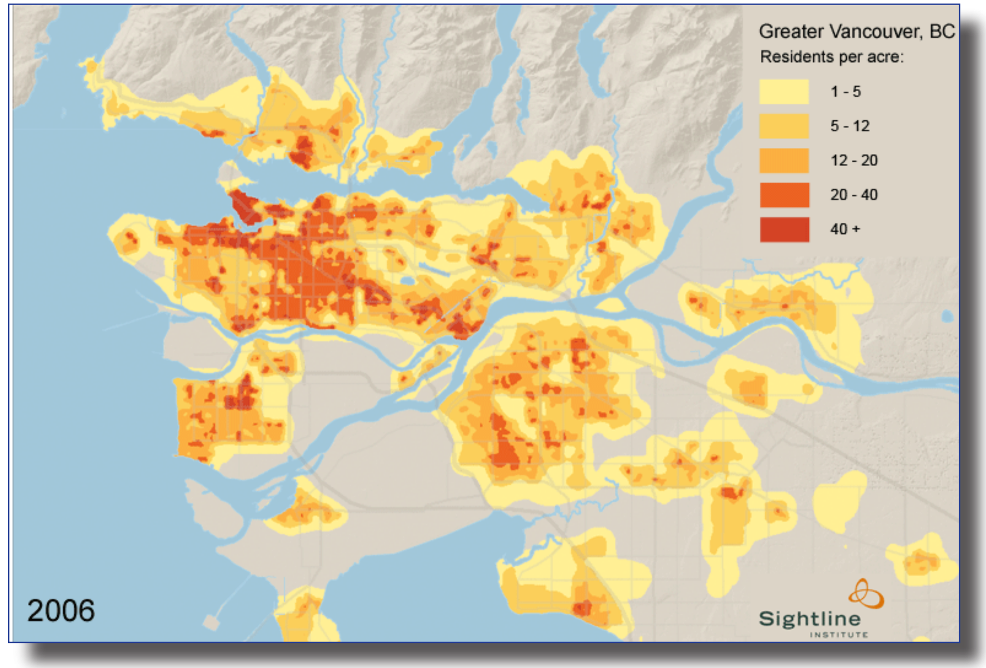
Although Canadian cities saw much more limited investments in highways than American cities in the post-war era, the Metro Vancouver and Greater Victoria regions present a unique situation, even within the Canadian context. Unlike most North American cities, comprehensive regional highway networks were never developed in Metro Vancouver or Greater Victoria. In fact, the entire City of Vancouver is almost untouched by limited-access highways, and there are no limited-access highways in the City of Victoria (although both cities have major roads that are considered to be part of their respective region's highway network). Even in the suburban areas of both regions, there are few highways compared to American regions. The consequences of this unique situation have enabled the endurance of the inner suburban neighbourhoods in the City of Vancouver and City of Victoria and have also resulted in a less extensive pattern of sprawling development in the outer suburban areas than in most American regions.

High use of non-automotive modes of transportation

In both the Metro Vancouver and Greater Victoria regions, a relatively high number of trips are taken by travel modes other than the automobile, such as transit, walking and bicycling. In the Metro Vancouver region, the regional transit network is increasingly well used. Vancouver is one of the few regions in North America in which transit ridership is increasing – transit ridership throughout the region increased by 11.7%

Figure 2-8

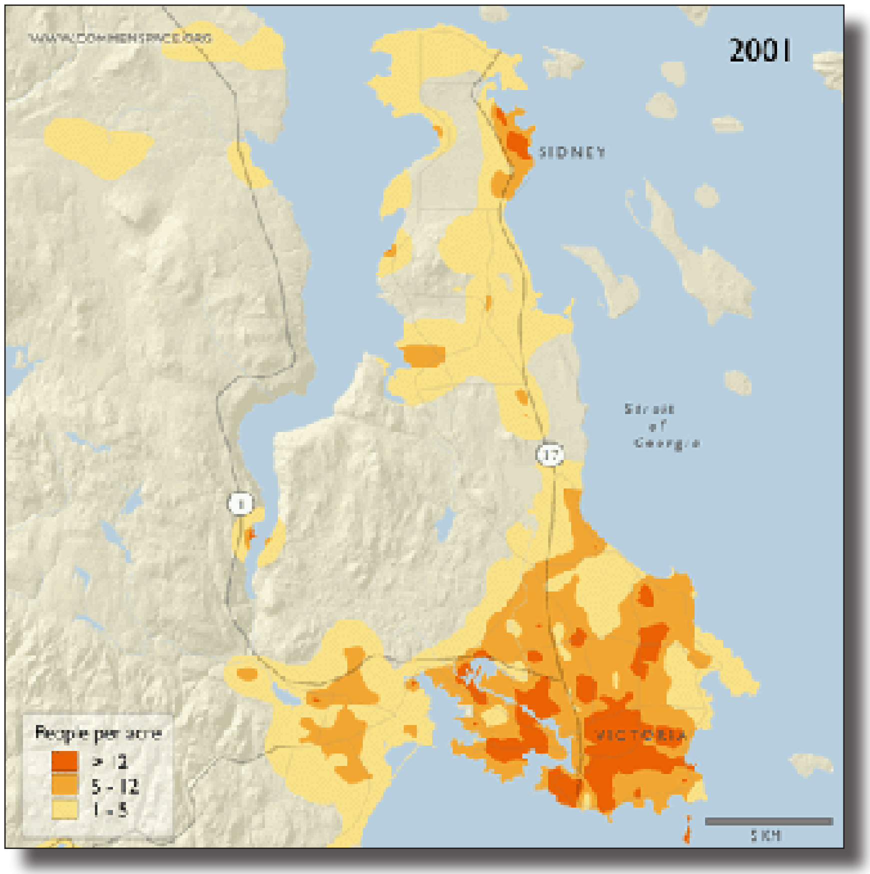
Metro Vancouver population density, 2006.



Source: Sightline Institute, 2009c.

Figure 2-9

Greater Victoria population density, 2001.



Source: Sightline Institute, 2009c.

and 8.3% in 2003 and 2004, respectively.[38] In addition to transit ridership, walking and bicycling are also important modes of transportation in Metro Vancouver. Based on a 1999 travel diary survey, 783,500 trips were made by walking or bicycling over a given 24 hour period, representing 14.3% of all trips in the region. The total number of walking and bicycling trips in the Metro Vancouver region increased by 28.8% between 1994 and 1999, while the mode share of walking and bicycling increased by 1.6% over this period.[39]

In Greater Victoria, transit ridership is also increasing. For example, in 2001 transit accounted for nearly 10% of all afternoon peak period trips, compared to 6% in 1992.[40] The Greater Victoria Regional Transit system currently accounts for 8% of the current travel demand, or about 80,000 passengers per day. The Capital Regional District is attempting to increase ridership to more than 10% by 2026, the equivalent of 160,000 to 220,000 people daily, and "envisages that by 2026, transit services in the CRD will be the best in Canada".[41] Perhaps more important for this project are the amount of pedestrian and bicycling trips made in the region. The Greater Victoria region is unique in Canada in that walking activity accounts for a significant share of all journey to work trips. Pedestrian travel currently accounts for 138,000 daily trips (11% of total trips), and the Capital Regional District strives to increase this figure to 240,000 daily trips (15% of travel) by 2026.[42] In addition, the Capital Region has a "widely held reputation as Canada's leading cycling community."[43] This can be attributed largely to the fact that more than 250km of bikeways have been developed in the region, and the region's municipalities plan to expand the network of on street bicycle routes to 550km.[44] Bicycling currently accounts for about 2% of daily travel demand, or 29,000 trips, and the Capital Regional District strives to increase this figure to 5%, or more than 80,000 trips, by 2026.[45]

Compact communities: town centres and "Living First"

Metro Vancouver and the Capital Regional District have both adopted regional growth management strategies that are similar in many respects. Metro Vancouver's current growth management strategy, the Livable Region Strategic Plan (LRSP), was adopted in 1996 sets out four broad, interrelating strategies: to protect the green zone, to build complete communities, to achieve a compact metropolitan region, and to increase transportation choice. Together, these strategies aspire to create a compact region with development focused in a network of complete communities. It should be noted that Metro Vancouver is currnetly in the process of preparing a new Regional Growth Strategy. The CRD's Regional Growth Strategy outlines many similar goals, including: to manage and balance growth by keeping urban settlement compact and by protecting the integrity of rural communities, to build complete communities, and to increase transportation choice.

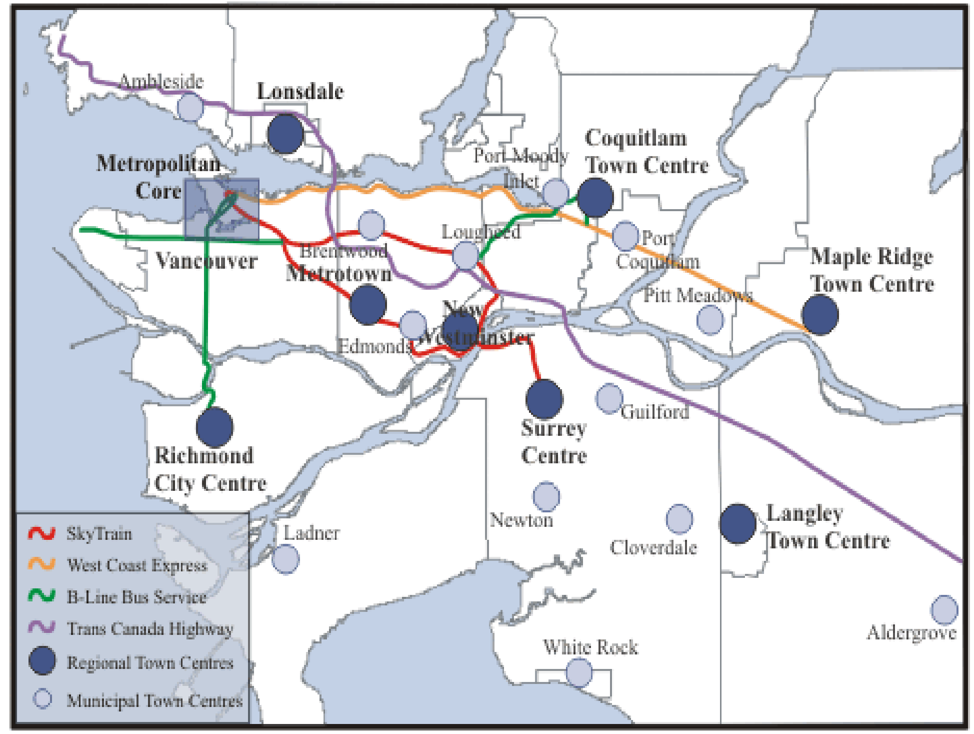
To achieve these goals, both growth management strategies have established a hierarchical network of centres in which future growth is intended to be focused. In Metro Vancouver's LRSP, this network consists of eight regional town centres and thirteen municipal town centres, in addition to the metropolitan core (see **Figure 2-10**). These town centres, which are located in suburban areas of the region, are intended to be primary concentrations of jobs, housing, culture, and recreation opportunities. Strategically focusing development in a network of centres distributed throughout the region has meant that residents have improved access to the services and facilities they need within their communities, reduced travel distances, and improved connections between communities, as the SkyTrain lines (and other forms of public transit) have been planned to connect these town centres. In fact, the existing SkyTrain lines have been an essential catalyst for intensification of development in many of these regional and municipal town centres. In the CRD, this network consists of either Major Centres in addition to the metropolitan core (see **Figure 2-11**). Future growth in the region will be focused in these centers, which will be "revitalized as walkable, transit-focused complete communities with a dense mix of businesses, housing, services and public open space."[46]

This proliferation of mixed-use and medium- to high-density communities is unique in North America. Today, more than six out of every ten Metro Vancouver residents and a third of Greater Victoria residents live in 'compact communities' –- ranking these regions first and second in the Pacific Northwest, respectively, for the number of residents living in compact communities. As such, the Metro Vancouver region has been dubbed "the Northwest's clear leader in compact growth,"[47] while the Greater Victoria region has been labelled "a midsize model of smart growth."[48]

The high number of residents living in compact communities throughout southwestern British Columbia has implications for this project, as many characteristics of these communities, such as density and land use mix, play powerful roles in influencing the physical activity patterns of its residents. This will be seen in more detail in Chapter Three.

Figure 2-10

Metro Vancouver town centres and regional transportation network.



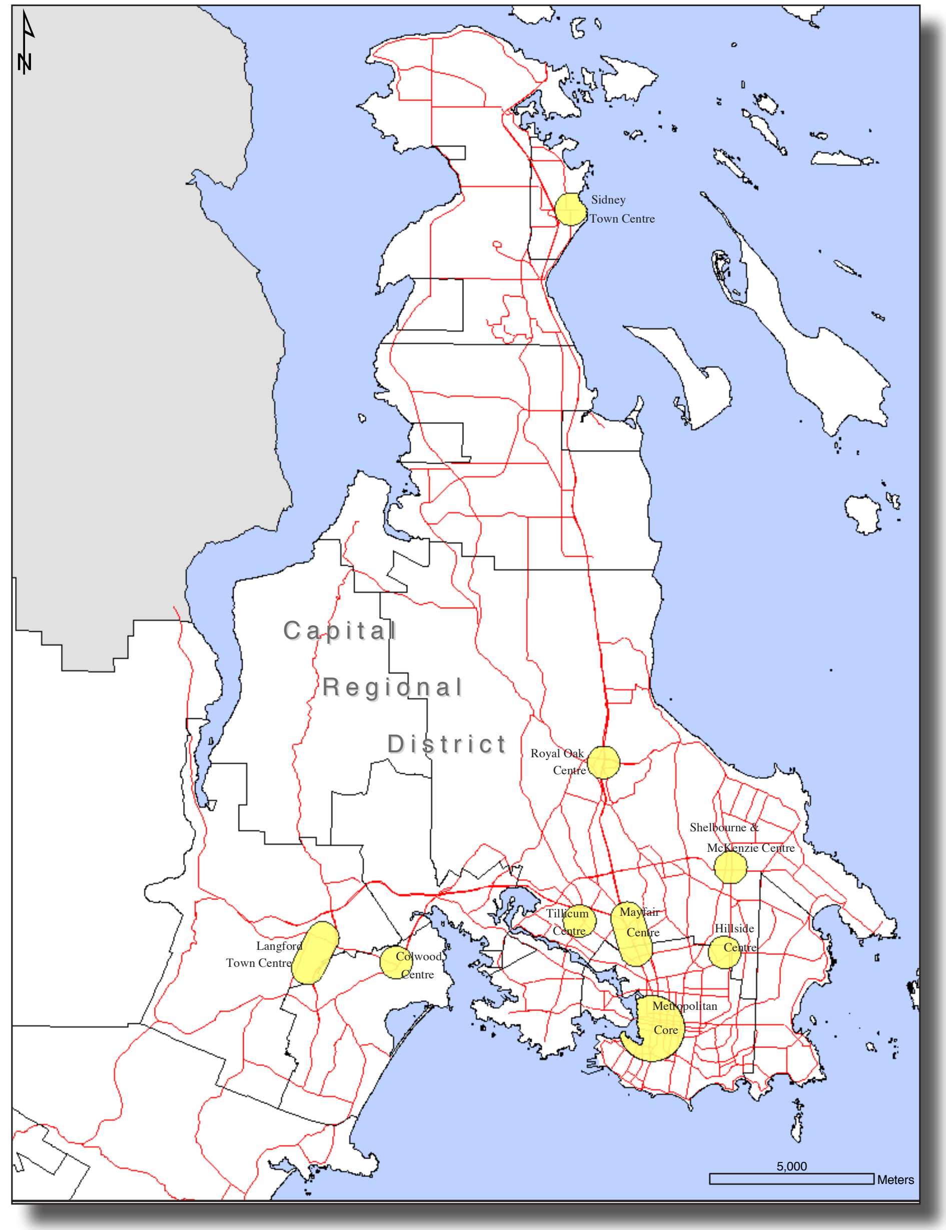
Source: Metro Vancouver, 2004.

SUMMARY

This chapter has outlined various natural and historic characteristics, unique to the Metro Vancouver and Greater Victoria regions, that have all combined to help contain sprawl and to create an area that is distinct within North America. Although suburban sprawl is prevalent in the region, the geographic extent of this sprawling development has been limited, which has enabled the creation of a more compact region, with higher densities, and higher levels of mixed use development. As a result of these, and other factors, the residents of the Metro Vancouver and Greater Victoria regions are among the healthiest and most physically active in North America, as will be seen in more detail in Chapter Three. Because the region is unique in North America in these and other ways, it is critical to explore the relationship between the built environment and physical activity patterns in this context to examine whether this relationship exists in such a setting, and if so, how this relationship compares to that found in other studies.

Figure 2-11

Greater Victoria town centres and regional transportation network.



Source: Capital Regional District, 2005b.

CHAPTER THREE

Urban Form, Physical Activity and Public Health

"Residents of 'walkable' locales more active"
The Vancouver Sun, February 18, 2005

"City, suburban designs could be bad for your health"
USA Today, April 22, 2003

"Sprawl may harm health, study finds"
The Washington Post, September 27, 2004

"As suburbs grow, so do waistlines"
The New York Times, September 4, 2003

A large body of research has emerged in recent years that suggests that there is a significant relationship between urban form, physical activity patterns and public health outcomes. This chapter will outline this relationship by first examining the rising rates of overweight and obesity throughout the United States and Canada and by arguing that a major factor contributing to this trend is insufficient physical activity levels among the majority of the North American population. This chapter will then outline different types of physical activity and will explore the ways in which the built environment is thought to influence physical activity levels, by presenting empirical evidence to demonstrate this relationship. The chapter will then discuss and criticize an argument known as residential self-selection, which hypothesizes that people's attitudes, values and beliefs may have a more significant influence than the built environment on physical activity patterns. The chapter will conclude by outlining a theoretical model known as the Behavioural Model of Environment that has been developed to explore the relationship between attitudinal and behavioural variables, built environment characteristics and physical activity patterns.

PUBLIC HEALTH CONCERNS: OVERWEIGHT AND OBESITY

Over the past few decades there has been a dramatic and alarming increase in the number of overweight and obese people throughout the world, and in North America in particular. Overweight and obesity are terms that are commonly used to classify adults' weight status according to their Body Mass Index (BMI) (see **Box 3-1**). Levels of overweight and obesity have been well documented in the United States. As shown in **Table 3-1**, in the period 1999-2002 nearly two thirds of American adults (aged 20-74) were either overweight or obese. More specifically, about 34% of the adult American population was overweight while about 31% was obese during this period. These figures are even more dramatic when compared with figures from only a few decades beforehand, as the number of overweight and obese people increased by about 37% between 1971-74 and 1999-2002. Particularly interesting to note is that, while the levels of overweight (but not obese) adults have not changed dramatically over this period, the levels of obese adults more than doubled in this same period.[50] It is also important to note that current and historic obesity levels are not spread equally among the population, as can be seen from the obesity trends throughout the United States shown in **Figure 3-1**.

BOX 3-1: DEFINING BODY MASS INDEX (BMI)

Body Mass Index (BMI is a measure of a person's ratio of weight (kg) to height (m). Individuals are classified into one of four groups based on their BMI:

- **Underweight:** BMI below 18.5 kg/m²
- **Acceptable Weight:** BMI is between 18.5-24.9 kg/m².
- **Overweight:** BMI is between 25-29.9 kg/m² and
- **Obese:** BMI exceeds 30 kg/m².[49]

These BMI categorizations are based on the effect body weight has on disease and health – as BMI increases, the risk for certain diseases increases.

In Canada, levels of overweight and obesity are also a major concern (see **Table 3-2**), although the figures are somewhat more moderate than found the United States (see **Figure 3-2**). According to the Canadian Community Health Survey (CCHS), which is a self-reported survey conducted by Statistics Canada to provide cross-sectional estimates of various health indicators, nearly half of all Canadian adults were either overweight or obese in 2001.[51] Over 6 million Canadian adults (or 32.5% of the adult population) were considered overweight, while nearly 2.9 million Canadian adults (or 14.9% of the adult population) were considered obese. When compared to similar surveys from the 1970s, the number of Canadian adults considered obese or overweight has increased by nearly 19%, while the number of obese Canadian adults has increased by a dramatic 49% over this period.[52] In fact, CCHS data shows that even in the short period between 1994/95 and 2000/01, the number of obese Canadian adults grew by 24%.[53] In sum, although the figures are more moderate in Canada than the United States, the trends are the same: in both countries, the number of overweight adults is increasing at a moderate rate, while the number of obese adults is increasing at a dramatic rate. Similar to the United States, these levels of overweight and obesity are not distributed equally among the Canadian population, as shown in **Figure 3-3**.

Furthermore, within British Columbia, there are significant variations in overweight and obesity levels, as shown in **Table 3-3**. As a whole, British Columbia has somewhat lower levels of overweight and obesity than found throughout the rest of Canada. Although about 47% of Canadian adults are overweight or obese, only about 42% of British Columbian adults are overweight or obese, while only about 37% and 42% of adults in the respective regions of Metro Vancouver and Greater Victoria are overweight or obese. Further, within Metro Vancouver and Greater Victoria, there are

Table 3-1

Overweight and obesity trends among American adults*.

YEAR	OVERWEIGHT (BMI 25-29.9)	OBESE (BMI 30+)	OVERWEIGHT AND OBESE (BMI 25+)
1960-62	31.5%	13.3%	44.8%
1971-74	33.1%	14.6%	47.7%
1976-80	32.3%	15.1%	47.4%
1988-94	32.7%	23.3%	56.0%
1999-2002	34.1%	31.1%	65.2%
Change between 1971-74 and 1999-2002	**+ 3%**	**+ 113%**	**+ 36.7%**

* = Adult refers to indivuals between 20 and 74 years of age.
Note: Standard error ranges from 0.5% to 1.0%.
Source: Adapted from CDC, 2004b. Page 84.

Table 3-2

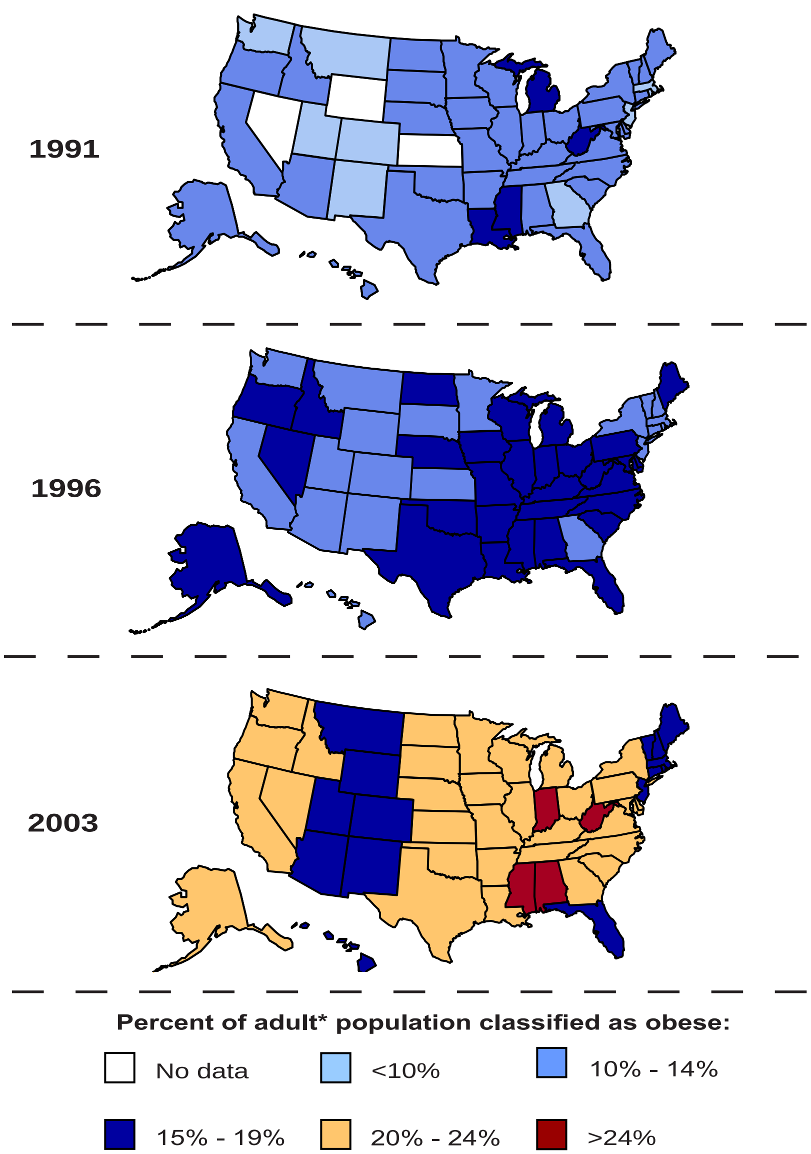
Overweight and obesity trends among Canadian adults*.

YEAR	OVERWEIGHT (BMI 25-29.9)	OBESE (BMI 30+)	OVERWEIGHT AND OBESE (BMI 25+)
Early 1970s	30%	10%	40%
2001	32.5%	14.9%	47.4%
Change between Early 1970s and 2001	**+ 8.3%**	**+ 49%**	**+ 18.5%**

* = Adult refers to indivudals between 20 and 64 years of age.
Source: Adapted from The Heart and Stroke Foundation, 2004 and Statistics Canada, 2002a.

Figure 3-1

Spatial distribution of obesity trends in the United States.



* = Adult refers to indivuals between 20 and 74 years of age.
Source: CDC, 2005b.

also variations. For example, within the Vancouver Health Region, only about 28% of the population is overweight or obese, compared to about 46% and 45% for the Simon Fraser and South Fraser Valley Health Regions, respectively.[54]

In addition, although obesity affects virtually all socio-demographic groups, certain groups exhibit consistently higher than average levels of overweight and obesity. For example, as shown in **Table 3-3**, Canadian men are more likely to be overweight or obese than women, as nearly 56% of Canadian men are overweight or obese compared to about 39% of Canadian women.[55] In addition, adult men accounted for two-thirds of the increases in obesity in Canada between 1994/95 and 2000/01.[56] Despite such differences, the increase in overweight and obesity levels appear to be affecting virtually all socio-demographic groups in North America to some degree.

These increasing levels of overweight and obesity are of concern primarily due to their public health implications. Individuals who are overweight or obese are at a higher risk of developing a variety of diseases such as heart disease, stroke, some types of cancer, diabetes, high blood pressure, high cholesterol, arthritis, and many others. The negative health risks related to overweight and obesity can not be understated. For example, obesity increases the risk of type 2 diabetes by as much as forty times[57] and the health impacts stemming from overweight and obesity now rival the health impacts of tobacco.[58] In addition, the Heart and Stroke Foundation states that the number of deaths in Canada attributable to overweight and obesity has almost doubled over the past fifteen years, increasing from 2,513 in 1985 to 4,321 in 2000. Even more dramatically, it is estimated that about 280,000 preventable deaths per year in the United States can be attributed to obesity,[59] making it the second leading cause of death in the United States behind tobacco.[60] It is clear that overweight and obesity pose a major health concern in both the United States and Canada, and this results in a significant financial burden being placed on its health care systems. For example, in the United States in 2002, 11.6% of all private heath care spending (or $36.5 billion) was attributable to obesity, compared to just 2% (or $3.6 billion) in 1987,[61] while in Canada, it is estimated that the direct cost of obesity in 1997 was $1.8 billion, or 2.4% of all health care spending.[62]

These increases in overweight and obesity are caused by many complex and interrelated factors, including a genetic predisposition to being overweight or obese. However, these increases can generally also be attributed to personal habits or modifiable behavioural factors, such as poor diet, smoking, and inadequate physical activity. In fact, many studies have found that such behavioural factors may play an even more important role than genetics in influencing the likelihood of becoming overweight or obese and developing chronic diseases or premature mortality.[63] As such, many efforts have focused on modifying such personal behaviours in an attempt to reduce levels of overweight and obesity and subsequent preventable diseases and premature mortality. Among the behavioural factors contributing to overweight and obesity, physical inactivity is one of the most common and most preventable. For example, in a study of data from national health surveys, the United States Centers for Disease Control (CDC) determined that a sedentary lifestyle was the most common modifiable risk factor for coronary heart disease.[64] With this in mind, and without disregarding the other influences on overweight and obesity levels, the next section will examine the influence of physical activity on overweight and obesity in more detail.

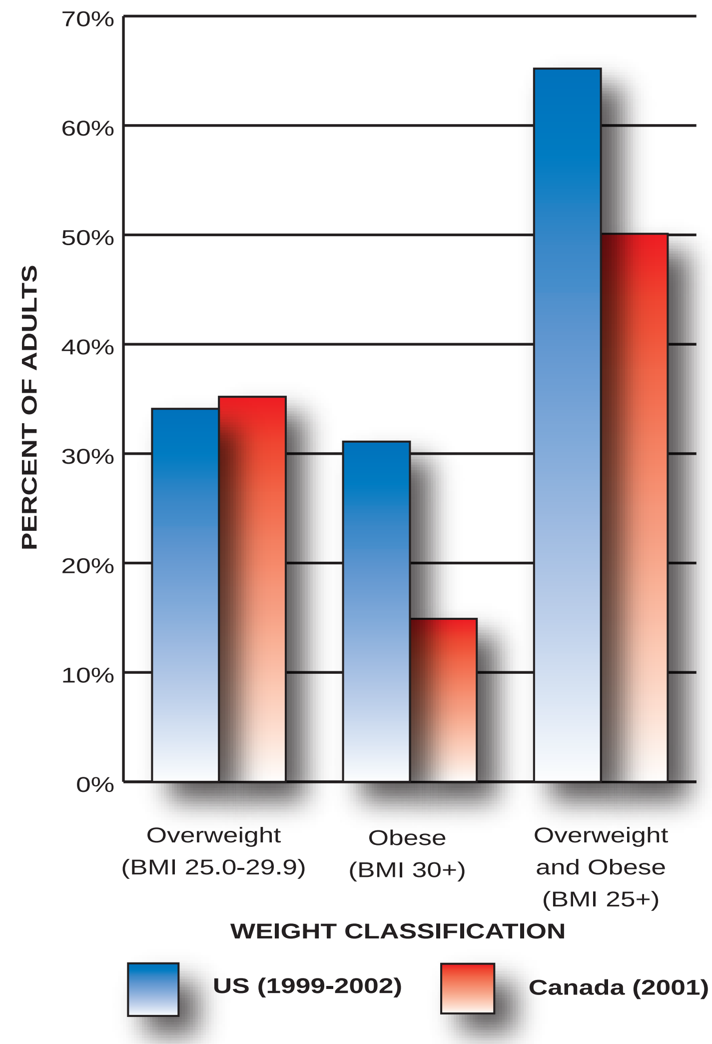
A LEADING CAUSE: PHYSICAL INACTIVITY

Physical activity is one of the most significant modifiable behavioural factors that can influence the likelihood of becoming overweight or obese and, by extension, developing a chronic disease or dying prematurely. However, until recently there has been a longstanding belief that meaningful health benefits could only be achieved by engaging in intense, vigorous physical activity. This belief has been problematic because only a small portion of the North American population is prone to engage in vigorous physical activity, largely because vigorous physical activity "simply may be too difficult, time-consuming or embarrassing for many people, especially for people who are elderly, overweight/obese, or out of shape due a prolonged sedentary lifestyle."[65] In addition, vigorous physical activity often requires specialized equipment and can be costly to engage in. Because of these factors, there was limited potential to reduce rates of overweight and obesity among the general population through personal behaviour interventions aimed at increasing vigorous physical activity levels.

The situation changed following the publication in 1996 of the groundbreaking report *Physical Activity and Health: A Report of the Surgeon General*,[66] which stated that health benefits could also be achieved by engaging in moderate levels of physical activity. In particular, the report indicated that health benefits could accrue if adults accumulated at least thirty minutes of moderately intense physical activity at least five days per week, and that this activity could be accumulated throughout the course of a day in short

Figure 3-2

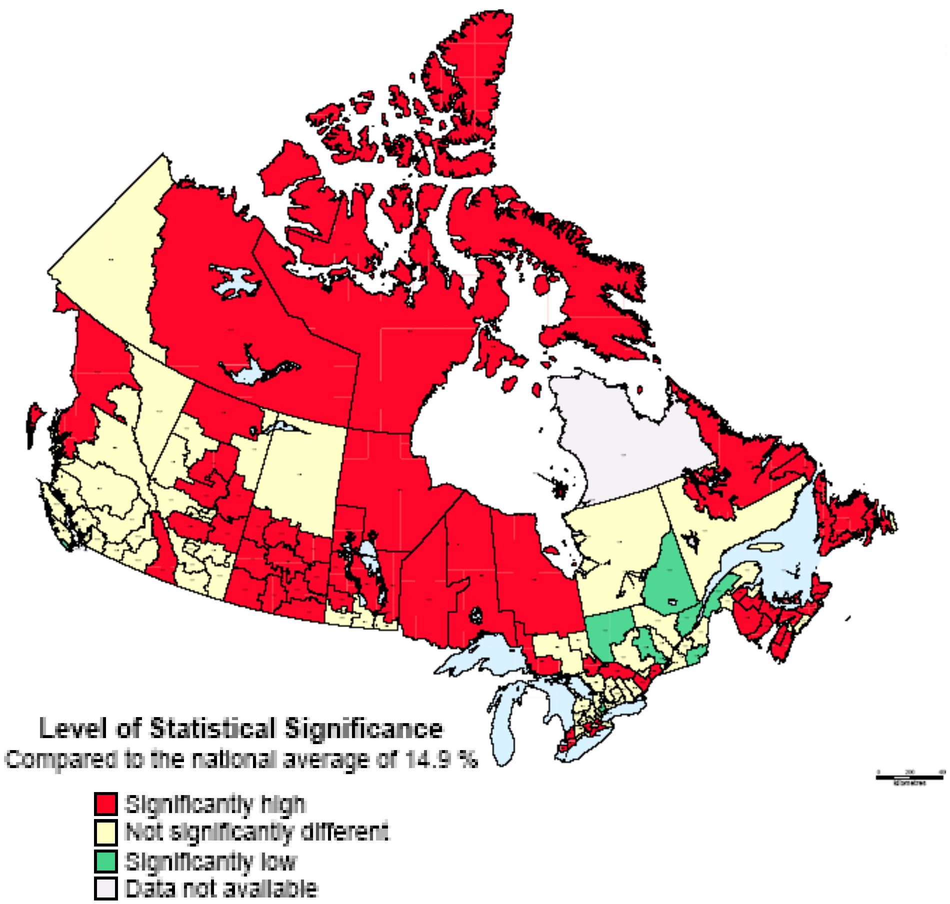
Comparison of overweight and obesity levels among American and Canadian adults.



Source: CDC, 2004b and Statistics Canada, 2002a.

Figure 3-3

Prevalence of obesity among Canadian adults*, 2001.



Note: Figures based on Canadian Health Regions (HR).
* = Adult refers to indivudals between 20 and 64 years of age.
Source: Statistics Canada, 2002a.

spurts.[67] This was an important finding because this report provided an opportunity to focus efforts on people who might not engage in vigorous activity but who may be likely to participate in moderate levels of physical activity. The implications of the finding that moderate physical activity can provide health benefits was important because it meant that health benefits could accrue from physical activity that takes place within one's daily routine. Also, moderate physical activity requires less in the way of specialized equipment and access to specialized facilities than vigorous physical activities, thereby reducing barriers to engage in physical activity. In sum, the Surgeon General's report

> "represented a watershed moment in the history of the public health community's approach to physical activity and fitness. Prior to this report, the general advice given by public health officials to the public was echoed in the phrase 'no pain—no gain', whereby individuals were advised to try and get at least twenty minutes of high intensity aerobic exercise three or more days a week. Implicit in this advice was the idea that anything less than a sustained high-energy effort would be a waste of time, resulting in little or no health improvement over time. While the Surgeon General's report recognized the benefits of the increased fitness that vigorous exercise can provide, it took a much more inclusive view of physical activity and health."[68]

Despite this more inclusive definition of recommended physical activity levels, most people do not engage in levels of physical activity sufficient to meet even these more moderate guidelines. This is not only a North American phenomenon, but a global phenomenon, as levels of insufficient physical activity are high in almost all developed and developing countries – at least 60% of the global adult population fails to achieve 30 minutes of moderate physical activity daily.[69] In the United States, according to data from the CDC's Behavioral Risk Factor Surveillance System (BRFSS), in 2003 over half the American adult population (52.8%) did not meet these recommended guidelines for moderate physical activity[70] and one in four American adults remains completely inactive during their leisure time.[71]

Similar patterns exist in Canada, according to a survey conducted among Canadian adults in 2001 for the CCHS. Among those who reported their physical activity levels, more than half were classified as physically inactive, while only about 24% were classified as moderately active and only about 23% as active (see **Table 3-4**).[72] It should be noted, however, that the number of Canadian adults who engaged in active or moderate physical activity actually increased by more than 10% between 1994/95 and 2000/01.[73] Not surprisingly, the CCHS also found that the people most in need of physical activity were the least likely to engage in such activity.[74] For example, as shown in **Figure 3-5**, fewer obese people engaged in active and moderate physical activity in both 1994/95 and 2000/01 than overweight people and people of an acceptable weight. Similar to overweight and obesity, there are significant geographic variations in the amount of physical activity people engage in, as shown by the distribution of physical activity levels throughout Canada in **Figure 3-6**. As shown in **Table 3-4**, although just 47% of Canadian adults who reported their physical activity levels were either moderately active or physically active in 2001, this figure rose to over 56% in British Columbian, 54% in the Metro Vancouver region, and 62% in the Greater Victoria region. Within the Greater Vancouver region, there were also significant variations, ranging from a high of 67.9% of residents of the North Shore Health Region being moderately active or physically active to a low of 44.5% in the Simon Fraser Health Region. It should also be noted that "physical activity patterns also vary by other demographics and socioeconomic patterns. Rates of physical activity are lower for females than males, generally lower for minorities, the elderly, the less educated, and the poor, and declines with age."[75]

TYPES OF PHYSICAL ACTIVITY

There are many different types of physical activity. As discussed above, physical activity types can be distinguished by their intensity – physical activity can demand either a light, moderate or vigorous level of exertion, with the thresholds for each measured in terms of the amount of oxygen the body is processing compared to a resting rate (known as a metabolic equivalent).[76] Light forms of physical activity include very easy activities such as croquet, shuffleboard, or very slow walks; moderate forms of physical activity include activities such as gardening, mowing a lawn, swimming, dancing, brisk walking, or moderately paced bicycle riding; vigorous forms of physical activity include many of the types of physical activity commonly associated with exercise, such as running, fast bicycling, high-impact aerobics, or basketball. For reasons already discussed, this project will focus primarily on moderate levels of physical activity. Moderate types of physical activity are emphasized because they can meet the minimum recommendations to achieve

Table 3-3

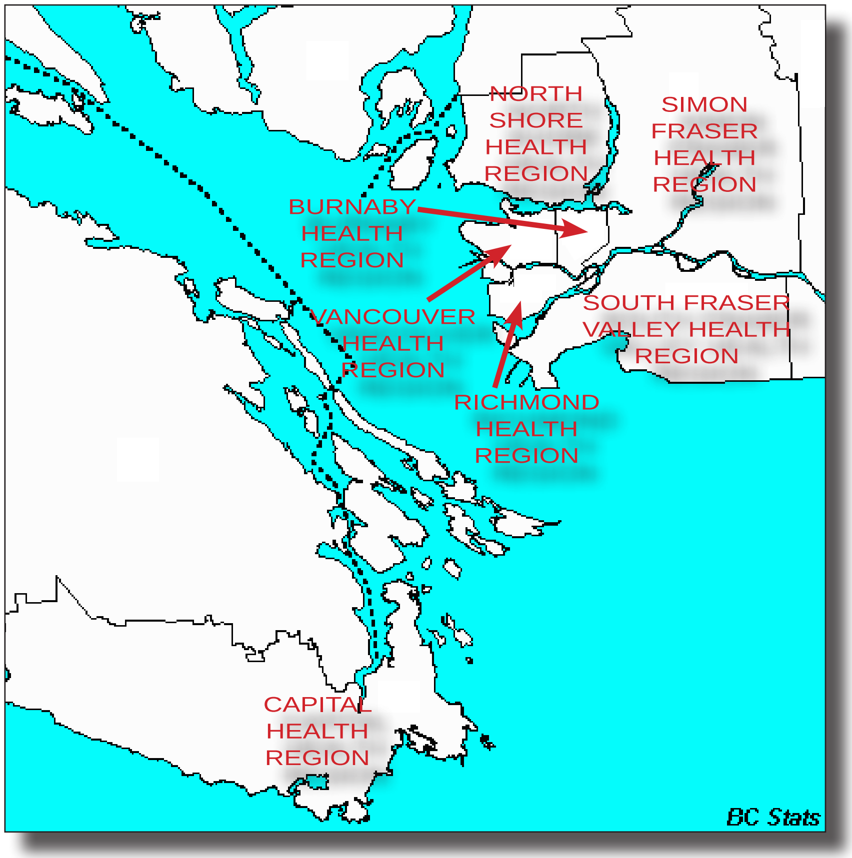
Overweight and obesity levels* in Canada, British Columbia, and Greater Vancouver Health Regions (HR)#, 2000-01.

LOCATION	OVERWEIGHT (BMI 25-29.9)	OBESE (BMI 30+)	OVERWEIGHT AND OBESE (BMI 25+)
Total - Canada	**32.5%**	**14.9%**	**47.4%**
Male	*39.6%*	*16.0%*	*55.6%*
Female	*25.3%*	*13.9%*	*39.2%*
Total - British Columbia	**30.2%**	**12.1%**	**42.3%**
Male	*38.1%*	*12.8%*	*50.9%*
Female	*22.1%*	*11.3%*	*33.4%*
Total - Greater Vancouver	**27.3%**	**10.1%**	**37.4%**
Male	*35.0%*	*10.8%*	*45.8%*
Female	*19.4%*	*9.4%*	*28.8%*
Vancouver HR	**20.1%**	**7.6%**	**27.7%**
Male	*27.1%*	*7.0%*	*34.1%*
Female	*13.0%*	*8.3%*	*21.3%*
Richmond HR	**26.7%**	**5.8%**	**32.5%**
Male	*34.5%*	*6.7%*	*41.2%*
Female	*18.8%*	*5.0%*	*23.8%*
North Shore HR	**26.5%**	**6.7%**	**33.2%**
Male	*38.0%*	*7.2%*	*45.2%*
Female	*14.9%*	*6.3%*	*21.2%*
Burnaby HR	**29.2%**	**8.0%**	**37.2%**
Male	*36.0%*	*8.1%*	*44.1%*
Female	*22.1%*	*7.9%*	*30.0%*
Simon Fraser HR	**32.7%**	**13.2%**	**45.9%**
Male	*41.7%*	*15.3%*	*57.0%*
Female	*23.5%*	*11.0%*	*34.5%*
South Fraser Valley HR	**31.1%**	**13.8%**	**44.9%**
Male	*37.9%*	*15.3%*	*53.2%*
Female	*24.2%*	*12.3%*	*36.5%*
Capital HR	**31.8%**	**9.7%**	**41.5%**
Male	*38.3%*	*10.3%*	*48.6%*
Female	*25.5%*	*9.1%*	*34.6%*

* = Data includes Canadian adults between 20-64 years of age
# = See **Figure 3-4** for map of Greater Vancouver Health Regions
Source: Statistics Canada, 2002a.

Figure 3-4

Southwest British Columbia Health Regions (HR).



Source: Adapted from BC Stats, 1999.

significant health benefits and because, theoretically, more people should be able to engage in moderate forms of physical activity than vigorous forms. Although there are many types of moderate physical activity, two of the most notable types of moderate physical activity are walking and bicycling because they can easily be incorporated into daily routines.

Physical activity can also be distinguished by its purpose. Activity can either be undertaken for a recreational purpose or for a utilitarian purpose. Recreational activity refers to those activities that are undertaken in one's leisure time for discretionary reasons. This includes the types of activities most people think of when they think of exercise, such as jogging, playing hockey, skiing, tennis, swimming, weightlifting or basketball, for example. In short, these activities are undertaken for their own sake. Utilitarian activity, on the other hand, refers to those physical activities that are undertaken as a means to accomplish another purpose. This occurs, for example, when somebody decides to walk or bicycle to work or school, to get their groceries, or to meet a friend for coffee. As such, utilitarian physical activity "is a by-product of achieving some other goal"[77] and can be worked into one's daily habits. This distinction is important because "utilitarian physical activity has the potential to be more important than recreational exercise precisely because it is integrated into other activities."[78] In sum,

> "all other things being equal, activities that have a lower exertion threshold, require little equipment or financial resources, do not take much time from other activities, and have some practical purpose have distinct advantages over other types. We argue that walking and bicycling are advantaged in this respect, in particular the fact that they are moderately intense, impose relatively few barriers on those wishing to begin participating in them, and, perhaps most importantly, can be done by a person while he or she is performing some other useful task."[79]

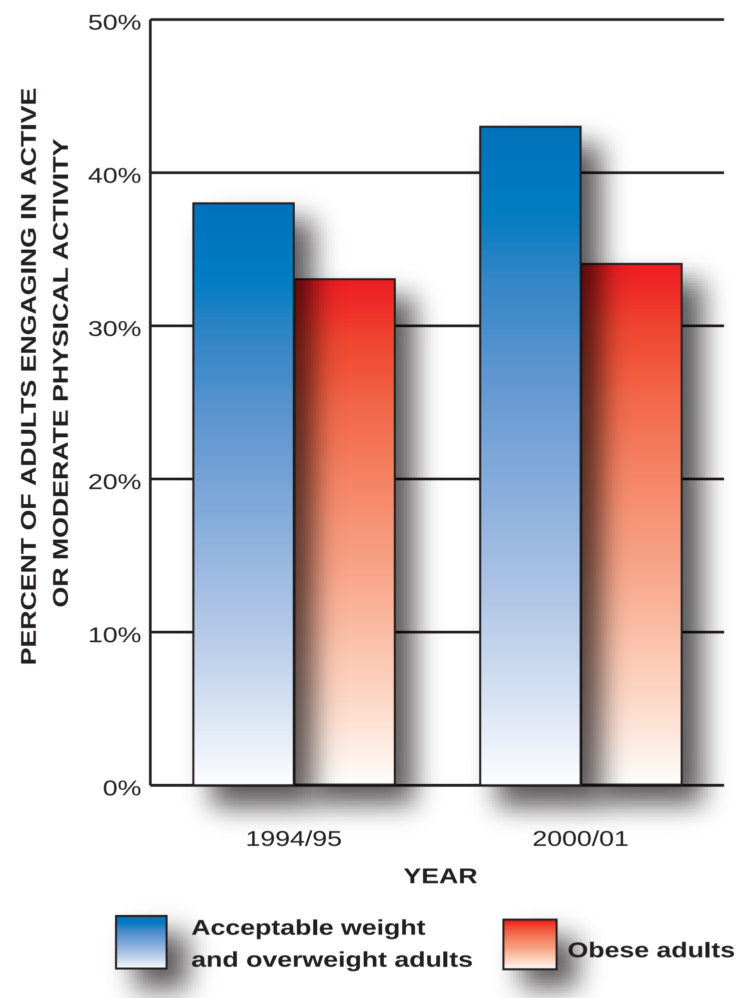
However, despite the fact that walking and bicycling are moderately intense physical activities that can be conducted for utilitarian purposes and integrated into one's daily routine, these types of physical activity remain a little used form of transportation for most North Americans. Instead, the automobile is used the vast majority of the time. According to the U.S. National Household Travel Survey, in 2001 over 86% of all person trips were made by the automobile, while only 8.6% were made by walking (the survey did not specifically ask about bicycling).[80] As shown in **Figure 3-7**, this small mode share for non-motorized transportation appears to be unique to North America when compared to many European countries. In the United States and Canada respectively, walking and bicycling together account for only 7% and 12% of all trips in urban areas, compared to European countries that range from a low of 16% in England and Wales to a high of 46% in the Netherlands. In the United States, the percentage of walking trips to work has decreased substantially in the past several decades – in 2000, walking accounted for 2.9% of all work trips, compared to 10.3% in 1960.[81] Further, when all trip purposes are taken into account, there was a similar decline between 1977, when walking and bicycling together accounted for 10% of all trips, and 1995 when they accounted for 6.3% of all trips.[82]

In contrast, levels of walking and bicycling appear to be increasing in Canada, where the absolute number of bicycle and walking trips to work actually increased by 18.5% and 3.6% respectively between 1996 and 2001. This led to a 10% increase in the mode share for bicycling over this period, although this translated to a decline for the mode share of walking trips from 7.0% to 6.6% in this period.[83] In addition, as shown in **Figure 3-8**, British Columbia leads the country in the percentage of people who commute to work by bicycle. In the Greater Victoria region in particular, bicycling accounts for 4.8% of all trips to work, by far the highest figure among all Canadian metropolitan regions (as this was almost double the percentage of the next closest Canadian city). Although the figures for Metro Vancouver are more moderate, this region is tied with Ottawa/Gatineau region for having the highest mode share for bicycling among Canadian regions with populations over 500,000, as 1.9% of all trips to work in the Greater Vancouver region are made by bicycle.[84] However, as can be expected, there are significant variations within the Metro Vancouver region, with only 0.3% of the suburban population bicycling to work, compared to 3.3% of all City of Vancouver residents, and 12.2% of City of Vancouver residents living in areas near the University of British Columbia.[85]

Based on the above discussion of overweight and obesity levels and the fact that moderate, utilitarian forms of physical activity, such as walking and bicycling, can play important roles in reducing the risk of overweight and obesity, the following sections will explore the relationship between physical activity and the built environment, by suggesting how the built environment can either work to either enhance or inhibit the likelihood of engaging in such physical activity.

Figure 3-5

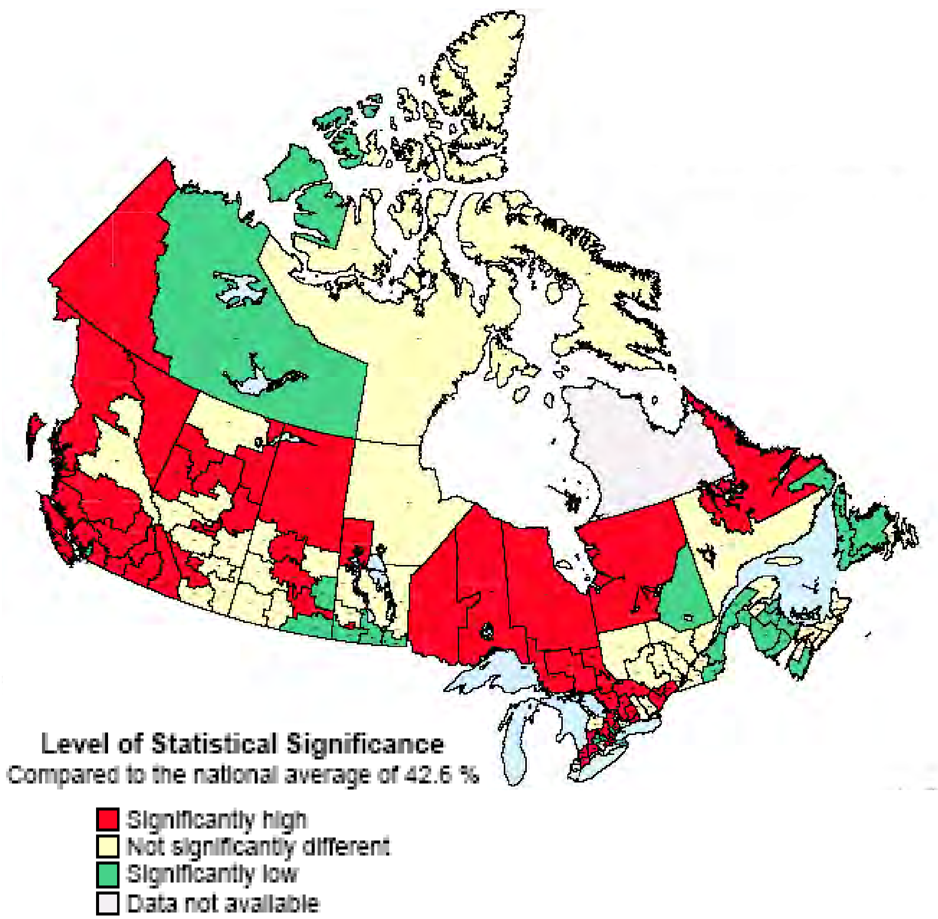
Physical activity trends among Canadian* adults.



* = includes Canadians between 20-64 years of age.
Source: Adapted from Statistics Canada, 2002c.

Figure 3-6

Physical activity levels* among Canadian adults#, 2001.



Note: Figures based on Canadian Health Regions (HR).
* = Physical activity refers only to leisure time, moderate physical activity
# = includes Canadians aged 12 and over
Source: Statistics Canada, 2002b.

THE RELATIONSHIP BETWEEN PHYSICAL ACTIVITY AND URBAN FORM

A large body of literature has emerged in recent years to show a correlation between the way communities are designed and the amount of physical activity that residents of those communities engage in. This research has focused primarily on the specific types of physical activity discussed above: namely, moderately intense, utilitarian types of physical activity such as walking and bicycling. Although recreational physical activity may also be influenced by community design, for example by the location of amenities such as trails, parks, or playing fields, recreational activity is often excluded from such research because, unlike utilitarian physical activity, it is generally not integrated into people's everyday lives. In addition, recent research has shown that the built environment has a less significant relationship with recreational types of physical activity than it does with utilitarian types of physical activity: "transportation research…finds no differences in walking for exercise but finds significant differences in walking for transport purposes between high- and low-walkability neighbourhoods."[86]

As such, recent empirical studies have examined whether a relationship does in fact exist between urban form and moderate, utilitarian types of physical activity, and if so, which built environment variables have the most significant positive or inverse relationships with these forms of physical activity. These studies have consistently shown a relationship between community design and utilitarian physical activity patterns and have shown that people who live in sprawling, suburban environments tend to engage in less physical activity than those who live in more dense, urban environments. This section will first provide a brief survey of the research design and findings of some recent empirical studies that have been conducted both at the macro-level (for example, studies looking at aggregate data to examine patterns between urban areas on a national scale) and at the micro-level (for example, studies looking at patterns within urban areas on a city-wide or neighbourhood scale) to examine the relationship between urban form and physical activity. This section will then provide a brief overview of the specific built environment variables that have the most significant positive or inverse relationships with physical activity. Although this section is based on a review of relevant literature, the findings presented below do not represent a comprehensive and complete review of relevant literature, as this is beyond the scope of this project and has been done elsewhere.[87] Instead, this review is intended to provide an overview of some of the more important findings on this topic.

Macro-scale studies

Several macro-scale studies have been performed in recent years using aggregate American national data to examine how the relationship between physical activity and urban form differs between urban areas throughout the United States. One of the first and most influential of these national studies was conducted by Ewing, Pendall and Chen for Smart Growth America.[88] To examine this relationship, the researchers developed a quantitative measure of sprawl referred to as a 'sprawl index' for 83 metropolitan regions in the Unites States, and then related travel patterns to this sprawl index for each metropolitan region. The sprawl index was developed based on four characteristics of typical sprawling development patterns:

- residential density;
- neighbourhood mix of home, jobs, and services;
- strength of activity centers and downtowns; and
- accessibility of the street network.

Each of these characteristics consisted of several components. The sprawl index that was developed consisted of 22 measurable components that were combined to create an overall score for each of 83 metropolitan regions in the United States – the higher the score, the more compact the region; the lower the score, the more sprawling the region. The researchers then assessed several 'quality-of-life' outcomes of sprawl by examining how the sprawl index scores related to factors such as vehicle ownership, driving distances, commute times, traffic fatalities, air pollution exposures, and, most importantly for this project, mode share for public transportation and walking trips to work. With regards to the latter, the project found that the degree of sprawl was a powerful predictor of whether or not people would walk to work or not, even after controlling for demographic and socioeconomic variables. The study found that, while only 2% of residents of more sprawling communities walked to work, 3.1% of residents of less sprawling communities walked to work. Further, the study found that there was a difference of 3 percentage points in walk share to work between the most sprawling and the least sprawling regions. In sum, the study stated that "thousands more residents walk to work in regions that sprawl less."[89] This study was important because it represented the most comprehensive effort undertaken to date to define, measure and evaluate sprawl. However, although the development of the sprawl index has been influential, the study did not comprehensively examine physical activity patterns in each of these metropolitan regions.

Table 3-4

Physical activity levels* in Canada, British Columbia, and Greater Vancouver Health Regions (HR)#, 2000-01.

LOCATION	PHYSICALLY ACTIVE	MODERATELY ACTIVE	PHYSICALLY INACTIVE
Total - Canada	**22.9%**	**23.6%**	**53.5%**
Male	*26.6%*	*23.7%*	*49.7%*
Female	*19.5%*	*23.5%*	*57.0%*
Total - British Columbia	**30.9%**	**25.5%**	**43.7%**
Male	*34.0%*	*25.2%*	*40.8%*
Female	*28.1%*	*25.7%*	*46.2%*
Total - Greater Vancouver	**28.8%**	**25.2%**	**46.0%**
Male	*32.4%*	*24.6%*	*43.0%*
Female	*25.6%*	*25.7%*	*48.7%*
Vancouver HR	**31.0%**	**24.0%**	**45.0%**
Male	*35.2%*	*21.5%*	*43.2%*
Female	*26.9%*	*26.4%*	*46.7%*
Richmond HR	**26.2%**	**24.9%**	**48.9%**
Male	*29.2%*	*28.0%*	*42.8%*
Female	*23.5%*	*22.2%*	*54.3%*
North Shore HR	**37.7%**	**30.2%**	**32.1%**
Male	*38.9%*	*31.2%*	*30.0%*
Female	*36.8%*	*29.4%*	*33.9%*
Burnaby HR	**29.7%**	**24.7%**	**45.6%**
Male	*33.4%*	*22.9%*	*43.7%*
Female	*26.5%*	*26.3%*	*47.2%*
Simon Fraser HR	**22.0%**	**22.5%**	**55.5%**
Male	*25.0%*	*23.7%*	*51.3%*
Female	*19.4%*	*21.6%*	*59.1%*
South Fraser Valley HR	**28.6%**	**26.6%**	**44.9%**
Male	*32.7%*	*26.0%*	*41.3%*
Female	*25.1%*	*27.0%*	*47.8%*
Capital HR	**34.9%**	**27.0%**	**38.0%**
Male	*39.8%*	*26.7%*	*33.5%*
Female	*30.6%*	*27.3%*	*42.1%*

* = Data includes all Canadians aged 12 and over
# = See **Figure 3-4** for map of Greater Vancouver Health Regions
Note: Figures exlude persons who did not state their physical activity levels
Source: Adapted from Statistics Canada, 2002b.

A pioneering nationwide American study conducted by Ewing, Schmid, Killingsworth, Zlot and Raudenbusch[90] followed from the development of the sprawl index, and used the sprawl index to focus more comprehensively on the association between urban sprawl, physical activity, obesity and morbidity throughout the United States. To do so, the researchers examined the degree to which sprawl within American counties or metropolitan areas was related to levels of physical activity, obesity, BMI, hypertension, diabetes, and coronary heart disease. The researchers used the sprawl index developed by Ewing, Pendall and Chen for metropolitan areas, and also developed a similar but simpler sprawl index for counties. This county sprawl index only included 2 characteristics of sprawl (residential density and street accessibility) that were operationalized by 6 land use and street network variables. This simpler country sprawl index was developed due to data limitations at the county level, as data was only readily available for these 6 variables. The researchers then assessed self-reported behavioural and health status data from the Behavioural Risk Factor Surveillance System (BRFSS), a random digit-dialled telephone survey administered annually to American adults. The sample consisted of 206,992 respondents from 448 counties and 175,609 respondents from 83 metropolitan areas across the United States between 1998-2000. The study found more significant relationships in counties than in metropolitan regions. It found that people living in counties with more sprawling development were likely to walk less during their leisure time (the BRFSS does not measure utilitarian physical activity) and weigh more than people who live in less sprawling counties, even after controlling for factors such as age, education, gender, and race and ethnicity. In fact, it was found that residents of a county that was one standard deviation above the mean sprawl index would be expected to walk for leisure 14 minutes more each month than residents of a county one standard deviation below the mean. The researchers found weaker relationships at the larger scale of analysis of the metropolitan level. However, the authors noted that the finding of weaker relationships between urban form and physical activity in metropolitan areas than counties was not surprising, due to the fact that most metropolitan areas consist of multiple counties whose built environments vary significantly between central and outlying counties. As such, the authors point to the need for further research at more micro-scales of analysis to examine differences within metropolitan regions. There is also a need for further research that examines utilitarian physical activity as opposed to leisure time physical activity. This study was groundbreaking because if was the first national study to establish a direct association between the form of community and the health of the people who live there.[91]

Berrigan and Troiano used an innovative approach to examine the relationship between urban form and physical activity at the national level.[92] In their study, home age was used as a proxy measure of environmental factors influencing physical activity, as home age is associated with factors such as density, street design, and building characteristics. In particular, the authors asserted that neighbourhoods containing older homes in urban areas are more likely to have sidewalks, have denser interconnected street networks, and often display a mix of commercial and residential uses. As such, the authors assessed the relationship between home age and leisure-time walking. The researchers analyzed data from the Third National Health and Nutrition Examination Survey (NHANES III), which is a nationally representative sample of the US population. Survey data included responses from 14,827 participants regarding measures of walking behaviour, the frequency of diverse forms of leisure-time physical activity, home age, rural vs urban/ suburban locale, region of the country, demographic characteristics of the respondent and any health related activity limitations. Home age was categorized as being built either before 1946, between 1946-1973, or after 1973. The study found that residents of homes built before 1973 in urban or suburban areas were significantly more likely to walk at least 1 mile, at least 20 times per month than residents of homes built after 1974, even after controlling for effects of gender, race/ethnicity, age, education, income, or health related activity limitations. With this innovative proxy measure for urban form, the study confi rmed the findings of previous studies that indicated that residents of more urban environments engage in more physical activity than residents of suburban environments.

Despite the findings of each of these macro-scale studies, they all face significant limitations because they rely on aggregate data to compare physical activity patterns between counties or urban regions throughout the United States. The use of aggregate data masks important differences in built environment variables and physical activity patterns within urban regions. Therefore, a further body of research has emphasized the relationship between the built environment and physical activity patterns at a more localized scale of analysis.

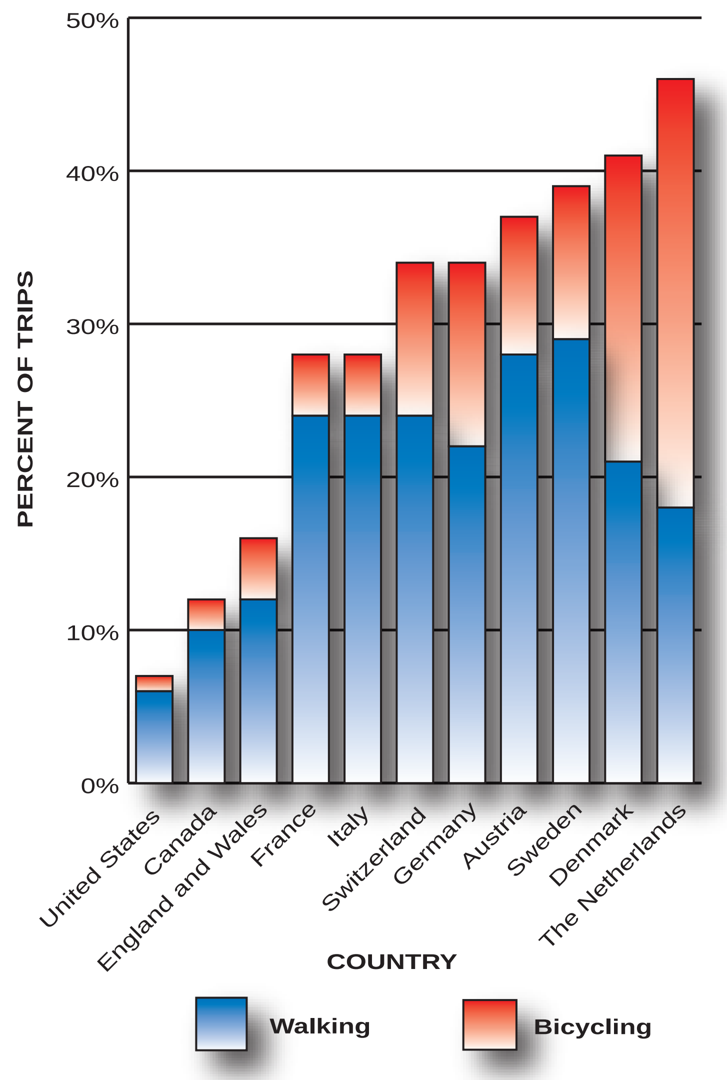
Micro-scale studies

In contrast to the nationwide studies discussed above, a number of studies have used a much more localized approach to assess urban form characteristics within urban regions and their relationships with physical activity patterns. These studies typically either use a case-control method, where physical activity patterns in specific neighbourhoods with similar socio-demographic characteristics but different built environment variables are compared; or they use a city-wide approach, where the physical activity patterns of a random sample of residents of an urban region are collected and analyzed based on the urban form characteristics of their place of residence and/or place of work.

Using a case control method, Saelens, Sallis, Black and Chen examined physical activity data from residents of two neighbourhoods in San Diego.[93] The study evaluated self reported measures of neighbourhood environmental variables that were thought to be important contributors to physical activity, and compared objective physical activity data and weight status among 107 adults in two neighbourhoods in San Diego. These two neighbourhoods were chosen because they exhibited similar socio-demographic characteristics (such as gender, age, ethnicity and education) but differed significantly regarding their urban form characteristics. One neighbourhood was characterized as being highly 'walkable' and the other was much less 'walkable', as defined by the level of residential density, land use mix, and connectivity in each neighbourhood. To obtain subjective neighbourhood assessments, participants responded to two surveys which assessed respondents' perceptions of their neighbourhood's residential density, land use mix; street connectivity; walking/cycling facilities (i.e. sidewalks, biking paths); aesthetics; traffic safety; and crime safety. The survey also asked respondents to self report the number of minutes spent walking for various purposes during the past seven days. To obtain objective physical activity data, participants also wore an accelerometer for seven consecutive days, which provided an objective minute by-minute measure of respondents' physical activity patterns and a classifi cation of physical activity as being light, moderate or vigorous. Therefore, the study combined objective physical activity data with self-reported data indicating the purpose of the physical activity. After controlling for age and education, the study found that residents in the high-walkability neighbourhood engaged in about 52 more minutes of moderately intense activity during the 7-day period than did residents of the low-walkability neighbourhood, and that the percentage of residents walking for errands was significantly higher in the high-walkability neighbourhood than in the low-walkability neighbourhood. In terms of the total physical activity over the 7-day period, average residents of the high-walkability neighbourhood met, or almost

Figure 3-7

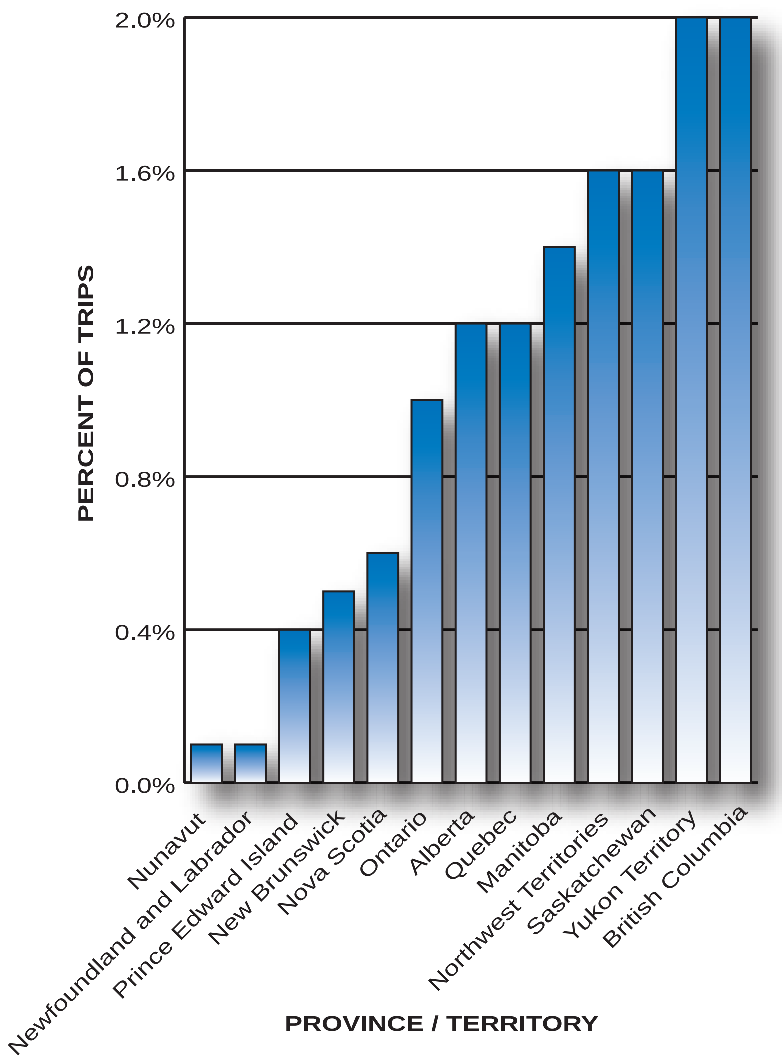
Mode share of walking and bicycling trips in the United States, Canada, and various European countries.



Note: Figures only include trips made in urban areas
Source: Adapted from Pucher and Dijkstra, 2003. Page 1510.

Figure 3-8

Mode share of bicycling in Canadian provinces and territories.



Source: Adapted from Pucher and Buehler, 2005. Page 44.

met, the guidelines of a minimum 30 minutes of moderate physical activity per day, whereas residents of the low-walkability neighbourhood averaged less than 20 minutes of moderate physical activity per day. The study further found that a higher percentage of residents from the low walkability neighbourhood were overweight (60%) than residents of the high walkability neighbourhood (35%). Although this study had a relatively small sample size, did not include bicycling activity, and relied on self-reported measures of environmental variables, it was "the first to objectively measure and document the association between neighbourhood design and physical activity."[94]

Similar findings resulted from study by Frank, Schmid, Sallis, Chapman and Saelens in the Greater Atlanta region.[95] In contrast to the previous study, this study did not rely on subjective measures of urban form. Instead, this study recognized that most research on physical activity and the built environment to date has been based largely on self-reported physical activity and perceived assessments of the built environment, which are known to have limited validity. To respond to these limitations, this study was developed as the first to use objective measures of physical activity and objective measures of urban form to assess the relationship between physical activity and the built environment. Between 2001- 2003, the researchers collected data from 357 participants who lived throughout the Atlanta region. To obtain objective physical activity data, participants wore an accelerometer for 2 days (although participants were randomly assigned different day pairs to ensure a range of data for all 7 days of the week). However, unlike the previous study, this study also used objective built environment data, using a regional parcel-level land use data set. Using a Geographic Information System (GIS), a 1-km street network buffer was established around each participant's household. Within each buffer, levels of net residential density, street connectivity and land use mix were calculated and combined to create a 'walkability index'. This index was categorized into quartiles ranging from the least walkable (low levels of net residential density, street connectivity and land use mix) to the most walkable (high levels of net residential density, street connectivity and land use mix). The study found that the walkability index was positively correlated with the likelihood of meeting the minimum 30-minute physical activity guidelines, after controlling for demographic factors. On average, participants were 30% more likely to record at least 30 minutes of activity with each quartile increase in the walkability index. In fact, 37% of the individuals in the highest walkability index quartile met the minimum 30-minutes of physical activity, compared to just 18% of individuals in the lowest walkability quartile. Finally, results demonstrated that the likelihood of meeting the recommended minimum 30-minutes of activity per day was 2.4 times greater for the most walkable quartile than the least walkable quartile. The results "indicate that when people have many destinations near their homes and can get there in a direct pathway, they are more likely to engage in moderate physical activity for ≥30 minutes on a random day."[96] The study concludes that "community design variables were significantly related to moderate intensity physical activity for all purposes"[97] and served to confi rm the findings of previous studies.

However, despite the findings of many studies that there is a significant relationship between the built environment and physical activity, there is still a need for further research, as many studies have also shown that evidence for such a relationship is "ambiguous, weak, or absent."[98] For example, Cervero and Duncan found a weak relationship between urban form and physical activity in a city-wide study in the San Francisco Bay Area.[99] This study was based on data from the 2000 Bay Area Travel Survey, which was a random sample survey of 15,066 households in the San Francisco Bay Area that collected household activity patterns for a 2-day period. The researchers first refined the dataset to exclude trips that had a low likelihood of walking (such as trips over long distances or trips that involved carrying items such as groceries) to yield a sample of 7,889 trip records. Each trip record contained the trip purpose, mode, time of day, day of week, and origin and destination coordinates. Control variables were also obtained, and included the attributes of trip makers and their households, as well as other variables that could potentially influence the likelihood of walking, such as topography, nightfall, precipitation, and security. The study found that built environment factors exerted far weaker, although not inconsequential, influences on walking and bicycling than control variables:

> "our research reveals that urban landscapes in the San Francisco Bay Area generally have a modest and sometimes statistically insignificant effect on walking and bicycling. Although well-connected streets, small city blocks, mixed land uses, and close proximity to retail activities were shown to induce nonmotorized transport, various exogenous factors, such as topography, darkness, and rainfall, had far stronger influences. Other control variables, such as demographic characteristics of trip makers, were also far stronger predictors of walking and bicycling choice than built environment factors".[100]

The researchers conclude that "stronger evidence on the importance of urban landscapes in shaping foot and bicycle travel is needed."[101]

In sum, the literature to date "documents relations between numerous environmental variables and physical activity but provides few definitive explanations. Further investigation of the environmental correlates of physical activity is needed and could lead to improved interventions."[102] In other words, many of these studies have shown that there is a correlation between the built environment and physical activity, but no studies have shown a causal relationship between the built environment and physical activity patterns. In addition, the overwhelming majority of research conducted to date has been in the American context – few such studies have yet been conducted in the Canadian context, and further research is required to see if similar patterns exist in Canada. The analysis undertaken for this project is designed to provide further research in the Canadian context to inform future studies throughout North America.

Built Environment Variables

As discussed above, many studies have shown a significant relationship between the built environment and physical activity patterns. Following from these findings, many studies have explored how the built environment affects physical activity patterns. In particular, many studies have examined which variables in the built environment exert the most significant relationships with physical activity patterns. In general, three interdependent built environment variables are thought to have a significant influence on physical activity patterns: street network connectivity, density, and land use mix. Together, these variables affect how close destinations are to each other and how easy it is to get to those destinations. Each of these variables is discussed below.

Connectivity is a measure of the efficiency of the transportation network and describes how directly a person can travel between two points using existing streets and paths. The way street networks are designed can influence the specific route and mode of transportation that people use. As shown in **Figure 3-9**, as connectivity increases, travel distances decrease and route options increase, allowing more direct travel between destinations. As such, high levels of connectivity are more conducive to walking or bicycling than lower levels. High levels of connectivity can typically be found in more urban environments with grid street networks which are characterized by relatively straight streets, four-way intersections, and a high number of blocks or intersections per unit of area. On the other hand, low levels of connectivity typically exist in more sprawling, suburban environments with dendritic, hierarchical street networks that are characterized by more curvilinear and dead-end streets and fewer blocks or intersections per unit of area. As such, connectivity is generally positively associated with walking or bicycling. Connectivity is typically operationalized as the number of intersections per unit of area or the number of three-way intersections (which indicate dead end streets and a disconnected street network) in a given area.

Density focuses on the land use characteristics in a given area. More specifically, density is a measure of urban form meant to convey objective information about how compactly a particular environment is built. Density can be measured in a number of different ways, such as the number of people, jobs or buildings in a given area. It typically refers either to residential density or to employment density, and can be measured as a gross or a net measure. Higher densities typically increase the number of potential destinations located within a geographic area, thereby increasing proximity between destinations, reducing travel distances and increasing the likelihood of walking or bicycling. Urban areas typically have high density levels, whereas more sprawling areas typically have low densities with fewer people living across a larger land area. Many studies have found a positive association between density and physical activity levels. For example, Frank and Pivo concluded that "higher density levels…reduce trip lengths, thereby increasing travel options (walking, bicycling, and transit) as well as obviating the need to own a vehicle."[103]

Land use mix refers to the number of different types of land uses (such as residential, commercial, institutional, or retail) within a given area. A typical urban environment with a high mix of land uses would generally include uses such as homes as well as offices, stores, restaurants and other services and amenities. In contrast, a typical suburban environment with a low level of land use mix is characterized by land uses that are segregated from each other (for example, housing is separated from office development, which is in turn separated from retail development). Mixing land uses increases the diversity of destinations in a given area, thereby reducing the distance required to travel to a variety of destinations. As such, land use mix is also positively associated with physical activity, because it shortens trip distances, thereby encouraging people to walk and bicycle. For example, Cervero found that "the relative proximity of mixed-use development matters greatly. If retail shops are within 300 feet, or several city blocks, from a dwelling unit, workers are more likely to commute by transit, foot or bicycle."[104]

The effects of connectivity, density and land use mix on travel behaviour are intertwined, as together they combine to effectively shorten trip distances, thereby potentially increasing utilitarian physical activity. As such, residents of typical urban neighbourhoods with highly connected street networks, medium to high densities, and a mix of land uses tend to engage in more physical activity than residents of typical suburban neighbourhoods with disconnected street networks, low density levels, and segregated land uses. In addition, physical activity patterns are also influenced by micro-scale urban design characteristics, such as the size and extensiveness of sidewalks, the number and width of traffic lanes, the type of pavement used for surfacing, the location and marking of crosswalks, the design of buildings, landscaping, and availability of amenities such as tree plantings, benches and lighting. Such urban design characteristics can influence an individual's perceptions about the desirability of walking or bicycling within a particular place.

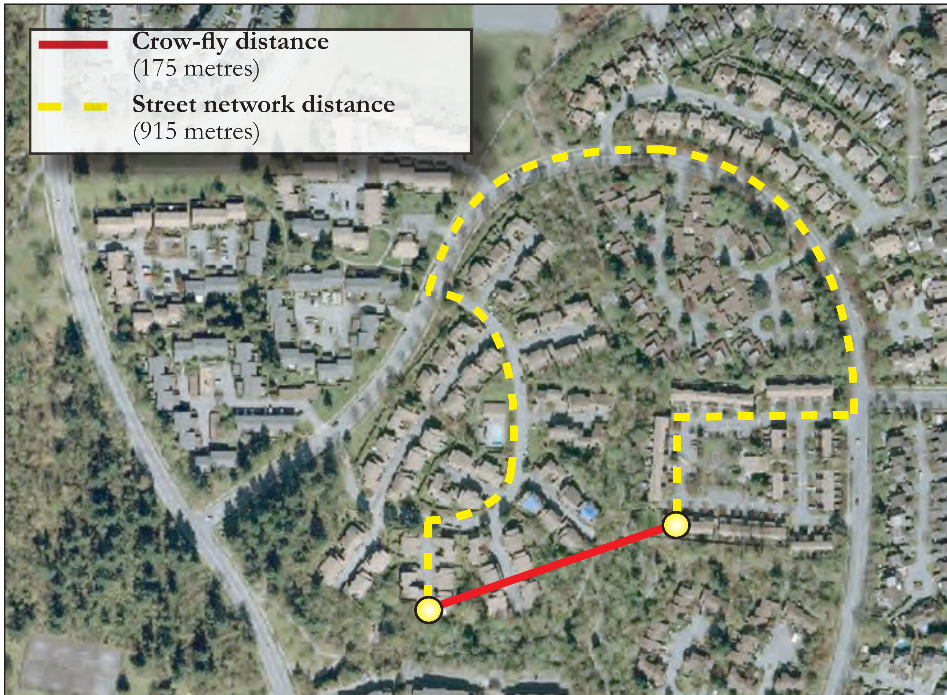
A COUNTER ARGUMENT: RESIDENTIAL SELF-SELECTION

As has been shown, many studies have demonstrated that residents of neighbourhoods with well-connected street networks, medium- to high-densities, and a mixture of land uses are likely to engage in higher levels of utilitarian physical activity such as walking and bicycling than residents of sprawling neighbourhoods with poor street connectivity, low densities, and segregated land uses. Many authors have concluded that these associations form a causal relationship: "Causality flows, roughly, from the built environment (the communities in which we live and environments in which we work) through physical activity patterns to public health outcomes."[105] As such, the justification for the development of well-connected, relatively dense, and mixed-use neighbourhoods has often been based on their potential to modify travel behaviour by increasing utilitarian physical activity levels.

However, as shown above, there are many researchers who maintain that the relationship between the built environment and travel behaviour is weak or non-existent. In addition, many critics have argued that it is not possible to determine if there is a causal relationship between the built environment and physical activity levels, since there

Figure 3-9

Connectivity. Arial photographs of two Greater Vancouver neighbourhoods (at the same scale) compare the crow-fly distance to the street network distance from two equidistance points (X and Y). On the left (a) is a typical suburban neighbourhood with a poorly connected street network, while on the right (b) is a typical urban neighbourhood with a well-connected grid street network (b). Because of the shorter street network distance in (b), it is more likely that people will walk or bicycle between points X and Y than they would in the neighbourhood in (a).



(a) A neighbourhood with low connectivity. The street network distance between X and Y is more than five times longer than the crow-fly distance. Because of the long street network distance, it is less likely that people will

(b) A neighbourhood with high connectivity. The street network distance is only slightly longer than the crow-fly distance. Because of the short street network distance, it is more likely that people will walk or bicycle between these destinations.

Source: Adapted from City of Vancouver, VanMap.

is a multitude of variables that influence physical activity levels. These critics state that it is not necessarily the built environment itself that influences physical activity levels, but rather the underlying values of the people who choose to live in these neighbourhoods. This argument is known as residential self selection, which purports that people are able to live where they would ideally like to live and, as such, that people may choose to locate in a particular residential area to realize their lifestyle preferences. This argument therefore states that individuals may walk and bicycle more in typical urban neighbourhoods because they have deliberately chosen to live in a neighbourhood in which walking and bicycling is a feasible option. In other words, people who live in these types of neighbourhoods may have chosen to do so because of their "attitudes, values, or demographic and socioeconomic attributes. These characteristics may be the true determinants of their travel behaviour."[106] As such, the self-selection argument asserts that travel behaviour is not necessarily influenced directly by land use. Proponents of the self-selection argument claim that "altering land use characteristics by itself would not affect the residents' travel behaviour."[107] This has also led to a concern among supporters of this argument that "processes of neighbourhood self-selection might lead to overestimates of the effects of urban form on travel behaviour."[108]

Proponents of the self-selection argument criticize the studies that attempt to demonstrate a causal link between the built environment and travel behaviour because these studies have often "lacked a clear behavioural framework, which limits both the credibility of the analyses and the persuasiveness of the policy recommendations."[109] As such, self-selection supporters claim that these other studies have incorrectly inferred "causality on the basis of observed association, and conjecture that land use policies can be deployed to curb travel demand, in particular automobile use."[110] It is therefore argued that researchers studying the association between land use and travel behaviour need to also consider a myriad of other factors, such as attitudinal and demographic variables, that could also affect travel behaviour in order to truly determine which variables have the strongest association with travel behaviour.

A number of studies have examined behavioural and attitudinal variables in addition to land use and transportation factors in order to determine which elements have the strongest relationship with travel behaviour and to determine the magnitude of the self-selection bias. Kitamura, Mokhtarian and Laidet designed a study that attempted to determine the relative impacts of land use and attitudinal factors on the travel behaviour of individuals by employing cross-sectional study that examined travel behaviour of residents in five diverse neighbourhoods in the San Francisco Bay Area.[111] The study was comprised of two components. First, based on the results of a 3-day travel diary, the effects of socio-economic and land use characteristics on travel demand were measured. Second, attitudinal variables were analyzed by examining participants' responses to 39 attitude statements. The results of these attitude statements were factor analyzed into eight attitudinal groups (pro-environment, pro-transit, suburbanite, automotive mobility, time pressure, urban villager, pro-transportation control measures, and workaholic). Factor scores were established that represented individuals' attitudes towards various aspects of urban life. These factor scores were introduced into the model to determine the relative contributions of the socio-economic, land use and attitudinal variables. It was found that, although all variables offered some significant explanatory power for variations in travel demand, the attitudinal variables explained a higher proportion of the variation in travel demand than did land use characteristics. They therefore concluded that "attitudes are certainly more strongly, and perhaps more directly, associated with travel than are land use characteristics."[112]

Using the same dataset, Bagley and Mokhtarian used a different approach to arrive at similar conclusions.[113] This study examined attitudinal and lifestyle variables using a Structural Equations Model (SEM). SEMs "are useful for representing multiple relationships among a set of variables, where the same variable that is the outcome (dependent variable) in one set of relationships may be a predictor of outcomes (explanatory variable) in other relationships."[114] This approach was used because the authors recognized that this study involved multiple relationships among a set of variables and involved multiple directions of causality: "For example, we can hypothesize that attitudes and lifestyle characteristics affect both residential location and travel demand and in turn are affected by them, and that residential location and travel demand affects the other."[115]

In addition to the attitudinal factors that were included in the Kitamura et al. study, this study also used lifestyle variables. Lifestyle variables were obtained from results of a questionnaire in the original study that examined more than 100 types of activities and interests of participants (such as which subjects they had read about within the last month, how they spent the last weekend and what activities they had conducted during the past year). The authors found that, among all the variables, attitudinal and lifestyle variables had the greatest impact on travel demand. They also found that residential location type had little impact on travel behaviour when attitudinal, lifestyle and sociodemographic variables were accounted for. The authors conclude that "this is perhaps the strongest evidence to date supporting the speculation that the association commonly observed between land use configuration and travel patterns is not one of direct causality, but due primarily to correlations of each of those variables with others."[116] Bagley and Mokhtarian further state, however:

> "as a philosophical observation, it is unlikely that self-selection based in prior attitudes completely explains the observed results…Rather, it seems quite plausible that the residential environment would have some impact on travel behaviour. If nothing else, the spatial configuration of the residential neighbourhood can impose constraints on the behaviour to which one may be predisposed…Thus, people do change, both their attitudes and their behaviour in response to external stimuli – the questions are, how many people, which kinds, how much, and how long does it take?"[117]

Krizek attempted to answer some of these questions by collecting and analyzing longitudinal data from the Seattle region.[118] Longitudinal data was used because it was felt that previous cross-sectional studies were not able to adequately address the determinants of travel behaviour since they relied on examining different participants from different neighbourhoods. Krizek employed a 'pretest-posttest' research strategy and examined travel patterns before and after participants changed residential locations to see if their travel behaviour changed. The data was obtained from the Puget Sound Transportation Panel (PSTP), which had been conducted annually for the previous seven years. The PSTP tracked socio-demographic and travel behaviour data of the same 2,000 households each year using a 2-day travel diary, and included the composition of the household and the location of the home and workplace. The study correlated travel behaviour data with urban form data for all households who moved within the region before and after their relocation. Households that moved to neighbourhoods with similar land use characteristics as their previous residential location were not included in the analysis, because the study was primarily concerned with households who moved to neighbourhoods with different land use characteristics than their previous residential location. 241 households in the PSTP moved to a residential location with different land use characteristics than before. Of these 241 households, the study found that there were generally relatively weak correlations between changes in travel behaviour and changes in urban form. In other words, travel behaviour did not significantly change before and after residents changed location. The authors note, however, that there may be a threshold effect for travel behaviour, meaning that changes in travel behaviour may only be attained once a certain level of density, connectivity and land use mix is achieved. From the point of view of the self-selection argument, this study was useful because it measured changes in behaviour among the same individuals, "allowing one to infer that changes in one variable (e.g., a change in residential location) affect travel behaviour."[119] The authors conclude that this research offers evidence in support of the hypothesis of self-selection and that "the undetectable changes (of travel behaviour) in many relocation pairs suggest that household attitudes toward travel appear to be largely predetermined. It just may be the case that, for most of the population, there is little that urban form can offer as far as providing alternatives for unwilling households not to drive."[120] Since the findings suggest that travel behaviour did not change significantly before and after a residential relocation, the author recommends that denser, mixed-used and connected neighbourhood types should be marketed to a low car-using population instead of a high-car-using population, since the latter may not modify their travel behaviour in these new environments. This study was limited in terms of its sample size of 241 participants and because of the time frame of 1 year between the pre-test and post-test scenarios. It may be possible that travel behaviour would change more significantly over a longer period of time.

However, Krizek's subsequent analysis of the same dataset (2003) indicates somewhat different results.[121] In this subsequent study, Krizek states that "when households relocate and change their NA (neighbourhood accessibility), their travel behaviour changes as well, all else being equal."[122] However, this study was primarily focused on vehicle miles traveled (VMT) and person miles traveled (PMT), and was not focused specifically on physical activity patterns. The study found that VMT, PMT, and number of trips were all reduced in neighbourhoods with higher accessibility. Since this study was primarily focused on vehicular travel, the effects of land use characteristics on other modes was not examined and "remains unknown."[123]

The above studies all contribute substantially to the self-selection hypothesis that attitudinal, lifestyle and socio-demographic characteristics may have a more significant effect on travel behaviour than land use characteristics. These studies suppose "that any observed differences in behaviour in one type of neighbourhood versus another have more to do with the kind of people who choose to live in each type of neighbourhood than it does with the attributes of the neighbourhood itself."[124] As such, supporters of the self-selection argument claim that the development of denser, mixed-use and well-connected neighbourhoods cannot be justified based on the premise that these types of environments have the potential to modify travel behaviour and increase physical activity levels. The residential self-selection argument raises a legitimate issue: "it is reasonable to assert that some people value driving more than others, and vice versa in the case of walking and bicycling. It is also reasonable to argue that people who choose to live in higher density, mixed-use, and transit-oriented neighbourhoods may have different beliefs with respect to social, political, cultural, and environmental issues…The built environment, of course, cannot explain everything."[125]

However, one of the main weaknesses of the self-selection argument is that it assumes that people are actually able to live where they ideally would like to live. In other words, in micro-economic terms, it assumes that the supply of alternative neighbourhood types is equal to the demand for these types of neighbourhoods. As such, the self-selection argument "fails to consider the possibility that a segment, perhaps even a significant segment, of the population is unable to find suitable housing in a neighbourhood that meets their preferences."[126] Therefore, the self-selection argument is weakened significantly if the supply of housing types does not align with peoples' preferences. Several studies have provided evidence that, in many regions, there is indeed a substantial gap between supply and demand of housing in dense, mixed-use and well-connected neighbourhood types. In regions where there is a gap between supply and demand of certain neighbourhood types, it is hypothesized that there is a significant latent demand for these types of neighbourhoods. Latent demand refers to a situation in which "there is a need in the marketplace that is presently unfulfilled."[127]

BEHAVIOURAL MODEL OF ENVIRONMENT

Following from the discussion above regarding the relationship between the built environment and physical activity patterns, as well as the influence of attitudinal and behaviour characteristics on physical activity patterns, several authors have proposed theoretical frameworks and conceptual models that strive to better understand and to link these various characteristics. These models generally place specific emphasis on the relationship between the built environment and pedestrian and bicycling activity. The models are often referred to as behavioural models of environment,[128] social-ecological models of human behaviour[129,130,131] or ecological models of behaviour.[132,133] Although each of these models differ somewhat in the way they are structured and applied, they have all adopted the same conceptual framework regarding the premise that the relationship between physical activity and the built environment "depends on the dynamic interaction of biological, behavioural, social and environmental factors."[134]

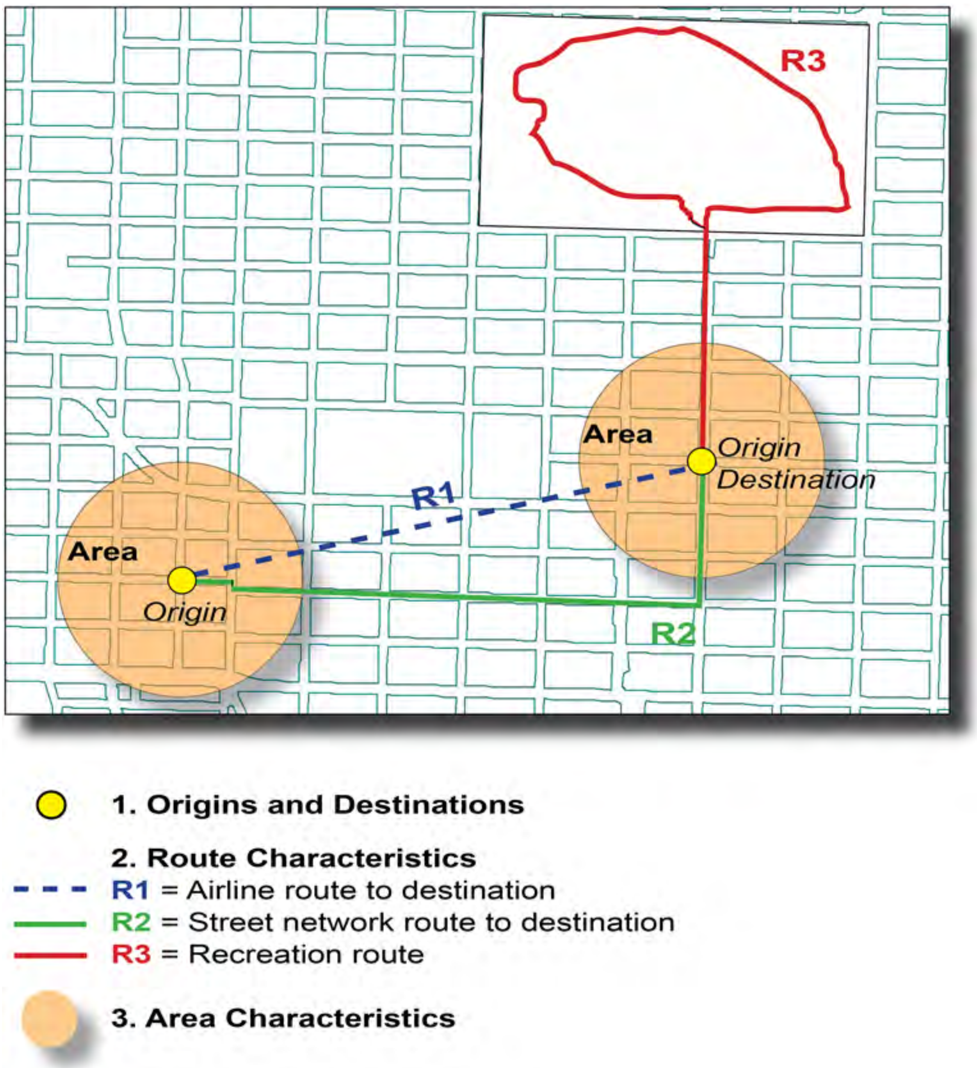
> "The general thesis of ecological models of behaviour is that environments restrict the range of behaviour by promoting and sometimes demanding certain actions and by discouraging or prohibiting other behaviours. This thesis implies that environmental and policy variables can add explanatory value above that provided by intrapersonal and interpersonal factors. No ecological model, however, goes as far as to claim that environmental variables are the only influences on behaviour."[135]

The models, which will be referred to as behavioural models of environment in this project, were developed in response to the fact that many traditional models of human behaviour have focused solely on the effects of interpersonal and intrapersonal factors on physical activity. Intrapersonal factors include "psychological and biological variables, as well as developmental history"[136] and interpersonal factors include the effects of "primary social groups, including family, friends, and coworkers."[137]

By focusing primarily on these intrapersonal and interpersonal influences on physical activity, however, these traditional models have not addressed environmental factors that may also influence physical activity. Behavioural models of environment attempt to rectify this by aiming to identify the "role for environmental influences, most often in terms of 'barriers', 'facilitating conditions', or 'contextual influences'…[in order] to provide an integrated account of the complex patterns of possible determinants."[138] These types of models recognize that human behaviour is influenced by a complex interaction between environmental, personal and behavioural factors, and that the relative influence of each of these factors varies for different activities, individuals and circumstances: "The impact of environmental conditions on health can be considered in relation to different criteria of well-being, ranging from physiological and emotional indices to social, spiritual, and

Figure 3-10

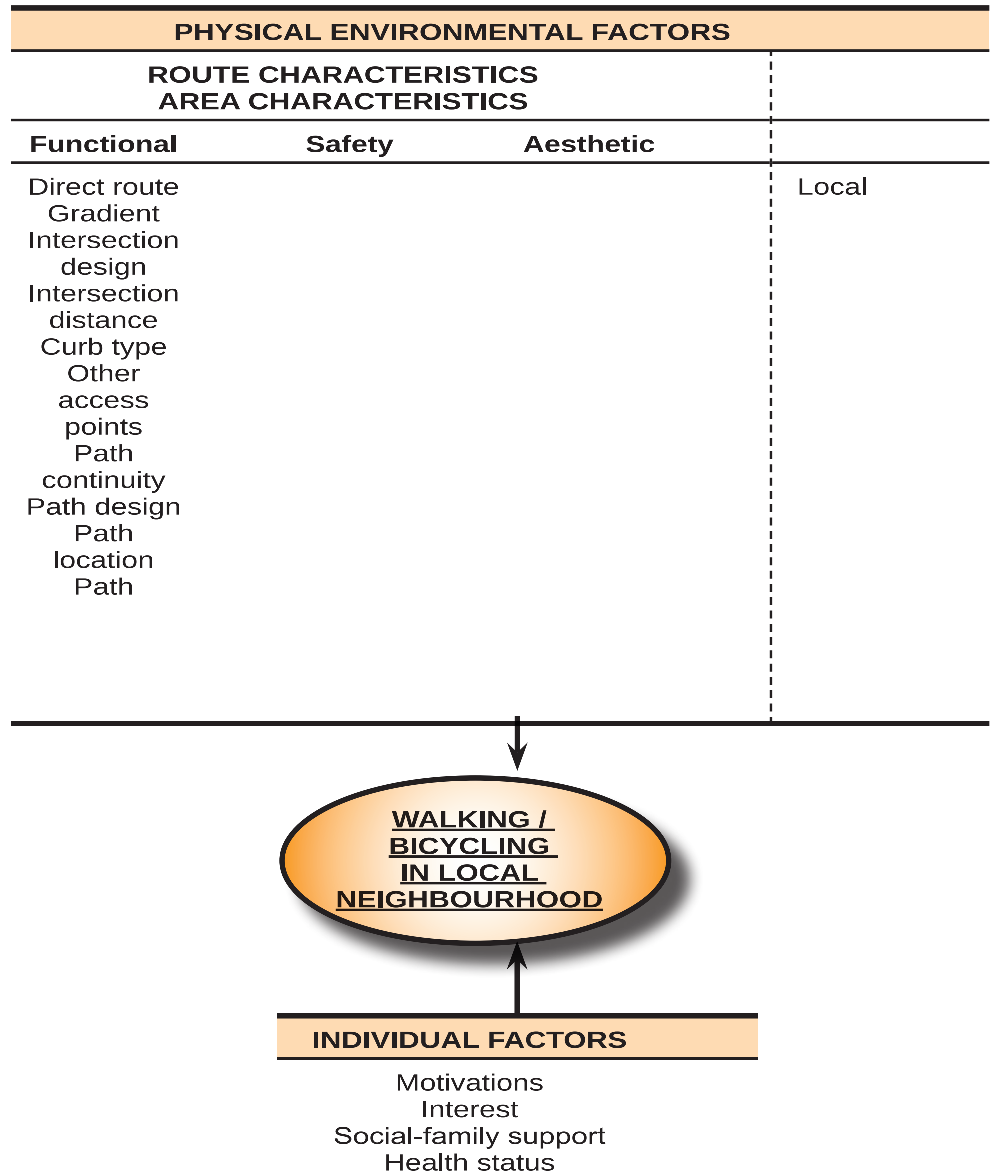
Spatial representation of the three components of the Behavioural Model of Environment.



Source: Adapted from Moudon and Lee, 2003. Page 23.

Figure 3-11

Factors influencing walking or bicycling in local neighbourhood.



Source: Adapted from Pikora et al., 2003. Page 1696 intellectual health outcomes."[139] The model also emphasizes, however, that when related to physical activity, environmental attributes "may be particularly influential."[140] As such, a primary emphasis in this model is placed on the effects of the physical environment on physical activity patterns, and a central goal of the model is to highlight how "physical activity can be promoted or encouraged within some environments, while made more difficult or restricted in others."[141] The model therefore "implies that environmental and policy variables can add explanatory value above that provided by intrapersonal and interpersonal factors."[142]

As specified by Moudon and Lee, the behavioural model is composed of three entities: spatiophysical, spatiobehavioural and spatiopsychological entities. Spatiophysical refers to human environments that are shaped by social systems. Spatiobehavioural refers to the type and intensity of human uses in the physical environment (as measured by volumes of pedestrians or cyclists and safety issues resulting from confl icts among users). Finally, spatiopsychological refers to people's "internal response to being in a physical environment, such as perceived comfort, attractiveness, safety."[143] With these three entities in mind, the model consists of three components of the environment: origins and destinations, route characteristics, and area characteristics, as shown in **Figure 3-10**.

Origins and Destinations

The first component of the behavioural model refers to the trip purpose and is concerned with the origin and destination of the pedestrian or bicycle trip. This component is concerned with where people walk and bike to and from. This component is considered to consist of both spatiophysical and spatiobehavioural entities. This first component of the behavioural model of environment is generally represented spatially using points for the origins and destinations. It is also noted that "walk and bike trips can be either recreation/exercise- or transportation-related."[144] In other words, walking and bicycling can be seen either as having a recreational purpose or a utilitarian purpose within this model. As discussed briefly above, when viewed as having a utilitarian purpose, walking and bicycling are viewed as being a derived demand, in which "individuals travel to consume goods or participate in activities at the destination. By understanding the demand for activities that require travel, one can understand the demand for travel."[145] Within the derived demand framework, Pikora et al. define this portion of the model as the destination (see **Figure 3-11**), which relates "to the availability of community and commercial facilities in neighbourhoods. Where there are appropriate local destinations, there is an increased chance that people will walk."[146] Handy et al. argue, however, that the derived demand framework was designed primarily to model travel behaviour for motorized forms of transportation, and might be inappropriate to accurately measure pedestrian and bicycling behaviour.[147]

Route Characteristics

The second component of the behavioural model consists of the characteristics of the route taken for these walk and bike trips, and includes "spatiophysical aspects, such as distance between origin and destination or the design of the roadway, and spatiobehavioural aspects, such as the number of cars, bicycles or people on the roadway."[148] In short, this component is concerned with the quality of the route with regards to issues of safety, comfort, experience, and perception of pedestrians and bicyclists. This second component of the model is spatially represented using lines that correspond to the route segment or network between the origin and destination. Pikora et al. indicate that there are 3 features that can influence the characteristics of the route: functional, safety, and aesthetic features (see **Figure 3-11**). The functional features relate to the "physical attributes of the street and path that reflect the fundamental structural aspects of the local environment."[149] These features include such things as the specific attributes of the path, the width of the street, and the connectivity of the street network. The safety features reflect the need for there to be (real or perceived) safe environments in order for people to walk or bicycle along that network.

Pikora et al. differentiate between two types of safety: "personal (such as presence of lighting and level of passive surveillance) and traffic (such as the availability of crossings)."[150] The aesthetic features are generally associated with the urban design characteristics of the route. Aesthetic features can include, for example, "the presence, condition and size of trees; the presence of parks and private gardens; the level of pollution; and the diversity and interest of natural sights and architectural designs within the neighbourhood."[151] For example, Rapoport[152] argues that in order to create environments that encourage pedestrian activity, design features should be relatively complex by having appropriate levels of noticeable differences in the pedestrian environment. This serves to maintain "the pedestrian's visual and sensory attention."[153] Aesthetic, or urban design, features are generally regarded as somewhat intangible, and, as such, they are often described and not measured directly.[154] Generally speaking:

> "factors that contribute to aesthetic qualities include, for example, the design of buildings, including the size and orientation of windows, the location of the door relative to the street, decoration, and ornamentation; landscaping, particularly trees and the shade they provide; and the availability of public amenities such as benches and lighting. Places with desirable aesthetic qualities are often said to have a strong 'sense of place,' a clear identity."[155]

Area Characteristics

The third component of the behavioural model refers to the characteristics of the area or neighbourhood in which the pedestrian or bicycle trip takes place. This component includes spatiophysical aspects, such as "the types and the intensity of uses of land (as proxies for activities that take place and their intensity) and the networks of streets (as proxies for choice in moving through space)."[156] This component of the model is represented spatially using polygons to identify the area or neighbourhood in question. As with the route characteristics discussed above, area characteristics also draw upon the functional, safety, and aesthetic features outlined in **Figure 3-11**, but at a more macro-scale of analysis.

This component of the model is strongly associated with density and intensity of development. As discussed earlier, this is important because higher densities have the effect of reducing distances and increasing the likelihood of walking or bicycling. Density is a primary measure of the area characteristics component of the model because it is "perhaps the easiest characteristic of the built environment to measure and thus (is) widely used."[157] As already mentioned, density can be measured in many ways. For example, it can be measured in terms of population, employment, or building square footage over a unit of area. However, this concept of density can be limited with respect to evaluating the effects of the physical environment on travel behaviour. Frank et al. indicate that instead

> "the ideal measure of density would be one that closely tracks the concentration of trip ends and yet forms a part of the built environment itself. One such measure might be the density of possible destinations that a person could travel from and to—businesses, post offices, parks, houses, apartments, and so on."[158]

While much more difficult to measure, this concept of density – based not on structures or populations, but on destinations – may provide a more accurate indicator of pedestrian or bicycling activity. A further problem with the concept of density is that there is little consensus as to what constitutes the differences between high, medium, and low density. The area characteristics are also associated with the mix of land uses within the area or neighbourhood in question. Mixed-use development is important to consider because

> "the mixing of uses decreases distances between destinations, while separating uses increases those distances. As distance is an important barrier to nonmotorized travel, mixing uses is believed to be an important strategy for increasing travel on foot or by bicycle."[159]

One of the major difficulties with this concept is due to the fact that measures of land use mix are not standardized, and there is little consensus regarding the scale at which land use mix should be defined. Land use mix can be measured at the geographic scale of the individual building, parcel, neighbourhood, census tract and can even be measured at the regional scale. Despite these different scales, the most common and most suitable scale of land use mix to examine pedestrian and bicycling activity is at the neighbourhood level: "mixing uses at this level might, so the argument goes, shift some travel that would otherwise be to destinations outside of one's neighbourhood (say, from home to a shopping mall or grocery store) to those that are within neighbourhood boundaries."[160]

In sum, the behavioural model of environment uses three spatial measures of the environment: lines, which correspond to the routes chosen to walk or bike, and points and polygons, which "correspond to the characteristics of the environment at and around the origins and destinations of trips."[161] The behavioural model requires that all three of these components be comprehensively considered in order to measure the effect of the environment on pedestrian and bicycling activity. The behavioural model of environments provides a useful theoretical framework to conceptualize and measure the relationships between the built environment and pedestrian and bicycling activity in a given area.

Scale of Analysis

One of the major challenges of applying the behavioural model of environment to walking or bicycling environments relates to the geographic scale that is used for data collection. This challenge has been referred to above, primarily with regards to measures of density and land use mix. The challenge arises because "capturing the environment with sufficient level of detail is essential."[162] This is difficult because people move through the environment at different speeds depending on the mode of transportation and this, in turn, affects people's perceptions of the environment. As Rapoport argues: "what is important is the rate of information, or, the number of noticeable differences per unit time. Thus, speed plays an important role in the perception of noticeable differences and hence of complexity. It can, therefore, be asserted that pedestrians and motorists differ greatly in the way they perceive urban environments."[163] As such, it is important to clearly identify the purpose of the study to so as to have an appropriate scale of analysis. When studying the relationship between the built environment and walking and bicycling behaviour, the scales of environments considered "range from the immediate surrounds of the pedestrian(s) or the bicyclist(s) to the larger areas that they experience."[164]

Moudon and Lee propose that there are two aspects of scale that are of relevance for obtaining data to examine the relationship between the built environment and physical activity. The first factor is the resolution of the data, which refers to the "relative precision in the measurement of environmental factors. These measurements vary according to the ratio of map distance to earth distance used in the investigation."[165] When examining environments that are experienced at relatively slow speeds, such as those experienced by pedestrians and bicyclists, the data resolution should be fine-grained to include such factors, for example, as the number and positioning of trees along the route and the condition of the buildings along the route. This level of analysis should allow for the inclusion of all the micro-scale elements that are thought to encourage or inhibit pedestrian and bicycling activity along the route. The difficulty with this factor arises because "a general lack of empirical knowledge on how fine the grain of such data needs to be has lead researchers to select the level of data resolution based on budget limitations and data availability."[166]

The second factor regarding scale of analysis is the extent of the area that is being considered. The area of the analysis should include, at minimum, the length of the walking or bicycling trips taken. Generally speaking, an average pedestrian trip is around 1 kilometre in distance or less, and bicycle trips generally range from 2-6 kilometres.[167] This relatively small geographic area requires the use of "spatial units of analysis that are smaller than those typically used in past car-oriented transportation and health research.[168] Therefore, to effectively study the effect of the built environment on pedestrian and bicycling activity, the analysis needs to be done at a fine-grained resolution and over a relatively small area. To address these challenges, "researchers have thus far taken one of two approaches: (1) using existing travel data and making do with data on the built environment available for the entire metropolitan area, or (2) conducting original travel surveys in selected neighbourhoods and building detailed data sets on the built environment for those neighbourhoods."[169]

SUMMARY

This chapter has argued that physical inactivity is a significant cause of overweight and obesity, and that the way communities are designed has a significant influence on the amount of physical activity people engage in. This chapter presented findings of numerous empirical studies which have shown such a relationship does in fact exist – although the question remains as to whether this relationship is simply a matter of correlation or if there is a causal relationship. Drawing on the findings of these studies, and working within the theoretical framework presented in the behavioural model of environment, the subsequent chapters in this project will outline the methodology that was used to examine this relationship in the Southwestern British Columbia and will present the results and implications of this analysis.

CHAPTER FOUR
Methods

The project study area included the Metro Vancouver region (including the lower Fraser Valley municipalities of Abbotsford, Chilliwack, and Mission) and the Capital Regional District. We employed a cross-sectional approach to analyze the association between socio-demographic factors, objectively measured urban form characteristics, and self-reported BMI and physical activity patterns. The study employed parcel-level land use data, transportation network data, and census demographic data, as well as physical activity and BMI outcomes from the Physical Activity Monitor survey, administered by the Canadian Fitness and Lifestyle Research Institute (CFLRI). The land use and transportation network Geographic Information System (GIS) data was used to develop and compute objective measures of residential density, land use mix, intersection density, and for retail development, the building to land ratio across the regions. Records for the physical activity and BMI status of respondents were integrated into the GIS according to self-reported postal code, so that each record in the CLFRI dataset could be spatially linked with urban form measures of each participants' residential neighbourhood. A 1 km street network buffer (outlining the area which could be reached by walking 1 km along a street network) was created from the center of the postal code in which each participant resided.

Floor space, land area, and numbers of parcels for 23 different land uses were calculated within a 1 kilometer area around each respondent's place of residence. In addition, the total number of intersections was calculated within each buffer. Urban form measures and a walkability index derived of these measures were constructed. Partial correlations, linear and logistic regression modeling was conducted to examine the statistical relationship between obesity and physical activity patterns and urban form characteristics, while controlling for demographic variables. This chapter first provides an overview of the data sources and will outline the attributes of each dataset. It then details the methods that were used to analyze this data, and concludes with a discussion of some limitations of the methods used for this project and suggestions for future research.

DATA SOURCES AND ATTRIBUTES

Three primary types of data were used for this project: regional parcel level land use data, regional transportation network data, and random sample physical activity data. The sources of this data, as well as the attributes of each of these datasets, are provided below.

Land use and transportation network data

The land use and transportation network data used for this project were developed for use in the Border Air Quality Study projects at the University of British Columbia and the University of Victoria, with funds provided by Health Canada via the British Columbia Centre for Disease Control. Data were obtained through academic data sharing agreements. In particular, the following land use and transportation network data were used:

- **CanMap Streetfiles (2001).** This dataset produced by DMTI Spatial provides detailed topographic and geographic features, including roads and land use, for all major Canadian urban areas.
- **Digital Road Atlas (2004).** This dataset was provided by the Base Mapping and Geomatic Services Branch of the Government of British Columbia Ministry of Sustainable Resource Management. Inputs to this dataset include roads data from Terrain Resource Information Mapping (TRIM), GIS Innovations, Elections BC, and the British Columbia Ministry of Transportation, and resource roads from the British Columbia Ministry of Forests. The Digital Road Atlas serves as a single source of all provincial roads data, where transportation or geographic position is the primary focus.

• **Multiple Enhanced Postal Code Data File (MEP) (2001).** This dataset produced by DMTI Spatial includes dwelling unit counts, population counts, links to Statistics Canada's demographic boundaries. Longitude and latitude coordinates of the centroid of each postal code boundary were developed using Statistics Canada file PCCF-4D, postal code conversion file version 4D.

• **Metro Vancouver Land Use.** This dataset was created by Metro Vancouver and contains 16 different land use classifications.

• **Spatial Cadastral Data (2004/05).** Spatial property data were provided by each municipality within the study area, with the exception of the Village of Anmore, the Village of Belcarra, and the University Endowment Lands, for which spatial data were not available in a usable format. GIS formats and parcel identifiers were standardized for the projects.

• **Standard Assessment Data Elements (2004/2005).** This dataset was provided by BC Assessment and includes a set of attributes:

- Assessment area;
- Jurisdiction;
- Roll number;
- School district;
- Street number;
- Apartment number;
- Street direction;
- Street name;
- Manual class code;
- Neighbourhood code;
- Electoral area;
- Actual use code;
- Property class;
- Land actual value;
- Improvement actual value;
- Total actual value;
- Lot dimensions;
- Land title document number;
- Land title PID number;
- Legal description;
- Equity code;
- Mailing address; and
- Mailing address postal code
- Residential square footage
- Residential units
- Commercial square footage
- Commercial units.

The assessment data were joined to the spatial cadastral data using unique parcel identifiers by project members.

BMI and Physical activity data

The BMI and physical activity data used for this project was collected and provided by CFLRI, a Canadian not-for-profit national research institute that advises, educates, and informs government, public health professionals, and the public about the importance of leading healthy, active lifestyles. The institute has been collecting nationwide physical activity data on an ongoing basis since 1995 through the Physical Activity Benchmarks/ Monitoring Program. The data that was used for this project was collected between 2003 and early 2005 as part of a nationwide survey of Canadian adults aged 15 and over. Participants were recruited through random digit dialing, with a 51% response rate. In total, the administration of this survey in the Metro Vancouver and Greater Victoria regions yielded 707 valid records, 696 of which had land use and transportation network data. Information regarding four demographic variables was collected from participants and categorized as follows:

• Age (15-17; 18-24; 25-44; 45-64; or 65-99 years of age);

• Gender;

• Total annual household income (under $20,000; $20,000-$39,999; $40,000-$69,000; ≥$70,000)

• Educational attainment (high school or less; some post-secondary; or completed university).

Body mass index data was based on self-reported height and weight values, where BMI (in kg/m^2) = weight (in kg) / (height (in m))^2. The continuous BMI measure was also categorized as: acceptable weight (BMI <25 kg/m^2), overweight (25 ≤ BMI <30) and obese (BMI ≥30). Physical activity data was obtained using a version of the International Physical Activity Questionnaire (IPAQ). The IPAQ is a set of surveys that were developed by an group of physical activity assessment experts in order to provide a uniform and systematic way to obtain internationally comparable estimates of self-reported physical activity levels. IPAQ assesses physical activity patterns across a comprehensive set of domains, including leisure time, domestic and gardening activities, work-related activities, and transport-related activities. There are two versions of the IPAQ: a short version designed for use in national and regional surveillance systems, and a long version which provides a comprehensive evaluation of daily physical activity habits. Both the short and long versions can be administered either by telephone or by self-administered methods. In 2000, the IPAQ was subject to extensive reliability and validity testing across 12 countries. The final results of this testing suggest that IPAQ has acceptable measurement properties for use in many settings and in different languages, and is suitable for national population-based prevalence studies of participation in physical activity. The survey data used here was obtained using the August 2002 version of the IPAQ Short Last Seven Days Telephone Format (see **Appendix A** for a sample copy of this research instrument). This brief 7-question survey asked participants to indicate the amount of time in which time they engaged in vigorous physical activity, moderate physical activity, walking, and sitting in the 7-day period prior to administration of the survey. In particular, these four physical activity categories were defined to participants as follows:

- *Vigorous physical activity.* This was defined as involving hard physical effort that resulted in breathing harder than normal. Examples provided to participants included heavy lifting, digging, aerobics, and fast bicycling.
- *Moderate physical activity.* This was defined as resulting in breathing that was somewhat harder than normal. Examples given included carrying light loads, bicycling at a regular pace, or playing doubles tennis. This category excluded walking.
- *Walking.* This was defined to include any walking done at work, at home, traveling from place to place, or any other walking that was undertaken for recreation, sport, exercise or leisure.
- *Sitting.* This was defined as the amount of time participants spent sitting only on weekdays during the previous 7 day period.

Participants were asked both the frequency of physical activity (number of days in which they had engaged in at least 10 minutes of vigorous physical activity, moderate physical activity or walking over the previous 7 days) and the duration of physical activity (amount of time that participants usually spent each day engaging in each of the four activities during the previous 7 day period). Because previous studies had shown a significant relationship between moderate physical activity and urban form, this analysis focused primarily on questions relating to walking and moderate physical activity. Based on the recommended guidelines for data cleaning and data analysis of IPAQ questionnaires, certain outliers with unreasonably high or low responses were assigned truncated scores (see **Appendix B** for the most recently published version of these guidelines). In particular, these guidelines suggest that certain data be truncated, or re-coded, in order to normalize the distribution of levels of activity, which are usually skewed in large population data sets. The most recently published version of the IPAQ guidelines recommends that all walking, moderate and vigorous time variables exceeding 4 hours, or 240 minutes, per day are truncated to be equal to 240 minutes in a new variable. However, a more recent, and as of yet unpublished, version of these guidelines instead recommends that all walking, moderate and vigorous time variables exceeding 3 hours, or 180 minutes, per day are truncated to be equal to 180 minutes in a new variable, thereby permitting a maximum of 21 hours of activity to be reported per week for each category of physical activity. This analysis used the most recent recommendation of a maximum truncated score of 180 minutes per day for each type of physical activity. In addition, as recommended by the IPAQ scoring guidelines, this analysis only included responses where participants engaged in 10 or more minutes of physical activity per day. Where participants only engaged in 1-9 minutes of a certain type of physical activity per day, that score was re-coded to zero. The rationale for this reclassification is based on scientific evidence that indicates that episodes or bouts of at least 10 minutes are required to achieve health benefits.

Environmental perception variables

For a subset of participants (n=344) CFLRI also collected data on their perceptions about attributes of their residential neighborhood. The following 8 perception domains were modified from the Neighborhood Environment Walkability Scale (NEWS) [1, 2]:

1. What is the main type of housing in your neighborhood?
2. Many shops, stores, markets or other places to buy things I need are within easy walking distance of my home.
3. It is within a 10-15 minute walk to a transit stop (such as bus, train, trolley, tram) from my home.
4. There are sidewalks on most of the streets in my neighborhood.
5. There are facilities to bicycle in or near my neighborhood, such as special lanes, separate paths or trails, or shared use paths for cycles and pedestrians.
6. My neighborhood has several free or low cost recreation facilities, such as parks, walking trails, bike paths, recreation centers, playgrounds, public swimming pools, etc.
7. The crime rate in my neighborhood makes it unsafe to go on walks at night.
8. There is so much traffic on the streets that it makes it difficult or unpleasant to walk in my neighborhood.

Response categories for the first question were: detached single family residence; town/row houses, apartments or condos; mix single-family town/row houses, apartments or condos; apartments/condos, 4-12 stories; apartments/condos more than 12 stories. Response categories for the remaining questions were: strong disagree; somewhat disagree; somewhat agree; somewhat disagree. For analytic purposes, the responses to questions 2-8 were aggregated into dichotomous disagree/agree categories. "Refused" or "don't know" responses were considered invalid.

Census variables

This study also employed demographic variables at the geographic scale of the buffer, derived from 2001 Canadian Census data. Detailed 2001 data for Census Dissemination Areas was spatially integrated with street network buffers. The following variables were considered as potential influences on obesity and physical activity:

Demographic	Measure
Age	Average age
	% of population under 20 years old
	% of population over 65 years old
Sex	% of population that is female
Education	% of population with university degree
Income	quintiles of household income in the region*
	% of families deemed low income
Citizenship/Race	% of population that is of visible minority
Family and Dwellings	% of dwellings that are single family occupancy

*Note that because of challenges with the aggregation process for census income variables, a quintiled household income variable provided by the Border Air Quality Study was used in analyses. This variable was derived from the 2001 census summary data, but associated with a postal code, not the buffer zone.

DATA ANALYSIS

Scale of analysis

Each postal code in the Metro Vancouver and Greater Victoria regions was buffered by a 1 kilometer street network area, as described above. A study of the relationship between BMI and physical activity patterns with urban form characteristics requires a scale of analysis that is sufficiently small to capture the actual environments in which people live and that impact their daily routines. Previous research suggests that this scale varies but that a 1 kilometer distance is about the best overall scale (Lee, 2006; Moudon and Lee; 2006). The spatial linkage in this project was performed using Canadian postal code data at the scale of Forward Sortation Areas and Letter Carrier Walks. The Canadian postal code is a six-character, uniformly structured alphanumeric code in the form "A2A 2A2" that is attached to every postal address in Canada. It is made up of two segments: the Forward Sortation Area (FSA) and the Local Delivery Unit (LDU). The FSA refers to the first three characters of the postal code and identifies a major geographic area in an urban or rural location. The first character of the FSA refers to the broadest level of geography, and identifies 18 major regions throughout Canada. For example, British Columbia is considered one of these major regions and, as such, the first character of every postal code in British Columbia is "V". The second character of the FSA identifies whether the postal code is in an urban or rural area, as urban postal codes contain figures between 1-9, whereas rural postal codes are indicated by 0. The LDU refers to the last three characters of the postal code and identifies the smallest mail delivery unit within an FSA. In urban areas, these last three characters may indicate a specific city block (one side of a street between two intersecting city streets), a single building or, in some cases, a large volume mail receiver. The 6-digit postal code self-reported postal code provided an approximation of the participants' residential location. The DMTI MEP data was used to identify the precise x and y coordinates of the centre of each discrete postal code that was included in the physical activity dataset.

A 1 km street network buffer (as opposed to crow-fly buffer) was then created around the centroid for each postal code. Crow-fly buffers, which are circular in shape, are based on the straight-line, direct distance from the centroid postal code, but do not present an indication of the land uses within a 1 walking distance from the centroid of a postal code. In contrast, a 1 km street network buffer has an irregular shape and displays the area that can be accessed using the actual street network within 1 km from a given centroid. Objective measures of urban form were then developed for the area within each 1 km street network buffer. This provided a scale of analysis that was useful because it accounted for the detailed, micro-environments in which people lived while providing an assessment of the different urban form characteristics that exist within reasonable walking or bicycling distances of an individual's approximate residential location.

Objectively measuring urban form

Chapter three presented the findings of several empirical studies that have shown that there are three urban form characteristics that have consistently been found to have a significant relationship with physical activity patterns: land use mix, residential density, and intersection density. This project included a fourth potential urban form characteristic that is hypothesized to influence physical activity patterns: the ratio of land area to building area in retail development. These measures were operationalized based largely on the methods that were used two similar studies recently conducted in the Atlanta, Georgia region. Before these measures could be calculated, it was necessary to define the use classifications that would be used for this project.

Land use classifications were developed from the Actual Use Code data included in the dataset provided by BC Assessment. Actual Use Codes are three digit numbers that are used to reflect primary use of each property. In total, there were 203 distinct Actual Use Codes, which were reclassified into the following 23 land use classifications (see Appendix C for the Actual Use Codes from which these classifications were derived):

- Agriculture;
- Civic;
- Convenience stores;
- Entertainment;
- Fast food;
- Groceries;
- Industrial;
- Large retail;
- Very large retail;
- Multi-family;
- Small neighbourhood retail;
- Large neighbourhood retail;
- Office;
- Office building;
- Other;
- Parking;
- Recreational;
- Restaurant;
- Retail/multi-family;
- Retail/office;
- Single family;
- Transport-utility;
- Unknown;
- Vacant; and
- No data.

The objective urban form measures of residential density, intersection density, land use mix, and the ratio of retail floor area were operationalized as follows:

- **Residential density:** this was defined as the number of residential units per residential acre within each 1 km street network buffer. This is a **net** measure of density as opposed to a **gross** measure, as the denominator is the total land area with residential use. The net measure is chosen as a more accurate indicator of the relevant density in a given area, because it does not include non-residential land area. Housing unit counts were derived from the census data, and building units were spatially located according to the parcel data. Locating the building within a parcel improves the accuracy of the measure where a parcel intersects the boundary of the network buffer (i.e., one can determine whether the building lies in or out of the buffer). This measure was operationalized by summing the total number of residential households in the buffer and the total acres of residential land base in each buffer. A simple ratio was then used: NRD = h/a where: NRD is the net residential density per acre; h is the number of households in the buffer area, and a is the residential land area in acres (calculated as the total area associated with the centroids of the housing unit). Residential density was expected to exhibit an inverse relationship with BMI, and a positive relationship with physical activity.
- **Intersection density:** this was defined as the density of intersections within each buffer. This required a simple count of the number of intersections in each buffer using DMTI Spatial street network data, and a calculation of the area of each buffer. The following formula was then used: ID = i /a where: ID is intersection density; i is the number of intersections; and a is the area of the buffer in km^2. In general, the higher the number of intersections, the better the intersection density. As such, intersection density was expected to exhibit a and inverse relationship with BMI and a positive relationship with physical activity.
- **Land use mix:** land use mix variable is a measure of the evenness of distribution of the area of various land uses within each buffer. These index is based on land use classifications which were deemed to contribute to walkability and were reclassified into 5 categories: a) single family residential; b) multi-family residential; c) entertainment (comprised of entertainment, restaurant, and fast food land uses); d) retail (comprised of small and large neighborhood retail, large retail, grocery and convenience store land uses, and excepting super large retail); and e) office buildings (comprised of office and office building land uses). In the land use mix term with 4 categories (LUM (4 categories)), single family and multi-family land uses were combined into one measure of residential building area. The other land use classifications, including agricultural, institutional, and

parking were excluded from the reclassification as they were not considered to encompass walkable areas. Both of the land use mix indices (LUM (5 categories) and LUM (4 categories)) were based on total **building floor area** for each of these land use categories, and was calculated for each buffer zone according to:

LUM (5 categories) =[(area (a)/total area)* ln (area (a)/ total area)*
(area (b)/ total area)* ln (area (b)/total area)*
(area (c)/ total area)* ln (area (c)/ total area)*
(area (d)/ total area)* ln (area (d)/total area)*
(area (e)/ total area)* ln (area (e)/ total area)] / ln (5);

LUM (4 categories) =[(area (a+b)/total area)* ln (area (a+b)/ total area)*
(area (c)/ total area)* ln (area (c)/total area)*
(area (d)/ total area)* ln (area (d)/ total area)*
(area (e)/ total area)* ln (area (e)/total area)] / ln (4);

Where area is the building floor area for the buffer in ft^2, a=single family residential, b= multi-family residential, c= entertainment, d=retail, and e=office, and total area is the sum of all of a-e. The scores ranged from a low of 0 (indicating exclusively single use development) to a high of 1 (indicating the most evenly mixed environments). However, although this index for land use mix indicated the evenness of distribution of various land uses, it did not indicate how much of each specific land use was present in a given area. For example, the same score could indicate that a given area was home to no residential land uses and an even mix of civic and commercial land uses (a less walkable environment) but could also describe an area with no civic land uses and an even mix of residential and commercial land uses (a more walkable environment). In general, though, it was hypothesized that the more even the distribution of land uses, the more walkable the environment. As such, the land use mix score was expected to exhibit an inverse association with BMI, and a positive association with physical activity levels.

- **Ratio of retail floor area:** this represents the proportion of the retail parcel area in the buffer which is occupied by retail buildings. This measure was operationalized by summing the **building floor area** for all retail uses within the buffer, as well as the total **parcel area** for retail uses. In this case, retail use includes grocery stores, small and large neighbourhood retail as well as large retail, but not the super large retail areas. This variable is the ratio of: rfa = rba/ ra where: rfa is the ratio of retail floor area, rba= total building area for retail in ft^2, and ra is the retail land area, also in ft^2. Rfa is a ratio and has no units.

Using a GIS, each of these three urban form measures were calculated within each 1 km street network buffer from the centroid of the postal code of each survey participant throughout the Greater Vancouver and Greater Victoria regions.

Creating a walkability index

Since measures of the measures of urban form (residential density, intersection density, land use mix, and the ratio of retail floor area) are often correlated, a walkability index was established to integrate these variables. A normalized distribution (z-score) was taken for the value of each urban form variable within a buffer, and the four normalized scores were then combined to create an overall walkability index for each buffer. The walkability index was created using the following formula:

$$WI_x = \text{z-score}(NRD_x) + 2*\text{z-score}(ID_x) + \text{z-score}(LUM_x) + \text{z-score}(RFA_x)$$

Where: WI_x is the walkability index, NRD_x is residential density, the ID_x is intersection density, LUM_x is land use mix, and RFA_x the ratio of retail floor area for the buffer zone x.

For examples of other studies using similar walkability indices, please see the Neighborhood Quality of Life Study (www. nqls.org), or other published studies (Frank 2006, Frank 2005 (SMARTRAQ paper). In the current work, four separate walkability indices were developed, to evaluate which was the strongest correlate with health outcomes. The first (walk_index_mix4) used the LUM (4 categories) variable for the land use mix measure. The second (walk_index_mix4_cap) used the same land use mix measure, and also capped the allowed values for each z-score at the mean score +/- 5 SD, excluding buffers with values outside of this range. Likewise, the other two indices (walk_index_mix5 and walk_index_mix5_cap) are the analogous measures using the LUM (5 categories) variable for the mixed land use measure. All of these walkability indices are highly correlated with each other (Pearson correlation coefficients >0.977). In the UBC walkability study, the decision was made to use the walk_index_mix5_cap index.

Descriptive statistics

Descriptive statistics were calculated to summarize each of the urban form variables within each participants' 1 km buffer in the Metro Vancouver and Greater Victoria regions. For each of these variables, the mean score (or percent) if applicable, the median score, standard deviation, and range of scores were calculated. Descriptive statistics were also calculated for the BMI, physical activity patterns and demographic characteristics of participants. In particular, the mean (or percent) and, if applicable, the median score, standard deviation, and range of scores were calculated for BMI, for the number of days per week, the number average minutes per day, and the total number of minutes that participants walked, engaged in moderate physical activity, or a combination of these forms of activity. In addition, in order to examine variations in physical activity patterns, mean scores were calculated and compared for sub areas within the Metro Vancouver and Greater Victoria regions.

Inferential statistics

The BMI and physical activity data was then spatially integrated into the GIS database to link this data with the land use and transportation network data. This allowed for a spatial analysis to be conducted regarding the relationship between each of the urban form measures and the physical activity levels obtained from the CFLRI survey. Inferential statistical analyses were used in order to reveal relationships among variables and to make inferences about populations. The analysis involved partial correlations and multiple linear and logistic regressions to explore the relationship among dependent BMI and physical activity outcome variables and independent land use variables, while controlling for demographic variables. Not all outcome variables described in this chapter were included in the analysis. For example, because vigorous physical activity has been shown elsewhere to have little relationship with urban form, this analysis excluded detailed analysis on this variable and instead focused on walking and moderate activity. All domain physical activity data was categorized according to the widely accepted guidelines based primarily on leisure-time activity and BMI was classified according to internationally accepted standards. The following outcomes were analyzed as dependent variables:

Health outcomes

- Self reported BMI; and
- Self reported overweight status (BMI ≥ 25).

Physical activity variables

- Total number of minutes spent walking over the previous week;
- Total number of minutes engaged in moderate physical activity over the previous week;
- Total number of minutes engaged in walking or moderate physical activity over the previous week;
- Had sufficient exercise by walking (i.e., at least 150 minutes in the previous week);
- Had sufficient exercise by walking and/or moderate activity.

The independent variables consisted of the urban form and census demographic measures for each buffer area and individual demographic characteristics of the participant. Specifically, the following independent variables were considered:

Urban form variables

- Walkability index;
- Residential area;
- Land use mix;
- Intersection density;
- Ratio of retail floor area;
- Presence of fast food parcels;
- Presence of convenience stores;
- Presence of restaurant parcels;
- Presence of grocery parcels;
- Presence of recreational parcels.

Census variables

- Average age;
- % of population under 20 years old;
- % of population over 65 years old;
- % of population that is female;
- % of population with university degree;
- quintile of household income;
- % of families deemed low income;
- % of population that is visible minority;
- % of dwellings single family occupancy.

Individual variables

- Age;
- Gender;
- Household income;
- Educational level.

Partial correlations and linear regression analyses were conducted for various combinations of these variables to determine which urban form and demographic variables exhibited the strongest relationships with various physical activity patterns.

LIMITATIONS

This study was based on an analysis of secondary data collected by a number of different organizations for a variety purposes and therefore attributes of these datasets present some limitations for the current analysis. This discussion of data limitations is not intended to be critical of the quality of the data that was used, but is instead meant to inform and direct future research on this topic in the Metro Vancouver and Greater Victoria regions. First, there were limitations regarding the physical activity data that was used for this project. Since this physical activity data was obtained from a national population-level study of the prevalence of physical activity with the purpose of revealing national physical activity trends, this data provided a limited amount of detail regarding specific physical activity patterns and demographic characteristics of the study population. Specific limitations of this dataset for this project include the fact that:

- The purpose of the physical activity (i.e.: recreational or utilitarian) was not solicited;
- With the exception of walking, the specific type of physical activity that participants engaged in (such as bicycling, gardening, tennis, or aerobics) was not obtained. Instead, this data only provided information about the intensity of the physical activity that participants engaged in.
- The specific geographic locations of the physical activity were not explicitly obtained, with the result that origins and destinations of any physical activity were not known. As such, this analysis made the assumption that all physical activity originated in participants' areas of residence;
- Detailed, daily physical activity patterns were not obtained. The data only provided a total score for number of days per week and an average score for number of minutes per day that participants engaged in physical activity, but did not reveal any variations in physical activity patterns during the 7-day period;
- BMI calculations were based on self-reported height and weight. Weight is well-known to be under-reported;
- Individual records were not spatially linked to participants' residential addresses, but instead to their residential postal codes;
- It was not feasible to consider residential self-selection bias as no data on attitudinal variable directly related this were collected; and
- The survey relied on self-reported measures of physical activity. Although the methods that were used to collect data were subject to extensive reliability and validity testing, self-reported measures generally have less valid measures of total activity than objective measures of physical activity that can obtained by the use of devices such as accelerometers.

Although the physical activity data was subject to these limitations, this dataset remained useful for several reasons. This dataset was particularly valuable to use because walking was explicitly distinguished from other types of moderate physical activity, which made it possible to analyze walking patterns in particular. It also represented a standardized method that has been used across Canada and internationally, allowing for meaningful national and international data comparison. However, future physical activity or travel behaviour research in the Metro Vancouver and Greater Victoria regions would benefit significantly from addressing these limitations.

Second, there were also limitations with the land use and transportation network data that was used for this project. Several important land use variables were not available in any of these datasets. For example, because this analysis was conducted on a regional scale, micro-scale urban design features – such as the presence and continuity of sidewalks, buffers from the street, building setbacks, adequate street lighting, street benches, sidewalk pavings, or bicycle facilities – were not taken into account. Such micro-scale data was not available on a regional basis and was beyond the scope of this project. Future research would benefit from attempting to capture these and other urban design variables in their analysis to determine the influence of these micro-scale features on physical activity patterns. Future research could potentially address this limitation by comparing physical activity patterns in a small number of neighbourhoods with different land use characteristics. Limiting the data to a small number of neighbourhoods, as opposed to an entire metropolitan region, would increase the feasibility of obtaining such micro-scale data. Also, topography was not explicitly addressed in this study. It is expected that topography would have a significant influence on physical activity patterns, particularly in a region such as Metro Vancouver, and future studies should aim to capture topography.

Despite the limitations noted above, the analysis conducted for this project was of significant value. The current project enabled and examination of the correlation between certain measures of urban form with various degrees of intensity of physical activity, and with obesity. It is the first study of its kind in Canada – and certainly the first with this level of detail about the built environment as related with physical activity and obesity. It therefore lays the groundwork and builds the foundation for future, more detailed research to be conducted on this topic across Canada.

CHAPTER FIVE
Results

This chapter presents the results from analyses on the relationships between aspects of the built environment (land use patterns and transportation network characteristics) with physical activity, and body weight. First, residential location and demographic characteristics of participants are provided with summaries of overall responses to physical activity questions from the physical activity questionnaire conducted by the Canadian Fitness and Lifestyle Research Institute (CFLRI). Descriptive statistics regarding physical activity and obesity patterns and attributes of participants' residential neighbourhoods are provided. These descriptive statistics outline the mean score or percent and, if applicable, the median score, standard deviation, and ranges for each variable. Findings are then presented on the relationship between land use and transportation network characteristics, physical activity, and BMI.

SAMPLE CHARACTERISTICS

There were 707 respondents in the Metro Vancouver and Greater Victoria regions in the Canadian Fitness and Lifestyle Research Institutes (CFLRI) Physical Activity Monitor Survey. Of these, 576 respondents (81% of the sample) lived in the Metro Vancouver region, while 131 respondents (19% of the sample) lived in Greater Victoria. As can be seen from **Figure 5-1**, respondents were spread relatively evenly throughout the Metro Vancouver and Greater Victoria regions; all municipalities for which land use and transportation network data were available were represented in the survey results.

The distribution of survey participation by municipality was broadly representative of each municipality's share of each region's (Vancouver and Victoria's) population. The difference between the proportion of survey participants and the proportion of the overall population in each municipality varied by an average of just 1.4%. The highest number of respondents lived in the City of Vancouver (about 25% of total respondents), followed by Surrey and Burnaby (each with about 9%), and Saanich and Victoria (each with about

Figure 5-1

Residential neighbourhood locations of survey participants.

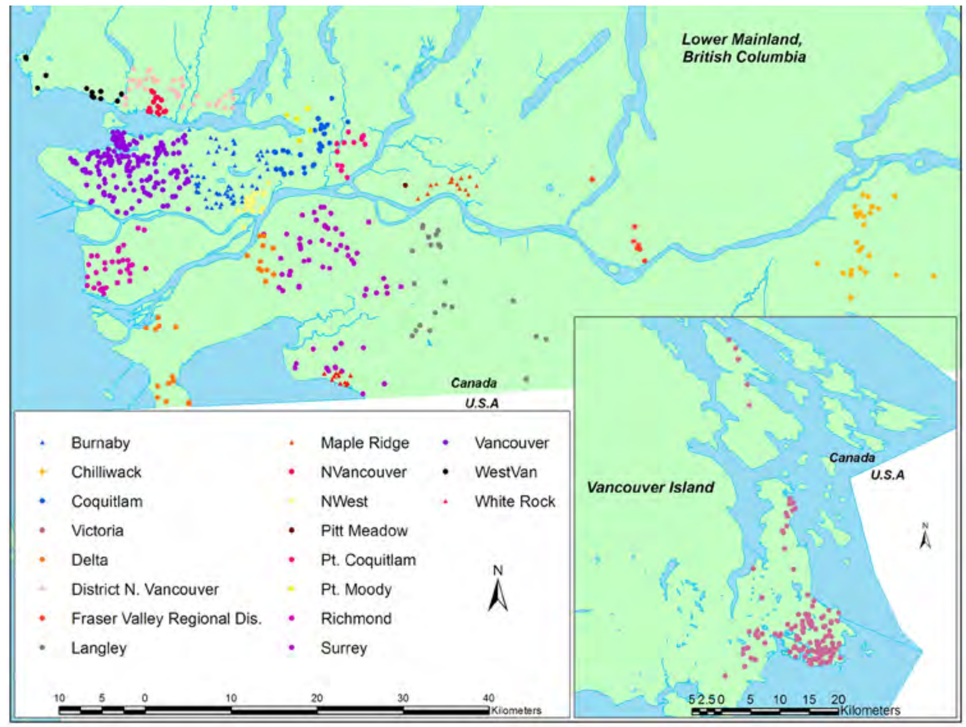


Table 5-1

Survey participation by municipality*.

Greater Vancouver municipalities	Number of survey participants	Proportion of Greater Vancouver survey participants	Proportion of total survey participants
Burnaby	61	10.6%	8.6%
Chilliwack	26	4.5%	3.7%
Coquitlam	28	4.9%	4.0%
Delta	25	4.3%	3.5%
Langley Township	22	3.8%	3.1%
Maple Ridge	14	2.4%	2.0%
Mission	7	1.2%	1.0%
New Westminster	23	4.0%	3.3%
North Vancouver City	18	3.1%	2.5%
North Vancouver District	38	6.6%	5.4%
Pitt Meadows	1	0.2%	0.1%
Port Coquitlam	13	2.3%	1.8%
Port Moody	7	1.2%	1.0%
Richmond	32	5.6%	4.5%
Surrey	62	10.8%	8.8%
Vancouver	176	30.6%	24.9%
West Vancouver	12	2.1%	1.7%
White Rock	11	1.9%	1.6%
Total Greater Vancouver	**576**	**100.0%**	**81.5%**

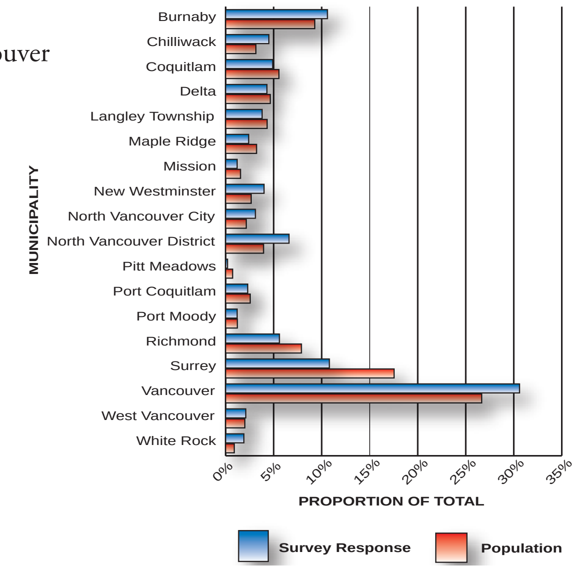
Greater Victoria municipalities	Number of survey participants	Proportion of Greater Victoria survey participants	Proportion of total survey participants
Central Saanich	2	1.5%	0.3%
Colwood	3	2.3%	0.4%
Esquimalt	6	4.6%	0.8%
Highlands	1	0.8%	0.1%
Langford	11	8.4%	1.6%
Metchosin	1	0.8%	0.1%
North Saanich	3	2.3%	0.4%
Oak Bay	8	6.1%	1.1%
Saanich	45	34.4%	6.4%
Sidney	7	5.3%	1.0%
Victoria	41	31.3%	5.8%
View Royal	3	2.3%	0.4%
Total Greater Victoria	**131**	**100.0%**	**18.5%**

* = Figures exclude data from residents residing in Abbotsford, Anmore, Belcarra, Langley City, Sooke, and the University Endowment Lands, as land use and transportation network data was unavailable for these municipalities.

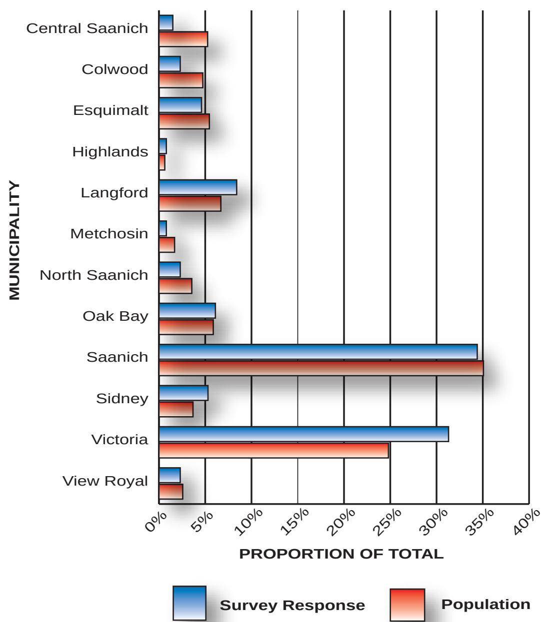
Figure 5-2

Comparison of proportion of population and proportion of survey participants from each municpality*.

a) Metro Vancouver



b) Greater Victoria



* = Figures exclude data from residents residing in Abbotsford, Anmore, Belcarra, Langley City, Sooke, and the University Endowment Lands for which land use and transportation network data was unavailable.

Source: Population statistics adapted from BC Stats, 2004.

6%). In contrast, the municipalities that were least represented in the survey responses were Pitt Meadows, Metchosin and Highlands (each with about 0.1% of respondents).

In a few instances, some of the primary municipalities were oversampled or undersampled relative to their population. Most notably, the City of Victoria was oversampled, with 6.5% more respondents in the survey than its share of Greater Victoria's regional population, while the City of Surrey was the most significantly undersampled, with 6.7% fewer respondents than its share of the Vancouver metro area population. **Table 5-1** provides the breakdown of sample by municipality.

The current study used a sub-sample of 620 (out of the 707 total) participants who provided complete data for the key variables of interest. A walkability surface was developed for this project which provides urban form measures for each postal code in both Metro Vancouver and the Capital Regional District. This database of urban form or walkability measures is actually a "surface" and was initially developed for the Georgia Air Basin (GAB) project. The 620 participants in the current study are described in **Table 5-2** based on their distributions across gender, age, income, and educations levels. A smaller subset of participants also provided responses to questions pertaining to neighborhood perception (n=302). Nearly 57% of respondents were female. Approximately two out of three survey respondents (66.3%) were between 25 and 64 years of age.

About one in five respondents (20.2%) was over 65 years of age, while about 13% of respondents were under 24 years of age. Educational levels were almost evenly split among survey respondents, with over a third of all respondents (36.9%) having completed high school or less; almost a third of respondents (30.5%) having completed some college or post-secondary education; and a third (32.6%) having completed university. Similarly, respondents were evenly distributed among annual household income levels, with about a quarter of respondents in each of the household income categories. The distribution of demographic variables in the subset of participants who were asked perception questions is comparable.

The data revealed that, in general, the population of the Metro Vancouver is relatively active in comparison with other regions. As shown in **Table 5-3**, over half of survey respondents (54.4%) indicated that they walked on each of the 7 days beforehand, and nearly two out every three respondents (67.1%) walked at least of 5 of the previous 7 days. In contrast, less than 10% of respondents indicated that they did not walk at all during the previous seven day period. One quarter of respondents indicated that they walked between 16-30 minutes on an average day during the previous week, while nearly a quarter of respondents (22.7%) indicated that they walked over 90 minutes on a given day during the previous week.

Moderate physical activity patterns are also shown in **Table 5-3**. In contrast to walking, a third of respondents (33.5%) indicated that they did not engage in moderate physical activity on any day during the previous week, while only about one in every five respondents (20.6%) indicated that they engaged in moderate activity at least five of the previous seven days. Only about 16% of respondents engaged in moderate activity for more than 90 minutes on a typical day during the previous week, while 36% of respondents did not engage in any moderate activity on a given day during the previous week.

DESCRIPTIVE STATISTICS

Body mass index (BMI) patterns

Descriptive statistics for the BMI characteristics of the sample population are outlined in **Table 5-4**. BMI was approximately normally distributed, with a mean of 25.3. Nearly half (47%) of respondents can be considered overweight according to BMI (BMI ≥ 25), while 14.5% are obese (BMI ≥ 30).

Physical activity patterns

Descriptive statistics outlining general physical activity patterns of the sample population are outlined in **Table 5-5**. Survey respondents reported that they walked an average of more than 5 days per week, for an average of 62 minutes on a typical day, significantly surpassing the minimum recommended guidelines for physical activity derived primarily from studies of leisure-time physical activity alone. Respondents engaged in moderate physical activity an average of nearly 2.4 days per week for an average of 45 minutes on each of those days. The average time walking was about 371 minutes per week (about 53 minutes per day); the average time engaged in moderate activity for an average of about 163 minutes of per week (about 23 minutes per day). However, the continuous physical activity outcomes are highly skewed, as shown by the high standard deviations and the difference between the means and medians of outcomes.

Table 5-2

General Sample Characteristics

	All participants with complete responses (n=620)		Subset of participants asked perception questions (n=302)	
Gender				
Male	270	43.5	122	40.4
Female	350	56.5	180	59.6
Age				
15-24	84	13.5	36	11.9
25-44	224	36.1	110	36.4
45-64	187	30.2	98	32.5
65-99	125	20.2	58	19.2
Highest Educational Attainment				
High school or less	229	36.9	111	36.8
Some college/post-secondary	189	30.5	89	29.5
Complete university	202	32.6	102	33.8
Total Annual Household Income				
Under $20,000	165	26.6	76	25.2
$20,000-39,999	135	21.8	60	19.9
$40,000-69,999	154	24.8	77	25.5
Over $70,000	166	26.8	89	29.5

Table 5-3

Number of days/week and minutes/day that participants walked or engaged in moderate activity

Number of days walked	Survey participants	
	Number	Percent
0	*57*	*9.2*
1	*19*	*3.1*
2	*42*	*6.8*
3	*48*	*7.7*
4	*38*	*6.1*
5	*51*	*8.2*
6	*28*	*4.5*
7	*337*	*54.4*
Total	*620*	*100.0*

Minutes walked per day	Survey participants	
	Number	Percent
0	*69*	*11.1*
1-15	*53*	*8.5*
16-30	*156*	*25.2*
31-45	*52*	*8.4*
46-60	*120*	*19.4*
61-75	*1*	*0.2*
76-90	*28*	*4.5*
>91	*141*	*22.7*
Total	*620*	*100.0*

Number of days with moderate activity	Survey participants	
	Number	Percent
0	*208*	*33.5*
1	*63*	*10.2*
2	*94*	*15.2*
3	*79*	*12.7*
4	*48*	*7.7*
5	*47*	*7.6*
6	*14*	*2.3*
7	*67*	*10.8*
Total	*620*	*100.0*

Minutes of moderate activity per day	Survey participants	
	Number	Percent
0	*223*	*36.0*
1-15	*45*	*7.3*
16-30	*119*	*19.2*
31-45	*21*	*3.4*
46-60	*90*	*14.5*
61-75	*1*	*0.2*
76-90	*19*	*3.1*
>91	*102*	*16.5*
Total	*620*	*100.0*

Table 5-4

Descriptive BMI statistics (n=620)

	Mean (or %)	Median	Standard Deviation	Range
Self-reported BMI	*25.3*	*24.5*	*4.6*	*16.1-46.1*
Obese (BMI>=30)	*14.5%*	*n/a*	*n/a*	*n/a*
Overweight (BMI>=25)	*46.5%*	*n/a*	*n/a*	*n/a*

Table 5-5 shows that 75% achieved the recommended minimum guidelines derived primarily from studies of leisure-time physical activity alone of over 150 minute per week of physical activity through walking and/or moderate activity during the previous week; 62% met these guidelines only through moderate activity, and 31% met these guidelines through walking alone .

Table 5-5

Descriptive physical activity statistics

	Mean (or %)	Median	Standard Deviation	Range
Walking				
Number of days per week	*5.1*	*7.0*	*2.4*	*0-7*
Number of minutes per day	*62.8*	*45.0*	*57.3*	*0-180*
Number of minutes per week	*370.7*	*210.0*	*386.6*	*0-1260*
Moderate physical activity				
Number of days per week	*2.4*	*2.0*	*2.3*	*0-7*
Number of minutes per day	*44.8*	*30.0*	*56.3*	*0-180*
Number of minutes per week	*162.5*	*60.0*	*259.2*	*0-1260*
Moderate physical activity and/or walking				
Number of minutes per week	*533.3*	*340.0*	*533.4*	*0-2520*
Met goal of 150 minutes per week of physical activity				
Only by moderate activity	*62.3%*	*n/a*	*n/a*	*n/a*
Only by walking	*31.3%*	*n/a*	*n/a*	*n/a*
By moderate activity and/or walking	*75.0%*	*n/a*	*n/a*	*n/a*

BMI varies significantly throughout Metro Vancouver and Greater Victoria. To examine the geographic distribution, we looked at BMI by proximity to the urban core. Municipalities were aggregated in to 4 geographic sub-areas: urban, inner suburban, outer suburban, and rural. These sub-areas were created because sample sizes in several municipalities were too small to allow meaningful comparison at the municipal level.

Urban core municipalities	Inner suburban municipalities	Outer suburban municipalities	Exurban municipalities
Vancouver	Burnaby	Surrey	Central Saanich
Victoria	North Van District	Saanich	Chilliwack
	Richmond	Coquitlam	Highlands
	New Westminster	Delta	Langford
	North Van City	Port Coquitlam	Langley District
	West Vancouver	White Rock	Maple Ridge
	Oak Bay	Port Moody	Metchosin
	Esquimalt	Colwood	North Saanich
		View Royal	Pitt Meadows
			Sidney

Table 5-6

BMI by regional sub-area

	N	Mean	Median	Std. Deviation	Range
BMI **					
URBANIZED					
urban core	189	24.13	23.51	4.06	16.10-46.10
innr suburban	176	25.06	24.43	4.38	17.17-39.28
outer suburban	174	25.88	25.41	4.84	17.76-44.39
NON-URBANIZED					
exurban	81	26.81	26.46	5.12	18.87-41.87
Total	*620*	*25.24*	*24.52*	*4.61*	*16.10-46.10*

** = significant trend in BMI by region

Table 5-6 shows the variation in BMI by sub-area (p for trend <0.001); the mean BMI increased from urban to rural suburban areas (from 24.13 in the urban core regions to 26.81 in the rural suburban area). The observed increase in BMI from the most to least urbanized areas of the region is likely related with levels of physical activity and dietary patterns of residents across these areas of each region. We report a few statistically significant relationships between physical activity and urban form features across regional location. We did not investigate dietary patterns in the current study. Recent findings from a recent study conducted for the BC Recreation and Parks Association (BCRPA) confirms significant increases in walking amongst residents in the more central areas of the region (Devlin and Frank 2009). Future studies should investigate these relationships and use objectively measured (through activity monitors) rather than self reported physical activity data. **Table 5-7** shows the distribution of overweight (BMI > = 25) and physical activity according to geographical location. Results are divided by urbanized and non-urbanized areas.

Nearly twice as many respondents in the surburban rural compared with urban core areas were overweight (61.7% compared with 35.4%). This relationship was significant at the 99.99% level. As noted, self reported physical activity data used in this study may likely have resulted in the inability to detect any statistically significant trend by sub-area. However, a steady decline in the proportion of respondents that met recommended levels of physical activity (150 minutes per week by walking, moderate activity, or the combination of the two) was observed across the urbanized areas -- as one moves from urban core, to inner and outer suburban areas. Respondents in the non-urbanized areas (rural suburban) showed higher levels of physical activity than their outer suburban neighbors. This may likely be due to increased activity associated with agriculture or other employment and possibly self selection to live near open space and recreate more frequently.

Urban form characteristics

As mentioned in Chapter four, a 1 km street network buffer was created around the centre of each participant's residential postal code. The shape of and gross area within each 1 km street network buffer can vary significantly, depending on the characteristics of the street network. For example, **Figure 5-3** shows the variation in size and shape of 1 km street network buffers around several postal code centroids in Chilliwack. In general, where the total area of the street network buffer is higher, this indicates a well-connected street network; in contrast, where the total area of the street network buffer is lower, this indicates a less well-connected street network.

Table 5-7

Percentage of respondents that were overweight, or that met the physical activity recommendation of 150 minutes per week, by regional sub-area

Regional sub-area	n	Overweight (BMI >=25) * (S)	≥ 150 minutes of walking ** (NS)	≥ 150 minutes of moderate activity ** (NS)	≥150 minutes of walking and/or moderate activity ** (NS)
URBANIZED					
Urban core	189	*35.4%*	*66.7%*	*31.7%*	*77.2%*
Inner suburban	176	*45.5%*	*61.9%*	*30.7%*	*76.1%*
Outer suburban	174	*52.3%*	*57.5%*	*27.0%*	*70.7%*
NON-URBANIZED					
exurban	*81*	*61.7%*	*63.0%*	*40.7%*	*76.5%*
TOTAL	*620*	*46.5%*	*62.3%*	*31.3%*	*75.0%*

*S = significant at the 99.99% level / **NS – Not Statistically Significant

Table 5-8

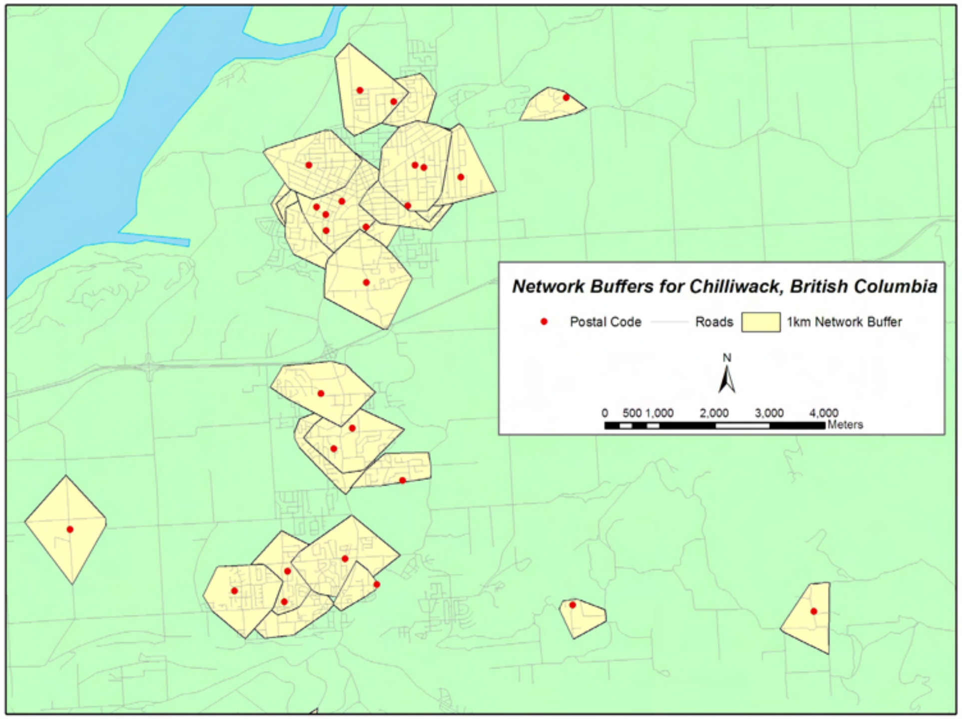
Descriptive statistics for urban form measures

	Mean (or %)	Median	Standard Deviation	Range
buffer area (in km²)	1.50	1.58	0.45	0.09-2.36
residential density (in households per acre)	36.13	11.27	73.17	0.02-588.15
intersection density (in intersections per km²)	48.08	47.17	15.99	0-112.41
land use mix index (4 categories)	0.23	0.15	0.23	0-0.89
land use mix index (5 categories)	0.37	0.37	0.24	0-0.91
ratio of land area for retail purposes	1.94	0.40	4.58	0-53.64
walkability index*	0.78	-0.27	3.66	-7.64-11.38

* 5 categories, capped extreme values >5 sd

Figure 5-3

1 km street network buffers around postal code centroids in Chilliwack.



As shown in **Table 5-8**, the mean area of street network buffers was 1.50 km^2 with a standard deviation of 0.45 km^2. Due to the fact there was a wide variation in the types of urban environments in which participants resided, there is a significant range in the overall area in each buffer, ranging from a low of 0.09 km^2 to a high of 2.36 km^2. Within each buffer, the following objective measures of urban form were calculated: residential area, intersection density, land use mix, the ratio of retail floor area, and a walkability index (composed of standardized scores for the previous 4 objective measures). The mean residential density of buffers was 36.13 households per acre, with a standard deviation of 73.17. The mean intersection density per buffer was 48.09 intersections/km^2, with a standard deviation of 15.99. The mean land use score when single family and multifamily parcels together as "residential" (land use mix (4 categories)) was 0.23 with a standard deviation of 0.23, and when single and multi-family are separated (land use mix (5 categories)) then the mean land use mix score was 0.37, with a standard deviation of 0.24. The walkability index composite score had a mean value of 0.78 and a standard deviation of 3.66.

Within each buffer the total number of parcels, total building floor area and the total parcel area was calculated for each of the 23 land use classifications used for this project. As shown in **Table 5-9**, by far the most dominant land use was single-family residential (with an average of about 821 parcels which encompassed a total mean parcel area of about 128 acres per buffer), followed by multi-family residential (with an average of about 341 parcels which encompassed a total mean parcel area of 53 acres per buffer). Other land uses which had a mean of at least 10 acres of parcel area in each buffer were (in order) those with no data, or unknown use, civic and recreational. However, perhaps a more accurate indication of the presence of each land use can be found by examining the mean total building area per buffer. Multi-family residential has the most building area per buffer (an average about 4500,000 ft^2 per buffer), followed by office buildings, single family residential, other, civic, industrial, and large neighborhood retail.

Similar to obesity and physical activity patterns, objective measures of urban form also varied significantly among sub-areas. **Table 5-10** shows the objective land use measures according to regional sub-area. A higher residential density generally represents a more walkable environment. The highest values for residential density were found in the urban core (about 84 households per acre). A similar association was expected with intersection density; again, the highest mean intersection density was in the urban core (about 61 intersections per km^2).

Table 5-9

Land uses in buffer

Land Use	mean number of parcels in buffer	mean total building floor area in buffer (1000 ft2)	mean total parcel area in buffer (acres)
Agriculture	0.4	1.2	2.8
Convenience Store	0.2	0.7	0.1
Civic	14.4	375.1	16.2
Entertainment	2.7	50.5	0.3
Fast food	1.2	9.2	0.2
Groceries	1.1	18.6	0.6
Industrial	17.4	401.5	4.6
Large neighborhood retail	11.2	343.5	1.7
Large retail	0.8	131.7	1.0
Multi-family residential	340.9	4417.5	52.6
Office building	24.5	2031.8	3.4
Other	76.4	1071.8	16.6
Office	12.7	143.7	1.0
Parking	19.0	56.2	4.8
Recreation	10.0	88.8	11.7
Restaurant	3.8	55.8	0.6
Single family residential	821.0	2039.9	128.1
Small neighborhood retail	51.9	287.1	2.9
Super large retail	0.2	123.0	1.1
Tranportation-Utility	2.3	5.4	1.2
Unknown	5.6	13.7	1.6
Vacant	14.7	0.1	9.7
No data	31.7	19.3	18.7

Table 5-10

Urban form measures, by regional sub-area

	Mean	Median	Std. Deviation	Range
residential density (households per acre)				
urban core	83.56	32.10	115.94	0.82-588.15
inner suburban	23.27	12.03	26.45	2.21-165.58
outer suburban	9.96	7.29	11.49	0.02-114.78
exurban	9.25	6.55	7.96	0.14-43.59
Total	*36.13*	*11.27*	*73.17*	*0.02-588.15*
intersection density (insections per km2)				
urban core	60.95	61.16	10.43	21.39-91.14
inner suburban	47.06	44.64	14.82	20.34-112.41
outer suburban	42.20	43.21	11.92	8.76-85.37
exurban	32.87	34.47	15.17	0-63.93
Total	*48.08*	*47.17*	*15.99*	*0-112.41*
land use mix (4 categories)				
urban core	0.41	0.41	0.23	0-0.86
inner suburban	0.17	0.12	0.18	0-0.78
outer suburban	0.13	0.04	0.17	0-0.67
exurban	0.14	0.04	0.21	0-0.79
Total	*0.23*	*0.15*	*0.23*	*0-0.86*
land use mix (5 categories)				
urban core	0.51	0.54	0.18	0.10-0.91
inner suburban	0.36	0.36	0.21	0-0.82
outer suburban	0.26	0.19	0.23	0-0.83
exurban	0.30	0.21	0.26	0-0.89
Total	*0.37*	*0.37*	*0.24*	*0-0.91*
ratio of retail floor area				
urban core	5.60	4.44	7.01	0-53.64
inner suburban	0.46	0.39	0.37	0-2.03
outer suburban	0.28	0.22	0.46	0-5.35
exurban	0.19	0.14	0.21	0-1.15
Total	*1.94*	*0.40*	*4.58*	*0-53.64*

With the land use mix measure, higher scores are indicative of more evenly mixed land use in the buffers. The mean land use mix indices (based on either 4 or 5 aggregated categories of land uses) are lowest in the rural suburban buffers and increase with proximity to urban core. Finally, a higher ratio of retail floor area indicates that a higher proportion of land area is used for retail options, and is generally considered a more walkable environment. Indeed, we see a much higher mean ratio in the urban core (5.60) than in the other sub-areas (0.19-0.46).

Because the urban form measures are commonly correlated, we employed a walkability index as a composite score of the measures in order to account for the influence of all each in multiple regression modeling. The variation of the walkability index by sub-area is shown in **Table 5-11**. A higher score for the walkability index is indicative of a more walkable area; we see the highest mean scores in the urban core (4.97), and decreasing in regions further out to the rural suburban area (-2.31).

Table 5-11

Walkability index, by regional sub-area

	Mean	Median	Std. Deviation	Range
walkability index				
urban core	4.84	4.99	2.81	-3.52-11.38
inner suburban	0.11	-0.47	2.61	-5.22-11.22
outer suburban	-1.26	-1.35	1.85	-6.05-4.11
exurban	-2.28	-2.59	2.52	-7.64-4.03
Total	*0.77*	*-0.27*	*3.66*	*-7.64-11.38*

INFERENTIAL STATISTICS

The next portion of the analysis involved determining the statistical relationship between obesity and physical activity patterns with urban form characteristics, while controlling for demographic variables (age, gender, income, and education). This section summarizes the results of the partial correlations, and of the linear and logistic regressions that were conducted to determine these relationships.

Correlations between independent variables

The first step was to look at co-linearity between the objectively measured urban form variables. **Table 5-12** outlines the relationship between intersection density, residential density, land use mix, and the ratio of retail floor area, and shows that these measures are significantly interrelated.

Table 5-12

Correlations between objective urban form measures

	Intersection density	Residential density	Land use mix (4 categories)	Land use mix (5 categories)	Ratio of retail floor area
Intersection density					
Pearson Correlation (r)	*1*	*0.29*	*0.38*	*0.34*	*0.24*
Residential Density					
Pearson Correlation (r)	*0.29*	*1*	*0.45*	*0.24*	*0.14*
Land use mix (4 categories)					
Pearson Correlation (r)	*0.38*	*0.45*	*1*	*0.83*	*0.47*
Land use mix (5 categories)					
Pearson Correlation (r)	*0.34*	*0.24*	*0.83*	*1*	*0.37*
Ratio of Retail Floor area					
Pearson Correlation (r)	*0.24*	*0.14*	*0.47*	*0.37*	*1*

Partial Correlations between outcomes and land use variables

To determine the relationship between physical activity patterns and urban form characteristics, several partial correlations were conducted which controlled for gender, age, income, and education. For correlations, the skewed physical activity outcomes were log-transformed to achieve a more linear relationship. Responses of 0 minutes of activity per week were imputed with 1 minute in order to avoid undefined values resulting from log transformation.

Table 5-13 outlines the relationship between the continuous measure of BMI and physical activity patterns (log transformed, in minutes per week) with intersection density, residential density, and land use mix, the ratio of retail floor area, and the walkability index.

Among the continuous outcome variables BMI had a significant correlation with the continuous urban form variables at the 95% confidence level. Land use mix was the most important explanatory factor of minutes walked per week (p=0.063 or 93.7% significant). After controlling for all four demographic variables, the walkability index was negatively correlated with BMI (r= -0.111, p =0.006), as expected. Correlations with other urban from measures were in the expected directions, and was significant with the ratio of retail floor area (r= -0.129, p =0.002), and close to significance with the other urban form measures of land use mix (4 categories) (r= -0.078, p =0.055) and intersection density (r= -0.070, p =0.087).

While the correlations between physical activity and urban form measure were in the expected direction (positive), they were not significant, except for walking with land use mix (at 93.7% confidence level). Since scatterplots indicate that the relationship between physical activity levels and urban form is not linear these outcomes may be better represented in logistical models.

Certain specific land uses are also associated with BMI in the study population. In partial correlations adjusting for demographic factors, the number of parcels of grocery stores (representing healthy food choices) in the buffer was also significantly correlated with BMI in the expected direction (r= -0.112, p =0.006), as was the number of small neighbourhood retail parcels (r= -0.113, p =0.005). The number of large neighbourhood retail (r= -0.073, p =0.073), and the number of parcels of convenience stores (unhealthy food) approached significance (r= 0.707, p =0.080), though the presence of fast food venues or restaurants was not significant. The presence of recreational land parcels, the number of recreational parcels or the land area of recreational parcels was also not significant.

While no composite urban form measures were correlated with the continuous physical activity outcomes, certain specific land uses were. The number of small neighbourhood retail parcels was positively correlates with minutes of walking per week (log transformed) (r= 0.086, p=0.033), and the number of large neighbourhood retail parcels approached significance (r= 0.069, p=0.088).

Table 5-13

Partial correlations between continuous BMI and physical activity outcomes and urban form measures, controlling for demographic factors

	Walkability Index	Intersection density	Residential density	Land use mix (4 categories)	Land use mix (5 categories)	Ratio of retail floor area
BMI (n=599)						
Pearson Correlation (r)	-0.111	-0.070	-0.099	-0.078	-0.032	-0.129
Significance (p)	0.006	0.087	0.016	0.055	0.432	0.002
Log (minutes of walking per week) (n=599)						
Pearson Correlation (r)	0.441	0.026	0.053	0.076	0.027	0.026
Significance (p)	0.280	0.525	0.192	0.063	0.517	0.529
Log (minutes of walking/moderate exercise per week) (n=599)						
Pearson Correlation (r)	0.025	0.030	0.046	0.043	-0.009	-0.011
Significance (p)	0.550	0.469	0.264	0.289	0.836	0.796

LOGISTIC MODELING

The outcomes for the obesity and physical activity were dichotomized according to important policy cut-off points, to evaluate the potential for urban form to affect public health. For obesity, the selected outcome was overweight (BMI ≥ 25) or not; as an aside, we also looked at comparing those who were obese (BMI ≥ 30) with those that were normal (BMI < 25). For physical activity, the outcome was sufficient activity per week (set at 150 minutes of walking, or else 150 minutes or walking and/or moderate activity per week) or not.

Overweight

Of the 620 respondents, 46.5% were considered overweight by their BMI. In simple bivariate analyses, there was a significant trend toward lower likelihood of being overweight in more urban regions. Females were less likely to be overweight than males and surprisingly, residents with lowest household incomes (<20K) are less likely to be overweight.

Looking at the urban form variables (as quartiles), a higher walkability quartile was significantly associated with a lower likelihood of being overweight (p for trend =0.001), as was a higher intersection density quartile (p=0.001), a higher residential density quartile (p<0.036), and a higher land use mix (using 4 categories) (p=0.001), and a higher ratio of retail floor area (p=0.001). The quartiles of land use mix (using 5 categories) approached significance (p=0.096). The number of grocery stores in the buffer was associated with being overweight (p=0.006) but the presence (Y/N) of land uses such as fast food venues, or recreational areas in the buffer did not change the likelihood of being overweight.

Comparing respondents that were obese (n=95) with those that had normal weight (n=347), living in urban areas and being female was associated with a lower likelihood of being obese. In terms of urban form measures, only quartiles the ratio of retail floor area was significant (p=0.046 for trend), though quartiles of walkability approached significance (p=0.069).

Final results of multivariable modeling for the outcome of overweight or not are shown in **Table 5-14**. In the base model, gender and education are significant variables after adjusting for other demographics. However, based on the findings of previous literature, all demographics are included in subsequent modeling regardless of significance. Adding certain urban form measures significantly improved the fit of the model. In model 1, quartiles of the walkability index (specifically the capped 5 index) were significant, after adjusting for demographic variables. Specifically, those residing in the most walkable quartile were half as likely to be overweight (OR=0.52, 95% CI: 0.21-0.85) as those in the least walkable buffers.

Similarly, in model 2, higher quartiles of intersection density were significantly associated with a lower likelihood of being overweight after adjusting for demographics, with an OR of 0.49 for the decreased risk from highest quartile as compared to lowest quartile. Model 3 shows the same result for quartiles of the ratio of retail floor area (OR=0.48 for the decreased risk for highest quartile compared with lowest quartile for ID and RFA, respectively). The urban form variables of walkability, intersection density, or retail floor area could not be combined in one model together to evaluate the adjusted effect sizes as the quartiled land use variables were correlated. We also built a model with the number of grocery store parcels, adjusted for demographics, where an increase of 1 land parcel for grocery store use was associated with an 11% less likelihood of being overweight (OR= 0.89, 95% CI: 0.82-0.98).

In summary, four urban form variables associated with likelihood of being overweight. A surprising result was that other than gender, none of the demographic variables measured were associated with the likelihood of being overweight.

Physical Activity

All respondents had complete physical activity data. In total, 62% of respondents (234/620) had sufficient physical activity (defined as >150 minutes per week) from walking alone, and 75% (155/620) from walking and moderate activities combined. In simple bivariate analyses, demographics were not significantly associated with dichotomous physical activity outcomes.

In univariate analyses, the likelihood of sufficient walking activity was associated with certain specific land uses. A higher odds of the outcome was associated with quartiles of retail floor area (p=0.043) and with quartiles of land use mix 4 (p=0.027), both in the expected direction. The association with quartiles of intersection density was near significance (p=0.06) as did the walkability quartiles (p=0.078). However, when each of land use variables was adjusted for demographics in a multivariable model, they were not associated with the outcome. This may have occurred due to co-linearity between the independent variables: quartiles of mixed use are associated with income (higher incomes tended to live in areas with lower quartiles of mixed use (p for trend=0.003)), and with education (higher education, higher quartile of ratio of retail floor area (p for trend and 0.005)). Also note that the multiple quartiled land use variables could not be entered into a single model as they are correlated.

Instead, we looked at specific land uses as predictors of walking. In bivariate analyses, the presence of grocery stores (p=0.043) was associated with a higher likelihood of sufficient walking, and sufficient walking also approached significance with presence of small neighbourhood retail parcels and large neighborhood retail parcels in the buffer (p=0.10 for both). **Table 5-15** shows the adjusted odds ratios for multivariable models for getting sufficient exercise by walking alone. Model 1 indicates that the presence of grocery stores in the buffer were associated with a higher likelihood getting sufficient exercise by walking (OR 1.42, 95% CI:1.00-2.00). In similar models, the presence of small neighbourhood retail and the presence of large neighbourhood retail also were near significant (OR 1.42, 95% CI:0.97-1.09 (p=0.073) and OR 1.33, 95% CI:0.96-1.87 (p=0.09), respectively), once each were adjusted for demographics. These specific land use types could not be combined in one model because buffers with grocery stores are also more likely to have small or large neighborhood retail (p for association <0.001).

Sub-analyses on the influence of perceptions of urban form on physical activity

Approximately one-half (302/620, 49%) of the respondents were asked a set of questions which targeted their perceptions of their residential environment. This subset of respondents was used to compare the relative importance of perceived versus objective measurements of the environmental variables. **Table 5-16** lists the survey questions, response rates, and percent of respondents that were in agreement. Responses were dichotomized from four levels (strongly agree, somewhat agree, somewhat disagree, strongly disagree) to a dichotomous agree/disagree. Note that because of the phrasing of the questions, the hypotheses are that higher levels of physical activity would be associated with those participants agreeing with questions 2-6, but for those disagreeing with questions 7-8. Also, many of the dichotomized perception variables are correlated with each other (i.e., if one agreed that there were shops they also agreed they were close to transit).

Table 5-14

Odds Ratios and 95% CI for multivariable logistic models for the likelihood of being overweight

	BASE MODEL				MODEL 1				MODEL 3				MODEL 4			
	OR	95% CI			OR	95% CI			OR	95% CI			OR	95% CI		
Constant	0.96				1.36				1.26				1.17			
AGE (reference 15-24)																
25-44	1.05	0.61	-	1.79	1.01	0.59	-	1.75	1.04	0.61	-	1.79	1.10	0.64	-	1.88
45-64	1.56	0.90	-	2.73	1.54	0.87	-	2.70	1.49	0.86	-	2.60	1.52	0.87	-	2.65
65-99	1.17	0.65	-	2.10	1.15	0.64	-	2.07	1.14	0.63	-	2.05	1.23	0.69	-	2.21
GENDER (reference male)																
female	**0.46**	**0.33**	**-**	**0.64**	**0.46**	**0.33**	**-**	**0.65**	**0.48**	**0.34**	**-**	**0.67**	**0.48**	**0.34**	**-**	**0.68**
INCOME (reference <$20,000)																
$20,000-39,999	1.60	0.99	-	2.59	1.63	**1.00**	**-**	**2.64**	1.76	**1.09**	**-**	**2.85**	1.73	**1.07**	**-**	**2.79**
$40,000-69,999	1.31	0.81	-	2.12	1.28	0.79	-	2.07	1.32	0.82	-	2.12	1.35	084	-	2.17
Over $70,000	1.56	0.96	-	2.52	1.48	0.91	-	2.40	1.49	0.92	-	2.42	1.56	0.96	-	2.51
EDUCATION (ref <=high school)																
Some college/post-secondary	1.05	0.69	-	1.59	1.08	0.71	-	1.64	1.09	0.72	-	1.64	1.10	0.73	-	1.66
Complete university	**0.64**	**0.42**	**-**	**0.97**	0.68	0.44	-	1.03	0.70	0.46	-	1.06	0.72	0.47	-	1.09
QUARTILES OF walkability																
q2					0.78	0.49	-	1.24	0.92	0.58		1.47	0.71	0.44		1.12
q3					0.62	0.39	-	1.00	0.56	0.35		0.90	0.76	0.47		1.21
q4					**0.52**	**0.32**	**-**	**0.83**	0.49	0.31		0.79	0.48	0.30		0.78
QUARTILES OF intersection density																
q2									0.92	0.58	-	1.47				
q3									**0.56**	**0.35**	**-**	**0.90**				
q4									**0.49**	**0.31**	**-**	**0.79**				
QUARTILES OF ratio of reatil floor area																
q2													0.71	0.44	-	1.12
q3													0.76	0.47	-	1.21
q4													**0.48**	**0.30**	**-**	**0.78**

* reference group for quartiles is lowest quartile- q1

bold indicates significant results

Table 5-15

Odds Ratios and 95% CI for multivariable logistic models for the likelihood of getting sufficient exercise (≥150 minutes per week) from walking

	BASE MODEL					MODEL 1				
	OR	95% CI			*Sig.*	OR	95% CI			*Sig.*
Constant	1.07					0.94				
AGE (reference 15-24)					*0.501*					*0.512*
25-44	1.21	0.72	-	2.04		1.23	0.72	-	2.07	
45-64	1.35	0.79	-	2.33		1.38	0.80	-	2.39	
65-99	1.53	0.86	-	2.72		1.52	0.85	-	2.70	
GENDER (reference male)					*0.186*					*0.193*
female	0.80	0.57	-	1.12		0.80	0.57	-	1.12	
INCOME (reference <$20,000)					*0.186*					*0.193*
$20,000-39,999	1.63	1.01	-	2.62		1.60	0.99	-	2.58	
$40,000-69,999	1.49	0.93	-	2.39		1.52	0.95	-	2.44	
Over $70,000	1.34	0.84	-	2.14		1.38	0.86	-	2.21	
EDUCATION (ref <=high school)					*0.651*					*0.738*
Some college/post-secondary	1.17	0.78	-	1.77		1.12	0.74	-	1.70	
Complete university	0.98	0.65	-	1.47		0.95	0.63	-	1.44	
PRESENCE OF GROCERY STORES (ref=none)						1.42	1.00	-	2.00	*0.048*

Physical activity rates in this subset were comparable with the larger dataset; 64% of respondents (192/302) had sufficient physical activity (defined as >150 minutes per week) from walking alone, and 76% (228/302) from walking and moderate activities combined.

In univariate analyses, demographic variables were not associated with physical activity levels. It may be that there was not enough power in this reduced dataset to detect associations noted in the full dataset.

The likelihood of having sufficient activity from walking had significant associations with perceived and objective land use measures. Separate models were built for each perception and land use variable, adjusting for demographics, with results of select models shown in **Table 5-17**. Significant predictors of getting sufficient physical activity from walking were the perception that there are many shops in walking distance (OR, adjusted for demographics =2.08, 95% CI: 1.21-3.58); the objective measure that there is small neighborhood retail in the buffer (adjusted OR=2.00, 95% CI: 1.14-3.49). Other perceived and objective urban form measures (transit, crime, quartiles of intersection density, residential density, retail floor area ratio, land use mix, or the walkability index) showed no association with the likelihood of sufficient walking in this subset. The two significant variables could not be combined in a model together as they were highly correlated ($p<0.001$).

We also modeled the continuous outcome of log-transformed minutes of walking per week, to assess how well perceived measures accounted for the variability in walking. None of the demographic variables were significantly associated with the outcome, but were adjusted for out of convention. A model including demographics only (age, gender, income and education) was not significant, and explained 1.5% of the variation in walking ($r2=0.015$, p for F-test=0.364). Including a variable for perception of shops nearby resulted in a model that fit significantly better than chance (F-test 2.30, p=0.039) with r2=0.036.
Finally, we applied a similar modeling technique for the likelihood of achieving sufficient activity through walking and/or moderate activity. In separate models adjusted for demographic variables, a higher likelihood of the outcome was associated with the objective measure of small neighborhood retail in the buffer (OR=2.04, 95% CI: 1.10-3.77); and neared significance with the perception that there are many shops in walking distance(OR=1.73, 95% CI: 0.96-3.14).

SUMMARY

This chapter has presented sample characteristics of survey participants; descriptive statistics outlining general weight and physical activity patterns, and urban form characteristics throughout Metro Vancouver and Greater Victoria; the results of several partial correlations and linear and logistic regressions that have outlined the relationship between obesity and physical activity patterns and urban form variables, while controlling for demographic characteristics; and the results of a sub analysis that evaluated the relative

Table 5-16

Neighbourhood environmental perception variables, valid responses and distribution

Perception Variable	Survey Question	Valid Responses (of 302)	% of respondents that agree
ENV 2	There are many shops, stores, markets or other places to buy things I need are within easy walking distance of my home.	298	74%
ENV 3	It is within a 10-15 minute walk to a transit stop (such as bus, train, trolley, tram) from my home.	295	90%
ENV 4	There are sidewalks on most of the streets in my neighborhood.	298	8%
ENV 5	There are facilities to bicycle in or near my neighborhood, such as special lanes, separate paths or trails, or shared use paths for cycles and pedestrians.	296	75%
ENV 6	My neighborhood has several free or low cost recreation facilities, such as parks, walking trails, bike paths, recreation centers, playgrounds, public swimming pools, etc.	297	90%
ENV 7	The crime rate in my neighborhood makes it unsafe to go on walks at night.	295	30%
ENV 8	There is so much traffic on the streets that it makes it difficult or unpleasant to walk in my neighborhood.	302	20%

Table 5-17

Crude and adjusted (for demographic variables) odds ratios for the likelihood of getting sufficient exercise (≥150 minutes per week) from walking in n=302 individuals asked about neighborhood perception

	Unadjusted		Adjusted (for demographics)	
	OR (95% CI)	P	OR (95% CI)	P
Environmental Perception Variables				
Many shops within easy walking distance (ref= disagree)	2.10 (1.24-3.57)	0.009	2.08 (1.21-3.58)	0.006
Parcel Land Use Data				
Small neighborhood retail in buffer (ref=no)	1.85 (1.08-3.21)	0.032	2.00 (1.14-3.49)	0.016

impact of perceptions of neighborhoods versus objective measures. The analysis revealed that certain urban form characteristics indeed exhibited significant relationships with obesity and physical activity patterns. In particular, intersection density, the ratio of retail floor area and the walkability index in the surrounding residential neighborhood had an influence on the likelihood of being overweight or not, as did the number of grocery store parcels. The presence of grocery stores in the surrounding residential buffer had influenced the likelihood of getting sufficient exercise by walking.

This work also collected data on neighbourhood perceptions in a subset of the study population. In this group, multivariable models for the likelihood of getting sufficient exercise by walking alone indicated that both the perception of being close to shops, and the presence of small neighborhood retail in the buffer were independently associated with a higher likelihood after adjustment for demographics. When the outcome was sufficient exercise by walking and/or moderate exercise, the presence of small neighborhood retail was independently associated with a higher likelihood of the sufficient physical activity.

CHAPTER SIX
Conclusion

This research explored the relationship between the prevalence of being overweight and meeting guidelines for physical activity with urban form characteristics in the Metro Vancouver and Greater Victoria regions. An increasing amount of research has emerged in the past several years that has shown that there is indeed a statistically significant relationship between body mass index (BMI), physical activity patterns, and urban form characteristics (as shown in Chapter Three). However, most of this research has been conducted in the United States, and few such studies have been conducted in the Canadian context. Canadian cities are indeed distinct from US cities; this distinction is likely due to historical differences in transportation investment priorities, financing of home loans and taxation, and social services such as how schools are funded. These and other policies, combined with differences in revenues and resources between the countries, have resulted in clear distinctions in our settlement patterns.

This study was conducted to help fill this gap in the literature and explore the relationship between BMI, physical activity and urban form in southwestern British Columbia. This region offers a significant variation in urban form characteristics, encompassing some of the most walkable to the most sprawling areas in the nation. This variation in urban form offers the ability to assess the relationships between physical activity and body weight across a wider range of urban settings that has been available to date in studies done in regions of the US. Vancouver is land locked by water and mountains, and possesses numerous recreational opportunities that promote physical activity.

Indeed, this project did reveal a different relationship between urban form characteristics and physical activity patterns than has been found in previous studies. In particular, this analysis revealed that Metro Vancouver and Greater Victoria residents are, on average, very active. This finding was consistent with national data and the region's reputation for being one of the healthiest and most physically active in North America. Furthermore, the analysis revealed that certain urban form variables were positively associated with a lower propensity to be overweight, or a higher likelihood of getting sufficient physical activity. Urban form variables were more commonly associated with BMI status than with walking patterns. Similarly, we found less of a relationship between the urban form variables measured and moderate forms of physical activity. This initial finding may be an artifact of the self reported physical activity data used in the study, and further assessments are needed to confirm or refute this result. In addition, we did not measure access to open space and recreational amenities in our study, a limitation which could impact the physical activity results.

This concluding chapter will first provide a general discussion of the findings before briefly answering the research questions presented in Chapter One. This chapter will then outline possible directions for future research into the relationship between physical activity patterns and urban form characteristics in Southwestern British Columbia.

DISCUSSION

This analysis revealed that, for the most part, residents of Metro Vancouver and Greater Victoria are quite active. More than half of all survey participants (54%) indicated that they walked every day over the previous week, and more than half of all respondents (55%) indicated that they walked for more than 30 minutes on a typical day over the previous week. In addition, one in five respondents (21%) indicated that they engaged in moderate activity at least 5 days over the previous week, while over a third of respondents (38%) indicated that they engaged in moderate physical activity for more than 30 minutes on a typical day over the previous week. Survey participants walked for an average of about 365 minutes per week (or 52 minutes per day); engaged in moderate activity for an average of about 159 minutes of per week (or 23 minutes per day); and engaged vigorous activity for an average of about 56 minutes per week (or 8 minutes per day). As a result, it is perhaps not surprising that the majority of survey participants

(31%) met the minimum guidelines for physical activity by walking alone, and three out of four survey participants (75%) had sufficient activity when both walking and moderate physical activity were considered. It is important to note the results from a similar study in the Atlanta region showed that only 38% of respondents in the most walkable and 18% in the least walkable areas of that region achieved the recommended 30 minutes of recommended physical activity per day prescribed by the Heart and Stroke Foundation and the U.S. Surgeon General (Frank et al 2005). That study however used objectively measured physical activity as opposed to the self reported data used in this study. It is well documented that people over report their physical activity levels.

Still, a substantial proportion of the Metro Vancouver and Greater Victoria population is overweight; nearly half (47%) of respondents can be considered overweight according to BMI (BMI ≥ 25), while 15 % are obese (BMI ≥ 30), according to self-reported height and weight. It is interesting that residents in this region have relatively high physical activity rates, but that many are overweight in terms of BMI- our results show significant but weak correlations between levels of physical activity and BMI (i.e., r= -0.13 between minutes of walking per week and BMI, after adjusting for demographics.

These findings are consistent with the results of previous analyses of BMI and physical activity patterns in the Metro Vancouver and Greater Victoria regions, and confirm the region's reputation for being among the most physically active and most healthy regions in North America. For example, as shown in Chapter Three, Statistics Canada's Canadian Community Health Survey revealed that 54% of Metro Vancouver adults and 62% of Greater Victoria adults were either moderately active or physically active in 2001, compared to just 47% of all Canadian adults (Statistics Canada, 2002). The result that Metro Vancouver and Greater Victoria residents are, on average, very active is an important finding in and of itself. The BMI results are also consistent with the CCHS survey, which reported that that 47% of Canadian adults aged 20-64 were overweight,

Although the analysis revealed that, on average, Metro Vancouver and Greater Victoria residents are very active, only certain aspects of urban form were found to be significantly associated with BMI status and physical activity patterns in this population. In addition, the relationship only appeared to extend to walking activity, and did not extend to over levels of moderate physical activity.

Our results confirm that urban residents are less likely to be overweight than their surburban counterparts, as only 35% of urban residents were overweight, compared to 62% of rural suburban residents. This project found that physical activity patterns did not vary significantly across the region according to geographical location, i.e. we did not observe increased physical activity with urban proximity, as was hypothesized. However, we did observe a steady reduction in physical activity levels as one moves from urban core to inner and then outer suburban areas. Participants in the most outlying areas exhibited increased levels of physical activity which may be associated with occupation and perhaps self selection to live near open space. When we evaluated the proportion of respondents that got sufficient physical activity by jurisdiction, respondents from certain suburban areas (Chilliwack, West Vancouver, the City of North Vancouver) were more likely to walk than those from Vancouver. This finding cannot be tested statistically due to the small numbers of respondents in many jurisdictions, but it could be suggested that high levels of activity in these areas may result from walking associated with work activities, or unique recreational opportunities. This project was not the first to find that distinct and unusual physical patterns exist in Metro Vancouver and Greater Victoria, as these results corroborate with those of the Canadian Community Health Survey, which showed that a higher percentage of residents were physically active in the North Shore Health Region than in the Vancouver Health Region or Capital Health Region (Greater Victoria).

As noted above, there are several possible reasons for these findings. The first possible reason is due to the various natural and historic factors that combine to make Metro Vancouver and Greater Victoria unique within North America. In particular, Chapter Two argued that because of various geographic constraints, as well as other factors such as the lack of substantial investment in freeways in either region, the geographic extent of suburban sprawl is much more limited in southwestern British Columbia than it is elsewhere in North America. Because of the limited land base in both Metro Vancouver and Greater Victoria, many compact and relatively dense communities have emerged throughout southwestern British Columbia. Also, the region is home to a favourable climate, which allows for moderate physical activity on a year-round basis, and has an abundance of regionally-serving recreational opportunities. These and other factors have combined to create a culture that encourages physical activity and healthy living in southwestern British Columbia. It is also arguable to people who prefer to be in more activity friendly environments move to southwestern BC (referred to as self-selection in the literature), which over time has created an ethos or culture of being active. This culture of physical activity may serve to reduce the overall variation in physical activity regionwide, and future studies will need to separate out influences on physical activity for leisure, for work, and for transport in order to guide policy action. In addition, as previously noted, it will be critical to assess the impact of proximity and accessibility to recreational amenities to better gauge the relative impact of walkability for transportation versus investments in open space on physical activity.

For these reasons, it is perhaps not surprising that there were fewer significant relationships between urban form and physical activity than have been found in previous studies. It is important to note that we only assessed urban form around participants' places of residence. If a small proportion of participants' overall physical activity patterns took place in their residential neighbourhoods, and a larger proportion of residents' physical activity patterns took place in other locations that are popular throughout the region (e.g., skiing, watersports, walking along the waterfront Seawall, going for a hike, or doing exercise at a gym), then the associations with urban form attributes of one's neighbourhood may be weaker. These types of activity would all have been accounted for in the results of the physical activity survey, but bear little relationship to the neighbourhood in which one lives. In summation, our findings may have been impacted by the fact that the self reported physical activity data employed for in this study design did not locate where people spend their time and where the activity actually takes place.

Following on this line of reasoning, there is a second potential bias which may result from the physical activity data that was applied to this project. It is important to note that these do not reflect weaknesses in the data, but rather the application of this data source for secondary purposes. The primary purpose of the physical activity data, collected using the International Physical Activity Questionaire (IPAQ), was to conduct a national, population-based study of the prevalence of physical activity patterns throughout Canada. However, this particular survey did not ask respondents where they engaged in physical activity or for what purpose they engaged in physical activity for work, for utilitarian or for recreational activities: behaviours which have been shown to be influenced by different aspects of urban form. In addition, the survey relied on self-reported measures of physical activity. At least one recent study has shown significant differences between the IPAQ self-reported measures of physical activity used in this study and objectively collected physical activity through activity monitors. Participants may report their overall levels of physical activity accurately, and objectively measured physical activity (using hipw worn monitoris) would be required to fully address test the relationship between activity levels and the built environment. In addition, questions about travel patterns and physical activity in a variety of locations might yield more conclusive results regarding the relationship between urban form characteristics and physical activity patterns.

With these findings in mind, the next section of this chapter will provide brief responses to the research questions introduced in Chapter One.

RESPONSES TO RESEARCH QUESTIONS

1. What is the spatial distribution of walkable and unwalkable environments in southwestern British Columbia?

The urban form variables revealed that, in general, the urban core areas (Vancouver and Victoria) are more walkable for utilitarian purposes than their surrounding suburban and more rural municipalities. This trend is evident in the walkability index developed in this project, as well as each of its individual components (residential density, intersection density, land use mix, and the ratio of retail floor area.

2. What is the spatial distribution of BMI and physical activity patterns in southwestern British Columbia?

Self-reported BMI was lowest for residents of the urban core, as compared to those in suburban and rural areas. Using the standard cut-off point for overweight (BMI≥25), those in urban areas were significantly less likely to be overweight (35% compared to 62% in rural areas). In terms of obesity (BMI≥30), those in urban areas were also less likely to be obese (10% compared to 21%).

The self reported physical activity data used in this study combines walking for all purposes: work, transport and leisure. It suggests that the highest levels of walking were amongst survey participants located in suburban and rural municipalities, whereas residents of the urban municipalities engaged in less walking. These results appear to be somewhat counter-intuitive, but may be influenced by certain suburban and rural jurisdictions where the reported likelihood of sufficient physical activity from walking was especially high (Chilliwack, West Vancouver, City of North Vancouver), or small sample sizes (e.g., < 10 respondents in many jurisdictions surrounding Greater Victoria).

So, although the urban municipalities were indeed found to have more walkable urban form characteristics than suburban municipalities, and urban residents were less likely to be overweight, physical activity patterns did not correlate with more walkable urban form characteristics. One hypothesis may be that suburban residents compensate for not being able to walk for transport with walking for leisure and finding other means to remain physically active.

3. Which built environment variables have the most significant relationships with overweight status and physical activity patterns in south-western British Columbia, after controlling for demographic variables?

The results show that certain aspects of the physical environment within a kilometer of one's residence were significantly associated with a lower likelihood to be overweight. The following findings were most significant:

• Residents living in the most walkable areas of each region (ie the top quartile of walkability) were half as likely to be overweight than those in the least walkable buffers;
• Residents living in buffers with the highest quartile of intersection density were half as likely to be overweight as those living in the lowest quartile;
• Residents living in buffers with the highest quartile of retail floor area were also half as likely to be overweight as those living in the lowest quartile;
• Finally, an increase in 1 grocery store parcel within a buffer was associated with 11% reduction in the likelihood of being overweight.

Similarly, particular land uses were associated with getting sufficient activity from walking. It was notable that none of the constructs of urban form (i.e., walkability, residential density, intersection density, land use mix, or the ratio of retail floor area) were significantly associated with sufficient activity by walking, once accounting for demographic characteristics. Key findings on physical activity were:

• Living in a buffer with at least one grocery store was associated with a nearly 1.5 times the likelihood of getting sufficient physical activity, as compared to living in an area with no grocery store in the buffer;
• The presence of either small neighbourhood retail land use (95 % significance) or large neighbourhood retail land use (90 % significance), was associated with an increased likelihood of getting sufficient physical activity.

This study also compared perceived and objective measures of urban form in a subset of individuals asked about their perceptions. Important findings in this population were:

• The perception of having many shops nearby was associated with over two times the likelihood of getting sufficient physical activity;
• The perception of having transit within a 10-15 minute walk from one's home approached a significant association in this small sample size;
• The objective measure of having at least one small neighborhood retail land parcel in the buffer was associated with two times the likelihood of sufficient walking.

4. What are the possible implications of these findings in terms of transportation investment and land use policy as they relate to public health in the Metro Vancouver and Greater Victoria regions?

The most significant implication of this analysis in terms of land use policy as it relates to public health in the Metro Vancouver and Greater Victoria regions is that certain types of land use are positively associated with weight status and physical activity. In particular, the analysis found that a lower likelihood of being overweight occurred in areas with higher walkability, intersection density, ratio of retail floor area, or with higher numbers of grocery stores. A higher likelihood of sufficient physical activity occurred in areas where grocery stores, and where small or large neighbourhood retail were present.. ALand use policy in Metro Vancouver and Greater Victoria should encourage higher connectivity and the mixing of land uses; in particular, the presence of grocery stores, and small and large neighbourhood retail venues. Although there are clearly other factors that can influence physical activity patterns, land use policies such as these can work to encourage people to walk or to engage in physical activity, instead of using their cars, thereby yielding public health benefits. In a more general sense, this analysis provides evidence favouring the creation of more mixed-use environments and discouraging segregated, single use patterns of development (whether it be exclusively residential uses or any other exclusive uses such as industrial business parks).

The possible implications of this analysis in terms of transportation investment are less clear. Previous research has demonstrated a clear association between street connectivity and physical activity patterns. In this project, higher intersection density (i.e., street connectivity) was associated with lower BMI, but showed no significant correlation with self reported walking, or other physical activity outcomes. We believe this may be a function of the way that the physical activity data was collected in this study, and the fact that walking for leisure is in part a function of access to open space and recreational amenities (Giles-Corti, Broomhall et al. 2005), which could not be captured in this study. It is important to note that the presence of retail establishments was a significant correlate of physical activity and walking, but street connectivity and density were not, though previous research shows that such a relationship exists particularly when using objectively measured physical activity.

The results do not provide evidence of a causal connection between community design, weight status, and physical activity. Our conclusions demonstrate the presence of an association between the built environment and health related outcomes, but further research (outlined below) is required to test these results in greater detail. In sum, this analysis provides the basis for an argument in favour of the promotion and development of walkable, mixed use communities for maintaining healthy body weight and for facilitating physical activity. By encouraging the development of mixed use communities, there is potential to reduce automobile dependence and encourage walking and other forms physical activity (e.g., bicycling), thus helping to improve the health status of residents of the region.

FUTURE RESEARCH

Although this analysis did reveal useful information regarding the relationship between urban form and certain types of land use with BMI and physical activity patterns, further work should probe determinants of BMI and physical activity in the Metro Vancouver and Greater Victoria region. The analysis highlighted the fact the Metro Vancouver and Greater Victoria regions are home to very active residents. This is a very different environment than places like Atlanta where residents are much less active overall (Frank et al 2005). This is an important finding and more research is required to determine other drivers of physical activity, in order to maximize the efficient use of public resources to encourage physical activity in less active regions of Canada. In particular, future research on this topic in this region and in other regions would benefit from the following:

- Obtaining objective measures of physical activity through hip-worn physical activity monitors;
- Determining the specific type of physical activity that residents engage in (such as bicycling, gardening, tennis, or aerobics);
- Capturing the location in which physical activity is taking place through global positioning system (GPS) technology
- Obtaining detailed, daily travel patterns through the use of a trip diary;
- Determining the purpose of the physical activity (utilitarian or recreational);
- Determining the specific geographic locations of the physical activity patterns, so that origins and destinations of physical activity can be deciphered;
- Considering the impact of the residential self-selection bias through longitudinal studies and the collection of data measuring factors that determine neighborhood preferences and selection;
- Explicitly considering the role of topography on specific physical activity patterns.

This study was the first of its kind to be conducted in the Metro Vancouver and Greater Victoria regions. It provides an informative preliminary assessment of the relationship between urban form and BMI and physical activity patterns in Metro Vancouver and Greater Victoria. Future studies will be able to build on the results of this study and address its limitations in order to assess the relationship between urban form and health in southwestern British Columbia in greater detail.

APPENDIX A

International Physical Activity Questionnaire (IPAQ)

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE (August 2002)

SHORT LAST 7 DAYS TELEPHONE FORMAT

For use with Young and Middle-aged Adults (15-69 years)

The International Physical Activity Questionnaires (IPAQ) comprises a set of 4 questionnaires. Long (5 activity domains asked independently) and short (4 generic items) versions for use by either telephone or self-administered methods are available. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data on health–related physical activity.

Background on IPAQ
The development of an international measure for physical activity started in Geneva in 1998 and was followed by extensive reliability and validity testing undertaken across 12 countries (14 sites) during 2000. The final results suggest that these measures have acceptable measurement properties for use in many settings and in different languages, and are suitable for national population-based prevalence studies of participation in physical activity.

Using IPAQ
Use of the IPAQ instruments for monitoring and research purposes is encouraged. It is recommended that no changes be made to the order or wording of the questions as this will affect the psychometric properties of the instruments.

Translation from English and Cultural Adaptation
Translation from English is supported to facilitate worldwide use of IPAQ. Information on the availability of IPAQ in different languages can be obtained at www.ipaq.ki.se. If a new translation is undertaken we highly recommend using the prescribed back translation methods available on the IPAQ website. If possible please consider making your translated version of IPAQ available to others by contributing it to the IPAQ website. Further details on translation and cultural adaptation can be downloaded from the website.

Data Entry and Coding
Attached to the response categories for each question are suggested variable names and valid ranges to assist in data management and interviewer training. We recommend that the actual response provided by each respondent is recorded. For example, "120 minutes" is recorded in the minutes response space. "Two hours" should be recorded as "2" in the hours column. A response of "one and a half hours" should be recorded as either "1" in hour column and "30" in minutes column.

Further Developments of IPAQ
International collaboration on IPAQ is on-going and an *International Physical Activity Prevalence Study* is in progress. For further information see the IPAQ website.

More Information
More detailed information on the IPAQ process and the research methods used in the development of IPAQ instruments is available at www.ipaq.ki.se and Booth, M.L. (2000). Assessment of Physical Activity: An International Perspective. Research Quarterly for Exercise and Sport, 71 (2): s114-20. Other scientific publications and presentations on the use of IPAQ are summarized on the website.

SHORT LAST 7 DAYS TELEPHONE version of the IPAQ. Revised August 2002.

Short Last 7 Days Telephone IPAQ

READ: I am going to ask you about the time you spent being physically active in the last 7 days. Please answer each question even if you do not consider yourself to be an active person. Think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

READ: Now, think about all the *vigorous* activities which take *hard physical effort* that you did in the last 7 days. Vigorous activities make you breathe much harder than normal and may include heavy lifting, digging, aerobics, or fast bicycling. Think only about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities?

    _____ Days per week [VDAY; Range 0-7, 8,9]
    8. Don't Know/Not Sure
    9. Refused

    [**Interviewer clarification**: Think only about those physical activities that you do for at least 10 minutes at a time.]

    [**Interviewer note**: If respondent answers zero, refuses or does not know, skip to Question 3]

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

    __ __ Hours per day [VDHRS; Range: 0-16]
    __ __ __ Minutes per day [VDMIN; Range: 0-960, 998, 999]
    998. Don't Know/Not Sure
    999. Refused

    [**Interviewer clarification**: Think only about those physical activities you do for at least 10 minutes at a time.]

    [**Interviewer probe**: An average time for one of the days on which you do vigorous activity is being sought. If the respondent can't answer because the pattern of time spent varies widely from day to day, ask: "How much time in total would you spend **over the last 7 days** doing vigorous physical activities?"

    __ __ Hours per week [VWHRS; Range: 0-112]
    __ __ __ __Minutes per week [VWMIN; Range: 0-6720, 9998, 9999]

SHORT LAST 7 DAYS TELEPHONE version of the IPAQ. Revised August 2002.

9998. Don't Know/Not Sure

9999. Refused

READ: Now think about activities which take *moderate physical effort* that you did in the last 7 days. Moderate physical activities make you breathe somewhat harder than normal and may include carrying light loads, bicycling at a regular pace, or doubles tennis. Do not include walking. Again, think about only those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities?

____ Days per week [MDAY; Range: 0-7, 8, 9]

8. Don't Know/Not Sure

9. Refused

[**Interviewer clarification**: Think only about those physical activities that you do for at least 10 minutes at a time]

[**Interviewer Note**: *If respondent answers zero,* refuses or does not know, skip to Question 5]

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

__ __ Hours per day [MDHRS; Range: 0-16]

__ __ __ Minutes per day [MDMIN; Range: 0-960, 998, 999]

998. Don't Know/Not Sure

999. Refused

[**Interviewer clarification**: Think only about those physical activities that you do for at least 10 minutes at a time.]

[**Interviewer probe**: An average time for one of the days on which you do moderate activity is being sought. If the respondent can't answer because the pattern of time spent varies widely from day to day, or includes time spent in multiple jobs, ask: "What is the total amount of time you spent over the **last 7 days** doing moderate physical activities?"

__ __ __ Hours per week [MWHRS; Range: 0-112]

__ __ __ __Minutes per week [MWMIN; Range: 0-6720, 9998, 9999]

9998. Don't Know/Not Sure

9999. Refused

READ: Now think about the time you spent walking in the last 7 days. This includes at work and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

____ Days per week [WDAY; Range: 0-7, 8, 9]

8. Don't Know/Not Sure

9. Refused

[**Interviewer clarification**: Think only about the walking that you do for at least 10 minutes at a time.]

[**Interviewer Note**: *If respondent answers zero,* refuses or does not know, skip to Question 7]

6. How much time did you usually spend **walking** on one of those days?

__ __ Hours per day [WDHRS; Range: 0-16]

__ __ __ Minutes per day [WDMIN; Range: 0-960, 998, 999]

998. Don't Know/Not Sure

999. Refused

[**Interviewer probe**: An average time for one of the days on which you walk is being sought. If the respondent can't answer because the pattern of time spent varies widely from day to day, ask: "What is the total amount of time you spent walking over **the last 7 days**?"

__ __ __ Hours per week [WWHRS; Range: 0-112]

__ __ __ __Minutes per week [WWMIN; Range: 0-6720, 9998, 9999]

9998. Don't Know/Not Sure

9999. Refused

READ: Now think about the time you spent sitting on week days during the last 7 days. Include time spent at work, at home, while doing course work, and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television.

7. During the last 7 days, how much time did you usually spend ***sitting*** on a **week day**?

__ __ Hours per weekday [SDHRS; 0-16]

__ __ __ Minutes per weekday [SDMIN; Range: 0-960, 998, 999]

998. Don't Know/Not Sure
999. Refused

[**Interviewer clarification**: Include time spent lying down (awake) as well as sitting]

[**Interviewer probe**: An average time per day spent sitting is being sought. If the respondent can't answer because the pattern of time spent varies widely from day to day, ask: "What is the total amount of time you spent *sitting* last **Wednesday**?"

__ __ Hours on Wednesday [SWHRS; Range 0-16]
__ __ __ Minutes on Wednesday [SWMIN; Range: 0-960, 998, 999]
998. Don't Know/Not Sure
999. Refused

APPENDIX B

IPAQ Scoring Protocol

Revised April 2004

Guidelines for Data Processing and Analysis of the International Physical Activity Questionnaire (IPAQ) - Short Form,

Version 2.0. April 2004

Introduction

This document provides an revision to the outline for scoring the short form of the International Physical Activity Questionnaire (IPAQ) . This is available on the website www.ipaq.ki.se.

There are many different ways to analyse physical activity data, but to-date there is no consensus on a 'correct' method for defining or describing levels of activity based on self–report surveys. The use of different scoring protocols makes it very difficult to compare within and between countries, even when the same instrument has been used.

IPAQ is an instrument designed primarily for population surveillance of adults. It has been developed and tested for use in adults (age range of 15-69 years) and until further development and testing is undertaken the use of IPAQ with older and younger age groups is not recommended. IPAQ is being used also as an evaluation tool in some intervention studies, but the range of domains and types of activities included in IPAQ should be carefully noted before using it in this context.

This document describes the *April 2004 revision* to the IPAQ short scoring protocol[1]. These revisions are have been suggested by the IPAQ scientific group, to examine variation among countries in more detail[2]. Given the broad range of domains of physical activity asked in IPAQ, new cutpoints need to be trialed and developed to express physical activity in the population. These cutpoints are preliminary, in the sense that they are not yet supported by epidemiological studies, which have typically used Leisure time physical activity (LTPA) to examine benefits or risks of being active. Hence, "30 minutes of moderate intensity PA on most days of the week" was evidence-based, using the estimates of risk (reduction) from these LTPA measures in numerous epidemiological studies.

A new set of suggested cutpoints is based on work in the area of total physical activity, specifically total walking, where recommendations of at least 10,000 steps, and possibly 12,500 steps per day are considered 'high active' (Tudor Locke reference). This equates to at least 2 hours of all forms of walking per day, which includes all settings and domains of activity, and could be a population goal for total HEPA (health-enhancing physical activity). With this background, new cutpoints are proposed for expressing physical activity levels in populations using generic physical activity measures such as IPAQ[3].

[1] The first version of an IPAQ scoring protocol was in August 2002; this is a revised version, April 2004. This revised version does not change the continuous forms of reporting data, but does suggest a new category for describing the most active groups in populations. The changes from the August 2002 scoring protocol are indicated in this document.
[2] Previous scoring algorithms returned high prevalence rates with limited variation among countries; hence a higher cutpoint is sought, as the IPAQ instrument measures total PA, including LTPA as well as incidental, occupational and transport related PA all in one question. This results in much higher prevalence estimates than measures of LTPA alone.
[3] This results in changes to the categories used for levels of activity, and in the truncation rules (as greater than two hours per day may be required as usable data for walking and other physical activity behaviour).

1

Characteristics of the IPAQ short-form instrument:

1) IPAQ assesses physical activity undertaken across a comprehensive set of domains including leisure time, domestic and gardening (yard) activities, work-related and transport-related activity;

2) The IPAQ short form asks about three specific types of activity undertaken in the three domains introduced above and sitting. The specific types of activity that are assessed are walking, moderate-intensity activities and vigorous intensity activities; frequency (measured in days per week) and duration (time per day) are collected separately for each specific type of activity.

3) The items were structured to provide separate scores on walking; moderate-intensity; and vigorous-intensity activity as well as a combined total score to describe overall level of activity. Computation of the total score requires summation of the duration (in minutes) and frequency (days) of walking, moderate-intensity and vigorous-intensity activity;

4) Another measure of volume of activity can be computed by weighting each type of activity by its energy requirements defined in METS (METs are multiples of the resting metabolic rate) to yield a score in MET–minutes. A MET-minute is computed by multiplying the MET score by the minutes performed. MET-minute scores are equivalent to kilocalories for a 60 kilogram person. Kilocalories may be computed from MET-minutes using the following equation: MET-min x (weight in kilograms/60 kilograms). The selected MET values were derived from work undertaken during the IPAQ Reliability Study undertaken in 2000-2001. Using the Ainsworth et al. Compendium (*Med Sci Sports Med* 2000) an average MET score was derived for each type of activity. For example; all types of walking were included and an average MET value for walking was created. The same procedure was undertaken for moderate-intensity activities and vigorous-intensity activities. These following values continue to be used for the analysis of IPAQ data: Walking = 3.3 METs, Moderate PA = 4.0 METs and Vigorous PA = 8.0 METs [4].

Analysis of IPAQ

Both categorical and continuous indicators of physical activity are possible from the IPAQ short form. However, given the non-normal distribution of energy expenditure in many populations, the continuous indicator is presented as median minutes or median MET–minutes rather than mean minutes or mean MET-minutes.

Categorical score

Regular participation is a key concept included in current public health guidelines for physical activity.[5] Therefore, both the total volume and the number of day/sessions are included in the IPAQ analysis algorithms. There are three levels of physical activity suggested for classifying

[4] Note that there is still some debate about whether 8 Mets for vigorous is sustainable, in occupational settings for several hours; we have no data on this, but it is likely to be less than that, maybe 7 METs or even less; however, for the moment, we suggest keeping with the compendium value of * METs.
[5] Pate RR, Pratt M, Blair SN, Haskell WL , Macera CA, Bouchard C et al. Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *Journal of American Medical Association* 1995; 273(5):402-7. and U.S.Department of Health and Human Services. ***Physical Activity and Health: A Report of the Surgeon General.*** Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, The Presidents' Council on Physical Fitness and Sports: Atlanta, GA:USA. 1996.

2

populations; these are the new proposed levels, which take account of the concept of total physical activity of all domains. The proposed levels are:
[i] 'inactive
[ii] 'minimally active'[6]
[iii] 'HEPA active' (health enhancing physical activity; a high active category).

The criteria for these three levels are shown below.

1. Inactive (CATEGORY 1)

This is the lowest level of physical activity. Those individuals who not meet criteria for Categories 2 or 3 are considered **'insufficiently active'** [CATEGORY 1].

2. Minimally Active (CATEGORY 2)

The minimum pattern of activity to be classified as 'sufficiently active' is any one of the following 3 criteria:

a) 3 or more days of vigorous activity of at least 20 minutes per day **OR**
b) 5 or more days of moderate-intensity activity or walking of at least 30 minutes per day **OR**
c) 5 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum of at least 600 MET-min/week.

Individuals meeting at least one of the above criteria would be defined as achieving the minimum recommended to be considered **'minimally active'** [CATEGORY 2]. This category is more than the minimum level of activity recommended for adults in current public health recommendations, but is not enough for "total PA" when all domains are considered. IPAQ measures total physical activity whereas the recommendations are based on activity (usually leisure-time or recreational) over and above usual daily activities.

3. HEPA active (CATEGORY 3)

A separate category labeled 'HEPA' level, which is a more active category [CATEGORY 3] can be computed for people who exceed the minimum public health physical activity recommendations, and are accumulating enough activity for a healthy lifestyle. This is a useful indicator because it is known that higher levels of participation can provide greater health benefits, although there is no consensus on the exact amount of activity for maximal benefit. Also, in considering lifestyle physical activity, this is a total volume of being active which reflects a healthy lifestyle. It is at least 1.5 – 2 hours of 'being active' throughout the day, which is more than the LTPA-based recommendations of 30 minutes[7].

In the absence of any established criteria, the IPAQ scientific group proposes this new cutpoint, which equates to approximately at least 1.5 -2 hours of total activity per day, of at least moderate-intensity activity. It is desirable to have a 'HEPA' activity category, because in some populations, a large proportion of the population may be classified as "minimally active' because the IPAQ instrument assess all domains of activity. Category 3 sets a higher threshold of activity and provides a useful mechanism to distinguish variation in sub-population groups.

[6] "Minimally active" implies some physical activity but is not an optimal level of total HEPA
[7] As Tudor-Locke and others have indicated, there is a basal level of around 1 hour of activity just in activity of daily living, and an additional 0.5 – 1 hour of LTPA makes a healthy lifestyle amount of total PA – hence, these new cutpoints are still consistent with the general LTPA based public health recommendations of at least half an hour per day of additional activity or exercise.

The two criteria for classification as 'HEPA active' are:

a) vigorous-intensity activity on at least 3 days achieving a minimum of at least 1500 MET-minutes/week **OR**
b) 7 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum of at least 3000 MET-minutes/week[8]

<u>Continuous score</u>

Data collected with IPAQ can be reported as a continuous measure and reported as median MET-minutes. Median values can be computed for walking (W), moderate-intensity activities (M), and vigorous-intensity activities (V) using the following formulas:

MET values and Formula for computation of Met-minutes

Walking MET-minutes/week = 3.3 * walking minutes * walking 'days'
Moderate MET-minutes/week = 4.0 * moderate-intensity activity minutes * moderate days
Vigorous MET-minutes/week = 8.0 * vigorous-intensity activity minutes * vigorous-intensity days

A combined total physical activity MET-min/week can be computed as the sum of Walking + Moderate + Vigorous MET-min/week scores.

The MET values used in the above formula were derived from the IPAQ validity and reliability study undertaken in 2000-2001 [9]. A brief summary of the method is provided above (see page 1).

As there are no established thresholds for presenting MET-minutes, the IPAQ Research Committee proposes that these data are reported as comparisons of median values and interquartile ranges for different populations.

<u>IPAQ Sitting Question</u>

The IPAQ sitting question is an additional indicator variable and is not included as part of any summary score of physical activity. Data on sitting should be reported as median values and interquartile range. To-date there are few data on sedentary (sitting) behaviors and no well-accepted thresholds for data presented as categorical levels.

<u>Data Processing Rules</u>

In addition to a standardized approach to computing categorical and continuous measures of physical activity, it is necessary to undertake standard methods for the cleaning and treatment of IPAQ datasets. The use of different approaches and rules would introduce variability and reduce the comparability of data.

There are no established rules for data cleaning and processing on physical activity. Thus, to allow more accurate comparisons across studies IPAQ has established and recommends the following guidelines:

1. Data cleaning

- time should be converted from hours and minutes into minutes

[8] Note: this replaces the previous IPAQ short form cutpoint of 1500 mets.mins/ week
[9] Craig *CL, Marshall A , Sjostrom M* et al. International Physical Activity Questionnaire: 12 country reliability and validity Med Sci Sports Exerc 2003;August.

- ensure that responses in 'minutes' were not entered in the 'hours' column by mistake during self-completion or during data entry process, values of '15', '30', '45', '60' and '90' in the 'hours' column should be converted to '15', '30', '45', '60' and '90' minutes, respectively, in the minutes column.
- time should be converted to daily time [usually is reported as daily time, but a few cases will be reported as optional weekly time – eg. VWHRS, VWMINS – convert to daily time]
- convert time to mets-mins [see above; days x daily time]
- must have the number of days for the day variables; for the 'time' variables, either daily or weekly time is needed – if 'don't know' or 'refused' or data are missing in walking, moderate or vigorous days or minutes, then that case is removed from analysis.

2. Maximum Values for excluding outliers

This rule is to exclude data which are unreasonably high; these data are to be considered outliers and thus are excluded from analysis. All Walking, Moderate and Vigorous time variables which total at least or greater than '16 hours' should be excluded from the analysis.
The 'days' variables can take the range 0-7 days, or 8,9 (don't know or refused); values greater than 9 should not be allowed and those data excluded from analysis.

3. Truncation of data rules

This rule is concerned with data truncation and attempts to normalize the distribution of levels of activity which are usually skewed in national or large population data sets. It is recommended that all Walking, Moderate and Vigorous time variables exceeding '4 hours' or '240 minutes' are truncated (that is re-coded) to be equal to '240 minutes' in a new variable[10]. This rule permits a maximum of 28 hours of activity in a week to be reported for each category of physical activity. *This rule requires further testing, but is an initial manner proposed for classifying these population data.*

When analysing IPAQ data and presenting the results in categorical variables, this rule has the important effect of preventing misclassification in the 'high active' category. For example, an individual who reports walking for 2.5 hours every day and nothing else would be classified as 'HEPA active' (reaching the threshold of 7 days, and ≥ 3000 MET mins. Similarly, someone who reported walking for 90 minutes on 5 days, and 4 hours (240 mins) of moderate activity on another day and 70 minutes of vigorous activity on another day, would also be coded as 'HEPA active' because this pattern meets the '7 day" and "3000 MET-min" criteria for 'HEPA active'.

4. Minimum Values for Duration of Activity

Only values of 10 or more minutes of activity will be included in the calculation of summary scores. The rationale being that the scientific evidence indicates that episodes or bouts of at least 10 minutes are required to achieve health benefits. Responses of less than 10 minutes [and their associated days] should be re-coded to 'zero'.

Summary of Data Processing Rules 1- 4 above

Data management rules 2, 3, and 4 deal with first excluding outlier data, then secondly, recoding high values to "4 hours", and finally describing minimum amounts of activity to be included in

[10] Note that this is a different truncation rule to the earlier scoring protocol; we have previously used 2 hours as a truncation point for LTPA measures. This higher truncation point is proposed in order to allow people who walk for 2.5 hours per day and do nothing else to be categorized as 'HEPA' active; if data were truncated, these individuals would be recoded to 2 hours per day, and over 7 days, total 2772 MET mins, due to the truncation rule. The new truncation rule allows 2.5 hours to be counted in full. The initial purpose of truncation was to normalize the distributions, and was based on expert judgments. It is now suggested that 4 hours / day be proposed as a truncation threshold for more inclusive 'lifestyle PA measures' such as IPAQ.

analyses. These rules will ensure that highly active people remain highly active, while decreasing the chances that less active individuals are coded as highly active.

5. Calculating Total Days for 'minimally Active' [category 2] and 'HEPA Active' [category 3]

Presenting IPAQ data using categorical variables requires the total number of 'days' on which all physical activity was undertaken to be assessed. This is difficult because frequency in 'days' is asked separately for walking, moderate-intensity and vigorous-intensity activity, thus allowing the total number of 'days' to range from a minimum of 0 to a maximum of 21'days' per week. The IPAQ instrument does not record if different types of activity are undertaken on the same day.

In calculating **'minimal activity'**, the primary requirement is to identify those individuals who undertake a combination of walking and/or moderate-intensity activity on at least '5 days'/week. Individuals who meet this criterion should be coded in a new variable called *"at least five days"*.

Below are two examples showing this coding in practice:

i) an individual who reports '2 days of moderate' and '3 days of walking' should be coded as a value indicating *"at least five days"*;

ii) an individual reporting '2 days of vigorous', '2 days walking' and '2 days moderate' should be coded as a value to indicate *"at least five days"* [even though the actual total is 6].

The original frequency of 'days' for each type of activity should remain in the data file for use in the other calculations.

The same approach as described above is used to calculate total days for computing the **'HEPA active'** category. The primary requirement according to the stated criteria is to identify those individuals who undertake a combination of walking, moderate-intensity and or vigorous activity on at least 7 days/week. Individuals who meet this criterion should be coded in a value in a new variable to reflect *"at least 7 days"*.

Below are two examples showing this coding in practice:

i) an individual who reports '4 days of moderate' and '3 days of walking' should be coded as the new variable *"at least 7 days"*.

ii) an individual reporting '3 days of vigorous', '3 days walking' and '3 days moderate' should be coded as *"at least 7 days"* [even though the total adds to 9] .

Summary: The algorithm(s) in Appendix 1 and Appendix 2 to this document show how these rules work in an analysis plan, to develop the categories 1 [inactive], 2 [minimally], and 3 [HEPA] levels of activity. A short form ['at a glance'] and a diagram showing these analytic steps for 'sufficient physical activity' and 'high active' categories are shown as appendix 1 at the end of this document.

IPAQ Research Committee
April 2004

Revised April 2004

APPENDIX 1

At A Glance
IPAQ Scoring Protocol (Short Versions)

Categorical Score- three levels of physical activity are proposed

1. *Inactive*

   - No activity is reported **OR**
   - Some activity is reported but not enough to meet Categories 2 or 3.

2. *Minimally Active*

   Any one of the following 3 criteria

   - 3 or more days of vigorous activity of at least 20 minutes per day **OR**
   - 5 or more days of moderate-intensity activity or walking of at least 30 minutes per day **OR**
   - 5 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum of at least 600 MET-min/week.

3. *HEPA active*

   Any one of the following 2 criteria

   - Vigorous-intensity activity on at least 3 days and accumulating at least 1500 MET-minutes/week **OR**
   - 7 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum of at least 3000 MET-minutes/week

Continuous Score

Expressed as MET-min per week: MET level x minutes of activity x events per week

Sample Calculation

MET levels	**MET-min/week for 30 min episodes, 5 times/week**
Walking = 3.3 METs	3.3*30*5 = 495 MET-min/week
Moderate Intensity = 4.0 METs	4.0*30*5 = 600 MET-min/week
Vigorous Intensity = 8.0 METs	8.0*30*5 = 1,200 MET-min/week
	TOTAL = 2,295 MET-min/week

Total MET-min/week = (Walk METs*min*days) + (Mod METs*min*days) + Vig METs*min*days)

Please review the document "Guidelines for the data processing and analysis of the International Physical Activity Questionnaire (Short Form)" for more detailed description of IPAQ analysis and recommendations for data cleaning and processing [www.ipaq.ki.se].

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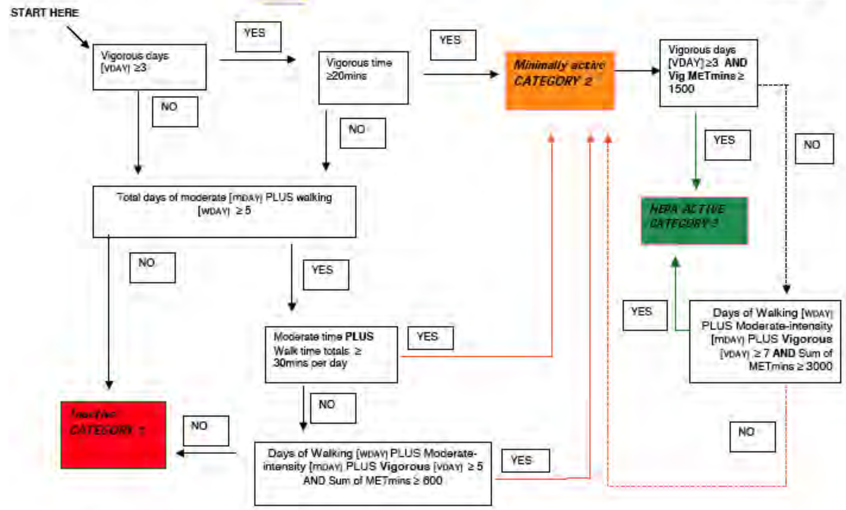

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APPENDIX 2: Flow chart algorithm for the analysis of IPAQ short form

APPENDIX C

Land Use Reclassification

Code	Actual Land Use	Primary Use	Reclassification
1	VACANT RESIDENTIAL LESS THAN 2 ACRES	Res, Res Parking	Vacant
2	PROPERTY SUBJECT TO SEC 19(8)	Res, Res Parking	Unknown
20	RESIDENTIAL OUTBUILDING ONLY	Res, Res Parking	Parking
29	STRATA LOT - PARKING RESIDENTIAL	Res, Res Parking	Parking
30	STRATA-LOT RESIDENCE (CONDOMINIUM)	Res, Res Parking	Multi-Family
31	STRATA-LOT SELF STORAGE-RES USE	Res, Res Parking	Industrial
32	SINGLE FAMILY DWELLING WITH BASEMENT SUITE	Res, Res Parking	Single Family
33	DUPLEX (/SUO FRONT)	Res, Res Parking	Multi-Family
34	DUPLEX - UP & DOWN (/SUO BOTTOM)	Res, Res Parking	Multi-Family
35	DUPLEX - SINGLE UNIT OWNERSHIP (SIDE)	Res, Res Parking	Multi-Family
36	DUPLEX - SINGLE UNIT OWNERSHIP, BACK	Res, Res Parking	Multi-Family
37	MANUFACTURED HOME - (WITHIN MANUFACTURED HOME PARK)	Res, Res Parking	Single Family
38	MANUFACTURED HOME - (NOT IN MANUFACTURED HOME PARK)	Res, Res Parking	Single Family
39	ROW HOUSING - SINGLE UNIT OWNERSHIP	Res, Res Parking	Single Family
40	SEASONAL DWELLING	Res, Res Parking	Single Family
41	DUPLEX - SINGLE UNIT OWNERSHIP, TOP	Res, Res Parking	Multi-Family
42	STRATA-LOT SEASONAL DWELLING (CONDOMINIUM)	Res, Res Parking	Multi-Family
43	PARKING - LOT ONLY, PAVED OR GRAVEL	Res, Res Parking	Parking
47	TRIPLEX	Res, Res Parking	Multi-Family
49	FOURPLEX	Res, Res Parking	Multi-Family
50	MULTI-FAMILY - APARTMENT BLOCK	Res, Res Parking	Multi-Family
51	MULTI-FAMILY - VACANT	Res, Res Parking	Vacant
52	MULTI-FAMILY - GARDEN APARTMENT & ROW HOUSING	Res, Res Parking	Multi-Family
53	MULTI-FAMILY - CONVERSION	Res, Res Parking	Multi-Family
54	MULTI-FAMILY - HIGH-RISE	Res, Res Parking	Multi-Family
55	MULTI-FAMILY - MINIMAL COMMERCIAL	Res, Res Parking	Multi-Family
56	MULTI-FAMILY - RESIDENTIAL HOTEL	Res, Res Parking	Multi-Family
57	STRATIFIED RENTAL TOWNHOUSE	Res, Res Parking	Single Family
58	STRATIFIED RENTAL APARTMENT - FRAME CONSTRUCTION	Res, Res Parking	Single Family
59	STRATIFIED RENTAL APARTMENT - HI-RISE CONSTRUCTION	Res, Res Parking	Single Family
60	2 ACRES OR MORE - SINGLE FAMILY DWELLING, DUPLEX	Res, Res Parking	Multi-Family
61	2 ACRES OR MORE - VACANT	Res, Res Parking	Vacant
62	2 ACRES OR MORE - SEASONAL DWELLING	Res, Res Parking	Single Family
63	2 ACRES OR MORE - MANUFACTURED HOME	Res, Res Parking	Single Family
70	2 ACRES OR MORE - OUTBUILDING	Res, Res Parking	na
110	GRAIN & FORAGE	Agriculture	Agriculture
111	GRAIN & FORAGE - VACANT	Agriculture	Vacant
120	VEGETABLE & TRUCK	Agriculture	Agriculture
121	VEGETABLE & TRUCK - VACANT	Agriculture	Vacant
130	TREE FRUITS	Agriculture	Agriculture
131	TREE FRUITS - VACANT	Agriculture	Vacant
140	SMALL FRUITS	Agriculture	Agriculture
141	SMALL FRUITS - VACANT	Agriculture	Vacant
150	BEEF	Agriculture	Agriculture
151	BEEF - VACANT	Agriculture	Vacant
160	DAIRY	Agriculture	Agriculture
161	DAIRY - VACANT	Agriculture	Vacant
170	POULTRY	Agriculture	Agriculture
171	POULTRY - VACANT	Agriculture	Vacant
180	MIXED	Agriculture	Agriculture
181	MIXED - VACANT	Agriculture	Vacant
190	OTHER	Agriculture	Agriculture
191	OTHER - VACANT	Agriculture	Vacant
200	STORE(S) AND SERVICE - COMMERCIAL	Comm, Mix, Com	Other
201	VACANT	Comm, Mix, Com	Vacant
202	STORE(S) AND LIVING QUARTERS	Comm, Mix, Com	Retail/Multi-Family
203	STORES AND/OR OFFICES WITH APARTMENTS	Comm, Mix, Com	Retail/Multi-Family
204	STORE(S) AND OFFICES	Comm, Mix, Com	Retail/Office
206	NEIGHBOURHOOD STORE	Comm, Mix, Com	Neighbourhood Retail
208	OFFICE BUILDING (PRIMARY USE)	Comm, Mix, Com	Office Building
209	SHOPPING CENTRE - NEIGHBOURHOOD	Comm, Mix, Com	Neighbourhood Retail
210	BANK	Comm, Mix, Com	Civic
211	SHOPPING CENTRE - COMMUNITY	Comm, Mix, Com	Large Retail
212	DEPARTMENT STORE	Comm, Mix, Com	Large Retail
213	SHOPPING CENTRE - REGIONAL	Comm, Mix, Com	Large Retail
214	SHOPPING CENTRE	Comm, Mix, Com	Large Retail
215	FOOD MARKET	Comm, Mix, Com	Groceries
216	COMMERCIAL STRATA-LOT	Comm, Mix, Com	Other
217	AIR SPACE TITLE	Comm, Mix, Com	Transport-Utility
218	STRATA-LOT SELF STORAGE-BUSINESS USE	Comm, Mix, Com	Industrial
219	STRATA LOT - PARKING COMMERCIAL	Comm, Mix, Com	Parking
220	AUTOMOBILE DEALERSHIP	Comm, Mix, Com	Other
222	SERVICE STATION	Comm, Mix, Com	Other
224	SELF-SERVE SERVICE STATION	Comm, Mix, Com	Other
225	CONVENIENCE STORE/SERVICE STATION	Comm, Mix, Com	Neighbourhood Retail
226	CAR WASH	Comm, Mix, Com	Other
227	AUTOMOBILE SALES (LOT)	Comm, Mix, Com	Other
228	AUTOMOBILE PAINT SHOP, GARAGES, ETC.	Comm, Mix, Com	Other
230	HOTEL	Comm, Mix, Com	Other

Code	Actual Land Use	Primary Use	Reclassification
232	MOTEL & AUTO COURT	Comm, Mix, Com	Other
233	INDIVIDUAL STRATA LOT - HOTEL/MOTEL	Comm, Mix, Com	Other
234	MANUFACTURED HOME PARK	Comm, Mix, Com	Other
236	CAMPGROUND (COMMERCIAL)	Comm, Mix, Com	Recreational
237	BED & BREAKFAST OPERATION 4 OR MORE UNITS	Comm, Mix, Com	Recreational
238	SEASONAL RESORT	Comm, Mix, Com	Recreational
239	BED & BREAKFAST OPERATION LESS THAN 4 UNITS	Comm, Mix, Com	Recreational
240	GREENHOUSES AND NURSERIES (NOT FARM CLASS)	Comm, Mix, Com	Other
250	THEATRE BUILDINGS	Comm, Mix, Com	Entertainment
252	DRIVE-IN THEATRES	Comm, Mix, Com	Entertainment
254	NEIGHBOURHOOD PUB	Comm, Mix, Com	Recreational
256	RESTAURANT ONLY	Comm, Mix, Com	Restaurant
257	FAST FOOD RESTAURANTS	Comm, Mix, Com	Fast Food
258	DRIVE-IN RESTAURANT	Comm, Mix, Com	Fast Food
260	PARKING - LOT ONLY, PAVED OR GRAVEL	Comm, Mix, Com	Parking
262	PARKING GARAGE	Comm, Mix, Com	Parking
266	BOWLING ALLEY	Comm, Mix, Com	Entertainment
270	HALL (COMMUNITY LODGE, CLUB, ETC.)	Comm, Mix, Com	Entertainment
272	STORAGE & WAREHOUSING - OPEN	Comm, Mix, Com	Industrial
273	STORAGE & WAREHOUSING - CLOSED	Comm, Mix, Com	Industrial
274	STORAGE & WAREHOUSING - COLD	Comm, Mix, Com	Industrial
276	LUMBER YARD OR BUILDING SUPPLIES	Comm, Mix, Com	Industrial
280	MARINE FACILITIES - MARINA	Comm, Mix, Com	Recreational
285	NURSING HOME	Comm, Mix, Com	Multi-Family
286	CONGREGATE CARE FACILITY	Comm, Mix, Com	Multi-Family
287	GROUP HOME	Comm, Mix, Com	Multi-Family
288	SIGN OR BILLBOARD ONLY	Comm, Mix, Com	Other
400	FRUIT & VEGETABLE	Industrial	Industrial
401	INDUSTRIAL - VACANT	Industrial	Vacant
402	MEAT & POULTRY	Industrial	Industrial
403	SEA FOOD	Industrial	Industrial
404	DAIRY PRODUCTS	Industrial	Industrial
405	BAKERY & BISCUIT MANUFACTURING	Industrial	Industrial
406	CONFECTIONERY MANUFACTURING & SUGAR PROCESSING	Industrial	Industrial
407	SOFT DRINK BOTTLING	Industrial	Industrial
408	BREWERY	Industrial	Industrial
409	WINERY	Industrial	Industrial
410	DISTILLERY	Industrial	Industrial
412	FEED MANUFACTURING	Industrial	Industrial

Code	Actual Land Use	Primary Use	Reclassification
413	FLOUR MILLS & BREAKFAST CEREAL PRODUCTS	Industrial	Industrial
414	MISCELLANEOUS (FOOD PROCESSING)	Industrial	Industrial
415	SAWMILLS	Industrial	Industrial
416	PLANER MILLS (WHEN SEPARATE FROM SAWMILL)	Industrial	Industrial
417	PLYWOOD MILLS	Industrial	Industrial
418	SHINGLE MILLS	Industrial	Industrial
419	SASH & DOOR	Industrial	Industrial
420	LUMBER REMANUFACTURING (WHEN SEPARATE FROM SAWMILL)	Industrial	Industrial
421	VACANT	Industrial	Vacant
424	PULP & PAPER MILLS (INCLUDING FINE PAPER)	Industrial	Industrial
425	PAPER BOX, PAPER BAG AND OTHER PAPER REMANUFACTURING.	Industrial	Industrial
426	LOGGING OPERATIONS, INCLUDING LOG STORAGE	Industrial	Industrial
427	LOGGING ROADS & BRIDGES	Industrial	Industrial
428	IMPROVED	Industrial	Industrial
429	MISCELLANEOUS (FOREST AND ALLIED INDUSTRY)	Industrial	Industrial
430	PETROLEUM AND GAS EXPLORATION (INCLUDING OIL AND GAS	Industrial	Industrial
431	PRODUCTION PIPELINES	Industrial	Industrial
432	OIL REFINING PLANTS	Industrial	Industrial
433	GAS SCRUBBING PLANTS	Industrial	Industrial
434	PETROLEUM BULK PLANTS	Industrial	Industrial
435	LIQUID GAS STORAGE PLANTS	Industrial	Industrial
436	OIL & GAS TRANSPORTATION PIPELINES	Industrial	Industrial
437	OIL & GAS PUMPING & COMPRESSOR STATIONS	Industrial	Industrial
438	MISCELLANEOUS (PETROLEUM INDUSTRY)	Industrial	Industrial
440	MINING - COAL	Industrial	Industrial
442	MINING & MILLING - METALLIC	Industrial	Industrial
443	MINING & MILLING - NON-METALLIC (INCLUDING ASBESTOS)	Industrial	Industrial
444	SMELTING & REFINING	Industrial	Industrial
445	SAND & GRAVEL (VACANT AND IMPROVED)	Industrial	Vacant
446	CEMENT PLANTS	Industrial	Industrial
447	ASPHALT PLANTS	Industrial	Industrial
448	CONCRETE MIXING PLANTS	Industrial	Industrial
449	MISCELLANEOUS (MINING AND ALLIED INDUSTRIES)	Industrial	Industrial
450	RUBBER & PLASTICS PRODUCTS	Industrial	Industrial
452	LEATHER INDUSTRY	Industrial	Industrial
454	TEXTILES & KNITTING MILLS	Industrial	Industrial
456	CLOTHING INDUSTRY	Industrial	Industrial

Code	Actual Land Use	Primary Use	Reclassification
458	FURNITURE & FIXTURES INDUSTRY	Industrial	Industrial
460	PRINTING & PUBLISHING INDUSTRY	Industrial	Industrial
462	PRIMARY METAL INDUSTRIES (IRON & STEEL MILLS	Industrial	Industrial
464	METAL FABRICATING INDUSTRIES	Industrial	Industrial
466	MACHINERY MANUFACTURING (EXCLUDING ELECTRICAL)	Industrial	Industrial
468	TRANSPORTATION EQUIPMENT INDUSTRY (INCLUDING AIRCRAFT	Industrial	Industrial
470	ELECTRICAL & ELECTRONICS PRODUCTS INDUSTRY	Industrial	Industrial
472	CHEMICAL & CHEMICAL PRODUCTS INDUSTRIES	Industrial	Industrial
474	MISCELLANEOUS & (INDUSTRIAL OTHER)	Industrial	Industrial
476	GRAIN ELEVATORS	Industrial	Industrial
478	DOCKS & WHARVES	Industrial	Industrial
480	SHIPYARDS	Industrial	Industrial
488	STRATA-LOT SELF STORAGE-INDUSTRIAL USE	Industrial	Industrial
490	PARKING LOT ONLY (PAVED OR GRAVEL)	Industrial	Parking
500	RAILWAY	Trans, Utility	Transport-Utility
505	MARINE & NAVIGATIONAL FACILITIES (INCLUDES FERRY)	Trans, Utility	Transport-Utility
510	BUS COMPANY, INCLUDING STREET RAILWAY	Trans, Utility	Transport-Utility
515	AIRPORTS, HELIPORTS, ETC.	Trans, Utility	Transport-Utility
520	TELEPHONE	Trans, Utility	Transport-Utility
525	FIBEROPTIC CONDUIT	Trans, Utility	Transport-Utility
530	TELECOMMUNICATIONS (OTHER THAN TELEPHONE)	Trans, Utility	Transport-Utility
540	COMMUNITY ANTENNA TELEVISION (CABLEVISION)	Trans, Utility	Transport-Utility
550	GAS DISTRIBUTION SYSTEMS	Trans, Utility	Transport-Utility
560	WATER DISTRIBUTION SYSTEMS	Trans, Utility	Transport-Utility
570	IRRIGATION SYSTEMS	Trans, Utility	Transport-Utility
580	ELECTRICAL POWER SYSTEMS (INCLUDING NON-UTILITY)	Trans, Utility	Transport-Utility
590	MISCELLANEOUS (TRANSPORTATION & COMMUNICATION)	Trans, Utility	Transport-Utility
600	RECREATIONAL & CULTURAL BUILDINGS (INCLUDES CURLING)	Civic, Institution, Rec	Recreational
601	CIVIC - INSTITUTIONAL & RECREATIONAL - VACANT	Civic, Institution, Rec	Vacant
610	PARKS & PLAYING FIELDS	Civic, Institution, Rec	Recreational
612	GOLF COURSES (INCLUDES PUBLIC & PRIVATE)	Civic, Institution, Rec	Recreational
614	CAMPGROUNDS (INCLUDES GOVERNMENT CAMPGROUNDS)	Civic, Institution, Rec	Recreational

Code	Actual Land Use	Primary Use	Reclassification
615	GOVERNMENT RESERVES (INCLUDES GREENBELTS (NOT IN FARM))	Civic, Institution, Rec	Recreational
620	GOVERNMENT BUILDINGS (INCLUDES COURTHOUSE, POST OFFICE)	Civic, Institution, Rec	Civic
622	ALRT	Civic, Institution, Rec	Civic
623	ALRT/MIXED USE	Civic, Institution, Rec	Civic
625	GARBAGE DUMPS, SANITARY FILLS, SEWER LAGOONS, ETC.	Civic, Institution, Rec	Civic
630	WORKS YARDS	Civic, Institution, Rec	Civic
632	RANGER STATION	Civic, Institution, Rec	Civic
634	GOVERNMENT RESEARCH CENTRES (INCLUDES NURSERIES)	Civic, Institution, Rec	Civic
640	HOSPITALS (NURSING HOMES REFER TO COMMERCIAL SECTION).	Civic, Institution, Rec	Civic
642	CEMETERIES (INCLUDES PUBLIC OR PRIVATE).	Civic, Institution, Rec	Civic
650	SCHOOLS & UNIVERSITIES, COLLEGE OR TECHNICAL SCHOOLS	Civic, Institution, Rec	Civic
652	CHURCHES & BIBLE SCHOOLS	Civic, Institution, Rec	Civic
654	RECREATIONAL CLUBS, SKI HILLS	Civic, Institution, Rec	Recreational
660	LAND CLASSIFIED RECREATIONAL	Civic, Institution, Rec	Recreational
0	RESIDENTIAL		Residential

End Notes

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