EVALUATING BICYCLE ACCESSIBILITY AND BIKE-BUS INTEGRATION INFRASTRUCTURE: SASKATOON, SASKATOON, SK, 2006

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ABSTRACT

The study proposes an application of Talen's (2003) methodological framework for assessing neighbourhood-level (i.e., non-motorised mode) accessibility, and offers recommendations for improving non-motorized transportation (NMT) accessibility to enhance multimodal integration between bicycles and buses in contemporary North American suburban neighbourhoods. Accessibility (or "access") is defined as the average travel time or distance between a given origin and destination along the shortest available street network route. The study considers characteristics of the transportation network such as available route directness, facilities, and transit service provision to determine their impacts on bicycle access. A further methodology for comparing bicycle versus bus modal efficiencies within suburban contexts is developed and applied to the case study. A review of approaches designed to promote bicycling while discouraging personal automobile use provides a toolbox of proven treatments that are applied to a case study of Saskatoon, Saskatchewan – a city of approximately 200,000 people. The approach provides a process that can be used by city or transit planners to identify neighbourhoods that lack sufficient access and apply treatments that improve bicycle accessibility and bicycle-transit integration. Results suggest existing potential for the bicycle as an access mode within contemporary suburban neighbourhood transportation networks. The case study supports the notion that suburban bicycle-bus integration could be used as a viable alternative to automobiles for daily home-to-node activity trips, and raises questions about the current allocation of public transit service to suburban routes within the context of the case study. Discussion and conclusions suggest directions for future research in this field of sustainable urban transportation planning.

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NMT -- Non-motorised Transportation	i
GHG -- Green-house Gases	5
CBD -- Central Business District	13
CMHC -- Canada Mortgage and Housing Corporation	19
BCI -- Bicycle Compatibility Index	42
FHA -- Federal Highway Administration	42
GIS -- Geographic Information System	47
WPDI -- Walking Permeability Distance Index	55
WPTI -- Walking Permeability Time Index	55

1 INTRODUCTION

Increasing usage of automobiles has resulted in air pollution, global warming, and most recently a dearth of health pandemics resulting from the lack of physical activity associated with driving too much (Government of Canada, 2002; Bunting and Filion, 2000, p. 235; Ewing, Schmid, Killingsworth, Zlot, and Raudenbush, 2003). As a result there is increasing support for multi-use pathways, bicycle lanes, and bicycle infrastructure meant to support walking and bicycle use, not only for recreation but also transportation. The shift from automobile-oriented planning and design practices toward physical activity and health, and land-use and designs that support and encourage NMT are gradually shifting the paradigm of what constitutes good development, and making biking much more viable in the process by creating new neighbourhoods that serve cyclists' needs.

Bicycles were designed with the goal of achieving more efficient transportation. Between 1790 and 1890, design, manufacturing and distribution improvements made bikes cheap and accessible. By the mid-1900s they became the main transportation mode for millions of people worldwide. In North America, the bicycle's importance as a transportation mode resulted in the formation of the League of American Bicyclists, a strong advocacy group for the construction of a paved roadway network (League of American Bicyclists, 2005). This literally paved the way for automobiles.

The introduction of automobiles at the start of the 20th Century led to a sharp decline in bicycling, and shifting policies to favour cars. Many countries continue to use cycles for utility trips. In Europe, for example, bikes are used in conjunction with buses and trains to create an efficient automobile alternative in what is referred to as multimodal transport chains. Many people in developing countries use the bicycle as a primary transport mode. In North America, however, bikes have mainly been relegated to recreational uses (Cyclingforums.com, 2005).

While it is often assumed by both the general public and researchers alike that low-density suburban neighbourhood designs have led to prohibitive conditions for the use of bikes for transport, there is no evidence to support this claim. Historically, neighbourhood-level research has been dominated by a focus on social issues rather than those pertaining directly to the physical transportation network availability of bicycles and pedestrians (i.e., neighbourhood level transport modes). Physical functionality of neighbourhood level transportation networks is a reflection of how well people are able to move from place to place within their neighbourhoods (e.g., between homes, workplaces, parks, stores, and other destinations). A high level of neighbourhood access for pedestrians and bicyclists to reach daily life needs such as parks, schools, and retail outlets, is important to daily functions of all citizens. Equitable access to destinations, not just for those with private automobiles, is a community-wide, public problem that has been largely neglected since the rise of the automobile, a century ago (Talen, 2003).

A recent trend in urban planning and design, known as "New Urbanism" supports this idea by promoting enhanced access through a variety of transportation alternatives, including non-motorized transportation (NMT) modes. New Urbanists contend that neighbourhoods should contain a complete mixture of community components, rather than completely separating all land uses from one another. They encourage compact urban form to aid neighbourhood-level transportation modes (i.e., walking and bicycling) (Newurbanism.org, 2005). New Urbanism principles, which embrace this notion of neighbourhood functionality, are beginning to be applied to new developments across the continent.

But what about all the existing neighbourhoods which cater to cars? Surely some thought and effort ought to be given to mitigating the damage that has resulted from these automobile-oriented, isolated and homogeneous places. This belief provides the impetus for this paper. Three studies that focus on assessment of non-motorised access at the neighbourhood level influence the focus of this paper. They examine various aspects of suburban transportation alternatives to private automobiles:

1. Rietveld (2000a) argued that bikes are viable for short trips, and can also be useful for long trips when combined with other modes such as transit. He identified viable ranges for bicycle trips based on Dutch survey data of suburban bicycle-transit integration.

2. Randall and Baetz (2001) identified a method for determining where shortcut retrofits could provide the most benefit to pedestrians in existing suburban non-motorized transportation networks, based on route directness and trip distance.

3. Talen (2003) developed a methodological framework for assessing non-motorised transportation accessibility (also referred to as neighbourhood-level "service provision").

The following study proposes an extension of Talen's approach that could be used to test the viability of Rietveld's findings within a North American suburban context. The approach examines,

1. the potential of existing suburban transportation networks to provide adequate NMT access
2. opportunities for improving existing suburban transportation networks for NMT by examining physical accessibility issues such as permeability and connectivity, and
3. application of appropriate treatments to improve bicycle access, based on a review of successful sustainable transportation promotion measures from Europe.

The approach is applied to a case study of neighbourhoods in Saskatoon, Saskatchewan. The question of how best to coordinate bicycle and bus services in order to achieve maximal efficiency for suburban multimodal transport chains is also addressed by comparing intra-suburban bus routes to bicycle route opportunities for trips between various home origins, and a bus transfer station that provides bus service to destinations throughout the rest of the city. The primary focus of this bicycle-bus integration portion of the study is to generate awareness of the potential for combining these modes for longer urban trips, and to critique the current potential for efficiently combining these two modes (i.e., bicycles and buses) within the context of suburban neighbourhoods. Results are analysed to provide general recommendations that could be used by municipal decision-makers to improve opportunities for automobile alternatives.

2 LITERATURE REVIEW

Sustainable transportation is an important theme in the context of Geography and Urban Planning. Three presumptions are central to research in this domain:

1. Current levels of automobile use are not sustainable.
2. Urban planning and design practices are largely responsible for high rates of automobile dependence in cities.
3. It follows that it is important to find ways to reduce automobile use and reform urban design practices to promote NMT.

This chapter provides a brief overview of the current issues surrounding sustainable transportation. The first section provides a synopsis of the many social and environmental problems associated with high levels of automobile use. Section two explores the connection between supposed automobile dependence and current urban planning and design practices by providing a brief history of how contemporary suburban design practices came to be. The third section reviews strategies to lower automobile use, incorporating bicycle-friendly planning. Section four narrows the focus to look at the importance of accessibility, and available approaches to measuring access at the neighbourhood level.

2.1. Social and Environmental Impacts of the “Car Culture”

2.1.1. Energy Cost, Greenhouse Gases, and Global Warming (i.e., “Climate Change”)

Roughly 85% of worldwide commercial energy use is derived from fossil fuels (Harris and Goodwin, 2003). While fossil fuel reserves can meet projected needs for at least two more decades, world oil production is expected to peak between 2010 and 2030 (Campbell and Laherrére, 1998; MacKenzie 1996).

The major contributor to global warming is the burning of fossil fuels, and the largest single use for fossil fuels is in transportation. Fossil fuel emissions-induced global warming – or “climate change” as it is now commonly referred – will lead to reduced crop yields, increased instances of extreme weather events, decreased water availability in water-scarce regions, increased flooding in other regions, increased spread of diseases, and inundation of low-lying areas (Harris and Goodwin, 2003).

Canadians use more energy per capita than any other nation on earth (Bunting and Filion, 2000, p. 235). The Canadian government ratified the Kyoto Treaty, an international agreement that "commits industrialised nations to reducing emissions of greenhouse gases, principally Carbon Dioxide, by around 5.2% below their 1990 levels over the next decade" (BBC News, 2003). As one of the world's leading producers of greenhouse gases (GHGs), Canadians must drastically reduce emissions to meet the targets set out by Kyoto. According to a study released by the Government of Canada (2002), "transportation is the largest source of GHG emissions, contributing about a quarter of Canada's total emissions". Personal automobile use is the primary source of transportation-related emissions, accounting for the single largest source of GHGs (Government of Canada, 2002; Bunting and Filion, 2000, p. 235). It is important to promote initiatives to reduce usage of personal automobiles and successfully meet Kyoto's goals.

2.1.2. Automobile Addiction and Health

Urban development practices have been widely blamed for further increasing our unprecedented reliance on automobiles, in spite of the evidence associating automobile use with health problems (Bunting and Filion, 2000, p. 235). One of the greatest challenges to the adoption of more sustainable transportation modes is the impact of low-density suburban development and segregated land use. Considering the widespread existence of these car-oriented developments, and the overwhelming automobile use that they produce, it is worthwhile to examine the automobile overuse problem within the suburban environment. "Automobile overuse" refers to the point where the negative impacts of automobiles on the environment and society outweigh their perceived benefits to the individual user. Overuse should be measured not only in terms of direct financial cost to individuals who choose to live in automobile-dependent locations, but by the costs absorbed by all taxpayers to subsidize inefficient infrastructure maintenance and health costs that result from too much driving. By recognising existing barriers and opportunities to improve the accessibility of automobile alternatives in suburban neighbourhoods, planners can progress toward their goal of promoting healthier and more sustainable transportation modes.

A 1978/79 Canada Health Survey found in a nationally representative sample of adults that the age-adjusted obesity rate of Canadians was 13.8%. In 2004, the obesity rate was found to be 23.1% (Statistics Canada website, accessed 2005). This represents an increase of 9.3% in 25 years. New evidence suggests that North Americans' high dependence on automobiles is a significant contributor to obesity and several associated health problems, such as heart disease and diabetes. Suburbanites, on average, are likely to walk less, experience more hypertension, and weigh more than residents of higher density urban areas (Ewing, et al., 2003). The study suggests that increased dependence of suburbanites on personal automobiles contributes to a more sedentary and unhealthy lifestyle. In addition to health costs associated with sedentary lifestyles, automobile accidents are responsible for many injuries and deaths each year.

2.2. Bicycling Challenges and Opportunities

Despite widespread popularity of bicycles in sustainable transportation strategies across Europe, several negative factors – some real, others imagined – have prevented most North Americans from considering the bicycle a serious transportation mode. Three major problem areas cover the wide spectrum of bicycling issues:

- Safety – "real" risks (i.e.,, empirically documented risks, including physical environmental threats such as collision incidents and air pollutants).
- Comfort – includes attractiveness and other environmental aspects, such as slope and elevation differences, weather and climate, perceived risks, and provision of quality infrastructure.
- Efficiency – refers to trip distance, travel time, and integration with other modes of transit.

2.2.1. Safety

Most bicycling literature addresses specific safety issues such as intersection accident risks (Doherty, Aultman-Hall, and Swaynos, 2000; Garder, Leden, and Thedeen, 1994; Franklin, 1999). According to Cleary, "one of the greatest disincentives to… cycling is fear of accident involvement" (2000, p. 50). Among the main threats to cyclist safety are collisions with automobiles at intersections, and falls resulting from poor surface conditions. Intersections represent the highest area of major accidents for urban cyclists (Doherty et al., 2000; Garder et al., 1994). In Gothenburg, Sweden, nearly 80% of serious bicycling injuries and fatalities occur at when cyclists cross roadways (Garder et al., 1994). Garder et al. (1994) cite poor visibility of offset bicycle paths at road crossings as a major contributor to bicycle-car collisions, however, they do not identify whether bicyclists or motorists are mostly to blame for intersection collisions. They suggest a design that merges segregated bicycle paths with automobile traffic at approaches to road crossings. This would allow motorists and cyclists to see each other, and coordinate road crossings.

A study of accident patterns in Toronto and Ottawa found that, overall, "35.5% of Toronto cyclist collisions and 40.0% of Ottawa collisions occurred at intersections", thus supporting Garder's et al. (1994) observation that intersections are the main location of most bicycling accidents (Doherty et al., 2000, p. 25). As in Garder et al.'s study, no data is provided to implicate fault to either user type for such collisions, and intersections are not distinguished as being either controlled (i.e., with traffic signage or lights) or uncontrolled (i.e., without signage or lights).

2.2.2. Comfort

Comfort as a condition or feeling of pleasurable ease, well-being, and contentment – is significant in the context of bicycling. Provision of "attractive routes to public transport interchanges for NMUs [non-motorised users], and pleasant waiting facilities, can all contribute towards offering an appealing alternative to the car" (Cleary, 2000, p. 51). The provision of safe and convenient bicycle parking is an important infrastructure consideration that can decrease negative perceptions of bicycling by providing cyclists with a sense of security and safety, thus, making bicycling easier and more comfortable (Mulroy, 2000, p. 56).

Weather is also an important factor in the decision to bicycle. A study of the impacts of weather and climatic conditions on the bicycle commuting patterns of students in Melbourne, Australia, verified the negative impacts of inclement weather on decisions to commute by bicycle (Nankervis, 1999, p. 418). Climatic conditions, especially in winter countries of the northern hemisphere, can severely decrease decisions to bicycle for several months each year.

Wind is an obstacle to bicycling. Strong winds are common in Saskatoon, and can significantly increase the energy expended by cyclists. Wind also increases the negative effects of cold air temperatures. This can be countered by wearing appropriate protective cold-weather gear.

Cold winter temperatures correlate with decreased use of bicycles in Saskatoon and other Canadian cities during winter (Pucher and Buehler, 2005). A significant factor that separates

Canada from most European countries, where a majority of bicycle research originates, is its cold temperatures and snow. These conditions affect most Canadian cities for most of the year, creating obvious challenges for cyclists.

Considering the significance of winter weather, it is apparent that conducting research in the Canadian context is necessary. There are several unstudied variables pertaining to winter climates, which make it difficult to prescribe successful strategies to cope with such conditions for cyclists. The characteristics of northern city climates provide unique challenges and opportunities to bicycle transportation planners. Future studies should address problems associated with winter bicycling. Presently, however, it is assumed that most cyclists use other transport modes during winter.

Snow and ice are by-products of winter weather in Saskatoon. While auto traffic usually clears ruts along major routes, most cyclists prefer to travel along the shoulders of roadways, rather than in the same path where they may slow auto flow and disrupt traffic. A study by Doherty, et al. (2000) recognizes obstacles and hazards such as snow, ice, and other roadway debris affecting winter bicycle commuting in Toronto. A transportation survey of University of Saskatchewan students confirmed the correlation between winter weather and decreased bicycle commuter trips between home and campus (USSU, 2003). Furthermore, Nankervis (1999) documented negative impacts of inclement weather on decisions to commute by bicycle. Timely removal of snow and debris from road shoulders could encourage some cyclists to ride throughout the winter. Ice is also a major contributor to bicycle accidents (Doherty et al., 2000). Advancements in bicycle technology, such as spiked tire treads may alleviate this problem.

Undoubtedly, programs developed to support bicycling at the provincial and municipal levels have successfully increased levels of winter bicycling. For example, Montreal and Quebec City share a 1.3% level of work trips by bicycle, as opposed to Toronto, which only has a 0.8% share of bicycle work trips (Pucher and Buehler, 2005, p. 8). Provincial efforts to encourage bicycling through public information, events, and infrastructure-building in Quebec, versus virtually no provincial government commitment to such activities in Ontario appear to be working, despite an overall colder climate (and much colder winters) in Quebec City and Montreal (Pucher and Buehler, 2005, p. 8). An Internet search of current policy and planning documents on the Ontario Ministry of Transport's website revealed that public transit is heavily subsidised by the province, however no direct funding commitment toward bicycle programs or infrastructure was found (Ontario Ministry of Transportation, accessed 2005).

While winter and inclement weather considerations should be part of a comprehensive bicycle plan, the purpose of this thesis is not to explore solutions to these problems. Instead, it focuses on suburban neighbourhood design issues affecting bicyclists; specifically, bicycle-bus interactions/interchange. With this in mind, the study assumes ideal summer weather conditions, and acknowledges that most Saskatoon residents are not likely to use their bicycles during inclement weather and climatic periods. However, relatively cool and comfortable climatic conditions in summer make this season an excellent time for cyclists.

There are two major reasons for bicycling:

1. Recreation – bicycling for fun, fitness, and competition
2. Utility bicycling – bicycling for transportation, such as commuting to work, or running errands

Within these classes are demographics with varying user characteristics, motivations, values, and needs that must be considered in bicycle infrastructure design to accommodate each group appropriately. For example, very young or very old cyclists probably do not value bicycle routes to downtown offices, but may benefit from paths to local parks and schools. They probably are not as concerned with bicycle network directness and speed as they are about safety features, such as provision of separate bicycle paths that keep inexperienced young cyclists far from fast-moving traffic. On the other hand, young professionals, for example, who choose to ride their bicycles instead of driving an automobile, typically value direct and efficient routing that allows them to reach their destinations quickly (Sharples, 1999). These users are often confident riders who prefer to share the road with automobiles if doing so will allow them to reach their destinations faster. This research paper is primarily directed toward meeting the needs of the latter type of utility cyclist.

2.2.3. Efficiency

Efficiency encompasses the primary purpose of this paper – to find ways to shorten bicycle trip distance and time. This goal is achieved by optimizing the systems and environmental aspects affecting bicycle journeys – in essence, maximizing efficiency. The remaining sections in this chapter explore the relationships between urban form, bicycle policies and practices (including bicycle-bus integration), and accessibility.

2.2.4. The Problem with Suburban Bus Service

Bus loops within suburbs offer minimal coverage and frequency, and often do not offer direct service to destinations outside the suburban area they serve, such as to downtown or other major destinations within the city. For service to the central business district, riders must disembark at the edge of suburbia and wait for another bus to come. This transfer results in longer waiting periods and longer overall travel times. While most suburbanites avoid the bus by driving personal automobiles instead, this makes uneconomical bus service improvements to suburbs even more expensive, due to low usage. The outcome of improving quality of suburban bus service would likely divert funds away from other well-used routes and increased inequity for those without access to personal automobiles. The cyclic nature of this problem is illustrated in Figure 2.1. Limited public transit resources are stretched thin to provide service within increasingly sprawling suburban neighbourhoods where relatively few citizens use public transit. This reduces the resources available to serve core transit routes along major arteries throughout the city. Limited public transit service to suburbs is simultaneously both the cause and the effect of low usage of these routes.

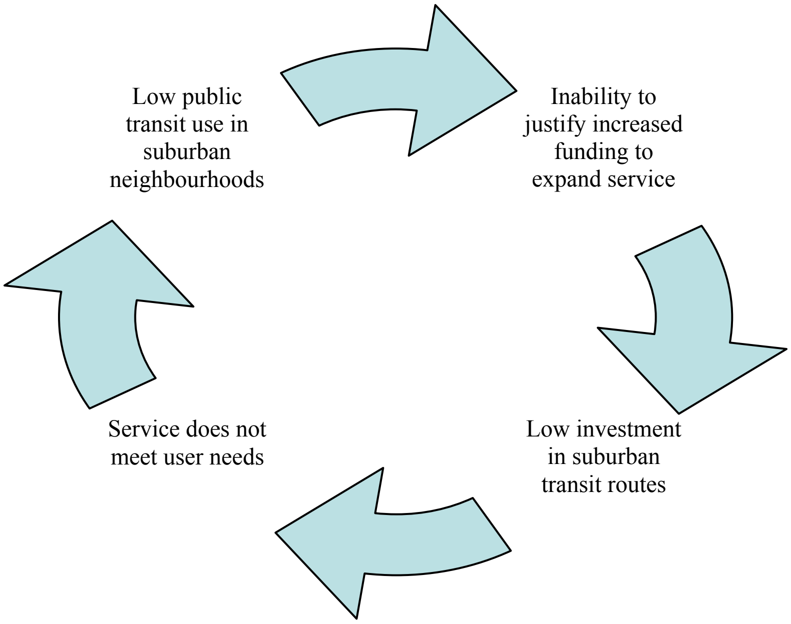

Figure 2.1. Typical suburban transit loop

For those suburbanites who rely on public transit, they may be better served if transit investments were diverted away from small neighbourhood-level routes toward major service route capacity and frequency. Cheap alternatives such as biking could be encouraged to reach transit hubs instead.

Using bicycles for suburban transportation. It is often suggested in the literature that bicycles are inherently less efficient than motorized transportation modes, and therefore impractical for non-recreational trips. Several authors assume that the characteristics of suburban design and land use in North America have made walking and bicycling impractical and led to automobile dependence among suburban residents (Kenworthy et al., 1999; Randall and Baetz, 2001). While it may not promote the use of non-motorized transport modes, this assertion is not completely accurate.

Piet Rietveld (2000a) proposed a new paradigm for studying transportation efficiency that makes it difficult to deny the usefulness of bicycles for utility trips. Rietveld (2000a; 2000b) explored the importance of bikes as access modes to transit in the Netherlands. He found that for trips of up to 3.5 kilometres, bicycles are efficient (i.e.,, cheap and reasonably fast) automobile alternatives. He suggested that bicycling is often more efficient than driving in cities, especially when used in combination with public transit (Rietveld, 2000a). Other research has confirmed the effectiveness of this concept, commonly referred to as multimodality.

Efficiency increases when bikes are used in conjunction with public transit because at both the start and end of the transit portion of the trip, a bicycle provides better range and closer parking opportunities than those available to automobile users (assuming that bicycle parking is provided). This is because auto trips typically start and end with walking trips from sometimes distant parking lots (Cleary, 2000; Replogle, 1992). Multimodal integration is especially effective when bicycles pair with public transport for longer trips (McClintock, 2000). Through integration of bicycling with other modes of transportation, access greatly improves for cyclists because the bicycle's suitability for shorter trips and public transit's suitability for regional express trips make the two modes complementary to one another (Replogle, 1992). If, for example, transit riders are typically willing to spend 10 minutes to access a bus stop, then bicycling at a conservative speed, rather than walking to transit, will increase the transit catchment area (i.e., the area that is served by the bus stop) by about ten-fold (TDM Encyclopedia, 2003). Bicycling may also improve public transit efficiency by allowing patrons to bypass low-frequency transit collector segments, thereby eliminating one or more walking segment and the wait linked to the corresponding bus segment.

Given the above considerations, the bicycle appears to hold advantages over walking and bus service when these modes are examined within the context of shorter trips made within suburban neighbourhoods. However, several factors play roles in determining transport modal efficiencies and mode choice. Trip distance, route directness, and travel time are the three variables that most influence the decision to bicycle or not (Hawthorne, 1989; Aultman-Hall, Roorda, and Baetz, 1997; Shriver, 1997; Randall and Baetz, 2001). However, aside from the physical obstacles, which decrease the competitiveness of the bicycle as a transport mode within suburban areas, modal choice is also influenced by innumerable psychological and sociological variables as well, which will not be reviewed in this paper. Needless to say, many people will never use a bicycle, no matter how much is done to support bicycling. It seems that North American suburbanites' dependence on cars may be as much a result of the same attitudinal, habitual, and sociological forces that led to the creation of automobile-oriented urban landscapes in the first place.

2.3. History of Urban Sprawl

2.3.1. Urban Growth Models

By examining how cities are organized, it is possible to gain insight into what factors influence their shape and composition, and how these influences might be controlled or altered to achieve desirable urban environments. Three main theories are commonly employed to describe the spatial arrangement of modern urban spaces:

1. Concentric Zone Model (Burgess, 1924) (Figure 2.2.)
2. Sector Model (Hoyt, 1939) (Figure 2.3.)
3. Multiple Nuclei Model (Harris and Ullman, 1945) (Figure 2.4.)

These theories are complementary to one another; each capturing a different aspect of urban evolution in American cities. They provide broad theories about how cities have grown and changed over the past century.

Burgess (1924) observed six major land use groups radiating outward from the centre of the city of Chicago:

1. The Central Business District (CBD) – The centre of the urban area that includes uses such as banks, theatres, museums, department stores, office buildings, restaurants and clubs.
2. Wholesaling – industrial, transport terminals such as ports and rail yards
3. A blighted area of slum dwellings – this occurs as CBD expansion infringes on the surrounding ring of low-income residential neighbourhoods
4. Middle-income industrial workers' residences
5. Upper income single-family residences
6. Upper income suburban commuters' residences

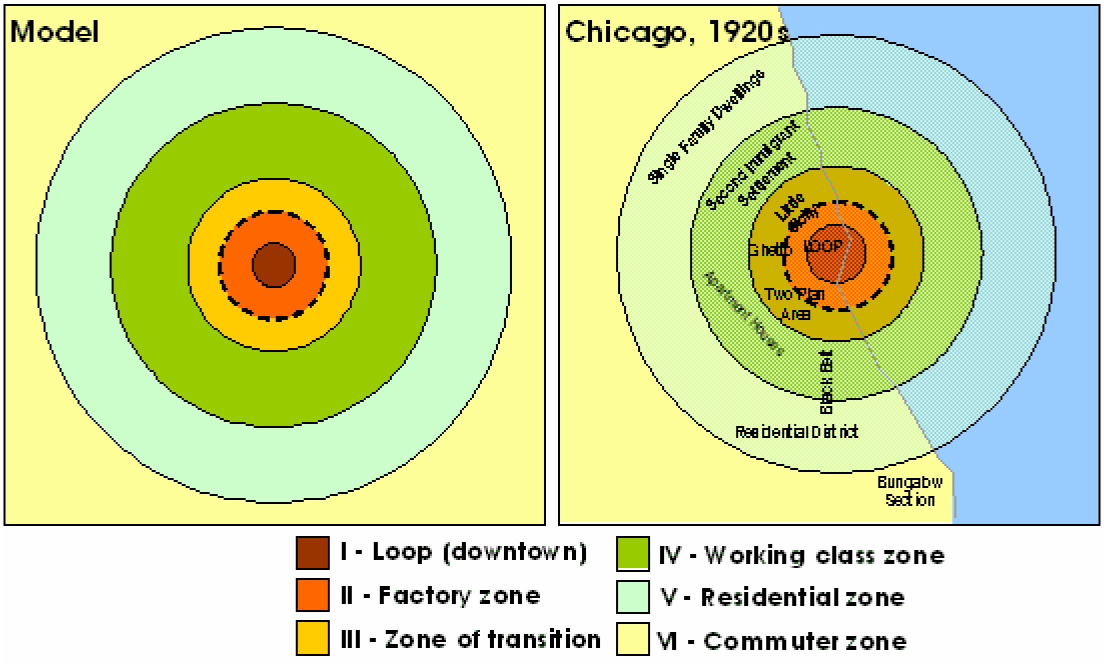

Figure 2.2. Burgess' Concentric Rings Growth Model (Source: Rodrigue, Comtois, and Slack, 2006)

Burgess further hypothesized that each ring of land-use expanded outward as the city grows, however their sequence remained intact. The resulting transition zones – areas where two land uses overlapped – led to an additional blighted zone outside of the ring of slum dwellings. He observed that, generally, the richer people are, the farther they live from the urban core (Burgess,1924).

Hoyt's (1939) Sector Theory deviated from Burgess' model by proposing that differentiation in land uses was not merely a result of the distance from the city core, but rather influenced by transportation axes. In other words, growth along a particular roadway is likely to consist of similar types of land uses. He perceived the city as a wheel, with the various land uses as spokes.

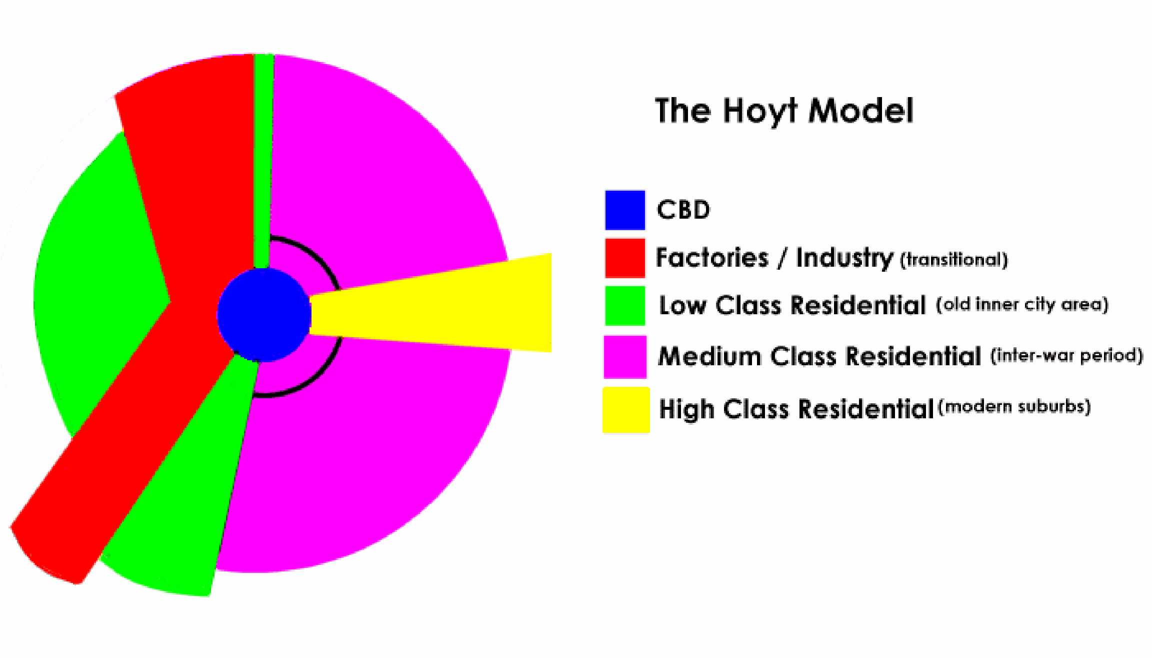

Figure 2.3. Hoyt's Sector Theory Model (Source: Learn on the Internet, 2002)

The urban model proposed by Harris and Ullman (1945) recognized that while cities typically have only one main centre, they are often surrounded by subcentres that serve as secondary business centres for localized residential neighbourhoods. These secondary centres may result because the CBD is not conveniently accessible to suburban residents. Another reason for satellite business districts may be that certain businesses cater to markets that are located away from the central core, and perhaps in a particular quadrant of the city. Typically subcentres occur for/in one or more of the following reasons/situations:

1. retail shopping centres to serve surrounding residential areas
2. junctions of major traffic arteries or transit routes
3. single large-scale unit (e.g. sports stadium)
4. formerly separate towns that have been swallowed by larger cities
5. special natural advantages of a site
6. near transport terminals to the outside world (e.g. airports)

(Harris and Ullman, 1945)

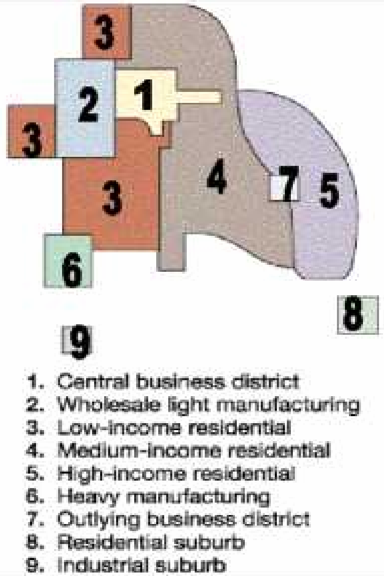

Figure 2.4. Multiple Nuclei Model (Source: York University, 2006)

A few trends are common to all three models. Wealthier residents live farthest from the CBD and manufacturing sectors. The order of sectors remains consistent throughout all three models. The most significant changes in urban form over the past century have undoubtedly resulted from widespread availability of automobiles. Major roadways have replaced trolley lines as facilitators for sectorization of urban areas. Another result of increased radial roadway corridors is the increased range of commuters, allowing individuals to drive great distances between the CBD and their suburban homes. The expansion of residential suburbs has led to the need for new satellite business districts to replace the CBD for suburbanites who live so far from the city's core that it is no longer feasible to make regular trips there.

The impact of sprawling city growth patterns can be spatially quantified by calculating how much area in square units a city is expanding. Using the equation:

$$\Pi R^2 - \Pi r^2 \text{ or } \Pi(R^2-r^2) = \Pi(R-r)(R+r) \qquad (2.1.)$$

Where: r = radius of existing urban area

R = radius of expanded urban area,

The exponential effect of radiating urban growth pattern is apparent (Figure 2.5).

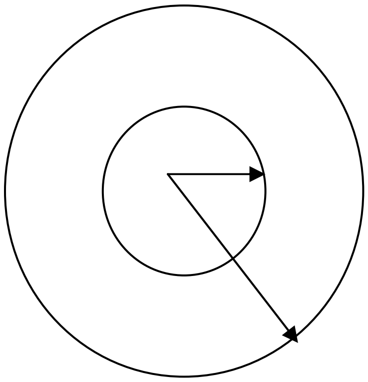

Figure 2.5. Exponential Nature of Suburban Growth

2.3.2. The Rise of Contemporary Neighbourhood Design Practices: From a “Garden City” to a “Car Culture”

In the late 1800s, Ebeneizer Howard began developing a design for the “Garden City” - a radially orientated plan that included a central garden, surrounded by rings of houses, then commercial and industrial uses, and finally vast agricultural lands – in response to increasingly negative effects resulting from intermingled industrial and residential uses (see Figure 2.6.). In North America, Howard’s vision was followed by that of Clarence Stein’s and Henry Wright’s. Together, they developed the first planned community of Radburn, New Jersey in 1929. The plan introduced the "super-block" concept, using cul-de-sacs, interior parklands, and separation of vehicular and pedestrian/bicycle traffic to promote safety by providing a car-free greenway network that connected residents to schools and other daily needs (Radburn, 2005).

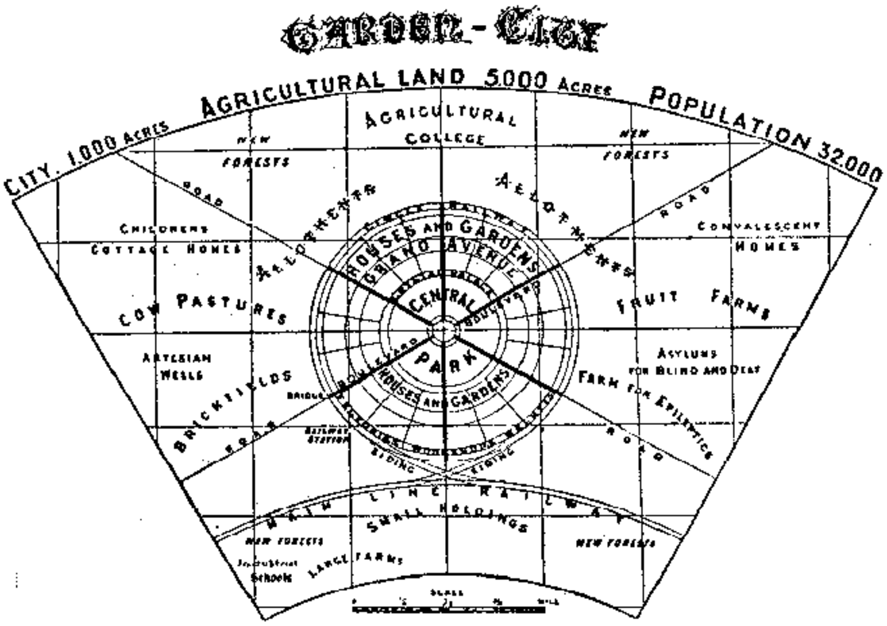

Figure 2.6. Garden City Diagram (Source: Howard, 1902)

Ironically, while these pioneers' concepts were designed to improve quality of life, their applications, combined with changes in transportation technology, have been distorted to the detriment of today's citizens. Cul-de-sacs and land-use separation remain common in today's residential subdivisions, however, the notion of providing separate pedestrian/bicycle networks have been widely abandoned practices in conventional developments.

Light rail, followed by the automobile age made us less concerned with spatial proximity of services, and efficient, high-density land use practices disappeared as newfound mobility made cheap land on urban fringes more accessible and practical. Finally, roads replaced tracks for more flexible and convenient private cars, with little thought for the future costs of building, maintaining, and fuelling this system.

2.3.2.1. The rise of the suburbs

The federal governments of both Canada and the USA actively supported suburban neighbourhood patterns. Ironically, in the United States, the desire for solitude and love of nature espoused by authors like Henry David Thoreau are thought to have inspired many Americans to move out of increasingly crowded, noisy, and dirty cities to the suburbs even before automobiles were widely available. These early commuters used street cars and trains to make their daily journey to the city around 1900. Racism has been blamed for increasing this trend as segregation laws were repealed in the 1950s. Many white families moved out of cities to avoid sharing schools with inner city blacks (Fishman, 1987). Aside from these value-based motives, a number of economic conditions made suburban living possible.

As perceived by Burgess, high per-capita wealth among a large middle class population, combined with cheap rural land, inexpensive transport, cheap housing, and government subsidies have made it possible for Americans to afford wasting the enormous amount of resources required to live in sprawling suburbs. Land is cheap because it is plentiful – especially at the urban fringe. Automobiles are cheap because they can be mass produced on assembly lines. Fuel was cheap because it was plentiful and easily extracted. Homes are cheap because they are framed with lumber, which is plentiful and cheap in America. Governments play a significant role in making sprawl economical. The United States federal government allows mortgages and property taxes to be deducted from taxable income. Additionally, local governments typically pay for the extension of sewers, roadways, and other utilities to suburban subdivisions, spreading the cost among all taxpayers rather than having the developers or suburban home buyers bear the burden (Jackson, 1985).

> Since the end of World War II, the American Dream has been defined as a house in the suburbs and two cars in the driveway. Sparked by a series of federal and state government policies, including home buying subsidies provided by the GI Bill, massive road building projects and community planning designed around the car, Americans abandoned the cities for greener pastures in suburbia. It is clear that public spending can, and does, affect private decisions about where to live, where to work, and where to build. (US EPA, 2006)

In Canada, the Canada Mortgage and Housing Corporation (CMHC) vigorously promoted Radburn-style subdivision designs during post-World War II rebuilding efforts. Examples include the Montreal and Verdun subdivisions of Cite Jardin and Crawford Park. The CMHC pushed municipalities across the nation to adopt planning and zoning by threatening not to approve mortgage lending (CIP, 2006) The CMHC's powerful influence on municipalities and developers, and its strong support for low density, car-oriented residential development standards during the post-War period resulted in an institutionalisation of residential subdivision patterns that continues to dominate the housing market today, despite its recent backing of higher density and more accessible designs (CMHC, 2002).

A “car culture” now dominates most North American cities. Current concerns over sustainability, and the degradation of quality of life resulting from automobile-oriented urban design, have spurred a growing number of researchers and planners to address the issue. As suburbanization increases, so does reliance on automobiles. Increased car use leads to more pollution, congestion, and the physical and social degradation of cities as a result of high economic, environmental, and health costs.

Given the existing sprawl of modern cities, there is little doubt that mobility is essential in the daily life of all urbanites. Even in the densest urban environments (e.g. Manhattan Island, New York City) NMT modes are not likely to meet all transportation needs. Sometimes subway, bus, or other motorised options are needed to practically reach destinations. It is generally assumed that residents of suburbs, where densities are ten times lower than vertically oriented downtown cores, need personal automobiles to meet daily transportation needs. While it may be true that the automobile is the most convenient and time-efficient transport mode for most longer trips, there are other viable alternatives to owning and driving a car for virtually all trips originating from suburban neighbourhoods. By budgeting time, using ingenuity, and coordinating modes, most able-bodied people can find reasonable ways to meet their transportation needs without using cars. The real problem is not that we are dependent, but rather that we are addicted or unwilling to change our habits. Car dependence is as much a sociological problem as it is a physical problem resulting from the built environment and systems that this culture has produced. This can be seen more clearly by looking at other cultures and seeing that economies can function with drastically less car use than in North America.

2.3.2.2. Suburban design impacts on transit and NMT

Urban form in North American cities is a challenge to bicycle use (Banister, 1999; Fraker, Marckel, Tambornino, and Lambert, 1994; Smith, Whitelegg, and Williams, 1998). It plays a vital role in determining not only cyclists’ routes, but also the decision to cycle in the first place. Trip distance and travel time, two factors directly influenced by urban form, are the most important components to utility cyclists’ route choices, and help to explain why bicycling is so much more popular in many densely developed European cities over sprawling and poorly connected North American cities of comparable population (Sharples, 1999). The main difference between North America and the rest of the world’s urban form is density of development. Cities in other parts of the world are typically denser than North American cities, because there is less available land for development, and less money and resources to support such inefficient development patterns. Horizontally oriented cities such as Calgary contrast this compact urban form. The result of sprawling cities is increased travel distances between nodes (i.e.,, destinations), greater spending on infrastructure to accommodate continuing neighbourhood expansion, and increasing congestion during peak commuter hours due to increased reliance on automobiles for mobility (Jain and Guiver, 2001). A recent study suggests that when people move from low-density urban areas to dense urban environments, they reduce their automobile trips by about 25% (Bento, Cropper, Mobarak, and Vinha, 2006).

Sustainable urban design is central to encouraging (or not discouraging) the use of NMT modes. Characteristics such as density of development, and availability of safe, attractive, and direct routing for non-motorized transportation users is vital to the adoption of these modes for utility and commuter trips (Banister, 1999; Lee and Stabin-Nesmith, 2001). North American suburban neighbourhood designs currently discriminate against non-motorized users, favouring cars instead. Walled communities, wide roadways with no sidewalks along them, large single-family dwellings situated in vast yards, and circuitous (i.e.,, winding, indirect) street designs, result in sprawling neighbourhoods that discourage NMT modes. These factors make NMT travel within the neighbourhood inefficient. They also add to the time spent on longer urban trips to destinations outside the suburbs; for example, bus trips to the city centre.

The spatial configuration of these suburbs thwarts efficient bus service to suburban neighbourhoods. While reasonably good service is available to major urban destinations from bus nodes at major suburban shopping hubs, access from the suburban dwellings they serve is often poor. All transportation modes suffer from this poor network, however, those users without access to private automobiles have less ability to reach distant modes, and thus suffer most. Simply put, non-motorized modes are unable to stretch as far as those aided by the flexibility afforded by on-demand motorized vehicles (Talen, 2003).

2.3.3. Land Use Factors Affecting Access

Access (or “accessibility”) is defined as the ability to reach a destination) is affected by factors such as time, monetary cost, discomfort, and risk associated with reaching a destination. High density and permeable land use patterns can shorten travel distances, thereby improving the feasibility of using non-motorized transportation modes which are more limited by long distances than modes such as automobiles (Litman, 2005).

2.3.3.1. Road network patterns

Accessibility is significantly affected by the directness of available transportation networks. As mentioned above, NMT modes are affected more by increased travel distances than are automobiles. Typical modern roadway networks are called hierarchical because they are composed of different classes of roads, each designed for different capacities and with different purposes in mind (see Table 2.1.).

Table 2.1. Hierarchical Functional Classification of Transportation Network

Classification	Function
Arterials	Major thoroughfare; high traffic speed and volume
Collectors	Moderate speed and volume; feed arterials
Local or Residential	Slow speed, low volume residential access
Lanes or Alleys	Access to public utilities and parking
Walkways	Pedestrian sidewalks and pathways

Grid street networks are the traditional arrangement for older, traditional cities, and are named for their grid-like pattern. Hierarchical street networks are organized as follows. Local roads channel traffic to minor roads (collectors), which in turn channel traffic to major roads (arterials). Local roads are narrower, and designed for slower traffic speeds than arterials. Arterials are wider, faster, and have fewer connections than collectors and local roads. Hierarchical road systems do not provide direct connections between minor roads, so most trips require travel on an arterial. This lack of connectivity, combined with increased congestion on higher roadway classes (i.e., collectors and arterials), and wide, high-speed, high-volume traffic corridors, degrades conditions for NMT modes. Grid street systems are more connected than hierarchical systems. This arrangement has fewer wide arterial roadways, and lower traffic speeds. More intersections provide more direct travel to destinations (a concept referred to as permeability), which usually translates into shorter travel times. Lower traffic speeds tend not to delay bicyclists, but may increase cyclist and pedestrian safety. Figures 2.7 and 2.8 represent extreme contrasts in permeability of street designs. While the traditional grid pattern illustrated in Figure 2.7 represents the most permeable network configuration (typical of older neighbourhoods), Figure 2.8 shows a contemporary example where connectivity and accessibility are ignored in favour of a hierarchical street network with many dead end cul-de-sacs.

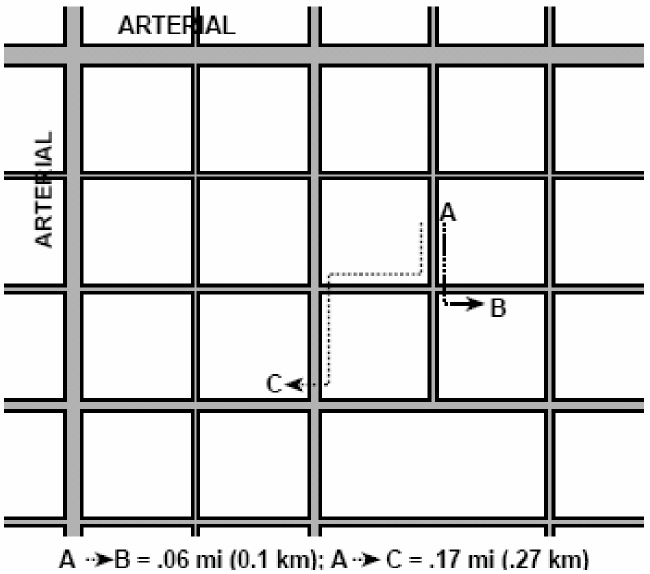

Figure 2.7. Well-connected grid street design (Source: ODOT, 1995, p. 66)

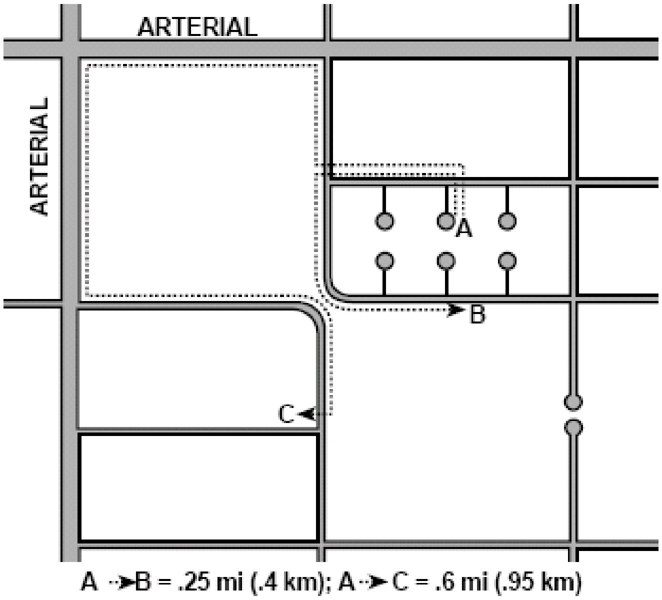

Figure 2.8. Poorly connected hierarchical street design (Source: ODOT, 1995, p. 66)

2.4. European Approaches to Sustainable Transportation Planning

In response to critical transportation issues faced by cities around the world, several studies have led to innovative solutions to the problem of sustainable transportation planning. Many successful transport plans currently promote bicycling and public transit as alternatives to driving. More research is being conducted toward sustainable transport practices in North American cities as urban transportation problems reach a critical point and planners realize that traditional "solutions" to traffic congestion (i.e.,, expanding roadway infrastructure) are no longer feasible. In the meantime, North Americans can learn a lot about sustainable solutions by looking to policies and programs used in other parts of the world. It is widely agreed among planners and scholars that successful transportation reform depends on a combination of both physical infrastructure *and* policy (Jones, 1989; Kraay, 1996; Louw and Maat, 1999; Mathers, 1999; Pucher, 1998; Wardman, Hatfield, and Page, 1997). Such approaches offer incentives to non-motorized users, and disincentives to automobile users.

Strategies involving either infrastructure improvements or policy encouragement to promote bicycling, but not both, typically fail. For example, the Redway Cycle Paths in Milton Keynes, U.K., provides an extensively linked bicycle network, segregated from automobile traffic. Despite its efficiency and convenience, negative public perceptions and a poor safety record on the pathway has stifled bicycle use (Franklin, 1999). The town of Milton Keynes also has an efficient automobile infrastructure, perhaps lessening bicycle use even further by providing similar ease and convenience incentives to motorists. The Milton Keynes project illustrates the failure of well-designed bicycle infrastructure to attract cyclists, in the absence of policy measures to limit automobile use, or encourage safe bicycling. Wardman et al., support this notion, stating that, "a wider programme of transport measures than just improving cycle facilities is required for a significant modal shift to cycling" (1997, p. 132).

This section identifies salient points found in articles and reviews of such policies and programs from three nations outside North America. Substantive examples of comprehensive sustainable transportation strategies, and reviews of such strategies, come from The Netherlands, Germany, and England, and are reviewed and compared to one another in the following paragraphs (Louw and Maat, 1999; Pucher, 1998; Jones, 1989). Like Milton Keyes, each of the following example programs relied on the provision of improved infrastructure for bicyclists. The crucial element present in the following examples, and missing in Milton Keynes, is the simultaneous implementation of disincentives to automobile users. Discouragements to motorists, such as access restrictions, taxes, and other user fees, combined with increased transportation infrastructure for bicyclists can successfully shift people out from their automobiles and onto their bicycles.

2.4.1. The Netherlands

An example of a winning transportation strategy is Enschede, Holland; a city with a population of 148,000 in 1999. Enschede's planners applied a transport package that combines incentives for non-motorized vehicles and disincentives for motorized vehicles. The focal point of these measures is the city centre. Main points of this plan include restricted car use in the downtown, encouragement of bicycling, and careful spatial consideration for new developments (Louw and Maat, 1999). Figure 2.9 illustrates the three-tiered automobile mitigation program that was adopted in Enschede's city centre, along with infrastructure, such as peripheral parking lots and commuter rail necessary to support access demands resulting from decreased auto traffic. The first and most restrictive zone, shown in black, is the "no car zone", where, as the name implies, only pedestrians and bicyclists are granted access. The second tier, shaded grey, allows only limited one-way access to automobiles on certain days and at certain times of the day. The third tier offers the least restraint to motorists, and contains opportunities for parking automobiles and accessing the downtown core on foot or by other non-motorized means.

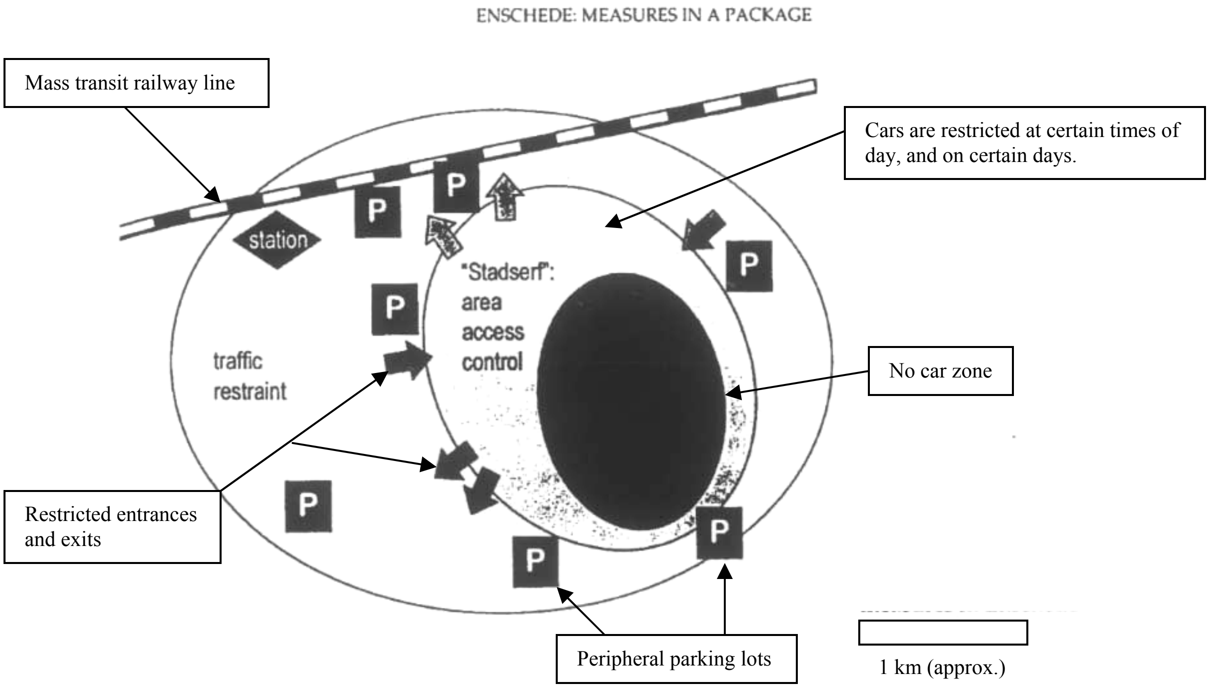

Figure 2.9. Increasing traffic control and restraint toward Enschede's city centre (Source: Louw and Maat, 1999)

Several improvements to bicycling conditions in the city, in combination with the automobile restrictions, helped to stop the trend of decreasing bicycle use and increasing car use. Bicycling incentives included significant infrastructure improvements. The provision of bicycle bypasses, priority at traffic lights, and traffic lights that stop car traffic twice in each light cycle to give cyclists a green light from all directions (see Photo 2.1), have improved the efficiency of bicycles, while delaying automobiles (Louw and Maat, 1999). Other infrastructure initiatives included the provision of secure and sheltered bicycle parking (financed by parking charges), addition of new cycle lanes (see Photo 2.2), and reconstruction of intersections to improve cyclist safety (Louw and Maat, 1999). The Enschede plan appears to have succeeded in halting the decrease in bicycle use in the city. It was first introduced in 1978, after bicycling traffic had decreased by 28% in the previous decade. Following the implementation of the combined plans, this trend reversed. The number of bicycle trips began to rise, while car trips declined (see Table 2.2). Table 2.2 highlights this trend.

Photo 2.1. Bicycle traffic signal (Source: Chicagoland Bicycle Federation, 2005)

Photo 2.2. On-street bicycle lane (Source: Ferndale, 2005)

Table 2.2. Modal split as a percentage of the amount of trips made by the residents of Enschede in 1987-1989, 1992-1994, and 1995

	1987-1989	1992-1994	1995
Car (driver + passenger)	51	44	42
Public transport	3	3	4
Bicycle and moped	31	38	38
Walking	14	14	17
Other	1	0	1
Total	100	100	100

(Source: Louw and Maat, 1999)

2.4.2. Germany

Despite being one of the most densely populated countries in Europe, Germans own more cars per capita than any other nation in the world, except the United States (Pucher, 1998). The practical social and environmental impacts of high automobile use in dense urban settings resulted in public policies designed to balance the benefits of private car use with these costs. As in the previous example of Enschede, Holland, the German approach aimed to limit car use in central areas, while expanding and improving public transport, pedestrian, and bicycling services and facilities. Table 2.3 demonstrates the clear trend toward increased automobile use for urban trips, while walking declined between 1972 and 1995 by 19 percent.

Table 2.3. Modal split trends for urban travel in West Germany, 1972-1995 (percentage of total urban trips by each mode)

	1972	1982	1995
Car (driver + passenger)	31	42	49
Public transport	17	17	16
Motorcycle or moped	3	1	1
Walking	41	30	22
Bicycle	8	10	12
Total	100	100	100

(Source: Adapted from Pucher, 1998, p. 291)

Pucher (1998) uses three cities as case studies, to provide examples of progressive transportation programs in Germany. They include Munich (population, 1,245,000 in 1995), Munster (population 270,000 in 1995), and Freiburg (population, 180,000 in 1995). After mass destruction of Freiburg and Munster during World War II bombing raids, these cities,

> …deliberately chose to preserve their historic layouts of narrow, winding streets, pedestrian passageways, and monumental squares in their old towns, thus ensuring the continued feasibility of walking and bicycling in their central districts…. The decision in all three of these cities to rebuild many destroyed structures and retain historic street patterns was probably the most important land-use policy they undertook and is certainly one reason for the success of public transport, bicycling and walking in the succeeding decades. (Pucher, 1998, p. 294)

This statement indicates the shifting paradigm of European urban planning philosophy in the past decade, which has resulted in German cities like Freiburg and Munster, demonstrating renewed appreciation for the value of streets that are designed for people, and not only cars.

Freiburg offers an excellent comparison to Saskatoon. Both cities have similar populations, and contain universities. Both provide public transit, and are faced with the challenges of providing service to suburban developments, however, the density of suburbs in Germany are much higher than in American cities, and much of the burden is relieved by extensive rail systems that link suburbs to city centres (Pucher, 1998, p. 297).

Convenience and affordability of regional public transit service has greatly improved in Freiburg due to new attractive fare structures, and coordination of services. Schedules of various public transport services are better coordinated, and tickets may be valid for multiple journey legs within a region, regardless of service provider or location (Pucher, 1998, p. 302).

Cars in Freiburg are increasingly restricted by policies intended to increase safety and efficiency to public transit users, pedestrians, and cyclists. For example, street networks with artificial dead ends and circuitous routing for cars, allow bicycles and pedestrians to pass through with ease. Other examples of measures restricting car use include bus lanes, bicycle lanes, car-free pedestrian zones, traffic calming, right-of-way priority and signal priority for non-car modes (Pucher, 1998, p. 305).

These improvements are costly to taxpayers. Germans pay nearly 4 times more, per capita, than Americans to subsidize public transit (Pucher, 1998, p. 303). They also collect more taxes from private automobile users, which is a direct financial deterrent to driving. Fuel taxes were 3 to 4 times higher in Germany than in the USA in 1995 (Pucher, 1998, p. 305). Vehicle excise tax is charged, with larger, more polluting motors receiving greater penalties. Despite the high taxes assessed to owners of private automobiles in Germany, roadway construction has slowed as a result of a new philosophy to channel car use rather than accommodate it. Although suburban development has led to some roadway improvements and increased capacity on key arteries outside the city centre, the opposite is true of inner city transportation networks, which have become havens for pedestrians and bicyclists, while shunning cars (Pucher, 1998, p. 306-307).

2.4.3. The United Kingdom

Oxford provides an example of a plan that has aimed to provide a fair and balanced approach to transportation planning. The strategy began with a series of policies intended to make the downtown core area more amicable for citizens not driving. The transport situation had deteriorated to the point that traditional traffic demand management methods of building more and bigger roads and parking areas were no longer financially possible. Initial policies aimed to redistribute the existing transportation network more equally between modes, recognising that pedestrians are highest priority, and car commuters the lowest. The main policies of Oxford's Balanced Transport Policy (Jones, 1989) include,

1. Giving more priority to buses by dedicating bus lanes and bus-only streets
2. Providing free park-and-ride sites at major entry points to the city, with frequent and cheap bus service to popular destinations
3. Providing segregated cycle routes, marked cycle lanes, and greater bicycle permeability in the downtown core area
4. Creating pedestrian-friendly areas by deterring cars from certain streets
5. Providing financial support for public transport, and free trips to pensioners outside of peak hours
6. Reductions in parking spaces, higher charges
7. Introducing loading bans on some streets during peak periods, and encouraging flexible work hours to spread peak travel demand
8. Continuing land-use policies that limit off-street private parking spaces in new developments.

(Jones, 1989)

These policies were relatively inexpensive to implement, and results have been generally positive. Since the strategy began in 1973, traffic flows have remained fairly constant, while increasing 17.5 per cent in the rest of the UK; bicycle use in the central area has more than doubled; bus use has declined less than the national average rate; and parking turnover has substantially increased in the central core, allowing more efficient use of spaces (Jones, 1989). The key to Oxford's success has been largely attributed to the flexibility of the cheap and easily implemented strategies, and also the complementary nature of its many parts. As in the Dutch and German strategies, Oxford's transport policy balances measures that discourage one transport mode with incentives and improved service to encourage other, more desirable modes. By providing a complete inventory of policies and infrastructure used by each of the examined European cities, Table 2.4 further emphasizes the importance of incorporating both bicycle incentives and car disincentives in successful mobility management strategies.

Table 2.4. Mobility management strategies by city

		City			
	Strategy	Milton Keynes	Enschede, Holland	Munich, Munster, and Freiburg, Germany	Oxford, U. K.
Bicycle (and bus) Incentives	Bicycle lanes		X	X	X
	Segregated bicycle path network	X			X
	Park-and-ride lots at urban entry points		X		X
	More frequent bus service			X	X
	Dedicated bus lanes			X	X
	More public transport service routes		X	X	
	Bicycle priority at traffic lights		X	X	
	Attractive public transport fare structures			X	X
	Expanded public transport, pedestrian, and bicycling services/facilities			X	
	Bicycle bypasses		X		
	Secure and sheltered bicycle parking		X		
	Intersection safety improvements		X		
	Extensive commuter rail system			X	
	Coordination of public transport services			X	
	Bus-only streets				X
	Improved bicycle permeability downtown				X
	Increased financial support for public transit				X
	Flexible work hours				X
Automobile Disincentives	Car-free districts		X	X	X
	Car-limited districts		X	X	X
	Increase cost of parking (toward city centre)			X	X
	Traffic calming street designs and devices			X	
	Restrict parking availability				X
	Restrict car permeability (while maintaining bicycle permeability)			X	
	Increased tax subsidies for public transit			X	
	Increased private automobile taxes			X	
	Increased fuel taxes			X	
	Excise tax for larger, more polluting vehicles			X	
	Maintain high development densities			X	
	Narrow, pedestrian-oriented street layout			X	
	Decreased road construction / expansion			X	

Note: Highlighted strategies are those that correspond to two or more programs.

Essentially, the governments of The Netherlands, Germany, and the U.K., agree that unnecessary car use must be curbed, and that the bicycle and public transit should be encouraged as alternatives (Kraay, 1996; Pucher, 1998; Wardman, et al., 1997). These countries have found a balanced approach, using both policies and infrastructure to discourage car use, while simultaneously encouraging bus, bicycle, and walking, is key to successful initiatives.

2.5. What have governments done to promote non-motorized transportation in Canada?

In Canada, non-motorized transportation policies are primarily handled by municipal governments. Provincial involvement and funding varies, with most provinces offering minimal support to bicycle programs. The federal government provides virtually no support for bicycling programs. Overall, bicycling promotion policies have employed many of the same techniques used in European countries, previously listed in this chapter.

2.5.1. Quebec

Quebec is the only province with strong involvement in bicycling promotion. The Province of Quebec undoubtedly provides more funding than any other province in Canada. Provincial support for the expansion of both off- and on-road bicycling facilities has been credited with more than doubling the number of cyclists in Quebec between 1987 and 2000 (Pucher and Buehler, 2005, p. 10). The province adopted an official Bicycle Policy in 1995, with its stated goal being to improve bicycling safety while increasing bicycle use for transport (Quebec Ministry of Transport, 2004 – in Pucher and Buehler, 2005). The province is achieving this goal by introducing uniform bikeway design and traffic control standards, and implementing mandatory bicycle accommodation on all provincial infrastructure and roadway projects. The provincial government pays for about half of all new bikeway projects by primarily funding bicycle facilities on provincial roads and offering matching grants for construction and maintenance projects in municipalities.

The Province of Quebec's focus on bicycle rights of way extends to provision of adequate bicycle parking facilities. Beyond this, however, there are few instances of infrastructure support by way of traffic calming, intermodal coordination, intersection modifications, or other facility improvements to assist cyclists. Instead, bicycle education and promotion programs appear to be the second major component to Quebec's bicycle promotion campaign. The Societe d'Assurance Automovile du Quebec (SAAQ, 2004) provides free bicycle safety information to schools, and works with police, motorists, and bicyclists to encourage adherence to traffic laws. Additionally, a private non-profit organization called Velo Quebec sponsors special events such as bicycle-to-work week, organized bicycle rides and tours. They also publish a magazine and provide online event listings and bicycling resources (Pucher and Buehler, 2005, p. 10-11).

2.5.2. Ontario

Ontario provides virtually no support (Pucher and Buehler, 2005, p. 19). Only two bicycling publications appear on the Ontario Ministry of Transportation's website (Ontario Ministry of Transportation, 2004); one entitled <u>Cycling Skills</u>, and another titled <u>Youth Cyclist's Guide</u>. Both teach basic safety skills and rules of the road.

Despite the Province of Ontario's almost complete lack of funding to promote bicycling programs or facilities, the Cities of Toronto and Ottawa are very actively encouraging cyclists. Primary infrastructure initiatives in the two cities include on-street bicycle lanes, separate bicycle paths, and shared roadway route signage. Traffic calming devices, bicycle signals and detectors at controlled intersections, and bicycle parking facilities throughout the city, including racks on buses and at transit stations have been used to encourage commuter cyclists. City zoning and building ordinances have mandated provision of showers for bicyclists in large commercial developments. Programs provide incentives to companies that provide showers for employees who bicycle to work. Bicycle lending programs, bicycle-to-work weeks, bicycle rodeos and organized tours are commonly put on by both municipalities and several active private non-profit bicycling groups. Further educational efforts include safe bicycling training courses and information provided through brochures, advocacy group and city websites (City of Ottawa, 2001; City of Toronto, 2004).

2.5.3. British Columbia

The British Columbia provincial government provides limited funding for infrastructure improvements via a 50% matching program. (Pucher and Buehler, 2005, p. 19). It provides funding for some joint projects such as "Bicycle to Work Week".

Vancouver and Victoria both have extensive and expanding bicycle paths, lanes, and shared roadway bicycle routes. Traffic calming is prolific in these cities, as well as on-demand green lights and bicycle detector loops at several controlled intersections. Bikes are accommodated on all public transit vehicles, to varying degrees, and parking is provided at transit stations. Gas taxes are used to finance much of the bicycle infrastructure improvements in Vancouver. Bicycle route maps and educational materials and resources that provide safe and responsible bicycling tips are widely available in and around Victoria and Greater Vancouver (Translink, 2005; Capital Regional District, 2003).

Most bicycling initiatives occur at the local level through municipal government and public advocacy groups. Construction of local bicycle infrastructure, combined with educational initiatives has successfully increased both bicycle use and safety simultaneously. The result is that bicycling levels in Canadian cities are roughly three times greater than in comparably sized USA cities where advocacy is not as strong (Pucher and Buehler, 2005, p. 21). There are still many challenges to be tackled in the area of sustainable transportation, including the following:

- Lack of restrictive measures for cars
- Increasing sprawl and poor coordination with public transport
- Piecemeal bikeway networks
- Lack of federal and provincial government support (Pucher and Buehler, 2005, p. 22)

2.5.4. Saskatoon

The City of Saskatoon Development Plan stated that the "establishment and enhancement of bicycling routes to the Downtown, and the promotion of bicycling as a viable means of transportation to the Downtown, shall be an on-going objective of the City of Saskatoon." (City of Saskatoon, 2001, p. 23).

The City of Saskatoon commissioned a study to identify local bicycling transport needs, and to develop a utility bicycling network plan for the entire city. The result is an economical system of bicycle routes that is scheduled for completion of the majority of improvements by 2009. On-road facilities make up 85% of the total network, since most roadways in the network are sufficiently wide to accommodate shared use of automobiles and bikes. The goal is to serve the University of Saskatchewan, SIAST/Kelsey, and Downtown, and to provide network access within one kilometre of all Saskatoon residents (City of Saskatoon, 2003).

Other Saskatoon bicycle initiatives include the following educational publications, and research to help identify bicycle needs and bicycle-bus integration opportunities:

- **Brochures**: "Bicycle Parking Facilities", "Cycling in Saskatoon: Quick tips for getting around the city by bicycle", "Share the Road: Information for Drivers and Cyclists".

These brochures are meant to promote bicycling by informing citizens of locations of bicycle-friendly routes and infrastructure, and by encouraging a better relationship between cyclists and motorists by teaching proper road-sharing procedures.

- **1999 City Transit Survey** (Tranplan Associates, 1999, in U of S Sustainability Assessment, 2002): This survey was commissioned to help determine citizen transportation trends and needs to be used for transit service planning. It found that 40-50% of students in Varsity View, Nutana, Grosvenor Park, and City Park walk or cycle to school, except in bad weather.

- The **2002 USSU Transportation Survey**, conducted as part of the University of Saskatchewan Sustainability Assessment, aimed to determine how people were accessing the campus and use this information to develop strategies to promote sustainable alternatives to single occupancy vehicle travel. They found that 8% of respondents used bikes as their primary access mode to reach campus.

Overall, Saskatoon has the second highest per capita bicycle use for work trips of any city in Canada, with 2.5% of "modal split" (i.e., the division of travel into the various transportation modes), behind Victoria, which boasts a bicycle share of 4.8% (Pucher and Buehler, 2005). Some of the factors that may contribute to the relatively high bicycle share in Saskatoon are that it is, for the most part, devoid of topographic obstacles, much of the city consists of a highly permeable grid street network, relatively low annual precipitation, and the presence of a high number of university students.

2.6. Accessibility

2.6.1. Determinants of Accessibility

A key determinant of the potential for bikes to provide effective transit access that improves overall transit chain quality is accessibility. There are various interpretations of accessibility, however it is generally defined as a reflection of the ease of reaching needed or desired activities, and thus reflects characteristics of both the land use system (where activities are located) and the transportation system (how the locations of activities are linked) (Handy and Clifton, 2001). Land use is defined by the geographic distribution of activities and destinations. Accessibility is reduced where land uses are more homogeneous and dispersed from one another because this typically increases the mobility required to cover greater distances between destinations. The level of mobility available becomes an increasingly important factor where land uses are segregated. Since, for example, a motorist has the ability to travel much farther, faster, and with greater ease than a pedestrian, many more destination opportunities exist for motorists that are not practical for pedestrians. The level of transportation system connectivity, which refers to the directness and density of connections within a transport network, can significantly increase or decrease accessibility by making available routes to destinations either shorter or longer. When travel distances are shortened, transport modes such as walking and bicycling become more viable, thus increasing accessibility for individuals who may not have access to more expensive transport modes such as personal automobiles. Clustering activities can also improve accessibility by reducing the number of trips between destinations. These accessibility factors are summed up in terms of costs and benefits in the following points:

- **Spatial distribution of potential destinations**: More time and money spent getting to a destination translates into lower accessibility, since these costs eventually outweigh the benefit of accessing a potential destination. Time and money expenditure usually increase with greater trip distances. Travel distance and time are directly affected by the available transportation network, as well as factors such as congestion and design speed of the network. Less time and money spent = increased accessibility.

- **Ease of reaching each destination**: Variety of modes available for getting to a desired destination. More ways to get there = greater accessibility.

- **Magnitude, quality, and character of activities found at a destination**: Increased concentration of destinations means greater chance to avoid multiple trips, leading to less need for transportation. More destinations and more variety of modes available = greater accessibility.

(Handy and Niemeier (1997)

2.6.2. Measuring Accessibility in terms of Transportation

Since the focus of this paper is to determine access efficiency as it relates to transport mode choices, the accessibility measures employed must reflect this central theme of transportation. There are three main measurement types used to evaluate how particular decisions or activities affect accessibility. Each evaluation method makes an assumption about what benefits consumers, and measures the corresponding unit of that particular characteristic to determine how a particular decision or activity affects accessibility.

2.6.2.1. “Traffic-based” measures

Standard transportation modeling and evaluation methods seek to understand issues such as how land use changes affect automobiles. These are called “traffic-based” measurements (TDM Encyclopedia, 2005). They use factors such as the number of miles travelled, and assume maximum motor vehicle travel and speeds to determine transportation. Since bicycle travel speeds are restricted by the physical abilities of the human powering them rather than merely the maximum design speed of the roadway, this technique is not appropriate for evaluating cyclists' transportation network accommodation and needs.

2.6.2.2. "Mobility-based" Measures

Similarly, "mobility-based" techniques measure movement of people and goods, correlating transportation improvements with greater movement volumes. Like traffic-based models, this method tends to treat mobility as an end in itself. Unlike traffic-based measures, which ignore land use impacts on travel decisions, mobility-based measures recognize that land use can affect travel choice. For the most part, both of these types of measures tend to focus on the maximum capacity and travel speed that the transportation network can accommodate. These ideas are often irrelevant to NMT modes, since user limitations, such as limited range and slow speed capabilities make them unable to take advantage of many improvements that may positively affect automobile accessibility. For example, a roadway with 60 km/h design capablilities may be able to accommodate fewer automobiles per hour than and one that is designed to accommodate 80 km/h traffic, but the difference is meaningless to cyclists who not capable of sustaining travel speeds of 30 km/h. Apparently, some of the factors that affect bicyclists are very different from those that impact motorists (TDM Encyclopedia, 2005).

2.6.2.3. "Access-based" Measures

"Access-based" measures consider maximum transport choice and generalized cost efficiency to be the main factors that benefit accessibility. While these factors benefit automobile users, they are especially relevant to NMT modes. These types of measures place value on the ability to obtain goods, services and activities, rather than merely being able to travel long distances at high speeds. Since NMT users are sensitive to travel distances, examining the transportation environment with an eye toward minimising distances to desirable destinations will likely have the most beneficial impact on them. Access-based measures are more difficult to measure than mobility-based measures because several factors affect them, however, the broader premise of access – the ability to reach a destination – shifts the focus from movement to instead look at generalized costs. Access-based measures assume that maximum transport choice and cost efficiency is the key to good access. This notion can be applied to all transport options, but is especially relevant to NMT modes since they are most impacted by the efficiency of transport networks (TDM Encyclopedia, 2005).

2.6.2.4. Common Access-based Measurement Approaches

Access-based measures vary greatly and require a wide assortment of techniques depending on research goals of the research and availability of data. Handy and Niemeier (1997) identify three main types of accessibility measures. Each type of measure has a transportation element and an activity element. Time is implicit to access. Factors such as transportation network configuration, which affects the distance one must travel to reach a destination, and available transport modes which affect the speed of travel and what transportation networks can be used, all impact accessibility.

Cumulative opportunities measures. These measures indicate the range of destination choices available, based on the number of opportunities (i.e., potential destinations) within a particular travel time or distance. The emphasis of this measure is on the number of potential destinations (opportunities) that fall within the cutoff time, and not their distances. All potential destinations that fall within the cutoff time are equally weighted. Thus the number of opportunities within a specified time range is used to indicate accessibility in terms of the range of choice available. Many researchers have used this approach (for example, McKenzie 1984; Sherman, Barber, Kondo, 1974; Wachs and Kumagai, 1973; and Wickstrom, 1971). The cumulative opportunities measure is a type of gravity-based measure, described below.

Gravity-based measures. Gravity-based measures predict the amount of activity at different destinations based on the cost, time, or distance required to get there (i.e., level of impedance). Destinations that are closer and larger (e.g. having more shops in a single location) are considered more accessible than those that are farther away and encompass fewer opportunities. The formula must be adjusted to account for changes in urban structures, opportunities, people’s desires and abilities, which affect the distance decay or impedance function.

Random utility theory. This measure estimates that the probability of an individual making one travel choice over another is dependent on the relative utility of that choice in relation to all other choices. The model assumes that the decision-maker will select a destination, and mode to reach that destination, based on the relative utility of all available destinations and modes. The assumptions that the analyst builds into the model must accurately reflect the choices that the study decision-maker will make for the result to be of any value. The following decision-making variables are often factored into random utility models that attempt to predict travel behaviour:

- destination attractiveness
- travel impedance to reaching the destination
- socio-economic characteristics of the individual or household, from which individual preferences are inferred

2.6.2.5. Discussion of access-based measurement approaches

Aggregate versus disaggregate measures. These three types of measures described above are considered to be aggregate in nature, meaning they require input of several different types of data to produce a single result that indicates the range of destination choices (cumulative opportunities), amount of activity (gravity-based), or likelihood of an individual to access particular destinations (random utility). The types of data incorporated into these methods include several individual pieces of data, both quantitative (e.g. definition of the origin and destination), and qualitative (e.g. measurement of attractiveness of a route). When these data are combined into a formula that produces in a single result, the individual significance of each piece of data within the formula is lost. According to Handy and Clifton (2001, p. 69), "[t]raditional measures of accessibility may help planners identify neighbourhoods with relatively high or low accessibility, but they do not, on their own, point to the specific factors contributing to accessibility." In other words, aggregate methods that incorporate multiple data sets into a single equation tend to produce results that are difficult to decipher, and the direct impacts of specific data may be impossible to extract using these types of methods (Handy and Clifton, 2001). This limits the usefulness of the above-described accessibility models to providing generalized results for an entire region such as a city. The aggregate methods do not contain the level of data detail needed to make specific accessibility conclusions regarding smaller localized areas such as neighbourhoods within larger study area (Kockelman, 1997). (see Table 2.5.)

Table 2.5. Aggregate vs. disaggregate

Accessibility measure type	Resulting data
Aggregate	Regional-level; generalized
Disaggregate	Local-level; detailed

Furthermore, existing aggregate models are based on those designed to study automobiles, and require more research and development to become well suited for bicycle trip studies. Factors such as comfort and speed, which can be affected by aspects such as weather, terrain, and physical condition of the cyclist, are not major concerns among automobile users – since they are protected from these elements – and therefore are not accounted for in automobile-oriented models. In contrast, methods available for automobiles mainly rely on speed and distance to calculate likelihood of motorists' route choices. While utility cyclists are mainly concerned with the same factors, more research must be done to understand other issues unique to cyclists such as the effects of weather and temperature, and bicycle usage data including flows, journey purposes, and time-related data – essentially more knowledge is required about how bicyclists behave (Sharples, 1999).

Qualitative data. In order to evaluate accessibility for specific roadway segments within a small area such as a neighbourhood, physical field surveys are used. When measuring accessibility at the neighbourhood level, qualitative data may be used to provide researchers with a better understanding of what components of the physical environment have the most impact on bicycle use. Qualitative factors are most often associated with assessing non-motorized accessibility since these modes are vulnerable to more environmental factors such as weather, topography, and distance (Handy and Clifton, 2001).

The Federal Highway Administration (FHA), a division of the United States Department of Transportation, developed the Bicycle Compatibility Index (BCI) to "evaluate the capability of specific roadways to accommodate both motorists and bicyclists" (FHA, 1999, p. 2). The index measures eight geometric and operational conditions to predict how comfortable a bicyclist would feel on a segment of roadway. These conditions were selected based on a study of more than 200 bicyclists in which the cyclists viewed video footage of 80 unique roadway segments, and rated each on a 6-point scale with respect to how comfortable they would feel riding there. The eight conditions are thought to account for 89 percent of the variance in comfort level of bicyclists (FHA, 1999). The resulting formula for calculating BCI is as follows:

Where:

1. BL = presence of a bicycle lane (no = 0; yes = 1)
2. BLW = bicycle lane or paved shoulder width (metres, to the nearest 10th)
3. CLW = curb lane width (metres, to the nearest 10th)

4. CLV = curb lane volume (vph/h in one direction)
5. OLV = other lane(s) volume (vph/h)
6. SPD = 85th percentile speed of traffic (km/h)
7. PKG = presence of a parking lane with more than 30 percent occupancy (no = 0; yes = 1)
8. AREA = type of roadside development (residential = 1; other = 0)

$$\mathrm{BCI} = 3.67 - 0.966\mathrm{BL} - 0.410\mathrm{BLW} - 0.498\mathrm{CLW} + 0.002\mathrm{CLV} + 0.0004\mathrm{OLV} + 0.022\mathrm{SPD} + 0.506\mathrm{PKG} \div 0.264\mathrm{AREA} \tag{2.2.}$$

While the eight conditions used in the BCI model are quantitative in nature, their weighted values are determined based on subjective input of the study participants. The qualitative premise of the BCI method is viewed with scepticism by some researchers. According to Handy and Clifton (2001, p. 73),

> …data on qualitative and subjective factors are scarce… and furthermore… the accuracy and stability of the observations are often questionable. Simple quantitative measures may be combined with qualitative evaluations to provide a much richer understanding of the accessibility characteristics of a community than may be possible with even very complex qualitative measures.
>
> (Handy and Niemeier, 1997)

2.6.2.6. Talen's (2003) Methodological Framework

Talen (2003) established a practical implementation procedure for studying the neighbourhood as a locale for the delivery of urban services. Talen's (2003) methodological framework for assessing neighbourhood accessibility is a basic approach for local planning departments to use for evaluating access to services, specifically designed to focus on the impacts of neighbourhood design characteristics from the perspective of non-motorized modes such as pedestrians and bicyclists. This, combined with the flexible characteristics of her framework, makes it a good starting point for developing a methodology to examine the potential of bicycles in North American suburbs. Talen's methodology provides several alternatives to the researcher, enabling the model to be applied to many types of studies. It accommodates use of both quantitative and qualitative accessibility measures, and is easily modified to fit a variety of test conditions and goals. Her framework can be used to study access at an urban level (i.e., between neighbourhoods) and neighbourhood level (i.e., within a single neighbourhood).

Talen proposes five methodological steps. Within each step is a task, and within each task is a series of alternatives that must be selected to shape the decision framework to meet the goals of a specific study. These options provide a model for customizing a methodology for neighbourhood-level accessibility assessments, based on the unique goals of the research. Table 2.6 summarizes Talen's five-step methodological framework. Each step is then discussed within the context of the objectives of this research.

Table 2.6. Talen's methodological steps

Step	Main Task	Decision framework
1	Determine purpose of accessibility analysis	Neighbourhood focus Regional focus
2	Select type of measurement and obtain relevant data	Origins Destinations Route characteristics
3	Compute distances	Street network Geometrics (dimensional characteristics)
4	Compute access measure	Nearest distance Total distance
5	Perform analysis	Citywide access Intraurban variation Targeted access

(Source: Talen, 2003)

Step 1.

The **first step** is to define the purpose of the accessibility analysis and define the scope of the study area. The purpose of this study is to determine whether bicycles could potentially be used as viable and competitive transportation options within suburban neighbourhoods, to access regional transit nodes. This purpose is accomplished by determining the relative efficiencies of available transport network routes and transport modes. In accessibility studies where non-motorized transportation (NMT) is examined, the range of modes such as bicycle and pedestrian warrant a smaller focus area. Since it is already known that cars and other motorized modes are more competitive as trips become longer (e.g., in larger regional focus areas), and because the goal of the study specifically targets neighbourhood transport networks, a "neighbourhood focus" is selected as the study's scope.

Step	**Main Task**	**Decision framework**
1	Determine purpose of accessibility analysis	Neighbourhood focus Regional focus

Step 2.

The second step involves collecting basic data needed to conduct the study. Since this study's goal is to determine relative route and mode efficiencies, first start (origin) and end (destination) points must be identified, and then available route characteristics – specifically those that impact access efficiencies – between these points must be assessed. These data include the following:

1. **Origins** – starting points, simulating typical distributions of residents in outlying suburban neighbourhoods,

2. **Destinations** – end point; in this case, a single destination (since the destination is a suburban transit hub), and

3. **Route characteristics** – factors between origins and destination that affect accessibility, or level of service of any given transportation mode.

Step	**Main Task**	**Decision framework**
2	Select type of measurement and obtain relevant data	Origins Destinations Route characteristics

Beyond origin, destination, and route characteristics data, the researcher must select the types of measurement that best suit the purpose of the study. Talen offers a variety of access measurement variations (see Table 2.7) from which those relevant to this study have been highlighted. Particularly the “type” of location (regarding origins and destinations) refers to whether these locations are points (e.g. individual housing units), or centroids of larger geographic units (e.g. blocks, block groups, or tracts).

The evaluation goal is to assess the urban spatial pattern’s impacts on transport modes, for which distance is the primary factor. Another component of this study is to directly compare bicycle versus bus efficiencies. These research goals make specific points of origin and destination necessary. Since bus stops represent both centroids of service areas and specific points along the available transport network, they make effective origins and destinations. Pertaining to travel route characteristics, the “quality of route” is a reflection of elements that affect the efficiency of trip made by the chosen modes of travel. For bicycles, important travel-route characteristics might include topography, design speed, number of lanes of traffic, and parking availability.

Table 2.7. Accessibility measurement variations: factors

Factors	**Description**
Origins	Location Type Quality
Destinations	Location Type Quality
Modes of travel	Pedestrian Bicycle Public transit Automobile
Travel route characteristics	Quality of route Sidewalks Design speed Safety
Distance calculations	Straight line (Euclidean) Manhattan block Network

(Source: Talen, 2003)

Steps 3, 4, and 5

Step three requires the researcher to measure the distances between origins and destinations. Geographic Information Systems (GIS) software such as Mapquest, Google Earth, and ArcView make it possible to collect measurements efficiently on digitized maps. There are different types of measurements required for different accessibility measurement approaches. For example, a "street network" measurement implies the distance between origin and destination along the shortest route available on the existing street network. Alternatively, a "Euclidean" distance measure is the direct distance between two points (e.g. straight-line distance), regardless of the street network. Deciding what measurements to make is dependent on the type of approach that is used.

The different types of neighbourhood-level accessibility approaches are discussed below. As noted above, factors that influence bicycle and other non-motorized mode access efficiency include,

1. **Distance of the travel route** (and corresponding time spent traveling)
2. **Urban form** (specifically density and permeability of the transportation network)
3. **Physical characteristics of the transportation routes** (e.g. topography, shoulder widths, lighting, signage, surface conditions, traffic volumes, among other physical environmental characteristics act as aids or impediments to bicycle use)

For evaluating the urban spatial pattern – specifically, the nature of the transportation system – Talen advocates using "place-based" accessibility approaches, which focus on spatial proximities of desired locations or activities. These provide measures that serve as a characteristic of a place (Talen, 2003, p.183). Talen lists five such approaches (listed below):

1. **Coverage**: The number of facilities within a given distance from a point of origin
2. **Container**: The number of facilities (i.e., destinations) contained within a given unit (e.g., census tract)
3. **Minimum distance**: The distance between a point of origin and the nearest facility
4. **Travel cost**: The average distance between a point of origin and all destinations; where cost is measured in terms of distance from an origin to a destination, the greater the distance, the greater the cost will be to access a destination.
5. **Gravity**: An index in which the sum of all facilities (weighted by size) is divided by the 'frictional effect' of distance (Talen, 2003, p.183). Using this approach, the level of access is determined by subtracting the distance between the origin and destination(s) (since distance is a negative factor) from the desirability of reaching a particular destination (the draw).

Only the "travel cost" approach is applicable to the objective of this research, since it is a simple calculation of the distance between origin and destination – a direct and specific reflection of the available transportation network. The other evaluation approaches listed measure trip distances, but they also place a value on the number or size, or which of a facility type is closest in proximity to the origin. In fact, none of these place-based approaches is directly relevant to or satisfies the study's goal of evaluating the impacts of suburban land patterns and transportation networks on bicycle access efficiency. They only address one aspect of this goal: distance. They do not specifically deal with issues of travel time, transportation network configuration, or quality of the transportation network. So, instead of adopting any of the above approaches, a new approach is developed in the Methodology chapter.

Step four, computing the access measure, requires the selection of relevant approaches from the five "place-based" alternatives given above. Since, as noted above, none of the approaches is directly relevant to the study's goals, a new methodology is developed instead (see Methodology chapter).

Step five is the analysis of study results.

Step	**Main Task**	**Decision framework**
3	Compute distances	Street network Geometrics (dimensional characteristics)
4	Compute access measure	Nearest distance Total distance
5	Perform analysis	Citywide access Intraurban variation Targeted access

2.7. Research Goals

So far this paper has examined the following issues:

1. Identified the major obstacles to bicycling, with emphasis on those affecting physical accessibility

2. Reviewed strategies that have been successfully used to improve biking conditions and encourage its viability and acceptance as a legitimate urban transport mode

3. Reviewed and discussed the strengths and weaknesses of existing methods for measuring access

The focus has narrowed from a broad review of the environmental and social problems caused by car dominance, to the opportunities and benefits of incorporating bicycles into our current transportation paradigm. Finally, it examined the tools used to measure access, and their usefulness for assessing bicycle accessibility in the suburban context. The next step is to address the following broad questions:

1. How bikeable are contemporary North American suburban neighbourhoods?
2. How can they be made more bikeable?

This is done by proposing an extension of Talen's (2003) methodological framework to address the following research goals:

1. Provide methods for preliminary identification of access-deficient neighbourhoods within an urban area (i.e., bikeability indicators)
2. Identify physical factors that impact bicycle efficiency and the potential to use bikes to access transit nodes within suburban neighbourhoods
3. Recommend solutions to bicycle efficiency and integration challenges, based on proven strategies (How can bicycle efficiency and bicycle-bus integration be improved?)

A further goal of the study is to examine the relative modal efficiencies of bikes versus buses for trips within the suburban neighbourhood case study area. This is done with the intention of highlighting opportunities for streamlining transit service by integrating accounting for complementary service potentials between buses and bicycles. Bicycles have limited use as a competitive mode of transportation when compared to motorized alternatives such as private automobiles for long distances. As previously mentioned, they are most competitive with motorized transport modes over short to moderate distances (i.e., 1.5-3.5km). While most destinations are too far to be efficiently reached from suburban neighbourhoods by bicycles alone, a bicycle may be optimal for trips within the scope of the neighbourhood.

Public transit, on the other hand, is optimally efficient for longer trips with fewer stops. It is ideal for bridging large gaps between destination areas, and could be used to extend the range of bicycle trips to destinations outside the neighbourhood scale (e.g. between a suburban neighbourhood hub and the central business district), provided that transit policies and facilities accommodate the needs of bicyclists. Bus service that circulates within suburban neighbourhoods is inherently inefficient because of a high number of stops over relatively short distances. This type of service is likely to be costly and underused. Furthermore, these bus loops compete directly with the proposed use for bikes in transport chains.

The next chapter proposes an application of Talen’s methodological framework that evaluates bicycle accessibility in terms of transportation network efficiency. It is applied to a case study of a suburban Saskatoon neighbourhood area, and tests the bicycle’s viability for trips from suburban homes to a suburban bus transfer station. A second methodology is described and implemented in the case study area to measure and compare relative accessibility between bicycles and buses. Results are analysed to confirm the potential usefulness of bicycles within transit chains, and to suggest possible modification of bus service to suburbs.

3 METHODOLOGY

3.1. Methodology for Evaluating Neighbourhood Level Bicycle Accessibility

The resulting approach for evaluating existing neighbourhood access is divided into two parts, as follows:

1. Access evaluation and problem definition phase:
    i. General access evaluation: The following indices may be applied to identify neighbourhoods that have generally poor accessibility, as defined by number of connections and directness of routes. City planning staff might apply these methods to neighbourhoods throughout the entire city, and could use the results to determine what areas should be examined in more detail.
        a. Connectivity Index
        b. Permeability Indices
    ii. Specific problem definition: Detailed evaluation of neighbourhood access would provide the specific information required to understand existing physical access barriers (in this case, between residents and transit opportunities).
        a. Physical Field Survey
2. Improvement phase: This phase matches proven access improvement strategies to solve problems defined in the previous phase of this methodology. Main strategies include the following:
    i. Decrease trip times/distances (action: retrofit community with bicycle/pedestrian shortcuts through parks an cul-de-sac heads)
    ii. Facilitate multimodality (action: provide secure bicycle parking at bus stops and stations; accommodate bikes on buses; identify bicycle-bus opportunities)
    iii. Dissuade motorists. This can be done by accommodating cyclists (e.g. adding bicycle cycles to traffic lights delays motorists; employing bicycle-permeable barriers and traffic calming devices to residential streets decreases access to and slows automobiles, which makes roads safer for bikes)

The first phase (access evaluation and problem definition) applies three methods to evaluating existing accessibility. It is composed of two quantitative index calculations to measure how directly street networks accommodate access between points of origin and destination. This measurement is based on quantitative data that can be gathered from a scaled street map without requiring on-the-ground site visits. Physical infrastructure and environmental conditions that are not identified by this preliminary evaluation are detected by a field survey to note actual conditions such as topography, pavement conditions, street widths, signalization, and traffic levels that may significantly impact the bikeability of a route. The quantitative indices are useful for targeting locations with major network access deficiencies from a broad area. The field survey provides specific data regarding specifics such as provision, condition and quality of infrastructure and amenities, which cannot be obtained from maps.

The second phase (improvement phase) involves matching the list of problems identified in part one with possible solutions from the literature. Strategies may include varying combinations of infrastructure, operational, and policy modifications.

3.1.1. Access Evaluation

3.1.1.1. Connectivity

Network connectivity is measured using Ewing's (1996) Connectivity index. It is calculated by dividing the number of street links by the number of intersections or cul-de-sacs (i.e., street ends) in a neighbourhood (e.g. 43 street links / 29 nodes = 1.48 Connectivity Index value). A "street link" is a segment of roadway between two intersections, or between an intersection and a street end. "Nodes" are points that separate street links. They can be either locations where streets cross one another to create an intersection, or points where streets terminate, such as cul-de-sac heads. Greater connectivity occurs where there are more links relative to nodes, and is represented by a relatively higher index number. For example, a neighbourhood with a mostly grid street pattern would have high network connectivity, and might receive an index number of 1.69. A poorly connected neighbourhood might have several cul-de-sacs, and have an index rating of 1.19, reflecting the lack of connections versus roadway segments. Ewing (1996, p. 57) identifies 1.40 as a "nice target for network planning purposes". Such a network would typically incorporate a mixture of grid streets and cul-de-sacs (see Figure 3.1.).

Network connectivity calculations produce index numbers that reflect important factors affecting accessibility, allowing the test neighbourhoods to be compared to other neighbourhoods in order to determine their relative accessibility.

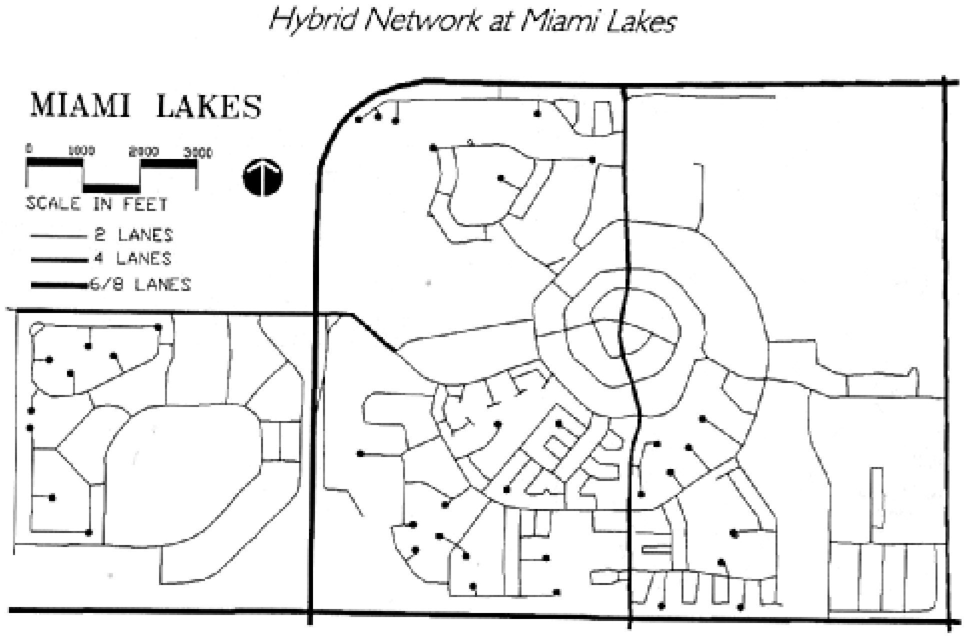

Figure 3.1. Combination of traditional and contemporary neighbourhood design (Ewing, 1996, p. 57)

3.1.1.2. Permeability / Route Directness

Allan (2000) studied walking as a transport option for work trips in urban settings. He asserted the following about walking as a form of transportation:

- Walking is the main interface between land uses and other transport modes. For example, there is almost always a short walking trip required between home and automobile on the origin end of a trip, and between automobile and office or store, on the destination end.

- Walking is limited by gait (speed or pace), and fatigue (dependent on fitness).

- Walking may be reasonable as a local transport modal choice – and therefore competitive with public transport – for up to 2 kilometres (approximately 20 minutes) in many urban environments.

Bearing in mind the above limitations associated with walking, cities with fine urban grains (i.e.,, more permeable pedestrian networks, which allow pedestrians to travel more directly to destinations) are more walkable, and should theoretically recruit more walking trips than cities with coarse-grained networks. This assertion is dependent on the existence of sufficiently high urban density, local access to transit (with service to regional destinations), attractive pedestrian routes, and heterogeneous land use zoning (i.e.,, mixed uses) to increase the number of destinations within walking range.

Network permeability is measured by applying the Walking Permeability Index, which "indicates how directly a pedestrian can reach a destination", to bicycle routes (Allan, 2001). The formula can be altered to reflect permeability in terms of distance, and time, as follows:

1. Walking Permeability Distance Index (WPDI) = Actual Distance / Direct Distance

2. Walking Permeability Time Index (WPTI) = Actual Distance in Time / Direct Distance Time

Since this study uses Walking Permeability Indices to measure bicycle trips, they are henceforth referred to as Bicycling Permeability Distance Index (BPDI), and Bicycling Permeability Time Index (BPTI), respectively.

"Actual Distance" refers to the shortest available street/sidewalk network route available, and "Direct Distance" refers to the straight-line or Euclidean distance between origin and destination (i.e., "as the crow flies"). A score of 1.0 implies the best network permeability possible; providing direct access between origin and destination (e.g. Actual Distance or Time =

Direct Distance or Time). A 1.5 is suggested as the limit of reasonable accessibility (e.g. Actual Distance or Time is one third greater than Direct Distance or Time).

Randall and Baetz (2001) considered the problem of how to improve physical accessibility for pedestrians in existing suburbs. They developed a methodology to identify neighbourhood locations where shortcut retrofits might benefit NMT modes by improving available route directness and decreasing trip lengths. It is based on a combination of two measures:

1. Pedestrian Route Directness (PRD, also referred to as "permeability"), which is the ratio of available route distance to geodetic (straight-line) distance

2. and simple Route Distance between home and destination, with a critical (i.e., reasonable) distance being assigned to indicate the approximate distance limitation of the mode (e.g. 400m being the critical distance value for pedestrians):

$$\text{PRD} = \frac{\text{route distance}}{\text{geodetic distance}} \qquad (3.1.)$$

They applied it to four possible scenarios:

1. PRD and distance < critical values
2. PRD not critical, but distance > critical value
3. PRD exceeds critical, but distance does not
4. PRD and distance both > critical value

The first two scenarios would indicate acceptable connectivity and little or no need for network shortcut retrofits. The last two scenarios are considered unacceptable, as either one or both measures exceed critical distances, thereby warranting improvements to the route.

Since critical PRD values change dramatically between neighbourhoods (e.g. conventional versus traditional street networks) it may not be practical to set the same critical PRD ratio values as guides for two separate neighbourhoods. Even where two conventional suburban neighbourhoods are concerned, the critical values will likely differ and should be set appropriately based on what is direct and indirect in a particular study area (Critical PRD is set at 1.5 in Randall and Baetz's study).

Their methodology is fundamentally similar to that which is developed in this paper to determine general neighbourhood accessibility, with the main difference being that bicycles are the subject mode here rather than pedestrians. Bicyclists differ from pedestrians primarily in the critical distance available to them. Keijer and Rietveld (1999) identify cyclists' critical distance in the Netherlands as approximately 3.5 km. Route directness is thought to similarly impact bicyclists, meaning it remains an important factor in bicycle connectivity assessment and analysis.

3.1.2. Physical Field Survey

A physical field survey is conducted to record qualitative data impacting route efficiency and bicycling feasibility. The minimum goal of the field survey is to record any obstacles that have the potential to cause a time delay to a bicyclist. Observations noted by the bicyclists provide helpful contextual information in the analysis section that may be useful to explain unexpected anomalies in the quantitative results.

Data to be collected includes the following:

1. presence of a bicycle lane, paved shoulder, or wide curb lane
2. presence and condition of bicycle short-cuts (i.e., off-road pathways exclusive of cars)
3. speed limit (or 85th percentile traffic speeds)
4. observed traffic volumes (measured, if available)
5. roadway gradients
6. roadway surface conditions
7. presence of traffic signals
8. presence of on-street parking
9. presence, location and quality of bicycle parking

No restrictions are placed on the extent of route data collected because there is no way to know what the surveyor would discover until he sees the route.

3.1.2.1. NMT efficiency improvement recommendations

Once the obstacles to NMT access have been identified, the second stage of the methodology is to address these problems. The approach is divided into three sections, described below.

Network recommendations. These pertain to physical alterations to the existing transportation network available to NMT modes that directly impact permeability and access. Recommendations may include changes such as the addition of short-cuts through open spaces, or retrofitting cul-de-sac heads to provide more direct routes to NMT.

Facility recommendations. Facility proposals include infrastructure to be located along the network, such as traffic calming devices, bicycle lanes, and bicycle parking locations. Also, the conditions of existing infrastructure are noted. This information would be used to estimate costs associated with optimizing bicycle facilities within a study area. Cost-benefit analyses would further enable city officials to determine the best allocation of funds on such improvements.

3.2. Methodology for Comparing Modal Efficiencies of Bikes versus Buses within Suburban Neighbourhoods

To determine relative efficiencies of buses and bicycles at the suburban neighbourhood scale, the study directly compares bicycle and bus access efficiency in terms of travel time and distance for trips within the suburban neighbourhood study area. This is done by using bus stops, which represent "proxies" for dwelling clusters, as common origins from which to measure the time and distance of bus and bicycle trips to reach a common destination (in this case, a transit station at the inner suburban fringe).

To simulate the home-to-bus segment of the trip, a distance of 450 metres is assumed as the distance that one must travel to reach the bus stop on the origin end of a bus trip. This is based on the transit authority's own equitable service coverage policy. Equitable service coverage means that bus stops are distributed throughout the neighbourhood so that the maximum walking access time (or distance) from any dwelling in the neighbourhood is 10 minutes (approximately 450 metres). It is assumed that this segment can be covered either on foot or by bicycle.

The resulting comparison of bicycle versus bus service from home to station involves two trip segments, as follows:

1. The trip from **home to bus stop**, and
2. The trip from **bus stop to bus station**.

Average walking speed is estimated as 5.4 km/hr, based on the premise that 450 metres represents a 5-minute walk (City of Saskatoon, 1998b; City of Calgary, 1993). Average bicycling speed is difficult to estimate. No study is available that offers a definitive average for bicyclists, however, data from *A Survey of North American Bicycle Commuters* (Moritz, 1997) suggests that bicycle commuters (i.e., those who bicycle between home and work over 50% of the time) average approximately 22.8 km/hr. Assuming that most commuters are well below this level of bicycle usage, and not likely to be as fit and fast, 15 km/hr seems a more conservative and accurate average, and is used in this study.

Each trip time calculation starts with the addition of a “home to bus stop” time and distance. While the distance of this trip segment remains constant at 225 metres, the time cost of the segment varies depending on whether the mode is bicycle or pedestrian. Pedestrian time cost is presumed to be greater than that of bicyclists, based on average modal speeds. The second part of the trip time calculation is the “bus stop to station” portion. This segment is calculated for bicycle and bus modes, and is the primary focus of the study. Bicycle and Bus trip time and distance calculations are summarized in Section 4.2. Access Evaluation.

3.2.1. Segment 1: Home to Bus Stop

The first segment of the home to interchange trip is between home and bus stop. In order to account for this segment, an estimated average walking time is calculated based on half of the maximum distance of the transit catchment (225 metres). If it takes 5 minutes to walk 450 metres, then, assuming equal displacement of homes and equal usage among residents within the catchment, the average walking trip to bus stops is 2 minutes, 30 seconds. Assuming an average speed of 15km/hr the corresponding bicycle trip time is 54 seconds.

3.2.2. Segment 2: Bus Stop to Station

The bicycle is assumed to travel at a speed of 15km/hr, and covers the shortest road network route available between the outlying suburban bus stop and the main suburban bus station/neighbourhood hub. Delays of 40 seconds are assumed for intersections with traffic lights, and 20 seconds for intersections with stop signs. The pedestrian boards the bus, and the transit segment is assumed to take precisely the time scheduled for regular bus service between the bus stop and bus station. Transit route schedulers factor reasonable delays caused by intersection traffic lights and other typical delays when developing route time programs. Various combinations of modal splits are examined in this comparison.

Service recommendations. This focuses on the challenges associated with integrating bicycles and buses to form efficient multimodal transport chains. It considers the potential for restructuring suburban bus routes around bicycle nodes to help streamline public transit. The following chapters apply this methodology to a case study of suburban neighbourhoods in Saskatoon, Saskatchewan.

4 RESULTS

4.1. Study Area

Saskatoon was chosen as the location for the case study because the researcher was living in the city at the time of the study, making it a readily accessible and familiar location for the researcher to conduct the required field survey data and other necessary information and resources from the City of Saskatoon. Furthermore, as a median-sized city (population of approximately 200,000), the researcher believed that Saskatoon would provide general results that might be applicable to both larger and smaller cities.

Three Saskatoon neighbourhoods are selected as trip origin locations for the study, based on the following suburban characteristics and transit conditions:

1. Suburban location – on the edge of the city's current development (see Figure 4.1.)
2. Segregated land use – no commercial services exist within the study neighbourhoods
3. Low density – primarily single-family dwellings with large lots and setbacks
4. Contemporary design – they provide an accurate reflection of current planning and design principles widely used across North America
5. Suburban bus service – two bus loops service the three study neighbourhoods, allowing direct comparison between buses and bicycles
6. Transit station location – the relationship of the study neighbourhoods is such that they are adjacent to each other, and surround a major transit hub (Wildwood Station) where suburban bus loops converge with urban routes.
7. Scale – the approximate 3 to 4 kilometre diameter of each neighbourhood makes them large enough for testing the upper limits of Rietveld's 3.5 kilometre bicycle efficiency hypothesis.

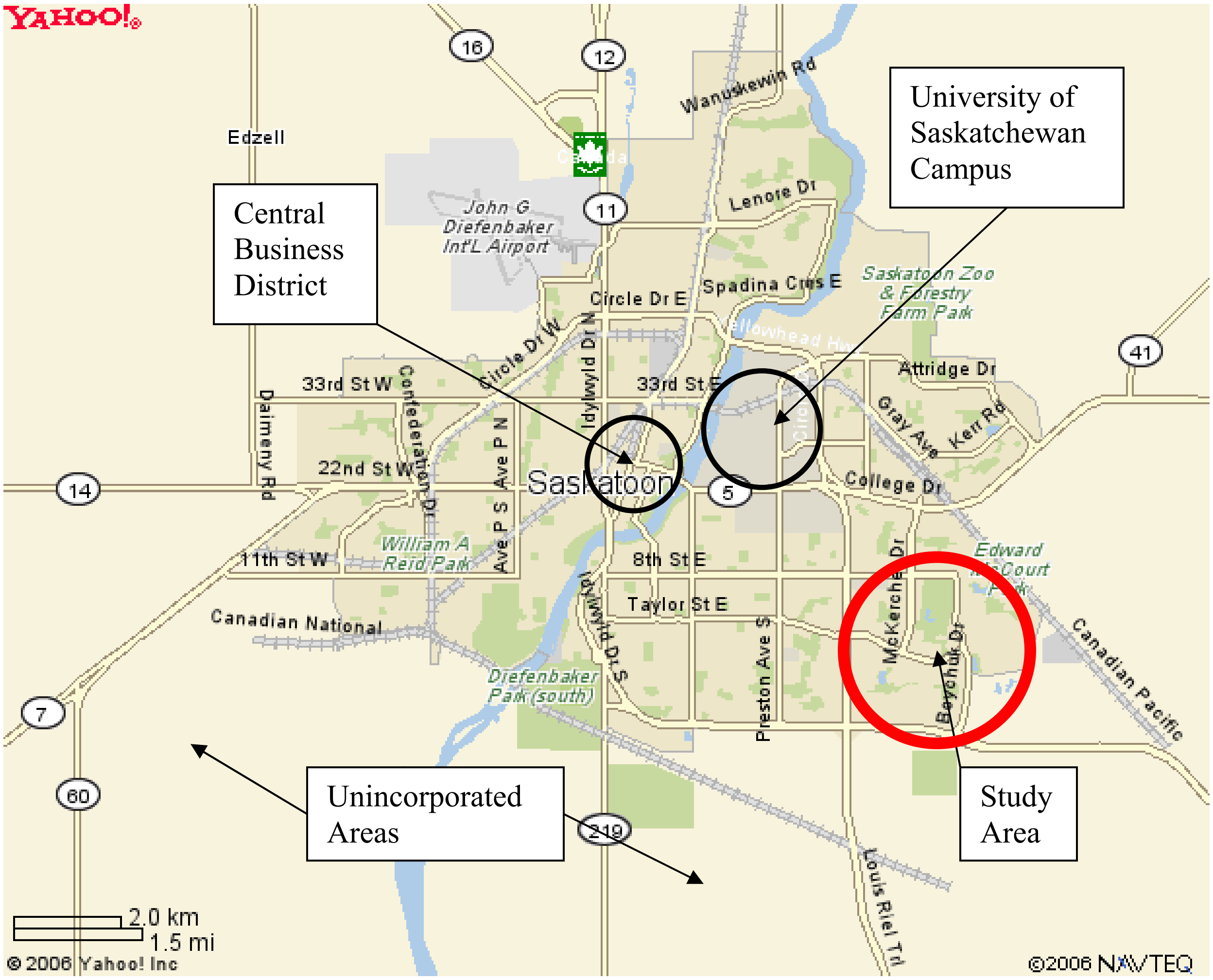

Figure 4.1. Study vicinity, showing study area within Saskatoon city context (Source: Yahoo, 2006)

4.1.1. Destination

The area's main transit hub, Wildwood Station, is located at Circle Centre Shopping Mall (see Figure 4.2.). It is situated at the northwest corner of the study zone, near the intersection of 8th Street East (the northern boundary of the study area) and Acadia Drive (a major corridor to between the study area and the rest of the city). Due to its situation adjacent to the shopping centre, and being a major access point to bus routes serving major destinations throughout the city, including the University of Saskatchewan and the CBD, Wildwood Station is the natural destination for all transit users within the test area.

Circle Drive and 8th Street act as north and west side physical boundaries, separating the suburban study area from the rest of Saskatoon. Although continuing transit service between Wildwood Station and the rest of Saskatoon's transit network is important to suburban transit users, it falls outside the suburban focus of this study.

Figure 4.2. Study area, showing the four suburban neighbourhoods of interest (Source: Mapquest, 2006)

4.1.2. Origin Selection

The case study trip origins were selected with intent to observe the effects of the suburban transportation configuration on each of the targeted test modes (i.e.,, bike and bus). Figure 4.3 indicates the direction of flow from the three radial outlying neighbourhoods toward the Wildwood Neighbourhood transit hub, as well as the straight-line geometry of these origins in reference to the common destination. The Lakeridge origin is farthest from the destination, followed by Briarwood, and Lakeview.

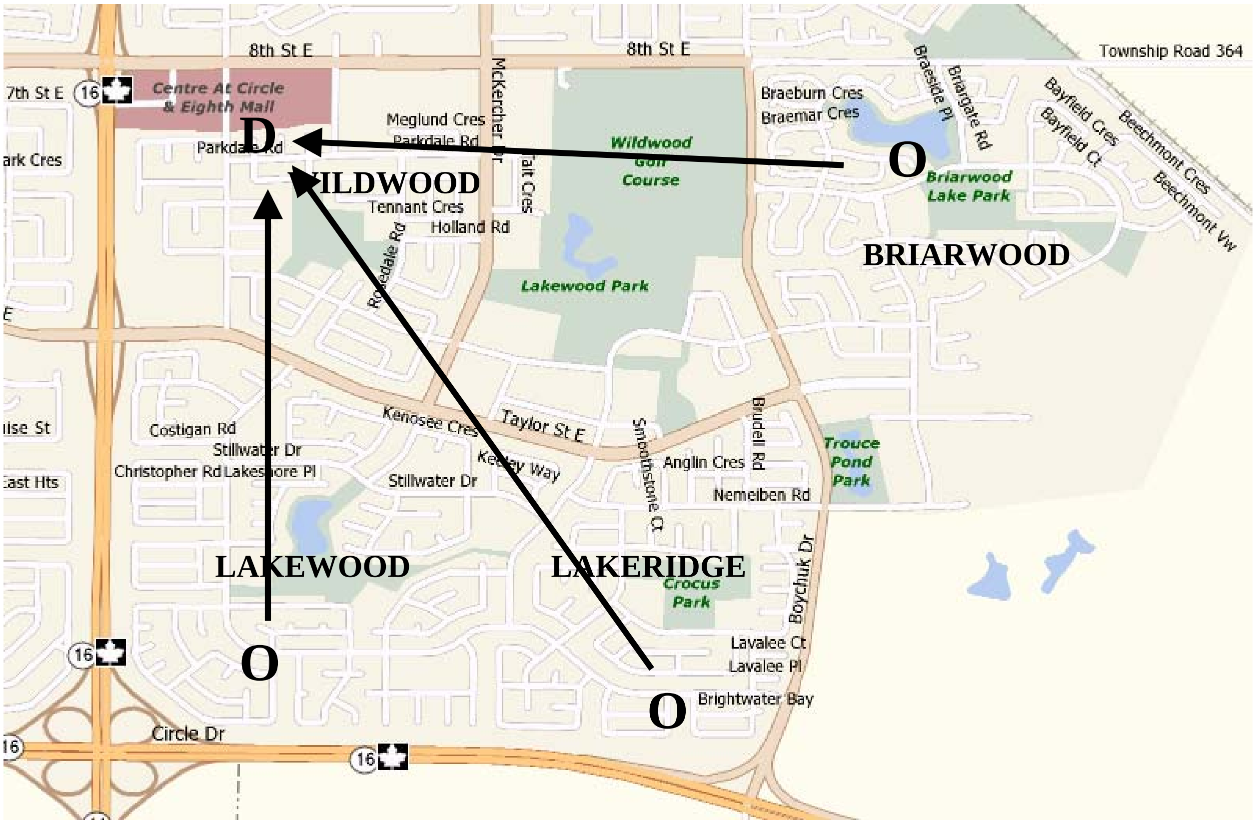

Figure 4.3. Destination (D) and Origin (O) neighbourhoods (Source: Mapquest, 2006)

Figure 4.4 illustrates the nearest available route distances between the origins and destination.

Figure 4.4. Route distances between origins and destination (Source: Mapquest, 2006)

Figures 4.5.a through 4.5.c illustrate the differences in route lengths available to bus riders versus those on bicycles. Note the differences in directness between bus and bicycle routes between the selected origins and destination. This visually demonstrates the clear advantage of route directness that individual bicyclists often have over bus loops, which are designed to maximize area coverage rather than direct access. A detailed comparison and analysis of the impacts of the apparent discrepancies between the modes is offered in the following chapter.

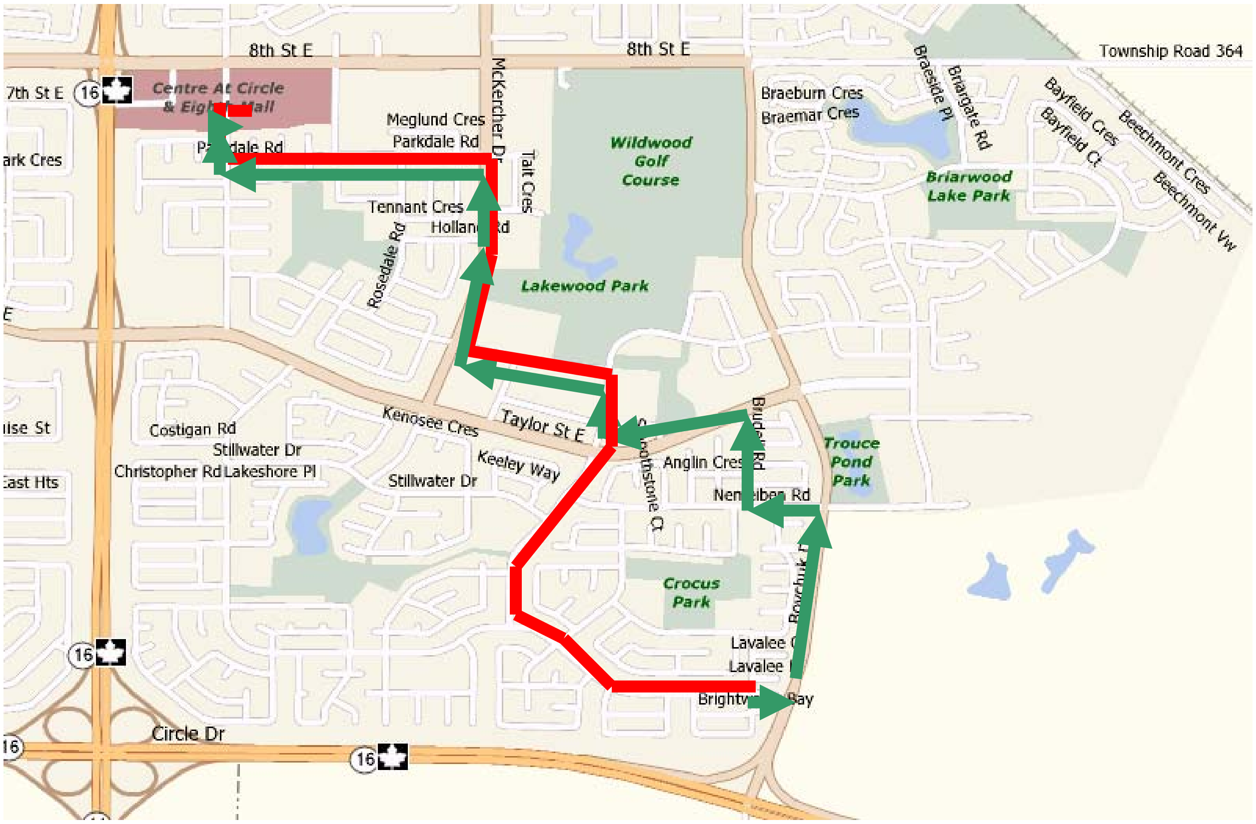

Figure 4.5.a. Lakeridge Origin: Bus service (arrows) versus bicycle route (simple line)

(Source: Mapquest, 2006)

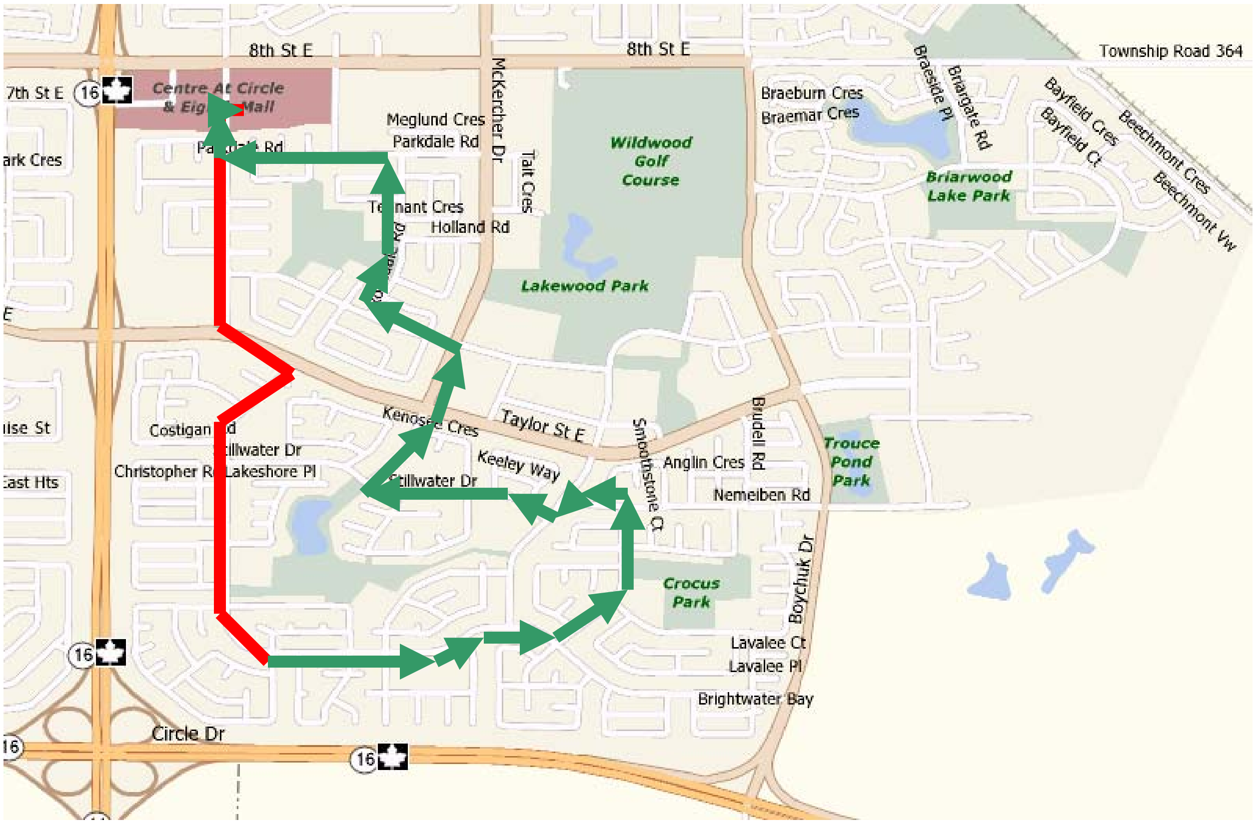

Figure 4.5.b. Lakeview Origin: Bus service (arrows) versus bicycle route (simple line)

(Source: Mapquest, 2006)

Figure 4.5.c. Briarwood Origin: Bus service (arrows) versus bicycle route (simple line) (Source: Mapquest, 2006)

Figure 4.6 shows the approximate 450 metre radius “catchment” surrounding each of the Origin bus stops in the study area. These catchments reflect the estimated distance that a person would likely be willing to walk in order to catch a bus. This distance is halved, to 225 metres, to estimate the average distance and time cost to the travel from home to bus stop from which an individual could continue their journey to the Wildwood Station destination. The home-to-bus-stop segment time cost is calculated for both pedestrian and bicyclist modes, making it possible to demonstrate more variations in modal splits and their impacts on overall trip times.

Figure 4.6. Pedestrian catchments (Source: Mapquest, 2006)

Bus service is assumed to be ideal (i.e.,, perfectly on time) for the purpose of creating consistent comparisons. The specific origins are selected based on their Euclidean (straight-line) distances from Wildwood Station, and their situations along bus routes. The goal is to select the bus stop in each neighbourhood that is farthest along the service loop from Wildwood Station. This tests the maximum horizontal extent of bus service. The Lakeridge origin is located at the farthest point (apex) of the route in relation to Wildwood Station. The Lakeview and Briarwood origins are approximately halfway between the apex and the end of the route (i.e.,, on the return segment of the loop), and halfway between the start of the route and the apex (i.e.,, on the outgoing segment of the loop), respectively (see Figures 4.5.a and 4.5.c).

4.2. Access Evaluation

4.2.1. Connectivity

At first glance, the study neighbourhoods' street configurations may appear to poorly facilitate permeable access of users. However, they produce high scores on the interconnectivity index, with a combined neighbourhood average of 1.71 (see Table 4.1). Although the streets contain several cul-de-sacs and crescents, the number of intersections permeating them is remarkably high, thus the high interconnectivity score. The study area's street configuration appears to incorporate aspects of both traditional grid and contemporary curvilinear street designs. The relatively high accessibility implied by the interconnectivity scores is reflected by the competitive bicycle trip times between nodes and station.

There are, however, several other characteristics of contemporary suburban neighbourhood design evident in the test area. These include lower development density and circuitous streets. While these factors may hamper bicycle efficiency, they do not appear to critically affect overall accessibility.

Table 4.1. Connectivity index calculations

Neighbourhood	**# street links**	**# intersections**	**Interconnectivity Index**	**Average Score**
Briarwood	**63**	**36**	**1.75**	**1.71**
Lakeridge	**105**	**64**	**1.64**	
Lakeview	**160**	**91**	**1.75**	

4.2.2. Permeability / Route Directness

The bicycle route network permeability average of 1.5 (see Table 4.2) for the test routes indicates borderline accessibility; the ideal score being 1.0, which would indicate that the route distance equals the shortest straight-line distance (Allan, 2001). The Lakeview test route has the best access of the three, with an index score of 1.2, indicating that the route is very direct. Lakeridge is borderline accessible, with a 1.5 index score. Briarwood scores a 1.8 index score, indicating very poor permeability (i.e.,, the shortest available network route is 1.8 times longer than the straight-line distance between origin and destination).

The Briarwood route is disadvantaged by Wildwood Park, which is situated directly in the path of a straight-line route to Wildwood Station. Walking trails permeate the park, however, these trails are very curvy, indirect, and surfaced with loose shale, making them ineffective as a shortcut to Wildwood Station. Most of Wildwood Park is occupied by a golf course. This area does not have access through it, for obvious safety reasons.

Theoretical travel times were calculated using assumed constant bicycling speed, intersection and traffic signal delays. The resulting theoretical route travel times are compiled in a shared table with permeability distance indices (see Table 4.3), and used as a basis for comparison with actual physical field survey results.

Table 4.2. Bicycle route network permeability index calculations

Neighbourhood	Euclidean distance	Bicycle route distance (from bus stop to Wildwood Station)	Permeability Index	Average Score
Briarwood	2.2	4.1	1.8	1.5
Lakeridge	2.8	4.2	1.5	
Lakeview	2.2	2.7	1.2	

Table 4.3. Bicycling permeability time and distance calculations

START	Euclidean (Direct) Distance (km)	Actual (Route) Distance (km)	Bicycle Permeability Distance Index	Direct (Euclidean) Distance (in minutes and seconds)	Actual (Route) Distance (in minutes and seconds)	Bicycle Permeability Time Index	END
Briarwood Bus Stop #4388	2.2	4.1	1.86	8’48”	16’24” + 1’ (2 stop signs; 1 light) = 17’24”	1.97	Wildwood Station
Lakeridge Bus Stop #3932	2.8	4.2	1.50	1’12”	16’48” + 1’20” (3 stop signs) = 18’08”	1.61	Wildwood Station
Lakeview Bus Stop #3938	2.2	2.7	1.23	8’48”	10’48” + 40” (1 light) = 11’28”	1.30	Wildwood Station

Notes: 1) Bicycling speed is 15 km/h; 2) Time delays for residential street intersections = 20 seconds; collector street intersections (with traffic lights) = 40 second delays; 3) Worst case scenarios used in estimating Actual Route Distance in Time, and WTPI values.

4.3. Physical Field Survey

The physical field survey was conducted on May 28, 2003, at approximately 10:00am. Cyclists, equipped with odometers travelled the shortest street network route between bus stops located at the farthest extent of two bus loops, which originate from Wildwood Station, within three suburban neighbourhoods. Ken Cockwill rode the Lakeview-Wildwood route, and Steve MacIntyre rode the Briarwood- and Lakeridge-Wildwood routes. Both surveyors rode at a relaxed pace (average speed for all test routes was 18.4 km/hr), and recorded their observations. Each route was travelled one time.

The bicyclists recorded the following quantitative data (see Table 4.4). The time of day, temperature, and wind conditions were very similar for each of the survey routes. The Briarwood and Lakeridge route distances, travel times, and average bicycling speeds were almost identical. The Lakeview route is much shorter compared to the other two routes, and resulted in a substantially shorter trip time. Average travel speeds of all the routes were faster than the assumed universal average bicycling speed of 15 km/h.

Table 4.4. Physical field survey: Quantitative route data

Neighbourhood	**Briarwood**	**Lakeridge**	**Lakeview**
Origin (bus stop #)	4388	3932	3938
Departure time	11 AM	10 AM	10 AM
Temperature (Celsius)	27	26	26
Wind	Light Westerly	Light Westerly	N/A
Destination	Wildwood Station		
Route distance (km)	4.1	4.2	2.7
Trip time (min. and sec.)	14’05”	14’19”	8’04”
Average speed (km/hr)	17.5	17.6	20.2

Notes and route illustrations are organized by starting point, below.

4.3.1. Bus Stop #3932 (Lakeridge; originating at Kingsmere and Brightwater intersection)

4.3.1.1. Route description

Starting at the bus stop located on the southeast corner of the intersection of Brightwater and Kingsmere, MacIntyre rode west on Kingsmere (a collector street), then turned north onto

Weyakwin (another collector), and paused briefly at a stop sign before crossing Taylor. He continued north, turning left (west) onto Heritage Crescent, and right onto McKercher, with another brief pause for a stop sign at this intersection. Next, MacIntyre turned left (west) onto Parkdale, stopped again at a stop sign before turning right (north) on Acadia, and finally right (east) into the Wildwood bus station, located on the east side of Acadia, behind The Centre Mall. (see Figure 4.7)

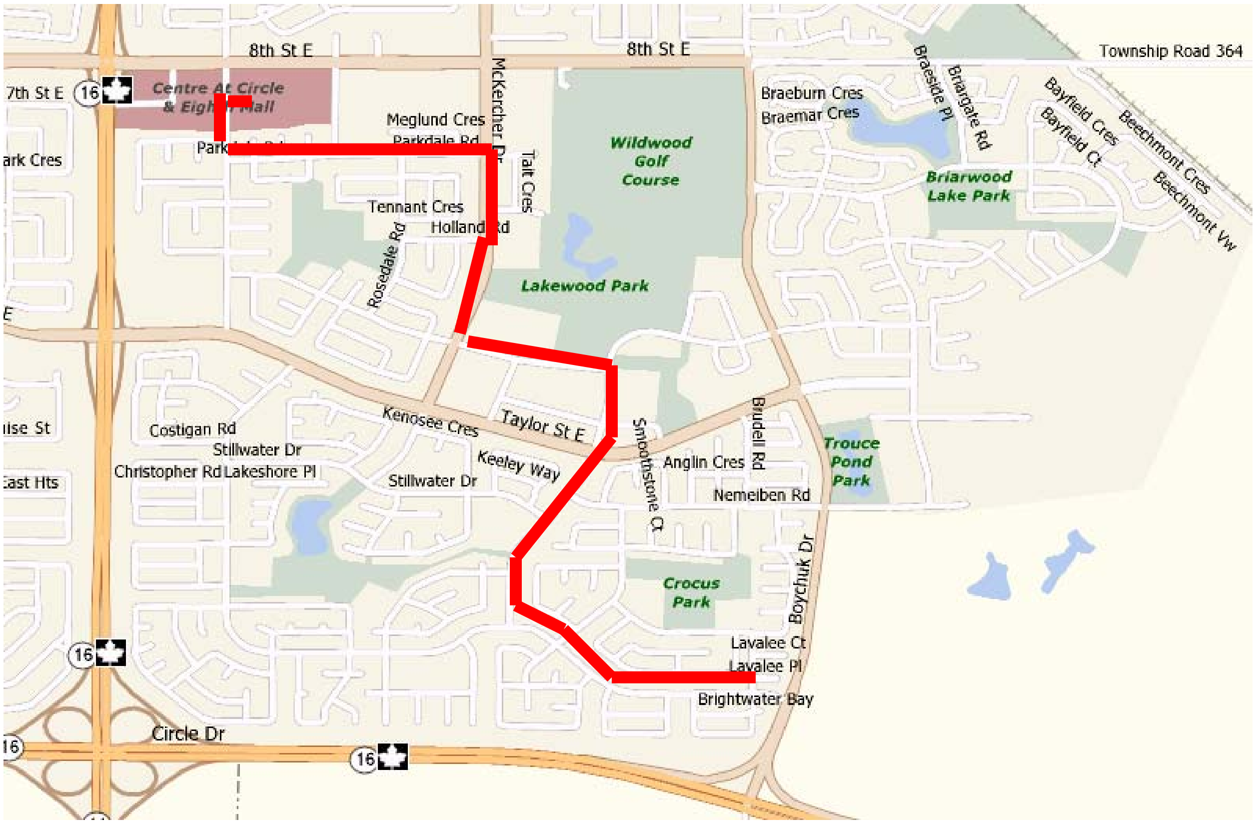

Figure 4.7. Route Description: Lakeridge bus stop to Wildwood Station (Source: Mapquest, 2006)

4.3.1.2. Notes

- Taylor and McKercher are 4 lanes wide
- 2 degree uphill on Parkdale, between McKercher and Acadia
- low traffic volumes
- no traffic lights
- road surfaces in good condition

4.3.1.3. Obstacles and Improvements

The following issues could be addressed to increase bicycle efficiency along this route:

1. Weyakwyn Drive/Taylor Street intersection crossing aids (traffic lights, signage, etc.) (see Figure 4.8.)

Figure 4.8. Weyakwyn Drive and Taylor Street intersection (Source: Google, 2006)

This intersection currently has no traffic lights. Traffic on Weyakwyn Drive is directed by signage to stop at the intersection and give right-of-way to Taylor Street traffic. During peak traffic hours, gaps in Taylor Street traffic may be insufficient to accommodate the crossing of slower moving bicycle traffic over the 4 lanes of traffic. If funds are available to install traffic lights at the intersection, efforts should be made to incorporate advance green for bicycles. Alternative treatments may include the installation of on-demand, button activated flashing yellow lights in combination with signage that direct motorists on Taylor Drive to yield to bikes and pedestrians when the lights are flashing.

2. Wildwood Park shortcut (0.4 km trip reduction)

Figure 4.9, below, illustrates the distance advantage that would be gained by cutting through Wildwood Park rather than following McKercher to Parkdale. The Wildwood Park option shortens this portion of the trip by approximately 0.4 km. Added benefits of this route modification include diversion of bicycle traffic to less intensively used residential streets and providing a bicycle route link to a school (adjacent to the park). Existing pathways through the park's grass fields are visible in aerial photographs, illustrating demand for the connection. Bicycles would be well accommodated by the addition of a paved pathway through the park and signage directing cyclists of this alternative route.

Figure 4.9. Wildwood Park shortcut (Source: Google, 2006)

4.3.2. Bus Stop #3938 (Lakeview; originating at Kingsmere and Delaronde intersection)

4.3.2.1. Route description

Starting at the bus stop located on the southeast corner of the intersection of Delaronde and Kingsmere, Cockwill rode west on Kingsmere, then turned 90 degrees to the north, and stopped at a stop light, located at the intersection of Kingsmere and Taylor. He turned west onto Taylor (a four-lane arterial street), after waiting for a left turn arrow. Next, he turned right at the intersection of Taylor and Acadia, and proceeded north to the Wildwood bus station (see Figure 4.10). Aside from passing through two traffic lights (the second was located at Taylor and

Acadia), Cockwill had the right-of-way over all other residential feeder streets that intersected with his route.

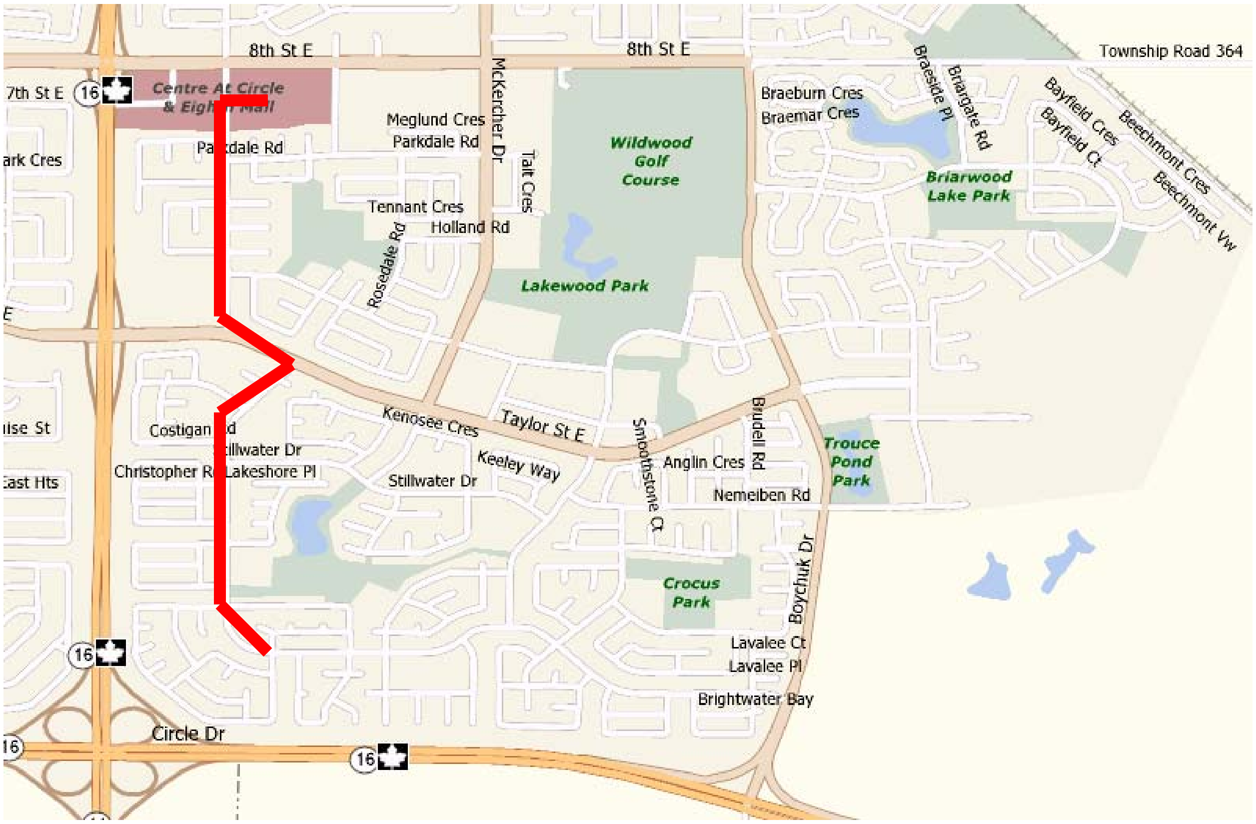

Figure 4.10. Route description: Lakeview bus stop to Wildwood station (Source: Mapquest, 2006)

4.3.2.2. Notes

- low traffic volumes
- waited at one traffic light for unknown time, and honked at by angry motorists (2X – double turning lane; should have been in right lane)
- road surfaces in good condition

4.3.2.3. Obstacles and improvements

1. Bicycle Lane on Taylor Street (Figure 4.11.)

As indicated in the field notes, the double left turn from McKercher to Taylor Street can be intimidating and confusing for inexperienced cyclists. This problem is worsened by automobile operators who often perceive bicyclists as recreational nuisances that do not have the same rights to the roads as motorists. One method of clarifying the legitimacy of bikes on roadways as well as showing where on the roadway they should be operated is to stripe bicycle lanes. The demarcation of bicycle lanes indicates to drivers and cyclists where each should be, and promotes more predictable (and safer) behaviour by both user groups. Bicycle lanes should be at least 5 feet wide and may require the removal of on-street automobile parking, narrowing automobile lanes, reducing the number of automobile lanes, and in some cases speed limit reductions should be considered.

Remove on-street parking option and add bicycle lanes to both sides of street.

Figure 4.11. Taylor Street, between McKercher and Acadia (Source: Google, 2006)

2. Advance green light at Taylor Street/Kingsmere Blvd (Figure 4.12.)

The shift toward equal treatment of bicyclists is happening slowly. Incorporating a bicycle-only green light into traffic light cycles is one method that reinforces the legitimacy of bicycles as transport modes. This may gradually shift public attitudes to be more accepting of bikes on roadways, thereby resulting in more respectful treatment of cyclists, which may result in a safer environment for cyclists. The basic benefit of having a separate signal for bikes is that it allows bicyclists to manoeuvre through intersections and between lanes without the threat of automobiles, since automobiles tend to accelerate faster than bikes.

Add signal with advance green for bikes.

Figure 4.12. Taylor Street and Kingsmere Blvd intersection (Source: Google, 2006)

4.3.3. Bus Stop #4388 (Briarwood; originating at Briarwood Road and Briargate Road)

4.3.3.1. Route description

Beginning at the bus stop located on the northwest corner of the intersection of Briarwood Road and Briargate Road, MacIntyre and Cockwill pedalled west along Briarwood Road. They stopped, then turned south on Boychuk Drive, west on Heritage Crescent, stopped again, and turned north onto McKercher. Next, they turned west on Parkdale Road, stopped, and turned north on Acadia, then east into the Wildwood bus station (see Figure 4.13).

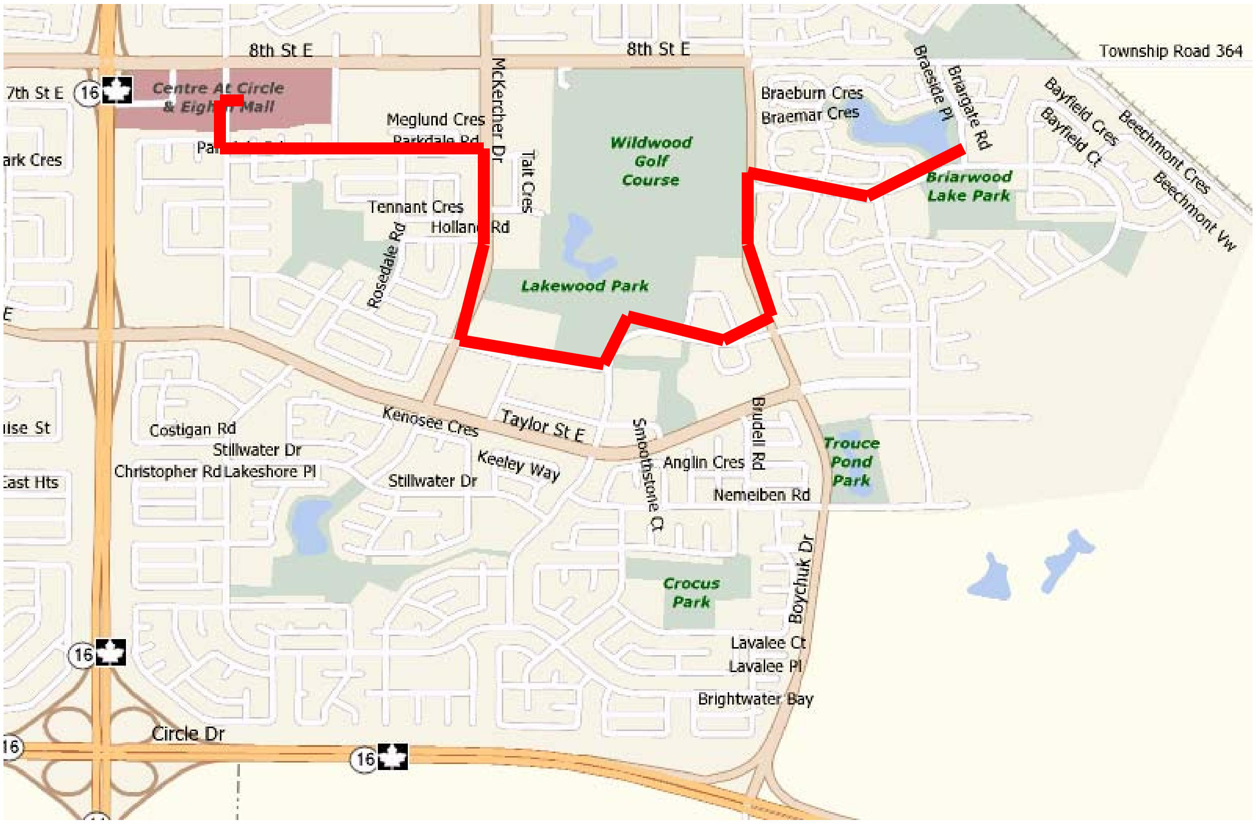

Figure 4.13. Route Description: Briarwood bus stop to Wildwood station (Source: Mapquest, 2006)

4.3.3.2. Notes

- No path available to cut across golf course and park
- Shale paths through Lakewood Park are recreational
- Path could be introduced between golf course/park boundary to decrease NMT travel distance and time between this O and D.

Route: Briarwood Road – Boychuck Drive – Heritage Crescent – McKercher – Parkdale – Wildwood Station

4.3.3.3. Obstacles and improvements

1. Park shortcut (0.9 km trip reduction) (Figure 4.14.)

This shortcut would offer a large time/distance savings to bicyclists by cutting between a golf course (north side) and a community recreation area (south side). The only requirement would be to pave and sign the shortcut path. Had NMT route directness been a higher priority in the planning stages of this development, the golf course might have been planned differently to allow a direct route between Briarwood Rd (east side) and Parkdale Rd (west side). This would have shortened the total route distance by approximately half. The proposed retrofit in the below image would still reduce total trip distance along this route by nearly one quarter of the existing route distance.

Figure 4.14. Park shortcut (Source: Google, 2006)

4.3.4. Improvements for All Routes

These are improvements that are applicable to all three test routes:

4.3.4.1. Bicycle route signage and bicycle lane striping

Arterial and Collector streets should be retrofitted with bicycle lanes where there is enough roadway width to accommodate them. This may require removal of parking along some streets. Additionally, signage reading "bicycle route" paired with destination signs reading "Wildwood Bus Station" and "Shopping Mall", and directional indications before each point where the route changes directions and after major intersections should be placed along each of these routes to indicate that they are direct and safe routes to access the indicated destination.

4.3.4.2. Bicycle parking at Wildwood bus transfer station (Figure 4.15.)

Provision of secure bicycle parking at bus stops and stations is central to accommodating the use of bicycles to access bus service. Bicycle racks should be located in the most convenient location possible to facilitate direct access to buses. This will usually be immediately adjacent to bus shelters, which adds to their security by increasing public surveillance.

Bicycle racks on buses can facilitate extended transportation range at both ends of the bus trip. Unfortunately, most racks on buses do not hold more than 3 bikes at once. Greater capacity might increase usage, as fewer cyclists are rejected this service by lack of space on the racks.

Add secure bicycle parking.

Figure 4.15. Wildwood bus station (Source: Google, 2006)

4.3.4.3. Bicycle Route and Facility Maintenance

Existing street conditions on all three test routes are good. Pavement condition is excellent. Dirt and debris along the outer edges of streets is a minor concern that could be improved by more frequent street sweeping. Since no bicycle facilities exist, the only consideration regarding facilities is that they are needed. Investment in high quality facilities will reduce the need for maintenance.

4.3.5. Field Survey versus Projected Mean Bicycle Trip Time Projections

There was virtually no traffic interference during the field survey, with the exception of approximately one-minute delay due to a traffic light at the Kingsmere/Taylor Street intersection on the Lakeview to Wildwood Station route. This was emphasized by the cyclist's uncertainty of left turn protocol where multiple lanes exist. Overall, the field tests had minimal delays due to stop signs and lights.

Estimated mean cyclist trip times are very conservative. Field survey test riders experienced less than the anticipated 20-40 second delays at stop signs and lights. Average delays at signed intersections averaged approximately 10 seconds, since little or no traffic was encountered on cross-streets. Also, 15 km/h is a very conservative speed estimate for most cyclists, and would likely be substantially exceeded by regularly commuting and experienced cyclists (see Table 4.5).

Table 4.5. Actual versus projected bicycle route trip times

Origin	Field Survey Trip Times	Projected Mean Trip Times	Difference
Briarwood	14'05"	17'24"	3'19"
Lakeridge	14'19"	18'08"	3'49"
Lakeview	8'03"	11'27"	3'24"

4.4. Bicycle versus Bus Comparison (Trip Time and Distance Calculations)

4.4.1. Bicycle versus Bus (see Table 4.6.)

Both Briarwood- and Lakeview-Wildwood Station trips are shown to be more efficiently accessed by bicycle, beating the corresponding bus service by over two and four minutes, respectively. The Lakeridge route shows bus service beating the bicycle by over four minutes. The Briarwood and Lakeview origins are situated relatively closer to the destination than the Lakeridge origin. Furthermore, bus service to Briarwood and Lakeview is provided earlier in the bus' service loop, meaning the bus has farther to travel after stopping to pick up passengers at these locations than before. Conversely, the Lakeridge origin is situated at the approximate apex of the corresponding bus service loop, meaning the bus has relatively less distance to travel to return to the Wildwood Bus Station after collecting passengers at this neighbourhood's test origin. Furthermore, bus service to the Lakeridge test origin offers a reasonably direct/short return path to Wildwood Station. The Briarwood and Lakeview origins' bus service proceeds to thoroughly meander through adjacent neighbourhoods before returning to Wildwood Station. Finally, it is appropriate to note that Rietveld never claimed cyclists could compete with buses over a 3.5 km distance, so his theory has not been disproved in the context of this case study.

Table 4.6. Bicycle versus bus route trip times, from home to Wildwood station

Origin	Bicycle Trip Times	Bus Trip Times, incl. Walking segment	Difference (bicycle time minus bus time)
Briarwood	18'18"	20'30"	-2'12" (bicycle is faster)
Lakeridge	19'02'	14'30"	+4'32" (bicycle is slower)
Lakeview	12'22"	16'30"	-4'08" (bicycle is faster)

4.4.2. Bicycle versus Bicycle-Bus (see Table 4.7.)

Based on estimated mean times, using the bicycle to access bus service from home instead of walking to the bus stop, appears to increase the efficiency of overall home-destination bus service. However, this assumes availability of bicycle parking, either at the bus stop, or on the bus. Furthermore, time spent attaching a bicycle to a bus rack, or securely parking it at the bus stop, combined with a likely delay to remove the bicycle from its parking area, may make walking as time efficient for such short access trips. Despite these factors, the bicycle could save time at other segments between public transit portions of the journey to and from the destination, thereby making the bicycle worth taking, even if it is not practicably more time-efficient than walking to the origin end of the home to destination bus trip.

Table 4.7. Bicycle versus bicycle-bus trip times, from home to Wildwood station

Origin	Bicycle Trip Times	Bicycle-Bus Trip Times	Difference
Briarwood	18’18”	18’54”	36”
Lakeridge	19’02”	12’54”	6’08”
Lakeview	12’22”	14’54”	2’32”

Tables 4.8 and 4.9, below, provide the assumed conditions used to calculate the modal trip time comparisons in Tables 4.6 and 4.7, above.

Table 4.8. Average bicycle trip estimates, from home to Wildwood station

Origins	Distance (home to bus stop) (km)	Distance (bus stop to station) (km)	Total Distance (km)	Time (home to bus stop)	Time (bus stop to station)	Total Time
Briarwood	0.225	4.1	4.325	54”	17’24”	18’18”
Lakeridge	0.225	4.2	4.425	54”	18’08”	19’02”
Lakeview	0.225	2.7	2.925	54”	11’28”	12’22”

Note: 1) Includes 40-second delays for traffic lights, and 20-seconds for stop signs; 2) Assumes average bicycle speed of 15km/h

Table 4.9. Average bus trip estimates, from home to Wildwood station

Origins	Distance (home to bus stop) (km)	Distance (bus stop to station) (km)	Total Distance (km)	Time (home to bus stop)	Time (bus stop to station)	Total Time
Briarwood	0.225	8.3	8.525	2’30”	18’	20’30”
Lakeridge	0.225	4.6	4.825	2’30”	12’	14’30”
Lakeview	0.225	4.8	5.025	2’30”	14’	16’30”

Note: Assumes on-time bus service, and zero wait time.

5 DISCUSSION

5.1. Potential Bicycle-Bus Market

Lawson and Morris (1999) found that males, aged 20-24 were most likely to take up bicycling for transportation purposes. This demographic represents the largest age group in most of Saskatoon's east-side Census Tracts, likely due to their close proximity to the University of Saskatchewan (City of Saskatoon, 1998a). The geographical relationship between the University and this large student population provides a market conducive to bicycle transportation (ITE, 1997). These facts provide evidence of pent-up demand, or at least, potential demand for bicycle infrastructure. In light of the City of Saskatoon's recently released Comprehensive Bicycle Plan, which calls for the provision of adequate facilities for cyclists, support for strategies to improve bicycle integration appears to be increasing (City of Saskatoon, 2002). At the time of this survey, in 2003, there were designated shared roadways on collector streets leading to the University campus, and a new roadway between the campus and a medium-density neighbourhood to the north was equipped with wide shoulders and a striped bicycle lane. The Meewasin Trail, along the South Saskatchewan River, also offered a safe and efficient route to campus from the north side of the river and CBD.

5.2. Bus Occupancy: Economic and Efficiency Considerations

While specific occupancy numbers for the bus routes in question were unavailable when the field work was done for this study, in Spring 2003, other studies of transportation modal split indicate extremely low usage of bus service, bicycles, and walking for commuting and utility trips; with one study showing that over 90% of trips are made by automobiles (National Highway Administration, p. 1995). Considering the Census Tract population characteristics of the study area – particularly the size of the 20-24 age group, the total number of student-aged residents is lower relative to other Saskatoon neighbourhoods situated closer to the University of Saskatchewan campus; except in Wildwood, where 20-24 age group is higher than any other age group (City of Saskatoon, 1998a). This might suggest lower overall bus demand in these neighbourhoods since the University of Saskatchewan is a major destination of transit users in Saskatoon.

When the field survey was conducted, the University was out for the summer, and the survey was done at off-peak hours. Bus ridership on neighbourhood loop routes was visually observed and appeared to be low. Despite the off-peak time of day and season of the field survey, this perception of low demand might indicate that Saskatoon Transit could meet peak service demands by using smaller, more economical buses or shuttles in the study service area. Such service would allow increased flexibility of suburban transit service as more shuttles could operate the routes for the same cost, providing increased service frequency and better coverage. Shuttles could be dispersed to provide service to new routes, thereby broadening the reach of transit and increasing overall level of service.

Since this study was conducted, the City of Saskatoon has released the Saskatoon Transit Strategic Plan Study (2005). While the document's primary objective is to increase transit's market share, it functions as a sustainable transportation plan for Saskatoon by covering a wide range of supporting alternative transportation policies and initiatives related to land use (Transit Oriented Development) and Transportation Demand Management. Significant public input and ridership counts confirmed this paper's observation of the need for major route restructuring. In particular, recommendations of the Strategic Plan Study that would improve potential bicycle-bus service include:

- More direct, faster, and more frequent routes, including Bus Rapid Transit (express service to major destinations)
- Removal of small looping suburban routes that required multiple transfers by combining these circuitous routes with trunk routes.

The final recommendations employ many of the strategies that have led to sustainable transportation improvements in European cities discussed earlier in this paper (e.g., Freiburg, Oxford, and Enschede). While it is too early to conclude whether or not the same level of success will be achieved in Saskatoon as was reached in the European countries examined in the Literature Review, the overall balanced approach can be expected to yield positive results for sustainable transportation alternatives.

5.3. Study Limitations and Future Research Directions

While the proposed methodology provides a simple quantitative tool that could be used by planners to identify problems and solutions to NMT accessibility in contemporary suburban neighbourhoods, does not address some important qualitative and context-related factors. This level of detail was considered secondary to the main purpose of establishing a generalized model for approaching NMT access issues, and therefore, received limited emphasis in the literature review. Most importantly, perhaps, is the fact that all of the access improvements and remedies used in phase two of the methodology are drawn from European strategies. While European countries may be significantly more advanced than North American cities regarding NMT encouragement and sustainable transportation encouragement, there may be unforeseen issues that arise from applying their engineering and policy solutions directly to North American cities. The fact that each of the European strategies represented a unique blend of solutions that was tailored to a specific locale based on regional values and goals makes it very likely that simply selecting piece-meal bits from each of these strategies, and applying them to North American neighbourhoods is not likely to be practical. First, consideration of local residents' values and needs must be considered, along with local philosophies and the political climate. If there is no support for NMT improvement, then it will not occur.

The methodology assumes that greater accessibility is always desirable. However, sometimes issues such as safety, property value, vandalism, and privacy may take precedent over providing NMT modes with more direct and faster routes and services. For example, where pedestrian routes are not well monitored, they may encourage undesirable activities such as graffiti, excessive noise, or loitering that detracts from the enjoyment or property values of nearby property owners. Furthermore, if there is no existing or future demand for improved accessibility in a neighbourhood, then it is pointless to apply the proposed methodology in the first place. This reinforces the importance of accounting for citizen needs, perhaps through a public input process such as neighbourhood focus groups, public hearings, and demographic data analyses.

Better understanding of critical values affecting the decision to bicycle may also be helpful in determining what improvements are most imperative to influence modal shift from cars to bicycles in North American cities. Particularly, issues pertaining to comfort should be considered as part of a complete review of bicycle accessibility since it is closely tied to the question of usefulness of access routes, in that what constitutes a reasonable critical biking distance or time is directly influenced by comfort. To this end, since most North American cities experience winter conditions that significantly reduce utility bicycling during several months each year, there is a great opportunity for future research to examine the role of winter on NMT access and use in North American (and particularly Canadian) cities.

The next problem pertains to the variation in what constitutes a "contemporary North American suburban neighbourhood." There are numerous variations of contemporary neighbourhood designs throughout North America. Each neighbourhood is unique from another in its mixture and degree of those characteristics that make it more or less automobile dependent. Neighbourhood designs have gradually evolved over time, and while two neighbourhoods may encompass all of those characteristics that define contemporary suburbs, their compositions are likely to be very different. The scale and context of the neighbourhoods themselves and the cities and their context within the urban areas of which they are a part will likely affect the degree, orientation, and necessity of NMT access within them. While good NMT access is considered to be a desirable goal in and of itself, it may be optimally designed to meet specific access aims (e.g., directed toward a shopping centre or bus station, as in the case study). This implies the need for a certain degree of good judgement in order to optimally apply the proposed methodology. Perhaps future research could examine the problem of standardizing application of the proposed methodology to ensure its best application.

5.4. Policy Issues

Aside from the architects, engineers, and developers who design and build subdivisions that are sensitive to accessibility needs, governments – both local and federal – have failed to legislate and enforce minimum accessibility standards for new major residential subdivision developments, which provide equitable transportation alternatives to automobiles. At least, incentives should be provided to encourage developers to strive to meet these goals. Many municipal zoning codes not only do not encourage more accessible community design, and actually discourage such patterns by requiring suburban residential zones to meet large minimum lot size and setback standards, and wide streets. Furthermore, land use segregation, resulting from zoning by-laws, has practically eliminated residential neighbourhood groceries and convenience stores, thereby increasing the distances between residences and these basic goods and services, and furthering dependence on motorized transport.

The problem of downtown abandonment, resulting from suburban development, is something that government should address. Currently, land is less expensive to buy and develop on the outer edge of cities. This is reflected in lower property taxes for suburbanites. Infrastructure, including roads, water, and sewer mains are paid for by the city to meet the demands of outer urban ring expansion. Ironically, it is the downtown property owner, with higher valued land, who pays more property tax, and thus a larger share for new services to reach suburban homes. Downtown redevelopment and higher density housing may cost more in terms of initial investment, however, the long-term savings is vast for the community as a whole.

Mortgage lenders typically ignore the cost of private automobiles when awarding loans to car-dependent suburbanites. Conversely, they do not recognize the lower transportation costs of urban dwellers that have access to good and cheap public transportation, and do not own a car. When a person considers whether to buy a home in a suburb, or in the city, they may not be able to get a mortgage on more expensive property in the city, because mortgage lenders do not factor in lower transportation costs (Hare, 1995). So, they end up purchasing a cheaper house in a suburb, and may spend a significant amount of their income on a private automobile.

The City of Saskatoon recently took steps toward downtown revitalization by adopting a policy to promote compact city form through "the development of a compact and efficient urban form"… which will be encouraged by …"setting overall density guidelines for new residential, commercial and industrial areas, and gradually increasing the overall density of the City." (City of Saskatoon, 2000, p. 20). Since 1998, the Zoning Bylaw has allowed smaller lot sizes in low density districts, and permitted development of secondary suites on lots in low density zones (City of Saskatoon, 2000, p. 20). Additionally, a new Urban Development Agreement between the Federal Government, Province of Saskatchewan, and City of Saskatoon will provide ten million dollars for projects primarily aimed at rejuvenating the Central Business District and older neighbourhoods by supporting activities that would attract visitors and citizens to the downtown, and improving safety, health, and attractiveness of older neighbourhoods (Government of Canada, 2006). These policies and investments should help to promote higher density and downtown developments. However, a conflicting trend toward larger lot sizes and massive single-family houses is occurring throughout North America. These land wasting subdivisions are likely to continue as long as there are no maximum lot and home size restrictions.

Some steps that might be taken by municipal governments to actively discourage sprawl include limiting extensions of utility services to outer areas identified as suitable for growth in a Comprehensive Plan. Other options include setting Urban Growth Boundaries and establishing regional planning agreements between the city and surrounding towns, and the province to ensure that consistent policies are adopted to curb undesirable land uses and densities on land adjacent to but outside of the City’s jurisdiction.

6 CONCLUSIONS

This paper has discussed the challenges associated with contemporary suburban design practices and using bicycles for transport. Namely,

- Poor connectivity and permeability of the transportation network
- Homogeneous land use
- Long travel distances to destinations
- Poor transit service
- Poor multimodal integration opportunities
- Lack of bicycle infrastructure

It proposed an application of Talen's (2003) methodological framework to test the assumption that suburban neighbourhood designs make the bicycle an impractical transportation mode by,

1. measuring general neighbourhood accessibility and permeability using established indices
2. identifying physical characteristics that impede NMT through physical field surveys
3. providing a toolbox of proven treatments that might be used to mitigate existing physical accessibility problems
4. examining issues and opportunities for bicycle-bus integration

The approach was tested by conducting general connectivity and permeability measures in an area comprised of four suburban Saskatoon neighbourhoods. Next, detailed field survey data was collected along routes between home proxies and a single bus transit destination within the study area to provide details regarding bicycling conditions and to identify infrastructure integration opportunities.

The results showed that, in the Saskatoon case study, bicycle accessibility is adequate in terms of street network directness and trip time costs, however multimodal integration opportunities are non-existent. Provision of bicycle lanes, bicycle racks, and bicycle short-cuts through parks would improve the ability of cyclists to compete with other transport modes, and might encourage more residents to try using their bikes as an alternative to driving automobiles.

Although the case study showed that bicycles could be competitive with buses for trips within suburban areas, they are unable to compete with cars. While some changes to the facilities provided to cyclists might improve efficiency, increasing the density of future developments is crucial to reaching a point where bicycles can compete with automobiles.

Generally, the results showed that bikes could be competitive with bus service routes in the subject neighbourhoods. Many of the strategies from Europe as well as suggested reforms from the Discussion chapter of this paper have been adopted in the Saskatoon Transit Strategic Plan Study (2005), however, retrofitting existing street networks to improve bicycling efficiency and safety was not mentioned in the Strategic Plan. As mentioned in the Literature Review and case study analysis, these measures could significantly influence the decision to use bicycles for utility trips either with or without complementary transit services. Students in suburban transit service areas might be likely candidates for bicycle-bus adoption where traditional bus service requires a transfer and consequently biking is more time efficient.

The study demonstrated that Talen's methodological approach for assessing neighbourhoods as service providers might be applied by urban and transit planners to identify alternative transportation issues and opportunities for improved bicycle access and transit integration in suburban contexts. The findings (i.e., relative access, based on distance, time, permeability, and route quality) of such assessments could be used to help determine allocation of transportation improvement funds for pedestrian, bicycle, and transit infrastructure and service projects.

Beyond the detailed examination of physical transportation network and facility needs required to maximize suburban bicycle efficiency, socio-economic factors such as age, income, and car ownership must also be considered by transit planners as part of a comprehensive re-examination of suburban bicycle and transit facility provision and service allocation. Differences in transit need and demand exist between neighbourhoods throughout any city. Although suburban neighbourhoods are usually farther from destinations, their residents are also more likely to have access to private automobiles. Perhaps a diversion of transit service in such neighbourhoods to better serve less mobile neighbourhoods would be more politically acceptable if infrastructure were added to establish bicycling as a viable alternative to reaching main transit hubs.

Recognizing and accommodating voluntary cyclists is a small part of the overall solution. In order to reach the necessary goals for automobile use reduction, strong evidence points to the need for balanced approaches that involve the implementation of tough anti-automobile measures. While pro-bicycle measures such as dedicating road space to bicycle lanes and including bicycle green lights into traffic signalization cycles inadvertently detracts from automobile efficiency by making motorists share limited time and space (right-of-way), a few additional methods are likely to be politically challenging to implement until utility bicycling becomes more mainstream. A few of the most obvious strategies include,

- increasing taxes for motorists (gas, Sport Utility Vehicle tax, parking, road maintenance), and using the extra revenue to support and improve sustainable alternatives
- restricting autos from certain streets or districts to balance out the relative efficiency of alternative modes
- limit construction and expansion of roadways that serve suburban fringe areas, as they encourage further undesirable suburban sprawl rather than supporting desirable inner city rejuvenation projects (e.g., high-density housing projects).

In addition, promotion is imperative to help change connotations and public perceptions to favour bicycling and bus/transit as a legitimate and respectable transport mode. Programs should aim to educate the public and change habits, as part of a comprehensive approach.

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