SUSTAINABLE TRANSPORTATION AND LAND USE PLANNING AT SIMON FRASER UNIVERSITY: A CASE STUDY OF THE BURNABY MOUNTAIN CAMPUS

by

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Abstract

This study examines the feasibility of developing a *Sustainable Transportation Plan* that aims to reduce single-occupant vehicle (SOV) trips to and from Simon Fraser University's (SFU) Burnaby Mountain Campus by a minimum of 20%. This target is based on other university transportation plans that seek to reduce SOV travel by 20% and the call for a 20% reduction in global greenhouse gas emissions by world policy-makers.

The STP focuses on improving the efficiency of the transportation and land use system by influencing how people travel (i.e. modal choice), where they travel (i.e. how far they travel to reach their desired destination), and when they travel (i.e. peak versus off-peak). To develop sustainable transportation and land use policies and a *Sustainable Transportation Plan* for SFU, a 'sustainability-planning' framework was developed. This framework identified appropriate categories, goals, objectives, indicators, and targets for this study's overall objective of reducing SOV travel by 20%. It thus acts as the foundation and template for policy formation. Furthermore, an examination of transportation demand management (TDM) measures and sustainable transportation and land use indicators (*Indicators Menu*) - identified through an extensive literature review - was completed and integrated into the development of the *Sustainable Transportation and Land Use Planning Framework*. "High" priority indicators were identified from the evaluation of the *Indicators Menu* and "1st" and "2nd" priority indicators were further identified - based on the achievement of certain sustainability criteria - from this list of "high" priority indicators. The result is the formation of the *Master Sustainable Transportation and Land Use Planning Framework* which is then used to develop 11 sustainable transportation and land use policies and 8 TDM strategies that are recommended to achieve a 20% (minimum) SOV trip reduction target.

The results of this study indicate that it is feasible for SFU to implement a *Sustainable Transportation Plan* that will reduce SOV travel to and from its Burnaby Mountain campus by a minimum of 20%, thus achieving several ecological, social, and economic objectives. Furthermore, the *Sustainable Transportation and Land Use Planning Framework* provides not only SFU, but other communities, municipalities, and regional districts with an effective 'template' for developing custom sustainability plans.

Dedication

To my two "M's" – my *Mom*, for your infinite support…and *Moni*, for your inspiration, faith, patience, and pure sunshine…*we did it!*

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This study is the result of 2 years of intense course work and research, a journey that has enabled me to forge relationships with a wide spectrum of people. I sincerely appreciate the assistance of all those that have helped me out along the way, and though I cannot acknowledge all of you, I will make every effort to mention those who played significant roles in this project.

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Chapter 1 Introduction

1.1 Background

1.1.1 Introduction

Policy-makers around the world are struggling with urban transportation and land use management issues. Population growth, decreasing rates of public transit use, and increasing levels of urban sprawl and automobile dependence are intensifying stress on the global environment and contributing to global climatic change. Strategies to manage these issues are plentiful and diverse; however, their diversity and lack of proven experience frustrate policy-makers when selecting the most appropriate sustainable transportation strategy. The Organisation for Economic Development (OECD) indicate that sustainable transportation aims to ensure that the needs for access to people, services, and goods are met without producing permanent harm to the global environment, damage to local environments and social inequity (OECD 1996). The key concept within this principle is *access*. Traditionally, access to these social objectives (e.g. employment, education, shopping, services, and recreation) was provided in the form of compact, walkable communities that were based on the foundations of "proximity-planning" and convenient public transit service. These communities, called "Traditional Neighbourhoods," relied on foot, bicycle, and transit travel to achieve daily movement throughout the local and broader region. Pockets of these neighbourhoods exist within older North American cities but are more commonly found in Europe. The benefits of these communities in reducing socio-environmental stress are now becoming more widely known, and hence, traditional neighbourhood design is gaining considerable attention as a potential solution to these transportation and land use problems (Roseland 1998; Bernick and Cervero 1997; Calthorpe 1993; GVRD and CUI 1994c).

Transportation and land use policy makers are also starting to investigate the application of demand-side management strategies in an attempt to reduce the ecological, social, and economic impacts associated with a highly automobile dependent society (Newman and Kenworthy 1999; Davidson 1997; Roseland 1998). Transportation Demand Management (TDM) is the emerging planning paradigm that seeks to reduce the demand for private vehicle travel by influencing *when* we travel (i.e. peak versus non-peak), *how* we travel (e.g. car versus transit), and *how far* we travel to access desired destination points. In other words, vehicle trips and congestion can be reduced by:

1. **Shifting the Mode of Transportation:** measures that attempt to influence the public to switch from single-occupant vehicles to public transit, carpools, vanpools, bicycles, and walking. This is called a *modal shift*.
2. **Eliminating Trips:** measures that attempt to reduce either the total number of person-trips made (e.g. telecommuting) or vehicle trips made (e.g. integrating mixed-use zoning into a community to enable citizens to walk to local grocery stores).
3. **Lowering Peak Demand:** measures that attempt to influence the time at which people travel, to reduce peak-hour travel and congestion.

To influence the extent, timing, and mode of travel, TDM policies use *economic incentives*, *regulations*, and *voluntary* measures (GVRD and Province of BC 1993a). Some common TDM initiatives include road pricing (i.e. tolls) and increased parking rates (economic incentives); vehicle and parking restrictions (regulatory); and flexible work schedules (e.g. compressed work weeks and telecommuting) and trip – or traffic – reduction programs (voluntary) (Litman 1995a).

1.1.2 Canada

Despite growing scientific and public concern on global climate change, energy consumption and associated greenhouse gas emissions are increasing in all but a few industrialised countries (IPCC 1996). From 1990 to 1995, Canadian emissions of all greenhouse gases rose by 9.5% – more than double the global rate. Projections suggest that without further action, Canada's total greenhouse gas emissions may be 19% higher in the year 2010 than in 1990 (NRTEE 1997). The primary sources of these increases are population and economic growth, coupled with low energy prices and a shift to fossil fuels, particularly natural gas, for electricity generation. This trend is occurring in spite of the Canadian government's commitment to stabilise greenhouse gas production at 1990 levels by the year 2000 (IPCC 1996).

In December 1997, governments from around the world met in Kyoto, Japan for the United Nations Framework Convention on Climate Change. The Kyoto Protocol calls for a global greenhouse gas reduction of 5.2% of 1990 levels to be achieved between 2008-2012, where Canada has committed to a 6% reduction of 1990 greenhouse gas levels (Cairns 1997). The greenhouse gases were defined as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). These emissions all contribute to what is commonly known as "global warming" (BC Environment 1995; IPCC 1990)

Carbon dioxide contributes approximately 55% to global warming from greenhouse gases produced by human activities (Miller 1994). Of this contribution, the transportation sector contributes approximately 35% towards total CO_2 emissions – that is, CO_2 emissions from transportation contributes to approximately 20% of the total global warming effect (Gordon 1991).

A growing scientific consensus concedes that global pollution will result in global climatic change. Global climatic models estimate that the earth's mean surface temperature will rise 1.5 ° to 5.5° Celsius by 2050 if inputs of greenhouse gases continue to rise at the present rate (Miller 1994). Closer to home, estimates quoted in provincial reports suggest that over the next 100 years average temperatures in BC are likely to rise by 7° Celsius in winter and 4° Celsius in summer with an uncertainty of 3° Celsius (McBean et al. 1992; Davidson 1997). Such a rate of change has not been experienced in the previous 160,000 years. By comparison, the transition from the last ice age to our present interglacial period led to an increase in temperature of approximately 6° Celsius over a period of 5,000 – 10,000 years (City of Vancouver 1990; Davidson 1997).

Such a dramatic and rapid change will likely cause major shifts in climatic patterns, possibly beyond the capacity of many ecosystems to adapt (Davidson 1997). The west coast of BC could experience rising sea levels and temperatures, more frequent and damaging storms, significant loss of plants and productivity, forest die back, and increased incidence of disease amongst humans and plant and animal species (Province of BC 1995a). According to the David Suzuki Foundation, some of the human health impacts are already being experienced, as studies indicate that more than 16,000 Canadians prematurely die each year from excessive air pollution (Last 1998).

As 46% of BC's energy-related greenhouse gas emissions come from the transportation sector, programs to reduce these impacts are required if Canada hopes to achieve its Kyoto greenhouse gas commitments (GVRD 1994a). A further incentive for government action is public opinion: 61% of Canadians believe that we should act now to reduce human impacts on climate, even if there are major economic and social costs (Duffy 1997).

1.1.3 Greater Vancouver Regional District (GVRD)

The population of the GVRD is growing each year by nearly 50,000, a population the size of West Vancouver. Yet the rate of automobile use is growing even faster. Between 1985 and 1992, the number of vehicles registered for commuting purposes increased 32% while the population increased by only 21% (Wood 1998). This trend supports the domination of private vehicle travel over other modes. Currently, private vehicles make up approximately 83% of all trips in the Greater Vancouver area, where transit and walking/bicycling make up only 9% and 8% respectively (GVRD and Province of BC 1993a). Recent reports from the GVRD indicate that these transportation trends are continuing (GVRD 1997a; GVRD 1998b). Given these transportation realities, it is no surprise that a public poll completed in 1996 indicated that transportation had surpassed crime as the public's primary concern within the GVRD (Bohn 1996).

While the GVRD's road system is fast approaching gridlock, social, environmental, and economic indicators continue to provide an imperative for change. Traffic congestion causes stress to commuters, exacerbates air pollution problems, increases greenhouse gas emissions, and stifles economic activity by delaying the movement of goods and people (Davidson 1997). For example, the incidence of child asthma attacks related to poor air quality in the GVRD has doubled in the last ten years (Last 1998). In 1990, 600,000 tonnes of primary air pollutants (i.e. carbon monoxide, volatile organic compounds, nitrogen and sulphur oxides and particulate matter) were emitted into our local atmosphere, with motor vehicles accounting for 77% of this pollution (GVRD 1994a). Furthermore, research indicates that transportation is responsible for 44% of Vancouver's energy-related CO_2 emissions (Davidson 1997).

Moreover, delays to goods movement due to traffic congestion causes serious economic impacts. Traffic-induced delays to the movement of goods in the GVRD cost $110 million in 1991. In 2021, it is expected that congestion related delays will cost approximately $300 million each year (GVRD and Province of BC 1993a). On a per capita basis, congestion costs each driver approximately $350 US annually (in 1990 dollars) in additional fuel and maintenance costs (Lomax, Bullard, and Hanks 1989).

To combat these impacts, the GVRD adopted *Creating our Future: Steps to a More Livable Region* in 1990 (GVRD 1990). This document laid out principles and strategic policies to guide development within the region. It stated that the GVRD will "sustain and develop a co-operative transportation planning process with the provincial government and its agencies based upon the GVRD Board's approved policies to give priority to walking, cycling, transit, and *then* the private automobile" (GVRD 1990, 14). This policy formed part of the terms of reference for *Transport 2021*, Greater Vancouver's long-range transportation plan (Davidson 1997; GVRD and Province of BC 1993a). Vancouver's recent *Draft Transportation Plan* also stresses the need for reduced reliance upon the auto, and states that "we should be willing to use transit, walk or bike where these are practical options, and leave our car at home" (City of Vancouver 1996, 1). In addition, the *Burnaby Transportation Plan* supports sustainable transportation, as its vision statement indicates that the City of Burnaby should "strive to facilitate the efficient movement of people and goods in Burnaby in a cost effective manner which enhances the environment and livability of the entire community" (City of Burnaby 1995, 24).

In 1996, The Livable Region Strategic Plan (LRSP) was approved by the GVRD (GVRD 1997a). The LRSP is based upon four fundamental objectives directed towards maintaining the environmental quality and livability of the region. These objectives are as follows:

1. **Protect the Green Zone**: is intended to protect Greater Vancouver's natural assets and to create a long-term urban growth boundary.
2. **Build Complete Communities**: is intended to provide more residents with access to the range of day-to-day activities within their own neighbourhoods, such as work, shopping, and school.
3. **Achieve a Compact Metropolitan Region**: is intended to concentrate urban growth in specified areas within the region, thereby enabling people to live closer to work and services and improving the transportation system within the region.
4. **Increase Transportation Choices**: is intended to increase the convenience and accessibility, and thus attractiveness, of transit and reduce dependence on single-occupant vehicle travel.

Transport 2021 identifies four policy levers that can be used to achieve these goals in an attempt to move people and goods efficiently, increase transport equity, reduce environmental impacts, and decrease automobile dependence within the region. These levers are (GVRD and Province of BC 1993a):

1. Control Land Use
2. Apply Transport Demand Management
3. Adjust Transport Service Levels
4. Supply Transport Capacity

The GVRD has put significant emphasis on complete communities, compact urban areas, and sustainable transportation and land use planning, thus highlighting their importance in reducing automobile dependence and minimising environmental degradation. For the purposes of this study, the integration of the land use and transportation demand management policy levers will be the focus.

1.1.4 The Study Area: Simon Fraser University – Burnaby Mountain Campus

SFU, with its unique mountain top location, is home to approximately 15,000 full-time equivalent students with an average daily campus population of 12,000 students, staff, and faculty (Moodie 1996). This mountain top location, coupled with its relative isolation from major centres within Greater Vancouver and its limited on-campus housing, make SFU a typical 'commuter campus'. Figure 1-1 and 1-2 provide a map of the Burnaby Mountain campus and its relationship to the Greater Vancouver area.

There are currently 6,719 pay-parking spaces on campus (Moodie 1996). With respect to alternative transportation, SFU is serviced regularly by TransLink buses and a carpooling parking permit program exists providing preferential parking privileges. However, to date there has not been any serious economic incentives provided for car/vanpooling and the co-ordinated ridesharing program that once existed has been discontinued. Dedicated bike lanes exist on parts of the Burnaby Mountain Parkway and Gaglardi Way/University Drive (i.e. the main arterials that access Burnaby Mountain from the west and east); however, their 'incomplete' and 'unconnected' status makes commuting by bicycle hazardous. Burnaby Mountain is also well connected with a series of walking and cycling trails, which are commonly used by local residents and some commuters. Therefore, the spectrum of transportation modes used to access SFU's Burnaby Mountain campus includes private vehicles, buses, cycling, and walking.

In 1995, SFU gained the right to develop residential communities within the university's Ring Road, a project aptly named the Burnaby Mountain Community Development (BMCD). The area involved consists of approximately 78 hectares of land along the south and east edges of the existing campus, which are slated for up to 4,536 residential units, with up to 10,561 residents (Moodie 1996). The Development Plan Concept (DPC) estimates a full-time student enrolment of 25,000 with a resultant daily campus population of 20,000 students, staff, and faculty (Moodie 1996). This doubling of the campus population presents serious transportation planning challenges for SFU and the development of a growth management plan must therefore incorporate adequate strategies to manage the increased transportation demands. These increased transportation impacts will play an integral role in shaping SFU's *Sustainable Transportation Plan* and will thus be incorporated into its design.

Figure 1-1. Simon Fraser University: Burnaby Mountain Campus

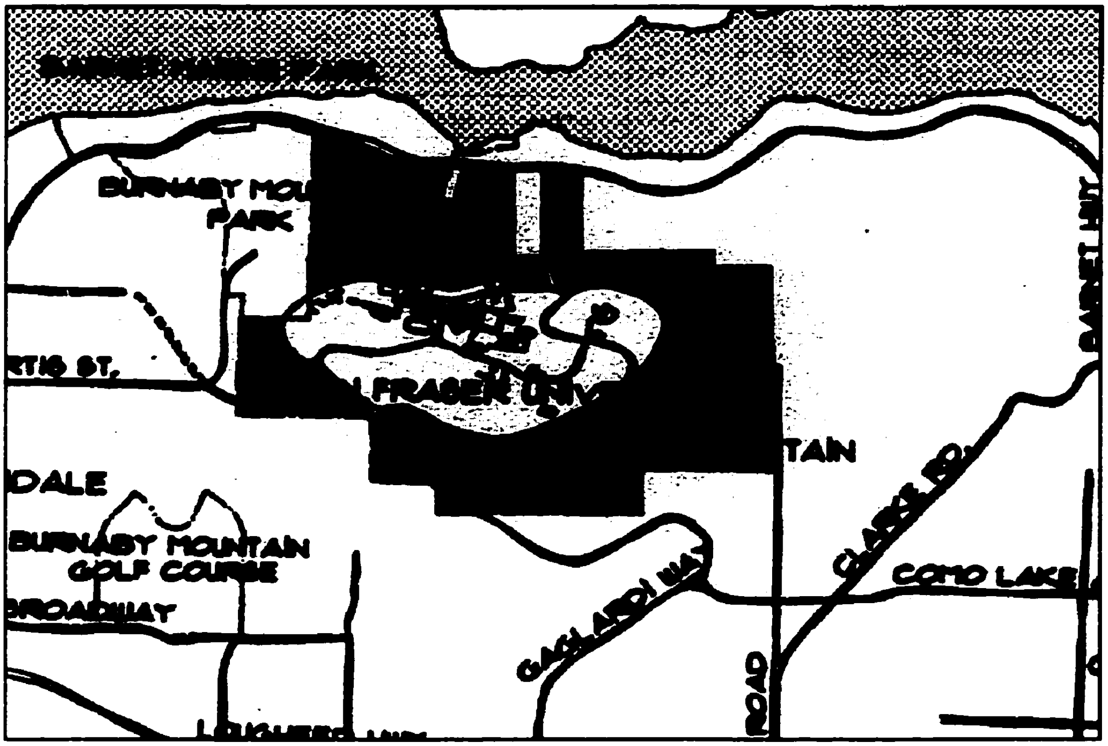
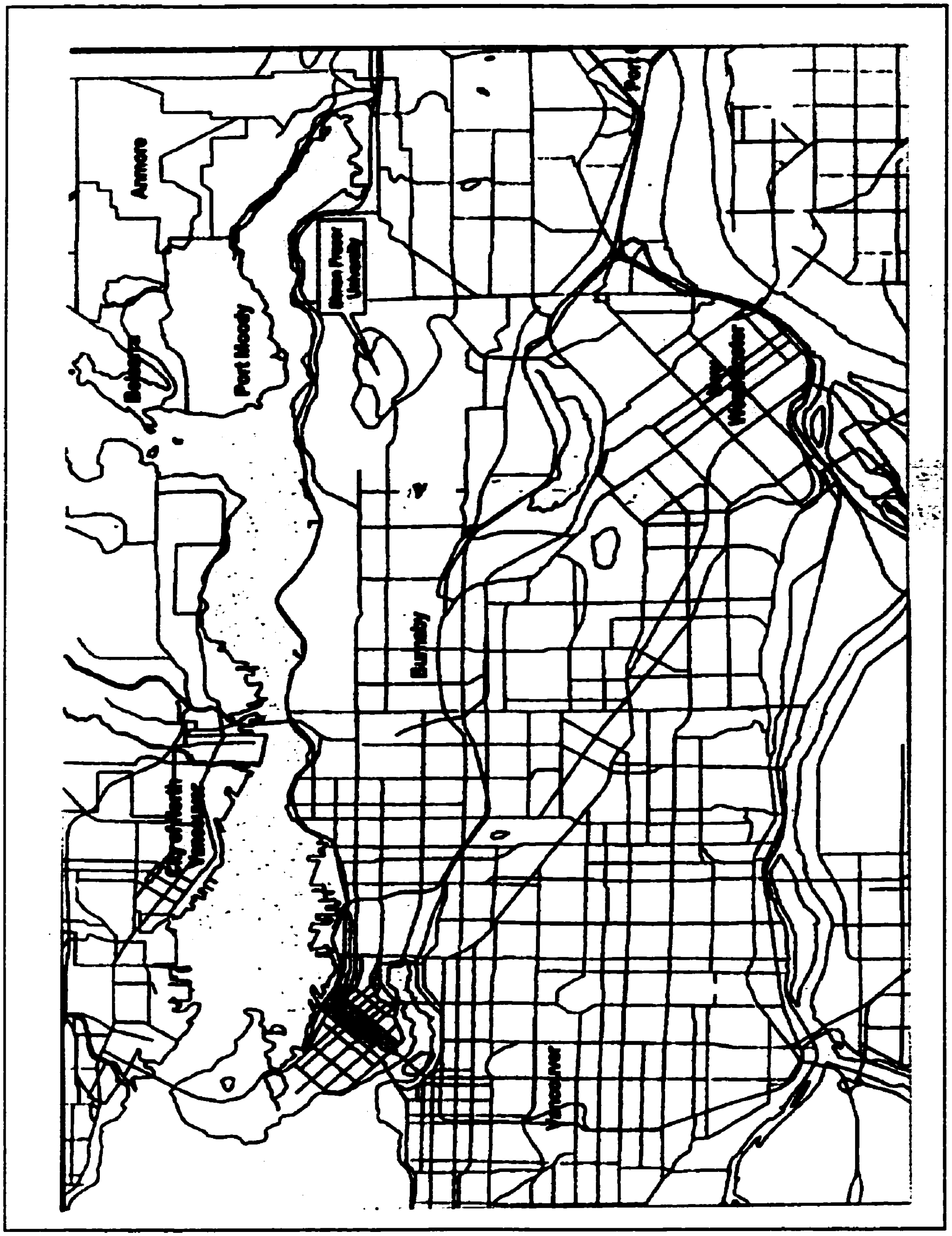


Figure 1-2. Greater Vancouver Regional District (not in its entirety) with Simon Fraser University's Burnaby Mountain Campus Highlighted



1.2 Research Questions and Objectives

1.2.1 Primary Research Questions

Transportation and land use planning lie at the core of sustainable development. These disciplines not only attempt to solve transportation efficiency problems, but address a spectrum of environmental, social, and economic challenges as well, thus integrating the three spheres of sustainable development. Furthermore, through managing transportation and land use systems, critical resources are affected, such as land, air, water, human, and other resources. It is in this sense that transportation and land use planning are considered an important part of resource management.

To reduce the threat of global environmental degradation, it is believed that local strategies play a significant role (Roseland 1992; Roseland 1998; Brugmann 1996; Newman and Kenworthy 1999; Engwicht 1993). In the late 1980s and early 1990s it was agreed that global emissions of carbon dioxide should be reduced by a minimum of 20% by 2005, an initiative of particular significance at the local level considering that the majority of the resulting policies would be implemented at this level (City of Vancouver 1990; Toronto Conference Statement 1988; Flavin 1990; IUCN, UNEP, and WWF 1991). Furthermore, it is agreed that a reduction in single-occupant vehicle (SOV) trips is one of the most effective means of achieving this target. In support of this, universities throughout North America are establishing traffic reduction plans aimed at reducing SOV trips by a minimum of 20% (Lovegrove 1998, Poinsatte and Toor 1999; Williams and Petrait 1993). In light of these recommendations and initiatives, it would therefore be rational to establish parallel goals in the development of local transportation and land use plans at SFU. The primary research questions for this study are as follows:

> ***What land use and Transportation Demand Management (TDM) strategies would be most effective in reducing single-occupant vehicle (SOV) trips to and from SFU's Burnaby Mountain campus by a minimum of 20%? What are the most appropriate short-term strategies and implications? What types of long-term strategies can we anticipate to manage future community growth?***

1.2.2 Secondary Research Questions

1. Is there a transportation problem at SFU? If so, what is it and why does it exist?
2. What transportation alternatives and TDM strategies exist? What are the associated benefits of implementing these strategies and what strategies prove most applicable to the SFU case study?
3. What impacts will the Burnaby Mountain Community Development (BMCD) have on transportation demand? How should these impacts be integrated into SFU's *Sustainable Transportation Plan*? What sustainable, or "complete community," design principles can be applied to this development?

1.2.3 Research Objectives

To design a *Sustainable Transportation Plan* that:

1. May educate and influence SFU – as an institution – to adopt, develop, and implement its own sustainable transportation, or traffic reduction, plan;
2. May influence members of the university community to become conscious of their personal transportation impacts and to induce behavioural changes with respect to transportation to achieve a minimum single-occupant vehicle trip reduction target of 20%;
3. May influence the design of the Burnaby Mountain Community Development (BMCD) to minimise auto dependence and its associated ecological, social, and economic impacts; and
4. Incorporates the development of a 'sustainability decision-making framework' that can be applied as a template to other community and regional planning processes to assist in the development of sustainable transportation and land use plans.

1.3 Methodology

1.3.1 Literature Review

Chapter 2 provides the foundations of this research study, explaining the importance and urgency of sound land use and transportation management. The literature review defines sustainable development and its relationship to this project; investigates the history of land use and transportation planning in North American urban centres; and discusses the 'old' versus 'new' planning paradigms, and the intricate relationship between land use and transportation planning and its influence on automobile dependence. The ecological, social, and economic impacts of unsustainable transportation and land use systems are highlighted and potential land use and transportation management solutions reviewed. In this review of transportation management solutions, TDM strategies are evaluated to identify measures that may be highly effective in this case study.

1.3.2 Framework Development

Chapter 3 focuses on the development of the *Sustainable Transportation and Land Use Planning Framework.* This framework is based on the identification and development of *indicators*, and Chapter 3 thus starts with a review of sustainability indicator definitions, objectives, and identification and development processes. Indicators are considered to be an effective tool in developing policies, as they represent the foundations of a community's values (i.e. its goals and objectives), and enable a community to measure their progress towards these values (Roseland 1998; Brugmann 1997; Jacobs, M. 1993; Hart 1995; Maclaren 1996a). Indicators thus play a central role in the development of both the sustainability framework and the *Sustainable Transportation Plan*.

Based on a local sustainability initiative, Sheltair's "Comprehensive Framework for Sustainable Urban Development" is selected as the model for the development of the *Sustainable Transportation and Land Use Planning Framework* (Sheltair 1998). This model is used to develop the 'categories', 'goals', and 'objectives' for the SFU case study.

An *Indicators Menu* is developed and includes over 100 sustainable transportation and land use indicators that cover the following categories: General Transportation;

Public Transit; Traffic Calming; Non-motorised Travel and Pedestrianisation; Parking; Education, Organisations, and Programs; Environment; Land Use; Economy; and Livability. Sustainable transportation and land use criteria are then developed to evaluate the list of indicators found within the *Indicators Menu*. They include: Transportation Efficiency, Land Use Efficiency, Environmental Impact, Human Livability, and Economic Efficiency. These criteria represent several sustainability objectives, such as increased access and density, reduced air and water pollution, calmed traffic, and improved economic equity among all transportation users.

The evaluation of the *Indicator Menu* identifies *LOW, MEDIUM,* and *HIGH* priority indicators. High priority indicators are then classified as either *1st Priority* or *2nd Priority* indicators, depending on their achievement of the outlined sustainability criteria. These indicators are finally matched with the 'goals' and 'objectives' outlined earlier in the framework development process. Chapter 3 thus develops the *Sustainable Transportation and Land Use Planning Framework* and identifies highly effective indicators that are used, in Chapter 6, to develop transportation and land use policies for the *Sustainable Transportation Plan*.

Geographic, or spatial, scale is an important issue with respect to the scope and objectives of this study. Sustainability plans have been developed on all scales, from the Kyoto Protocol at the global level, to Transport Canada's "Sustainable Development Strategy" at the national level, to Hamilton-Wentworth's "Sustainable Community Indicators Project" at the regional and local level (Transport Canada 1997; Roseland 1998). With respect to transportation and land use sustainability planning, it is important to differentiate between the spatial scales and identify at what level (i.e. geographic area) the planning is intended. The spatial scale will thus help focus the criteria, goals, objectives, and indicators to the appropriate scale. For example, fuel efficiency may be a more appropriate indicator at the national level, whereas the lane kilometres of cycle-ways (i.e. bike routes) through a community may be more suitable to the local level. It is the intention of this study to focus primarily on the local, or community scale (SFU's

Burnaby Mountain campus), with some obvious overlap at the regional level (i.e. the City of Burnaby and the remaining municipalities of the Greater Vancouver area).

It is important to further point out that the development of indicators for this study, given its limited scope, did not include community, or stakeholder, input. However, in the event that SFU commits to the development of a sustainable transportation plan – or any other 'plan' that affects the community – stakeholder involvement should not be overlooked and should thus be integrated into the planning process.

1.3.3 Case Study Development and Preliminary Evaluation

Chapter 4 outlines SFU's Burnaby Mountain campus as the case study for this research. The history of SFU is reviewed and background is provided with respect to current transportation and growth management issues – in particular, the Burnaby Mountain Community Development (BMCD) project. An evaluation of the potential transportation-related impacts associated with the BMCD is discussed, such as air quality, accessibility, water, and habitat impacts. Finally, the SFU's Official Community Plan (OCP), Development Plan Concept (DPC), and general transportation management policies are summarised for evaluation in Chapter 5.

Chapter 5 evaluates SFU's OCP, DPC, and general transportation policies against the 1st and 2nd Priority indicators from the *Sustainable Transportation and Land Use Planning Framework*. This evaluation highlights what policies and plans may *positively* or *negatively* influence the 1st and 2nd Priority indicators and explains the significance of these results. This evaluation is used in the development of indicator *targets* and the eventual formation of land use and transportation policies and strategies for the *Sustainable Transportation Plan* (Chapter 6).

1.3.4 Development of the Sustainable Transportation and Land Use Plan

Chapter 6 integrates the literature review findings, the *Sustainable Transportation and Land Use Planning Framework* and its *1st* and *2nd Priority* indicators, and the evaluation of SFU's OCP, DPC, and general transportation policies. The 'framework' is completed with the development of indicator *targets*, which are used, in conjunction with the previous evaluations, to develop policies for the *Sustainable Transportation Plan*. TDM and land use strategies are then recommended to achieve the policies outlined in this plan. These strategies identify the estimated single-occupant vehicle impacts that may result with their implementation. Overall, the outlined *Sustainable Transportation Plan* and prescribed TDM strategies should achieve the minimum single-occupant vehicle trip reduction target of 20% for SFU's Burnaby Mountain campus, for both the 1998 traffic levels (i.e. short-term) and the expected post-BMCD/student population growth traffic levels (i.e. long-term). The achievement of this 20% target is based on the results of other TDM and land use planning studies and programs that indicate total vehicle travel reductions ranging from 10-50%.

1.4 Importance of Research

Simon Fraser University is at a crossroads. The Burnaby Mountain Community Development, coupled with the expected student population increase, will nearly double the on-campus population by 2020-2030. Meanwhile, transportation to and from the Burnaby campus will likely continue to be dominated by single-occupant vehicles (SOVs), as indicated in a 1998 traffic survey where 40% of all trips made were in SOVs and nearly 75% of all trips were vehicle based (i.e. SOVs and car/vanpools) (Petz et al. 1998). This in turn will reduce local and global air quality and impact community and public health.

At the regional scale, SFU plays an important part in managing transportation demands. There are currently over 10,000 vehicles that travel to and from SFU's Burnaby Mountain campus daily (i.e. over 20,000 one-way trips), making SFU one of the largest 'trip generators' in the Greater Vancouver area (Coutu 1999). These vehicles produce over 40,000 kg of air emissions per week equating to approximately 8 million kg per year (see Chapter 4). Transportation demands, however, will further increase with the University's proposed growth in full-time student enrolment and community development, an increase estimated at 150-200% over the next 20-30 years. Therefore, SFU's role in both air quality and growth management is both significant and important if the GVRD is to achieve the goals and objectives of the region's Livable Region Strategic Plan (GVRD 1996).

At the national and global scale, Canada is searching for innovative solutions to meet its Kyoto greenhouse gas emissions target. Given that nearly 50% of Vancouver's energy-related carbon dioxide emissions are from the transportation sector, it is appropriate and necessary that TDM and sustainable land use plans are implemented to offset the threat of global climatic change.

This research also provides great value to not only the SFU community but other communities and regions that are, or will be, involved in the development of transportation and/or land use plans. The *Sustainable Transportation and Land Use Planning Framework* thus acts as a 'template' and can be applied to any community or regional planning process where the achievement of certain sustainable development objectives (e.g. reduction in per capita vehicle kilometres travelled) are development and/or planning priorities, such as the growth management policies found within the GVRD's Livable Region Strategic Plan. This framework therefore provides the 'tools' to manage the transportation and growth management issues facing SFU and other interested communities.

Chapter 2 Sustainable Transportation and Land Use Planning – Literature Review

2.1 Introduction

The following chapter will provide context to the above mentioned transportation and land use dilemma. The literature review will define sustainable development, sustainability, sustainable transportation, and sustainable communities; investigate the transportation and land use connection, 'old' versus 'new' transportation planning paradigms, and automobile dependence; identify the ecological, social, and economic impacts of an automobile dependent society; define and evaluate transportation demand management (TDM) and discuss its application to university communities; and finally, define and discuss transit-oriented and traditional neighbourhood developments.

2.2 Sustainable Development: Definitions

2.2.1 Sustainable Development and Sustainability

In 1987, the World Commission on Environment and Development, chaired by Gro Harlem Brundtland, defined sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987, 8). This definition is found within the visionary book, entitled *Our Common Future*, a by-product of the 'Brundtland Commission', as it is more commonly known. This vision encourages the development of a societal ethic, or value-system, that strives to find a balance between the achievement of economic, social, and environmental goals. Other research supports this definition of sustainable development, indicating the need to balance environmental goals with a strong economy and a more just and equitable society (Newman and Kenworthy 1999; Roseland 1998; BCRTEE 1991; Environment

Canada and Transport Canada 1997; NRTEE 1996; NRTEE 1997). Maclaren, however, believes that there is no single accepted definition of sustainable development (Maclaren 1996a). Each community is different with respect to its economic, social, and environmental conditions, and these conditions thus set its priorities. Given this diversity of conditions and priorities, each community will thus define sustainable development differently. On the other hand, Jacobs and Roseland indicate that there are accepted core elements of any interpretation of the term (Jacobs, M. 1993; Roseland 1998). The term 'sustainable development' has been considered somewhat controversial since its inception but has nonetheless provided a strong foundation for further discussion, debate, and development with respect to environmental, economic, and social development.

Since its inception, sustainable development has evolved into a more detailed description of the balance between economic, social, and environmental goals. For some commentators, the term sustainable development is currently recognised as simply 'sustainability,' and is defined as the "need to improve the human condition while at the same time caring for and protecting the natural environment" (Sheltair 1998, 20). Adding to this basic definition, Remiz defines sustainability as:

> *Creating and maintaining a certain capacity in all domains, so that various functions of the natural environment can be performed, and that there is an appropriate degree of community economic and political self-reliance in relation to regional and global goals.* (Remiz 1998, 1)

Sustainable development and sustainability thus address the following six key principles (WCED 1987; Sheltair 1998):

1. **Inter-generational equity**: current development and growth should ensure future generations with the same, or better, quality of life standards as that of our own.

2. **Carrying capacity**: the environment is limited through its assimilative capacity to absorb waste discharges, its ability to regenerate renewable resources, and the finiteness of non-renewable resources.

3. **Social equity**: given limited resources, the distribution and access to these resources should be more equitable, recognising the fact that everyone has the right to a fair portion of the earth's resources.

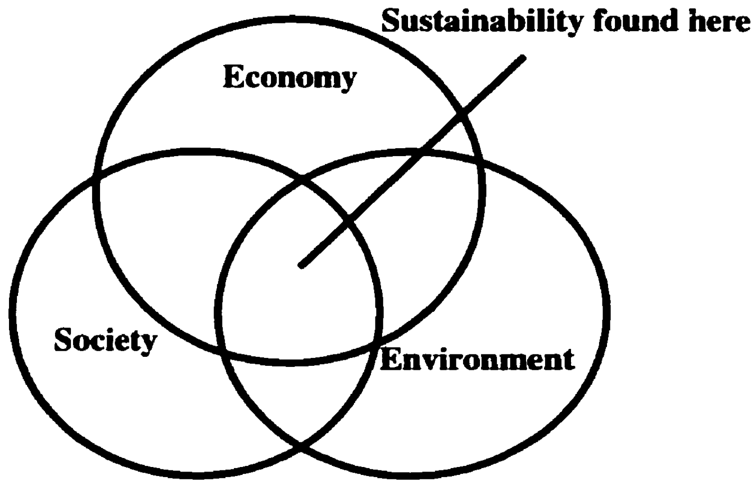
4. **Prosperity**: to provide employment opportunities and a strong economy.
5. **Diversity**: to ensure significant diversity in society, the economy, and the environment to maintain health in all spheres.
6. **Individual and community health**: to ensure physical health and safety for citizens, and provide opportunities for participation in the governance of communities.

As mentioned above, sustainability is successfully achieved when social, economic, and environmental sustainability are in unison. These objectives are defined as:

1. **Social Sustainability**: refers to the on-going ability of a community to function as a safe, healthy, and viable setting for human interaction, education, employment, recreation, and cultural development. Social sustainability is characterised by such fundamental principles as social equity, diversity, urban livability, universal accessibility, and self-determination.
2. **Economic Sustainability**: involves the production and distribution of wealth in a manner that provides goods and services for both present and future generations and that ensures the long-term promotion of a satisfying, high quality of life. Characteristics include the presence of diverse and viable economic opportunities, the involvement of relevant stakeholders in decision-making, integrated management and production processes, and responsiveness to changing circumstances.
3. **Environmental Sustainability**: involves the maintenance of clean air, soil, and water, and a variety of species and habitats through practices that minimise damage to the carrying capacity of the natural environment and that ensure the long-term integrity of a healthy ecosystem. Characteristics of environmental sustainability include self-sufficiency, resilience and adaptability, efficiency, interdependence, and biodiversity (Sheltair 1998, 23).

Sustainability is therefore found in the overlapping areas of society, the economy, and the environment, as shown in Figure 2-1. This area is where synergistic energies are realised between the three spheres of sustainability, thus creating a functional unit that is much greater than the sum of its parts (Sheltair 1998).

Figure 2-1. The Three Spheres of Sustainability



Though sustainability's primary context is global change, research indicates the need for local (i.e. regional and community-based) implementation of sustainability initiatives to achieve global sustainability goals (Newman and Kenworthy 1999; Roseland 1998; Dilks 1996). To encourage sustainable development activities at the community level, the International Council for Local Environmental Initiatives developed "Local Agenda 21" plans, a spin-off of the "Agenda 21" plan developed in 1992 at the United Nations Conference on Environment and Development (Roseland 1998). These plans empower local citizens to develop sustainable development strategies for their community. To date, there are approximately 1,200 initiatives of "Local Agenda 21s" in 33 countries world-wide (Brugmann 1996).

2.2.2 Sustainable Transportation

There is currently no widely accepted definition of sustainable transportation, though one could be established based on the foundations of balancing the three spheres of sustainable development. The Organisation of Economic Cooperation and Development and the National Round Table on the Environment and the Economy define the three spheres of a sustainable transportation system as follows (OECD 1996; NRTEE 1996):

1. **Environment:** transportation that does not endanger public health or ecosystems and meets mobility needs consistent with (a) use of renewable resources at below their rates of regeneration and (b) use of non-renewable resources at below the rates of development of renewable substitutes. In other words, a sustainable transportation system would reduce and/or eliminate air, water, and land pollution, as well as minimise resource consumption.
2. **Economy:** transportation that optimises infrastructure, labour, capital operating costs, and logistics costs and benefits. In other words, a sustainable transportation system is one that would ensure full cost accounting (i.e. include externalities) to send the appropriate price signals (i.e. economic incentives and disincentives) to society to ultimately shape transportation behaviour, and to provide equity within the transportation system (i.e. equitable allocation of transport subsidies for all modes of transportation).
3. **Society:** transportation that reduces noise, accidents and their associated impacts (i.e. human, environmental, and economic), travel time and the associated stress and frustration arising from congestion, feelings of social isolation and disconnectivity from the community, dysfunctional social behaviours, decaying urban fabric; and increases social equity and empowerment, and personal and community health. In

other words, a sustainable transportation system is one that supports healthy, livable communities that are rich in social capital.[1]

The OECD thus indicates that sustainable transportation aims to ensure that the needs for access to people, services and goods are met without producing permanent harm to the global environment, damage to local environments and social inequity (OECD 1996). The key concept within this principle is *access*.

A sustainable transportation system can minimise environmental, economic, and social impacts through the application of *energy* and *spatial* efficiencies. Energy efficiencies are achieved when either renewable energy sources are used for transportation, such as electricity for cars or carbohydrates for walking and cycling; or non-renewable energy sources are used more effectively, such as transit and ridesharing (i.e. carpooling). Spatial efficiencies are achieved through land use practices that optimise public space and the utility of land. With respect to transportation, spatial efficiencies exist when transportation systems maximise the person carrying capacity of a roadway (i.e. favour mass transit over single-occupant vehicle travel) and land use policies encourage compact, dense, and mixed-use zoning, which ultimately increase access (Ciuffini 1995). Therefore, a sustainable transportation system aims to achieve improved access (for all levels of mobility), safety and security, environmental preservation and regeneration, economic vitality and affordability (i.e. efficient exchange of goods with full cost accounting), and convenience such that travel times are not excessively long (Remiz 1998; Duncan and Hartman 1998).

To date, sustainability planning has primarily focused on the need to reduce local and global air emissions through attempts at reducing personal automobile dependence. Given that vehicle related emissions from excessive fuel consumption have a significant impact on global environmental and human health, it is imperative that transportation-

[1] Social capital is defined as the "shared knowledge, understandings, and patterns of interactions that a group of people bring to any productive activity" (Roseland 1998, 8).

related fossil fuel consumption be curbed for society to achieve many sustainable development goals.

2.2.3 Sustainable Communities

Sustainable communities integrate many of the principles of sustainable transportation, but focus on the greater range of environmental and social impacts by integrating strategies to minimise total energy use, solid-waste production, water pollution, sensitive ecosystem and habitat destruction, and social inequities. Moreover, the foundations of any sustainable community are found within the land use policies that dictate what shape, form, and use that land will take, along with the buildings that occupy it.

As the focus of this study is to develop sustainable transportation policies for SFU and the BMCD, it is necessary to integrate community land use planning into the study. Community land use planning plays a large role in determining how the residents of the community will travel within, and outside of, the community (Newman and Kenworthy 1999; Bernick and Cervero 1997). Therefore, community land use planning is critical in developing sustainable transportation plans and policies.

2.3 An Historical Perspective on Transportation and Land Use Planning

2.3.1 The Beginnings of North American Urban Planning

Land use patterns in Canadian urban areas are mainly the result of post-World War II urban design philosophies. These planning philosophies were based on two primary assumptions: that energy resources were somewhat infinite and would remain inexpensive in the long term; and that land and water resources were limitless (IBI Group

1993; FCM 1995). These assumptions formed the foundations of a planning paradigm that promoted the widespread use of the private automobile through an urban form based on low density, segregated land uses. In addition, the increasing affordability of automobile travel, reduced investments in public transit infrastructure, and the 'green field' status of most urban development sites led to the development of what is commonly know as 'urban sprawl': the development of low-density single family dwelling units in outlying areas (i.e. non-core) surrounding the city (IBI Group 1993; FCM 1995; Gordon 1991; Jacobs 1961).

However, these land use patterns (i.e. low density, segregated) are the result of many complex social, political, and economic factors, which are commonly referred to as the 'push' and 'pull' effects of low-density land use planning. The 'pull' effects include matters such as the differential tax and subsidy treatment accorded to municipalities in the core and suburban areas that favour suburban housing and commercial developments; the subsidisation of suburb infrastructure and services by regional and provincial governments; and the federal and provincial subsidies on energy and their continued emphasis on road building over public transit, which supports private vehicle use (FCM 1995). Coming from the other side, the 'push' effects support low-density and segregated land uses through higher property taxes in core areas due to inequitable tax and subsidy treatment among municipal governments; reduced levels of services in core areas; and the public perception of increasing levels of crime in the core areas (FCM 1995).

There is continued debate regarding the overall impact of low-density, single-use land use planning. Opponents to urban sprawl indicate that this land use form results in the inefficient use of energy; higher levels of per capita air and water pollution; increased levels of CO_2 emissions; increased pressure on undeveloped land; higher social and economic costs, such as public health and infrastructure; and reduced levels of transportation equity, particularly amongst the elderly, children, women, and the economically disadvantaged (FCM 1995; Newman and Kenworthy 1989; Newman and Kenworthy 1999; Alexander 1967; OECD 1990; Angotti 1993; Engwicht 1993; Roseland

1998). On the other hand, proponents of urban sprawl indicate that the majority of the above claims include some levels of scientific uncertainty, as well as reduced democratic rights to choose one's preferred housing and neighbourhood type (FCM 1995). Furthermore, some research indicates that increased vehicle traffic, crime, noise, and decreased property values are common in mixed-use, high density cities (Coleman 1985). The ecological, social, and economic impacts of transportation and land use planning at different densities will be discussed further in later sections.

However, it is believed that the 'low-density, segregated' land use planning paradigm is slowly changing (Davidson, Roseland, and Alexander 1998; Ewing 1995a; Newman and Kenworthy 1999; Litman 1999). As the economy shifts from an industrial to a more service-oriented sector, pressure to segregate industrial, commercial, and residential land uses is expected to decrease (Davidson 1997). Furthermore, the ecological, social, and economic impacts of this land use pattern are becoming socially and politically unacceptable, further supporting the movement towards moderate-to-high density, mixed-use zoning.

2.3.2 'Old' Versus 'New' Transportation Planning Paradigms

Research indicates that a 'paradigm shift' in transportation planning and policy development is required for society to move towards a more sustainable transportation system (Ewing 1995a; Litman 1997b; Litman 1999; Newman and Kenworthy 1999; Carlson et al. 1995; Engwicht 1993; Davidson 1997; Raad 1998; Davidson, Roseland, and Alexander 1998). Traditionally, a roadway's system performance was, and typically still is, measured by its level of service (LOS). It is this framework – the 'old paradigm' – that is used for making most transportation decisions. LOS is defined as:

> *...a qualitative measure describing operational conditions within a traffic stream, and their perception by motorists and/or passengers. A level-of-service definition generally describes these conditions in terms of such factors as speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience, and safety* (Transportation Research Board 1992, 1).

This framework thus emphasises the desire to move vehicles, which is achieved by increasing average travel time speeds (Ewing 1995a; Sale 1980). Table 2-1 summarises standard LOS guidelines, with 'A' representing free flowing traffic and 'F' representing gridlock. The obvious objective of this transportation decision-making framework is to thus optimise average travel speeds, making it simply a proxy for speed (Davidson 1997).

Table 2-1. Urban and Suburban: Arterial Level of Service

[illegible]	[illegible]	[illegible]	[illegible]
A	35	30	25
B	28	24	19
C	22	18	13
D	17	14	9
E	13	10	7
F	13	10	7

Source: Transportation Research Board 1989. Highway Capacity Manual. Washington, DC: TRB:11-4.

The goals of current transportation decision-making contradict, as LOS analysis and sustainability goals run counter to each other (Litman 1997b). LOS indicators typically measure vehicle traffic volumes or congestion levels. It is these indicators that support planning decisions to increase the LOS – that is, to increase travel speeds through investing in the expansion of roadway capacity (i.e. road building). However, a negative feedback cycle exists with this planning technique. As roadway capacity is increased to increase traffic speeds, and thus decrease congestion levels, a phenomena known as 'generated' or 'induced' travel is experienced. By increasing roadway capacity, the latent demand for travel – that is, the additional vehicle travel that would not otherwise exist without roadway expansion – is released (Litman 1997b). Therefore, vehicle volumes and congestion levels (i.e. LOS average speeds) return to their pre-roadway expansion levels soon after development. This negative feedback cycle is well documented in the transportation planning and policy-making literature (Litman 1997b; Newman and Kenworthy 1989; Newman and Kenworthy 1999; Ewing 1995a).

There exist other problems associated with the use of LOS transportation planning. For example, this practice typically leads to inequitable and inefficient investments of public finances (Litman 1997b). When public investments are made based on current travel behaviour (i.e. traffic volume and congestion levels), persons that are more automobile dependent (i.e. higher vehicle kilometres travelled (VKT) per capita) receive higher levels of public investment, in terms of transportation expenditures per capita. Therefore, the LOS planning paradigm not only rewards people (i.e. financially) that are highly automobile dependent but also encourages further automobile dependence by releasing the latent demand for vehicle travel (Litman 1997b). Litman concludes that the costs heavily outweigh the benefits when transportation planning decisions are based on LOS criteria. Table 2-2 summarises the associated short-term benefits and long-term costs typically associated with LOS transportation planning.

Table 2-2. Costs and Benefits of Level of Service Transportation Planning (Litman 1997, 1)

Short-term Benefits (i.e. reduced costs)	Long-term Costs (i.e. increased costs)
1. User travel time	1. Vehicle ownership
2. Congestion levels	2. Parking
3. Vehicle operating costs	3. Road Facilities
	4. Accidents
	5. Air pollution
	6. Barrier effect
	7. Municipal services
	8. Land use impacts
	9. Water pollution
	10. Roadway land
	11. Noise
	12. Equity and option value
	13. Resource externalities
	14. Waste disposal

There currently exists a conflict in growth management priorities, as goals of environmental health, neighbourhood and urban revitalisation, and energy conservation compete with LOS for priority in urban planning (Ewing 1995a). To combat the momentum of LOS transportation planning, a 'new paradigm' is emerging. This paradigm focuses on the elements of *mobility*, *accessibility*, *livability*, and *sustainability* (Ewing 1995a; Litman 1997b; Litman 1999; Newman and Kenworthy 1999).

Mobility, defined as the ease at which individuals are able to move about, focuses on the movement of people over vehicles (Altshuler, Womak, and Pucher 1979; Lomax 1986; Ewing 1995a; Litman 1997b). Therefore, "mobility-planning" can be thought of as putting an emphasis on moving people, and thus induces a shift in transportation planning priorities. This shift encourages the investment in more efficient transportation modes, such as transit, ridesharing, cycling, and walking (Litman 1997a; Litman 1997b). However, though a step in the right direction, Litman indicates that "mobility-planning" is not ideal. The focus on mobility "implies that movement is an end in itself rather than a means to an end" (Litman 1997b, 2).

Research indicates that "accessibility-planning" is a more effective strategy in achieving sustainability goals (Litman 1997b; Litman 1999; Newman and Kenworthy 1999; Ewing 1995a; Remiz 1998). Accessibility is defined as the ability to reach desired activities (e.g. goods, services, recreation, employment, and education) from any location (Litman 1997b; Hansen 1959; Ewing 1995a). Accessibility is thus a function of the land use and transportation system that exists, and is therefore an excellent indicator of sustainable land use and transportation planning. "Accessibility-planning" is thus a more holistic planning strategy as it not only focuses on the energy efficiency of moving people, but also the spatial efficiencies of access. Dalvi supports this conclusion by stating (Dalvi 1979):

> *It is not enough to focus simply on the characteristics of the transport system. It is equally necessary to consider the spatial distribution of opportunities, so that transport policies might be evaluated not only in terms of moving the people to the opportunities but also moving the opportunities to the people*. (emphasis added).

Livability aims to maintain, or create, an environment that contributes to an individual's personal development and their physical, social, and mental well being

(Sheltair 1998). In other words, livability strives to achieve a community's need for safety, peace and quiet, good health, attractive neighbourhoods (i.e. trees, parks, roads), empowerment and participation in local decision-making, a sense of community and place, strong social cohesion, and a dynamic street and public life. From a transportation perspective, "livability-planning" focuses on calming traffic, both speed and volume, and increasing transportation options, such as providing more accessible and convenient transit, bicycle routes, and pedestrian infrastructure. Therefore, community planning that focuses on livability attempts to "put the auto in its rightful place as one among many options for travel" (Lowe 1990, 5).

"Sustainability-planning" focuses on achieving the goals of sustainable development. With respect to transportation, vehicle related emissions from excessive fuel consumption have a significant impact on global environmental and human health, and thus threaten the achievement of sustainable development. These impacts are a direct function of total and per capita VKT (reflect gasoline consumption), vehicle trip rates (reflect automobile dependence and thus gasoline consumption), and congestion levels (reflect travel speeds, which impact fuel consumption, as 'cold starts' and low vehicle operating speeds consume more fuel and thus add to air pollution). Therefore, VKT, vehicle trips, and travel speeds are three effective transportation indicators, as they have the largest impact on air quality (Ewing 1995a).

The movement away from segregated, low-density land use zoning, and LOS transportation planning that focuses primarily on reducing congestion, are critical steps in moving towards a more sustainable urban form and transportation system. The 'new' transportation and land use paradigm should focus on "accessibility-planning" and policies that prioritise the movement of people over vehicles. This paradigm will undoubtedly reduce urban air quality problems, the threat of global climatic change, water and other resource impacts, social inequities, and improve the overall livability of urban areas.

2.4 The Transportation – Land Use Connection and Automobile Dependence

2.4.1 The Transportation – Land Use Connection

There exists an intimate relationship between transportation and land use planning, one where a certain level of 'co-dependency' must exist to achieve efficiency in their respective functioning. This relationship has evolved over a long period of time, from the beginning of modern urban planning in Europe, and more recently, North America, and is influenced by a multitude of forces (Replogle 1995). Land use decisions, investments in transportation infrastructure and services (i.e. automobile, public transit and non-motorised modes), and market forces, which influence the pricing of transportation modes, all play a significant role in determining the urban form that exists today and thus the ways in which we travel. These factors determine our level of energy and resource use, environmental impacts, such as air and water pollution, social impacts, and public costs. Ultimately, transportation systems and land use patterns determine the level of sustainability in our urban centres (NRTEE 1997; Roseland 1998; Replogle 1995; FCM 1995; Newman and Kenworthy 1989; Newman and Kenworthy 1999). It is therefore important for urban centres to 'integrate' transportation and land use planning into a more comprehensive discipline. By recognising and utilising the 'synergies' that exist between transportation and land use planning, and allowing land use planning to guide transportation, future planned growth can be more effectively accommodated (Cervero 1991; Replogle 1990). "Integrated transportation and land use planning" can therefore reduce the social, environmental, and economic costs that are associated with traditionally isolated planning professions (Roseland 1998).

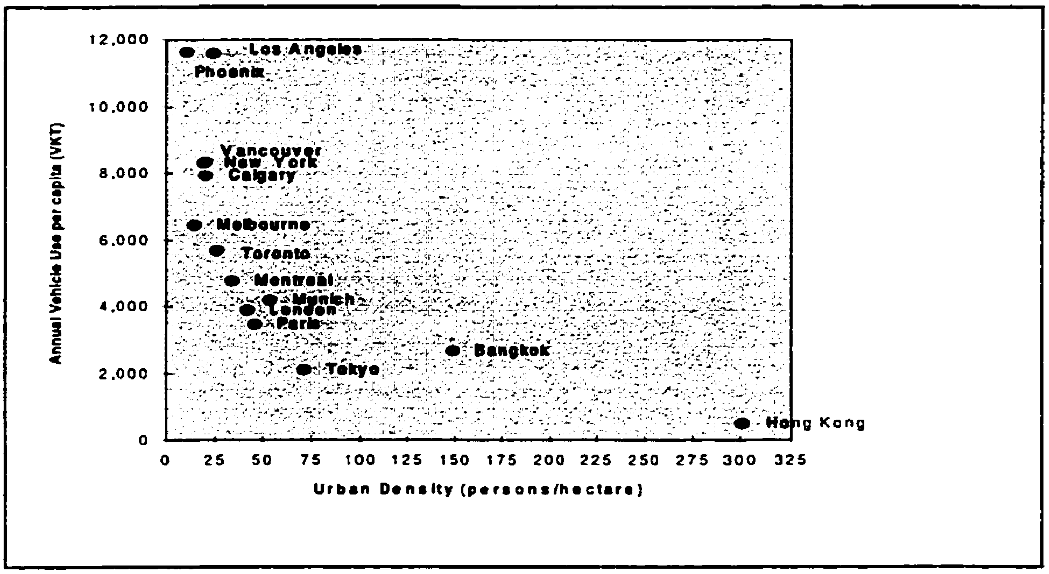
At the heart of this relationship lies *density*. Density is the critical link that ties land use and transportation planning together, and plays a significant role in determining the efficiency of land use patterns and transportation systems, and thus travel distances and modal splits (Pushkarev and Zupan 1977; Newman and Kenworthy 1999). For example, for public transit to improve its ridership numbers, it is important that there exists a critical mass, or density, of people that live within close proximity of transit services. Thus, urban and suburban densities must increase to encourage people to ride transit. Research indicates that high density, compact and complete urban form can lead to higher rates of transit use. One study found that when residential densities increased from 7 to 16 dwelling units per acre (upa), transit ridership increased sharply (Smith 1984). A study sponsored by the Transit Cooperative Research Program in the US found that a 10% increase in population density surrounding a transit station increased ridership by approximately 5% (Zupan et al. 1995).

Newman and Kenworthy, in their internationally acclaimed *Cities and Automobile Dependence* (1989), further support the movement towards higher density urban form (Newman and Kenworthy 1989). Their research indicates that residents of Phoenix and Houston consume four to five times as much gasoline per annum than a comparably sized (i.e. population) European city with urban densities 3-5 times higher. Furthermore, Canada and the US lag far behind European and Asian nations with respect to transit use, as European countries use transit for approximately 20% of trips (2 to 4 times higher) and walk or cycle for approximately 40-50% of trips (10 times higher). In addition, automobiles are used for approximately 80% of trips in North America versus only 30-50% in Europe. These modal differences explain the large gap in carbon dioxide (CO_2) production, as residents of Canadian urban centres produce twice the level of CO_2 per year (20 tons) than urban residents in Europe (10 tons) (FCM 1995). There are many factors that influence these modal differences, but their research indicates that land use and urban form play a significant role in determining transportation behaviours, as up to 50% of this difference is a direct result of the urban form that exists in these cities (Newman and Kenworthy 1989). It is widely accepted that this transportation and land use connection forms an *inverse relationship*, where VKT increase as urban densities decrease and VKT decrease as densities increase (GVRD and Province of BC 1993a; Newman and Kenworthy 1989; Newman and Kenworthy 1999; Raad and Kenworthy 1998). Table 2-3 highlights this relationship, where per capita VKT and urban densities are identified for selected world cities. Figure 2-2 summarises this relationship graphically.

Table 2-3. Urban Density vs. Vehicle Use in Selected World Cities (Raad and Kenworthy 1998, 16; Newman and Kenworthy 1999, 94-95)

City	[illegible]	[illegible]
Phoenix	10.5	11,608
Melbourne	14.9	6,436
New York	19.2	8,317
Vancouver	20.8	8,361
Calgary	20.8	7,913
Los Angeles	23.9	11,587
Toronto[3]	25.9	5,680
Montreal	33.8	4,746
London	42.3	3,892
Paris	46.1	3,459
Munich	53.6	4,202
Tokyo	71	2,103
Bangkok	149.3	2,664
Hong Kong	300.5	493

Figure 2-2. Urban Density vs. Vehicle Use in Selected World Cities (Raad and Kenworthy 1998; Newman and Kenworthy 1999)



[2] Densities are net, incorporating all developed land and excluding all agricultural land, forest, large-scale open space and undeveloped areas.
[3] The data shown represents the Greater Toronto Area (4.2 million persons) versus the Municipality of Metropolitan Toronto (2.3 million persons).

Newman and Kenworthy conclude that "there appears to be a critical point (about 20 to 30 persons per hectare) below which automobile-dependent land use patterns appear to be an inherent characteristic of the city (Newman and Kenworthy 1999, 100).

Furthermore, of great significance are the research results that investigated density and private single-occupant vehicle (SOV) use in the San Francisco area. These studies indicate that every doubling of mean residential densities is associated with a 20-30% decrease in SOV commute trips (Bernick and Cervero 1997). Furthermore, it was also discovered that the number of automobiles and vehicle-miles travelled (VMT) per household fell by 25% as densities doubled (Holtzclaw 1994).

To support transit and create a pedestrian-friendly environment with a sense of place, Blumenfeld believes that residential densities should be between 12 (minimum) and 60 (maximum) dwelling units per acre (upa) (Blumenfeld 1968). Jacobs, however, advocates that densities should be between 50 (minimum) and 150 (maximum) upa to achieve these objectives (Jacobs 1961). According to Rydin – who completed a thorough literature review on the environmental dimensions of residential development – transportation and energy efficiencies are achieved when urban densities are a minimum of 65 upa (Rydin 1992).[4] Other planners and academics indicate that densities should be within the *minimum range* of 8-20 upa (i.e. Condon indicates a minimum range between 8-14 upa; Calthorpe indicates a minimum range between 10-25 dwelling units per net residential acre[5]) (Condon 1996; Calthorpe 1993). However, most literature agrees that a minimum of 10 upa is required to make transit and commercial facilities viable.

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[4] Optimal urban density for a complete sustainable community is 80 upa, which accounts for capital energy requirements of construction, spacing for passive solar energy, operational energy consumption, and transport energy consumption.

[5] Net residential acre, or "net density", refers to "the number of dwellings located on residential building sites and excludes roads, parks, and other non-residential land uses" (Roseland 1998, 128). A corresponding "gross density" (density that includes non-residential land uses) would typically be lower (i.e. fewer upa). For the purposes of this study, Calthorpe's minimum range of 10-25 upa (net density) has been reduced by 20% (i.e. from 10-25 upa to 8-20 upa) to take into account the differences between net and gross density.

Research indicates that a housing mix where half of the units are single-family dwellings at 12 upa, 30% are row houses at 36 upa and 20% are mid-rise apartments at 160 upa, can create an average density (49 upa) where transit trips can outnumber auto trips (Bernick and Cervero 1997). Furthermore, it is found that people are willing to trade-off higher densities in return for more amenities and better quality living environments (Bookout and Wentling 1988). However, the most successful and attractive densities, according to Bernick and Cervero, have been found to lie in the 10-20 upa (25-50 units/hectare) range (Bernick and Cervero 1997).

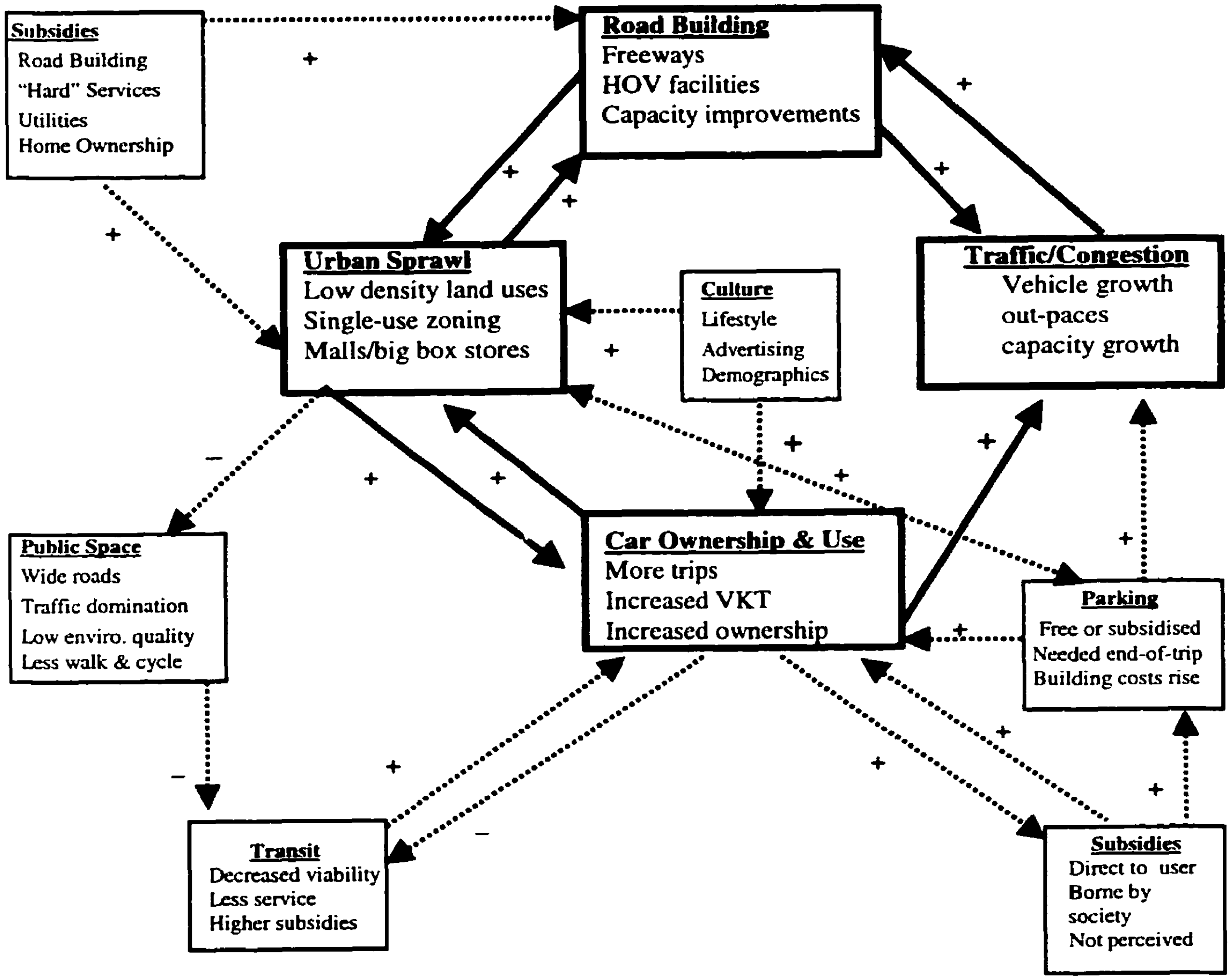
Given the range of 'optimal' densities proposed and the general lack of consensus regarding these densities within the planning community, this study will set a upa benchmark based on the average of the minimum densities proposed above. In other words, an average of the following minimum densities (to achieve transportation and energy efficiencies) will be the basis of the upa benchmark for this study: 12 upa (Blumenfeld), 50 upa (Jacobs), 65 upa (Rydin), 11 upa (Condon), and 14 upa (Calthorpe). This *minimum* density is 30 dwelling units per acre (gross).

2.4.2 Automobile Dependence

The expression "automobile dependence", as coined by Newman and Kenworthy, is widely accepted within transportation, land use, and sustainability planning circles as the term defining urban transportation efficiency (Newman and Kenworthy 1989). As described above, their research indicates that urban density, single-use zoning, and transportation planning that favours private automobiles, play a large role in determining automobile dependence. Particularly relevant is Figure 2-2, where automobile dependence is reflected in the level of VKT per capita. Automobile dependent cities can experience up to 93% of all trips being made in private automobiles, as low density and segregated land use patterns reduce the viability of non-vehicle modes of travel, such as transit, cycling, and walking (Raad 1998). Therefore, cities with limited transportation choices encourage vehicle ownership, and thus vehicle use.

There are number of factors that influence automobile dependence. Raad indicates that these factors are interrelated and form a positive feedback loop that accelerates automobile dependence. Figure 2-3 outlines this relationship.

Figure 2-3. Positive Feedback Relationships in Automobile Dependence (Raad 1998, 19)



Note: Plus (+) indicates increased effect
Minus (-) indicates decreased effect

Road building, traffic and congestion, car ownership and use, and urban sprawl are identified as the biggest factors, with subsidies, culture, parking, transit, and public space playing smaller roles in this larger 'formula' for determining automobile dependence. Positive feedback loops are defined as an "action that leads to a reaction which in turn intensifies the condition responsible for the initial action" (Raad 1998, 23). The above positive feedback loop plays a significant role in the functioning of everyday urban life, which ultimately impacts the health of local and global ecosystems, communities, and economies (Raad 1998, 23; Newman and Kenworthy 1999).

2.5 The Impacts of Unsustainable Transportation and Land Use Planning

2.5.1 Introduction

Ecological impacts, such as air and water pollution, are the most commonly debated, discussed, and accepted impacts associated with automobile-oriented land use patterns and transportation systems. This is partly due to their impacts on society and the ecosystems we depend on. However, there are several social and economic impacts that should not go unmentioned. The following sections review the literature and provide a strong argument for the application of sustainable development principles in the transportation and land use planning disciplines.

2.5.2 Ecological Impacts

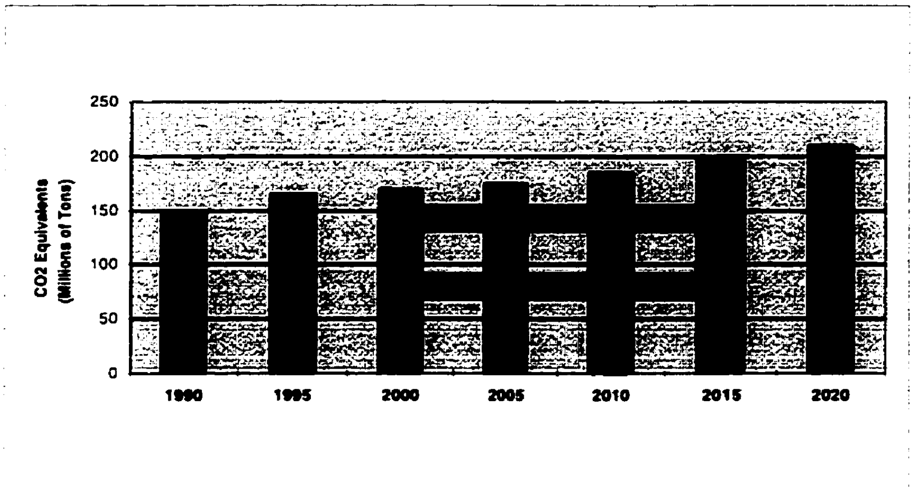
Air Quality: Greenhouse Gas Emissions

Ecological impacts from transportation typically tend to focus on air pollution, as concerns over local air quality and global climatic change have been in the policy spotlight for some time. Furthermore, air pollution is perceived by the public to be more 'tangible' than other ecological impacts. As indicated in Chapter 1, this study's attempt to reduce vehicle trips to and from SFU's Burnaby Mountain campus is primarily motivated by air quality concerns. Other impacts will therefore only be highlighted.

Motor vehicles produce emissions, through the internal combustion process, that contribute to local, regional, and global environmental degradation. The environmental impacts include smog, acid rain, ozone depletion and the enhanced greenhouse effect, as well as many secondary impacts (Raad 1998).

Of particular concern is the trend in greenhouse gas emissions from the transportation sector. Current trends indicate that the increase in per capita VKT will more than offset advanced fuel efficiency technologies, resulting in an increased use of fossil fuels and emissions of greenhouse gases (NRTEE 1997). Research indicates that the number (i.e. quantity) of VKT per capita is the primary determinant of vehicle pollution levels (Gordon 1991; Newman and Kenworthy 1989). Furthermore, trends in vehicle sales show a large increase in the number of 'sport utility vehicles' (SUVs) being purchased. These vehicles are typically larger in size that the standard car and use six-cylinder engines. This vehicle size and engine type significantly reduce the vehicle's fuel efficiency – by up to 50% – from that of the standard four-cylinder vehicle. These trends - increasing VKT per capita and SUV sales – are expected to result in growing greenhouse gas emissions levels. Figure 2-4 highlights this trend.

Figure 2-4. Trends in Greenhouse Gas Emissions from Transportation (NRTEE 1997, 15)



Source: Data from Natural Resources Canada, Canada's Energy Outlook - 1996-2020 (1997), Annex C, p. C-7.

A growing scientific consensus concedes that global pollution will result in global climatic change (IPCC 1990; NRTEE 1997). Global climatic change is expected to increase global temperatures from 1.5 to 5.5 degrees Celsius, shift climatic patterns, increase sea levels and storm frequency, and reduce plant biota and productivity (Miller 1994; Province of BC 1995a). To combat the threat of global warming, governments from around the world met in Kyoto, Japan in December 1997 for the United Nations Framework Convention on Climate Change. The Kyoto Protocol calls for a global greenhouse gas reduction of 5.2% of 1990 levels to be achieved between 2008-2012, where Canada has committed to a 6% reduction of 1990 greenhouse gas levels (Last, Trouton, and Pengelly 1998; Cairns 1997). As 46% of BC's energy-related greenhouse gas emissions come from the transportation sector (primarily in the form of carbon dioxide – CO_2), programs to reduce these impacts are required if Canada hopes to achieve its Kyoto greenhouse gas commitments and reduce the threat of global climatic change (GVRD 1994a).

Air Quality: Local Emissions

Vehicle emissions and pollutants that are of concern at the local and regional level include particulate matter (PM-10, PM-2.5, PM-1), sulphur dioxide (SO_2), carbon monoxide (CO), oxides of nitrogen (NO_x), volatile organic compounds (VOCs), which are also known as hydrocarbons, and tropospheric (ground-level) ozone (Raad 1998). Of local and regional concern are the impacts to air, water, and soil quality, and thus ecosystem and human health (French 1990).

In the GVRD, approximately 75% of total emissions are attributed to the use of private vehicles. Table 2-4 outlines the proportion of selected transportation-related emissions in the GVRD that are produced by mobile sources (i.e. all transportation, including motor vehicles, trains, aircraft, marine vessels, and off-road equipment).

Table 2-4. Emissions from Transportation in the GVRD (% of Total, 1991) (Raad 1998, 43)

Transportation Source	NO_x	VOCs	SO_x	CO	PM	Total
Light-duty Vehicles	41%	47%	6%	91%	6%	**76%**
Heavy-duty Vehicles	16%	2%	8%	2%	9%	4%
Other Transport Sources	25%	4%	18%	4%	5%	6%
Total Transport	**82%**	**53%**	**32%**	**97%**	**20%**	**86%**

Source: ARA and BOVARD-CONCORD 1994

These results indicate that private automobiles (i.e. light-duty vehicles) produce the majority of local air pollutants, and should therefore be the primary focus of air quality management plans that attempt to reduce local and global air emissions.

Table 2-5 summarises the major types of air emissions (including global) and their associated production of air emissions per vehicle kilometre driven. For simplicity, it is assumed that all vehicles are light-duty passenger vehicles (i.e. cars and light trucks).

Table 2-5. Average Emission Factors for Light-Duty Vehicles (GVRD 1998a)

[illegible]	[illegible]
Carbon Monoxide (CO)	13.4
Nitrogen Oxides (NO_x)	1.3
Particulate Matter (PM or Total Suspended Particulates)	0.026
Sulphur Oxides (SO_x)	0.047
Volatile Organic Compounds (VOC)	1.5
Carbon Dioxide (CO_2)	250
Methane (CH_4)	0.039
Nitrous Oxides (N_2O)	0.13
CO_2 Equivalent[6]	291

This data may seem insignificant at this level (i.e. grams per kilometre), but vehicle-based air emissions cause serious economic, social, and ecological impacts on the larger, more cumulative scale. This breakdown of emission type per vehicle kilometre travelled will be important for later calculations of SFU's vehicle-related air quality impacts, as SFU's expected growth in transportation demands will put further pressure on local, regional, and global air quality.

Both local and global air emissions have significant impacts on the ecological, social, and economic health of local communities, regions, and nations. These impacts are well documented in the literature, and range from smog, acid rain, ozone depletion, and global climatic change; to human health problems, including death; and reduced economic efficiency and poorly invested public finances. Table 2-6 provides a complete outline of air pollution and emissions from urban transportation.

[6] Carbon Dioxide Equivalent Factor (CO_2E) is the global warming potential of Carbon Dioxide (CO_2), Methane (CH_4) and Nitrogen Dioxide (N_2O) (GVRD 1998a). Carbon Dioxide, Methane and Nitrogen Dioxide's global warming potential is equal to 1, 21, and 310 respectively. The following equation is used in calculating the total Carbon Dioxide Equivalent Factor: $CO_2 + CH_4(21) + N_2O(310)$.

Table 2-6. Air Pollution and Emissions from Transportation

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Carbon Monoxide (CO)	• internal combustion process	• may contribute to global warming at 2.2 times the rate CO_2 through tropospheric reactions • increases methane (a powerful GHG) levels	• exacerbates heart disease; causes drowsiness; comprises brain function; threatens fetal development	• Local • Regional • Global
Nitrogen Oxides (NO)	• int. combustion process • malfunctioning catalytic converters • up to 80% from motor vehicles	• ozone precursor; reacts with nonmethane hydrocarbons to form ground level ozone • causes haze/smog • acid rain precursor (see SO_2 below)	• increases susceptibility to viral infections, irritates lungs, and causes bronchitis and pneumonia	• Local • Regional • Global
Particulate Matter (Total Suspended Particulates)	• incomplete combustion • diesel • road dust	• reduces visibility	• contributes to human morbidity and mortality; lung damage	• Local
Sulphur Dioxide (SO_2) (Sulphur Oxides (SO_x) are somewhat similar)	• internal combustion process	• acid rain precursor; reacts with NO_x and leads to acid rain; changes soil and water chemistry • increases solubility of heavy metals in water • harms vegetation and aquatic biota; enters food chain; damages buildings	• sulphate particles are carriers for toxic metals and gases; responsible for 2% of annual mortality in US • contaminates drinking water • respiratory ailments	• Local • Regional
Volatile Organic Compounds (VOC) (also known as hydrocarbons)	• incomplete internal combustion process • fuel vapours • up to 50% from vehicles	• ozone precursor	• drowsiness, eye irritation, and coughing	• Local
Carbon Dioxide (CO_2)	• internal combustion process • cars/trucks are the largest single source of CO_2 in Canada	• global warming: shifts in climate patterns; ocean warming; rising sea level; more frequent and stronger weather events; agricultural and ecosystem disruption	• secondary impacts associated with global warming • potential of increased disease	• Global
Methane (CH_4)	• internal combustion process • production of petroleum products for transp. sector	• global warming (see CO_2) • 21 times the strength of CO_2	• see CO_2	• Global
Nitrous Oxides (N_2O)	• internal combustion process • ageing catalysts	• global warming: contributes 270 times the global warming potential (GWP) of CO_2 • 70% of N_2O in GVRD is from vehicles	• see CO_2	• Global

Adapted from: Raad, T. "The Car in Canada: A Study of Factors Influencing Automobile Dependence in Canada's Seven Largest Cities, 1961-1991." Masters Thesis, University of British Columbia, 1998.

Note: Acid rain and smog are both formed as a result of reactions between other pollutants in the atmosphere.

Water Quality

Transportation-related water quality impacts range from the contamination of waterways from road runoff to disruptions of natural hydrological systems (Raad 1998). These impacts are largely the result of suburban sprawl, where large tracts of land are cleared for development and paved, in turn increasing soil erosion, sedimentation, and flooding. Furthermore, approximately 45% of all cars leak hazardous fluids onto the roadways, including transmission fluid, crankcase oil, and hydraulic fluid. These pollutants are then washed down storm sewers and into soils (Bein, Litman, and Johnson 1994). These impacts, combined with the increase in private automobile use associated with suburban sprawl, significantly reduce water quality in local streams, thereby threatening marine and terrestrial life. Table 2-7 summarises some of the major sources of water pollution and hydrological disruptions associated with vehicle use.

Table 2-7. Sources of Water Pollution and Hydrological Disruptions due to Automobile-Related Activities (Raad 1998, 31)

[illegible]	[illegible]
Leaks of hazardous fluids	Increased impervious surfaces
Road de-icing (salt) damage	Concentrated runoff
Pavement and vehicle wear	Loss of wetlands
Leaking underground storage tanks	Shoreline modifications
Air pollution settlement	Increased water temperature
Asphalt leachate	Construction disruptions of riparian zones

Source: Bein, Litman, and Johnson 1994.

Water pollution, though not publicly perceived as important as air pollution, is a serious concern. Transportation-related pollutants that enter the hydrological cycle eventually end up in the food chain, and should thus be of great concern to local citizens, planners, and municipal governments.

Other Ecological Impacts

There are a myriad of transportation and land-use related ecological impacts, and they can be categorised as land, resource consumption, waste disposal, and habitat and wildlife impacts. Table 2-8 identifies and describes these impacts.

Table 2-8. Other Transportation and Land-Use Related Ecological Impacts (Raad 1998; Roseland 1998; Newman 1991)

[illegible]	[illegible]
Land	The consumption of land for transportation and urban development include the following impacts: the loss of agricultural lands and sensitive ecosystems; and increased water and energy (transportation and domestic heating) use from low-density, single-use land development.
Resource Consumption	Automobile dependence and urban sprawl increase the demand for vehicles, infrastructure (such as utilities, pipes, and roads), non-renewable fuels, and building materials for housing and commercial development.
Waste Disposal	The disposal of vehicle parts has significant ecological impacts, including the land used for dumps, toxic leachates from solid waste, and air emissions from incineration and burning (particularly the burning of tires).
Habitat and Wildlife	Transportation and urban development fragment and destroy sensitive wildlife habitat and wildlife populations, due to road barrier effects and vehicle collisions ('road kill').

2.5.3 Social Impacts

There are several social impacts associated with unsustainable transportation and land use policies. With the exception of health, these impacts are not as widely accepted as the ecological impacts. Social impacts are wide ranging, and include human health, equity, decaying urban fabric and lost sense of community, livability, isolation, and dysfunctional social behaviours (Raad 1998; Engwicht 1999; Engwicht 1993; Newman and Kenworthy 1999).

Health impacts include death from vehicle accidents and disease; increased respiratory illnesses, heart disease, cancers, and viral infections from pollution; and a less independently-mobile (i.e. more sedentary) society due to an increasing dependence on private automobiles for personal travel, both non-recreational and recreational.

Equity impacts include the inequitable distribution of transportation costs and benefits, which typically favour automobile users in "Auto Cities" (Newman and Kenworthy 1999). For example, the opportunities for accessibility and mobility are reduced for non-drivers, the elderly, children, and often women (i.e. the 'transportation disadvantaged'), when transportation and land use policies prioritise the movement of vehicles over people.

Urban livability is reduced when public land is dominated by the private automobile, decaying the social fabric of the city and reducing one's sense of community as noise levels and safety concerns increase and opportunities for social interactions, or "spontaneous exchanges" (i.e. the opportunity for unplanned social interactions and economic transactions), decrease (Engwicht 1999; Engwicht 1993; Kunstler 1993; Appleyard 1981). Furthermore, high traffic volumes and low-density urban sprawl tend to cause feelings of social isolation and alienation, particularly for those that are transportation-disadvantaged, as citizens tend to socialise less, stay indoors, spend more time commuting, and feel physically removed from social networks and opportunities (Engwicht 1999; Engwicht 1993; Appleyard 1981; Jacobs 1961).

And finally, unsustainable transportation and land use policies that encourage vehicle use over public transit and non-motorised transport options are believed to cause dysfunctional social driving behaviours, such as increased driver frustration and aggression. These behaviours are more commonly known as "road rage."

2.5.4 Economic Impacts

The economic impacts of unsustainable transportation and land use policies are not widely known, and thus not fully accounted for when we make transportation decisions. For example, most Canadians are likely not aware of the following facts:

- the average citizen spends a higher proportion of household income on transportation than food (Clement 1998);
- owning a vehicle costs the average Canadian approximately $7,000 per year (Roseland 1998);
- social and environmental damage in 1994 cost $2 billion (accidents and emissions only) (Irwin 1998);
- congestion, in terms of the delayed movement of goods and lost productivity, costs Toronto more than $2 billion per year and is expected to cost Vancouver over $300 million per year by 2021 (GVRD and Province of BC 1993a); and
- in the US, it is estimated that the total costs of driving are well over $700 billion annually, with *only* just over 50% of this cost being paid by its users (Komanoff 1995).

These are only a few examples of the 'transportation trivia' that typically do not get figured into the transportation decision-making equation.

However, it is widely accepted within transportation planning circles that economic inequities exist within the transportation system, as its costs and benefits are not fairly distributed amongst all users of the transportation system (i.e. drivers, transit users, cyclists, and pedestrians) (Roseland 1998; Litman 1995a; Litman 1997a; Litman 1999; Replogle 1995; Newman and Kenworthy 1989; Newman and Kenworthy 1999; GVRD and Province of BC 1993c; Lowe 1990; Durning 1996; KPMG 1996). These costs include both market and non-market costs, internal (borne by user) and external (borne by society) costs, and variable (costs that vary with use, such as gas and parking) and fixed costs (costs that are long-term and involve few payments, such as vehicle purchase and insurance) (Litman 1998c; Durning 1996). Automobile-oriented land use patterns and transportation systems conventionally underprice the use of private automobiles by excluding social and ecological externalities, such as air pollution and its associated health impacts. The underpricing of private automobiles is also a function of the ratio between variable and fixed costs, where a high proportion of costs are currently fixed. The combination of high external costs and high fixed costs relative to internal and variable costs leads to increased levels of automobile use, as the 'full' costs of transportation are not fully borne by the user. Research indicates that up to one-third of total transportation costs are external and nearly 25% are fixed (Litman 1998c; Durning 1996). Table 2-9 highlights the estimated full costs of driving.

Table 2-9. Estimated Full Costs of Driving a Mile in the US (early 1990's) (Durning 1996, 49)

[illegible]	[illegible]	[illegible]
Market Costs (monetary)	**Fixed Driver Costs: $0.24**	Subsidised road network and emergency services
	Vehicle purchase	"Free" parking
	Vehicle maintenance	Defense of oil supplies
	Insurance and registration	Productivity lost to congestion
	Home parking	
	Variable Driver Costs: $0.13	
	Fuel and fuel taxes	
	Tires and oil	
	"Pay" parking	
	Total Market Costs: $0.37	**$0.10**
Non-Market Costs (non-monetary)	Personal time	Others' time lost to congestion
	Stress	Environmental damage
	Own risk of accident	Risk of accident to others
	Total Non-Market Costs: [illegible]	**$0.21**
Total Costs	[illegible]	**$0.31**

The above cost analysis is effective in answering a part of the automobile dependence 'puzzle,' as it highlights some of the true inequities in transport economics. This inequity reduces opportunities for accessibility and mobility by the transportation disadvantaged, and wastes public finances through investments in inefficient automobile-oriented transportation infrastructure (Litman 1998c; Newman and Kenworthy 1999; GVRD and Province of BC 1993c). In other words, automobile drivers are rewarded for choosing the car as their mode of transport through subsidies; such as road, fuel, and other land use and infrastructure subsidies, that encourage them to drive more. On the other hand, non-drivers – such as transit users, cyclists and pedestrians – do not receive the same direct benefits as those who travel by car, as public transit systems and cycling and pedestrian facilities are typically inefficient and under-financed (e.g. infrequent service, high transit fares, and lack of bike/walk paths and lanes, showers, and bike racks). To combat these inefficiencies, efforts should be made to *internalise* fixed and external costs so that transport consumers integrate these costs into their decision-making process – that is, into their selection of a transport mode (Litman 1998c; Durning 1996; Newman and Kenworthy 1999).

2.5.5 Conclusion

There is a plethora of ecological, social, and economic impacts associated with unsustainable transportation and land use policies. The above literature review is only a small glimpse of the bigger picture. However, it provides a broad perspective of the large inequities and externalities that exist within our current transportation systems.

2.6 Building Sustainable Transportation and Land Use Plans

2.6.1 Transportation and Land Use Management Measures

In an effort to reduce the domination of private automobiles in urban transport, there exist several different 'tools', within the transportation and land use management 'toolbox', that policy makers can use. The literature indicates that this toolbox includes the following transportation management measures and strategies.

Table 2-10. Transportation and Land Use Management Measures and Strategies (Davidson 1997, 26-27; Litman 1995a; Litman 1998a)

[illegible]	[illegible]	[illegible]
Enabling Programs	Provide a foundation for the evaluation, implementation, and ongoing review of transportation management programs.	Least cost planning and funding; public education, communication, and encouragement; increased co-operation and partnerships; planning and management, and institutional structure; transportation management associations (TMAs) and administrators; management and regulation of special transport classes and activities (e.g. freight, special events); and sustainable transportation program monitoring and adjustment.
Land Use	Influences the accessibility of common destination points.	Higher density, mixed-use, and growth management (jobs-housing balance); traditional neighbourhood development and transit-oriented development; and transportation and location-efficient mortgages.
Transport-ation System Management (TSM)	Attempts to encourage the use of alternative transport modes by increasing the person carrying capacity of the transportation system without investing in additional road capacity, and by improving alternative modes, such as walking, cycling, and transit.	***Pedestrians***: addressing security concerns; and pedestrian environment and facility improvement. ***Cycling***: bicycle and transit intermodal treatment; bicycle network improvements; and end-of-trip facility improvements. ***Transit***: service innovations and improvements; payment innovations; HOV lanes/dedicated transit lanes and preferential treatment; and integration of taxis and shared services into transport system.
Transport-ation Demand Management (TDM)	Uses economic incentives, regulations, and voluntary measures to influence the extent, timing, and mode of travel.	***Economic Incentives/Disincentives***: increased fuel tax; road pricing; prorating of insurance, licensing and registration by mileage; full cost pricing; allowing strategic congestion; and increased and marginalised parking prices. ***Regulatory Measures***: Cashing out paid/free parking; trip reduction bylaws (TRBs); vehicle restrictions; parking supply restrictions and relaxed requirements; and preferential parking for rideshare vehicles. ***Voluntary Measures***: development of car co-operatives and encouragement of car rentals; telecommuting; guaranteed ride home programs; voluntary commuter traffic reduction programs (CTR); alternative work hours; transportation allowance; park-and-ride facilities; and ridesharing programs.
Traffic Calming	Describes various physical and design changes that allow roads to better accommodate a range of different road uses, such as transit, cycling, and pedestrian activity.	Introduction of sidewalks, narrow streets, bicycle lanes, street trees, chicanes (i.e. small landscaped protrusions that turn street into a winding road), speed bumps, traffic circles, street furniture, alternative road surfaces (e.g. cobblestones), curb blow-outs and sidewalk extensions, landscape islands, and bus bulges.

The above mentioned transportation and land use management measures and strategies are typically referred to as simply "TDM," or Transportation Demand Management (though TDM is listed as a separate category in Table 2-10), as their primary objectives are to influence the extent, timing, and mode of travel (GVRD and Province of BC 1993a). In other words, TDM attempts to change transportation behaviours by introducing transportation and land use policies that reduce the *need to travel*, particularly by vehicle, *when we travel*, and *how we travel*. Therefore, vehicle trips and congestion can be reduced by:

1. **Eliminating Vehicle and/or Person-Trips:** measures that attempt to reduce the total number of vehicle and/or person-trips made (i.e. traffic/trip reduction programs). Mixed-use development (i.e. the integration of residential, commercial, employment, and recreational services into a building and/or community) improves the accessibility to one's daily needs, thus reducing the need to travel by vehicle. Telecommuting is an example where an employee works at home by being connected to the office via phone, fax, or modem, thus reducing the number of person-trips made.
2. **Lowering Peak Demand:** measures that attempt to influence the time at which people travel, to reduce peak-hour travel and congestion.
3. **Shifting the Mode of Transportation:** measures that attempt to influence the public to switch from SOVs to public transit, carpools, vanpools, bicycles and walking. This is called a *modal shift*.

The overarching goal is thus to reduce personal automobile dependence. This is achieved through the use of economic incentives and disincentives, referred to as 'sticks,' voluntary measures, referred to as 'carrots,' and regulatory measures. Some common incentives/disincentives, voluntary measures, and regulatory measures are listed above, in Table 2-10.

To use TDM measures and strategies in the development of a transportation and/or land use plan, such as the one proposed within this study, it is important that these strategies are defined and evaluated to ensure their proper use in attempting to reduce private automobile use. An evaluation of TDM measures and strategies was recently completed for the downtown Vancouver area, and the results of this study may prove highly applicable to the SFU case study (Davidson 1997). These results are summarised below, including an assessment of each strategy for application to the SFU case study, indicated as "HIGH," "MEDIUM," and "LOW" applicability. This assessment is subjective and based primarily on each strategy's applicability at the local and institutional scale. For example, the development of HOV and transit priority lanes is applicable at the regional, more so than the local (i.e. SFU), scale and is thus considered to be of LOW applicability to SFU.

Table 2-11. An Evaluation of TDM Strategies (Davidson 1997)

[illegible]	[illegible]	[illegible]	[illegible]
Enabling Programs			
Least Cost Planning and Funding	Strategies to reduce demand are considered equally with those of increasing road capacity.	Unknown, but provides a foundation for the implementation of sustainable land use and transportation policies.	HIGH
Public education, communication, and encouragement	The public is more likely to participate in TDM programs if they receive direct encouragement from their local and provincial governments, as well as their employers. Education is a critical component of encouraging voluntary transportation behavioural changes.	Unknown, but provides a foundation for the delivery of TDM programs.	HIGH
Increased co-operation and partnerships	Important in building support for TDM measures, developing a larger knowledge-base, building consensus and improving stakeholder participation, and bridging the gap between private and non-profit sectors.	Unknown.	MEDIUM
Planning and management, and institutional structure	A successful TDM program requires clear goals and objectives, long term planning and data gathering, co-operation and co-ordination amongst stakeholders, leadership to overcome problems, funding mechanisms, and ongoing management.	Unknown, but provides a foundation for the implementation of sustainable land use and transportation policies.	HIGH
Transportation management associations (TMAs) and administrators	TMAs co-ordinate transport activities at worksites and neighbourhood/municipal levels, including information campaigns, transportation fairs and events, co-ordinate ridematching/carpooling, manage parking, co-ordinate guaranteed ride home programs, and help plan transit, bicycle, and pedestrian facilities and improvements.	Unknown, but are critical in the delivery of TDM programs.	HIGH
Management and regulation of special transport classes and activities (e.g. freight, special events)	Transportation efficiencies can be gained through the co-ordination and management of particular activities, such as providing shuttle buses for special events.	Emissions reductions significant for freight transport management, low for 'event' planning.	MEDIUM

Table 2-11. An Evaluation of TDM Strategies (Davidson 1997) – continued

[illegible]	[illegible]	[illegible]	[illegible]
Sustainable transportation program monitoring and adjustment.	It is important to monitor and assess TDM programs to measure their effectiveness in achieving their pre-set goals. The development of goals, objectives, and indicators are helpful in this process. The results of monitoring activities should be widely communicated to the public, helping build support, motivation, and encourage change.	Unknown, but provides a foundation for the implementation of sustainable land use and transportation policies.	HIGH
Land Use			
Higher density, mixed-use, growth management (e.g. jobs-housing balance)	The development of communities and regions above 10 dwelling units per acre, that provide easy accessibility of daily needs within walking, cycling, and transit, and mix residential, retail/commercial, employment, and recreation land uses. The integration of land use and transportation plans to improve urban efficiencies, such as transit, and the jobs-housing balance (i.e. living and working in same community/municipality).	High impacts. The LUTRAQ (Land Use, Transportation and Air Quality) model and other research estimate a 20-40% reduction in VKT and daily trips, with a jobs-housing balance making up 2.5-13.6% of this reduction.	HIGH
Traditional Neighbourhood Development and Transit-Oriented Development	The integration of moderate-high density development, with mixed land uses, small-scale lots and short blocks, with excellent pedestrian and bicycle infrastructure, typically clustered around a transit station to ensure that all residents are within a 1,000-2,000 foot walking distance of the community core/transit station (5-10 minute walk).	As above, significant impacts on reducing VKT, from 20-40%.	HIGH
Transportation and location-efficient mortgages	Enable citizens to apply the transportation savings associated with living near transit (and thus using transit), retail, and work into their mortgage assessments, which can total more than $300 US per month in savings.	Moderate impacts in reducing VKT, and an important strategy in encouraging a jobs-housing balance.	HIGH

Table 2-11. An Evaluation of TDM Strategies (Davidson 1997) – continued

[illegible]	[illegible]	[illegible]	[illegible]
TSM			
Pedestrians			
Addressing security concerns	Improved aesthetic and safety conditions, such as lighting, phones, shelter, high pedestrian traffic, and clear visibility can reduce unsafe and uncomfortable feelings.	Indirect impact moderate, as it supports efficient land use and increased transit ridership.	HIGH
Pedestrian environment and facility improvement	The development of 'pedestrian-friendly' environments, through the introduction of sidewalks, benches and street furniture, street trees, and traffic crossing improvements. Can reduce traffic speeds and volumes.	Indirect impact moderate, as it supports efficient land use and increased transit ridership. Research indicates that VKT can decrease by up to 10%.	HIGH
Cycling			
Bicycle and transit intermodal treatment	The integration of cycling and transit, through the introduction of bike racks on buses/vanpools, bike racks and storage lockers at transit stops/stations, and routes to transit stops/stations. Increases efficiency of bicycle travel, as bikes are effective in quickly accessing transit stops/stations, with transit providing the transportation service to the end destination.	Low to moderate impacts, depending on the level of ridership achieved.	HIGH
Bicycle network improvements	The introduction of bicycle paths that provide shortcuts and avoid heavy traffic, and secured, covered storage facilities, such as racks and lockers.	Low to moderate impacts, depending on the level of ridership achieved.	HIGH
End-of-trip facility improvements	The provision of locker rooms, showers, and storage facilities for bikes and personal belongings are important in encouraging bicycle commute trips.	Low to moderate impacts, depending on the level of ridership achieved. Moderate to high impacts when combined with other bicycle improvement programs.	HIGH

Table 2-11. An Evaluation of TDM Strategies (Davidson 1997) – continued

[illegible]	[illegible]	[illegible]	[illegible]
Transit			
Service innovations and improvements	The introduction of additional routes, higher frequencies, increased transit capacity, express services, rail development, bus shelters and information, reduced fares, and various comfort improvements. For example, free transit zones, shuttle services, and discount programs, such as the popular UPASS (Universal Pass, used extensively at US universities), are highly effective in encouraging transit use.	Moderate to high impact, and the potential to reduce VKT by 5-50% when combined with other transit improvement programs. UPASS programs, and express and high frequent services contribute the most to this impact.	HIGH
Payment innovations	The use of weekly, monthly, semester, and annual pass programs eases the use of transit as it is economical, encourages repeat use, makes boarding faster, and avoids the need for exact change. The UPASS program is an example of payment innovation	Moderate to high impact, and the potential to reduce VKT by 5-50% when combined with other transit improvement programs.	HIGH
HOV/dedicated transit lanes and preferential treatment	Act as incentives – through savings in travel time – to encourage travellers to travel in higher occupancy vehicles. High occupant vehicles include transit buses, vanpools, and carpools with either 2+, 3+, or 4+ passengers. HOV facilities include dedicated traffic lanes and queue-jumpers, as well as traffic light controls that allow transit buses to receive preferential treatment in urban arterial traffic. Make transit and car/vanpools more competitive with the car.	Moderate impact, and the potential to reduce VKT by 5-50% when combined with other transit improvement programs.	LOW
Integration of taxis and shared services into transport system.	The utilisation of existing transport infrastructure, such as using idle school buses and vanpools in mid-day (e.g. UBC uses fleet vehicles at night for employee vanpools), and the development of private shuttle/taxi services to augment the existing transit system, such as 'Dial-a-Ride' services.	Moderate to high impact, and the potential to reduce VKT by 5-50% when combined with other transit improvement programs.	MEDIUM -HIGH

Table 2-11. An Evaluation of TDM Strategies (Davidson 1997) – continued

TDM M[illegible] & S[illegible]	[illegible]	[illegible]	[illegible]
TDM [illegible]	[illegible]	[illegible]	[illegible]
Economic Incentives/Disin-centives:			
Increased fuel tax	Increased charges for using gas in private transport, and though easy to implement as the collection mechanisms are already in place, it is considered politically infeasible. Increases economic efficiency by internalising external costs.	Low to moderate impacts. The elasticity of driving with respect to fuel price is low, with a 50% increase in fuel price in the GVRD expected to decrease VKT by 1-3%.	LOW
Road pricing	Involves the use of tolls, area licensing, and electronic charge systems to charge drivers for the use of a specific roadway. Used primarily for congestion relief during peak periods.	Moderate to high short and long-term impacts.	LOW
Prorating of insurance, licensing and registration by mileage	Changing insurance pricing to make it distance-based, and thus variable, rather than one lump sum payment can reduce VKT, and increase economic efficiency and equity. Drivers are thus charged for the kilometres they drive, on a per-kilometre basis.	Moderate to high impacts. Potential to reduce VKT from 5-10% over long-term.	LOW
Full cost pricing (Full Cost Accounting)	Integrating full (or more) social, economic, and environmental costs, such as air pollution related costs, into the price of automobile travel.	Moderate to high, but is a long-term process.	HIGH
Allowing strategic congestion	Maintaining roadway capacity at congested levels without building more capacity. More effective if strategic congestion areas run parallel with HOV and dedicated transit lines.	Moderate impacts over the short-term, with larger impacts over the longer term, as it prohibits traffic growth.	LOW
Increased and marginalised parking prices	Replacement of 'free' parking with parking fees, and switch from long-term to short-term parking services (i.e. from monthly parking passes to daily and hourly meters). Parking rates should be higher for SOV and peak period parking.	High short-term and long-term impacts. Potential to reduce peak hour commute trips by 5%, as well as a significant number of non-work trips.	HIGH

Table 2-11. An Evaluation of TDM Strategies (Davidson 1997) – continued

[illegible]	[illegible]	[illegible]	[illegible]
Regulatory Measures			
Cashing out paid/free parking	Giving vehicle and non-vehicle commuters the cash equivalent of parking fees, allowing commuters to choose between a parking space, or cash to be used for transit, cycling, walking, or at the employees discretion. Successful in increasing equity.	High impacts. Potential to reduce SOV trips by up to 20% and total VKT 3%.	MEDIUM -HIGH
Trip reduction bylaws (TRBs)	Mandatory region-wide trip reduction laws that require employers and developers to reduce the number of automobiles travelling to a specific location.	High impacts. Potential to decrease VKT from 10-40%; 10% higher than voluntary initiatives. More effective when combined with legal requirement, financial incentives or subsidies, traffic reduction target, guidance on measures required to reach the target, and monitoring and enforcement mechanisms.	LOW
Vehicle restrictions	Strategies that discourage and/or prohibit vehicle use in various communities and regions. For example, license plate programs that allow only specific plates to enter downtown on certain days.	Low to moderate impacts.	LOW
Parking supply restrictions and relaxed requirements	Focus on short-term, residential, and commuter visitors, through parking code measures and flexible zoning that limit parking stalls/resident, employee, or area.	Moderate to high impacts. Potential to reduce residential and employee parking requirements by 20% and 25% respectively.	HIGH
Preferential parking for rideshare vehicles	Provision of subsidised or discounted parking, in close proximity to destination points. For example, some universities provide free parking for car/vanpools.	Unknown impacts. More effective as part of voluntary traffic reduction program, where a 10% reduction in VKT is possible.	HIGH

Table 2-11. An Evaluation of TDM Strategies (Davidson 1997) – continued

[illegible]	[illegible]	[illegible]	[illegible]
Voluntary Measures			
Development of car co-operatives and encouragement of car rentals	Car co-operatives and neighbourhood car rental agencies encourage individuals to share access to a vehicle, without incurring the high costs associated with owning a vehicle and reducing per capita air emissions by up to 50%. The Co-operative Auto Network of Vancouver provides a car-sharing opportunity for many West End citizens.	Low impact over the short-term with moderate impact over the long-term.	HIGH
Telecommuting	The use of communications technology to enable people to work at home, connected to work via the phone, fax, or modem.	Moderate to high impacts. Could reduce VKT from 10-15%.	HIGH
Guaranteed ride home service	Provides employees with a free or subsidised guaranteed ride home, typically in a taxi or company car, in times of emergency.	Low to moderate impacts. Effectiveness increases when combined with other traffic reduction programs, such as ridematching, alternative work hours, transportation allowances etc.	HIGH
Voluntary commuter traffic reduction programs (CTR)	Similar to Trip Reduction Bylaws, but voluntary programs that attempt to reduce vehicle-based trips to work. Typically organised at the employer and institutional level. Combine many of the strategies within this summary, such as financial incentives (transportation allowances, subsidies), parking benefits (preferential and subsidised rideshare parking, restricted and more expensive parking), flexible work schedules ('flex time', compressed work weeks, telecommuting, course schedules), assistance programs (information centres, fairs, new hire orientation, employer based ridematching service, company owned vanpools/shuttles), award programs ('commuter of the month', newsletters), and special services (day-care, cafeteria, retail).	Moderate to high impacts. Potential to decrease VKT from 10-40%. More effective when combined with other measures.	HIGH

Table 2-11. An Evaluation of TDM Strategies (Davidson 1997) – continued

Alternative work hours	Flexible work hours ('flextime' and alternative university course schedules), and compressed work weeks ('4/40' schedule) provide flexibility to employees, allowing them to work when they want to, and improving the likelihood of using ridesharing and transit services.	Moderate impacts. Compressed work weeks can reduce vehicle commute trips by 20%, however, non-work trips may increase. 'Flextime' is primarily effective in reducing peak period congestion.	HIGH
Transportation allowance	Provide subsidies and/or discounts for using alternatives to the SOV, such as transit discount programs, and moneys for cycling and walking. A very popular component of most commuter traffic reduction programs in the US.	High impact. VKT reductions in the range of 10-20% with a $40/month allowance.	HIGH
Park-and-ride facilities	Allow suburban commuters to drive part way to work, park in organised parking lots, and ride transit, or carpool, the rest of the way to work.	Low impact on reducing VKT and air emissions. Are effective in reducing congestion but not air emissions, as the majority of emissions are produced in the first 5 km of driving (i.e. 'cold start'). May also encourage sprawl as supports those who live in suburban areas.	LOW
Ridesharing programs	Typically organised by the employer, ridesharing programs provide car and vanpool matching to reduce SOV trips.	Moderate to high impact. Ability to reduce VKT by 20%, but can be expensive to co-ordinate as part/full-time TMAs are required.	HIGH
Traffic Calming			
(as above)	Describes various physical, design, and psychological changes that allow streets to better accommodate a range of different uses, such as transit, cycling, and pedestrian activity. Introduction of sidewalks, narrow streets, bicycle lanes, street trees, chicanes, speed bumps, traffic circles, street furniture, alternative road surfaces (e.g. cobblestones), curb blow-outs, landscape islands, and bus bulges. Traffic calming also includes "street reclaiming" activities, such as street parties/games, and the re-design/reclaiming of auto-space into public space (parks, shops, services).	Low to moderate impacts over the short-term, larger impacts over the long-term. Improves livability, prohibits traffic growth, increases exchange opportunities (social and economic) and encourages the use of alternative modes.	HIGH

Table 2-11 provides a comprehensive menu of transportation and land use measures and strategies that may be applied to the SFU case study, or any other local or regional transportation and land use planning initiative. There are 39 strategies to select from, of which 27 were identified as "HIGHLY" applicable to the SFU case study, and 2 "MODERATELY" to "HIGHLY" applicable. The highly applicable TDM strategies, along with the *Sustainable Transportation and Land Use Planning Framework* that will be developed in Chapter 3, will be used to develop the SFU *Sustainable Transportation Plan* (Chapter 6).

2.6.2 The Application of TDM Measures and Strategies at Universities and Colleges

Introduction

Sustainable transportation planning is not new to university campuses. TDM programs, such as carpooling and discounted transit passes, have been around since the 1970s. The following sections will discuss some of the TDM programs being used at universities and colleges across North America.

TDM Programs in North American Universities and Colleges

The application of TDM measures and strategies is becoming commonplace at many North American universities and colleges, particularly in the US. The reasoning for this stronger US participation is unknown; however, larger urban populations, higher automobile dependence - and thus air emissions - and increased environmental awareness, specifically on university campuses, may play a large role in motivating these US initiatives. Universities and colleges are experiencing some significant growth management challenges. Student enrolment is increasing and with it, the demand for parking, as a higher proportion of students are gaining access to private automobiles. At the same time, university campuses are experiencing a resurgence of environmental awareness and activism, as student groups are fighting for cleaner air, cheaper and more efficient transportation options, and more green space. All of these forces are occurring under severe federal and provincial/state funding cut-backs, and university boundaries (i.e. lands) that are more likely to shrink than increase to accommodate automobile-oriented infrastructure demands, such as parking.

The solution to some of these growth management challenges has been the application of TDM measures across many universities and colleges in the US and Canada. Table 2-12 provides a 'snap-shot' of the leading and most common strategies that universities and colleges have implemented, or are implementing, to manage transportation demands. The most comprehensive and effective US programs are highlighted. Appendix 1 focuses on the UPASS program, as it is the major feature of most university TDM programs, providing a larger inventory of its application, results, and costs in both US and Canadian universities and colleges.

Table 2-12. Application of TDM Measures and Strategies at Universities in the US (Poinsatte and Toor 1999; Graves 1993; Brown, Hess, and Shoup 1998; Williams and Petrait 1993)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Univ. of Washington	√	√	√	√	√	√	√	√	21% SOV decrease, 35% transit increase, 20% rideshare increase.
Cornell University - Ithaca	√	√	√	√	?	√	√	√	22% SOV decrease.
Univ. Of California - LA	√	√	?	√	?	√	?	√	22% SOV decrease, 50% carpool and transit increase.
Univ. of Minnesota - Minneapolis	√	√	√	√	√	√	√	√	?
Univ. of Wisconsin - Milwaukee	√	?	?	?	?	?	?	?	28% SOV decrease, 100% transit increase.
Univ. of Illinois - Champaign/Urbana	√	?	?	√	√	√	√	?	370% transit increase.
Univ. of Wisconsin - Madison	√	√	?	?	?	√	√	?	?
Univ. of California - Davis	√	?	?	?	?	?	?	√	255% transit increase.
Univ. of Colorado - Boulder	√	?	?	?	?	?	?	√	400% transit increase.

TDM Spotlight – University of Washington (UofW)

The University of Washington in Seattle has successfully implemented the UPASS (Universal Pass) program, which was developed in response to campus and community concerns for traffic reduction and improved commuter services in view of possible impacts from planned campus development. The UPASS program, which started in 1991, is a flexible package of transportation benefits offered through a pass that provides students, faculty, and staff with the opportunity to choose from a variety of commuting options at a greatly reduced price ($9.00 per month). The 'flagship' service of this, and most, UPASS programs is the 'unlimited access' transit pass that all participating students, staff, and faculty receive. The UPASS program, with a 75% participation rate (voluntary at UofW), has reduced single-occupant vehicle trips by 21%, and increased transit ridership by 35%, carpools by 21% and vanpools by 20%. These results were realised within 9 months of implementation (Williams and Petrait 1993). The University of Washington's UPASS program is considered a model of successful TDM implementation and is used extensively at universities across North America.

TDM Spotlight – University of Victoria (UVic)

The University of Victoria has been active in TDM initiatives for the past few years, where their first project saw a student-supported parking fee price increase. The additional revenue generated was used to subsidise bus passes and to pay for bicycle infrastructure, such as showers and bike lockers (Cantwell and MacDonald 1995). More recently, UVic successfully voted in the UPASS program, to start in the fall term of 1999. This initiative was supported by an overwhelming majority of students, who will receive an 'unlimited access' transit pass for $44.00 per term. In its first term of implementation, UVic has experienced an overwhelming response to its UPASS program, as the demand for parking permits decreased by 40% (Evans 1999). Camosun College of Victoria has also implemented a UPASS program as of September 1999, though results are not known at this time.

TDM Spotlight – University of British Columbia (UBC)

Closer to home, the University of BC is currently developing a Strategic Transportation Plan. UBC is aiming to reduce vehicle trips by 20% by the year 2002 in hopes of improving local air quality and reducing campus-related traffic accidents. This traffic reduction goal is part of the recently signed Official Community Plan, which requires UBC to reduce vehicle trips to and from campus. The UBC Strategic Transportation Plan, entitled *UBC Trek*, will use the UPASS program as its 'centrepiece,' and combine preferential parking benefits and discounted rates to car/vanpoolers; ridematching services; increased parking rates to SOVs; reduced parking supply; increased parking enforcement; improved bicycle and pedestrian facilities, such as the new 2.5 kilometre bike lane down University Boulevard and improved end-of-trip facilities (e.g. showers, lockers); telecommuting options; guaranteed ride home services; on-campus shuttles; public bikes; walking shuttles for security; class timetable adjustments; flexible land use guidelines; and improved freight transportation co-ordination and management (Lovegrove 1998). UBC's UPASS program, and most of the other initiatives, are expected to be on-line by the fall of 2000.

Conclusions

TDM is an effective tool in reducing automobile trips to and from universities and colleges. Table 2-12 and Appendix 1 indicate that the application of TDM at universities can reduce SOV trips by up to 28%, increase transit ridership by up to 400%, and increase car/vanpooling by up to 50%. The cornerstone of the majority of successful TDM initiatives is the UPASS, or discounted transit pass, program. These programs not only provide 'unlimited access' to transit, but also car/vanpool benefits (i.e. preferential parking and lower fees), ridematching services, nightride and guaranteed ride home services, campus shuttles, improved bicycle infrastructure, including end-of-trip facilities, and merchant discounts. Furthermore, the most effective UPASS programs are funded through mandatory student fees (and potentially staff and faculty fees), which secures a revenue stream for the transit authority, and reduces the unit price of the UPASS to its lowest possible point.[7] This discounted user fee currently costs students in US universities approximately $31 (US) per year (average cost), equating to unlimited transit use for just over $2.50 per month (Brown, Hess, and Shoup 1998). Effective TDM programs also ensure that programs are integrated to complement one another, such as a parking fee increase with free carpool parking; use both incentives ('carrots') and/or disincentives and regulation ('sticks'); are flexible and comprehensive; are safe and convenient; involve community stakeholders in the planning and implementation process; include periodic monitoring; and use exciting marketing techniques (Poinsatte and Toor 1999).

2.6.3 Sustainable Land Use Planning

To achieve a 20% SOV trip reduction rate at SFU, it is important that the future transportation demands associated with the proposed Burnaby Mountain Community Development (BMCD) are integrated into the long-term transportation plan. Research indicates that community and urban form play a significant role in influencing transportation behaviours, and it is therefore critical to investigate and highlight ideas regarding sustainable community and land use planning (Condon 1996; Calthorpe 1993; Van der Ryn and Calthorpe 1986; Newman and Kenworthy 1989; Newman and Kenworthy 1999; Bernick and Cervero 1997; Ewing 1995a; Litman 1998a; FCM 1995; IBI Group 1993; GVRD and Province of BC 1993a; GVRD 1995; Roseland 1998). The following sections will discuss Transit-Oriented Development (TOD) and Traditional

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[7] The unit price of the UPASS is a function of the following: the university and transit authority agree to an up-front transit revenue fee, which is based on the university's contribution to the farebox (i.e. student, and potentially staff and faculty fares) over the previous year, as well as the costs of increased and/or improved transit service. The unit price of the UPASS is then calculated by dividing the transit revenue fee by the total number of users (i.e. students, and potentially staff and faculty). This equation provides a secure revenue stream for the transit authority and a highly discounted transit pass to its users (e.g. University of Washington students, staff, and faculty pay only $9.00 per month for their UPASS).

Neighbourhood Development (TND) as a potential solution to conventional land use planning (i.e. suburban sprawl).

Traditional Neighbourhood and Transit-Oriented Developments Defined

TND and TOD are aspects of what is more formally known as "New Urbanism." New Urbanism is an emerging set of planning principles designed to reinvigorate communities and provide a meaningful alternative to suburban sprawl (Roseland 1998). The Congress of New Urbanism, in its charter developed in 1992, advocate the following (Kelbaugh 1997, 132):

> *Neighbourhoods should be diverse in use and population; communities should be designed for pedestrians and transit as well as the car; cities and towns should be shaped by physically defined and universally accessible public spaces and community institutions; and urban places should be framed by architecture and landscape design that celebrate local history, climate, ecology, and building practice.*

In more recent years, New Urbanism has evolved into many different theme-names. Variations include Transit-Oriented Development (TOD) or Transit Villages, Traditional Neighbourhood Development (TND), often referred to as *neo*-traditional development, Pedestrian Pockets, Urban Villages, and Compact and Sustainable Communities. For the remainder of this study, TOD and TND will be investigated.

Though different in detail and emphasis, TODs and TNDs share a common perspective, design principles, and set of goals (Calthorpe 1993). Both development styles are committed to environmental protection and social diversity, affordability, and sustainability, as well as transit and walkability (Kelbaugh 1997). Furthermore, they both aim to restore a human-scaled and humane sense of public and private place to neighbourhoods, towns, and cities (Kelbaugh 1997). However, TODs focus primarily on the integration of transit and communities on a community and regional basis, whereas TNDs emphasise local community planning that focuses on accessibility and mixed-use development. Furthermore, TODs evolved from an energy and environmental design ethic whereas TNDs grew out of a more Euro-American urbanism (Kelbaugh 1997). Despite their differences in origin, methodology, and scale, both TODs and TNDs are so similar in intent and results that architects and planners have embraced these development styles with great enthusiasm under the name of New Urbanism (Kelbaugh 1997).

Peter Calthorpe, a prominent architect and urban designer, defines a TOD as (Calthorpe 1993, 56):

> *..a mixed-use community within an average 2,000 foot walking distance of a transit stop and core commercial area. TODs mix residential, retail, office, open space and public uses in a walkable environment, making it convenient for residents and employees to travel by transit, bicycle, foot or car.*

New urbanists argue that designing compact communities that provide residents with commercial and retail, leisure and recreational, and employment opportunities is an essential step towards reducing automobile dependence and its associated environmental, social, and economic impacts.

Principles of Transit-Oriented Development

The fundamental principles of Transit-Oriented Developments are as follows (Calthorpe 1993).[8] The majority of these principles also apply to TNDs.

1. Organise growth on a regional level to be compact and transit-supportive;
2. Design communities that emphasise a nodal layout;
3. Place commercial, housing, jobs, parks, and civic uses within walking distance of transit stops;
4. Create pedestrian-friendly street networks which directly connect local destinations;
5. Provide a mix of housing types, densities, and costs;
6. Preserve sensitive habitat, riparian zones, and high quality open space;
7. Make public spaces the focus of building orientation and neighbourhood activity; and
8. Encourage infill and redevelopment along transit corridors within existing neighbourhoods.

[8] For more specific TOD guidelines, refer to Appendix 2.

In achieving these principles, Calthorpe advocates the use of the following TOD and TND design schematics (Figure 2.6 and 2.7) over the conventional suburban development schematic shown in Figure 2-5.

Figure 2-5. Conventional Suburban Development Design Schematic (Calthorpe 1993, 49)

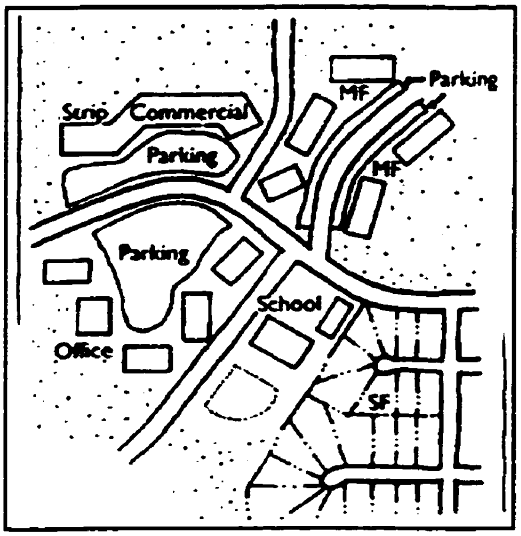


Figure 2-6. Transit-Oriented Development Design Schematic (Calthorpe 1993, 56)

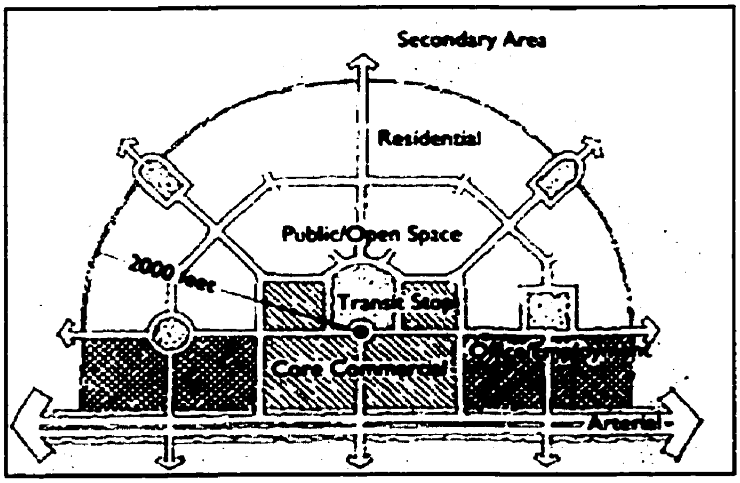
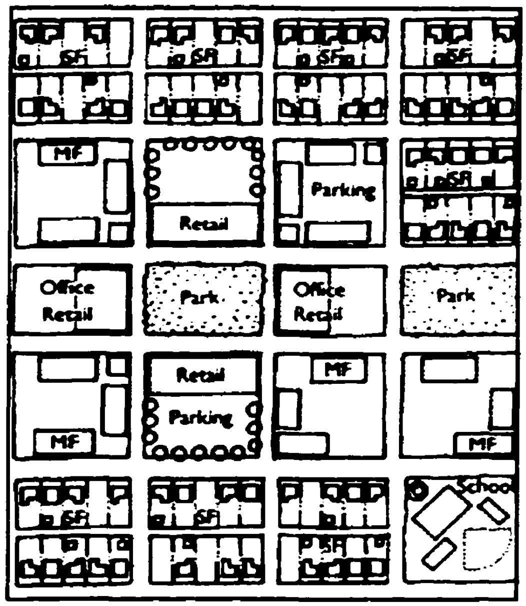


Figure 2-7. Traditional Neighbourhood Development Design Schematic (Calthorpe 1993, 49)



The most striking differences between the conventional suburban development model and the two 'alternative' development models can be found in the land use zoning and street pattern. The conventional suburban development model separates land uses into large, single-use zones, with a tree-like circulation system that encourages automobile use. On the other hand, the TOD and TND models integrate uses into a mixed-use environment and improve accessibility (for pedestrians, cyclists, and vehicle drivers) through the development of compact communities and a grid-like street pattern. As indicated above, it is believed that urban form plays a significant role in determining automobile dependence and thus influencing ecological, social, and economic health (Calthorpe 1993; Kelbaugh 1997; Newman and Kenworthy 1999; Roseland 1998).

Transit-Oriented Development – Research Results

Research on TODs indicate a positive trend towards fewer vehicle trips and kilometres travelled, lower congestion levels on roads, higher transit use and non-motorised travel (walking and cycling), safer streets, financial benefits, and an overall greater 'sense of place' for residents (Bernick and Cervero 1997). These results all contribute to reducing automobile dependence. Highlighted below are some encouraging research results from the TOD movement.

Work Trips

Recent research from the San Francisco Bay area that matched seven transit-oriented neighbourhoods to auto-oriented neighbourhoods (holding incomes and other factors constant) indicates the following (Bernick and Cervero 1997):

- transit-oriented neighbourhoods produced 48% more transit trips for work than auto-oriented neighbourhoods.
- transit-oriented neighbourhoods produced 50-70% more walk and cycling trips than auto-oriented neighbourhoods.
- 9.7% of work trips (i.e. commuting) are completed via transit in transit-oriented neighbourhoods versus only 6.5% in auto-oriented neighbourhoods.
- 10.4% of work trips are completed by walking and cycling in transit-oriented neighbourhoods versus only 3.8% in auto-oriented neighbourhoods.

Research that analyses resident proximity to transit stations indicates that residents who live within walking distance of a major transit station (preferably rail) are 5 to 7 times more likely to commute via transit for work trips as the average urban citizen. In addition, new residents of transit villages choose transit 30% more for work trips than when they previously lived in a conventional, auto-oriented neighbourhood (Bernick and Cervero 1997). This has significant environmental benefits as per passenger energy used (per mile) in rail is 3-4 times lower than that of the private automobile (Bernick and Cervero 1997).

Proximity and ridership research from Canada and the US reveals that proximity is critical at both ends – the residence and workplace – for transit ridership to increase. US studies indicate that transit ridership declined by approximately 0.65-0.75% for every 100 foot increase in distance from home or work to a transit station. This sensitivity is most likely larger for an express or conventional bus system, such as the #135 service that exists at SFU (JHK 1987; JHK 1989). It is important to point out that the Burnaby Mountain Community Corporation (BMCC) and SFU have the ability to only partially influence this planning reality. The BMCD may provide many residents with efficient access to school, employment, retail, and transit opportunities. However, as some residents will be employed off-site, the responsibility to provide convenient and efficient access to transit at the workplace becomes the responsibility of the GVRD and TransLink (i.e. Greater Vancouver Transportation Authority).

On the other hand, Canadians are willing to walk much further to access transit from home or work, as their "impact zone" can extend as far as 4,000 feet versus the 500-1,000 foot range in the US (Stringham 1982). For example, approximately 60% of rail users in Toronto and Edmonton walk to the transit station when the distance from their home or work is a maximum of 1,500 feet. In Washington and California, only 40% and 20% of people walk to the transit station when it is located at a distance of 1,500 feet.

Non-Work Trips

Though the above results are impressive for transit-oriented neighbourhoods, it is thought that this community design style would have its greatest impact on non-work travel, which make up 60-75% of trips (Van der Ryn and Calthorpe 1986). Given their mixed-use, compact design that integrates residential, retail, commercial, employment, education, and recreation into one community, TODs should enjoy higher levels of pedestrian, bicycle, and transit trips than conventional suburban developments. In an analysis of non-work travel in transit versus auto-oriented neighbourhoods, the following modal splits were observed (Bernick and Cervero 1997).

Table 2-13. Modal Split by Neighbourhood Type for Non-Work Trips

[illegible]	[illegible]	[illegible]
Auto	85%	96%
Transit	5%	2%
Walk	7%	1%
Bicycle	3%	1%

These results indicate that residents of these transit-oriented neighbourhoods are five times as likely to travel by foot or bike for non-work trips than residents of the auto-oriented neighbourhoods. This can be directly attributed to the fact that trips are shorter in TODs, which is a by-product of their unique structure and design features. Furthermore, TOD residents travel by private vehicles 11% less than their counterparts for non-work related trips. This is important as an 11% reduction in auto use results in a significant reduction in energy consumption, and thus vehicle emissions. Bernick and Cervero's study concludes that a transit-oriented development can, on average, decrease private automobile travel by approximately 10%.

As a function of distance, research indicates that for non-work trips of less than 1 mile (1.6 km), pedestrian, cycling, and transit can account for approximately 37% of trips made within transit-oriented neighbourhoods, of which 28% of these are via foot and bicycle. Auto-oriented residents only achieved a 20% pedestrian, bicycle, and transit trip rate. As this distance increases to 2 miles (3.2 km), non-motorised and transit accounted for 22% of trips in TODs and only 7% in auto-oriented neighbourhoods. Furthermore, automobile travel only accounted for 66% of non-work trips in TODs versus 81% in auto-oriented communities (Bernick and Cervero 1997).

Richard Untermann, an urban designer from the University of Washington, indicates that the following pedestrian behaviours exist in the US with respect to walking to non-work and casual destinations (Untermann 1984):

- most people are willing to walk 500 feet to reach non-work destinations.

- 20% of the population will walk 1,000 feet to reach non-work destinations.
- 10% of the population will walk a half-mile (approximately 2,700 feet) to reach non-work destinations.

However, for work trips, most people will endure a greater distance when walking. Untermann indicates that up to half of the middle-aged or younger will walk up to a quarter of a mile (approximately 1,300 feet). Therefore, these results indicate that proximity and accessibility are critical in designing communities that encourage walking and cycling and in reducing automobile dependence.

All Trips

Proximity-ridership research in Canada indicates the following sensitivity to density: as density increases from single-family dwellings (low-density) to apartment dwellings (moderate-to-high density), rail ridership increases by approximately 10-15%. The following table highlights this relationship as a function of distance to the transit station from one's residence (Bernick and Cervero 1997).

Table 2-14. Percent Rail Modal Share as a Function of Distance and Dwelling Type

Dwelling Type	500 feet	1000 feet	2000 feet	3000 feet	4000 feet
Single-Family	50%	47%	40%	25%	8%
Apartment	63%	61%	55%	35%	17%

Traditional Neighbourhood Development – Research Results

Research from TNDs in San Diego, Sacramento, Portland, and Maryland indicate that residents travel approximately 50% less by automobile than similar residents in modern, auto-oriented communities. Furthermore, residents of these traditional neighbourhoods travel by transit and walking/cycling by as much as 400% and 200% more. For example, residents of Rockridge, a traditional neighbourhood in San

Francisco, drove 15,707 miles in one year versus 31,291 miles travelled by residents in Danville, a typical, sprawl-like suburban development in San Francisco. This difference in VMT represented a savings of approximately $9,000 (US) for the residents of Rockridge (Calthorpe 1993).

Other research from the San Francisco Bay area indicate that residents of a dense, mixed-use and pedestrian-friendly neighbourhood drove, on average, only one-third as many miles each year as residents of a low-density, auto-oriented suburb with similar incomes (Holtzclaw 1990). Modal splits in these neighbourhoods were 23% and 22% for walking and transit respectively. However, suburban residents travelled by foot only 9% of the time and used transit for only 3% of trips (Holtzclaw 1990).

Traditional versus auto-oriented community travel behaviours from two San Francisco neighbourhoods indicate that residents of traditional neighbourhoods are less auto-dependent. The results are as follows (Calthorpe 1993):

Table 2-15. Modal Split by Neighbourhood Type for All Trips

Mode	Traditional Neighbourhood	Auto-Oriented Neighbourhood
Auto	64%	86%
Transit	17%	3%
Walk	17%	8%
Bicycle	2%	3%

This represents a 25% reduction in auto-use, a 200% increase in walking, and a 600% increase in transit use by residents of traditional neighbourhoods. This contributes significantly to improving local air and environmental quality, and provides many economic and social benefits, such as reduced levels of congestion. It is important to note, however, that these levels of reduced automobile use may not exist without the appropriate investments in pedestrian, bicycle, and public transit infrastructure (e.g. bike lanes, pedestrian paths). Furthermore, in planning TNDs and TODs, walking distance to transit stops (more importantly, the main station) and neighbourhood centres (i.e. retail, office, and recreational services) should be no longer than 2,000 feet in the US and 3,000 feet in Canada (Bernick and Cervero 1997). As David Engwicht states in his internationally acclaimed *Reclaiming Our Cities and Towns*, "the goal should be that every person, if physically capable, will be able to reach the neighbourhood hub by foot or cycle, in safety and without being discouraged by conflict with motorised traffic" (Engwicht 1993, 127).

In conclusion, these results indicate that traditional neighbourhood developments are less auto-dependent and thus reduce vehicle emissions and road congestion. When work and non-work travel are combined, transit-oriented and traditional neighbourhood design have the potential to significantly reduce auto travel by 10-50%.

It is important to note that both TODs and new TNDs (commonly referred to as 'neo-traditional') have not fully matured to offer solid research results (Calthorpe 1993). However, the above research results (i.e. San Francisco Bay area studies) are based on comparing "older" traditional parts of the city that are not found directly in the city centre (i.e. not located in the inner-cities with high densities) – thus representing the physical characteristics of modern TNDs as well as providing established neighbourhood travel patterns (i.e. sound data) – to new suburban neighbourhoods.

Furthermore, the private automobile remained dominant in traditional neighbourhoods, capturing more than the majority of trips. This could be a function of the greater region's overall form and its influence on transportation behaviour. This influence could be stronger on the macro-level than the one-off, micro transit-oriented scale. Therefore, it is important for traditional neighbourhoods to not stand in isolation, but to create a critical mass and connect an entire region. Disconnected and isolated traditional neighbourhoods may not significantly influence transportation behaviours (Bernick and Cervero 1997).

Finally, it is important to put transportation economics in perspective. These evaluations are taking place in a distorted marketplace, where inexpensive automobile travel, through subsidised gasoline prices and infrastructure costs, and the exclusion of social and environmental externalities, plays a large role in shaping travel behaviours. As Bernick and Cervero state, "it is no surprise that the effects of the built environment on travel have been suboptimal in a world of suboptimal pricing" (Bernick and Cervero 1997, 111).

2.7 Conclusion

It is believed that the above literature review provides sufficient evidence to motivate the application of sustainable transportation and land use planning to not only the SFU community, but to all local and regional planning initiatives. Chapter 3 will examine 'sustainability indicators,' develop the *Sustainable Transportation and Land Use Planning Framework*, and investigate its application to the proposed sustainable transportation plan.

Chapter 3 Development of a Sustainability Planning Framework

3.1 Introduction

'Sustainability planning' is a process tool that can be used by a broad spectrum of society, from federal government agencies to local community associations, to assist them in the development of vision statements, goals, indicators, and targets in an effort to achieve sustainable development objectives (Brugmann 1997; Sustainable Seattle 1993; Maclaren 1996a, Hart 1995, Roseland 1998). It is the objective of this chapter to develop a 'framework' that uses indicators for developing sustainable transportation and land use policies. Sustainability indicators will be first defined and their purpose, benefits, and development criteria further discussed. This literature review will then be used in the development of the *Sustainable Transportation and Land Use Planning Framework* – a sustainability assessment and decision-making tool to be used in assisting communities develop sustainability plans and policies. This framework will finally be applied to the SFU and BMCD case study in an effort to develop a *Sustainable Transportation Plan* for SFU's Burnaby Mountain campus.

3.2 Sustainability Indicators: Literature Review

3.2.1 Definitions, Background, Initiatives, and Caveats

Definitions

Indicators are useful for helping communities achieve sustainability, as they provide communities with a 'toolkit' to measure the progress of their efforts. They can help a community identify and understand where they are, which way they are going, and how far they are from where they want to be (Hart 1995). In other words, they act as 'benchmarks' that enable communities to determine their level of sustainability (Beatley and Manning 1997). Furthermore, the development of indicators enables citizens to discover what is important to them, thus identifying value-systems (Craig 1995; Kemmis 1990). However, perhaps most important is the fact that established goals and indicators *motivate* citizens to become active in helping their community achieve sustainability. In other words, the expression "what gets measured tends to get done," captures the true value of indicators (Osborne and Gaebler 1993). It is important at this stage, however, to stress that it is the direction, more so than the destination, that a community should be striving towards (Kline 1997).

There is much literature on sustainability indicators, their definitions, value, purpose, and methods for development. For example, the Sustainable Seattle project defines urban sustainability indicators as:

> *...bellwether tests of sustainability and reflect something basic and fundamental to the long term economic, social, or environmental health of a community over generations* (Sustainable Seattle 1993, 4).

The Jacksonville (Florida) Community Council, another example of a local sustainability initiative, defines indicators as:

> *...a way of seeing the 'big picture' by looking at a smaller piece of it. They tell us which direction we are going: up or down, forward or backward, getting better or worse or staying the same* (Dilks 1996, 2).

In other words, indicators help identify the general 'health' of the environment, society, and economy. It is important that sustainability indicators include all three spheres, otherwise they will not be effective in helping a community achieve its sustainability goals.

Background

Sustainability indicators play a large role in sustainability planning (Brugmann 1997; Jacobs, M. 1993). Jacobs indicates that there are two stages in this process. In the first stage, key environmental indicators are identified and goals are then set. In an attempt to achieve these goals, regulation and economic policies are implemented to influence behaviour in the second stage. The objective of stage two is thus to ensure that the sustainability targets set in stage one are not exceeded. Jacobs further indicates that there are two types of environmental indicators to consider when setting performance targets: primary and secondary (Jacobs, M. 1993). Primary indicators assess the environmental capacity of an ecosystem, such as the quantities of carbon dioxide in the atmosphere. Secondary indicators, on the other hand, measure the activities that influence the primary indicators, such as vehicular emission rates. Therefore, a close relationship exists between primary and secondary indicators, as it is the targets set to achieve the secondary indicators that influence whether or not the primary environmental indicators will be achieved. Jacobs concludes that "it is the primary indicators that measure sustainability and the secondary indicators that influence policy to achieve the preset sustainability goals" (Jacobs, M. 1993, 120). The selection of community goals, indicators, and targets is thus an important process as it sets the stage for future policy-making (Litman 1998c).

Initiatives

A number of initiatives are under way to develop and apply sustainability indicators, both in Canada and internationally. Initiatives exist at all levels within Canada (i.e. national, provincial, and municipal) and range from programs that assess quality of life and the state of the environment on the local level to broader sustainability assessments at the national level (Dilks 1996). Some examples of national programs include Environment Canada's "National Environmental Indicators Program" and Canada Mortgage and Housing Corporation's "Quality of Life Indicator Framework and

Applications." At the provincial level, examples include the BC Round Table's "Urban Sustainability Indicators Report." At the local level, examples include the Hamilton-Wentworth "Sustainable Community Indicators Project," and the Metropolitan Toronto and Richmond (BC) "State of the Environment Reports." Internationally, the United Nations Centre for Human Settlements' "Indicators Program" is widely accepted as a tool to assess conditions in human settlements throughout the world (Dilks 1996).

Sustainability indicator initiatives are gaining serious recognition world-wide. Their value as a tool for assessing community health, direction, and the development of sustainability plans is increasing and thus, the application of this planning tool is multiplying. However, there exist some caveats with respect to the use of indicators as a tool in moving toward a sustainable society. These constraints are described below.

Caveats

Newman stresses the importance of integrating 'community values' into the process of selecting sustainability indicators (Newman 1998). This ensures that the diversity of interests and value-systems held by citizens is incorporated into the community planning process, thus ensuring that the community's goals, and hence indicators, will be sustained into the future. However, due to this diversity within value-systems and communities, Maclaren recommends that indicators should not be applied in a 'cookie cutter' approach, as a 'one size fits all' template does not exist (Maclaren 1996a). Furthermore, Hart notes that not every widely used indicator is applicable to all communities (Hart 1995). For example, transit rides per capita may be particularly important and relevant in Vancouver but not in a small community, such as Fernie, BC, where public transit does not exist. Hence, communities must decide what indicators are relevant to their own particular situation.

Furthermore, some research raises cautions concerning the use of indicators, particularly when they are not linked to a process that can lead to an improvement in the conditions they measure (Newman and Kenworthy 1999). Newman and Kenworthy believe that indicators will not be effective if their main purpose is to gain public relations points. Instead, indicators need to be tied into policies and programs that can create some potential for real improvement for the whole city (Newman and Kenworthy 1999).

A further caveat is the use of single versus multiple indicators. In community sustainability assessments, indicators can be used either singly, or in combination. However, the application of a single indicator in an assessment process may not be ideal as an important component, or element, may be neglected (Remiz 1998). Furthermore, due to the interconnectedness of indicators, it may be ineffective to measure one indicator without considering others.

To assess sustainability over time, sustainability indicators should not only include a measure, or indicator, for assessing the impact or condition, but also a reference value, such as baseline data, for evaluating the impact or condition. Baseline data can range from the national to the community level. For example, a traffic volume count, at either the national, regional, or community level, is an excellent starting point and can provide an effective set of transportation reference values (Remiz 1998). However, because sustainability requires a vision of what *could be*, not what is, data may not be readily available for many of the good indicators. In addition, some indicators may not have adequate definition. Traditionally, communities have used conventional data sources and have selected indicators based on the availability of common data. However, it is recommended to first develop the best indicators for the community and then decide later when and how to get the necessary information. This method therefore ensures that sustainability indicators are progressive and ideal and are not influenced by typically conservative data sets (Hart 1995).

Overall, the use of sustainability indicators is still strongly encouraged. However, the literature does highlight some important concerns that all potential users should be conscious of, particularly the fact that as diversity exists between communities, diversity may also exist in the indicators applied to these different communities. Thus, the sustainability indicator process should not be applied in a 'cookie cutter' process but rather applied in a highly participatory environment where the diversity within the community influences the development of indicators (Maclaren 1996a).

3.2.2 Objectives and Characteristics

Objectives

Indicators provide great value to communities, as they help their citizens deal constructively with change, and can provide a practical framework for defining community sustainability and measuring progress towards that goal (Hart 1995). In other words, the use of sustainability indicators can help communities achieve the following objectives (Zachary 1995; Beatley and Manning 1997; Remiz 1998):

1. Enable a community to identify what it values and prioritises those values.
2. Hold individuals and larger groups accountable for achieving those results.
3. Through collaboration, community members engage in community-building, which further builds democratic decision-making.
4. Enables communities to measure what is important and to make decisions based on these measurements. That is, the results help communities discover whether they are achieving their previously established goals, or, if they should re-assess their direction, investments, and/or goals.
5. Enables communities to assess equity, across both demographic profiles and geographic scales, and therefore empowers a community to make decisions that benefit the greater public good.
6. Provides political power to citizens, which can be used to inject a performance measure into the political arena.

Furthermore, sustainability indicators can be used to assist in achieving compliance with a certain policy or legislation; improve the efficiency and/or effectiveness of municipal services and functioning of sites; provide public information and improved citizenship; and identify distressed urban areas and create opportunity for intervention (Dilks 1996).

The application of indicators is therefore quite broad, encompassing several objectives at all levels of government and at the community scale.

Characteristics

Effective sustainability indicators typically have a common denominator – they share distinct characteristics that make them productive and useful to communities and their citizens. According to the literature, effective sustainability indicators possess the following characteristics (Hart 1995; Remiz 1998; Dilks 1996):

1. **Relevant to Sustainability**: indicators must fit the purpose for measuring. With respect to sustainability, they must indicate the health of a complete system (i.e. environment, economy, and society) to be effective.
2. **Understandable to the Community at Large**: indicators must be easily understood and applied, or useable, by the general public. Indicators should not be an esoteric concept but rather a simple, user-friendly tool that is accessible to all. For example, a gas gauge (which is an indicator of fuel in a fuel tank) that only displayed the number of BTUs of gas in the tank would not be an effective and understandable indicator to the user.
3. **Developed and Accepted by the People in the Community**: to be effective and sustaining, community involvement in the process of developing indicators is critical, as it is the community that will be challenged to achieve these goals. Furthermore, it is the community that is rich with 'local knowledge,' thus providing valuable insight with respect to managing its social, economic, and ecological resources.
4. **Link Economy, Society, and Environment**: indicators must identify the link between the economic, social, and environmental elements of a community. A sustainable community is one where the interweaving of economy, society, and environment serves to strengthen its overall fabric, and indicators should highlight these links whenever possible. For example, the median income of a community – a frequently used economic indicator – is not a strong example of an indicator that links

all three spheres (i.e. ecology, society, and economy), as it purely represents the economic health of the community's citizens. However, a more effective indicator would be one that integrates the percentage of income spent on housing costs into the median income indicator. This indicator now provides a stronger link between the economic and social health of the community and its citizens.

5. **Focus on Long Range View**: indicators should be developed with a long-term perspective of the community in mind; to ensure long-term community health, indicators must address this time scale. For example, the number of houses built per year is not an effective indicator for long-term sustainability, as it does not identify the type of development, the materials used, and the land-types utilised.
6. **Advance Local Sustainability within Global Context**: sustainability indicators should also integrate a macro-perspective, where global sustainability concerns are taken into account and integrated into local sustainability indicators and plans. Therefore, indicators, and their associated policies, should not attempt to simply re-locate problems from one community to another in an effort to achieve local sustainability.
7. **Based on Reliable Information**: indicators must be reliable (i.e. represent the truth) to develop faith by their users and to be effective in moving towards sustainability. The validity of data sources and measuring techniques is thus key to ensure reliable information. Furthermore, it is important that data are available and accessible. In addition, though ideal indicators may not have available data when they are developed, it is important that the data can be eventually created or made accessible.
8. **Based on Timely Information**: in order for an indicator to be useful in preventing or solving a problem, it must give you the information when there is still time to correct the problem. Therefore, effective indicators provide early warnings and reveal changes in chronic and widespread problems.
9. **Responsive**: indicators should respond to policy initiatives, or other actions taken, to communicate to the community their effectiveness.

10. **Compatibility with other Indicators**: indicators should be compatible with those used in other communities, thereby allowing comparisons to be made with meaningful references, or benchmarks.
11. **Inexpensive**: the use of indicators in community assessment and sustainability planning should not be overly taxing on financial resources.
12. **Independent**: indicators should be relatively independent of linked factors, such as income levels and gasoline prices.
13. **Attractive to the Media**: indicators should be useable and topical to gain attention by local media sources. This provides great value to communities as knowledge is disseminated, awareness is increased, and through recognition, citizens are empowered with the potential to make change.

These characteristics are therefore very important in the process of developing sustainability indicators and plans, as they provide a road map to follow and 'rules' to stay on the road, or path, to successful sustainability planning.

3.2.3 Identification and Development

Identification

The identification and development of sustainability indicators are two critical stages in the sustainability planning process. These stages are highly dependent on strong stakeholder input, as it is imperative that a diversity of values and visions are included in these processes to truly develop 'sustaining' planning policies, whether they be for transportation, community development, or stream restoration. The integration of community values is important as their inclusion typically increases the community's sense of ownership and personal level of accountability, responsibility, and commitment.

At this time, it is important to highlight one study caveat, as previously discussed in Chapter 1. Due to scoping limitations, the development of sustainable transportation and community indicators in this study did not include community and stakeholder involvement. In addition, the final *Sustainable Transportation and Land Use Planning Framework* will not be a 'one size fits all' planning tool but should be viewed rather as a template for communities and individuals to build upon. In other words, the framework developed in this study aims to enhance and support a public process that may develop at a future stage – a stage where community input will be required. It is on these conditions that the lack of stakeholder involvement in this study is justified.

In identifying sustainability indicators, Remiz proposes the following 'step-wise' process (Remiz 1998, 4):

1. Conceptualise the issue of interest;
2. Clarify the goal(s) and objective(s);
3. Determine the target audience and the general purpose;
4. Choose an appropriate framework (e.g. domains (e.g. environment, economy), goals, jurisdictions (e.g. roads, parks), policy response capabilities);
5. Define the selection criteria;
6. Identify a set of potential indicators; and
7. Evaluate them against the selection criteria.

This process of identifying indicators is common within the literature and is considered an appropriate and effective starting point for communities (Maclaren 1996a, Hart 1995).

Development

In the development of sustainability indicators, Hart proposes the use of a 'checklist' that assesses the degree to which an indicator incorporates *community capital* and *carrying capacity* (Hart 1995). Community capital and carrying capacity are two key components of sustainability. Community capital includes all the things a community has that allow its citizens to live and interact productively, and consists of the following three elements: natural capital, social capital, and built capital (Hart 1995). Carrying capacity, on the other hand, is the ability of a community's capital to provide for the community's needs over the long term (Hart 1995). In identifying and developing indicators, it is important to determine whether or not the indicator addresses community capital and carrying capacity. Furthermore, it is also important to determine if the indicator holds qualities similar to those outlined in the "characteristics of effective indicators" section above.

Keeping this 'checklist' in mind, the next step in identifying sustainability indicators is to select an appropriate framework for their development, as indicated above. This framework, or conceptual model, can then be used to identify and select indicators based on the needs of the particular community (Dilks 1996). There exist three frameworks that are typically used in the development of urban sustainability indicators: *theme-based*, *condition-stress-response*, and the *Community Oriented Model for the Lived Environment* (Maclaren 1996b).

The *theme-based* framework develops indicators for certain sustainability themes or principles. For example, carrying capacity and quality of life were the broad principles used by the UK's Local Government Management Board and indicators were developed to support these principles (Maclaren 1996b).

The *condition-stress-response* framework is based on 'state of the environment reporting' that takes place in many municipalities. This framework is based on the understanding that human activities affect environmental health, which in turn impact social and economic health. This framework therefore identifies cause-effect relationships and enables policy makers to not only identify *stressors*, but to understand them and to react by implementing appropriate policies. This framework is typically considered more effective than the theme-based framework as it is successful in linking the three spheres of sustainability.

The final framework, the *Community Oriented Model for the Lived Environment (COMLE)*, identifies areas of municipal government responsibility and then attempts to link these areas with the themes of environmental integrity, economic vitality, and social well-being. This framework is also considered superior to that of the theme-based, as it is more urban-focussed and links local responsibility with economic, social, and environmental sustainability (Maclaren 1996b).

These frameworks – either separately, in combination, or as hybrids – are considered very effective in the development of sustainability indicators (Maclaren 1996b; Dilks 1996).

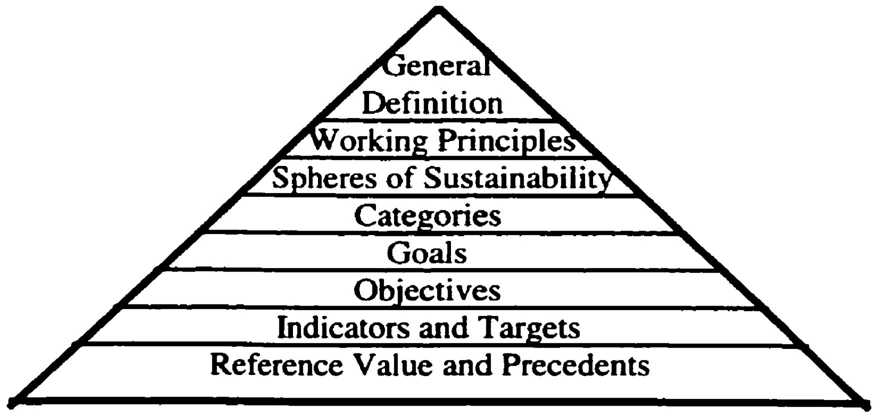
The identification and development techniques outlined above have guided the indicator development methodology to be used in this study. However, as stated above, these methodologies go beyond the scope of this study, as they are far too comprehensive to undertake at this stage. These methodologies therefore act as a foundation for understanding the fine details of sustainability planning, and are discussed in hopes of creating a stronger awareness amongst the readers of this study.

3.2.4 The 'Sheltair Model'

On October 26, 1995, the Vancouver City Council endorsed a plan to apply sustainable development principles to the Southeast False Creek (SEFC) site, an area of approximately 80 acres of industrial land in downtown Vancouver. City Council authorised the creation of an Advisory Group of stakeholders, made up of landowners, nearby residents, developers, engineers, and planners, to name a few. This Advisory Group, along with a Technical Team and the Sheltair Group Inc. (Project Manager), responded to the principles of the Sheltair report as it was being developed, and contributed to the design of the principles and policies of sustainable community development that are to be applied to the SEFC site.

In developing guidelines for sustainable urban development in the SEFC area of Vancouver, the following model, or 'pyramidal framework,' was developed and applied.

Figure 3-1. A Comprehensive Framework for Sustainable Urban Development (Sheltair 1998, 13)



The Comprehensive Framework for Urban Sustainable Development provides a step-by-step process for developing sustainability indicators and setting targets. This 'road map' thus provides a user-friendly approach in the development of policy. An easy way to understand the concept of this pyramidal framework is to think of it as a 'tree,' where the level of detail and precision increases as one moves from the top 'branches' (i.e. General Definition) to the bottom branches (i.e. Reference Values and Precedents).

The Comprehensive Framework for Urban Sustainable Development starts with a *general definition* of sustainable urban development, and then works its way through *principle identification* and its relationship with the three *spheres of sustainability*: ecology, society, and economy. These spheres are then organised into subject areas. For example, transportation is a *category* within the ecology sphere of sustainability. *Goals* are then developed for each category and *objectives* further define these goals. For example, a community may select the goal of "minimising the number of vehicle trips made outside the neighbourhood for basic needs" (Sheltair 1998, 17). One objective that would help in achieving this goal would be to "increase the proximity of housing to key activity centres" (Sheltair 1998, 17). With this goal and objective set, a community can then proceed with establishing *indicators* and setting appropriate *targets*. An appropriate indicator to achieve the above stated goal and objective is the "percentage of dwelling units within 350 meters of basic shopping needs and personal services" (Sheltair 1998, 52). Sheltair proposes that "100% of the dwelling units" in the SEFC sustainable community development be within 350 meters of basic shopping needs and personal services (Sheltair 1998, 53). The final stage in this process is to research other related case studies to understand, and adjust if need be, the previously established targets. These case studies thus act as *reference values* and *precedents* of what other communities are attempting to do, or have successfully achieved. However, this final stage may be more effective if completed before the indicator development and target setting stage, as it should play a large role in guiding target setting and policy formation.

Due to this study's limited scope, it is believed that the following stages of the Sheltair model are most appropriate to use in the development of the *Sustainable Transportation and Land Use Planning Framework* (Sheltair 1998):

1. **Categories:** subject areas that are organised into topics of concern. Categories either reflect different parts of the physical world (e.g. air) or sectors and services (e.g. transportation).
2. **Goals:** broad statements that define the community's desired condition.
3. **Objectives:** more detailed description of the goals, which typically indicate the direction of change that is required (e.g. increased proximity of housing to key activity centres).
4. **Indicators:** should 'indicate' performance, and are therefore a conceptual tool used to measure progress towards an objective. Indicators should be expressed in clear and precise terms, to avoid confusion and misrepresentation.
5. **Targets:** establish the desired level of performance. Targets should be challenging but both economically and technically feasible. It is important to remember that targets are intended to function as *guides* rather than standards.

Given its successful application to the development of urban sustainability guidelines in Vancouver, coupled with its user-friendly format, it is believed that the 'Sheltair Model' will be an effective and thorough method for developing the *Sustainable Transportation and Land Use Planning Framework* for this study.

3.2.5 Reporting and Monitoring

In the development of sustainability indicators, Maclaren recommends that communities understand and be eager to participate in the whole process of sustainability planning, from first definitions of sustainability, to indicator development, and then through to indicator evaluation, monitoring, and reporting (Maclaren 1996a). The Sheltair Model (Figure 3.1) selected for the development of this study's sustainability framework unfortunately does not include a 'reporting' and 'monitoring' stage. However, it is important to discuss the role of reporting and monitoring within a sustainability planning process.

Urban sustainability reporting is an iterative and cyclical process that enables a community to constantly re-evaluate its goals and to re-adjust its indicators, if necessary, to align itself with its desired future condition. Therefore, the urban sustainability reporting process looks at the full cycle of sustainability planning, from defining goals, to monitoring and reporting on progress, to re-evaluating sustainability strategies. Furthermore, sustainability reporting is a tool used to inform local government, business, communities, and individuals about their progress towards achieving urban sustainability (Maclaren 1996a). Maclaren proposes that the urban sustainability reporting process be used at all levels, from federal governments to local community associations.

It is important to note, as previously mentioned, that continual improvement, more so than one-time achievement, should be the goal of this process. A community should refine goals that have been achieved in an effort to preserve the positive evolution of the community. Therefore, it is not recommended that communities "pack it in" once the "job is done," as its performance may return to its original position (i.e. pre-achievement of community goals) and community spirit may erode.

Furthermore, 'monitoring' plays a large role in the process of continual improvement. The process of evaluating indicator performance is a form of monitoring, where the users are 'checking up' on not only the performance of the indicator, but the direction, the scope, measurement technique and other related issues surrounding the sustainability planning process. Monitoring is therefore a critical stage in the sustainability planning process, as it enables a community to truly understand the state of their local environment (i.e. economy, society, and ecology), and to adjust their 'sails' if required.

3.2.6 Conclusions

In conclusion, sustainability indicators are unique in that they combine elements from the economy, society, and the environment in one set of evaluative criteria. Furthermore, they can bring enormous benefit to a community, as they provide a framework for assessing, and moving towards, a sustainable community; empowering citizens through local initiatives and accountability; and nurturing the development of social capital within a community.

The literature is fairly consistent with respect to the process of identifying and developing sustainability indicators. The above referenced processes provide a suitable foundation to build upon, and an excellent starting point for most communities. However, the 'Sheltair Model,' based on Sheltair's SEFC sustainable community development guidelines, is believed to be an effective framework for the development of sustainable transportation and land use policies on the local (i.e. community) scale. This model will therefore be used in the development of indicators for the *Sustainable*

Transportation and Land Use Planning Framework. The following sections will define the categories, goals, objectives, and indicators; as well as identify and define the sustainability criteria that will be used to assess the indicators.

3.3 The Development of the *Sustainable Transportation and Land Use Planning Indicator Framework*

3.3.1 Identification and Development of Categories, Goals, and Objectives

The 'Sheltair Model,' described above, will be used for developing sustainable transportation and land use indicators for this study. A four-stage process – a sub-set of the 'Sheltair Model' – is as follows:

1. Identify the Categories;
2. Identify the Goals for each Category;
3. Identify the Objectives for each Goal; and
4. Identify the Indicators for each Objective.

Given the objectives of this study, the following categories have been selected: *Transportation and Accessibility*, *Air Quality*, *Water Quality*, and *Housing*. It is believed that they will be essential to achieving the study's main objective of designing a transportation plan that will reduce SOV travel to and from SFU's Burnaby Mountain campus by 20% (both short-term and long-term traffic). The objectives are therefore to reduce automobile dependence at SFU, minimise environmental impacts, such as air and water pollution, and maximise accessibility to transit and services for the citizens of the SFU community, specifically the residents of the future BMCD. Research indicates that these outlined *objectives* are very effective in measuring a community's level of sustainability with respect to transportation and land use planning (Sheltair 1998; Newman and Kenworthy 1999; NRTEE 1996; TAC 1996; Transport Canada 1997; GVRD and Province of BC 1993a; GVRD and Province of BC 1993d; Raad 1998; Davidson 1997).

Table 3-1 below outlines the categories, goals, and objectives that have been selected for the development of the *Sustainable Transportation and Land Use Planning Framework*.

Table 3-1. Sustainable Transportation and Land Use Planning Framework: Categories, Goals, and Objectives

[illegible]	[illegible]	[illegible]
Transportation and Accessibility	1. Minimise SOV travel	a. Increase car-free living opportunities
		b. Increase access to basic needs
		c. Increase transportation choices
		d. Increase incentives for non-SOV travel
		e. Minimise the need to expand transport infrastructure
	2. Increase safety, community interaction, and livability	f. Introduce traffic calming measures
	3. Minimise the need to travel outside the neighbourhood for basic needs (e.g. food, work)	g. Increase proximity of housing to key activity centres
		h. Increase pedestrian, bicycle, and transit infrastructure within the neighbourhood
	4. Promote a balance of jobs and housing	i. Match housing types and affordability with the needs of working and non-working population within the community
		j. Increase employment opportunities to match residential stock or; increase residence opportunities to match employee and student base
Air Quality	5. Minimise harmful emissions, both local and global	k. Reduce concentrations of ground level ozone (smog), fine particulate matter, sulphur dioxide (SO_2), carbon monoxide (CO), and nitrogen dioxide (NO_2)
		l. Reduce carbon dioxide emissions (CO_2)
Water Quality	6. Minimise Water Pollution	m. Reduce and manage surface water run-off
Housing	7. Optimise community densification	n. Increase densities towards sustainability standards

The first category, *Transportation and Accessibility*, plays the largest role in this analysis with four identified goal statements. ***Minimise SOV travel***, or the need to travel by SOV, is critical in achieving a 20% SOV traffic reduction target at SFU (both in the short and long-term). SOV travel can be reduced through enhancing the accessibility and service levels of alternative modes, such as walking, cycling, and public transit. Research indicates that the outlined objectives support the achievement of this goal through efficient land use planning, improvements in transit service accessibility, increased accessibility to services, employment, and recreation for pedestrians and cyclists, and more equitable transport economics (Sheltair 1998; Newman and Kenworthy 1999; Litman 1998a). Improvements in transportation and accessibility, as indicated in the literature review, improve transportation efficiency (i.e. the ability to move people), and therefore reduce local and global environmental impacts (such as air and water pollution), improve social and economic equity, reduce pressure on land for further infrastructure development, and increase community and urban livability (Sheltair 1998; Newman and Kenworthy 1999; Litman 1997b; Litman 1998a; Ewing 1995a; Davidson 1997; Raad 1998; Engwicht 1993; Roseland 1998; NRTEE 1996). For the purposes of this study, it is therefore important to focus on the following objectives: *increase car-free living opportunities, access to basic needs, transportation choices and their associated incentives;* and *decrease the need to expand transport infrastructure.*

Increase safety, community interaction, and livability – through the introduction of traffic calming measures – is an important goal in creating healthy, sustainable communities. This can be accomplished through efforts to calm the speed and volume of vehicle traffic in neighbourhood streets, essentially reducing what Appleyard refers to as the "zone-of-influence" of private automobiles (Appleyard 1981). Research indicates that the speed at which vehicles travel, and the volume at which they flow, through neighbourhood streets have significant impacts on the safety and livability of these neighbourhoods (Appleyard 1981). Appleyard concludes in his study that the zone-of-influence increases with vehicle speeds and volumes, therefore leaving residents with less 'exchange space' (i.e. area in which people interact) and 'home territory' (i.e. area that one feels is part of their greater home) in their streets and homes, fewer social interactions and friends, and decreased levels of safety (Appleyard 1981). Therefore, the introduction of traffic calming measures may prove effective in curbing traffic speeds and volumes within the SFU community, and thus improving the community's livability. Furthermore, traffic calming may persuade citizens to choose alternative modes of transport since travelling by personal vehicle may be less convenient. Therefore, for the purposes of this study, it is important to focus on the following objective: *introduce traffic calming measures.*

Minimise the need to travel outside the neighbourhood for basic needs is an effective goal for improving accessibility and increasing transportation options within a community. Accessibility to employment, education, goods and services, recreation and green space within the community, and preferably within a 10-minute walk from one's residence (i.e. 400-500 meters), is important in improving livability and reducing automobile dependence, and thus pollution and personal economic expenditures (i.e. percentage of income spent on transportation). This form of community planning is found in Traditional Neighbourhood Developments (TNDs) and Transit-Oriented Developments (TODs), as indicated in Chapter 2. As 60-75% of total trips are non-work related (e.g. for groceries), it is believed that TND/TOD land use planning is an effective method in reducing vehicle travel (Van der Ryn 1986; Bernick and Cervero 1997). Research indicates that efforts to locate housing near key activity centres, such as shopping, employment, and recreational facilities, improves the transportation modal split in favour of walking, cycling, and public transit and can decrease vehicle travel from 10-50% (Bernick and Cervero 1997; Calthorpe 1993). Furthermore, the provision of adequate pedestrian, bicycle, and transit amenities within a community (such as sidewalks, pedestrian/cycle trails, bike racks, and transit stops and shelters) can encourage residents to use local services rather than driving to outside communities to satisfy basic needs (Sheltair 1998).

For the purposes of this study, it is therefore important to focus on the following objectives: *increase proximity of housing to key activity centres* and *increase pedestrian, bicycle, and transit infrastructure within the neighbourhood.*

Promote a balance of jobs and housing aims to achieve the spatial efficiencies of having people work and live in the same community, or municipality/region. Sheltair indicates that a "regional balance of jobs and housing is one of the most effective means of reducing trip lengths and associated transportation costs" (Sheltair 1998, 35). The difficulty with achieving a jobs-housing balance in many urban areas is the fact that the majority of jobs are located in the downtown core and the surrounding neighbourhoods are typically not affordable to the average wage earner (though this trend is changing, with more employment opportunities becoming available in suburban areas, such as research parks). These citizens then seek housing in the suburbs, particularly when real estate and commuting costs are low. The lack of affordable housing in, or near, the downtown core thus plays a critical role in achieving jobs-housing, and general land use, efficiencies. Therefore, jobs-housing efficiencies can be gained through initiatives to match housing affordability with the needs of the local working and non-working population.

In SFU's case, however, it is not the lack of affordability that challenges the jobs-housing balance, but rather the lack of housing supply at the university. Therefore, it is important for SFU to initiate efforts to provide greater housing options, as is envisioned in the proposed 'University Village' development (i.e. BMCD). Moreover, it is still important that housing be affordable in university communities, as the income of students is low. Therefore, a university must seek to meet the housing needs of a diverse community where the range of income levels and housing needs varies widely between staff/faculty and student populations.

In a university setting, a jobs-housing balance can also be thought of as an 'education-housing,' or 'student-housing' balance, as students make up the majority of a university's population. Moreover, there are many opportunities for universities to capture strong jobs-housing balances, particularly with faculty and staff. From this point forward in this study, the term 'jobs-housing' balance will include both employment (i.e. staff and faculty) and student populations.

A jobs-housing balance produces the same benefits as the previous goal of 'reducing the need to travel outside the neighbourhood,' since the need to travel by automobile is reduced when work destinations are easily accessible by foot, bicycle, and public transit (Bernick and Cervero 1997; Ewing 1995b). For the purposes of this study, it is important therefore to focus on the following objectives: *match housing types and affordability with the needs of the working and non-working population within the community*, and *increase employment (or residence) opportunities to match residential stock (or employee and student base).*

The remaining three categories – *Air Quality, Water Quality,* and *Housing* – include only a single goal for each due to this study's primary focus being transportation and accessibility. This is not to say that environmental quality and housing are less important, but rather to note that these issues can be improved significantly, and therefore managed, through sound transportation and land use policies (Newman and Kenworthy 1989; Newman and Kenworthy 1999; Roseland 1998).

Minimise air emissions, both local and global aims to reduce poor air quality, and its associated impact on human health, and greenhouse gas emissions that contribute to global climatic change (i.e. global warming). Vancouver's geographic location contributes to the severity of its air quality problem, as the Cascade Mountains to the south-east and the Coast Mountains to the north inhibit the free movement of air in the region. Together, these natural features form the 'walls' of the Lower Fraser Valley air basin – walls that contain the air and often prevent dispersion of pollutants (GVRD 1994a). Furthermore, studies indicate that the population of the Greater Vancouver area is highly automobile dependent, with higher VKT per capita (8,361 km) than the average

Canadian city (6,645 km), high automobile modal splits (approximately 80-85% of all trips), and below average annual transit ridership per capita (117 trips) compared to the average Canadian city (131 trips) (GVRD and Province of BC 1993a; Raad and Kenworthy 1998). In combination, air quality management is becoming a pressing issue in the Greater Vancouver area as local air quality, and its associated impacts, are becoming more intense and concerns over global climatic change are increasing. To improve local air quality, it is important to focus on *reducing concentrations of ground level ozone (smog), fine particulate matter at street level, sulphur dioxide (SO_2), carbon monoxide (CO), and nitrogen dioxide (NO_2) emissions.* On the global scale, it is important to focus on *reducing carbon dioxide (CO_2) emissions.*

Minimise water pollution aims to reduce the quantity of vehicle-related pollution, such as hydrocarbon runoff into streams. In addition, policies to increase the percentage of pervious surface materials, to allow rainwater to be absorbed into the soil, help achieve reduced pollution levels. This is particularly important in the context of this study, as the Greater Vancouver area, and more specifically, Burnaby Mountain, receive extremely high levels of annual rainfall. Burnaby Mountain typically receives approximately 2,200 mm of rain per year, twice that of the rest of the Greater Vancouver area (Yarnell and Sandmann 1997). It is therefore critical that surface water is managed to minimise the threat of water pollution within the Burnaby Mountain area. Surface water management programs that strive to achieve low hydrocarbon pollution levels and general water runoff are effective in maintaining healthy water ways, thus supporting the health of fish populations and aquatic ecosystems, as well as human populations. For the purposes of this study, it is therefore important to focus on *reducing and managing water runoff levels.*

Optimise community densification aims to achieve spatial efficiencies and minimise land use. A compact, medium to high-density community provides greater accessibility to its residents, particularly if the community includes mixed-use zoning (i.e. the integration of residential and retail). Urban and suburban densities must therefore increase to enable people to meet their daily needs via transit and non-motorised modes (i.e. bicycle and walking). As indicated in Chapter 2, research supports the movement towards higher density urban form, as higher density, compact and complete urban form lead to higher rates of transit use, non-motorised travel, and lower levels of personal automobile use (Newman and Kenworthy 1989; Newman and Kenworthy 1999; Jacobs 1961; Roseland 1998; Engwicht 1993; Bernick and Cervero 1997; Holtzclaw 1994).

Therefore, as spatial and energy efficiencies are gained in communities and urban areas that are built to a minimum of 30 dwelling units per acre, it is important to encourage policies that strive to achieve this target in an attempt to accomplish urban sustainability objectives. For the purposes of this study, it is therefore important to focus on *increasing densities towards sustainability standards.*

The outlined goals and categories (Table 3-1) have been identified as effective and appropriate for the objective and scope of this study. The *Sustainable Transportation and Land Use Planning Framework* is now starting to take shape and will be further defined in the following section, where sustainability indicators are identified and evaluated.

3.3.2 Identification of Sustainable Transportation and Land Use Indicators

In a sustainable community, transportation will be less dependent on single-occupancy vehicles that use non-renewable fuels and more dependent on multi-occupant, renewable energy vehicles. The need for transportation, or mobility, will be reduced in many cases because cities and towns will be designed so that walking and cycling are easy and convenient. Therefore, the emphasis of sustainable transportation indicators is on reducing automobile dependence, and thus the consumption of non-renewable fuels, and the environmental impacts (e.g. air and water pollution, resource consumption) that are associated with their use. Sustainable transportation indicators also emphasise decreasing the amount of transportation that is necessary and increasing the ease with which people can fulfil their daily needs, such as basic goods and services (Hart 1995).

As outlined in Chapter 1, the focus of this study will primarily be at the local scale – that is, Simon Fraser University's Burnaby Mountain Campus. However, given that many local strategies are interconnected to the municipal/regional scale, this study will also include (to a limited degree) some of these broader indicators. Therefore, the identification and selection of sustainable transportation and land use indicators will be based on the range of local and municipal/regional indicators.

The literature on sustainability indicators is growing rapidly, with a wide range of indicators currently in use (Roseland 1998; Newman and Kenworthy 1999; Litman 1997b; Remiz 1998; Sheltair 1998; TAC 1996; Hart 1995; Dilks 1996; WRG and S5 Services 1997). To develop the *Sustainable Transportation and Land Use Planning Framework*, a literature review was completed and relevant indicators were identified. Table 3-2 outlines some common sustainable transportation and land use indicators.

Table 3-2. Common Sustainable Transportation and Land Use Indicators (Newman and Kenworthy 1999; Litman 1997b; Hart 1995)

Common Indicators	
1.	Annual vehicle kilometres (non-recreational) travelled per capita (VKT)
2.	Annual vehicle hours travelled (non-recreational) per capita (VHT)
3.	Modal split between all modes for work and non-work trips
4.	Average vehicle occupancy
5.	Total number of trips made per day per capita
6.	Number of vehicles per household
7.	Average work commute time and distance
8.	Per capita transportation energy consumption (MJ or litres/capita)
9.	Annual number of transit trips per capita
10.	Transit cost recovery
11.	Transit service kilometres per capita
12.	Population density
13.	Percentage of population that live within 400 meters (10-minute walk) of basic goods and services
14.	Percentage of population that live within 400 meters (10-minute walk) of transit
15.	Total length of bicycle routes
16.	Average portion of household expenditures devoted to transportation (including direct expenditures (e.g. vehicles and fares) and indirect expenditures (e.g. parking and taxes))
17.	Number of car accidents involving pedestrians and/or cyclists

It is evident from the literature that sustainable transportation and land use indicators cover a wide spectrum of transportation and land use issues, or categories. Categories range from personal automobile use, environmental impacts, and transit service to the quality of the pedestrian and bicycle infrastructure, density and accessibility, parking provisions, and safety. The *Sustainable Transportation and Land Use Planning Framework* will incorporate this range of categories to provide a broad scope of local and municipal/regional indicators that can be used in the development of transportation and land use policies.

In selecting indicators for the aforementioned framework, an *Indicators Menu* was developed to represent the range of available indicators – specifically at the local and municipal/regional level – that relate to sustainable transportation and land use planning. This menu is based on an extensive literature review[9], and while not all references appear in the *Indicators Menu*, some have been identified to supplement the literature identified below.

This menu is not completely inclusive however, as indicators that are not applicable at the local level, not well documented, or that do not measure the condition or identify a desired direction, have been excluded. However, it is believed that the list of indicators described below is comprehensive and provides an excellent toolkit for communities to use in developing local sustainability indicators and policies. The following list should therefore be used like a 'menu,' where communities can select the appropriate indicators to fit the goals and objectives they hope to achieve.

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[9] Litman 1995a; COMSIS 1993; Hart 1995; Newman and Kenworthy 1999; City of the Hague 1995; Ciuffini 1995; Ewing 1995a; GVRD 1997a; Beatley and Manning 1997; Roseland 1998; Kline 1997; Sheltair 1998; Maclaren 1996a; BCRTEE 1991; Davidson 1997; Raad 1998; GVRD Transport 1993a; DOT nd; Engwicht 1993; Raad and Kenworthy 1998; Newman 1998; WRG and S5 Services 1997a; WRG and S5 Services 1997b; GVRD 1998b; City of Vancouver 1998; ; GVRD and FVRD 1997b; Ward 1995; Van Vliet 1994; TAC 1996; Litman 1997b; Remiz 1998; Dilks 1996; NRTEE 1996.

Based on the literature, selected indicators are separated into the following categories:

- General Transportation
- Public Transit
- Traffic Calming
- Non-motorised Travel and Pedestrianisation
- Parking
- Education, Organisations, and Programs
- Environment
- Land Use
- Economy
- Livability

These categories cover the broad spectrum of transportation and land use indicators that are associated with sustainable development. The *Indicators Menu* below outlines these categories and their associated indicators.

Table 3-3. *Indicators Menu*: Sustainable Transportation and Land Use Indicators

General Transportation	
1.	Vehicle Hours of Travel (VHT) – non-recreational – per capita per year (Litman 1997b)
2.	Vehicle Kilometres Travelled (VKT) – non-recreational – per capita per year (Litman 1997b)
3.	Modal split for work and non work trips
4.	Total number of vehicle trips made per day per capita
5.	Percentage of trips made by vehicle outside the neighbourhood for basic needs
6.	Average vehicle occupancy
7.	Average work commute (time and distance) by mode
8.	Average speed by mode
9.	Percentage of citizens living within 30 minutes of work by transit/bicycle/walking
10.	Vehicle ownership per capita (number)
11.	Number of vehicles per household
12.	Number of vehicle accidents per capita
Public Transit	
1.	Annual number transit trips per capita
2.	Annual transit service kilometres per capita
3.	Transit service kilometres relative to road provisions per capita
4.	Transit cost recovery (Newman and Kenworthy 1999)
5.	Percentage of peak period transit frequencies that are 15 minutes or less
6.	Percentage of non-peak period transit frequencies that are 30 minutes or less
7.	Percentage of transit connections less than 5 minutes long
8.	Number of 'special event'/'late-night' transit services
9.	Percentage of transit vehicles accessible for prams/wheelchairs/bikes
10.	Number of quality transit waiting facilities per capita (e.g. shelter, schedules and maps, seating, bins)
11.	Number of safety provisions between transit stations/stops and footpaths

Table 3-3. *Indicators Menu*: Sustainable Transportation and Land Use Indicators – continued

Public Tr [illegible]	
12.	Percentage of public who feel transit is safe
13.	Percentage of communities that receive transit responsibilities (e.g. bus shelter maintenance)
14.	Percentage of transit boards that include user/community representation
15.	Percentage of residences/businesses that receive transit service information
Traffic C [illegible]	
1.	Percentage of neighbourhood streets that are traffic-calmed (e.g. traffic circles, textured surfaces, 30 km/hr speed limits, narrow roads (25-30 ft), chicanes, street furniture, stop signs, speed bumps, street planting, wide sidewalks, islands, removal of curbs, signage, pedestrian crossings, street parties/games, reclaiming of road space for public space) (Newman and Kenworthy 1999; Condon 1996; Engwicht 1999)
Non-Mo [illegible]	
1.	Annual number of bicycle/walk trips made per capita
2.	Kilometres of separated cycleways
3.	Percentage of transportation budget allocated to cycling/pedestrian infrastructure
4.	Percentage of transit stations/stops with bicycle/walk facilities (e.g. bike/walk lanes, racks, and showers)
5.	Percentage of employment/public facilities with bicycle/walk infrastructure
6.	Percentage of streets that are "Pedestrian-Friendly" (e.g. benches, trees, sidewalks) (WRG and The City of Richmond 1999)
7.	Percentage of intersections with pedestrian/cyclist-activated technology
8.	Percentage of pedestrian/cyclist-activated lights that change within 15 seconds
9.	Percentage of pedestrian/cyclist crosswalks that provide longer than 15 second signal phases
10.	Number of car accidents involving pedestrians and/or cyclists
11.	Number of fatalities involving cars with pedestrians or cyclists
Parking	
1.	Ratio of parking fees to transit fees
2.	Proportion of residential parking with 1.25 (or less) parking stalls per unit (Condon 1996)
3.	Percentage of employers that meet the following parking criteria: 2-4 stalls/1,000 feet^2 (office); 3-5 stalls/1,000 feet^2 (retail); 1-3 stalls/1,000 feet^2 (light industrial) (Calthorpe 1993)
4.	Percentage of residential parking that is in back-alley garages/lanes
5.	Percentage of parking facilities that provide ridesharing privileges (e.g. closer/discount parking)
6.	Ratio of short-term to long-term parking facilities (Litman 1998b)
7.	Percentage of total parking (e.g. in urban centre, community) that is 'free' (i.e. no charge)
8.	Percentage of parking facilities that are multi-purpose (e.g. fairs, markets, recreation)
Education, Or [illegible]	
1.	Number of sustainable transportation education programs offered to schools/employers/public
2.	Number of 'Clean Air' days/campaigns/transportation fairs per year
3.	Percentage of cities/municipalities with transportation management associations (TMAs)
4.	Percentage of employers with employee transportation administrators (ETAs)
5.	Number of sustainable transportation services (e.g. car sharing, home delivery, 'dial-a-ride,' bike co-ops, 'walking school bus') available
6.	Percentage of communities with 'Community Environmental Targets' (e.g. traffic reduction)
7.	Availability and institutional support for 'Green'/Location Efficient Mortgages (LEM)
8.	Percentage of local retailers that offer 'Buy Local and Save' cards; 'car-free' shopper discounts

Table 3-3. *Indicators Menu*: Sustainable Transportation and Land Use Indicators – continued

[illegible]	
9.	Percentage of institutions/employers (over 100 employees – though effective programs do exist for smaller organisations) that offer traffic reduction programs (voluntary or mandatory) that include:
a)	tele-commuting options
b)	'Guaranteed Ride Home' programs
c)	alternative work hours and/or flexible hours (incl. academic timetables)
d)	a transportation allowance/subsidy for transit and bike/walk (e.g. UPASS, 'car-free' shopper discounts, 'frequent green flyer' points)
e)	'Cashing Out' paid parking
f)	compressed work weeks
g)	commuter information centres/commuter fairs/award recognition programs
h)	'New Hire Orientation' programs on traffic reduction
i)	employer based ridematching services
j)	company owned/leased vanpools
k)	on-site services (e.g. childcare, cafeteria, retail)
Envir[illegible]	
1.	Annual gasoline consumption (MJ or litres) per capita (Newman and Kenworthy 1999)
2.	Total quantity of air pollutants per capita (local and global emissions in kg)
3.	Number of 'Poor' air quality days per year (poor = 50-100 on the Canadian national air quality index – Index of the Quality of Air (IQUA)) (Newman and Kenworthy 1999)
4.	Gasoline consumption as a percentage of all car fuels (bridging and renewable fuels)
5.	Percentage of buses running on natural gas, electricity, or other bridging fuel
6.	Percentage of community (incl. roads, public places, parks) that is pervious to water (e.g. alternative surface materials) (Sheltair 1998)
7.	Lane kilometres through watersheds
8.	Lane kilometres through green zones
9.	Per capita land area paved for roads and parking facilities
10.	Land consumed per housing unit
Land Use	
1.	Population density (persons/hectare)
2.	Employment density (jobs/hectare)
3.	Percentage of residents who live and work in the same community (jobs-housing balance)
4.	Percentage of residential units that are 'live-work' (i.e. work at home units)
5.	Percentage of city/community that is mixed-use zoning
6.	Percentage of city/community with a minimum average density of 30 units per acre (gross)
7.	Percentage of dwelling units within 400 meters of basic shopping needs (Sheltair 1998; Calthorpe 1993; GVRD and Province of BC 1993a)
8.	Percentage of dwelling units within 400 meters of 30 ft^2 retail space/resident (Condon 1996)
9.	Percentage of dwelling units within 400 meters of transit service (Sheltair 1998; Calthorpe 1993; GVRD and Province of BC 1993a)
10.	Percentage of residential units within 400 meters of transit with 15 minute frequency (max) in peak hours
11.	Percentage of population within 1 kilometre of rapid transit (GVRD and Province of BC 1993e)
12.	Number of zoning incentives (e.g. density bonus, integration with existing transit/bike/walk infrastructure)
13.	Percentage of city/community specially zoned for transit-oriented/traditional neighbourhood development (Newman and Kenworthy 1999)

Table 3-3. *Indicators Menu*: Sustainable Transportation and Land Use Indicators - continued

Land Use
14. Percentage of street area that is dedicated to walking, cycling, and transit (Sheltair 1998)
15. Percentage of residential units that are not single-family homes
16. Percentage of single-family homes that are 'small lot' units (i.e. smaller lots, reduced setbacks and increased lot coverages)
17. Percentage of new street blocks that are smaller than modern block sizes
18. Percentage of neighbourhood streets with back lanes
19. Percentage of street layout that is grid
20. Proportion of residential areas integrated with children play areas with no traffic separation
21. Percentage of streets/public areas that are 'car-free'
22. Percentage of single-family homes/townhomes that offer ancillary rental suites (i.e. basement suites)
23. Mix of housing and funding types, tenures, tenants, and income levels
24. Number of 'car-free' housing units available
Economy
1. Public/private savings from reduced auto dependence over and above any necessary increases in transit, bicycle, and pedestrian expenditures (e.g. infrastructure, less fuel, fewer roads, less parking, lower external costs) (Litman 1997b)[10]
2. Percentage of dwelling units that are affordable, relative to the income distribution and family size of the particular community
3. Percentage of disposable income spent on transportation (direct and indirect; fixed and variable costs)
4. Affordability of public transit by lower income citizens (fares as a percent of lowest income quintile)
5. Percentage of citizens paying more than 30% of income for housing (Hart 1995)
Livability
1. Number of crimes per capita
2. Percentage of people feeling safe to walk alone (day and night)
3. Provision for public security and safety (e.g. good street lighting, clear sight lines, few hiding places, views from kitchen/living room into public areas)
4. Number of traffic-related noise complaints per year
5. Number of seats available for public (e.g. in streets, squares, parks and other public areas)
6. Number of public events/activities in public areas (e.g. street theatre, buskers, fairs)
7. Percentage of buildings that are "common-use"/multi-purpose (e.g. recreation rooms)
8. Average number of "spontaneous exchange" experiences per capita per day (e.g. meeting friends at market)
9. Average number of people in public places throughout the day and night
10. Amount of public space per capita (ft^2) (e.g. parks, pedestrian pockets, squares, trails, traffic-calmed streets)
11. Number of opportunities for citizens to participate in community planning and decision-making
12. Degree of integration of local culture and climate in community and transportation planning

[10] Percentage Saved (Lost) = $\frac{\text{Full Cost Accounting (Auto-Oriented Development) - FCA (Sustainable Community Development)}}{\text{FCA (Auto-Oriented Development)}}$

The identification of categories, goals, objectives, and the development of an indicators menu is now complete. The following section will identify the sustainable transportation and land use criteria to be used in the evaluation of the indicators found within the ***Indicators Menu***. This will be the final stage in the development of the *Sustainable Transportation and Land Use Planning Framework* template. Indicators will then be evaluated, based on the identified criteria, and ranked into ***High***, ***Medium***, and *Low* priority. High priority indicators that fit best with the scope of this study (i.e. the identified goals and objectives) will then be matched with the appropriate study objectives. The result will be the 'Master' indicators framework, identified as the ***Master Sustainable Transportation and Land Use Planning Framework***.

3.3.3 Sustainable Transportation and Land Use Evaluative Criteria

A review of the literature suggests that there are numerous categories into which sustainability criteria fall. For the purpose of this study, the following five broad categories have been selected:

- Transportation Efficiency;
- Land Use Efficiency;
- Environmental Impact;
- Human Livability; and
- Economic Efficiency

Within each category, however, exist sub-criteria that further define the principal criteria. Overall, these categories integrate many objectives of sustainable development and are considered more holistic. The following section will define the five broad categories in more detail.

Transportation efficiency is defined as the optimisation of the 'person moving' capacity of the transport system. Research indicates that to achieve this objective, the following transportation modes should be given priority in policy-making:

Table 3-4. Person Moving Capacity of Roadway (Rock 1998)

[illegible]	[illegible]
Walk	7,200 persons
Bicycle	6,000 persons
Transit Bus (dedicated lane)	4,000 persons
Private Automobile (average occupancy = 1.2)	2,000 persons

Transportation efficiencies exist in transport systems that prioritise non-automobile travel, specifically single-occupant vehicle travel, through programs of transportation demand management (TDM) and/or supply management (i.e. increased transportation options and road capacity). In other words, transportation efficiency is directly correlated with automobile dependence: as automobile dependence decreases, transportation efficiencies increase, and vice versa.

Furthermore, transportation efficiencies are gained through mechanisms that increase opportunities for access. Accessibility, as defined in Chapter 2, is the ability to reach desired activities (e.g. goods, services, recreation, employment, education, and green space) from any location (Litman 1997b; Hansen 1959; Ewing 1995a). Furthermore, access, or "accessibility-planning," pays particular attention to the needs of the economically disadvantaged and physically challenged, as well as non-drivers and others who do not have access to the full range of transportation options (Davidson 1997). Accessibility is thus dependent upon the land use and transportation system that exists. Accessibility is therefore an excellent criterion for sustainable land use and transportation planning. For the purpose of this study, the assessment of transportation efficiency will be based on *automobile dependence*, *access*, and *the range of transportation choices available.*

Land use efficiency is defined as the optimisation of spatial efficiencies through the minimisation of land consumption (i.e. maximising the full value of the land – economically, socially, and environmentally – while minimising land use). It is the application of land use policies that minimise land consumption – through initiatives such as increased density, mixed-use zoning, compact and complete community development, and transit-oriented and traditional neighbourhood development – in an effort to conserve land for future activities (e.g. agriculture, development) and thereby increasing the utility of the land. For the purpose of this study, the assessment of land use efficiency will be based on *population density*, the achievement of *complete communities*, the *ratio of jobs to housing within a community or municipality* (i.e. jobs-housing balance), and the *amount of land dedicated to automobile travel* (i.e. automobile-oriented public space).

Environmental impact is defined as those activities that impose stress, such as excessive air emissions, on the carrying capacity of the environment. The environmental impacts associated with transportation are wide ranging and include air, water, and noise pollution; habitat loss and wildlife impacts; destruction of green space; and resource consumption. For the purpose of this study, the assessment of environmental impacts will be based on *air* and *water pollution*, *the protection of wildlife habitat,* and *green space.*

Human livability is defined as a community that maximises its social capital, such that it supports and encourages healthy and safe living, social contact and cohesion, a sense of community and place, citizen and community empowerment, and equity. Research indicates that human livability is enhanced when citizens experience peace and quiet, aesthetic beauty, animated street life, and social interaction within their community (Crawthurst-Lennard and Lennard 1995; Appleyard 1981). For the purpose of this study, the assessment of human livability will be based on the *level of calmed traffic, sense of community and place, participation in decision making*, and *health and safety.*[11]

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[11] "Health and safety" could be measured by pre- and post-TDM data, such as the number of hospital visits related to autos and vehicle-pedestrian/bicycle accidents and mortalities. "Sense of community" and "participation in decision making" could be measured by surveys and the level of involvement in community activities.

Economic efficiency is defined as balancing the economic equity[12] (i.e. benefits and costs) for citizens across all modes of a transport system. In other words, economic efficiency aims to level the playing field to ensure that all users of the transportation system are receiving the correct economic price signals – through incentives, disincentives, and subsidies – so that all citizens receive the appropriate benefits and pay the appropriate costs in order to provide equitable access to the full range of transport modes. Economic equity can be achieved through efforts to increase a traveller's 'internal variable' costs by including 'internal fixed' and 'external' costs (Litman 1998c). Internal variable costs are defined as those costs that are short term in nature, vary with the amount of travel – such as gasoline and parking expenses – and directly affect the transportation decision-making process (i.e. the selection of transport mode). Internal fixed costs are those costs that are long term in nature, are incurred less frequently, and are *perceived* to not vary with the amount of travel. Examples of these costs are vehicle capital costs, insurance, depreciation, and registration. External costs are those costs typically not borne by individual users, such as roadway and parking facilities, congestion, accident costs, health costs, and environmental and social impacts. Research indicates that increasing internal variable costs, through policies that make users responsible for their incurred internal fixed and external costs, increases economic equity and significantly reduces automobile travel (Litman 1998c).

Economic efficiencies can also be achieved through the application of Full Cost Accounting (FCA) and Least Cost Planning (LCP) principles. FCA is defined as a "technique for assigning all costs and benefits, both internal and external, to all parties associated with or impacted" by a project over the long-term (Sheltair 1998, 191). In other words, FCA focuses on integrating all costs and benefits, including social and environmental externalities, into the decision-making process. Building on this, LCP then compares transportation investment alternatives, such as mass transit versus roadway expansion, to determine optimal economic, social, and environmental investments.

[12] "Economic equity" in this study refers to 'fairness' rather than 'financial' or monetary equity.

In addition to economic equity, economic efficiency is also determined by the level of community economic development potential. Transportation and land use planning policies should encourage economic development through all spatial scales, from the national to the community level. For example, high density and mixed-use zoning policies support the development of complete communities. These land use policies further support the development of local, community-based industries, such as home delivery systems (non-motorised or motorised), community bike and car co-operatives, neighbourhood shuttle programs, and retail services. For the purpose of this study, the assessment of economic efficiency will be based on *economic equity* and *community economic development potential.*

The above outlined sustainability criteria will be used to evaluate the indicators found within the *Indicators Menu.* Table 3-5 summarises the sustainable transportation and land use criteria and their associated objectives.

Table 3-5. Sustainable Transportation and Land Use Evaluative Criteria

[illegible]	[illegible]
[illegible]	[illegible]
a. Reduce automobile dependence	Measures that reduce the need to travel by personal automobile, such as TDM and/or TSM programs.
b. Increase access	Measures that reduce trip length, and improve access to goods, services, and transportation choices.
c. Increase transportation choices	Measures that increase the number of transport options, as well as their frequency and convenience.
[illegible]	[illegible]
a. Increase density	Measures that increase population densities to achieve transportation planning efficiencies and optimise land use.
b. Promote complete communities	Measures that provide mixed-use zoning to achieve transportation planning efficiencies and optimise land use.
c. Jobs-Housing balance	Measures that enable people to live and work in the same community/municipality to reduce pressure on land and investments in transportation infrastructure.
d. Minimise automobile-oriented public space	Measures that reduce auto-dominated land use and increase the availability of public space.
[illegible]	[illegible]
a. Reduce air pollution	Measures that reduce local air emissions, such as particulate matter (PM), nitrous oxides (NO_x), volatile organic compounds (VOCs), sulphur oxides (SO_x), carbon monoxide (CO), and ozone (O_3) (secondary pollutant – product of photochemical reactions between NO_x, VOC, and sunlight); and global emissions of carbon dioxide (CO_2).
b. Reduce water pollution	Measures that reduce water runoff and contamination.
c. Reduce destruction of wildlife habitat and green space	Measures that prohibit development in sensitive wildlife habitat and public green space areas.
4. [illegible]	[illegible]
a. Calmed traffic	Measures that reduce both the volume and speed of vehicle traffic.
b. Sense of community and place	Measures that attempt to connect the citizens of a community to one another and their immediate geography (i.e. place).
c. Participation in decision-making	Measures that encourage public involvement in the decision-making process, thus empowering citizens and communities.
d. Health and safety	Measures that ensure high levels of public health and safety so that citizens are comfortable and secure.
5. [illegible]	[illegible]
a. Increase economic equity	Measures that increase equity for society across all modes of transportation (i.e. improve access/mobility equitably – through the re-organisation of how and what transport costs are paid and the re-distribution of transport subsidies to ensure all users receive a fair share of benefits and costs).
b. Increase community economic development opportunities	Measures that increase the potential for the development of local commerce, providing services and employment.

The major components of this framework have now been identified (i.e. categories, goals, objectives, and criteria) and a 'template' of the *Sustainable Transportation and Land Use Planning Framework* is shown in Figure 3-2 on the next page.

3.3.4 The Scale for Evaluating Sustainable Transportation and Land Use Indicators

In order to compare and evaluate the selected sustainable transportation and land use indicators against the criteria set out in Section 3.3.3, the following scale has been developed:

Table 3-6. Evaluative Scale

Symbol	Definition
++	Indicator would likely have a significantly positive impact upon the criterion
+	Indicator would likely have a moderately positive impact upon the criterion
≅	Indicator would likely have a variable impact upon the criterion
b (blank)	Indicator would likely have a neutral impact upon the criterion
-	Indicator would likely have a moderately negative impact upon the criterion
--	Indicator would likely have a significantly negative impact upon the criterion

More than one symbol may appear for each indicator evaluated, depicting the range of possible impacts. For example, the evaluation "+/++" would represent an indicator that may have a moderately to significantly positive impact on the sustainability criterion, thus representing an indicator that holds potential for basing policy development upon. Due to the lack of previous evaluation and the subjectivity of this type of analysis, however, the indicator evaluations will be typically represented by a range of symbols, such as "≅/+/++."

Figure 3-2. Sustainable Transportation and Land Use Planning Framework: Template

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Transportation and Accessibility	1. Minimise SOV travel	a. Increase access to basic needs							
		b. Increase transportation choices							
		c. Increase incentives for non-SOV travel							
		d. Increase car-free living opportunities							
		e. Minimise the need to expand transport infrastructure							
	2. Increase safety, community interaction, and livability	f. Introduce traffic calming measures							
	3. Minimise the need to travel outside the neighbourhood for basic needs	g. Increase proximity of housing to key activity centres							
		h. Increase pedestrian, bicycle, and transit infrastructure within the neighbourhood							
	4. Promote a balance of jobs and housing	i. Match housing types and affordability with the needs of working and non-working population within the community							
		j. Increase employment opportunities to match residential stock or; increase residence opportunities to match employee and student base							
Air	5. Minimise harmful emissions, both local and global	k. Reduce concentrations of ground level ozone (smog), fine particulate matter (PM), sulphur dioxide (SO_2), carbon monoxide (CO), and nitrogen dioxide (NO_2)							
		l. Reduce carbon dioxide emissions (CO_2)							
Water	6. Minimise water pollution	m. Reduce and manage surface water run-off							
Housing	7. Optimise community densification	n. Increase densities towards sustainability standards							

3.4 Evaluation of Sustainable Transportation and Land Use Indicators

To identify indicators that are relevant to this study, indicators were assessed according to their potential to accomplish the goals and objectives set out in Section 3.3.1, in the larger effort to achieve this study's principal goal of reducing SOV trips to and from SFU's Burnaby Mountain campus by a minimum of 20% in the short and long-term. Indicators that have been selected for the 'Master' framework have therefore been identified as being of high importance, or 'High' priority, and effective in the short-to-medium term (i.e. most important for immediate implementation). The assessment of the selected indicators against the sustainability criteria is based on the findings from the literature review – specifically research completed by Davidson (1997), Raad (1998), Zupan (1992), Apogee (1994), and Litman (1995a, 1998a) – which are typically based on qualitative rather than quantitative analyses.[13] Furthermore, not all selected indicators have been previously evaluated. The assessment of these indicators is thus subjective. However, Downs indicates that this "is inescapable: no purely scientific method of evaluating such policies (land use and transportation) can be devised, because doing so inherently requires value judgements" (Downs 1992, 148). Furthermore, the subjective nature of these types of rating systems are not arbitrary as they are based upon findings of much research and the experience of several international initiatives (Davidson 1997).

Using the above methodology, the menu (i.e. *Indicators Menu*) of sustainable transportation and land use indicators is evaluated and is represented in Figure 3-3. This evaluation further identifies these indicators as being of *High*, *Medium*, or *Low* priority.

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[13] Altshuler 1979; Ciuffini 1995; COMSIS 1993; City of the Hague 1995; De Leuw, Cather, and Company 1976; Davidson 1997; Dilks 1996; DOT nd; Downs 1992; Durning 1996; Ewing 1995a; Frank and Pivo 1994; GVRD 1993b; GVRD 1997a; GVRD and Province of BC 1993a; GVRD 1998b; GVRD and FVRD 1997b; Hart 1995; Hart and Spivak 1993; IBI Group 1993; Johnston and Ceerla 1996; Kenworthy and Newman 1994; Litman 1995a; Litman 1995b; Litman 1997b; Mackenzie, Dower, and Chen 1992; Newman 1998; Newman and Kenworthy 1988; Newman and Kenworthy 1989; Newman and Kenworthy 1999; OECD 1995; Pucher 1998; Raad 1998; Raad and Kenworthy 1998; Remiz 1998; Rothengatter 1994; Sheltair 1998; Shoup 1997; Ward 1995; WRG and S5 Services 1997a; WRG and S5 1997b; Williams et al. 1991; Zupan 1992.

High priority indicators are those that would be suitable for short to medium-term implementation and are applicable at the local level. Generally, high priority indicators scored high on the evaluation (e.g. +/++), particularly the transportation efficiency, land use efficiency, and environmental impact criteria. Indicators receiving medium and low priority status are not suitable at the local scale (i.e. more applicable at the regional or national level) and/or are long-term in nature. The identified high priority indicators are then matched – if possible – to the appropriate framework objectives (e.g. "increase access to basic needs"), thus completing the final stage in the development of the *Master Sustainable Transportation and Land Use Planning Framework* (Figure 3-4). The majority of the identified high priority indicators can be found within this framework; however, some indicators have been grouped and others have not been selected due to repetition, spatial scale, and other factors that make them unsuitable for the purposes of this study.[14]

[14] For example, the indicators "VKT and VHT per capita" and "annual gasoline consumption per capita" could be grouped as one indicator, given that these indicators represent very similar objectives (i.e. air emissions). Furthermore, due to its scale, the indicator "annual transit service kilometres per capita" has not been included in the further development of this master framework (i.e. not as effective at the local scale).

Figure 3-3. An Evaluation of Sustainable Transportation and Land Use Indicators

General Transportation						
1. Annual Vehicle Hours of Travel (non-recreational) per capita	++	++	++	≅/+	+/++	H
2. Annual Vehicle Kilometres Travelled (non-recreational) per capita	++	++	++	≅/+	+/++	H
3. Modal split for work and non work trips	++	++	++	≅/+/++	+/++	H
4. Number of vehicle trips made per day per capita	++	++	++	≅/+	+	H
5. Percentage of trips made by vehicle outside the neighbourhood for basic needs	++	++	++	+/++	+	H
6. Percentage of citizens living within 30 minutes of work by transit/bicycle/walking	++	++	++	+/++	+	H
7. Average vehicle occupancy	+	≅/+	≅/+	b/≅/+	b/≅	M
8. Average work commute (time and distance) by mode	+/++	+/++	+/++	≅/+	≅/+	M
9. Average speed by mode	+/++	+/++	≅/+	-/b/≅	b/≅	M
10. Vehicle ownership per capita (number)	≅/+	b/≅/+	≅/+	≅/+	+	L
11. Number of vehicles per household	++	+	++	≅/+	+	H
12. Number of vehicle accidents per capita	b/≅/+	b/≅/+	b/≅	≅/+/++	b/≅	L
Public Transit						
1. Annual number of transit trips per capita	++	++	++	≅/+/++	+/++	H
2. Annual transit service kilometres per capita	++	≅/+	+/++	≅/+	+/++	M
3. Transit service kilometres relative to road provisions per capita	+/++	≅/+	+	≅/+	+/++	M
4. Transit cost recovery	b/≅/+	≅/+	b/≅	b/≅	≅/+	L
5. Percentage of peak period transit frequencies that are 15 minutes or less	+/++	+/++	≅/+/++	≅/+	b/≅/+	M
6. Percentage of non-peak period transit frequencies that are 30 minutes or less	+/++	+/++	≅/+	≅/+	b/≅/+	M
7. Percentage of transit connections less than 5 minutes long	≅/+	≅/+	b/≅/+	b/≅/+	b≅/+	L
8. Number of 'special event'/'late-night' transit services	≅/+	b/≅/+	≅/+	≅/+	≅/+	L

Figure 3-3. An Evaluation of Sustainable Transportation and Land Use Indicators - continued

Public Transit - continued						
9. Percentage of transit vehicles accessible for prams/wheelchairs/bikes	+/++	b/≅/+	≅/+	≅/+	≅/+/++	M
10. Number of quality transit waiting facilities per capita	≅/+	b/≅	≅/+	+	≅/+	L
11. Number of safety provisions between transit stations/stops and footpaths	+	≅/+	≅/+	≅/+/++	≅/+	M
12. Percentage of public who feel transit is safe	+	+	≅/+	≅/+/++	≅/+	M
13. Percentage of communities that receive transit responsibilities (e.g. bus shelter maintenance)	b/≅/+	b/≅	b/≅	≅/+/++	b/≅	L
14. Percentage of transit boards that include user/community representation	b/≅/+	b/≅	b/≅	≅/+/++	b/≅/+	L
15. Percentage of residences/businesses that receive transit service information	b/≅/+	b/≅	b/≅/+	b/≅	b/≅	L
Traffic Calming						
1. Percentage of neighbourhood streets that are traffic-calmed (e.g. roundabouts, textured surfaces, 30 km/hr speed limits, narrow roads (25-30 ft), chicanes, street furniture, stop signs, speed bumps, street planting, wide sidewalks, islands, removal of curbs, signage, pedestrian crossings, and redesign of auto-space into public space)	≅/+	b/≅/+	≅/+	++	+/++	H
Non-Motorised Travel and Pedestrianisation						
1. Annual number of bicycle/walk trips made per capita	++	++	++	++	+/++	H
2. Kilometres of separated cycleways	++	+/++	+/++	+/++	+/++	M
3. Percentage of transportation budget allocated to cycling/pedestrian infrastructure	+/++	≅/+	+	+	+/++	M
4. Percentage of transit stations/stops with bicycle/walk infrastructure (e.g. bike/walk lanes/racks/showers)	++	≅/+	≅/+/++	+/++	+/++	H
5. Percentage of employment/public facilities with bicycle/walk infrastructure	++	≅/+	≅/+/++	+/++	+/++	H

Figure 3-3. An Evaluation of Sustainable Transportation and Land Use Indicators - continued

Non-Motorised Travel and Pedestrianisation - continued						
6. Percentage of streets that are "Pedestrian-Friendly" (e.g. benches, trees, sidewalks)	≡/+/++	b/≡/+	≡/+	+/++	+/++	H
7. Percentage of intersections with pedestrian/cyclist-activated technology	≡/+	b/≡	≡/+	+	+	M
8. Percentage of pedestrian/cyclist-activated lights that change within 15 seconds	≡/+	b/≡	≡/+	+	+	L
9. Percentage of pedestrian/cyclist crosswalks that provide longer than 15 second signal phases	≡/+	b/≡	≡/+	+	+	L
10. Number of car accidents involving pedestrians and/or cyclists	b/≡/+	b/≡/+	b/≡	≡/+/++	b/≡	L
11. Number of fatalities involving cars with pedestrians or cyclists	b/≡/+	b/≡/+	b/≡	≡/+/++	b/≡	L
Parking						
1. Ratio of parking fees to transit fees	b/≡/+	b/≡	b/≡/+	b/≡/+	≡/+	M
2. Proportion of residential parking with 1.25 (or less) parking stalls per unit	b/≡/+	≡/+	b/≡/+	b/≡	b/≡/+	L
3. Percentage of employers that meet the following parking criteria: 2-4 stalls/1,000 feet^2 (office); 3-5 stalls/1,000 feet^2 (retail); 1-3 stalls/1,000 feet^2 (light industrial)	≡/+	≡/+	b/≡/+	b/≡/+	b/≡/+	L
4. Percentage of residential parking that is in back-alley garages/lanes	b/≡	b/≡/+	-/b/≡/+	+	b/≡	L
5. Percentage of parking facilities that provide ridesharing privileges (e.g. closer/discount parking)	≡/+/++	b/≡/+	≡/+/++	b/≡/+	≡/+	H
6. Ratio of short-term to long-term parking facilities	≡/+	b/≡/+	≡/+	b/≡/+	≡/+	M
7. Percentage of total parking (e.g. urban centre/community) that is 'free' (i.e. no charge)	+/++	+	+/++	b/≡/+	++	H
8. Percentage of parking facilities that are multi-purpose (e.g. fairs, markets, recreation)	b/≡	≡/+	b/≡	b/≡	b/≡/+	L
Education, Organisations, and Programs						
1. Number of sustainable transportation education programs offered to schools/employers/public	b/≡/+	b	b/≡/+	b/≡	b/≡	L

Figure 3-3. An Evaluation of Sustainable Transportation and Land Use Indicators - continued

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Education, Organisations, and Programs - continued						
2. Number of 'Clean Air' days/campaigns/transportation fairs per year	b/≡	b	b/≡	b/≡	b/≡	L
3. Percentage of cities/municipalities (employers) with TMAs (ETAs)	≡/+	b	≡/+	b/≡	≡	L
4. Number of sustainable transportation services (e.g. car sharing, home delivery, 'dial-a-ride,' bike co-ops, 'walking school bus')	≡/+/++	b/≡	≡/+	≡/+/++	+/++	H
5. Percentage of communities with 'Community Environmental Targets' (e.g. traffic reduction)	b/≡/+	b/≡	b/≡/+	b/≡/+	b/≡/+	L
6. Availability and institutional support for 'Green'/Location Efficient Mortgages	++	+	+/++	≡/+	+/++	H
7. Percentage of local retailers that offer 'Buy Local and Save' cards, 'car-free' shopper discounts	b/≡	b/≡/+	b/≡/+	b/≡/+	b/≡	L
8. Percentage of institutions/employers (over 100 employees) that offer traffic reduction programs (voluntary or mandatory) that include:	++	b/≡/+	++	b/≡/+	+/++	H
a. telecommuting options	≡/+	b	≡/+	b/≡/+	b/≡/+	M
b. 'Guaranteed Ride Home' programs	≡/+	b	b/≡/+	b/≡/+	≡/+	M
c. alternative work hours and/or flexible hours (including academic timetables)	-/b/≡/+	b	-/b/≡	b/≡	b/≡	L
d. a transportation allowance/subsidy for transit, rideshare, and bike/walk (e.g. UPASS, 'frequent green flyer points')	++	b/≡	++	b/≡/+	++	H
e. 'Cashing Out' paid parking	+/++	b	≡/+	b/≡/+	+/++	H
f. compressed work weeks	≡/+	b	≡/+	b/≡	b/≡	M
g. commuter information centres/'commuter fairs'/award recognition programs	b/≡/+	b	b/≡/+	b/≡/+	b/≡	M
h. 'New Hire Orientation' programs on traffic reduction	b/≡/+	b	b/≡/+	b/≡	b/≡	L
i. employer based ridematching services	≡/+/++	b	≡/+/++	≡/+	b/≡/+	H
j. company owned/leased vanpools	≡/+/++	b	≡/+/++	b/≡/+	≡/+	H
k. on-site services (e.g. childcare, cafeteria, retail)	≡/+	b/≡/+	≡/+	≡/+	b/≡/+	M

Figure 3-3. An Evaluation of Sustainable Transportation and Land Use Indicators - continued

Environment						
1. Annual gasoline consumption (MJ or litres) per capita	++	++	++	≅/+	+/++	H
2. Total quantity of air pollutants per capita (local and global emissions in kg)	++	++	++	≅/+	≅/+	M
3. Number of 'Poor' air quality days per year (poor = 50-100 on Cdn. Air Quality Index)	+/++	+	++	+	b/≅/+	H
4. Gasoline consumption as a percentage of all car fuels (bridging and renewable fuels)	b/≅	b	≅/+/++	b/≅/+	b/≅	L
5. Percentage of buses running on natural gas, electricity, or other bridging fuel	b/≅	b	+/++	b/≅/+	b/≅	L
6. Percentage of community (including roads, public places, parks) that is pervious to water (e.g. alternative surface materials)	b/≅	≅/+	++	b/≅	b/≅	H
7. Lane kilometres through watersheds	≅/+	≅/+	+/++	b/≅	b/≅	M
8. Lane kilometres through green zones	≅/+	≅/+	+/++	≅/+	b/≅/+	M
9. Per capita land area paved for roads and parking facilities	≅/+	≅/+	+/++	b/≅	≅/+	M
10. Land consumed per housing unit	b	b/≅/+	+	b/≅	b/≅/+	L
Land Use						
1. Population density (persons/hectare)	+/++	++	+/++	+/++	+/++	H
2. Employment density (jobs/hectare)	≅/+	+/++	≅/+/++	b/≅/+	b/≅/+	M
3. Percentage of residents who live and work in the same community/municipality (jobs-housing balance)	++	++	++	+/++	+	H
4. Percentage of residential units that are 'live-work' (i.e. work at home units)	≅/+	≅/+/++	+	≅/+	b/≅/+	L
5. Percentage of city/community that is mixed-use zoning	++	++	++	+/++	+/++	H
6. Percentage of city/community with a min. average density of 30 upa	++	++	++	≅/+/++	+/++	H
7. Percentage of dwelling units within 400 meters of basic shopping needs	++	++	++	+/++	+/++	H

Figure 3-3. An Evaluation of Sustainable Transportation and Land Use Indicators - continued

Indicator	Transport	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Land Use - continued						
8. Percentage of dwelling units within 400 meters of 30 ft^2 retail space/resident	++	++	++	+/++	+/++	M
9. Percentage of dwelling units within 400 meters of transit service	++	++	++	+/++	+/++	H
10. Percentage of residential units within 400 meters of transit with 15-minute frequency (max) in peak hours	++	++	++	+/++	+/++	M
11. Percentage of population within 1 kilometre of rapid transit	+/++	+/++	+/++	-/≅/+	≅/+	L
12. Number of zoning incentives (e.g. density bonus, integration with existing transit/bike/walk infrastructure)	≅/+/++	++	+/++	≅/+/++	≅/+/++	H
13. Percentage of city/community specially zoned for transit-oriented/traditional neighbourhood development	++	++	++	+/++	+/++	H
14. Percentage of street area that is dedicated to walking/cycling/transit	++	++	≅/+/++	+	+	H
15. Percentage of residential units that are not single-family homes	++	++	++	+	≅/+	H
16. Percentage of single-family homes that are 'small lot' units	+/++	++	++	+	≅/+	H
17. Percentage of new street blocks smaller than modern block sizes	b/≅	≅/+	≅/+	b/≅/+	≅/+	L
18. Percentage of neighbourhood streets with back lanes	b/≅	b/≅/+	-/b/≅/+	+	b/≅	L
19. Percentage of street layout that is grid	b/≅/+	≅/+	b/≅/+	b/≅	b/≅	L
20. Proportion of residential areas integrated with children play areas with no traffic separation	b/≅	b/≅/+	b/≅	+/++	b/≅	L
21. Percentage of streets/public areas that are 'car-free'	+	≅/+	≅/+	+/++	≅/+	M
22. Percentage of single-family homes/townhomes that offer ancillary rental suites (i.e. basement suites)	b/≅/+	+/++	≅/+/++	≅/+/++	b/≅/+	H
23. Mix of housing and funding types, tenures, tenants, and income levels	b/≅/+	++	b/≅/+	≅/+/++	≅/+	H
24. Number of 'car-free' housing units available	+	+/++	+/++	+	≅/+/++	H
Economy						
1. Public/private savings from reduced auto dependence over and above any necessary increases in transit/bicycle/pedestrian expenditures	+	+	+/++	+	+/++	H

Figure 3-3. An Evaluation of Sustainable Transportation and Land Use Indicators - continued

Economy - continued						
2. Percentage of dwelling units that are affordable, relative to the income distribution and family size of the particular community	b/≅/+	b/≅/+	b/≅/+	+	+	H
3. Percentage of disposable income spent on transportation (direct and indirect; fixed and variable costs)	+	+	≅/+	≅/+	+/++	H
4. Affordability of public transit by lower income citizens (fares as a percentage of lowest income quintile)	≅/+	b/≅	≅/+	b/≅/+	+/++	L
5. Percentage of citizens paying more than 30% of income for housing	b/≅	b/≅/+	b/≅	b/≅/+	≅/+/++	L
Livability						
1. Number of crimes per capita	b/≅/+	b/≅	b/≅/+	+/++	≅/+	M
2. Percentage of people feeling safe to walk alone (day and night)	≅/+	b/≅/+	≅/+	+/++	≅/+	L
3. Provision for public security and safety (e.g. good street lighting, clear sight lines, few hiding places, views from kitchen/living room into public areas)	≅/+	b/≅/+	≅/+	+/++	≅/+	M
4. Number of traffic-related noise complaints per year	b/≅/+	-/b/≅/+	b/≅/+	+	b	L
5. Number of seats available for public (e.g. streets, squares, parks)	b/≅/+	≅/+	b/≅/+	≅/+/++	b/≅	M
6. Number of public events/activities in public areas	b/≅	b/≅	b/≅	+	b/≅	L
7. Percentage of buildings that are "common-use"/multi-purpose	b/≅	≅/+	b/≅/+	+	b/≅	L
8. Average number of "spontaneous exchange" experiences per capita per day (e.g. meeting friends at market)	b/≅/+	≅/+	b/≅/+	+/++	b/≅	H
9. Average number of people in public places throughout the day and night	b/≅	b/≅/+	b/≅	≅/+/++	b/≅	M
10. Amount of public space per capita (ft^2)	b/≅	b/≅/+	b/≅	≅/+/++	b/≅	M
11. Number of opportunities for citizens to participate in community planning and decision-making	b/≅/+	b/≅/+	b/≅/+	+	b/≅/+	M
12. Degree of integration of local culture and climate in community and transportation planning	b/≅/+	-/b/≅/+	≅/+	+	b/≅/+	M

Figure 3-4. Master Sustainable Transportation and Land Use Planning Framework

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Transportation & Accessibility	1. Minimise SOV travel	a. Increase car-free living opportunities	• Number of vehicles per household	++	+	++	/+	+
			• Availability and institutional support for 'Green'/Location Efficient Mortgages	++	+	+/++	≡/+	+/++
			• Percentage of city/community specially zoned for transit-oriented/traditional neighbourhood development	++	++	++	+/++	+/++
		b. Increase access to basic needs	• Annual VKT/VHT per capita (non-recreational)	++	++	++	≡/+	+/++
			• Percentage of city/community that is mixed-use zoning	++	++	++	+/++	+/++
			• Percentage of citizens living within 30 minutes of work by transit/bicycle/walking	++	++	++	+/++	+
		c. Increase transportation choices	• Modal split for work and non work trips	++	++	++	≡/+/++	+/++
			• Annual number of walk/cycle/transit trips per capita	++	++	++	≡/+/++	+/++
			• Number of sustainable transportation services (e.g. car sharing, home delivery, bike co-ops, 'walking school bus')	≡/+/++	b/≡	≡/+	≡/+/++	+/++
			• Percentage of dwelling units within 400 meters of transit service	++	++	++	+/++	+/++
		d. Increase incentives for non-SOV travel	• Percentage of institutions/employers (over 100 employees) that offer traffic reduction programs	++	b/≡/+	++	b/≡/+	+/++
		e. Minimise the need to expand transport infrastructure	• Public/private savings from reduced auto dependence over and above any necessary increases in transit, bicycle, and pedestrian expenditures	+	+	+/++	+	+/++
	2. Increase safety, community interaction, and livability	f. Introduce traffic calming measures	• Percentage of streets that are traffic-calmed	≡/+	b/≡/+	≡/+	++	+/++
			• Average number of "spontaneous exchange" experiences per capita per day	b/≡/+	≡/+	b/≡/+	+/++	b/≡

Figure 3-4. Master Sustainable Transportation and Land Use Planning Indicator Framework - continued

Transportation & Accessibility - continued	3. Minimise the need to travel outside the neighbourhood for basic needs	g. Increase proximity of housing to key activity centres	• Percentage of dwelling units within 400 meters of basic shopping needs	++	++	++	+/++	++
		h. Increase pedestrian, bicycle, and transit infrastructure within the neighbourhood	• Percentage of employment/transit/public facilities with bicycle/walk infrastructure	++	≡/+	≡/+/++	+/++	+/++
			• Percentage of street area that is dedicated to walking, cycling, and transit	++	++	≡/+/++	+	+
	4. Promote a balance of jobs and housing	i. Match housing types and affordability with the needs of working and non-working population within the community	• Mix of housing and funding types, tenures, tenants, and income levels	b/≡/+	++	b/≡/+	≡/+/++	≡/+
		j. Increase employment opportunities to match residential stock or; increase residence opportunities to match employee and student base	• Percentage of residents who live and work in the same community/municipality (jobs-housing balance)	++	++	++	+/++	+
Air	5. Minimise harmful emissions, both local and global	k. Reduce concentrations of ground level ozone (smog) and fine particulate matter	• Annual gasoline consumption (MJ or litres) per capita (non-recreational), or VKT/capita indicator	++	++	++	≡/+	+/++
		l. Reduce carbon dioxide emissions (CO_2)	• Annual VKT/VHT per capita	++	++	++	≡/+	+/++
Water	6. Minimise water pollution	m. Reduce and manage surface water run-off	• Percentage of community (incl. roads, public places, parks) that is pervious to water (e.g. alternative surface materials)	b/≡	≡/+	++	b/≡	b/≡
Housing	7. Optimise community densification	n. Increase densities towards sustainability standards	• Percentage of city/community with a min. average density of 30 upa (gross)	++	++	++	≡/+/++	+/++
			• Percentage of residential units that are not single-family homes	++	++	++	+	≡/+

3.4.1 Transportation Efficiency

Transportation efficiency is achieved through improvements in a transport system's ability to move people. This can be accomplished through programs of TDM, TSM, and/or integrated land use planning that influence transportation behaviours through voluntary or regulatory measures, provide greater transport options, and enable people to access their daily needs more efficiently (e.g. shorter trip distances). These efforts therefore aim to reduce personal automobile dependence. The indicators that demonstrate the greatest potential to increase transportation efficiency (i.e. ++), with respect to the goals of this study, are outlined in Table 3-7 (not listed in order of importance).

Table 3-7. Effective Indicators for Achieving Transportation Efficiency

1. Annual VKT/VHT per capita (non-recreational)
2. Percentage of city/community with a minimum average density of 30 units per acre (upa)
3. Percentage of city/community that is mixed-use zoning
4. Percentage of citizens living within 30 minutes of work by transit, bicycle, or walking
5. Percentage of residents who live and work in the same community/municipality (jobs-housing balance)
6. Modal split for work and non-work trips
7. Annual number of walk, bicycle, and transit trips per capita
8. Percentage of dwelling units within 400 meters of transit service
9. Percentage of dwelling units within 400 meters of basic shopping needs
10. Number of vehicles per household
11. Percentage of city/community specially zoned for transit-oriented/traditional neighbourhood development
12. Percentage of institutions/employers (over 100 employees) that offer traffic reduction programs
13. Percentage of employment, transit, and public facilities with bicycle/walk infrastructure (e.g. bike/walk lanes, racks, showers)
14. Percentage of street area that is dedicated to walking, cycling, and transit
15. Annual gasoline consumption (MJ or litres) per capita
16. Percentage of residential units that are not single-family homes
17. Availability and institutional support for 'Green'/Location Efficient Mortgages

3.4.2 Land Use Efficiency

Land use efficiency is achieved through initiatives that improve the utility of the land. This can be achieved through the implementation of policies that increase density; promote complete communities, such that employment, education, recreation, goods and services, and residential units can be found within the boundaries of the community; and minimise automobile-oriented public space. The indicators that demonstrate the greatest potential to increase land use efficiency (i.e. ++), with respect to the goals of this study, are outlined in Table 3-8 (not listed in order of importance).

Table 3-8. Effective Indicators for Achieving Land Use Efficiency

1. Annual VKT/VHT per capita (non-recreational)
2. Percentage of city/community that is mixed-use zoning
3. Percentage of citizens living within 30 minutes of work by transit, cycling, or walking
4. Modal split for work and non-work trips
5. Percentage of dwelling units within 400 meters of transit service
6. Percentage of dwelling units within 400 meters of basic shopping needs
7. Percentage of residents who live and work in the same community/municipality (jobs-housing balance)
8. Gasoline consumption (MJ or litres) per capita per year
9. Percentage of city/community with a minimum average density of 30 units per acre (upa)
10. Mix of housing and funding types, tenures, tenants, and income levels
11. Percentage of street area that is dedicated to walking, cycling, and transit
12. Annual number of walk/cycle/transit trips per capita
13. Percentage of city/community specially zoned for transit-oriented/traditional neighbourhood development
14. Percentage of residential units that are not single-family homes

3.4.3 Environmental Impact

Transportation-related environmental impacts are minimised when private automobile use is reduced. Reduced auto use decreases fuel consumption, thus reducing air pollution; wildlife mortality rates (i.e. roadkill); and the demand to expand automobile infrastructure, which impacts wildlife habitat and green space. The indicators that demonstrate the greatest potential to decrease environmental impacts (i.e. ++), with respect to the goals of this study, are outlined in Table 3-9 (not listed in order of importance).

Table 3-9. Effective Indicators for Reduced Environmental Impacts

1. Annual VKT/VHT per capita (non-recreational)
2. Number of vehicles per household
3. Percentage of residents who live and work in the same community/municipality (jobs-housing balance)
4. Percentage of institutions/employers (over 100 employees) that offer traffic reduction programs
5. Percentage of community (incl. roads, public places, parks) that is pervious to water (e.g. alternative surface materials)
6. Percentage of city/community with a minimum average density of 30 units per acre (upa)
7. Percentage of city/community specially zoned for transit-oriented/traditional neighbourhood development
8. Percentage of city/community that is mixed-use zoning
9. Percentage of citizens living within 30 minutes of work by transit, cycling, or walking
10. Modal split for work and non-work trips
11. Annual number of walk, cycle, and transit trips per capita
12. Percentage of dwelling units within 400 meters of transit service
13. Percentage of dwelling units within 400 meters of basic shopping needs
14. Annual gasoline consumption (MJ or litres) per capita
15. Percentage of residential units that are not single-family homes

3.4.4 Human Livability

Human livability is achieved through improvements in the social wealth, health, equity, and spirit of a community and its citizens. Research indicates that livable communities enjoy calmed traffic; increased social interaction and personal contact with place, thereby increasing one's sense of community and place; increased opportunities for participating in decision-making processes; and environments that are safe without any threat to human health. The indicators that demonstrate the greatest potential to increase human livability (i.e. +/++ and ++)[15], with respect to the goals of this study, are outlined in Table 3-10 (not listed in order of importance).

[15] Due to the highly qualitative aspect of this sustainability criterion, the range for identifying "effective indicators" has broadened to include the evaluation: "+/++."

Table 3-10. Effective Indicators for Achieving Human Livability

1. Percentage of streets that are traffic-calmed
2. Percentage of city/community specially zoned for transit-oriented/traditional neighbourhood development
3. Percentage of residents who live and work in the same community/municipality (jobs-housing balance)
4. Percentage of city/community that is mixed-use zoning
5. Percentage of citizens living within 30 minutes of work by transit, cycling, or walking
6. Annual number of walk, cycle, and transit trips per capita
7. Percentage of dwelling units within 400 meters of transit service
8. Average number of "spontaneous exchange" experiences per capita per day
9. Percentage of dwelling units within 400 meters of basic shopping needs
10. Percentage of employment, transit, and public facilities with bicycle/walk infrastructure (e.g. bike/walk lanes, racks, showers)

3.4.5 Economic Efficiency

Economic efficiency is achieved through improvements in the equity of transport economics. This can be achieved through the application of full cost accounting and least cost planning measures that aim to increase internal variable costs, through the inclusion of internal fixed and external costs, as well as policies that redistribute subsidies from automobile-based transport to transit and non-motorised modes of transport. Furthermore, economic efficiencies are gained when community economic development opportunities are realised. The indicators that demonstrate the greatest potential to increase economic efficiency (i.e. +/++ and ++)[16], with respect to the goals of this study, are outlined in Table 3-11 (not listed in order of importance).

[16] Due to the highly qualitative aspect of this sustainability criterion, the range for identifying "effective indicators" has broadened to include the evaluation: "+/++."

Table 3-11. Effective Indicators for Achieving Economic Efficiency

1.	Availability and institutional support for 'Green'/Location-Efficient Mortgages
2.	Percentage of city/community specially zoned for transit-oriented/traditional neighbourhood development
3.	Annual VKT/VHT per capita (non-recreational)
4.	Percentage of city/community that is mixed-use zoning
5.	Percentage of institutions/employers (over 100 employees) that offer traffic reduction programs
6.	Modal split for work and non-work trips
7.	Annual number of walk, cycle, and transit trips per capita
8.	Number of sustainable transportation services (e.g. car sharing, home delivery, 'dial-a-ride,' bike co-ops, 'walking school bus')
9.	Percentage of dwelling units within 400 meters of transit service
10.	Percentage of dwelling units within 400 meters of basic shopping needs
11.	Public/private savings from reduced auto dependence over and above any necessary increases in transit, bicycle, and pedestrian expenditures
12.	Percentage of streets that are traffic-calmed
13.	Percentage of employment, transit, and public facilities with bicycle/walk infrastructure (e.g. bike/walk lanes, racks, showers)
14.	Annual gasoline consumption (MJ or litres) per capita
15.	Percentage of city/community with a minimum average density of 30 units per acre (upa)

3.4.6 Identification of 1st and 2nd Priority Indicators within the Master Sustainable Transportation and Land Use Planning Framework

Sustainable transportation and land use indicators have now been evaluated (Figure 3-3), matched with the objectives of the sustainability framework (Figure 3-4), and key indicators for achieving a range of sustainability goals with respect to this study have been identified (Figure 3-4 and Tables 3-7 to 3-11). To develop transportation and land use policies for SFU and the future BMCD, it is important to identify which indicators within the *Master Sustainable Transportation and Land Use Planning Framework* are effective in achieving multiple sustainability goals, as well being important for short-term implementation, from those that achieve fewer sustainability goals and are less important with respect to short-term implementation. These indicators are identified as being of either *1st* or *2nd* priority in Tables 3-12 and 3-13 below. First priority indicators are selected on the basis of achieving three or more sustainability goals; that is, achieving three or more of the goals of Transportation Efficiency, Land Use Efficiency, Environmental Impacts, Human Livability, and Economic Efficiency, as indicated in Tables 3-7 to 3-11. Second priority indicators are the remaining indicators outlined in Tables 3-7 to 3-11 that achieved no more than two sustainability goals. However, it is important to note that these lower priority indicators hold significant value and will remain an integral part of the evaluation and policy development process in Chapters 5 and 6. Therefore, all 'master' indicators will be used in the evaluation of SFU's Official Community Plan, Development Plan Concept, and other transportation and land use management policies at SFU, as well as for the development of sustainable transportation and land use policies for SFU.

Table 3-12. Master Sustainable Transportation and Land Use Planning Framework: 1st Priority Indicators

[illegible]	[illegible]
1. Percentage of dwelling units within 400 meters of transit service and basic shopping needs	TR, LU, EV, L, EC
2. Annual number of walk, bicycle, and transit trips per capita	TR, LU, EV, L, EC
3. Percentage of city/community that is zoned for mixed-use and transit-oriented/traditional neighbourhood development	TR, LU, EV, L, EC
4. Annual VKT/VHT per capita (non-recreational)	TR, LU, EV, EC
5. Modal split for work and non-work trips	TR, LU, EV, EC
6. Percentage of city/community with a minimum average density of 30 units per acre (gross)	TR, LU, EV, EC
7. Percentage of residents who live and work in the same community/municipality (jobs-housing balance)	TR, LU, EV, L
8. Percentage of citizens living within 30 minutes of work by transit, bicycle, or walking	TR, LU, EV, L
9. Annual gasoline consumption (MJ or litres) per capita	TR, LU, EV, EC
10. Percentage of institutions/employers (over 100 employees) that offer traffic reduction programs	TR, EV, EC
11. Percentage of employment, transit, and public facilities with bicycle/walk infrastructure (e.g. bike/walk lanes, racks, showers, locker rooms)	TR, L, EC
12. Percentage of residential units that are not single-family homes	TR, LU, EV

Table 3-13. Master Sustainable Transportation and Land Use Planning Framework: 2nd Priority Indicators

1. Number of vehicles per household	TR, EV
2. Percentage of street area that is dedicated to walking, cycling, and transit	TR, LU
3. Percentage of streets that are traffic-calmed	L, EC
4. Availability and institutional support for 'Green'/Location-Efficient Mortgages	TR, EC
5. Percentage of community (including roads, public places, parks) that is pervious to water (e.g. alternative surface materials)	EV
6. Mix of housing and funding types, tenures, tenants, and income levels	LU
7. Average number of "spontaneous exchange" experiences per capita per day	L
8. Number of sustainable transportation services (e.g. car sharing, home delivery, 'dial-a-ride,' bike co-ops, 'walking school bus')	EC
9. Public/private savings from reduced auto dependence over and above any necessary increases in transit, bicycle, and pedestrian expenditures	EC

3.4.7 Application of the *Master Sustainable Transportation and Land Use Planning Framework*

The true value of this framework lies in its ability to adapt to the particular needs of a community and/or region. For example, if the goals and objectives of a community focus on improving livability, more emphasis may be put on traffic-calming measures, pedestrianisation, car-free streets and areas, noise management, safety, and community interaction. Therefore, once goals and objectives are set, using the 'Sheltair Model' applied in this study, a community could review the *Indicators Menu* and select the appropriate indicators for their purpose. The framework and *Indicators Menu* thus act as a 'template' for community associations and regional planners to use in mapping out strategic sustainability plans. As stated before, not all indicators will fit with the goals of each community initiative, and the master framework provided in this study should not be used as a 'one size fits all' model.

In building this framework, communities may question the number of indicators that are appropriate for their initiative. The number of indicators selected is entirely up to the community and depends on a number of factors, including: the size of the community, the number of critical issues, and the resources available to track and report on the indicators (Hart 1995). The final list should not be so short that critical areas are overlooked, nor so long that measuring and reporting is overwhelming. Most importantly is that there be a diversity of indicators (Hart 1995). However, the BC Round Table suggests that the 80 indicators used in their State of Sustainability (1994) assessment were too many. It was concluded that too many indicators reduce the impact on understandability for audiences, as well as usefulness for policy makers (Dilks 1996). Therefore, communities should be aware of this potential problem and make efforts to integrate this concern into their sustainability plans.

3.4.8 Conclusion

The above evaluation has identified a core set of indicators that accomplish two goals. First, and most importantly, they achieve the preset goals and objectives of this study, that is they provide a framework for improving transportation efficiency and accessibility at SFU's Burnaby Mountain campus, thereby reducing the environmental impacts associated with a highly automobile dependent community. Second, these 'master' indicators satisfy the sustainability criteria outlined in Section 3.3.3. These criteria are widely accepted within the transportation and land use planning disciplines as core principles of sustainable urban development, and therefore act as important 'checks and balances' when developing transportation and land use policies. The *Master*

Sustainable Transportation and Land Use Planning Framework is now ready to be used in the development of sustainable transportation and land use policies for the SFU Burnaby Mountain campus.

Chapter 4 Simon Fraser University: A Case Study of the Burnaby Mountain Campus

4.1 Introduction

Chapter 4 is intended to provide the setting, or background, for the application of the *Master Sustainable Transportation and Land Use Planning Framework* to SFU's Burnaby Mountain campus, the focus of this study. This chapter will provide an historical context with respect to location, population, transportation, and community development. Furthermore, regional growth management planning will be discussed, highlighting SFU's role and relationship to the GVRD's Livable Region Strategic Plan. Finally, growth management issues at SFU will be identified and their associated transportation and land use impacts assessed.

4.2 Background

4.2.1 History and Context

Simon Fraser University is located in the north-east corner of the City of Burnaby, in a unique site atop Burnaby Mountain, and is part of the Greater Vancouver Regional District (refer to Figure 1-2 for site map). SFU opened its doors to students on September 9, 1965, and is now home to approximately 15,000 full-time equivalent students with an average daily campus population of 12,000 students, staff, and faculty (with approximately 500 additional staff at Burnaby Mountain in the Discovery Park and BC Hydro facilities) (Moodie 1996). This mountain top location, coupled with its relative isolation from major centres within Greater Vancouver and its limited on-campus housing, make SFU a typical 'commuter campus.' These characteristics shape SFU's 'commuter campus' like travel behaviours, as the majority of people arrive between 8:00 and 10:00 a.m. and leave between 3:00 and 6:00 p.m. (Petz et al. 1998).

It is important to point out that SFU shares its location with a city park. Burnaby Mountain is an ecologically diverse and active area. The unique concerns and situation of a mountain campus pose special access problems. Therefore, programs and planning initiatives aimed at increasing the supply of roadways and parking are not feasible options within the university's commitments to "environmental integrity" (Alexander, Sandmann, and Yarnell 1997; Moodie 1996; City of Burnaby 1996).

4.2.2 Transportation

Transportation options to and from SFU include all standard modes, such as private automobiles, transit, cycling, and walking. Road access is provided through Burnaby Mountain Parkway (off Hastings Street) and Gaglardi Way (off Lougheed Highway). The following section will provide a brief history and status report on transportation management at SFU.

Public Transit

Since its inception, SFU's remote and isolated location atop Burnaby Mountain has posed some serious transportation planning challenges. Transit service was provided by BC Hydro[17] at that time, with two direct routes, and investments were made in five special 'hill-climber' buses to access the SFU campus. The steepness of Burnaby Mountain, however, was too severe for the regular buses that were used as replacements when the 'hill-climber' buses were receiving maintenance. Students, staff, and faculty often found themselves walking up when regular buses stalled while climbing Burnaby

[17] BC Hydro was the original transit operator in the GVRD and was operating transit in the 1960's when SFU opened.

Mountain (Petz et al. 1998). The Gaglardi Way route was used more often in these circumstances due to its lower grade (i.e. steepness). Transit service has improved significantly since 1965, with major additions in 1982 (by what was then known as the Urban Transit Authority); in 1986, with the Vancouver Expo and SkyTrain development (then known as BC Transit); and in the mid-1990 s with the development of the transit loop in the east corner of campus. Furthermore, the mid-1990s saw the addition of express routes from Metrotown and downtown Vancouver, particularly the #135 service that links SFU's Burnaby Mountain and Harbour Centre campuses. SFU is currently serviced regularly by TransLink (formerly know as BC Transit), with 6 direct routes travelling from downtown Vancouver, Metrotown (Burnaby), Edmonds Station (Burnaby), Coquitlam Station (Coquitlam), Lougheed Mall (Burnaby), and Scott Road Station (Surrey).

Plans are also underway to expand TransLink's SkyTrain service, which may have significant impacts on transit ridership to SFU. The "Broadway-Lougheed" line – extending from Broadway Station to Lougheed Mall – is planned to be complete before December 2001. This rapid transit service will help connect SFU – via the Production/University Way station – to Burnaby, Coquitlam, and Vancouver, and should provide an attractive incentive for students, staff, and faculty to commute by transit.

Parking

Historically, SFU's most significant transportation crisis has centred around the demand for parking. Parking management has been in the spotlight since 1965, when a student rally blocked a tow truck attempting to remove an illegally parked car (Petz et al. 1998). These struggles continue today, as thousands of students recently lined up in hope of receiving the 'privileged' parking permit. Persistent drivers that are unsuccessful in obtaining a parking permit have relied on parking their cars in nearby neighbourhoods at the base of the mountain, at Burnaby Mountain Park (half way up the mountain), and on Gaglardi Way and Burnaby Mountain Parkway. These areas are not managed parking sites and are therefore 'free' to park in. However, some residential areas have initiated strict by-laws to prohibit parking and informal park-and-ride activities (Petz et al. 1998). Access to the campus from these locations is typically achieved via transit, hitchhiking, and walking. This 'spillover' effect of parking mismanagement has created tension between SFU and neighbouring communities – particularly the ones receiving excess traffic – and has increased concerns for safety along Gaglardi Way and Burnaby Mountain Parkway.

There are approximately 6,500 pay-parking spaces on campus, with the majority being surface parking stalls (Moodie 1996). These parking facilities provide approximately 1 stall for every 2 persons on campus. However, due to the varying schedules of students, the university oversells parking permits at 30-50% (i.e. approximately 10,000 parking permits are sold), thus attempting to optimise parking stall use and revenue. Therefore, approximately 10,000 vehicles commute to and from SFU everyday (Coutu 1999). The 'oversell' of parking permits, however, does not satisfy the demands for vehicle travel and thus parking facilities, as the 'wait list' for permits typically falls in the 2,000-plus range for every academic term (Petz et al. 1998).

Parking management has recently become a top priority at SFU. A "Committee on University Parking" (CUP) was formed in 1999 to deal with issues such as growth management, car and vanpooling permits and incentives, and parking supply. There has also been discussion around the idea of a 'parking development moratorium,' whereby the university may commit to maintaining its parking supply and managing transportation and parking demands without the development of supplementary parking facilities. This potential commitment is likely a function of the university's limited land, particularly with the proposed community development within the Ring Road, and the high costs of building underground or multi-tiered parking facilities. Though this commitment would be a strong statement of SFU's dedication to sustainable transportation planning, Traffic and Security has indicated that there has been no official commitment at this stage (Yeager 1999).

Car and Vanpooling

Efforts to curb the demand for parking have centred primarily around carpooling. In 1991, SFU developed 'RideShare,' a program where students, staff, and faculty could enter into computers their residential and travel information. The program would then provide the user with a list of other people within the SFU community that match their own travel data. When carpools were formed, special RideShare parking permits and locations were allocated. RideShare thus acted as an informal carpooling program, encouraging the SFU community to voluntarily participate by contacting other participants, organising, and co-ordinating car and vanpools. This program is formally supported by the Jack Bell Foundation (JBF) vanpool service. Participants could become members of the JBF vanpool program by paying a monthly fee to travel to and from SFU in designated JBF vans. By 1995, nearly 2,500 students were registered in the RideShare database and approximately 250 parking stalls were dedicated to car and vanpools. However, these statistics do not fairly represent the true car and vanpooling behaviours, as not all students registered in the database were active car/vanpoolers, and 250 parking stalls represent less than 5% of the total parking lot infrastructure, which is significantly less than the parking requirements of 2,500 car/vanpoolers. Unfortunately, by 1997 this program had slowly died out, as the software for RideShare (called "Easy Rider") became outdated and poorly managed, reducing the number of carpool users and the JBF's presence on campus to only 4 vans. The diminished popularity of this program may be partially due to the parking and management policies that existed up to early 1999. The price of this permit is currently in debate, as many students believe the permit price does not provide any economic incentive, as RideShare permits are nearly double the price of a general parking permit ($170.00 versus $93.00). Furthermore, the limited transferability (i.e. ability to transfer permit between cars within a car/vanpool) may have reduced its success. These issues, as well as other parking-related issues, are being discussed in SFU's newly formed CUP.

Bicycle and Pedestrian Travel

Due to the severe length and slope of Burnaby Mountain, cycling and walking are not popular travel options. However, dedicated bike lanes due exist on *parts* of the Burnaby Mountain Parkway and Gaglardi Way/University Drive. Nevertheless, their 'incomplete' and 'unconnected' status makes commuting by bicycle both difficult and dangerous. This problem may likely be a function of the diversity of road ownership and management that exists. SFU is responsible for University Drive and all roads within Ring Road. However, the City of Burnaby is responsible for Gaglardi Way and Burnaby Mountain Parkway. Therefore, the problem may be rooted in the fact that these two jurisdictions have yet to fully integrate and co-ordinate their bicycle infrastructure plans (i.e. bike lanes and routes) to provide convenient and safe cycling options for SFU commuters.

A full bike lane follows the Gaglardi Way/University Drive route, providing bicycle access from the south-east side of Burnaby Mountain. However, the bike lane on Burnaby Mountain Parkway stops at the turnoff for the Burnaby Mountain Park (approximately half way up the mountain). From that point on, cycling is considered dangerous due to the lack of a dedicated bike lane and a road shoulder measuring less than 0.5 meters in width, particularly given the high vehicle speeds and a roadway that faces east (thus receiving a rising morning sun that tends to limit visibility for drivers and cyclists). Once the Burnaby Mountain Parkway/University Drive intersection is reached, the bike lane resumes. Many cyclists that access the mountain from the south-west turn off the Burnaby Mountain Parkway and ride up the mountain through Burnaby Mountain Park. This route, though providing safety from vehicles, is steeper and adds an average of 10-20 minutes to a cyclist's commute. According to SFU's Traffic and Security, this was the original intention, as they believe this route is a better option for cyclists. Cyclists, however, may challenge this intention, arguing that re-routing vehicles through a longer and less convenient route would be irrational.

Burnaby Mountain is also well connected with a series of walking and cycling trails. These trails are commonly used for commuting and recreational purposes by both local residents and the students, staff, and faculty of SFU.

Intra-Campus Travel

Intra-campus travel is dominated by pedestrians, as is the case in most university campuses. However, the opportunities for intra-campus bicycle travel are limited. There are no dedicated bicycle routes that travel through the centre of the campus and the general layout and design of the campus does not facilitate convenient bicycle travel (e.g. campus connected with pedestrian routes and stairs).

Private vehicles, buses, cycling, and walking therefore make up the spectrum of transportation modes used to access SFU's Burnaby Mountain campus. However, SFU's unique mountain top location and steep grade limits accessibility primarily to private vehicles and public transit. Pedestrian travel is the primary means of transport within campus, however, intra-campus bicycle travel is non-existent given the general campus layout.

As part of a "Greening the Campus" Resource and Environmental Management 100 tutorial that investigated transportation issues at SFU, a traffic screen count was conducted (October 1998) to assess the transportation behaviours of SFU's Burnaby Mountain community (Petz et al. 1998). Over a 2-day period, a transportation survey team collected the following data: the number of vehicles entering SFU and the number of occupants per vehicle; the number of buses entering SFU and the number of occupants per bus; and the number of cyclists and walkers that commute to SFU. The results of this investigation are as follows:

Table 4-1. Transportation Modal Split for the SFU Burnaby Mountain Campus

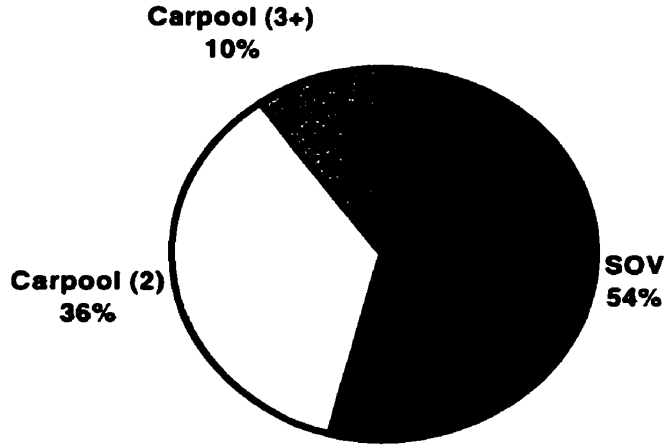
Mode of [illegible]	[illegible]
Single-occupant vehicle (SOV)	**40%**
Public Transit	**27%**
Carpool (double-occupant)	**26%**
Carpool (3 or more occupants)	**7%**
Cycle	**0.5-1.0%**[18]
Walk	**0.10%**

The transportation modal split for SFU's Burnaby Mountain campus indicates a high degree of automobile dependence, where nearly 75% of all trips are made in private vehicles (SOVs (40%) plus carpools (26% + 7%)). This high level of auto dependence is also represented in the extremely low average automobile occupancy (AAO) rate (i.e. persons per vehicle). This rate is calculated at approximately 1.34 persons per vehicle and matches the GVRD's 1991 AAO (GVRD and Province of BC 1993a). The traffic screen count further supports the hypothesis that SFU's Burnaby Mountain campus is not accessible by bicycle and foot, as less that 1% of the campus population travel via these non-motorised modes.

Figure 4-1 indicates that over half of all private vehicle trips are made in single-occupant vehicles, an equally troubling transportation statistic, given that SOV travel is the most polluting form of urban travel.

[18] Bicycle and walk counts only include persons that passed the Burnaby Mountain Parkway/Gaglardi Way intersection (i.e. persons that accessed SFU via the trails of Burnaby Mountain Park were not counted).

Figure 4-1. Modal Split for Vehicle-based Trips to SFU's Burnaby Mountain Campus



While its specific reasons have not previously been explored, this high level of automobile dependence may be a direct function of the following elements:

- Inexpensive parking fees relative to transit fees ($93 per term versus $220 per term).
- Parking management policies that encourage automobile use through a large supply of parking. The official parking-to-population ratio is approximately 1:2, given SFU's 6,000+ parking stalls and an average on-campus population of 12,000. However, given that 10,000 vehicles are driven to SFU daily, a more accurate estimate of SFU's parking-to-population ratio is 1:1.2 (i.e. at any given time, there exists 1 parking stall for every 1.2 persons) (Coutu 1999).
- Parking management policies that discourage carpooling through: economic disincentives (i.e. parking permits for 'formal' carpooling are nearly double the cost ($170/term) of those for 'regular' parking permits ($93/term), where students can organise 'informal' carpools); and insignificant allocations of priority carpool parking (only 4% of the total parking supply).
- A limited supply of student, staff, and faculty housing opportunities on-campus. On-campus housing provides accommodation for only 10% (approximately) of the student population, whereas other universities offer housing for a much larger

proportion of the community (e.g. UBC provides housing for 20-25% of its student population). Furthermore, there exists no on-campus housing opportunities for staff or faculty at the Burnaby Mountain campus.

- A large proportion of SFU students are from the GVRD (approximately 70-80%) and are likely to live at home with their parents. Should they reside in areas with poor transit accessibility and/or inconvenient service to SFU's Burnaby Mountain campus – for example, in suburban areas such as Richmond, South Vancouver, or Surrey - they may have no option but to reach campus via private vehicles.
- A potentially high rate of private vehicle ownership, or access to private vehicles, amongst the SFU community – particularly the students.
- Only two express transit services exist to/from the Burnaby Mountain campus, with minimum headways (i.e. frequency of service) of 15 minutes in peak hours.
- The geography of the Burnaby Mountain campus (i.e. mountain top location) does not encourage access by non-motorised modes, such as cycling and walking.

While not exhaustive, these factors may explain the transportation behaviours described in Table 4-1 and Figure 4-1 above. These behaviours, as well as SFU's transportation policies, will be further examined in Chapter 5.

4.2.3 Burnaby Mountain Community Development

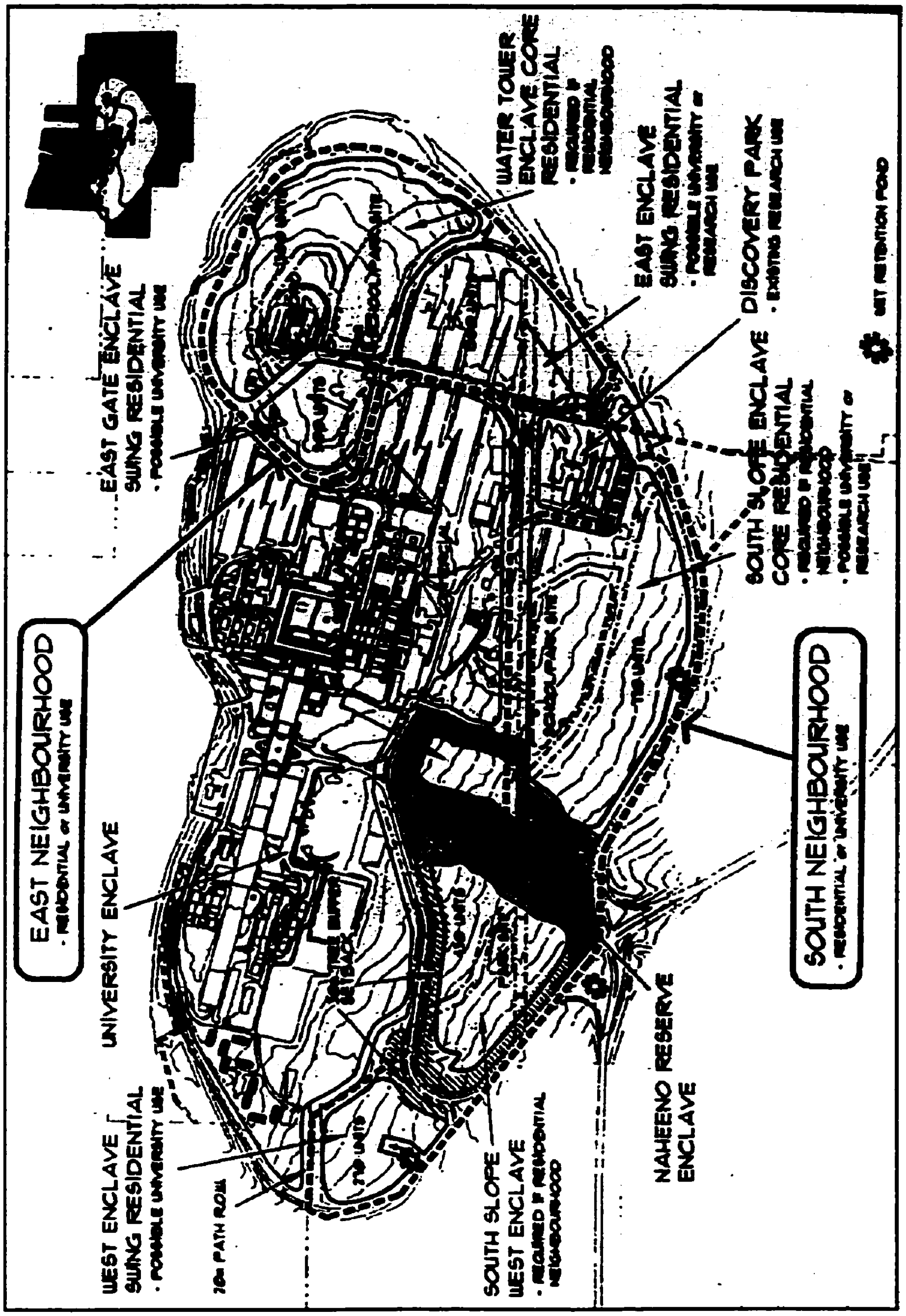
On November 16, 1995 the provincial government, the City of Burnaby, and SFU announced the pending transfer of SFU's 332 hectares of land outside the university's Ring Road to the City of Burnaby for the establishment of the Burnaby Mountain Conservation Area. In exchange for these lands, SFU received funding for a Burnaby Mountain Endowment Fund and has gained the right to develop residential communities within the university's Ring Road. The area involved consists of approximately 78 hectares of land along the south and east edges of the existing campus, which are slated for 4,536 residential units (maximum), with up to approximately 10,000 residents (Moodie 1996).

SFU and the Burnaby Mountain Development Corporation (BMCC) are confident that this development opportunity will provide reciprocal benefits for the University and the larger Burnaby community. John Stubbs, Past President of SFU, states:

> *If we approach this undertaking boldly and with imagination, we can create a community on Burnaby Mountain that is exceptional, internationally acclaimed, and fully capable of contributing materially, and in many other ways, to the rich and vibrant future of the university.* (E&S 1999, 2)

In February 1996, the Development Plan Concept (DPC) was completed by Moodie Consultants Inc. (Project Manager). This plan provided the first 'vision' of the proposed community development and is represented in Figure 4-2.

Figure 4-2. Development Plan Concept: Simon Fraser University (Moodie 1996, 33)



The DPC is an analysis of land use, density, and other planning issues surrounding the development of a Burnaby Mountain community. The objectives of this analysis were as follows (Moodie 1996, 2):

1. To identify environmentally sensitive areas and develop strategies to protect ecosystems and ecological functions.
2. To identify areas within the Ring Road that are potentially suitable for both University and for non-University uses, including specific combinations of uses where desirable.
3. To define an appropriate level and mix of residential, commercial, support services, and facilities that will serve both the University and non-university communities, including specific combinations of uses where desirable.
4. To determine development types, forms, and densities that support University and City objectives while respecting and complementing the natural heritage of Burnaby Mountain.
5. To maintain the quality, consistency, and integrity of the University's architectural environment.

The DPC investigated the environmental impacts associated with this development project, such as impacts to water, soils, vegetation, and wildlife habitat; and issues surrounding transportation, site servicing, storm water management, and the geology and topography of the land. The DPC proposes a land use concept that includes the following guidelines: population and development densities, environmental, building design and setbacks, landscaping, circulation plans (including pedestrian paths, roads, transit, service access, bicycles, and parking), community service and facilities, outdoor recreation and greenspace, and engineering site services. Transportation-related components of this plan will be further investigated in later sections of this chapter.

The completion of the DPC initiated the development of a new Official Community Plan (OCP) between SFU and the City of Burnaby. This plan was completed and adopted by Burnaby City Council on September 9, 1996. SFU's OCP is a condensed version of the previously completed DPC, and outlines the vision, goals, objectives, and land use development guidelines for the proposed Burnaby Mountain Community Development (City of Burnaby 1996). The OCP's community development vision is consistent with the DPC's proposed community development plan, as shown above in Figure 4-2.

Furthermore, the following primary and secondary objectives are also shared by the DPC and OCP (Moodie 1997, 2).

Primary Objectives:

1. To establish an integrated vibrant community complementary to existing and future University development.
2. To establish an ongoing endowed source of revenue to support future University purposes.

Secondary Objectives:

1. Subdivision of property should be carried out in such a way that land within the Ring Road is not alienated from University ownership. Land within the Ring Road should be leased for development purposes, not sold.
2. Significant regulatory approvals should be sought by the University acting on its own behalf (e.g. such matters as zoning and subdivision).
3. Consistent with the disciplines of the market and sound financial practices, the University should endeavour to produce development projects within the Ring Road that are outstanding examples of their type. Projects should reflect *sound traffic management* and *reduction principles, resource efficient design principles,* and *sound energy conservation principles* (emphasis added).
4. Consistent with the goal of establishing an integrated, balanced, and vibrant community on Burnaby Mountain, residential and commercial development should be compatible with institutional development and in harmony with the character of the University.
5. Environmental sensitivity to the nature of the mountain is an important consideration in the development of University lands. In development of its property, the University will endeavour to set and maintain *high standards of environmental responsibility* (emphasis added), consistent with the inevitable impact of development. All relevant environmental assessment review and approval processes will be followed.
6. The University is committed to an open, communicative process of consultation with its community on Burnaby Mountain and the community of Burnaby prior to proceeding with any development projects.

The construction of this 'village' is expected to start in the year 2001 once the Master Plan is developed in 1999-2000. The BMCC has recently formed an Advisory Committee and Board of Directors who will play a key role in the development of the Master Plan, through an extensive public consultation and land use planning process.

The DPC and OCP indicate that the development may be shaped into two main communities, the South and East Neighbourhoods, and the developable area within the Ring Road has been zoned according to this vision. Development is planned to be concentrated in one area first (i.e. South or East Neighbourhood), with construction most likely to start on the East Neighbourhood. Each neighbourhood may consist of one or two core communities (enclaves) as well as a swing area for future residential or university development. The East Neighbourhood may concentrate two-thirds of the units (3,049 units), including swing areas, with an average occupancy rate of 2 persons per unit, representing approximately 6,000 residents. The remaining 33% of units are expected to be concentrated within the South Neighbourhood (1,488 units), with an average occupancy rate of 3 persons per unit, representing approximately 4,500 residents. Please refer to Figure 4-2 for further explanation.

The DPC estimates a full-time student enrolment of 25,000 with a resultant daily campus population of more than 20,000 students, staff, and faculty by project completion (approximately 2010 to 2030) (Moodie 1996). This doubling of the campus population presents serious transportation planning challenges for SFU. Therefore, SFU's growth management plan must incorporate adequate strategies to manage the increased transportation demands. For example, the DPC states that "future transportation networks will need to provide for increased transit services responding to the possibility of reduced parking availability relative to the size of the future student population" (Moodie 1996, 7). These increased transportation impacts should play an integral role in designing a 'car-smart' community, as well as a sustainable transportation plan for the university.

The development objectives highlighted above, particularly the secondary objectives, fit well with the principles of sustainable urban development. The BMCD project represents a unique opportunity for SFU to develop a model sustainable community, one that fully integrates the existing campus community and the natural environment of Burnaby Mountain, along with sustainable community design principles, into the final community vision. The integration of the natural and built environments should be pursued, encouraging community participation in the planning process. For instance, development should minimise ground disturbance and vegetation removal; practice sound site location for buildings; minimise energy and waste flows; minimise road development and the need for personal vehicle travel through transportation alternatives; encourage sustainable community economic development through the provision of employment and commercial service opportunities on-site; and enhance the power of 'community' and the key role it plays in achieving sustainability. Furthermore, the principle of 'connectivity' should be stressed when planning the integration of the new communities within themselves, as well as with the existing campus community, the Harbour Centre campus community, and the broader Burnaby communities. In support of these principles, the following statements were made during an official envisioning session in the summer of 1998:

> *Community is about connections. It's about the street, the people you see on the street and what you do on the street. What we are lacking now is that environment. We have an opportunity to build an unbelievably interesting community where you can work and study and see exhibitions, go shopping...all within walking distance. It's an incredible opportunity for us – all of us.* – Jack Blaney, President, Simon Fraser University (E&S 1999, 27)

> *The technology is coming that will allow us to move more people more effectively and with less environmental harm. SFU will be a model of how an integrated transportation system can work* (emphasis added). – Bob Glover, City of Burnaby (E&S 1999, 15)

These statements speak loudly to the ideas and principles of new urbanism, people-oriented communities, and integrated land use and transportation planning, as discussed in Chapter 2. It is hoped that this vision will remain fresh in the minds of these key players, as well as the general SFU community, during the Master Plan development process.

4.3 SFU in context with Regional Growth Management Planning

4.3.1 Greater Vancouver Regional District

In 1990, the GVRD adopted *Creating our Future: Steps to a More Livable Region*. This document laid out principles and strategic policies to guide development within the region. It stated that the GVRD will "sustain and develop a co-operative transportation planning process with the provincial government and its agencies based upon the GVRD Board's approved policies to give priority to walking, cycling, transit, and *then* the private automobile" (GVRD 1990, 14). This policy formed part of the terms of reference for *Transport 2021,* Greater Vancouver's long-range transportation plan (Davidson 1997; GVRD and Province of BC 1993a). Vancouver's recent *Draft Transportation Plan* also stresses the need for reduced reliance upon the auto, and states that "we should be willing to use transit, walk or bike where these are practical options, and leave our car at home" (City of Vancouver 1996, 1). In addition, the *Burnaby Transportation Plan* supports sustainable transportation, as its vision statement indicates that the City of Burnaby should "strive to facilitate the efficient movement of people and goods in Burnaby in a cost effective manner which enhances the environment and livability of the entire community" (City of Burnaby 1995, 24).

In 1996, The Livable Region Strategic Plan (LRSP) was approved by the GVRD (GVRD 1997a). The LRSP is based upon four fundamental objectives directed towards maintaining the environmental quality and livability of the region. These objectives are as follows:

1. **Protect the Green Zone**: is intended to protect Greater Vancouver's natural assets and to create a long-term urban growth boundary.
2. **Build Complete Communities**: is intended to provide more residents with access to the range of day-to-day activities within their own neighbourhoods, such as work, shopping, and school.
3. **Achieve a Compact Metropolitan Region**: is intended to concentrate urban growth in specified areas within the region, thereby enabling people to live closer to work and services and improving the transportation system within the region.

4. **Increase Transportation Choices**: is intended to increase the convenience and accessibility, and thus attractiveness, of transit and reduce dependence on single-occupant vehicle travel.

Transport 2021 identifies four policy levers that can be used to achieve these goals in an attempt to move people and goods efficiently, increase transport equity, reduce environmental impacts, and decrease automobile dependence within the region. These levers are (GVRD and Province of BC 1993a):

1. Control Land Use
2. Apply Transport Demand Management
3. Adjust Transport Service Levels
4. Supply Transport Capacity

The LRSP and Transport 2021 therefore provide a vision and plan for integrated land use and transportation planning in the GVRD. The GVRD has put significant emphasis on complete communities, compact urban areas, and sustainable transportation and land use planning, thus highlighting their importance in reducing automobile dependence and minimising environmental degradation.

4.3.2 Simon Fraser University

SFU is in full support of the LRSP and Transport 2021 growth management plans (Gill et al. 1994).[19] Gill et al. indicate that "If we are to have effective regional planning and growth management, it is imperative that the GVRD, the Government of BC, along with the Ministry of Transportation and Highways, work together on a jointly developed and accepted strategy" (Gill et al. 1994, 4). According to Gill et al., SFU believes that increased density, compact urban form, and the creation of complete communities are essential to improving the livability of its community, as well as those of the GVRD (Gill

[19] Warren Gill is a Transportation Geographer in the Department of Geography at SFU, Executive Director of SFU's Harbour Centre Campus, and lead author of a University driven discussion paper that investigated SFU's relationship to, and role within, the GVRD's Livable Region Strategic Plan.

et al. 1994). SFU recognises that it lacks the balance of commercial and residential development required to be a complete community. This is evident in the university's plans to develop a residential and mixed-use community within the Ring Road of the Burnaby Mountain campus (i.e. the BMCD). These plans somewhat complement the LRSP's Growth Concentration Areas (GCA) plan, where population densification is encouraged in the Burnaby/New Westminster area, one of three GCAs identified in the LRSP (GVRD 1997a). However, Burnaby Mountain is considered part of the "green zone" within the LRSP, thus creating some uncertainty with respect to the development of this land.

Furthermore, Gill et al. indicate that TDM and transit should play an integral role in shaping future growth at SFU and the GVRD (Gill et al. 1994). In particular, future university developments should be integrated with existing transit services, transportation infrastructure investments should be targeted at transit development, and traffic reduction programs should be implemented at the institutional level.

And finally, SFU believes that regional governance is key for successful implementation of growth management mechanisms (Gill et al. 1994). SFU is thus most likely in favour of the recently formed Greater Vancouver Transportation Authority (i.e. TransLink), a regional body that manages the GVRD's transportation infrastructure, public transit system, transportation demand management, and the Air Care program.

4.4 Growth Management Issues at SFU

SFU faces some serious transportation management challenges in the coming years. These challenges are a direct function of the following university growth plans:

1. The proposed Burnaby Mountain Community Development may provide residence for approximately 10,000 people through the development of 4,000-5,000 housing units; and
2. SFU's Burnaby Mountain campus expects its full-time equivalent (FTE) student population to increase from 15,000 (1997) to 25,000 students.

As indicated before, these combined growth pressures will double the university's on-campus population from 12,000 to 20-25,000 people between 2010 and 2030. This population forecast therefore makes one, or both, of the following assumptions:

1. A large proportion of future university population growth (i.e. students, staff, and faculty) will be accommodated in the new university community; or
2. A large proportion of the future residents of this community will be employed off-site, thus not contributing to the daily on-campus population in peak operational periods (i.e. 8:00 a.m. – 5:00 p.m.).

The DPC and OCP do not fully explain how this growth will be managed by the university, thus leaving it open to speculation, criticism, as well as the opportunity for creative public input. The following sections will identify and analyse the potential transportation-related ecological impacts of the growth pressures identified in the DPC and OCP.

4.4.1 Transportation-Related Impacts

Of greatest concern with respect to the development of this community and the expected future university growth may be the transportation-related impacts on local, regional, and global environments. These potential impacts are as follows:

A. Traffic flow;
B. Air pollution;
C. Noise pollution;
D. Vehicle-pedestrian/bicycle conflict;
E. Infrastructure;
F. Water quality;
G. Habitat and wildlife; and
H. Recreation and cultural.

A. Traffic Flow

Delcan Engineers Planners completed the transportation analysis for the DPC (Delcan 1996). The estimated growth in vehicle travel is summarised in the following two tables:

Table 4-2. Future Vehicle Traffic Estimations (Number of Single-Occupant Vehicles)

Travel [illegible] A.M. [illegible] P.M. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A.M. Peak: To SFU	1,564	2,519	955	61%
A.M. Peak: Away from SFU	223	1,588	1,365	612%
P.M. Peak: To SFU	455	1,927	1,472	324%
P.M. Peak: Away from SFU	1,279	2,717	1,438	112%
Total Growth in A.M. Vehicle Trips	1,787	4,107	2,320	**130%**
Total Growth in P.M. Vehicle Trips	1,734	4,644	2,910	**168%**
Total Vehicle Trip Growth	3,521	8,751	5,230	**149%**

Table 4-3. Percentage of Total Single-Occupant Vehicle (SOV) Trips by Category: Existing, BMCD, and Student Growth

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A.M. Peak: To SFU	62% (1,564)	22% (560)	16% (395)	100% (2,519)
A.M. Peak: Away from SFU	14% (223)	81% (1,279)	5% (86)	100% (1,588)
P.M. Peak: To SFU	24% (455)	65% (1,262)	11% (211)	100% (1,927)
P.M. Peak: Away from SFU	47% (1,279)	34% (926)	19% (512)	100% (2,717)

Findings

Delcan's trip generation rate analysis concludes that in peak hours of travel, the number of single-occupant vehicles (SOV) travelling to and from SFU will increase by 150%. There are several key criticisms of this analysis:

1. The vehicles per hour (VPH), or traffic volume, estimates completed by Delcan used 1990 traffic data, in combination with the university's projected population growth estimates. It is of concern that data from 1990 may be outdated. As well, it is not known how Delcan incorporated the future population growth estimates into its projected trip generation rates. For example, Delcan would have had to estimate what proportion of the BMCD residents studied and/or were employed on- versus off-campus (i.e. what percentage of residents are from the SFU, Discover Park, and BC Hydro communities?). This distribution has not been identified by Delcan.
2. Delcan's VPH estimates only identified peak-hour traffic flows. Currently, the majority of 'work-trips' (i.e. work and school) are made in the morning peak hour. That is, nearly 50% of the 10,000 vehicles commuting to SFU each day travel in the morning – in particular, during the morning peak hour from 8:00-9:00 a.m. (Petz et al. 1998; Coutu 1999). However, there are 5,000 vehicles that commute to SFU later

each day that are not included in Delcan's analysis. Therefore, it is important that these trips be included in order to understand the full transportation impacts related to SFU's future growth management plans.

3. Of further concern is the fact that the majority of trips, 60-75% of total trips, are non-work related, such as personal, shopping, and recreational trips (Van der Ryn and Calthorpe 1986). In addition, Van der Ryn and Calthorpe's research indicates that the average one-way non-work trip is 12.5 km in distance (Van der Ryn and Calthorpe 1986). At this time, the demographics and mix of the future community resident population is unknown (i.e. percentage of students, staff, and faculty that will reside in the BMCD). Furthermore, though the DPC states that there may be 10-20,000 m^2 (approximately 110,000-220,000 ft^2) of retail and commercial services within the BMCD, at this time it is not completely known what this allocation of space will be nor if it will be sufficient to satisfy the daily needs of its residents (Moodie 1996). Therefore, it is difficult to predict what transportation behaviours may develop for these residents. To avoid excess vehicle travel to Lougheed Mall and other 'big box' shopping centres, the BMCD should supply sufficient retail and commercial opportunities to satisfy the daily needs of the BMCD residents. Lougheed Mall is the nearest retail facility and is located at a distance of approximately 5 km (one-way) from SFU. The transportation realities and uncertainties mentioned above should be of obvious concern to SFU, the City of Burnaby, and the Greater Vancouver area. Through the lack of sustainable transportation and land use planning, the non-work trips of the BMCD residents could seriously degrade local, regional, and global air quality.

4. The VPH traffic volume estimates calculated by Delcan are estimates for single-occupant vehicles only. The 1998 traffic survey indicates that 36% of total vehicle trips have one passenger (i.e. 2-person carpool) and 10% have 2 or more passengers (i.e. 3-person plus carpool) (Petz et al. 1998). Therefore, nearly 50% of total vehicle trips are unaccounted for in Delcan's analysis. As stressed above, Delcan's VPH estimates do not capture the true vehicle flows of SFU's transportation system, thus they do not account for the full transportation impacts.

5. Table 4-2 indicates that a.m. peak hour travel to SFU is expected to increase by only 61%. Furthermore, Table 4-3 indicates that only 395 trips will be generated by the university's "new" students (i.e. FTE growth) in the morning peak hour. This equates to only 16% of the total estimated a.m. peak hour trips to SFU. From a sustainability perspective, this would be an honourable achievement, as these traffic flow estimates are extremely low relative to the expected growth in the student population (i.e. 10,000 new students). Though SFU has committed to quadrupling student residence facilities on campus, there would need to be a larger allocation of housing units to students to accommodate this growth for this low traffic volume estimate to be reasonable. Unfortunately, there is no indication within the DPC or OCP that supports this housing allocation (Moodie 1996; City of Burnaby 1996). Therefore, these traffic flow estimates may not accurately reflect the transportation realities of SFU's future growth challenges.
6. Of further concern are the "Estimated BMCD Vehicle Traffic" results identified in Table 4-3. In the a.m. peak hour, it is estimated that approximately 1,300 residents of the BMCD will leave Burnaby Mountain, most likely for work-related reasons, and return in the p.m. peak hour. As mentioned above, there has been no indication within the DPC or the OCP that this community will cater to the members of the SFU, Discovery Park, or BC Hydro communities. In fact, the DPC and OCP emphasise the development of market housing, which may likely attract more investment from people outside the SFU community (Moodie 1996; City of Burnaby 1996). Therefore, the potential for the BMCD to become another sprawl-like community increases if the housing needs of the general public are SFU's first priority. Thus, Delcan's estimated traffic flows may be low if the majority of residents of the BMCD are not employed or study at SFU, Discovery Park, or BC Hydro.
7. Table 4-3 indicates that 560 BMCD ("expansion") trips will be generated for travel to SFU in the a.m. peak hour. Furthermore, it is estimated that approximately 1,000 "BMCD Vehicle" trips will be made off Burnaby Mountain in the p.m. peak hour. These estimates pose the following concerns:

- The DPC does not indicate why approximately 600 and 1,000 BMCD-related vehicles will travel to and from SFU in the a.m. and p.m. peak hours. One theory may be that these trips are work-related. That is, 600 people travel to the BMCD in the a.m. peak hour for employment purposes. If this is the case, one should be curious as to why these employment opportunities are not satisfied by residents of the BMCD. If this hypothesis proves true, these work-trips would put additional stress on SFU's transportation system and contribute to its status as a major 'trip-generator.'
- In addition, assuming that this theory is correct, it may be safe to further assume that the 600 people travelling to SFU in the morning for work are part of the 1,000 people leaving Burnaby Mountain in the p.m. peak hour. Therefore, there remain 400 trips off of Burnaby Mountain in the p.m. peak hour that are not accounted for. Again, the DPC does not indicate the purpose of these trips. If these trips are based on typical non-work trip estimates, such as shopping and recreation, this may indicate that the potential services provided within the BMCD do not fully satisfy the daily needs of its residents. Therefore, the BMCD may act as a 'reverse trip-generator,' where its lack of services and facilities encourage residents to travel off-site to satisfy their needs, such as the case now with the students that live on campus.

8. The OCP provides support for public transit, as Section 4.2.4 states that "public transit is to be facilitated through the design of development and roads...and pedestrian facilities that support transit" (City of Burnaby 1996, 11). However, unlike the Stormwater Management Plan in the DPC, Delcan's Transportation Analysis does not identify any new transit facilities, services, or stops to achieve this objective (Kerr Wood Leidal Associates 1996; Delcan 1996). This is a major shortcoming of its analysis.

In summary, Delcan's traffic flow estimates do not capture the full transportation impacts of the university's planned growth. Non-peak hour trips and trips made by carpoolers (i.e. 2 or more persons per vehicle) were not accounted for in Delcan's analysis. Furthermore, it is not indicated within the DPC what proportion of the future university population growth will reside in the BMCD. The distribution of housing units will likely have the largest impact on future transportation demands at SFU. It is therefore concluded that total traffic flows may increase from 150-200% over existing volumes. That is, future vehicle trips may increase from 20,000-25,000 to 50,000-75,000 one-way trips per day (i.e. 10,000-12,500 to 25,000-37,500 return trips per day). This growth in traffic volume will have serious ecological, social, and economic impacts.

B. Air Pollution

SFU's expected growth in transportation demands will put further pressure on local, regional, and global air quality. Table 2-5, outlined in Chapter 2, identifies the major types of air emissions and their associated production per vehicle kilometre driven. This table will be used in the following analysis to identify SFU's (Burnaby Mountain campus only) air emissions inventory and to calculate air emissions levels as of 1998.

The average one-way commute to work within the GVRD is 14 km (GVRD and Province of BC 1993a). In determining SFU's total vehicle emissions per day, it is assumed that the average one-way commute to SFU is slightly less than that of the GVRD average. This assumption is based on the results of a digital mapping exercise that identified where students with parking permits commute from – showing that many students drive from relatively close distances – and the fact that the majority of vehicle commuters are students (Moore 1999). A 10 km one-way distance is used in calculating SFU's daily emissions (i.e. 20 km return).

As indicated earlier, SFU's parking facilities provide stalls for approximately 6,500 vehicles at any one time. These stalls are utilised at nearly 100% during the peak hours of the day, which is between 8:00 a.m. and 3:00 p.m. (Coutu 1999). In addition, approximately 10,000 vehicles travel to SFU each weekday, as travel times and course schedules are dispersed throughout the day such that some parking facilities become vacant, particularly for night courses (Coutu 1999). As well, approximately 150 vehicles drive to the base of Burnaby Mountain each weekday and park on either Gaglardi Way, Burnaby Mountain Parkway, or in nearby residential areas (Coutu 1999). These students do not have parking permits and resort to driving to the base of the mountain, parking, and either hitchhiking or riding transit to access SFU.

The following data and assumptions are used to calculate SFU's daily vehicle air emissions levels:

- Average return commute to/from SFU is 20 km (10 km one-way).
- 10,150 vehicles travel to and from SFU each week day.
- 54% of vehicles (5,481 vehicles) are single-occupant vehicles (Petz et al. 1998).
- 36% of vehicles (3,654 vehicles) are 2-person carpools (Petz et al. 1998).
- 10% of vehicles (1,015) are 3 or more person carpools (Petz et al. 1998).
- 2-person carpools produce 50% less air emissions than single-occupant vehicles (Gordon 1991).
- 3 or more person carpool produce at least 67% less air emissions than single-occupant vehicles (Gordon 1991).
- Carbon Dioxide Equivalent Factor (CO_2E) is the global warming potential of Carbon Dioxide (CO_2), Methane (CH_4) and Nitrogen Dioxide (N_2O) (GVRD 1998a). Carbon Dioxide, Methane and Nitrogen Dioxide's global warming potential is equal to 1, 21 and 310 respectively. The following equation is used in calculating the total Carbon Dioxide Equivalent Factor (CO_2E): $CO_2 + CH_4(21) + N_2O(310)$.
- There are 40 weeks per year that SFU is in regular session (i.e. the daily on-campus population is approximately 12,000 people for 40 weeks per year).

Tables 4-4 to 4-6 highlight the quantities of vehicle air emissions per weekday for each vehicle passenger mode (i.e. SOV, 2-person carpool, and 3 or more person carpool). Table 4-7 indicates the total vehicle air emissions per weekday at SFU's Burnaby Mountain campus.

Table 4-4. Single-Occupant Vehicle Air Emissions Per Weekday at SFU

Type of Air Emissions	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CO	13.4	20	5,481	1,468,908	1,469
NO_x	1.3	20	5,481	142,766	142.75
PM	0.026	20	5,481	2,850.12	2.85
SO_x	0.047	20	5,481	5,152.14	5.15
VOC	1.5	20	5,481	164,430	164.43
CO_2	250	20	5,481	27,405,000	27,405
CH_4	0.039	20	5,481	4,275.20	4.28
N_2O	0.13	20	5,481	14,250.60	14.25
CO_2E	291	20	5,481	31,899,420	**31,899**

Table 4-5. 2-Person Carpool Vehicle Air Emissions Per Weekday at SFU

Type of Air Emissions	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CO	6.7	20	3,654	489,636	489.64
NO_x	0.65	20	3,654	47,502	47.50
PM	0.013	20	3,654	950	0.95
SO_x	0.0235	20	3,654	1,717.40	1.72
VOC	0.75	20	3,654	54,810	54.81
CO_2	125	20	3,654	9,135,000	9135
CH_4	0.0195	20	3,654	1,425.10	1.43
N_2O	0.065	20	3,654	4,750.20	4.75
CO_2E	145.5	20	3,654	10,633,140	**10,633.14**

Table 4-6. 3 or More Person Carpool Vehicle Air Emissions Per Weekday at SFU

Type of Air Emissions	[illegible]	[illegible] Distance	[illegible] Vehicles	[illegible] (grams)	[illegible] Weekday (kg)
CO	4.422	20	1,015	89,766.60	89.77
NO_x	0.429	20	1,015	8,708.70	8.71
PM	0.00858	20	1,015	174.17	0.17
SO_x	0.01551	20	1,015	314.85	0.31
VOC	0.495	20	1,015	10,048.50	10.05
CO_2	82.5	20	1,015	1,674,750	1,674.75
CH_4	0.01287	20	1,015	261.26	0.26
N_2O	0.0429	20	1,015	870.87	0.87
CO_2E	96.03	20	1,015	1,949,409	**1,949.41**

Table 4-7. Total Vehicle Air Emissions Per Weekday at SFU's Burnaby Mountain Campus (All Vehicles)

Type of [illegible]	[illegible]
CO	2,048.41
NO_x	198.96
PM	3.97
SO_x	7.18
VOC	229.29
CO_2	38,214.75
CH_4	5.97
N_2O	19.87
CO_2E	**44,481.55**

Table 4-7 indicates that approximately 45,000 kg of air emissions are released from vehicles travelling to and from SFU each weekday, with SOVs contributing over 50% of these emissions. This equates to over 200,000 kg over a given week and over 8 million kg of air emissions per year. These are discouraging results when one considers the fact that SFU is only one of many major trip destinations in the Lower Mainland. In addition, these emissions threaten the Kyoto Protocol, which calls for a 6% reduction from 1990 greenhouse gas emission levels in Canada (Last, Trouton, and Pengelly 1998). These transportation trends pose serious challenges to the success of the Kyoto Protocol.

Of greater concern however, are the expected future transportation demands associated with the university's student growth and community development. As indicated above, vehicle transportation demands may increase two to three times from its existing level once the university's growth period is completed. Therefore, daily air emissions could jump to 100-150,000 kg per day, or 20-25 million kg per year (i.e. assuming current levels of vehicle technology and transit service). These results indicate the urgent need to find realistic solutions to SFU's growing level of automobile dependence.

C. Noise Pollution

Road traffic is considered to be the most common source of unwanted noise (OECD 1995). Though the impacts of noise are largely subjective, excessive noise levels can result in the loss of environmental amenity and psychological well-being (Miller and Moffet 1993; Raad 1998). Furthermore, excessive noise can result in health, sleep, and productivity losses, as well as negatively impact wildlife (Raad 1998; Reinjin, Foppen, and Veenbaas 1997). Reijnen et al. indicate that traffic noise is the most critical factor in reduced wildlife densities and bird breeding in zones adjacent to busy roads (Reinjin, Foppen, and Veenbaas 1997).

A near tripling of vehicle traffic will thus have an impact on local, as well as regional, noise quality. In particular, the communities of SFU and BMCD may experience excessive noise levels due to this increase in vehicle traffic. This may therefore affect the quality of SFU as a working, research, and educational facility, as well as the overall livability of the BMCD. Furthermore, increased vehicle traffic and noise may intensify wildlife disturbance on and around Burnaby Mountain, not to mention the increased likelihood of road kill.

D. Vehicle-Pedestrian/Bicycle Conflict

The original design of SFU highlights the importance of strong pedestrian corridors that connect the community to most university facilities. Dedicated bike lanes from the Gaglardi Way and Burnaby Mountain Parkway intersection and off-road bike paths also exist in support of bicycle traffic. This design helps limit vehicle-pedestrian/bicycle conflicts, particularly, vehicle-pedestrian. However, as vehicle traffic increases with university growth, it will be critical for university and community planners to be conscious of the potential for serious vehicle-pedestrian/bicycle conflicts. In particular, the planning and design of the BMCD should make every attempt to accommodate pedestrians and cyclists first, transit second, and the private automobile last. This prioritisation is echoed within the GVRD's *Creating Our Future: Steps to a More Livable Region Plan*, where policies were approved to "give priority to walking, cycling, transit and then the private automobile" (GVRD 1990, 14). Furthermore, Section 2.9.3 of the OCP indicates that vehicular interference with pedestrian movement is to be minimised (City of Burnaby 1996). It is therefore important to reduce the possibilities for vehicle-pedestrian/bicycle conflict when designing livable communities. This will be an important element in planning the BMCD.

E. Infrastructure

Future transportation demands will place obvious stress on SFU's transportation infrastructure. The DPC indicates that there may be need to expand certain road facilities, extend roads, and build parking lots (Delcan 1996). On the other hand, the DPC and OCP both indicate the importance of protecting certain natural and ecologically sensitive areas (Moodie 1996; City of Burnaby 1996). These infrastructure developments require the use of land and may thus impact the local and regional environments. The following analysis investigates these impacts:

1. Naheeno Reserve road development;
2. South and East Neighbourhood road development;
3. West Campus Road extension;
4. Gaglardi Way, University Drive, and Burnaby Mountain Parkway expansion; and
5. The development of car washing stalls.

The DPC indicates the importance of linking the two South Neighbourhoods "to permit parents to drive children to school" (Moodie 1996, 30). This 'link' would require the development of a road through Naheeno Reserve. However, Section 2.4.1 of the OCP indicates that the "forested ravine and watercourse area popularly known as Naheeno Park has been identified as the most ecologically significant area within the Ring Road, and is to be maintained as a natural undeveloped park area" (City of Burnaby 1996, 3). Furthermore, Section 2.4.4 states that "no road is to be developed through Naheeno Park"

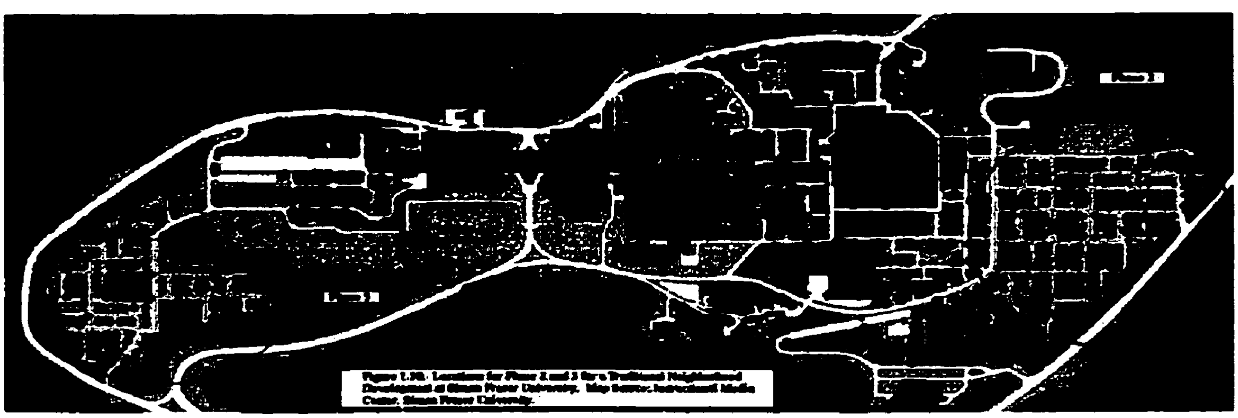
(City of Burnaby 1996, 4). This inconsistency in community planning threatens SFU's credibility in "continuing the university's record of combining environmental integrity with internationally recognised design excellence" (Moodie 1996, 1). Furthermore, it facilitates the development of automobile dependence, which increases vehicle air emissions, contributes to local and regional ecological degradation through increased water volume, velocity and contamination, and limits children's ability to develop "mobility-independence" (Engwicht 1993). Unfortunately, there is no mention within the DPC of the use of 'walking school buses,' or even motorised school buses, to transport children to and from school.

The development of roads within the South and East Neighbourhoods is proposed by Delcan (Delcan 1996). The need to develop some roads will exist within almost any community development. However, the community roads outlined in Delcan's transportation analysis present some concerns. The proposed South Neighbourhood roads that access Gaglardi Way and University Drive East may require controlled traffic light infrastructure. These investments would be costly and will be reflected in the market costs of the residential units. Furthermore, this infrastructure may cause serious transportation flow problems, particularly for vehicles turning left onto Gaglardi Way from the Southwest Neighbourhood enclave (refer to Figure 4-2). The estimated 1,500 vehicles travelling up Gaglardi Way to SFU in the a.m. peak hour will make it difficult for residents of this neighbourhood to turn left to access Gaglardi Way (Delcan 1996). Furthermore, cyclists travelling to SFU will be impeded if traffic lights are installed on Gaglardi Way to accommodate left-turning residents of the South Neighbourhood. Climbing Burnaby Mountain on a bicycle poses enough difficulty without having to stop cyclists on a grade to accommodate South Neighbourhood vehicle commuters.

Furthermore, previous Burnaby Mountain impact assessments recommend that the area known in the DPC as the South Neighbourhood (directly north of the Gaglardi Way/Burnaby Mountain Parkway intersection) should not be used for development (Sigma 1979). Sigma indicates that the environmental and aesthetic significance of the vegetated areas are too valuable to sacrifice for development. Furthermore, this area is highly valued as an educational resource, as several students and faculty use this area as a 'living classroom' (which has recently been echoed in a petition from SFU students to protect this area for academic purposes). Therefore, SFU should consider these concerns, along with the potential impacts of building roads through the Naheeno Reserve, into the decision making process regarding the development of this area.

In servicing the residents of the West Enclave Swing Residential area, Delcan proposes an extension of the West Campus Road to connect with Gaglardi Way (Delcan 1996). However, this road may not be required if development is concentrated in one area, rather than being spread throughout the developable site. In particular, the East Neighbourhood location may prove invaluable as a 'single-neighbourhood,' as a large majority of this area is well connected with roads. However, the greatest benefit of developing only the East Neighbourhood area is the fact that it has been previously cleared for surface parking. This parking area can serve as the foundation for the majority of housing units to be found within a 'single-neighbourhood,' thus providing space for low-impact, environmentally sensitive development (MacDonald 1999; Roppel and Roppel 1998; Plamondon et al. 1999). Lost parking could be replaced with either underground or multi-level parking facilities. This vision is illustrated in Figure 4-3, where the majority of residential development is located in the East Neighbourhood area on top of parking lots B, C, and E (refer to Figure 4-2 for a more detailed map of SFU).

Figure 4-3. Strategic Concept Plan for the BMCD Project (Plamondon et al. 1999)



Delcan proposes the need to upgrade the Gaglardi Way, University Drive, and Burnaby Mountain Parkway intersection due to the expected increase in transportation demands (Delcan 1996). In particular, a second left-hand turning lane on University Drive East to improve access to Gaglardi Way is proposed to be developed. It is important to note that the DPC does not mention the use of TDM measures to manage future transportation demands in order to avoid the increased infrastructure investments and associated ecological degradations. Delcan's ideology regarding transportation planning is 'supply-side' oriented, thereby suggesting that an increase in transportation infrastructure (i.e. roads) is the optimal strategy to manage increasing transportation demands. On the other hand, Least-Cost Planning (LCP) principles suggest that in some cases it is more economical to invest in TDM over supply-side management measures (Davidson 1997). LCP is a cost-benefit analysis tool that enables one to compare roadway expansion to TDM measures when evaluating strategies to manage transportation demands. Davidson indicates that total capital costs of building left-hand turn bays in Vancouver range from $1-2 million per bay (Davidson 1997). This public capital may be invested more wisely in appropriate TDM strategies, such as traffic reduction programs that reduce transportation demands, thereby reducing the need to construct costly road infrastructure.

Finally, Section 511.14 of the OCP recommends the development of 1 car wash stall per 100 units of housing (City of Burnaby 1996). This equates to the development of approximately 50 dedicated car washing stalls, thereby reducing the amount of productive land and increasing the amount of impervious surfaces (i.e. paved surfaces) on the developed site. This ultimately leads to higher water runoff and downstream ecological impacts to the Burnaby Mountain streams. This investment in additional infrastructure is excessive and it is recommended that car washing stalls be integrated into the general parking facility plan (i.e. multi-purpose parking stalls), thus reducing the need to build dedicated car wash stalls.

E. Water Quality Impacts

The above mentioned transportation impacts arising from the estimated increase in traffic flow also negatively impact water quality in the surrounding watersheds. Burnaby Mountain receives 2,200 mm of rain annually, twice the amount of south Burnaby, which should be of serious concern when planning this development (Yarnell and Sandmann 1997). The following list outlines some of the key concerns with respect to water quality on and around Burnaby Mountain:

- The clearing of forested areas for roads and neighbourhood developments increase water runoff which may lead to erosional impacts;
- The increased impervious surfaces contribute greater levels of contaminants, such as hydrocarbons, to the Burnaby Mountain waterways;
- The proposed community development and roads impact hydrological patterns, thus changing soil drainage characteristics; and
- The proposed diversion of Silver Creek in the South Neighbourhood may have unforeseen ecological impacts.

The DPC proposes that the majority of forested area within the Ring Road be cleared for the development of residential units. However, Sigma indicates that peak runoff rates significantly increase when forested areas are cleared for development (Sigma 1979). Increased water runoff contributes to soil erosion and tree instability, due to the water logging of soil, which further contributes to the 'silting' of downstream waterways. This contamination has adverse effects on the fish-bearing streams of Stoney, Silver, and Piper Creeks. Principle 5, in the City of Burnaby's *State of the Environment Report (SOER)* (1993), mandates that development must "achieve a zero net increase in runoff and avoid the degradation of water flowing into the three watersheds (Burrard Inlet, Central Valley, which includes Burnaby Mountain, and the Fraser River)" (Stewart 1996, np). Furthermore, Burnaby Bylaw Number 9044 "prohibits the discharge of silt and other contaminants to streams, creeks, waterways, watercourses, waterworks, ditches, drains, sewers, and storm sewers" (Stewart 1996, np). The increase in impervious surfaces associated with this community development will increase the volume and velocity of water runoff. This increased flow will also collect additional contaminants, such as hydrocarbons from parking lots and roads, as well as other residential pollutants, and may significantly impact local water quality (Yarnell and Sandmann 1997). Furthermore, hydrological patterns may change, thus impacting soil drainage characteristics.

Previous studies indicate that some creeks on Burnaby Mountain are contaminated. Studies completed by Stewart Environmental Ltd. suggest that water samples collected from Naheeno Creek, which is the most significant watercourse flowing south off of Burnaby Mountain, have very high suspended solids counts (217 mg/l) (Stewart 1996). In particular, nitrate, aluminium, iron, zinc, and total and fecal coliforms exceeded the Canadian Water Quality Guidelines (Stewart 1996). Naheeno Creek provides high value for flow, nutrient, and fish food organisms for downstream areas including Piper, Silver, and Stoney Creeks and the Brunette River. It may be critical, therefore, that this watercourse is retained in its natural state.

As mentioned above, Stoney, Piper, and Silver Creeks are all fish-bearing streams. Of great concern is the release of contaminated stormwater directly to these streams. However, the stormwater assessment completed by Kerr Wood Leidal Consultants overlooks the full ecological impacts associated with building road and parking infrastructure, such as water quality, stormwater runoff, and habitat loss (Alexander, Yarnell, and Sandmann 1997). Fortunately, the OCP supports the maintenance of water quality, indicating in Section 4.5.2 that development must protect the environmental resource values of the downstream watercourses through the maintenance of *pre-development runoff rates and water quality* (City of Burnaby 1996).

An intact forest is critical to the health of the forest ecosystem, as it acts as a sponge and absorbs rain and snowwater and further feeds this recharge into the Brunette River (Alexander, Yarnell, and Sandmann 1997). Section 3.3.1 of the OCP mildly supports this perspective by indicating that it is important to retain significant trees (City of Burnaby 1996). However, "significant trees," or the criteria to identify these trees, has not been explained within the OCP. In addition, the protection of "significant trees" may not be sufficient to maintain the overall health of the Burnaby Mountain ecosystem.

To manage these concerns, the DPC states that the "university's goal is to implement and maintain an environmentally sensitive, technically sound, and fiscally responsible Master Drainage Plan for the university's environment and the surrounding community" (Moodie 1996, 20). However, this management plan involves further diversions of waterways into culverts, retention ponds, and oil/water separators. There is no indication within the DPC of the integration of treatment systems to remove contaminants or suspended sediments (Yarnell and Sandmann 1997). Furthermore, there is no discussion regarding 'proactive' community design strategies, such as the development of a single-neighbourhood on the parking lots in the East Neighbourhood area to minimise the potential water runoff and contamination problems. This approach to a Master Drainage Plan is inconsistent with Principle 4 of the City of Burnaby's SOER (1993), which states that "all streams should be left in their natural state and vegetation removal and channelling should be avoided" (Stewart 1996, np). This principle further states that the "headwaters of twelve creeks occur on Burnaby Mountain and it is therefore imperative that the remaining undeveloped lands be protected from development in order to ensure that the sensitive habitats are not disturbed and destroyed" (City of Burnaby 1993, np).

Increased water flow off Burnaby Mountain may pose serious threats to the health of the local and regional ecosystems. The above stated concerns should therefore be addressed by SFU. Furthermore, consideration should be given to the development of a 'single-neighbourhood' on the east parking lots (Lots B, C, and E), as envisioned by Roppel and Roppel (1998), MacDonald (1998), and Plamondon et al. (1999) (see Figure 4-3). This alternative community design could minimise water runoff and other associated ecological impacts, as well as provide many social and environmental benefits.

F. Habitat and Wildlife Impacts

Stewart states that "impacts to important wildlife habitats should be minimised wherever possible" (Stewart 1996, np). Burnaby Mountain, being one of the last large greenspaces in the GVRD, provides a home to many species of plants and animals. There exist eleven rare and/or endangered species on Burnaby Mountain (Stewart 1996). The proposed South Neighbourhood and associated community road pose great threats to the wildlife of this area. These forests are classified as "mixed deciduous/coniferous" and provide the most valuable habitat for the wildlife of Burnaby Mountain (Moodie 1996). Furthermore, the Naheeno Reserve and Hydro right-of-way act as a "natural wildlife migration corridor" (Moodie 1996, 21). In discussing the value of the study site, Stewart states, "although development with respect to the study area will permanently remove habitats currently utilised by wildlife, no wildlife populations of Burnaby Mountain are expected to be extirpated due to development activity" (Stewart 1996, np). This assessment of wildlife impacts should be of great concern to the BMCC, as it may be unreasonable for Stewart to indicate that wildlife populations will not be impacted by development activity given the fact that their habitat will be destroyed.

Furthermore, wildlife may be impacted by traffic noise, as excessive traffic noise causes the most significant impacts to wildlife populations (Reinjin, Foppen, and Veenbaas 1997). In addition, 'road kill' potential increases with the development of roads, particularly through wildlife habitat, and increases in traffic volume, especially round-the-clock traffic.

Therefore, the proposed community development and road in the South Neighbourhood area may create serious risks to wildlife health, as critical habitat will be lost, migration corridors cut off, and noise pollution may cause excessive disturbance.

G. Recreation and Cultural Impacts

Burnaby Mountain provides recreational opportunities for many residents of the local and Greater Vancouver area. Walking and cycling trails are heavily used by casual walkers, serious cyclists and hikers, and naturalists. This area therefore holds great value to many people of the GVRD as it represents an opportunity to re-connect with nature. However, the value of viewing wildlife, old-growth stumps, and an intact forest has not been addressed within the DPC or OCP.

Yarnell and Sandmann indicate that there may be some cultural and/or social impacts due to the change from a student-dominated campus to a mixed-use neighbourhood (Yarnell and Sandmann 1997). Possible social impacts include the "alienation of the university population from the Burnaby Mountain environment and potential conflicts between residents and students with respect to 'ownership' of the mountain" (Yarnell and Sandmann 1997, 26).

The cultural history of Burnaby Mountain, where massive stumps of old-growth forest can be found, is also very rich. This richness should be protected to provide educational and interpretive opportunities for the residents of the BMCD, the community of SFU, and the citizens of the GVRD. As the DPC indicates, community development should respect and complement the natural heritage of Burnaby Mountain (Moodie 1996).

Conclusion

The transportation impacts associated with the proposed BMCD are of great concern. Traffic flow may increase 200% from 25,000 to 75,000 one-way trips per day. This would increase SFU's vehicle air emissions levels from 45,000 to over 100,000 kg per day (assuming current levels of technology and transit service), having obvious impacts on local, regional, and global air quality. It is unfortunate that neither the DPC nor OCP commit to a *no net increase in transportation flows*, as mandated for water management at SFU (Moodie 1996; City of Burnaby 1996). Noise pollution may increase, thus impacting the livability of the campus, and in particular, the BMCD. In addition, traffic flow may impede the movement of pedestrians and cyclists, further reducing the community's livability. The development of road infrastructure may be detrimental to the local environments of Burnaby Mountain. The clearing of forests and increased impervious surfaces may increase the velocity and volume of water flowing down Burnaby Mountain, thus impacting the quality of water in local fish-bearing streams. Furthermore, habitat loss will impact local wildlife. The economics of road investments may not be sound, and investments in TDM measures may prove more economically efficient and productive in managing transportation demands. Finally, the sensitive development of Burnaby Mountain should maintain the many recreational, cultural, and educational opportunities for the future residents of the Burnaby Mountain community, the citizens of the Greater Vancouver area, and visitors from around the world.

4.5 Summary of SFU's Land Use and Transportation Management Policies and Plans

4.5.1 Official Community Plan

The OCP, adopted by the City of Burnaby Council in September 1996, provides a broad vision of the community development to take place at SFU within the next 10 to 30 years. The OCP outlines policies that will guide development, unless otherwise amended by Council, and these are based on the preliminary vision put forward in the DPC. The OCP will be discussed first – though based on the DPC's vision – due to its official policy status (i.e. official City of Burnaby land use policies). The policies that are related to the focus of this study are highlighted below, and will be later evaluated against the *Master Sustainable Transportation and Land Use Planning Framework*.

Table 4-8. Official Community Plan Policies Related to Transportation and Land Use Planning at SFU (City of Burnaby 1996, 2-12)

OCP Section	[illegible]
2.2.2	University development includes student housing, which currently accommodates 1,400 residents. This is expected to quadruple to about 5,600 residents over the long term. This development will be in the University Enclave area and is not considered part of the BMCD project. However, there may be opportunities to integrate student housing with the mixed-use commercial development (see OCP Section 2.9.2).
2.4.4	An improved pedestrian/bicycle trail is to be developed along the utility corridor through Naheeno Park to link the east and west portions of the South Residential Neighbourhood. The trail will be 4 m (13 ft.) in width and will include bridges or open arch structures over the Eagle and Silver Creek tributaries. Although the trail may also provide for occasional service vehicle access for the utilities located within the corridor, no road is to be developed through Naheeno Park (zoned as P3 – protected park area).
2.5.1	Two market Residential Neighbourhoods (South and East) totalling up to approximately 65 ha (160 acres) in area can be potentially developed within the Ring Road. A total of up to 4,536 housing units can be developed in the two Neighbourhoods. Either one, or both, or neither Neighbourhood at the option of the University may be developed for residential uses, as an alternative to University use.
2.5.4	South Neighbourhood Development Statistics • P11 zoning: single-use zoning • Core = 16.2 ha (40 acres), 1,214 units • Swing = 3.6 ha (9 acres), 273 units • Total = 19.8 ha (49 acres), 1,487 units • Maximum unit density (net): 75 units/ha (30 units/acre) with underground parking, 30 units/ha (12 units/acre) with surface parking. • Population density: 225 persons/ha (90 persons/acre) with underground parking, 90 persons/ha (36 persons/acre) with surface parking (based on average occupancy of 3 persons per unit). • Floor Space Ratio (FSR)[20]: 0.7 - 0.9 with underground parking (moderate density), 0.45 maximum with surface parking (low density). • Maximum Lot Coverage: 0.30 East Neighbourhood Development Statistics • P11c zoning: mixed-use and horizontal zoning • Core = 8.7 ha (21.6 acres), 1,312 units • Swing = 11.6 ha (28.6 acres), 1,737 units • Total = 20.3 ha (50.2 acres), 3,049 units • Maximum unit density (net): 150 units/ha (60 units/acre) with underground parking, 30 units/ha (12 units/acre) with surface parking. • Population density: 300 persons/ha (120 persons/acre) with underground parking, 60 persons/ha (24 persons/acre) with surface parking (based on average occupancy of 2 persons per unit). • Floor Space Ratio (FSR): 1.1 - 1.7 with underground parking (high density), 0.45 maximum with surface parking (low density). • Maximum Lot Coverage: 0.35

[20] FSR, or "Floor Space Ratio," is defined as the number of square feet of floor space in buildings relative to the square footage of the property or lot. FSR = Floor Area divided by Lot Area (Roseland 1998, 128; Moodie 1997).

Table 4-8. Official Community Plan Policies that are Related to Transportation and Land Use Planning at SFU (City of Burnaby 1996, 2-12) – continued

OCP Section	[illegible]
2.6.1	A school site with an area of 2.8 ha (6.9 acres) is provided within the Core area of each Residential Neighbourhood.
2.7.2	Neighbourhood park sites located and sized as follows are also to be provided to the City on a coterminous leasehold basis at no cost at the time of initial residential subdivision within a Neighbourhood.
2.8.1	The University commits to developing one furnished childcare facility within each Neighbourhood, with capacity based on one space per 40 residential units, to a maximum of 60 children.
2.8.3	The University has committed to making every effort to provide residents of the Residential Neighbourhoods with reasonable access to the University's Library and Recreation Services on a user-pay basis, subject to the priority that must be accorded to the University community.
2.9.1	Commercial development to serve the University and residential communities is to be located at the east end of the University's main axis adjacent the East Neighbourhood.
2.9.2	Total commercial floor area should be 10,000 to 20,000 m^2 (110,000 to 220,000 $ft.^2$). The commercial development should consist of retail, personal service and office uses servicing the day-to-day needs of residents of the Neighbourhoods and members of the University Community. Mixed-use commercial development also incorporating University uses or offices, or student or market housing, may be feasible. Relocation of the existing gasoline service station to the identified commercial area, subject to appropriate design considerations, is encouraged.
2.9.3	The commercial development should be designed as a primarily pedestrian-oriented area with strong links to the University and residential pedestrian and bicycle networks. Vehicular interference with pedestrian movement is to be minimised.
3.1.1	Subdivision, servicing, site planning and design for development within the Ring Road is to be sensitive to the existing natural environment including topography, watercourses, significant trees and wildlife habitat.
4.2.3	The pedestrian and bicycle modes of transportation are to be promoted and facilitated within the Ring Road through the provision by the University of sidewalks, bicycle and pedestrian path networks (generally on statutory rights-of-way) to City standards as a condition of subdivision. Bicycle parking facilities are to be provided within developments. Pedestrian facilities should provide for access for the mobility impaired.
4.2.4	Public transit is to be facilitated through the design of development and roads, and through the provision of pedestrian facilities which support transit usage and provide convenient and safe pedestrian access to existing and potential transit stops.
4.5.2	The Watercourse and Storm Water Management Plan is intended to allow land development in accordance with this Plan to proceed within the Ring Road while protecting the environmental resource values of the downstream watercourses; i.e. Stoney Creek, Eagle Creek and Silver Creek. Issues to be addressed include: • maintaining pre-development stormwater runoff rates, volumes and seasonal variations to maintain existing downstream hydrologic patterns. • maintaining pre-development water quality to ensure downstream aquatic life is not adversely affected.
511.6 (Zoning Bylaw)	Each lot shall have an area of not less than 4,000 m^2 (43,057.05 $ft.^2$) and a width of not less than 37 m (121.39 ft.)

Table 4-8. Official Community Plan Policies that are Related to Transportation and Land Use Planning at SFU (City of Burnaby 1996, 2-12) – continued

[illegible]	[illegible]
511.9 (Zoning Bylaw)	A front yard shall be provided of not less than 7.5 m (24.61 ft.) in depth, except that where lots front on the Ring Road or Gaglardi Way, the front yard shall be not less than 15 m (49.2 ft.) in depth.
511.10 (Zoning Bylaw)	A side yard shall be provided on each side of the building of not less than 7.5 m (24.61 ft.).
511.11 (Zoning Bylaw)	A rear yard shall be provided of not less than 7.5 m (24.61 ft.).

511.12 (Zoning Bylaw)	Off-street parking shall be provided and maintained in accordance with Schedule VIII of this Bylaw (City of Burnaby). Related sections of Schedule VIII are as follows (City of Burnaby 1999)[21]:
	• Single-family, two-family, and row-house dwellings: 1 parking space/unit
	• Multiple family dwellings:
	    • Townhouses: 1.75 parking space/unit; 0.25 spaces/unit for visitor parking.
	    • Townhouses in RM6 Districts: 1 space/unit.
	    • Apartments in C8 and C8a Districts: 1 space/unit.
	    • Apartments (access by common corridor): 1.6 spaces/unit; 0.25 spaces/unit for visitor parking.
	    • Non-profit housing (townhouse or apartment): 1.5 spaces/unit; 0.2 spaces/unit for visitor parking.
	• Dwellings related to commercial or other premises: 1 space/unit.
	• Boarding, lodging or rooming houses, fraternity or sorority houses: 1 space/2 sleeping units.

511.14 (Zoning Bylaw)	One car wash stall with a "No Parking" sign affixed to it shall be provided for each 100 dwelling units.

4.5.2 Development Plan Concept

The DPC was submitted to SFU and the City of Burnaby in February 1996, and set the envisioning and planning process in motion. Though the DPC is not a policy statement, it does provide a development plan for the future community at SFU. This plan is highlighted below and will be later evaluated against the *Master Sustainable Transportation and Land Use Planning Framework.*

[21] Refer to Appendix 3 for details of other parking bylaws (e.g. retail and commercial parking).

Table 4-9. Development Plan Concept Plans that are Related to Transportation and Land Use Planning at SFU (Moodie 1996)

A. University Growth Management
• Development of a 10,000 person community (market housing with allocation unknown).
• Increased student enrolment from 15,000 FTE to 25,000 FTE.
B. Land Use
• Public open space and recreational facilities: • expansion of the range of available recreation options.   • equitable access to public open space, within a reasonable walking distance.   • development of useable public open space as a central feature of new development enclaves.   • provision of play facilities and opportunities within neighbourhood enclaves.
• Commitment by SFU that should market residential development proceed, it must result in one or two viable neighbourhoods, with sufficient amenities and facilities to satisfy the needs of a diverse community (G.2.1, page 29). The functioning University will provide, where possible, access to the Art Gallery, Archaeology Museum, athletic events, credit courses, guest lecturers, children's programs, University Library, indoor and outdoor recreation programs, and interaction with the University in general (G.4, page 31).
• Along major roadways, University Drive, and South Campus Road, setbacks will be 10.7 m from non-University uses. Other setbacks will be 7.6 m from the development to local roadways, pedestrian pathways, and internal property lines (H.1.4, page 38).
C. Transportation Management
• 150% increase in SOV travel.
• Naheeno Reserve road development – proposed to link the two South Neighbourhoods "to permit parents to drive children to school, and to access this major community facility without having to venture on to the Ring Road" (page 30) – would result in the development of a road through Naheeno Reserve.
• South and East Neighbourhood road development.
• West Campus Road extension.
• Gaglardi Way, University Drive, and Burnaby Mountain Parkway expansion – development of a second left-hand turn bay at the intersection of these roads to manage transportation demands.
• The future transportation network will need to recognise the importance of bicycle lanes and pedestrian links, as well as increased transit services responding to the likelihood of significantly reduced parking availability relative to the size of the future University population (E.2, page 17).
• Pedestrian network (D.3.4, page 8; G3.1, page 30):   • expansion of the pedestrian network of safe, well-lit roadside sidewalks and forest paths, including emergency telephone posts.   • provision of paved sidewalks based upon evaluation of road traffic volume, bus stop requirements, tree retention opportunities, and the context of other pedestrian route options. Sidewalks on both sides of a road, or on one side only, may be considered to balance road safety, tree retention, and road character objectives.   • integration of the pedestrian network with development enclaves, providing direct links to neighbourhood destinations.   • integration of the pedestrian network with the trail network.   • provision of barrier free route options, where possible, to neighbourhood destinations.   • minimisation of damage to water courses, soils, vegetation, and wildlife.

Table 4-9. Development Plan Concept Plans that are Related to Transportation and Land Use Planning at SFU (Moodie 1996) – continued

• Bicycle network (G.3.2, page 30): • provision of a place for cyclists within the road network. • provision for bike locking and storage at neighbourhood and campus destinations. • development of some trails as shared cycle and pedestrian routes. Upgrade development of these routes to control trail damage.
• University's desire to efficiently service people and vehicles while not disrupting pedestrian traffic (G.3.2, page 30).
D. Environmental Management
• Site planning and design based upon an understanding of natural systems (F.1, page 19; Province of BC 1995b)
• Minimisation of negative environmental impacts (F.1, page 19).
• Most valuable wildlife habitat is mixed deciduous/coniferous forest, which makes up the entire South Neighbourhood area (South Slope Enclave Core and West Slope Enclave) and the majority of the East Neighbourhood area (Water Tower Enclave Core and East Gate Enclave Swing) (F.7, page 21).

4.5.3 Transportation Management Policies at Simon Fraser University

SFU has dedicated a large portion of its transportation management resources to 'supply-side' strategies, that is, the provision of parking facilities for the majority of the community. This is represented in the official parking-to-population ratio, where approximately one parking stall exists for every 2 persons on campus, as the daily on-campus population is 12,000 people and there are over 6,000 parking stalls available on campus. Unofficially, however, the parking-to-population ratio is 1 stall for every 1.2 persons, as approximately 10,000 vehicles are driven to campus each day given the flexibility of schedules and travel times (Coutu 1999).

On the other hand, SFU has also invested time and resources in the development of ridesharing programs and transit infrastructure and services. These transit services, nonetheless, are directly managed by TransLink, which thus develops the majority of policies for service to and from SFU campuses, such as express routes and pricing. Tables 4-10 and 4-11 outline the parking and transit policies in existence today that bear relevance to this study.

Table 4-10. Parking Policies at Simon Fraser University

[illegible]
Parking-to-population ratio is 1:2 (official) or 1:1.2 (unofficial).
Parking permit price schedules: • general permit = $93, $102, $255 (reserved) per 4 month term. • rideshare (car/vanpool) = $170/vehicle per 4 month term.
The percentage of total parking dedicated to car/vanpool parking is approximately 4%.
Committee on Parking Policy Proposals: • All permit holders should be allowed to register a maximum of four (4) vehicles per permit account. • Vanpool vehicles should be assigned a complimentary 'reserved' space in more highly visible area of C-Lot or be allowed to negotiate a parking space that is convenient to the vanpoolers. • As an additional incentive for vanpooling, each vanpool vehicle should be allowed enough complimentary parking vouchers to accommodate instances when members must use their personal vehicles to attend SFU. • Each vanpool member should receive a complimentary Evening/Weekend Permit to allow personal vehicles to be used during non-peak periods. • Parking Services should initiate a program to encourage Faculty/Staff to carpool in order to free up parking spaces on campus. • Carpool incentives should be introduced to encourage more Faculty/Staff carpooling. • Additional carpool incentives should be added to the Rideshare Program to encourage formal carpooling among undergraduates.

Table 4-11. Transit Policies at Simon Fraser University[22]

[illegible]
Dedicated transit users pay approximately $220 per term ($54/month for 4 months), assuming they use the Fastrax discount program ($3 sticker), where students get unlimited all-zone travel for the price of a one-zone monthly transit pass.
Six direct routes with minimum headways of 15 minutes.

The above policies and plans provide an insight into the land use and transportation management perspectives at SFU. These policies and plans will now be evaluated against the 1st and 2nd priority indicators identified in the *Master Sustainable Transportation and Land Use Planning Framework*. In other words, this framework will be used to identify the strengths and weaknesses of the above outlined plans. This evaluation will provide the foundation for developing sustainable transportation and land use policies for SFU's Burnaby Mountain campus in an attempt to achieve a minimum 20% SOV traffic reduction target in both the short and long-term.

[22] Transit policies at SFU are mainly the result of TransLink management policies.

Chapter 5 Evaluation of Simon Fraser University's Land Use and Transportation Management Policies and Plans

5.1 Introduction

The evaluation of SFU's Official Community Plan, Development Plan Concept, and general transportation management policies against the *Master Sustainable Transportation and Land Use Planning Framework* will be completed in this chapter. This evaluation will identify the relationship between these policies and plans and the master sustainability indicators developed in Chapter 3. That is, the evaluation will indicate whether SFU's current policies and plans will positively or negatively impact the master indicators, and thus how these impacts may influence the achievement of the sustainable transportation and land use goals of this study. These results will then form the basis for the development of sustainable transportation and land use policies for SFU, which will be completed in Chapter 6.

5.2 Evaluation of Policies and Plans

The policies and plans outlined above will now be evaluated against the 'master' sustainability indicators. That is, each policy or plan will be assessed as to how they impact each of the 1st and 2nd priority indicators. For example, policies that reduce accessibility to transit and shopping will negatively impact many of the master sustainability indicators. Likewise, policies that encourage mixed-use development, thus reducing the need to drive off-site to satisfy daily needs, will positively impact the master sustainability indicators. The following sections will investigate the potential impacts of the OCP, DPC, and SFU's general transportation policies (refer to Tables 4-8 through 4-11) on the *Master Sustainable Transportation and Land Use Planning Framework*.

5.2.1 Official Community Plan

Section 2.2.2

Though not officially part of the BMCD project, SFU's commitment to quadrupling its on-campus student residence is an ambitious and progressive initiative that will achieve significant transportation efficiencies, as fewer students will need to travel to and from campus. According to Section 2.9.2, student housing opportunities may be integrated with the mixed-use commercial development (e.g. apartments mixed with retail) and thus may be part of the BMCD project (though there is no indication as to whether this type of student housing would be University owned/operated or operated by private home owners). This policy will *positively* influence the following master indicators: percentage of residents who live and work in the same community (jobs-housing balance); percentage of dwelling units within 400 meters of transit service; annual number of walk, bicycle, and transit trips per capita; annual VHT and VKT per capita; modal split for work and non-work trips; percentage of citizens living within 30 minutes of work (or study) by transit, bicycle, or walking; annual gasoline consumption (MJ or litres) per capita; percentage of city/community with a minimum average density of 30 upa; percentage of residential units that are not single-family homes; mix of housing and funding types, tenures, tenants, and income levels; and the average number of "spontaneous exchange" experiences per capita per day.

Section 2.4.4

This policy achieves two significant sustainable transportation principles. First, pedestrian and bicycle travel are encouraged through the development of trails. Second, road development is prohibited in ecologically-sensitive areas, indicating SFU's priorities for conservation over vehicle mobility. This policy will thus *positively* impact the following master indicators: annual number of walk, bicycle, and transit trips per capita; percentage of employment, transit, and public facilities with bike/walk infrastructure (e.g.

bike/walk lanes, racks, showers, and locker rooms); annual VHT and VKT per capita; modal split for work and non-work trips; annual gasoline consumption (MJ or litres) per capita; percentage of dwelling units within 400 meters of transit service; percentage of street area that is dedicated to walking, cycling, and transit; percentage of institutions/employers (over 100 employees) that offer traffic reduction programs; and public/private savings from reduced auto dependence.

Section 2.5.1

The adaptability of this policy to develop one, both, or neither of the neighbourhoods has both positive and negative characteristics. On the *positive* side, this policy provides the University with great flexibility in designing the community. SFU and the City of Burnaby have designed an open land use plan that is adaptable to the numerous design alternatives that will be proposed, thus enabling them to eventually develop with little, or no, re-zoning.

On the other hand, the OCP land use concept (Figure 4-2) indicates that two distinct neighbourhoods can be developed. If pursued, the development of these two neighbourhoods may not achieve certain sustainability objectives, as accessibility to the commercial core and transit station will be reduced for residents of outlying residential areas, such as the South Neighbourhood core and swing areas, thus increasing the need to travel by private vehicle to access one's daily needs. For example, the majority of South Neighbourhood residents (all enclaves) will not be able to access the proposed commercial area and transit station, located in the East Neighbourhood, within a 5-10 minute walk (approximately 400 meters). This greater distance becomes even less attractive when the slope of the mountain and climatic conditions (i.e. high level of rainfall) are included in the transportation decision-making process. With accessibility reduced, due to the increased distance to transit and commercial services, the majority of transportation-related master indicators may be *negatively* impacted. These include the percentage of residential units within 400 meters of transit and shopping, VHT and VKT, gasoline consumption, and the number of walk, bicycle, and transit trips taken per year. The impacts of this policy on the master indicators thus depends on how the community is developed.

Sections 2.5.4, 511.6, and 511.9 – 511.11

The South and East Neighbourhood development statistics highlighted in this policy also include both positive and negative characteristics. On the *positive* side, the East Neighbourhood densities are sufficient to achieve transportation and land use efficiencies if underground parking facilities are developed. That is, if the East Neighbourhood community is developed with underground parking, its maximum net density of 60 units per acre satisfies the 30 dwelling units per acre (gross) criteria identified in the master indicators framework. However, if surface parking facilities are developed for the East Neighbourhood, its unit densities will not achieve this indicator benchmark of 30 upa. Furthermore, this holds true for the South Neighbourhood, as maximum net densities for both underground and surface parking scenarios do not satisfy the 30 upa density benchmark, given that "net" densities are lower than "gross" densities.

The P11e zoning status for the East Neighbourhood also provides some critical land use benefits. This zoning proposal allows for mixed-use development, where institutional, commercial, retail, and residential uses can be integrated in one area. This integration of uses fits well with the principles of traditional neighbourhood development and sustainable communities, as discussed in Chapter 2. However, its weakness lies in its focus on 'horizontal' versus 'vertical' development zoning. Horizontal zoning allows for only single-use buildings (i.e. offices in one building, residences in another building), thus requiring more land to develop the proposed institutional, commercial/retail, and residential units. Vertical zoning, on the other hand, enables buildings to integrate the mixed uses of office, retail, and residences in each building. For example, typical vertically zoned buildings will have retail and commercial services at the street level (i.e. first floor), professional services and offices on the second level, and private residences on the upper levels (i.e. third floor and up). Vertical mixed-use zoning thus conserves significant land resources and increases accessibility. Though it lacks vertical zoning, the proposed P11e zoning for the East Neighbourhood is progressive and will achieve several sustainability objectives. This policy may therefore *positively* impact the following master indicators: percentage of community that is zoned for mixed-use and transit-oriented/traditional neighbourhood development; mix of housing and funding types, tenures, tenants, and income levels; the number of vehicles per household; percentage of dwelling units within 400 meters of transit and shopping; annual number of walk, bicycle, and transit trips per capita; percentage of city/community with a minimum average density of 30 upa (excluding the East Neighbourhood with underground parking scenario); percentage of residents who live and work in the same community/municipality (jobs-housing balance); percentage of citizens living within 30 minutes of work by transit, bicycle, or walking; annual number of VHT and VKT per capita; modal split between work and non-work trips; annual gasoline consumption (MJ or litres) per capita; average number of "spontaneous exchange" experiences per capita per day; availability and institutional support for 'Green'/Location-Efficient Mortgages; public/private savings from reduced auto dependence; percentage of residential units that are not single-family homes; and the percentage of the community that is pervious to water.

The South Neighbourhood P11 zoning proposal allows for only residential development, however, thus segregating commercial and institutional uses from residential. Without commercial opportunities in the South Neighbourhood, this policy, as indicated above, reduces accessibility to transit and commercial services as the proposed commercial centre and transit station fall outside the 400 meter 'walkability' radius. It is therefore of concern that this zoning schedule will offset the land use and transportation efficiencies gained in the East Neighbourhood (P11e zoning). The P11 zoning proposal may thus *negatively* impact the master indicators listed above for the P11e zoning.

Of further concern are the proposed maximum lot coverage guidelines and the City of Burnaby Zoning Bylaws (511.6, and 511.9 – 511.11). The maximum lot coverage of 0.30 and 0.35 in the South and East Neighbourhoods indicates that only 30-35% of the entire lot will be used to develop residential and commercial units, with 65-70% dedicated to private yard and public space. The zoning bylaws further support these lot coverage guidelines. Lot sizes are land intensive, using a minimum of 4,000 m^2 per lot – though it has been indicated that this lot size is excessive and may require a zoning amendment (Geller 2000). In addition, private yards are also land intensive, with front yards having a minimum setback depth of 7.5 meters (15 meter minimum for lots that front Ring Road and Gaglardi Way), dedicated side yards on each side of the building at a minimum depth of 7.5 meters, and rear yards also at a minimum depth of 7.5 meters. From a land use efficiency perspective, these lot coverage standards and zoning bylaws reduce densities and demand greater amounts of land in order to satisfy development requirements. In other words, with more space dedicated to front, back, and side yards than the building itself, the "footprint" (i.e. total land area used) of the entire community increases and expands across the potentially developable area (Wackernagel and Rees 1996). This 'sprawling' of development will impact accessibility to transit and the retail/commercial needs of residents, thus increasing the number of vehicle trips made per day and reducing local and global air quality; and increase the need for infrastructure such as roads, which ultimately impacts water runoff levels and water quality.

This policy may therefore *negatively* impact the following master indicators: percentage of dwelling units within 400 meters of transit and shopping; percentage of city/community with a minimum average density of 30 upa; annual number of walk, bicycle, and transit trips per year; modal split for work and non-work trips; annual number of VHT and VKT per capita; annual gasoline consumption (MJ or litres) per capita; percentage of streets that are traffic calmed; average number of "spontaneous exchange" experiences per capita per day; the number of vehicles per household; public/private savings from reduced auto dependence; and the percentage of the community that is pervious to water.

Related to land use and density are the proposed floor space ratios (FSR) indicated in the OCP. Of particular concern is the 0.45 maximum FSR in the South and East Neighbourhoods if surface parking is developed. Roseland indicates that FSRs of less than 0.6 represent low density development (Roseland 1998). The critical factor here is thus parking facility type, as FSRs drop by 50-300% in the South and East Neighbourhoods respectively when underground parking options are compared with surface parking (i.e. 0.7-0.9 versus 0.45 FSR in the South Neighbourhood and 1.1-1.7 versus 0.45 FSR in the East Neighbourhood). As discussed in Chapter 2, low density urban development fuels the negative feedback loop that leads to increasing levels of automobile dependence, as low density development reduces accessibility for pedestrians and cyclists and decreases the efficiency of transit, which in turn increases the demand for automobile travel (Raad 1998; Newman and Kenworthy 1989; Newman and Kenworthy 1999). These land use and transportation phenomena cause significant ecological, social, and economic impacts (Newman and Kenworthy 1999; Roseland 1998; Gordon 1991; NRTEE 1997; Durning 1996; Engwicht 1993; Jacobs 1961). The FSR ratios associated with underground parking represent moderate to high density development, and therefore achieve certain sustainable development objectives (Roseland 1998). It is thus recommended that the development of surface parking be prohibited to achieve land use and transportation efficiencies. This policy may *positively* impact the majority of the master indicators; such as the percentage of dwelling units within 400 meters of transit and shopping; the percentage of the community with a minimum average density of 30 upa; other transportation-related indicators; and the average number of "spontaneous exchange" experiences per capita per day.

Sections 2.6.1, 2.7.2, 2.8.1, and 2.8.3

These policies indicate the University's desire to provide elementary schools, parks, childcare facilities, and the use of University facilities, such as the library and recreational services, to the future residents of the BMCD. An important element of sustainable communities is the integration of a variety of activities within the neighbourhood, thus providing its residents with ample opportunity to satisfy their daily needs within walking and cycling distance (Roseland 1998; Newman and Kenworthy 1999; Calthorpe 1993). Of particular benefit is the University's commitment to making available its services, such as the library, to the new community members. These initiatives are effective in reducing resource consumption (i.e. resources required to construct similar facilities in the new neighbourhoods) and/or vehicle trips to similar facilities outside the community. These policies thus support mixed-use development and achieve several sustainability objectives, as indicated above. In particular, these policies may *positively* impact the following master indicators: percentage of community that is mixed-use zoning; annual number of walk, bicycle, and transit trips per capita; annual number of VHT and VKT per capita; modal split between work and non-work trips; the number of vehicles per household; annual gasoline consumption (MJ or litres) per capita; percentage of dwelling units living within 400 meters of basic shopping and transit needs; availability and institutional support for 'Green'/Location-Efficient Mortgages; public/private savings from reduced auto dependence; average number of "spontaneous exchange" experiences per capita per day; percentage of institutions/employers (over 100 employees) that offer traffic reduction programs; and the percentage of the community that is pervious to water.

Sections 2.9.1 and 2.9.2

The integration of commercial and retail services within the proposed community development is critical in the design of 'complete communities.' This policy indicates that 110,000-220,000 ft^2 of mixed-use commercial space, including retail, personal services, office space, and potentially student and market residences, may be developed in the East Neighbourhood area. This would provide opportunities for the residences of the East Neighbourhood to satisfy their daily needs within walking and cycling distance, while the majority of those located in the South Neighbourhood may likely resort to accessing this commercial area via private vehicles, as the distance and slope may deter non-motorised travel (i.e. walking and cycling). This policy may thus prove successful in reducing vehicle travel for East Neighbourhood residents.

However, the allocation of floor space (i.e. the quantity) poses a concern. With respect to commercial/retail space, Rosenau indicates that a minimum of 5,000-10,000 ft^2 per 1,000 residents of retail space is required to satisfy *basic neighbourhood shopping* needs (Rosenau 2000). However, Condon indicates that a *complete community* – which SFU and the BMCD should strive to be – should provide a minimum of 30,000 ft^2 of commercial/retail space per 1,000 residents to ensure that the majority of daily needs can be satisfied within the community (Condon 1996). This figure represents 70% of the 42,000 ft^2 per 1,000 persons commercial floor space ratio that currently exists in the GVRD – a calculation believed to be appropriate for GVRD communities that integrate transit and shopping opportunities within walking distance (Condon 1996). Calthorpe, believes this allocation should be higher, proposing 60,000 ft^2 of commercial/retail space per 1,000 residents (Calthorpe 1993). In other words, sustainable and complete communities should provide each resident with a minimum of 30 ft^2 of commercial/retail space. This OCP policy proposes only 7 ft^2 (minimum) to 15 ft^2 (maximum) of commercial/retail space per resident (based on 110,000-220,000 ft^2 of commercial space divided by the expected resident population of approximately 15,000, which includes current and future student residence beds and BMCD beds) – and therefore does not achieve the target proposed by either Condon or Calthorpe. In addition, with an expected daily on-campus population of 25,000 people, there will exist significant purchasing power to sustain retail and commercial operations, thus encouraging the development of at least 30 ft^2 of commercial space per resident.

Overall, these policies may achieve several sustainability objectives and are a step in the right direction, particularly for a community that lacks any sort of commercial/retail opportunities at the moment. In particular, these policies may *positively* impact the following master indicators: percentage of dwelling units within 400 meters of basic shopping needs; percentage of community that is zoned for mixed-use and transit-oriented/traditional neighbourhood development; percentage of residents who live and work in the same community (jobs-housing balance); mix of housing and funding types, tenures, tenants, and income levels; availability and institutional support for 'Green'/Location-Efficient Mortgages; number of sustainable transportation services (e.g. bike delivery); annual number of walk, bicycle, and transit trips per capita; annual number of VHT and VKT per capita; modal split between work and non-work trips; annual gasoline consumption (MJ or litres) per capita; average number of "spontaneous exchange" experiences per capita per day; percentage of citizens living within 30 minutes of work by transit, bicycle, or walking; public/private savings from reduced auto dependence; percentage of institutions/employers (over 100 employees) that offer traffic reduction programs; and the number of vehicles per household. However, these policies should be re-evaluated by SFU and the City of Burnaby, as their provision of commercial/retail floor space may not be sufficient to satisfy the daily needs of the future BMCD residents, thus potentially encouraging excess vehicle trips.

Sections 2.9.3, 4.2.3, and 4.2.4

Sustainable transportation planning encourages the use of non-motorised travel modes, such as walking and bicycling, and public transit. These policies strongly indicate that pedestrians and cyclists should have roadway priority, as demonstrated in the proposal for pedestrian-oriented places with minimal vehicle interference, strong pedestrian/bicycle networks and facilities, and transit-supportive community design. However, there is a lack of a commitment to "end-of-trip" facilities for pedestrians and cyclists. Though policy 4.2.3 indicates that bicycle parking and mobility impaired facilities should be provided, there is no commitment within these polices for complete end-of-trip facilities, such as showers and locker rooms. Research indicates that these are important elements in a sustainable transportation strategy that aims to encourage bicycle and walk trips, particularly to cyclists and runners who require the use of locker rooms and showers to prepare for work (Lovegrove 1998; BEST 1999; Davidson 1997; Martin 1995).

The design of development and roads can facilitate the use of public transit, as supported in policy 4.2.4. In particular, community development that is clustered around a transit node to ensure access within 400 meters can significantly facilitate transit use (Bernick and Cervero 1997; Calthorpe 1993; Newman and Kenworthy 1999). Research indicates that transit ridership decreases as distance from one's residence to a transit station/stop increases. For example, one study indicates that 61% of apartment residents use transit as a primary transportation mode when located 1,000 feet (approximately 300 meters) from a main transit station, whereas only 35% of residents use transit when located 3,000 feet (approximately 900 meters) from a main transit station (Bernick and Cervero 1997). Transit-supportive design, or transit-oriented development (TOD), as discussed in Chapter 2, can thus play a large role in shaping transportation behaviours.

Again, these policies are a step in the right direction. By giving priority to pedestrians and cyclists through the development of strong pedestrian/bicycle networks and facilities and designing transit-supportive communities, these policies help achieve several sustainability goals. In particular, these policies may *positively* impact the following master indicators: percentage of employment, transit, and public facilities with pedestrian/bicycle infrastructure; percentage of street area dedicated to walking, cycling, and transit; percentage of streets that are traffic-calmed; percentage of city/community that is zoned for mixed-use and transit-oriented/traditional neighbourhood development; annual number of walk, bicycle, and transit trips per capita; annual number of VHT and VKT per capita; modal split for work and non-work trips; annual gasoline consumption (MJ or litres) per capita; percentage of dwelling units within 400 meters of transit and basic shopping needs; average number of "spontaneous exchange" experiences per capita per day; number of vehicles per household; number of sustainable transportation services available (e.g. bike co-ops, or 'free' public bikes, and non-motorised home deliveries); public/private savings from reduced auto dependence (e.g. savings in auto-oriented infrastructure); percentage of institutions/employers (over 100 employees) that offer traffic reduction programs; and the percentage of the community that is pervious to water.

Sections 3.1.1 and 4.5.2

This policy indicates the University's commitment to the protection of ecosystems and ecological functions on Burnaby Mountain, which is one of the five outlined principles in SFU's OCP (City of Burnaby 1996, 1). In particular, development is intended to be sensitive to the topography, watercourses, significant trees, and wildlife habitat of the Burnaby Mountain area. At first glance, this policy may seem unrelated to the master sustainability indicators outlined in this study, due to their focus on transportation. However, the design of this community and the resulting density and land uses are closely related to this policy and the master sustainability indicators. To minimise ecological impacts to the wildlife and watercourses of the mountain, it is important to minimise the land area developed. In other words, it may not be ecologically sustainable to utilise the entire developable area, as indicated in the proposed land use concept (Figure 4-2), due to the potential for increased impacts to wildlife, water flow, and water quality over that of an alternative development proposal where less land is required (see Figure 4-3). This is particularly relevant to policy 4.5.2, where pre-development stormwater runoff rates and water quality are to be maintained to ensure that downstream aquatic life is not adversely affected. Therefore, if the University's intentions of ecological protection are genuine, it should pursue a land use plan that minimises the total land area required to develop a community for 10,000 citizens. For example, this could be achieved through the densification of the East Neighbourhood and the elimination of the South Neighbourhood plan, where the majority of streams and wildlife habitat are located. This land use strategy may require SFU and the City of Burnaby to re-examine and revise their original OCP.

Furthermore, if this alternative policy is actively pursued, the minimisation of land disturbance through densification achieves several sustainable land use and transportation objectives. In particular, this policy may *positively* impact the following master indicators: percentage of dwelling units within 400 meters of transit and shopping needs; percentage of community with a minimum average density of 30 upa; percentage of residential units that are not single-family homes; percentage of city/community that is zoned for mixed-use and transit-oriented/traditional neighbourhood development; annual number of walk, bicycle, and transit trips per capita; annual number of VHT and VKT per capita; modal split for work and non-work trips; annual gasoline consumption (MJ or litres) per capita; percentage of citizens living within 30 minutes of work by transit, bicycle, or walking; average number of "spontaneous exchange" experiences per capita per day; number of public/private savings from reduced auto dependence (e.g. savings in auto-oriented infrastructure); number of sustainable transportation services available (e.g. bike co-ops, or 'free' public bikes, and non-motorised home deliveries); percentage of employment, transit, and public facilities with pedestrian/bicycle infrastructure; percentage of street area dedicated to walking, cycling, and transit; percentage of institutions/employers (over 100 employees) that offer traffic reduction programs; availability and institutional support for 'Green'/Location-Efficient Mortgages; number of vehicles per household; and the percentage of the community that is pervious to water.

Sections 511.12 and 511.14

Policy 511.12 outlines a range of parking requirements for different residential types. As the OCP does not indicate what type of residential units are proposed (i.e. single-family homes, townhouses, or apartments) and the proportion of each residence type (e.g. 50% townhouses), it is difficult to assess the parking impacts of the OCP's land use plan with respect to the City of Burnaby's parking schedule. Relevant residence parking requirements range from 2 parking spaces per townhouse unit (1.75 private, 0.25 visitor); 1.85 spaces per apartment (1.6 private, 0.25 visitor); 1 space per unit attached to commercial facilities and townhouses in RM6 zoning and per single-family, two-family and row-house dwelling; to 0.5 spaces per residence bed.

It is important here to illustrate the relationship between parking lot development and sustainability. Research indicates that parking supply is positively correlated with automobile dependence (Raad 1998; Shoup 1997, Shoup 1995; Litman 1998a; Litman

1998b). That is, as parking supply increases, particularly "free" parking, vehicle use increases. Furthermore, parking lots cause significant ecological, social, and economic impacts (Litman 1998b; Shoup 1995). Land paved for parking leads to increased runoff and higher water contamination from hydrocarbon spills. Furthermore, the opportunity costs of the land are lost when parking is developed, such as the opportunity to create green space, develop a community recreation centre, or build private residences. Therefore, it is critical to minimise parking lot development when attempting to achieve sustainable land use and transportation objectives. Research indicates that parking lot development for sustainable communities should be limited to 1.25 spaces per unit, a target lower than most of the requirements within the City of Burnaby's Schedule VIII zoning bylaw (Condon 1996).

This analysis is also relevant to the proposed car washing stall development, as indicated in policy 511.14. This policy increases the amount of impervious surfaces within the community through the development of approximately 50 additional parking stalls (1 stall/100 units) dedicated solely to washing vehicles. This represents a significant amount of land, as standard parking stalls are built to a minimum of 5.5 meters in length and 2.6 meters in width (City of Burnaby 1992). Therefore, this development will further reduce water absorption and increase water runoff, due to the additional paved surface, and decrease water quality, as the introduction of detergents and other chemicals used to clean vehicles will likely find there way into the streams of Burnaby Mountain. Dedicated car washing stalls could thus be replaced with community gardens and play areas, reducing ecological impacts and improving the livability of the community.

As indicated above, it is difficult to assess the full impacts of the parking policies outlined in section 511.12, and thus their relationship to the master indicators. However, both policies outlined may *negatively* impact the following master indicators: percentage of street area dedicated to walking, cycling, and transit; percentage of community that is pervious to water; percentage of streets that are traffic-calmed; percentage of dwelling units within 400 meters of transit and shopping needs; percentage of community with a minimum average density of 30 upa; number of vehicles per household; mix of housing and funding types, tenures, tenants, and income levels; average number of "spontaneous exchange" experiences per capita per day; public/private savings from reduced auto dependence (e.g. savings in auto-oriented infrastructure); annual number of walk, bicycle, and transit trips per capita; annual VHT and VKT per capita; modal split for work and non-work trips; and annual gasoline consumption (MJ or litres) per capita.

Conclusion

In summary, the OCP provides a fairly strong foundation with which to build upon. The development of residences on the Burnaby Mountain, particularly those dedicated to the SFU community, may prove to be the most successful land use strategy in reducing automobile dependence. The OCP supports the protection of some ecologically-sensitive areas, such as the Naheeno Park area; encourages the development of a mixed-use community (i.e. P11e zoning), one where retail and recreational opportunities will be accessible by foot and bicycle for those in the East Neighbourhood; and gives priority to pedestrians, cyclists, and transit users through the design and development of a strong pedestrian/bicycle network and transit-supportive infrastructure. Furthermore, the flexibility of the OCP may prove to be its strongest asset, as it leaves open the question of "where" and "how much" to develop. This provides for the opportunity to test alternative development designs, such as a single-neighbourhood design concept located in the East Neighbourhood area, as illustrated in Figure 4-3.

There are, however, some policies within the OCP that need to be re-evaluated and amended to achieve the sustainable transportation and land use objectives of this study. As indicated above, the development of the South Neighbourhood poses accessibility concerns for walkers and cyclists, as the retail/commercial area proposed for the East Neighbourhood may prove to be too distant, and the P11 zoning schedule does not allow for any mixed-use, or retail development. This may increase dependence on private vehicles to access the East Neighbourhood commercial area, or other, commercial/retail services. Furthermore, there are serious concerns that development may negatively impact the local ecology of the South Neighbourhood area. Policies for end-of-trip facilities are not comprehensive, as the OCP commits only to bike racks and not the full spectrum of infrastructure required to encourage walking and cycling, such as locker rooms and showers. The proposed commercial/retail development, though a significant step towards building complete communities, may not provide the sufficient services required of a diverse community, such as SFU's, as its floor area may prove too small to satisfy the majority of SFU's everyday needs. Proposed density and land intensity standards are also of concern, as the unit densities in the majority of the land use concept are too low to achieve land use and transportation efficiencies. Development should aim to achieve the densities proposed in the East Neighbourhood (with underground parking), at 60 upa, or at a minimum, 30 upa. Furthermore, the proposed lot coverage policies further encourage low density development, thus consuming more land and increasing the overall "footprint" of the community. In addition, surface parking should be prohibited due to its intense appetite for land and its negative impacts on development density. Finally, vertical zoning policies were not supported in this OCP, and, given their ability to increase land efficiency and density, should be adopted.

5.2.2 Development Plan Concept

University Growth Management

SFU is faced with some serious growth management challenges as the population growth associated with the BMCD and SFU's policy to increase full-time students will double the on-campus population from 12,000 to nearly 25,000 people. However, the BMCD and University Enclave development (i.e. student residence) may prove to be the most critical land use strategy in managing this growth. To achieve "smart growth" – a term coined by Peter Newman and US vice-president Al Gore – and minimise ecological impacts, such as air emissions from private transportation, future development should provide sufficient residence opportunities for the SFU community in order to absorb its own population growth. That is, a significant percentage of the market residential units should be targeted to the students, staff, and faculty of Burnaby Mountain (i.e. "staff" includes staff from Discovery Park and BC Hydro).

The allocation of units is not outlined in the DPC, thus making it difficult to assess the real impacts of this growth within the context of this study. Therefore, one can only hypothesise how this growth will influence the master sustainability indicators. For example, *if* the majority of the future BMCD residents are not from the Burnaby Mountain community (i.e. not students, faculty, or staff), the master sustainability indicators will be ***negatively*** impacted, as SFU will become a "cross-commuter" campus for students, staff, and faculty travelling to Burnaby Mountain for studies/work and residents travelling away from Burnaby Mountain for work. In particular, the following master indicators would be negatively impacted: percentage of residents who live and work in the same community (jobs-housing balance); percentage of citizens living within 30 minutes of work by transit, bicycle, or walking; annual number of walk, bicycle, and transit trips per capita; annual VHT and VKT per capita; annual gasoline consumption (MJ or litres) per capita; modal split for work and non-work trips; mix of housing and funding types, tenures, tenants, and income levels; number of vehicles per household; the availability and institutional support for 'Green'/Location-Efficient Mortgages; average number of "spontaneous exchange" experiences per capita per day; public/private savings from reduced auto dependence (e.g. savings in auto-oriented infrastructure); and the percentage of residential units that are not single-family homes.

Land Use

As indicated above in Sections 2.6.1, 2.7.2, 2.8.2, and 2.8.3 of the OCP, the integration of recreational facilities and services into the design of a community is important in developing complete communities. The proposal for expanded public spaces and recreation facilities within easy walking distance will reduce the need for residents to travel off-site to satisfy green space and recreational needs. Furthermore, SFU's commitment to provide "sufficient amenities and facilities to satisfy the needs of a diverse community" will also reduce the need to travel off-site, thus reducing air pollution impacts on local and global environments (Moodie 1996, 29). Access to facilities such as the library, swimming pool and gym, art centres, and academic courses provides residents with diverse opportunities to become involved in their community, and thus partially satisfy the requirements of a mixed-use, complete community.[23] These commitments may therefore *positively* impact the following master indicators: percentage of community that is mixed-use zoning; annual number of walk, bicycle, and transit trips per capita; annual number of VHT and VKT per capita; modal split between work and non-work trips; annual gasoline consumption (MJ or litres) per capita; number of vehicles per household; average number of "spontaneous exchange" experiences per capita per day; percentage of dwelling units living within 400 meters of basic shopping and transit needs; percentage of institutions/employers (over 100 employees) that offer traffic reduction programs; availability and institutional support for 'Green'/Location-Efficient Mortgages; public/private savings from reduced auto dependence; and the percentage of the community that is pervious to water.

Setbacks outlined in the DPC are of concern, as large setbacks are more land intensive. In addition, smaller setbacks improve the accessibility of buildings, and create safer and more active streets as their human scale calms traffic (Calthorpe 1993; Jacobs 1961). Calthorpe indicates that new residential building setbacks should be between 10 and 15 feet, a much lower standard than the quoted 25-foot setback indicated in the DPC (Calthorpe 1996). Therefore, the setbacks proposed in the DPC may *negatively* impact the following master indicators: percentage of community with a minimum average density of 30 upa; percentage of streets that are traffic calmed; average number of "spontaneous exchange" experiences per capita per day; percentage of dwelling units

[23] However, "congestion" – or over-use – of these resources (e.g. library, swimming pool, academic courses) has yet to be explored by SFU. Congestion poses a serious concern to the overall livability of the

within 400 meters of transit and basic shopping needs; annual number of walk, bicycle, and transit trips per capita; modal split for work and non-work trips; the number of vehicles per household; annual number of VHT and VKT per capita; annual gasoline consumption (MJ or litres) per capita; public/private savings from reduced auto dependence; and the percentage of the community that is pervious to water.

Transportation Management

With the population growth expected at SFU, the DPC's transportation impact analysis indicates that single-occupant vehicle trips will increase by 150%. As discussed in Chapter 4, however, this estimate may not be accurate as the resident composition of the future BMCD and the quantity of commercial development is unknown; and non-SOV, off-peak, and non-work trips were not accounted for in Delcan's analysis. Therefore, it is estimated that the growth in SOV trips could exceed 200%, proving the urgency to implement sound transportation demand management solutions. This growth, if realised, would *negatively* impact the majority of the master sustainability indicators as it would indicate that the residents of the BMCD were primarily non-Burnaby Mountain citizens (i.e. did not study or work on Burnaby Mountain) and that "smart growth" and TDM strategies were not adopted by SFU and the City of Burnaby. In particular, the following master indicators would be negatively impacted: annual number of walk, bicycle, and transit trips per capita; annual VHT and VKT per capita; annual gasoline consumption (MJ or litres) per capita; percentage of citizens living within 30 minutes of work by transit, bicycle, or walking; percentage of residents who live and work in the same community (jobs-housing balance); mix of housing and funding types, tenures, tenants, and income levels; availability and institutional support for 'Green'/Location-Efficient Mortgages; percentage of street area that is dedicated to walking, cycling, and transit; percentage of streets that are traffic-calmed; modal split for work and non-work trips; public/private savings from reduced auto dependence; number of vehicles per

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community and should be explored and debated thoroughly.

household; average number of "spontaneous exchange" experiences per capita per day; and the percentage of the community that is pervious to water.

There are several proposals within the DPC for road development and expansion. Such developments that aim to permit "parents to drive their children to school" and to improve vehicle traffic flow at the expense of bicycle traffic do not achieve the sustainable transportation and land use objectives of this study. Furthermore, these auto-oriented infrastructure proposals may be economically unjustified, as demand management and least-cost planning (LCP) strategies were not investigated as an alternative to supply-side transportation management. These proposals may thus *negatively* impact the following master indicators: public/private savings from reduced auto dependence (e.g. savings in auto-oriented infrastructure such as roads and parking infrastructure); number of vehicles per household; percentage of street area dedicated to walking, cycling, and transit; the percentage of the community that is pervious to water; annual number of walk, bicycle, and transit trips per capita; annual VHT and VKT per capita; modal split for work and non-work trips; annual gasoline consumption (MJ or litres) per capita; percentage of streets that are traffic-calmed; average number of "spontaneous exchange" experiences per capita per day; and the number of sustainable transportation services available, such as the "walking school bus" concept.

The DPC, like the OCP, also highlights the importance of strong pedestrian/bicycle links and networks, and improved transit services. As outlined above, proposals to provide pedestrians, cyclists, and transit users with transportation priority will *positively* impact the following master indicators: percentage of employment, transit, and public facilities with pedestrian/bicycle infrastructure; percentage of street area dedicated to walking, cycling, and transit; percentage of streets that are traffic-calmed; percentage of city/community that is zoned for mixed-use and transit-oriented/traditional neighbourhood development; annual number of walk, bicycle, and transit trips per capita; annual number of VHT and VKT per capita; modal split for work and non-work trips; annual gasoline consumption (MJ or litres) per capita; percentage of dwelling units within

400 meters of transit and basic shopping needs; average number of "spontaneous exchange" experiences per capita per day; number of vehicles per household; number of sustainable transportation services available (e.g. bike co-ops, or 'free' public bikes, and non-motorised home deliveries); public/private savings from reduced auto dependence (e.g. savings in auto-oriented infrastructure); percentage of institutions/employers (over 100 employees) that offer traffic reduction programs; and the percentage of the community that is pervious to water. However, the DPC proposals do not provide sufficient end-of-trip facility development, such as showers and locker rooms, therefore reducing the incentives to walking and cycling.

Environmental Management

Given that SFU participated in the development of the *Environmental Guidelines* manual for BC University, College, and Institute Facilities, it is understandable that the DPC indicates strong support for ecological protection (Province of BC 1995b). Principles such as "site planning and design based upon an understanding of natural systems," "minimisation of negative environmental impacts," and "stewardship of streams" are found within the DPC. These principles are important and relevant to the objectives of this study as their inclusion in the community design process will impact transportation and land use planning.

As indicated above, the South Neighbourhood area is highly valued wildlife habitat, due to its "mixed deciduous/coniferous" status and water accessibility, and is the location of several important fish-bearing streams, such as Stoney, Silver, and Piper creeks. It therefore seems paradoxical to indicate the importance of ecological protection and impact minimisation while promoting the development of the South Neighbourhood area, as suggested in the DPC and OCP. If development in the South Neighbourhood area is pursued, one may question the ethics of SFU and the City of Burnaby with respect to their commitment to ecological protection. It is therefore difficult at this time to assess the DPC's commitment to ecological protection with respect to the master sustainability indicators. However, as outlined in Section 2.5.4 of the OCP, if ecological protection is secondary to development interests and the South Neighbourhood is developed, the following master indicators may be *negatively* impacted: percentage of community that is zoned for mixed-use and transit-oriented/traditional neighbourhood development; mix of housing and funding types, tenures, tenants, and income levels; the number of vehicles per household; percentage of dwelling units within 400 meters of transit and shopping; annual number of walk, bicycle, and transit trips per capita; percentage of city/community with a minimum average density of 30 upa; percentage of residents who live and work in the same community/municipality (jobs-housing balance); annual number of VHT and VKT per capita; modal split between work and non-work trips; annual gasoline consumption (MJ or litres) per capita; average number of "spontaneous exchange" experiences per capita per day; availability and institutional support for 'Green'/Location-Efficient Mortgages; public/private savings from reduced auto dependence; percentage of residential units that are not single-family homes; and the percentage of the community that is pervious to water. Strong commitments to ecological protection thus play a critical role in the development of sustainable transportation plans, as well as the overall development of responsible land use plans.

Conclusion

In conclusion, the DPC presents some essential elements of sustainable development, which have been carried forward in the OCP. Most importantly perhaps, is the opportunity for the BMCD and University Enclave development to absorb the population explosion expected to occur on Burnaby Mountain, thus reducing the ecological, social, and economic impacts typically associated with unsustainable urban growth. Furthermore, the DPC supports the development of a mixed-use community, as well as a community that supports pedestrian, bicycle, and transit travel. Finally, the ecological principles outlined in the DPC further indicate SFU's desire to be environmentally-responsible throughout the planning and development process.

However, concerns surround the DPC's proposal of a South Neighbourhood. This land use proposal would reduce accessibility, thus encouraging automobile dependence and increasing air emissions, and may seriously impact the habitat and water quality of the entire Burnaby Mountain ecosystem. The DPC's estimate of transportation impacts are incomplete and its analysis lacks any significant suggestion of sound management measures to control future transportation demands. Furthermore, the 'pro-road' development perspective indicates the DPC's priorities of providing road capacity over managing transportation demands. Finally, the setback standards proposed are significantly larger than standards set in the sustainable community design literature, reducing accessibility and increasing the overall "footprint" of the community.

5.2.3 Transportation Management Policies at Simon Fraser University

Parking and Transit

SFU provides a plethora of parking opportunities on campus, where the official parking-to-population ratio is 1:2. That is, with an average daily campus population of 12,000 people (i.e. students, staff, and faculty) and parking facilities providing over 6,000 stalls, there exists 1 stall for every 2 people that travel to SFU. However, due to the diversity in class schedules and travel times, it is estimated that approximately 10,000 vehicles drive to campus each day, thus providing 1 stall for every 1.2 people travelling to SFU (Coutu 1999).

Nevertheless, parking is still in high demand, as more than 2,000 students are currently on wait lists for parking permits. Generous parking supply, as indicated above, encourages the use of private vehicles, particularly when the parking is either free or inexpensive.[24]

[24] According to Traffic and Security, there is no free parking on campus.

Relative to transit and the market price of parking within the Greater Vancouver area, SFU's average permit price of $93.00 for a 4-month term is extremely low. This represents an average parking cost of between $0.95 and $1.80 per day, assuming travel behaviour ranging from 6 days/week over 16 weeks to 4 days/week over 13 weeks. UBC, on the other hand, provides parking at a minimum charge of $3.00 per day. Transit users, however, are subject to a $54.00 pass per month (set by TransLink), equating to $216.00 per term, and an average cost ranging from $2.25 to $4.15 per day. This represents an average cost differential (i.e. savings) that favours vehicle drivers, ranging from $1.30 to $2.35 per day, thus providing strong economic incentives to drive.[25]

In a recent transportation survey completed by Petz et al., students indicated that if the price of parking permits increased by 25-50% (i.e. from $93.00 per term to $116.25-$139.50), the demand for parking would decrease by up to 65% (i.e. 65% of respondents indicated that they would choose to ride transit or carpool). These economic inequities and survey results encourage the development of programs such as the UPASS, where transit becomes more economically attractive, the demand for parking decreases, and transportation behaviours change to favour alternative modes of travel.

In addition to the economic disincentives for transit use, transit service to and from SFU's Burnaby Mountain campus is considered poor, as the most frequent headways are 15 minutes and only 2 express services exist (Petz et al. 1998; Smith and Franklin 1999).

Carpooling, an important element of TDM, is also not strongly encouraged at SFU, as only 4% of parking facilities are dedicated to car and vanpooling. Furthermore, at a price of $170.00 per term, it does not provide sufficient economic incentive to encourage 'formal' versus 'informal' carpooling. That is, it is currently cheaper for

[25] Transit costs are compared solely to parking costs as both are internal variable costs that are directly associated with each trip. More importantly, however, is the fact that many vehicle drivers only compare parking costs to transit costs in determining the economic benefits of each mode – completely ignoring other internal variable costs such as gasoline (Litman 1998c).

students to informally carpool as the per-person cost is lower (i.e. $93.00 versus $170.00 split amongst riders).

Therefore, given SFU's parking policies – particularly with respect to pricing – and its lack of transit-priority measures, such as a UPASS transit program and multiple express services, it is evident that SFU's current transportation management plan may be in favour of automobile-based transportation. These policies do not achieve the transportation goals of this study and thus *negatively* impact the following master sustainability indicators: annual number of walk, bicycle, and transit trips per capita; number of vehicles per household; annual number of VHT and VKT per capita; modal split for work and non-work trips; annual gasoline consumption (MJ or litres) per capita; percentage of employment, transit, and public facilities with bicycle/walk infrastructure; percentage of employers with traffic reduction programs; average number of "spontaneous exchange" experiences per capita per day; number of sustainable transportation services offered (e.g. student shuttle services, UPASS); public/private savings from reduced auto dependence; percentage of street area dedicated to walking, bicycling, and transit; percentage of streets that are traffic-calmed; and the percentage of community that is pervious to water.

5.3 Conclusion

The policies and plans evaluated above provide a strong foundation for the development of sustainable transportation and land use plans at SFU. Commitments to increasing on-campus living opportunities for students will reduce vehicle travel to and from campus. Furthermore, the potential for the BMCD to house other Burnaby Mountain citizens (i.e. students, staff, and faculty of SFU and staff from Discovery Park and BC Hydro) may also reduce the ecological, social, and economic impacts associated with unsustainable land use planning. The future make-up of the Burnaby Mountain community is thus critical, as this land use plan will play the largest role in shaping transportation behaviours. Furthermore, commitments to a mixed-use and pedestrian-oriented community will further reduce the need for personal vehicle travel.

However, there are concerns surrounding community design and density. The proposed South Neighbourhood reduces accessibility to the commercial/retail area and transit station located in the East Neighbourhood. Furthermore, surface parking should be prohibited as densities are reduced significantly when surface parking is developed. Only the East Neighbourhood, with underground parking, satisfies the sustainable density requirement of 30 dwelling units per acre. In addition, setbacks from streets and lot coverage standards proposed also reduce community density, as more land is required to fully develop the community. This also reduces accessibility, increasing automobile dependence and air emissions, and increases the "footprint" of the development.

A complete summary of the above evaluations are found in Tables 5-1 through 5-3 on the following pages. In the following chapter, the above analysis will be used to develop sustainable transportation and land use policies and the *Sustainable Transportation Plan* for SFU's Burnaby Mountain campus.

Table 5-1. Summary Evaluation of Simon Fraser University's Official Community Plan[26]

MASTER INDICATORS	OFFICIAL COMMUNITY PLAN Sections (see T[illegible])									
1st PRIORITY	2.2.2	2.4.4	2.5.1	2.5.4 (if P11c in E. Neigh. with undrgr. pkg.)	511.6, 511.9-511.11	2.6.1, 2.7.2, 2.8.1, 2.8.3	2.9.1-2.9.2	2.9.3, 4.2.3, 4.2.4	3.1.1, 4.5.2	511.12, 511.14
1. Percentage of dwelling units within 400 meters of transit service and basic shopping needs	+	+	-	+	-	+	+	+	+	-
2. Annual number of walk, bicycle, and transit trips/capita	+	+	-	+	-	+	+	+	+	-
3. Percentage of city/community that is zoned for mixed-use and transit-oriented/traditional neighbourhood development	?	n/a	-	+	n/a	+	+	+	+	?
4. Annual VKT/VHT per capita (non-recreational)	+	+	-	+	-	+	+	+	+	-
5. Modal split for work and non-work trips	+	+	-	+	-	+	+	+	+	-
6. Percentage of city/community with a minimum average density of 30 units per acre (gross)	+	n/a	-	+	-	n/a		n/a	+	-
7. Percentage of residents who live and work in the same community/municipality (jobs-housing balance)	+	n/a	?	+	n/a	n/a	+	n/a	?	n/a
8. Percentage of citizens living within 30 minutes of work by transit, bicycle, or walking	+	?	?	+	n/a	n/a	+	?	+	?
9. Annual gasoline consumption (MJ or litres) per capita	+	+	-	+	-	+	+	+	+	-
10. Percentage of institutions/employers (over 100 employees) that offer traffic reduction programs	?	+	n/a	?	n/a	+	+	+	+	n/a
11. Percentage of employment, transit, and public facilities with bicycle/walk infrastructure (e.g. bike/walk lanes, racks, showers, locker rooms)	?	+	?	?	n/a	n/a	?	+	+	?
12. Percentage of residential units that are not single-family homes	+	n/a	?	+	?	n/a	n/a	n/a	+	?

[26] The following evaluation scale is used: '+' is used for 'positive' influence on the indicators, '-' for 'negative' influence, 'n/a' for not applicable, and '?' for unknown (i.e. it could be a positive, negative, or no impact at all).

Table 5-1. Summary Evaluation of Simon Fraser University's Official Community Plan - continued

MASTER INDICATORS	OFFICIAL COMMUNITY PLAN Sections (see Table 4.8 for reference)									
2nd PRIORITY	2.2.2	2.4.4	2.5.1	2.5.4 (if P11e in E. Neigh. with undrgr. pkg.)	511.6, 511.9-511.11	2.6.1, 2.7.2, 2.8.1, 2.8.3	2.9.1-2.9.2	2.9.3, 4.2.3, 4.2.4	3.1.1, 4.5.2	511.12, 511.14
1. Number of vehicles per household	?	n/a	+	+	-	+	+	+	+	-
2. Percentage of street area that is dedicated to walking, cycling, and transit	n/a	+	?	?	?	n/a	?	+	+	-
3. Percentage of streets that are traffic-calmed	n/a	n/a	?	?	-	n/a	?	+	?	-
4. Percentage of community (incl. roads, public places, parks) that is pervious to water (e.g. alternative surface materials)	n/a	n/a	-	+	-	+	?	+	+	-
5. Mix of housing and funding types, tenures, tenants, and income levels	+	n/a	?	+	n/a	n/a	+	n/a	n/a	-
6. Average number of "spontaneous exchange" experiences per capita per day	+	?	-	+	-	+	+	+	+	-
7. Availability and institutional support for 'Green'/Location Efficient Mortgages	n/a	n/a	?	+	n/a	+	+	n/a	+	?
8. Number of sustainable transportation services (e.g. car sharing, home delivery, 'dial-a-ride,' bike co-ops, 'walking school bus')	?	?	?	?	n/a	?	+	+	+	?
9. Public/private savings from reduced auto dependence over and above any necessary increases in transit, bicycle, and pedestrian expenditures	?	+	-	+	-	+	+	+	+	-

Table 5-2. Summary Evaluation of Simon Fraser University's Development Plan Concept

MASTER INDICATORS	DEVELOPMENT PLAN CONCEPT (see Table 4.9 for reference)						
	University Growth Management	Land Use		Transportation Management			Environmental Management
1st PRIORITY	(if BMCD housing is not allocated to Bby Mtn. community)	Integration of Facilities	Setbacks	150% SOV growth	road dev.	Ped./bike & transit priority	South Neighbourhood development
1. Percentage of dwelling units within 400 meters of transit service and basic shopping needs	n/a	+	-	n/a	?	+	-
2. Annual number of walk, bicycle, and transit trips per capita	-	+	-	-	-	+	-
3. Percentage of city/community that is zoned for mixed-use and transit-oriented/traditional neighbourhood development	n/a	+	n/a	n/a	?	+	-
4. Annual VKT/VHT per capita (non-recreational)	-	+	-	-	-	+	-
5. Modal split for work and non-work trips	-	+	-	-	-	+	-
6. Percentage of city/community with a minimum average density of 30 units per acre (gross)	?	n/a	-	n/a	n/a	n/a	-
7. Percentage of residents who live and work in the same community/municipality (jobs-housing balance)	-	n/a	n/a	-	n/a	n/a	-
8. Percentage of citizens living within 30 minutes of work by transit, bicycle, or walking	-	n/a	n/a	-	?	?	n/a
9. Annual gasoline consumption (MJ or litres) per capita	-	+	-	-	-	+	-
10. Percentage of institutions/employers (over 100 employees) that offer traffic reduction programs	?	+	n/a	?	n/a	+	?
11. Percentage of employment, transit, and public facilities with bicycle/walk infrastructure (e.g. bike/walk lanes, racks, showers, locker rooms)	n/a	n/a	n/a	n/a	?	+	?
12. Percentage of residential units that are not single-family homes	-	n/a	?	?	n/a	n/a	-

Table 5-2. Summary Evaluation of Simon Fraser University's Development Plan Concept - continued

MASTER INDICATORS	DEVELOPMENT PLAN CONCEPT (see Table 4-5 for reference)						
	University Growth Management	**Land Use**		**Transportation Management**			**Environmental Management**
2nd PRIORITY	**(if BMCD housing is not allocated to Bby Mtn. community)**	Integration of Facilities	Setbacks	150% SOV growth	road dev.	Ped./bike & transit priority	South Neighbourhood development
1. Number of vehicles per household	-	+	-	-	-	+	-
2. Percentage of street area that is dedicated to walking, cycling, and transit	n/a	n/a	?	-	-	+	?
3. Percentage of streets that are traffic-calmed	?	n/a	-	-	-	+	?
4. Percentage of community (incl. roads, public places, parks) that is pervious to water (e.g. alternative surface materials)	?	+	-	-	-	+	-
5. Mix of housing and funding types, tenures, tenants, and income levels	-	n/a	n/a	-	n/a	n/a	-
6. Average number of "spontaneous exchange" experiences per capita per day	-	+	-	-	-	+	-
7. Availability and institutional support for 'Green'/Location Efficient Mortgages	-	+	n/a	-	n/a	n/a	-
8. Number of sustainable transportation services (e.g. car sharing, home delivery, 'dial-a-ride,' bike co-ops, 'walking school bus')	?	?	n/a	?	-	+	?
9. Public/private savings from reduced auto dependence over and above any necessary increases in transit, bicycle, and pedestrian expenditures	-	+	-	-	-	+	-

Table 5-3. Summary Evaluation of Simon Fraser University's Transportation Management Policies

MASTER INDICATORS	SFU's TRANSPORTATION MANAGEMENT
1st PRIORITY	**Parking and Transit**
1. Percentage of dwelling units within 400 meters of transit service and basic shopping needs	n/a
2. Annual number of walk, bicycle, and transit trips per capita	-
3. Percentage of city/community that is zoned for mixed-use and transit-oriented/traditional neighbourhood development	n/a
4. Annual VKT/VHT per capita (non-recreational)	-
5. Modal split for work and non-work trips	-
6. Percentage of city/community with a minimum average density of 30 units per acre (gross)	n/a
7. Percentage of residents who live and work in the same community/municipality (jobs-housing balance)	n/a
8. Percentage of citizens living within 30 minutes of work by transit, bicycle, or walking	n/a
9. Annual gasoline consumption (MJ or litres) per capita	-
10. Percentage of institutions/employers (over 100 employees) that offer traffic reduction programs	-
11. Percentage of employment, transit, and public facilities with bicycle/walk infrastructure (e.g. bike/walk lanes, racks, showers, locker rooms)	-
12. Percentage of residential units that are not single-family homes	n/a
2nd PRIORITY	
1. Number of vehicles per household	-
2. Percentage of street area that is dedicated to walking, cycling, and transit	-
3. Percentage of streets that are traffic-calmed	-
4. Percentage of community (incl. roads, public places, parks) that is pervious to water (e.g. alternative surface materials)	-
5. Mix of housing and funding types, tenures, tenants, and income levels	n/a
6. Average number of "spontaneous exchange" experiences per capita per day	-
7. Availability and institutional support for 'Green'/Location Efficient Mortgages	n/a
8. Number of sustainable transportation services (e.g. car sharing, home delivery, 'dial-a-ride,' bike co-ops, 'walking school bus')	-
9. Public/private savings from reduced auto dependence over and above any necessary increases in transit, bicycle, and pedestrian expenditures	-

Chapter 6 The Development of a Sustainable Transportation and Land Use Plan for Simon Fraser University – Burnaby Mountain Campus

6.1 Introduction

The development of a sustainable transportation and land use plan for SFU's Burnaby Mountain campus will be based on the previous evaluations of TDM strategies (Table 2-11), and the 'sustainability framework' that outlined the categories, goals, objectives, and indicators required for SFU to improve its transportation efficiency and reduce automobile dependence and its associated ecological, social, and economic impacts (Figure 3-4). It is believed that the analysis and research presented in this study provides the appropriate foundation in which to build the *Sustainable Transportation Plan* for SFU's Burnaby Mountain campus.

To develop policies for this plan, *targets* will be set for the 1st and 2nd Priority indicators identified in the *Master Sustainable Transportation and Land Use Planning Framework*. TDM strategies will then be proposed to achieve the targets defined. Finally, transportation and land use policies will be developed based on the proposed targets and TDM strategies.

As indicated in Chapter 1, the purpose of this study is to develop and recommend policies that would assist the University in reducing single-occupant vehicle trips by 20% (minimum) over the short and long-term (i.e. pre-BMCD/student growth (within the next 1-5 years) and post-BMCD/student growth). That is, in the short-term the *Sustainable Transportation Plan* is designed to reduce SOV trips by a minimum of 20% from that of the 1998 traffic levels (or new traffic count figures if SFU commissions a traffic screen count to be completed within the next few years). In the long-term, the *Sustainable Transportation Plan* is designed to reduce SOV trips by a minimum of 20% from that of the traffic levels that exist at that time (circa 2010-2030) (i.e. a traffic screen count should be conducted once SFU completes the BMCD project and the growth in the FTE student population is complete to use as the baseline data for assessment). The 20% SOV trip reduction target is based on recognised and successful sustainable transportation plans, such as those found at the University of Washington, University of Colorado, Cornell University, and the University of British Columbia; as well as the carbon dioxide reduction goal of 20% by 2005 established by world policy-makers (City of Vancouver 1990; Toronto Conference Statement 1988; Flavin 1990; IUCN, UNEP, and WWF 1991). For the purposes of this study, a 20% SOV trip reduction target would result in the following future 'target' modal splits (off-campus and on-campus modal splits are identified separately as transportation behaviours will differ between residents of Burnaby Mountain and those residing elsewhere in the GVRD).

Table 6-1. Current (1998) and Future Target Transportation Modal Splits for the SFU Burnaby Mountain Campus

Mode of [illegible]	[illegible]	[illegible]	[illegible]
Single-occupant vehicle (SOV)	**40%**	**25-32%**[28]	**15-32%**
Public Transit	**27%**	**27-40%**	**25%**
Carpool (2 or more occupants)	**33%** (2 pers. = 27%; 3-pers.+ = 6%)	**27-35%**	**10%**
Walk and Bicycle: including intermodal travel (e.g. bike-transit-bike travel using bike racks on transit)	**0.5-1.0%**	**1-5%**	**33-50%**

[27] Excludes students living in on-campus residence facilities (approximately 10% of daily on-campus population).

[28] For the purposes of this study, the 1998 traffic count baseline data is used for the both the short-term and long-term traffic reduction targets, as no data exists at this time to represent actual traffic demand in 2010-2030 (i.e. post-BMCD/student growth). The estimated modal splits incorporate a minimum 20% SOV trip reduction achieved through the implementation of the *Sustainable Transportation Plan* outlined in Table 6-8. Given the difficulty of forecasting transportation behavioural changes with respect to the implementation of the *Sustainable Transportation Plan*, modal split ranges are shown for each transport mode.

6.2 Development of Indicator Targets, Transportation Demand Management Strategies, and Preliminary Sustainable Transportation and Land Use Policies for SFU

6.2.1 Introduction

Targets complete the sustainability planning process, as setting targets for indicators moves the process from 'talk' to 'action.' Targets should thus be user-friendly and enable communities to fully understand the changes that need to take place, both at the individual and community level, for sustainability goals to be achieved. Targets should act as benchmarks; however, it is important to recognise that targets are intended to function more as guides than standards (Sheltair 1998). If understood and accepted, targets will inspire and motivate the community towards the achievement of the planned sustainability goals and objectives.

The 'Sheltair Model' outlined in Chapter 3, and used as the basis for the development of the *Sustainable Transportation and Land Use Planning Framework*, outlines a sustainable urban development process that includes the development of indicator targets. The following section will identify indicator targets for the 1st and 2nd Priority indicators, and propose TDM strategies that may be most effective in achieving these targets, as well as preliminary sustainable land use and transportation policies. To simplify the following analysis, the *Master Sustainable Transportation and Land Use Planning Framework* has been reformatted and is summarised on the next page. Targets have been included in this summary for convenience and to provide a glimpse of the policy formation to follow. Furthermore, the identified TDM strategies that are highly applicable to the SFU case study are also summarised below.[29]

[29] Note that some of the strategies have been grouped where practical.

Figure 6-1. Master Sustainable Transportation and Land Use Planning Framework

[illegible] Sustainability Indicator Development [illegible]				
[illegible]	[illegible] Goal [illegible]	[illegible] Objectives [illegible]	[illegible]	[illegible]
Transportation & Accessibility	1. Minimise SOV travel	a. Increase car-free living opportunities	• Number of vehicles per household (2nd)	**1.25/unit (BMCD) 0.33/student bed (SFU)**
			• The availability and institutional support for 'Green'/Location-Efficient Mortgages (2nd)	**Yes/High (BMCD)**
			• Percentage of city/community specially zoned for transit-oriented/traditional neighbourhood development (1st)	**100% (BMCD)**
		b. Increase access to basic needs	• Annual vehicle hours of travel (VHT) per capita (non-recreational) (1st) (VKT indicator used for simplicity)	**VKT used instead. 4,000 km/yr (on-campus) 6,500 km/yr (off-campus)**
			• Percentage of city/community that is mixed-use zoning (i.e. integration of employment, recreation, goods and services, and residential - incl. 'shop-top' housing) (1st)	**100% (BMCD)**
			• Percentage of citizens living within 30 minutes of work by transit/bicycle/walking (1st)	**50% (min.) (BMCD)**
		c. Increase transportation choices	• Modal split for work and non work trips (1st)	**20% decrease in SOV travel (min.)[30] (SFU/BMCD)**
			• Annual number of walk/cycle/transit trips per capita (1st)	**20% increase (min.)[31] (SFU/BMCD)**
			• The availability and institutional support for sustainable transportation services (e.g. car sharing, home delivery, 'dial-a-ride,' bike co-ops, 'walking school bus') (2nd)	**Yes/High (SFU?BMCD)**
			• Percentage of dwelling units within 400 meters of transit service (1st)	**100% (BMCD)**
		d. Increase incentives for non-SOV travel	• Percentage of institutions/employers (over 100 employees) that offer traffic reduction programs (that include ridesharing privileges, services, and vehicles; transportation allowance; 'cashing out' paid parking; UPASS. (1st)	**100% (SFU/BMCD)**
		e. Minimise the need to expand transport infrastructure	• Public/private savings from reduced car dependence over and above any necessary increases in transit, bicycle, and pedestrian expenditures (e.g. infrastructure, less fuel, fewer roads, less parking, lower external costs) (2nd)	**20% (min.) (SFU?BMCD)**

[30] In the short-term, from 1998 traffic volumes. In the long-term (i.e. post-BMCD/student growth), a 20% SOV trip reduction should be based on transportation data collected through a traffic screen count after the BMCD and student population growth phases are complete.

[31] As above.

Figure 6-1. Master Sustainable Transportation and Land Use Planning Framework - continued

Sustainability Indicators Development Process				
Category	**Goals**	**Objectives**	**Indicators**	**Targets**
Transportation & Accessibility - continued	2. Increase safety, community interaction, and livability	f. Introduce traffic calming measures	• Percentage of neighbourhood streets that are traffic-calmed (e.g. traffic circles, textured surfaces, 30 km/hr speed limits, narrow roads, street furniture, speed bumps, street planting, wide sidewalks, islands, signage, pedestrian crossings, street parties/games, reclaiming of road space for public space) (2nd)	**60% (min.) of streets (BMCD)**
			• Average number of "spontaneous exchange" experiences per capita per day (e.g. meeting friends on street) (2nd)	**1/day (min.) (BMCD)**
	3. Minimise the need to travel outside the neighbourhood for basic needs (e.g. food, work)	g. Increase proximity of housing to key activity centres	• Percentage of dwelling units within 400 meters of basic shopping needs (1st)	**100% (BMCD)**
		h. Increase pedestrian, bicycle, and transit infrastructure within the neighbourhood	• Percentage of employment/transit/public facilities with bicycle/walk infrastructure (e.g. bike/walk lanes, racks, showers) (1st)	**100% (SFU/BMCD)**
			• Percentage of street area that is dedicated to walking, cycling, and transit (2nd)	**60% (BMCD)**
	4. Promote a balance of jobs and housing	i. Match housing types and affordability with the needs of working and non-working population within the community	• Mix of housing and funding types, tenures, tenants, and income levels (2nd)	**High (SFU/BMCD)**
		j. Increase employment opportunities to match residential stock or; increase residence opportunities to match employee and student base	• Percentage of residents that live and work in the same community/municipality (jobs-housing balance) (1st)	**50% (min.) (BMCD/SFU's Student Residence)**
Air	5. Minimise harmful emissions, both local and global	k. Reduce concentrations of ground level ozone (smog) and fine particulate matter	• Annual gasoline consumption (litres) per capita (non-recreational) (1st) (VKT indicator used for simplicity)	**VKT used instead. 4,000 km/yr (on-campus) 6,500 km/yr (off-campus)**
		l. Reduce carbon dioxide emissions (CO_2)	• Annual vehicle kilometres travelled (VKT) per capita (1st)	**4,000 km/yr (on-campus) 6,500 km/yr (off-campus)**
Water	6. Minimise water pollution	m. Reduce and manage surface water run-off	• Percentage of community (incl. roads, public places, parks) that is pervious to water (e.g. alternative surface materials) (2nd)	**50% (min.) (BMCD)**
Housing	7. Optimise community densification	n. Increase densities towards sustainability standards	• Percentage of city/community with a min. average density of 30 units per acre (gross) (1st)	**100% (BMCD)**
			• Percentage of residential units that are not single-family homes (2nd)	**90% (min.) (BMCD)**

Table 6-2. TDM Strategies Highly Applicable to SFU's Burnaby Mountain Campus[32]

[illegible]
1. Full Cost Accounting; and Least Cost Planning and Funding.
2. Development of a central co-ordinating management body to: • implement programs of public education, communication, and encouragement (e.g. information centres, fairs, new hire orientation, award programs); • support the development of transportation management associations (TMAs) and employee transportation administrators (ETAs); and • monitor TDM programs.
[illegible]
3. Development of higher density and mixed-use communities, such as traditional neighbourhood and transit-oriented developments.
4. Development of transportation- and location-efficient mortgages.
[illegible]
5. Transit service improvements include: • service innovations and improvements; • payment innovations and improvements (e.g. discounted bus pass/UPASS); and • community-based shuttle service (on-campus feeder service and off-campus commuter service).
6. Pedestrian improvements include: • security concerns addressed; and • pedestrian environments and facilities.
7. Cycling improvements include: • intermodal travel for bicycles and transit; • bicycle networks; and • 'end-of-trip' facilities.
Transportation Demand Management (TDM) [illegible]
8. Increase and marginalise parking prices (to at least match transit costs) include: • higher rates for peak, SOV, and permit parking; and • reduced long term parking capacity in favour of short-term parking.
9. Parking supply restrictions and relaxed requirements include: • commitment to minimise parking stall development; • reduced parking stall requirements for new developments in favour of transit-supportive design, traffic reduction programs, and car-sharing opportunities.
10. Voluntary commuter traffic reduction programs (CTR) include: • ridesharing privileges (e.g. subsidised fees and preferential parking), services/co-ordinated programs, and access to vehicles; • transportation allowance and discounted transit programs (e.g. UPASS); • guaranteed ride home service; • flexible work schedules (e.g. telecommuting; 'flex time,' compressed work weeks); • car sharing co-ops and discounted car rentals; • 'Walking school bus' programs; • 'public bikes' or bike sharing co-ops; and • non-motorised home delivery services and 'Buy Local & Save' programs.
[illegible]
11. Including: sidewalks, narrow streets, bicycle lanes, street trees, speed bumps, traffic circles, street furniture, alt. road surfaces (e.g. cobblestones), bus bulges, and other "street reclaiming" activities.

[32] Some of the high priority TDM strategies have been amalgamated into one strategy (i.e. there now exist 11 strategies versus the 27 identified in Chapter 2).

6.2.2 Targets, TDM, and Preliminary Land Use and Transportation Policy Recommendations

The development of indicator targets, and the application of TDM strategies, is based on the literature reviewed in this study. Where literature does not exist, or where indicators are considered subjective and more qualitative than quantitative, targets will be based on personal experience and the expertise developed throughout this study. In the following discussion some indicators have been grouped where practical, as many of the 1st and 2nd Priority indicators selected for this framework are interconnected and thus may replicate one another (i.e. several indicators may be equally effective in measuring air quality).

1st Priority Indicators:

1. Modal split for work and non-work trips
Target (SFU/BMCD)= Reduce SOV trips by a minimum of 20% in both the short and long-term (thus increasing the modal shares for transit, carpooling, cycling, and walking)

This indicator and target represents the primary objective of this study – to reduce SOV trips by a minimum of 20% – and is summarised in Table 6-1 above. Transportation modal split data provides an effective 'snapshot' of travel behaviour, as it captures the reality of how we transport ourselves throughout the region. It is therefore an excellent indicator of how sustainable our transportation and land use systems are, as these systems shape travel behaviours. Furthermore, research indicates that modal splits that favour transit, cycling, and pedestrian travel over automobile travel achieve several sustainability goals, such as reduced environmental impacts, improved urban livability, and improved equity with respect to economic distributions of public finances (e.g. road versus bike lane expenditures) (Ewing 1995a; Newman and Kenworthy 1999; Hart 1995).

This indicator and target is also fairly well represented by the following 1st Priority indicator: *annual number of walk, bicycle, and transit trips per capita.* This indicator captures the significance of non-motorised and transit travel; however, it neglects trips made in automobiles, hence reducing its effectiveness as an evaluative indicator of transportation behaviour. The "modal split" indicator will thus be used for the purposes of this study, as both sets of data are required to calculate modal splits (i.e. non-motorised/transit and automobile trips).

It is therefore recommended that future modal split targets for the SFU community should aim to reduce SOV trips by a minimum of 20% in both the short-term (i.e. based on 1998 traffic statistics) and the long-term (i.e. based on the completion of the BMCD and student population growth phases and the collection of new traffic statistics for that period).

Given that this indicator and target represent the primary objective of this study, recommendations for land use and TDM strategies will be based on the following targets and policy proposals recommended for the remaining 1st and 2nd Priority indicators. These policy recommendations will be summarised at the end of this chapter.

2. Percentage of dwelling units within 400 meters of transit service and basic shopping needs
Target (BMCD) = 100%

This indicator and target aim to reduce SOV travel through increasing both transportation choices and the proximity of housing to key activity centres. Research indicates that accessibility to transit (i.e. distance and ease of access from home) is a key component to improving transit ridership (Newman and Kenworthy 1999; Bernick and Cervero 1997). Studies completed by Bernick and Cervero indicate that as distance from one's home to transit decreases, transit use increases significantly (Bernick and Cervero 1997). Furthermore, similar results exist for distance to daily shopping, as residents who live near grocery and other retail opportunities tend to walk and cycle more often to access these destinations (Ewing 1995a; Bernick and Cervero 1997). The widely accepted accessibility standard for 'proximity-planning' is thus a 5-10 minute walk, which falls in the 300-500 meter range (Calthorpe 1993; Condon 1996; Katz and Lennertz 1998; Ewing 1995b; Litman 1997b; Newman and Kenworthy 1999; Calthorpe 1993; Engwicht 1993; Durning 1996; Sheltair 1998). The 400 meter distance used in this study has therefore been selected as a guideline for community development at SFU, as it falls within the standards indicated above.

This indicator and target are based on Sheltair's proposal for the development of a sustainable community in Southeast False Creek (SEFC), Vancouver, BC (Sheltair 1998). Sheltair indicates that 100% of residential units in SEFC should be within 350 meters of transit, based on the transit use-density relationships in central Toronto, where over 90% of units are within 350 meters and transit use is very high; Portland, where approximately 65% of units are within 350 meters and transit use is relatively high; the West End of Vancouver, where over 30% of units are within 350 meters and transit use is 65% higher than other areas of the GVRD; and the Canadian average, where only 20% of residential units are within 350 meters and transit accounts for only 9% of all trips (Price 1999; Sheltair 1998; Raad 1998; Raad and Kenworthy 1998; Newman and Kenworthy 1999). Furthermore, research indicates that Vancouver's West End, where 90% of residents live within 350 meters of shopping opportunities, experiences 5 times as much foot and bicycle travel and over 50% fewer vehicle trips than the rest of the GVRD (Sheltair 1998; Durning 1996; Price 1999). Similar results also hold true for central Toronto, where close proximity to shopping and personal services (80% of units within 350 meters), encourages a high level of pedestrian and bicycle travel.

Most importantly, as indicated in the literature, is the fact that travel time is more significant than travel costs in determining the modal choice of most travellers (Sheltair 1998; Engwicht 1993; Newman and Kenworthy 1999; Ewing 1995a). Therefore, if the majority of basic needs, such as shopping and transit, are accessible within a 5-10 minute walk of housing (i.e. 300-500 meters), the perceived need to not only travel by car, but to *own* a vehicle, is greatly reduced.

It is important to note that the microclimate (e.g. higher levels of rain, fog, and snow) and slope of Burnaby Mountain should be considered in the 'proximity-planning' process, as these conditions will affect transportation behaviours (i.e. the decision to walk or drive). Therefore, providing even greater accessibility, such as developing a large proportion of the residential units within 300-350 meters of transit and the core commercial area (i.e. 75% or greater), may be required to achieve the transportation and land use efficiency goals of this study.

Overall, it is recommended that 100% of the residential units developed on Burnaby Mountain be within 400 meters of transit service (i.e. station, loop, or stop) and the commercial node(s) (including smaller retail nodes integrated into the neighbourhood). To achieve this target, the following TDM strategies are highly recommended:

1. *Develop higher density and mixed-use communities, such as traditional neighbourhood and transit-oriented developments.*
2. *Restrict parking supply and reduce parking lot development requirements.*
3. *Apply Full Cost Accounting, and Least Cost Planning and funding measures/principles.*
4. *Improve transit/cycling/pedestrian facilities, environments, and services.*

3. Perc[illegible] transit[illegible]
Target (BMCD) = 100%

This indicator and target aims to reduce SOV travel through increasing both car-free living opportunities and accessibility. Mixed-use and transit-oriented/traditional neighbourhood development zoning is directly related to – but not the same as – the previous indicator, as communities that provide its residents with access to transit and shopping within 400 meters have clearly been successful in developing mixed-use and transit-oriented/traditional neighbourhoods. Therefore, as the above research suggests, built environments that integrate employment, residential, recreational, retail and commercial, and transit opportunities within a close walking distance experience higher pedestrian, bicycle, and transit trips and fewer automobile trips, thus reducing ecological impacts, such as emissions of local (e.g. NO_2) and global (e.g. CO_2) air pollutants.

Furthermore, research indicates that transit-supportive design provides opportunities for people to live without a car, or "car-free" (Durning 1996; Bernick and Cervero 1997; Scheurer 1998). According to the Canadian Automobile Association, car-free living can save Canadians $7,000 per year, providing a significant incentive for people to invest and lobby for transit-oriented community development (Roseland 1998).

It is therefore recommended that 100% of the future Burnaby Mountain community be zoned for mixed-use and transit-oriented/traditional neighbourhood development. To achieve this target, the following TDM strategies are highly recommended:

1. *Develop higher density and mixed-use communities, such as traditional neighbourhood and transit-oriented developments.*
2. *Develop and introduce transportation- and location-efficient mortgages.*
3. *Apply Full Cost Accounting, and Least Cost Planning and funding measures/principles.*
4. *Improve transit/cycling/pedestrian facilities, environments, and services.*
5. *Apply traffic calming measures.*

4. Annual number of VKT/VHT and gasoline consumption (litres) per capita (non-recreational travel)
Target (on-campus residents) = 4,000 km/year (non-recreational)   ***Target (off-campus residents – approximate) = 6,500 km/year (non-recreational)***

This indicator and target aim to reduce SOV travel and both local and global air emissions, such as nitrogen oxides (NO), volatile organic compounds (VOC), and carbon dioxide (CO_2). Given that automobile travel accounts for over 75% of all contaminants in our air – the largest source of air pollution in Greater Vancouver – vehicle use data provides an effective measuring stick for air quality (Sheltair 1998). Research indicates that the hours spent travelling via private automobiles (VHT), and the distance travelled in that time (VKT), are both strong indicators of personal automobile dependence, and thus local and global air quality impacts (Newman and Kenworthy 1999). Furthermore, annual vehicle-related energy consumption per capita (i.e. gasoline consumed per person per year in litres, gallons, or megajoules) is also an effective indicator in measuring automobile dependence and its associated air quality impacts. However, to simplify the policy development process, the target for this indicator is defined in VKT, as little literature exists to develop sound sustainability targets and policies based on per capita VHT and gasoline consumption data. As well, calculating VHT is more difficult and expensive than reading an odometer to record VKT (Ewing 1995a).[33]

However, Ewing and Newman indicate that annual per capita VHT and gasoline consumption may be superior indicators compared with VKT, as VHT accounts for the degree of congestion and thus the time it takes to reach destinations and the total air emissions produced; and gasoline consumption accounts for the variation in fuel efficiencies amongst different vehicle types, thus representing total emissions per person (or vehicle) more accurately (Ewing 1995a; Newman 1998). As indicated above, travel time is the primary determinant of modal choice, thus making VHT a more effective measure of accessibility than VKT. Furthermore, the VKT indicator does not fully account for all air emissions produced. For example, a decrease in VKT may not necessarily result in a decrease in emissions, as the VKT indicator does not account for emissions produced while in congestion. Therefore, as emissions per VKT are dependent on vehicle operating speeds and vehicle fuel efficiencies, it may be more effective to measure emissions per VHT or per litre of gasoline consumed as these emissions are independent of vehicle speed and take into account differences in vehicle fuel efficiencies (Ewing 1995a; Newman 1998). However, for the purposes of this study, it is believed that the VKT indicator is an effective starting point, given that it is a more user-friendly measure and that data is easier to collect, which is of particular importance when it comes to monitoring. The VHT or gasoline consumption indicator should be adopted when the community development project is complete, residents have fully moved in, and a

[33] VHT/person (Ewing 1995a) = $\frac{\text{avg. trip frequency x avg. trip length x (1 - avg. walk/bike modal share)}}{\text{average vehicle occupancy x average vehicle operating speed}}$

community sustainability monitoring project has been initiated (i.e. trip diaries, sustainability 'report cards').

For obvious reasons, this target has been separated between 'on-campus' and 'off-campus' members of the Burnaby Mountain communities (i.e. SFU, Discovery Park, and BC Hydro), as off-campus persons will most likely require the use of a private vehicle *more* than persons residing on-campus. This assumption is based in the fact that the BMCD will provide residence for approximately 10,000 people, some of whom will also work and study on Burnaby Mountain. Therefore, the BMCD provides SFU and the other members of the Burnaby Mountain community with the opportunity to achieve a strong jobs-housing balance, and thus improving transportation efficiency as fewer people will require a car to travel to work/school.

This target is based on Sheltair's proposal for the SEFC community, where Sheltair recommends an annual VKT target of 3,392 km per resident (matching that of Vancouver's West End community); the GVRD's per capita VKT 'potential' of 4,145 km (based on planned improvements in transportation infrastructure, transit efficiency, and the implementation of TDM measures); and the GVRD's average VKT per capita of 8,361 km (1991) (Sheltair 1998; Raad and Kenworthy 1998). It is believed that future residents of Burnaby Mountain (i.e. 'on-campus') can achieve a VKT target between that of SEFC and the GVRD's per capita 'potential' (i.e. the 4,145 VKT target), given that a proportion of these residents will be from the Burnaby Mountain community and will thus not need to commute to work/school, a proportion of these residents may be students with limited access to private vehicle travel, and transit-supportive and mixed-use community design (for the BMCD) should strongly influence travel behaviour in favour of transit, cycling, and walking. Furthermore, with implementation of TDM strategies and programs at SFU, 'off-campus' residents should also be able to significantly reduce vehicle travel to and from Burnaby Mountain, as well as within the Greater Vancouver region as a whole. For example, the introduction of a UPASS transit program could reduce vehicle trips not only to Burnaby Mountain, but also to other destinations within the region, as the UPASS program provides unlimited transit travel (i.e. all zones). This result has been experienced in several other urban centres, as UPASS participants shift their transportation modal choice from automobiles to transit for many trips (Brown, Hess, and Shoup 1998).

However, it is important to note that VKT by off-campus residents will also be influenced by the larger transportation system in existence, transport economics (e.g. inexpensive gas), and the transportation and land use planning priorities of the local municipalities. In addition, the transportation behaviours for non-Burnaby Mountain travel (e.g. trips made to regional town centres) are unknown, thereby making it difficult to estimate future vehicle-based transportation demands for off-campus residents. Given these uncertainties, the target set for off-campus residents assumes that students, staff, and faculty will accumulate similar VKT per year to that of the average GVRD citizen. The 6,500 km target (approximate) is thus based on a 20% reduction in the 1991 annual VKT data for GVRD residents (8,361 km), as indicated by Raad and Kenworthy (Raad and Kenworthy 1998).

It is therefore recommended that an annual VKT target should be set at 4,000 and 6,500 kilometres per capita for on-campus and off-campus residents respectively. To achieve these targets, the following TDM strategies are highly recommended:

1. *Develop higher density and mixed-use communities, such as traditional neighbourhood and transit-oriented developments.*
2. *Develop and introduce transportation- and location-efficient mortgages.*
3. *Develop a central co-ordinating management body to implement TDM programs, establish ETAs, and monitor progress.*
4. *Develop a voluntary traffic reduction program (see Tables 6-2 and 6-3 for highlights).*
5. *Improve transit/cycling/pedestrian facilities, environments, and services.*
6. *Increase and marginalise parking prices, restrict parking supply, and reduce parking lot development requirements.*
7. *Apply Full Cost Accounting, and Least Cost Planning and funding measures/principles.*
8. *Apply traffic calming measures.*

Target (BMCD) = 100%

This indicator and target aim to increase city and community densities to sustainability standards, and is closely related to the following indicators discussed above: *percentage of dwelling units within 400 meters of transit service and basic shopping needs,* and the *percentage of city/community zoned for mixed-use and transit-oriented/traditional neighbourhood development.* Research indicates that a minimum of 11-65 upa are required to achieve the transportation and land use efficiencies necessary to reduce the demand for private automobile travel (Blumenfeld 1968; Jacobs 1961; Calthorpe 1993; Condon 1996; Rydin 1992). For the purposes of this study, a target of 30 upa has been selected, based on the average of this range of minimum densities. At 30 upa, transit is significantly more efficient, as the population base required to sustain transit is present (Calthorpe 1993; Newman and Kenworthy 1999). Furthermore, communities with similar densities experience higher numbers of walk and bicycle trips (Bernick and Cervero 1997). Given this, impacts to local and global air quality are reduced.

An effective strategy to achieve this density standard is to relax development parking bylaws, as parking – in particular surface parking – consumes significant amounts of land. Some cities in Scotland and Germany have taken this idea a step further through the development of "car-free" communities, where parking requirements have been reduced, or eliminated, in favour of higher densities, more green space, and the use of community car sharing co-ops (Scheurer 1998; Roseland 1998). Residents of these communities enjoy the many benefits of being car-free, such as extra public space; better building designs (i.e. saved capital is typically re-invested to improve the technical and environmental character of the building); lower rents and mortgage payments (savings of approximately $27,000 per new home, which is typically consumed in parking capital costs and maintenance); and increased safety and individual freedom, especially for children who play outside, due to the reduced traffic volumes. Furthermore, the property developer and city planners enjoy the benefit of being able to build more residential units, thus providing economic and density rewards. Car-free community development thus not only reduces the size of the development's "footprint," but also significantly influences travel behaviour (Scheurer 1998; Wackernagel and Rees 1996; Bernick and Cervero 1997; Calthorpe 1993). For example, a car-free community in Cologne, Germany experienced the following modal shift: cycling increased from 11% to 26%, transit use increased from 17% to 39% and car use decreased from 42% to 1% (Scheurer 1998). As indicated in the OCP's development statistics, parking lot development consumes large tracts of land and can reduce overall community density by 60-80% (City of Burnaby 1996).[34] Lower density communities thus encourage automobile dependence, as distances to destinations increase, and should therefore be avoided in the BMCD project.

It is therefore recommended that 100% of the future Burnaby Mountain community be developed to a minimum average density of 30 dwelling units per acre (gross). To achieve this target, the following TDM strategies are highly recommended:

1. *Develop higher density and mixed-use communities, such as traditional neighbourhood and transit-oriented developments.*
2. *Restrict parking supply and reduce parking lot development requirements.*
3. *Develop and introduce transportation- and location-efficient mortgages.*
4. *Apply Full Cost Accounting, and Least Cost Planning and funding measures/principles.*
5. *Develop a voluntary traffic reduction program, particularly a car-sharing program to offset the reduction in parking facilities necessary to achieve 30 upa.*

6. Percenta[illegible] residents who live and work/study in the [illegible] community/university [illegible] Perce[illegible] within 30 minu[illegible] of walk[illegible]
Target (BMCD plus SFU's Student Residence) = 50% (minimum)

[34] Based on surface versus underground parking statistics for the South and East Neighbourhoods (e.g. 12 upa with surface parking versus 30 upa with underground parking in the South Neighbourhood equals a 60% reduction in density).

These indicators and target aim to reduce SOV travel and promote a healthy jobs-housing balance (i.e. large proportion of people living and working/studying in the same community/municipality) through increasing accessibility to destinations, such as work and school, and matching housing needs with employment/study opportunities. The target set for these indicators is based only on the future residents of the BMCD and University student residence developments (i.e. on-campus, excluding those that live in existing student residences[35]), as there are many factors that influence the jobs-housing ratios and transportation characteristics (i.e. time) of off-campus residents, such as those students that live with their families in suburban areas. Given this, and the fact that these two indicators are closely related, the target set above represents both indicators.

Research indicates that a strong jobs-housing balance is one of the most effective land use strategies in reducing automobile travel (Davidson 1997; Newman and Kenworthy 1999; Roseland 1998; GVRD and Province of BC 1993a; GVRD 1990). For example, for every 100 new housing units developed in central Toronto, there were approximately 120 fewer vehicle trips into the downtown per day (Sheltair 1998). Furthermore, Davidson indicates that improved jobs-housing ratios within the downtown Vancouver area could reduce vehicle-kilometres travelled (VKT) by up to 8.5% in the long-run (Davidson 1997). Other research indicates that VKT in cities can be reduced by up to 14% with the implementation of aggressive jobs-housing policies (Loudon and Dagang 1992; Kessler and Schroeer 1995).

Given that there are currently over 2,000 students on the residence 'wait list' at SFU, significant transportation efficiencies could be gained through the development of student residence and other on-campus housing opportunities, such as secondary suites (i.e. basement suites). Therefore, for example, if 2,000 student residence rooms were developed (keeping the on-campus population constant at 12,000 people), vehicle-based

[35] For simplicity, and to highlight the important role the BMCD and University student residence development plays in achieving a strong jobs-housing balance, current on-campus residents have been excluded from the development of this target.

trips to and from SFU could be reduced by 11.5% (i.e. VKT).[36] Jobs-housing strategies are thus an effective land use tool for improving modal splits and reducing the need to travel by private automobile, particularly in university communities where there is a 'captured market' of people (i.e. students, staff, and faculty) located in one compact, distinct area.

Given the development statistics outlined in SFU's OCP, the future BMCD may provide market housing for approximately 10,000 people. To achieve the 50% jobs/study-housing ratio identified above (i.e. in conjunction with the development of student residence in the University Enclave), there would need to be approximately 3,000 people living and working/studying in the BMCD community. Therefore, 30% of the new BMCD units would have to be occupied by members of the current Burnaby Mountain community, such as the students, staff, and faculty of SFU and/or the employees of Discovery Park and BC Hydro.[37] The achievement of such a jobs/study-housing balance would significantly reduce automobile dependence at SFU and be considered a progressive and sustainable approach to land use planning. However, the target set above is only a minimum benchmark. Even greater transportation and land use efficiencies can be gained if a larger percentage of the Burnaby Mountain community resided on-campus. Therefore, though SFU's commitment to quadruple student housing is a progressive and sustainable approach to campus land use planning, even further benefits can be achieved if attractive incentives are provided to locals to encourage local investment in residential property (i.e. investment in the BMCD project).

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[36] Based on the 1998 modal split results indicating that approximately 75% of trips to SFU are vehicle-based (i.e. SOVs and carpools) and the 1996 on-campus population estimate of 12,000 people (Petz et al. 1998; Moodie 1996). Therefore, assuming that 75% of the 2,000 students requesting residence currently commute by car, approximately 1,150 fewer cars would be commuting to/from campus (based on the vehicle-based modal split between SOVs (54%), 2-person carpools (36%), and 3(+)-person carpools (7%). This would represent a 11.5% decrease in vehicle-based travel (i.e. 1,150 cars divided by 10,000 cars/day).

[37] The commitment to quadruple student residence beds (4,200 extra beds) is included in the OCP's development plans but is not officially part of the BMCD project to build housing for approximately 10,000 people. Therefore, it is expected that there will be an additional 14,200 residents on campus by project completion. A 50% jobs/study-housing balance (i.e. 7,100 residents) is based on the 4,200 student residence beds (30% of 14,200) and 2,900 residents from the BMCD (20% of 14,200). The BMCD jobs/study-housing target is thus based on the 50% target, where 2,900 out of 10,000 BMCD residents equals a 30% BMCD jobs/study-housing target (approximate).

There exist incentive programs that are effective in encouraging members of a particular community to invest in their own community development, as well as providing financial incentives to the larger public for investing in sustainable development. Some of these incentive programs are applicable to the BMCD project and are as follows:

1. ***Mortgage Subsidy Plans***: where students, staff, and faculty become eligible to receive a mortgage subsidy for being members of the SFU community. For example, "equity-sharing" programs are an effective method for encouraging 'local' investment (i.e. investment by people from the Burnaby Mountain community), where the property owner provides a discount, or subsidy to the investor to encourage investment in exchange for a share of any future profits that accrue from real estate appreciation. Mortgage subsidies typically range from 20-25% below market values.
2. ***'Green' Mortgages***: if the BMCD is designed to reduce material and energy flows, provide alternatives to the private automobile, provide a strong jobs-housing balance, and meet other sustainability criteria, SFU and the BMCC could make an application to its, or another, financial institution to provide lower interest rate mortgages to its borrowers as a benefit for investing in sustainable development. Green mortgages come in all shapes and sizes. Neworld Bank in Massachusetts offers energy-efficient mortgages, whereby energy-efficient homes can qualify for a reduced mortgage rate of 1 to 2 percent below prime (Roseland 1998). Some other examples of 'green' mortgages are as follows:
    a. ***Location-Efficient (or Transit) Mortgages (LEM)***: pioneered by the Centre for Neighbourhood Technology (CNT) and offered by the Federal National Mortgage Association in the US (Fannie Mae), LEMs encourage buyers to invest in homes that are close to work, shopping, transit, and recreational facilities. These institutions factor the savings involved in urban transit alternatives into mortgage eligibility calculations. This can provide a substantial boost in buying power for low and moderate-income home buyers – up to $500 per month (US) can be saved through investing in location-efficient housing – thereby reducing mortgage interest rates (Hoeveler 1998).

Therefore, this lower interest rate provides financial leverage to investors and security to financial institutions (Durning 1996). "Affordability and Choice Today" is a program funded by the Canadian Mortgage and Housing Corporation (CMHC) and provides innovative community development projects, such as sustainable communities that integrate flexible and mixed-use land development, with project funding. This funding could be used to subsidise investments made by the faculty, employees, and students of Burnaby Mountain.

b. ***Car-Free Housing Mortgages***: in Edinburgh, Scotland, the city council recently approved an auto-free development whereby residents are required to join the community's car-sharing club. This program, like LEMs, provides residents with lower mortgages as development costs are lower due to the limited development of parking infrastructure, which can add an additional $20,000-25,000 per home (Scheurer 1998).

These programs are only a few of the many incentive-based strategies that are effective in attracting local investment. SFU and the BMCC should consider approaching progressive financial institutions, like VanCity, in organising some form of "equity-sharing" and/or 'green' mortgage plans for its future residents, particularly those from the Burnaby Mountain community.

It is therefore recommended that a minimum of 50% of the new residential units (both BMCD and student residence) are inhabited by members of the SFU, Discovery Park, and BC Hydro communities (i.e. the BMCD jobs-housing ratio is a minimum of 30%). To achieve this target, SFU and the BMCC would need to go beyond their original commitment of 4,200 student beds and develop policies to attract local investment in the BMCD project. *This can be achieved through a program of strategic mortgage subsidy planning that includes equity-sharing and location-efficient incentives.* To complement this policy proposal, the following TDM strategies are highly recommended:

1. *Develop higher density and mixed-use communities, such as traditional neighbourhood and transit-oriented developments.*

2. *Develop and introduce transportation- and location-efficient mortgages.*
3. *Apply Full Cost Accounting, and Least Cost Planning and funding measures/principles.*

7.5 Pe[illegible] traffic [illegible]

Target (SFU/BMCD) = 100%

This indicator and target aim to reduce SOV travel by increasing incentives for non-SOV travel. Voluntary traffic reduction incentives vary widely, but are typically made up of one or more of the following measures.

Table 6-3. Examples of Traffic Reduction Measures

Financial Incentives
- Transportation Allowance
- Bike and Walk Subsidies
- Car/Vanpool Subsidy
- Vanpool Seat Subsidy
- Transit Subsidy (e.g. UPASS)
- Rideshare Parking Subsidy
- Other Financial Subsidy

Parking Programs
- Preferential Reserved Parking
- Restricted Parking
- Parking Charges

Flexible Work Schedules
- 'Flexible Time'
- Telecommuting
- Compressed Work Week
- Strategic Class Scheduling

Assistance Programs
- Commuter Information Centres
- Commuter Fairs
- New Hire Orientation
- Other Marketing Elements
- Special Interest Group
- Employer Based Matching Services
- Information Booths
- Company Owned/Leased Vanpool
- Other Parking Management
- Guaranteed Ride Home

Award Programs
- Prize Drawing, Commuter-of-the-Month Award
- Recognition in Newsletter
- Additional Time Off with Pay

Other
- Childcare Services
- On-site Services (e.g. cafeteria, post office etc.)

Adapted from: Davidson, Gavin. "Area Wide Traffic Management: A Strategy for Improving the Economic, Social and Environmental Health of Urban Centres." Masters Project, Simon Fraser University, 1997.

These measures are all effective in reducing the demand for automobile travel, as research indicates that voluntary traffic reduction programs that include elements of the above can reduce vehicle commuting travel by 10% or more (Davidson 1997; COMSIS 1993; Litman 1995a; Litman 1998a). Furthermore, community-based shuttle programs, car and bike sharing co-operatives, 'walking school bus' programs, home delivery services, and 'buy local' incentive programs can also contribute significantly to reducing the need to travel by car. The impacts on vehicle travel from these measures are uncertain; however, the walking school bus program has achieved significant traffic reduction results and media attention in the past few years (Kennedy 1998).

Voluntary traffic reduction programs are more politically feasible than regulatory and market-based measures but are typically less effective in reducing vehicle trips (Davidson 1997). However, voluntary programs are considered to be an appropriate starting point for the implementation of traffic reduction measures. These programs are generally co-ordinated by employers through the establishment of Employee Transportation Administrators (ETAs). As of 1997, there were over 100 ETAs established (voluntarily) in firms throughout the GVRD (Davidson 1997). The recent *Burnaby Transportation Plan*, under Policy 18, indicates that the City of Burnaby should pursue the development of voluntary traffic reduction programs (City of Burnaby 1995). However, in California and Washington states, employers with over 100 employees are required by law to co-ordinate trip (or traffic) reduction programs, commonly known as "trip reduction bylaws."

It is therefore recommended that SFU develop, co-ordinate, and manage a voluntary traffic reduction program for its students, staff, and faculty. The program should include the following 'high priority' measures: co-ordinated ridesharing program with subsidised parking fees and preferential parking; a transportation allowance for non-SOV travel and discounted transit pass programs, such as the implementation of a UPASS program; guaranteed ride home service; flexible work schedules; implementation of the 'walking school bus' program; development of a community-based shuttle service *for on-campus (i.e. feeder and connector service) and off-campus travel (e.g. the "StudentMover" concept); and the development of car and bike sharing opportunities (e.g. co-ops, clubs).* Given these TDM recommendations, the following TDM strategies are highly recommended to complement the effectiveness of this proposal:

1. *Develop a central co-ordinating management body to implement TDM programs, establish ETAs, and monitor progress.*
2. *Improve transit/cycling/pedestrian facilities, environments, and services.*
3. *Increase and marginalise parking prices, restrict parking supply, and reduce development requirements for parking.*
4. *Apply Full Cost Accounting, and Least Cost Planning and funding measures/principles.*
5. *Develop higher density and mixed-use communities, such as traditional neighbourhood and transit-oriented developments.*
6. *Apply traffic calming measures.*

[illegible]
Target (SFU/BMCD) = 100%

This indicator and target aim to minimise the need to travel outside the neighbourhood for basic needs by increasing pedestrian and bicycle amenities in the neighbourhood. This can be achieved by developing 'end-of-trip' infrastructure at workplaces, transit stations, and public facilities; improving general walk/bike infrastructure, such as sidewalks and bike lanes; and integrating cycling and transit travel (i.e. intermodal) through the provision of bike racks on buses.

With respect to end-of-trip facilities, access to showers and change rooms removes a major barrier for many potential commuter cyclists, providing them with the opportunity to 'freshen up' after their commute. Research indicates that the integration of end-of-trip facilities, such as locker rooms with showers, bike racks and storage facilities, and direct walk/bike routes, into community and urban design make walking and cycling more convenient and enjoyable, thus encouraging their use (Calthorpe 1993; Engwicht 1993; Newman and Kenworthy 1999; Gehl 1992; Roseland 1998; Davidson 1997). The

City of Vancouver has recently enacted a bylaw that requires all new multiple residence dwellings and office developments to include end-of-trip facilities. Furthermore, the *Burnaby Transportation Plan*, under Policies 21 and 23-25, indicate that safe and convenient pedestrian and bicycle facilities should be provided, including the integration of end-of-trip infrastructure at major office and industrial developments (City of Burnaby 1995).

Standard pedestrian and bicycle infrastructure, such as sidewalks and bike lanes, also play an integral role in the development of sustainable transportation plans. For example, the number and frequency of cycling trips increased significantly in Davis, California and Toronto when cycling facilities were improved (Roseland 1998). In Boulder, Colorado, commitments have been made to shift 15% of all vehicle trips to walking, cycling, and transit by 2010 (Davidson 1997). Investments in the Pearl Street Pedestrian Mall and the Boulder Creek Path have resulted in increased pedestrian and cycling trips, particularly bicycle commuting trips on the Boulder Creek Path. Between 1989 and 1995, the City of Boulder managed to reduce vehicle trips by 3%.

Furthermore, Jan Gehl – a prominent urban designer from Copenhagen, Denmark – and others believe that pedestrian-oriented design features play an important part in encouraging pedestrian travel (Jacobs 1961; Gehl 1992; Bernick and Cervero 1997; Engwicht 1993; Engwicht 1998; Calthorpe 1993; Jacobs, A. 1993). Design features that include attractive landscaping, continuous paved sidewalks, street furniture, urban art, activity areas, central plazas and public places, retail opportunities, building over hangs and weather protection, and safe street crossings create an inviting public realm that encourage foot traffic. Bernick and Cervero indicate that these pedestrian design elements alone could be as significant in reducing vehicle travel as 'density' and 'diversity' – the other design elements of transit-oriented development (Bernick and Cervero 1997). Therefore, the design of pedestrian and bicycle environments is important in encouraging and inviting cyclists and walkers, and play an integral role in reducing air emissions from vehicle travel.

Finally, the integration of cycling and transit travel can achieve significant transportation benefits. Direct bike lanes, secured bike storage, and bike racks on transit (e.g. buses, light rail) enable cyclists to reach their destinations faster and more conveniently. For example, the City of Seattle provides bike racks on all local and regional buses, connects major transit stations with bike routes, and provides secured bike storage facilities at all major stations (Replogle and Parcells 1992; COMSIS 1993). Recently, all buses on the TransLink express bus route travelling to UBC (99 B-Line) have been equipped with a bike rack (holding a maximum of 2 bikes). There has also been a commitment by TransLink to extend this program to some buses travelling to SFU by September 1999 (implemented in November 1999 on the #135 route), followed by all TransLink buses travelling throughout the GVRD by 2005. Bicycle and transit intermodal treatment can thus save travel time, as cycling to transit stops is faster than walking, and express transit service can often compete with the car.

It is therefore recommended that 100% of the future community development include strong pedestrian and bicycle infrastructure, and that facilities within the existing SFU campus be improved to encourage pedestrian and bicycle travel. This infrastructure proposal should include the development of end-of-trip facilities, at both SFU and BMCD; direct pedestrian and bicycle links within campus; and improved 'connector' bike lanes between SFU, the existing GVRD bikeways, and local communities/regional centres. Furthermore, the climatic conditions of Burnaby Mountain should be integrated into infrastructure and facility design (i.e. weatherproofing). To achieve this target, the following TDM strategies are highly recommended:

1. *Improve transit/cycling/pedestrian facilities, environments, and services.*
2. *Develop a central co-ordinating management body to implement TDM programs, establish ETAs, and monitor progress.*
3. *Develop higher density and mixed-use communities, such as traditional neighbourhood and transit-oriented developments.*
4. *Apply traffic calming measures.*
5. *Apply Full Cost Accounting, and Least Cost Planning and funding measures/principles.*

[illegible]

(a) Target (BMCD) >= 90% (minimum)
(b) Target (BMCD) = High

These indicators and targets aim to increase densities to sustainability standards and promote a jobs-housing balance through matching housing types and affordability with the needs of the working and non-working population within the community. The indicators are represented together here, though with separate targets, as their objectives of densification, housing affordability, and housing mix are interconnected. Research indicates that a diversity in housing types is important to increasing densities, and thus improving transit, bicycle, and walk efficiencies (Roseland 1998; Calthorpe 1993). Communities made up of primarily single-family homes are more land intensive, thereby spreading residences across a greater area and thus reducing densities and accessibility. It is therefore important that the development of single-family homes is limited in the future community development on Burnaby Mountain.

Neither the OCP nor DPC indicate the type of housing that is proposed for the BMCD, though both documents state that their will be a mix of housing types (City of Burnaby 1996; Moodie 1996). However, it has been informally indicated that there will be no single-family residential development in the BMCD project (Johnson 1999, Geller 2000). Single-family residential development is thus capped at 10% for this study, thereby allowing for some flexibility in housing types and providing room for any unforeseen changes in the vision of the BMCD or the OCP.

Furthermore, a diversity in housing availability, cost, tenures, and tenants are also important elements in developing a healthy jobs-housing balance, as well as a rich and strong social environment (Sheltair 1998; Engwicht 1993). In Burnaby Mountain's case, the demographics (i.e. housing needs and income potential) vary widely between the student population, the staff and faculty of SFU, and the employees of Discovery Park and BC Hydro. Therefore, in order to achieve a high jobs-housing ratio, it is important to match housing types and affordability for both the non-working (i.e. students) and working populations of the Burnaby Mountain community. In other words, both low-income/short-term accommodations and moderate- to high-income/long-term accommodations will be required to satisfy the needs of the market that currently exists on Burnaby Mountain and to achieve a healthy jobs-housing balance. Given the subjectiveness of the indicator selected to achieve this objective, it is appropriate that the established target – *High* – also be subjective and qualitative. In other words, it is recommended that there is a *high*, or diverse, mix of housing and funding types, tenures, tenants, and income levels represented in the future BMCD. To achieve this mix, Sheltair recommends the following policies and programs, which may also be applicable to the SFU case study:

- provision of density bonusing criteria;
- alteration of zoning codes and building design guidelines;
- investigation of innovative building designs, such as "city homes" that allow ground-oriented housing for families on lower floors and smaller apartment units above for singles and couples;
- encouragement of live/work and home office facilities to provide flexible employment opportunities for residents; and
- provision of equity and non-equity housing co-operatives that support mixed-use facilities for a wide range of family types (Sheltair 1998).

It is therefore recommended that no more than 10% of the residential units developed in the BMCD be single-family homes (maximum), and that there be a highly diverse mix of housing and funding types, tenures, tenants, and income levels represented in the future Burnaby Mountain residential community. To achieve these targets, the following TDM strategies are highly recommended:

1. *Develop higher density and mixed-use communities, such as traditional neighbourhood and transit-oriented developments.*
2. *Develop and introduce transportation- and location-efficient mortgages.*
3. *Restrict parking supply and reduce development requirements for parking.*
4. *Apply Full Cost Accounting, and Least Cost Planning and funding measures/principles.*

2nd Priority Indicators:

[illegible]
Target (BMCD – market housing) <= 1.25 vehicles/unit
Target (SFU – student residence) <= 0.33 vehicles/student bed

This indicator and target aim to minimise SOV travel by increasing car-free living opportunities on Burnaby Mountain. The number of vehicles per household is considered to be a strong indicator of the demand for vehicle travel, thus reflecting the state of local and regional land use patterns and the efficiency of alternative modes of transportation (Newman and Kenworthy 1999; Litman 1997b; Hart 1995). The targets for this indicator have been separated between market and student housing, as the demand and opportunity for vehicle travel will vary between the two groups. Both targets, however, are based on the establishment of relaxed development requirements for residential parking, the development of a pedestrian and transit-oriented community that encourages car-free or 'car-smart' (e.g. one car family) living opportunities, and the implementation of effective traffic reduction measures that reduce the demand for vehicle travel, such as UPASS and car-sharing programs.

Davidson indicates that mixed-use neighbourhoods are ideal for reducing parking stall development in new buildings (both residential and commercial), as the demand for vehicle travel is reduced in this type of community design (Davidson 1997). For example, only 61% of households in the Burrard peninsula of Vancouver (i.e. downtown) own a vehicle, and it is believed that this area's high density, mixed-use, and transit-supportive design features play a large role in shaping the demand for vehicle travel (GVRD 1994b). Davidson thus recommends that city parking codes should change to reflect this pattern and that 10-20% of future developments in downtown Vancouver be car-free. Therefore, both community design and the degree of integration with alternative transportation infrastructure play an integral role in shaping the demand for vehicle travel, and thus the supply of parking necessary to meet this demand.

Sustainable urban design guidelines indicate that a maximum of 1.25 parking spaces per residential unit be allowed for new residential developments (Condon 1996). This target is lower than the approximate 1.5-2.0 parking stalls/unit standard identified in the City of Burnaby's parking schedule.[38] This design target is an average and can thus be made up of higher standards for some residential units (e.g. 2 stalls/unit) in combination with lower, or car-free, standards (e.g. 1 stall/unit or 0 stalls/unit). With respect to this study, it is not necessary to identify the range of parking development possibilities, rather, it is more important to set the maximum standard to guide overall community and land use planning.

The current student residence parking standard is approximately 1 stall per 2 beds, matching that of Schedule VIII, the City of Burnaby's parking bylaw (City of Burnaby 1999). It is believed that this development requirement for parking can also be relaxed, particularly if the BMCD is designed to be a moderate- to high-density, mixed-use community with efficient transit service and pedestrian/bicycle networks. One parking stall per three student residence beds has thus been established as the target for this study.

Successful car-free developments typically provide access to a car-sharing club, where residents of car-free communities can conveniently rent vehicles when required. The provision of a 'travelcard,' or UPASS, is also common within these communities, as transit passes are included in rent/mortgage payments. Both programs are not only effective in supporting car-free living environments and reducing vehicle travel, but are also economical for the tenant, landlord, and developer (Scheurer 1998). Car-sharing clubs save the developer on parking development costs, the landlord on parking maintenance, and the tenant in vehicle ownership and rent costs. As well, UPASS programs are particularly effective in reducing the tenant's transportation costs.

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[38] Parking stall bylaws differ for each type of residential development. As the type, or mix, of residential development has not been established in either the OCP or DPC, it is difficult at this time to identify the exact parking lot requirements for the BMCD.

Though the concept has not taken off in North America yet, car-free community development is becoming more commonplace, particularly in Europe. However, both car-sharing clubs and UPASS programs are becoming more popular in North America, with established car-sharing clubs in Vancouver, Victoria, Toronto, Montreal, Portland, and Boulder; and UPASS programs existing at over 30 US universities, most universities in Ontario and Quebec, the University of Victoria, and the University of British Columbia (September 2000). It is thus only a matter of time before these concepts are integrated with community development. SFU and the BMCC – both being institutions that pride themselves on innovation – therefore have the opportunity to champion these innovations and become a leader in community development.

It is believed that relaxed development requirements for parking (i.e. reduced parking supply) and the development of a mixed-use, transit-oriented community that implements a traffic reduction program, such as car-sharing clubs and the UPASS, will significantly shape transportation behaviours to favour transit, bicycle, and pedestrian travel. Vehicle ownership per household will thus be influenced by these design guidelines and the implementation of sustainable transportation services.

It is therefore recommended that the future BMCD be designed to encourage car-free living. In combination with a mixed-use, high density, transit-oriented community design that includes traffic reduction services, the BMCD should allow for a maximum of 1.25 parking stalls (i.e. vehicles) per market residential unit and 1 parking stall (i.e. vehicle) for every 3 student residence beds. To achieve these targets, the following TDM strategies are highly recommended:

1. *Develop higher density and mixed-use communities, such as traditional neighbourhood and transit-oriented developments.*
2. *Develop and introduce transportation- and location-efficient mortgages.*
3. *Increase and marginalise parking prices, restrict parking supply, and reduce development requirements for parking.*
4. *Develop a voluntary traffic reduction program (see Tables 6-2 and 6-3 for highlights).*
5. *Improve transit/cycling/pedestrian facilities, environments, and services.*

6. *Apply Full Cost Accounting, and Least Cost Planning and funding measures/principles.*
7. *Apply traffic calming measures.*
8. *Develop a central co-ordinating management body to implement TDM programs, establish ETAs, and monitor progress.*

[illegible]
Target (BMCD) = 60% (minimum)

These indicators and target aim to minimise the need to travel outside of the neighbourhood for basic needs by increasing pedestrian, bicycle, and transit amenities; and increase safety, community interaction, and livability within the neighbourhood by introducing traffic calming measures. Both indicators are represented by one target due to the interconnected nature of pedestrian/bicycle/transit design and traffic calming. Given that a large proportion of urban land is dedicated to automobile infrastructure – over 30% in Vancouver – the percentage of streets dedicated to alternative transportation modes is considered an effective indicator of pedestrian orientation (Sheltair 1998). As indicated above, pedestrian-oriented community design can significantly influence and shape transportation behaviours (Gehl 1992; Bernick and Cervero 1997; Engwicht 1993). Neighbourhoods that provide safe, direct, convenient, and inviting pedestrian environments typically experience higher levels of pedestrian, bicycle, and transit travel (Gehl 1992; Bernick and Cervero 1997; Newman and Kenworthy 1999).

This target is based on Sheltair's proposal for the SEFC community, where it recommends dedicating 60% of the street area to walking, cycling, and transit uses (Sheltair 1998). Sheltair's proposal is based on pedestrian orientation in European cities, where nearly 80% of Trondheim, Norway's streets are dedicated to alternative transportation modes, while the average European city dedicates over 30%. This orientation towards non-motorised and transit travel in Europe has resulted in 20-50% of trips being completed on foot or bicycle and 20-40% of trips on transit (Newman and Kenworthy 1999; GVRD and Province of BC 1993a). In Vancouver, on the other hand, where less than 10% of its streets are dedicated to pedestrian, bicycle, and transit uses, the modal splits for alternative transportation modes are significantly lower. According to Raad and Kenworthy, only 5.7% of Vancouverites travel by foot and/or bicycle and only 6.5% travel on transit (Raad and Kenworthy 1998). The GVRD, however, indicates that up to 8% and 9% of people travel by non-motorised and transit modes respectively (GVRD and Province of BC 1993a). Regardless of these differences, the land use and associated transportation behaviours in Europe and Canada suggest that pedestrian and transit-oriented urban design can significantly influence transportation decisions.

To achieve the 60% target in the SEFC community, Sheltair recommends the creation of a system of standards requiring minimum amenities for alternative modes (e.g. similar to bicycle parking bylaws); the development of pedestrian-friendly site designs, including direct, pleasant routes from building entrances to sidewalks and transit stops, and the provision of protected waiting areas and rain shelters at doorways and transit stops; the development of a grid-like street pattern and short block lengths; and orientating buildings to provide pedestrians and cyclists with direct access to streets without having to traverse parking areas (i.e. building setbacks are minimised and parking is located in the back of buildings) (Sheltair 1998). These proposals are also applicable to the SFU case study.

Traffic calming devices, such as wider sidewalks, bicycle lanes, 30 km/hr speed limits, narrow roads, traffic circles, textured road surfaces, street trees, street furniture, and pedestrian/bicyclist crossings also support the 60% target set in this and the SEFC study. A program that was first introduced in Germany to slow vehicle traffic, traffic calming has become popular in many parts of the world, including Vancouver. Research indicates that traffic calming has been effective in not only reducing vehicle speeds and vehicle use, but also in reducing the number of vehicle-pedestrian/cyclist accidents, noise pollution, and the barrier effects associated with automobile-oriented land use patterns (Newman and Kenworthy 1999). Furthermore, the general livability of neighbourhoods has improved with the introduction of traffic calming devices (e.g. kids playing on the streets, increased social interaction) and local economic activity has increased (Engwicht 1999; Engwicht 1993; Newman and Kenworthy 1999). Therefore, traffic calming and street orientation go hand in hand, as both aim to improve pedestrian, bicycle, and transit environments, as well as the general livability and 'sense of community' experienced within neighbourhoods.

It is therefore recommended that a minimum of 60% of the total street area in the future BMCD is dedicated to pedestrian, cyclist, and transit uses.[39] To achieve this target, the following TDM strategies are highly recommended:

1. *Apply traffic calming measures.*
2. *Increase and marginalise parking prices, restrict parking supply, and reduce development requirements for parking.*
3. *Improve transit/cycling/pedestrian facilities, environments, and services.*
4. *Develop higher density and mixed-use communities, such as traditional neighbourhood and transit-oriented developments.*
5. *Develop and introduce transportation- and location-efficient mortgages.*
6. *Develop a voluntary traffic reduction program (see Tables 6-2 and 6-3 for highlights).*
7. *Apply Full Cost Accounting, and Least Cost Planning and funding measures/principles.*

3. [illegible]
Target (BMCD/SFU) = Yes/High

These indicators and target aim to minimise SOV travel by encouraging car-free living opportunities and increasing transportation choices. As indicated above, both LEMs and sustainable transportation services, such as car-sharing and walking school bus programs, reduce the demand for vehicle travel. Given that both indicators are also

[39] The measurement of this indicator can be based on the percentage of all street area within the BMCD that is dedicated to pedestrian, cycling, and transit uses (though some space is shared between all modes, including vehicles, potentially making it difficult to measure).

effective TDM measures, the target established above simply encourages their development in this case study.

It is therefore recommended that the BMCC and SFU provide 'Green' and/or LEM opportunities to the residents of the community, as well as several sustainable transportation services. To achieve this target, the following TDM strategies are highly recommended:

1. *Develop higher density and mixed-use communities, such as traditional neighbourhood and transit-oriented developments.*
2. *Develop and introduce transportation- and location-efficient mortgages.*
3. *Develop a voluntary traffic reduction program (see Tables 6-2 and 6-3 for range of sustainable transportation services and programs).*
4. *Improve transit/cycling/pedestrian facilities, environments, and services.*
5. *Develop a central co-ordinating management body to implement TDM programs, establish ETAs, and monitor progress.*
6. *Apply Full Cost Accounting, and Least Cost Planning and funding measures/principles.*

4. Percentage of community [illegible]
Target (BMCD) = 50% (minimum)

This indicator and target aim to minimise water pollution by reducing surface run-off flows. Research indicates that automobile-oriented land use patterns have significant impacts on water quality, particularly where low density development encourages urban sprawl and large portions of land is paved for vehicle infrastructure (e.g. roads, parking) (Raad 1998; Bein, Litman, and Johnson 1994). Impacts range from soil erosion, sedimentation, and flooding (i.e. major hydrological disruptions) to road runoff that contaminates local streams (e.g. hydrocarbons, transmission fluids). It is therefore important to integrate sustainable community design principles into the BMCD project to reduce water quality impacts.

There are numerous strategies to reduce the impervious areas of urban developments, such as reducing the impact area for development through design (i.e. the footprint of the site), separating impervious areas with pervious areas, and encouraging the planting of vegetation which provides higher permeability than turf (Golden 1999). The following table outlines some of the design solutions that are effective in minimising the imperviousness of a development site.

Table 6-4. Development Design Solutions to Minimise Impervious Areas

• reduced road widths	• vertical/underground parking structures
• cul de sac donuts	• swales rather than curb/gutters
• cluster/high density development	• commercial open space landscaping
• reduced parking requirements/ratios	• reduce setbacks and frontage
• smaller parking stalls	• flexible minimum lot sizes
• angled parking	• "t" or "v" shaped turnarounds
• shared parking/driveways	• shorter road lengths
• reduced cul de sac radii	

Adapted from: Golden, Shira. "Ecological Infrastructure in the Brentwood Town Centre: Implications of a Design Charrette on Stormwater Management." Masters Project, Simon Fraser University, 1999.

Permeable pavement is also a solution to threatened water quality. Research indicates that porous pavements (e.g. porous asphalt and concrete) contain sufficient "void space" (e.g. 'donut-like' surface material) to infiltrate runoff in the underlying base and soil of the development site, while providing a surface suitable for walking and driving (Golden 1999; Richman 1997). The application of permeable pavement can thus significantly reduce the impervious surface coverage of a development site without sacrificing intensity of use. Furthermore, permeable pavement is more economical than investments in conventional asphalt (Scheuler 1995). However, permeable pavement is restricted to soils with a high infiltration capacity. The following table summarises the advantages and disadvantages of an array of permeable pavement types, which can be investigated by the BMCC in the future development planning process.

Table 6-5. Permeable Pavements: Methods and Results (Golden 1999, 29)

[illegible]	[illegible]	[illegible]
Pervious paving		
a. Pervious concrete	• does not require curbs and gutters	• not good in high traffic areas • sealing and clogging of pavement is possible even with rigorous maintenance
b. Porous asphalt	• used on parking lots/light duty roads, little maintenance required • works in areas with flat slopes, sandy soils, winter sanding/salting is minimal • oldest porous pavement – 1973 University of Delaware Visitor's Centre, still permeable • overall performance not significantly compromised	• more difficult to install • lack of long-term testing • greater cost but offset by not having to build curbs and gutters
Unit pavers on sand (discrete blocks set in a pattern on a prepared base)		
a. Turf block	• open celled • successful when planted with turf	• not good for high traffic areas
b. Brick	• permeability between blocks	• not good for high traffic areas
c. Natural stone	• laid on sand • permeability between stones	• high cost
d. Concrete unit pavers	• permeability between stones • solid unit	• can bear heavy loads
Granular materials		
a. Crushed aggregate (gravel)	• permeable, easy to install, inexpensive • versatile	• dusty • inappropriate for high use
b. Cobbles	• good for median islands, low use areas	• inappropriate for high use
c. Wood mulch	• outdoor play areas, light pedestrian use	• inappropriate for high use

The target established for this study is based on Sheltair's recommendation for the SEFC community, where a target of 54% average site imperviousness is set (Sheltair 1998). This target is based on other developments, such as the *Gilmore Catchment* in Burnaby, where 55% of the community is impervious (development mix: 71% residential, 23% commercial, 6% green space); the *Meydenbauer Catchment* in Bellevue, Washington, where 50% of the community is impervious (development mix: 42% residential, 33% commercial, 19% roads, 6% open space); and the *Eagle Catchment* in Burnaby, where an impressive 25% of the community is impervious (development mix: 30% residential, 31% commercial, 39% green space). These impervious percentages are based on ratings for footprints of buildings, decks, driveways, streets, sidewalks, and roofs (lawns and gardens are not included in these ratings). The numerical ratings are as follows – roofs (95), roads (75-95), permeable paving (60-80), and grass (40-60) – and the above percentages are based on these ratings (Golden 1999).

The above case studies identify a correlation between site imperviousness and land use mix. Communities with less land developed for residential, commercial, and transport purposes and more green space development have significantly lower impervious percentages. The *Eagle Catchment* community is an excellent example of this relationship. For sustainable community design, however, Calthorpe advocates the following neighbourhood land use mix: 10-15% public space (e.g. green space, public squares), 10-40% community core and employment (e.g. retail, commercial, professional offices), and 50-80% residential development (Calthorpe 1993). These guidelines thus recommend less public space than the *Eagle Catchment* community, though the objectives of sustainable community design are much more comprehensive and holistic than simply developing pervious communities. Therefore, given that the land use mix for the BMCD site is unknown at this time (i.e. percentage of total site dedicated to residential, commercial, road, and green space development), it is difficult to develop a site specific target. The target set for this study is thus based on the Sheltair recommendations for sustainable community development at SEFC, the local case studies identified above, and the sustainable community design guidelines put forth by Calthorpe. Furthermore, the target is based on the BMCD site only, and includes all roads, green space, residential areas, and all other land uses within this site.

It is therefore recommended that the BMCD achieves an average site perviousness of 50% (minimum). To achieve this target, the following TDM strategies are highly recommended:

1. *Develop higher density and mixed-use communities, such as traditional neighbourhood and transit-oriented developments.*
2. *Increase and marginalise parking prices, restrict parking supply, and reduce development requirements for parking.*
3. *Apply traffic calming measures (alternative road surfaces and/or permeable paving).*

4. *Apply Full Cost Accounting, and Least Cost Planning and funding measures/principles.*

5. Ave[illegible]
Target (BMCD) >= 1/day

This indicator and target aim to increase safety, social interaction, and overall community livability through the introduction of traffic calming measures. Research indicates that community design that emphasises pedestrian, bicycle, and transit travel – through the development of an inviting pedestrian environment and the introduction of traffic calming measures – integrated with distinct public places and destinations (e.g. markets, grocery stores, cafes, and community squares), reduces the speed and volume of vehicle traffic and increases a community's sense of safety, the number of unplanned interactions, both social and economic (i.e. "spontaneous exchanges"), and the general livability of the neighbourhood (Engwicht 1993; Jacobs 1961; Calthorpe 1993; Newman and Kenworthy 1999).

Since the subjectiveness of this indicator makes it difficult to establish a sound target, the target has been set at a reasonable "1 spontaneous exchange per day per resident" (minimum). However, given this, it is believed that this indicator will be an effective measure of sustainable community design on Burnaby Mountain, as this design approach focuses strongly on not only developing pedestrian-oriented places, but also on developing a 'sense of community.'

It is therefore recommended that the BMCD be designed to enhance the 'sense of community' experienced by its residents. The average number of "spontaneous exchange" experiences per capita per day should thus be greater than, or equal to, 1.[40]

[40] The measurement of this indicator could be based on community-wide interviews or surveys.

To achieve this target, the following TDM strategies are highly recommended:

1. *Develop higher density and mixed-use communities, such as traditional neighbourhood and transit-oriented developments.*
2. *Improve transit/cycling/pedestrian facilities, environments, and services.*
3. *Apply traffic calming measures.*
4. *Increase and marginalise parking prices, restrict parking supply, and reduce development requirements for parking.*
5. *Develop a voluntary traffic reduction program (see Tables 6-2 and 6-3 for highlights).*
6. *Develop a central co-ordinating management body to implement TDM programs, establish ETAs, and monitor progress.*
7. *Develop and introduce transportation- and location-efficient mortgages.*
8. *Apply Full Cost Accounting, and Least Cost Planning and funding measures/principles.*

6[illegible] Public [illegible]

Target (SFU/BMCD) = 20% (minimum)

This indicator and target aim to minimise SOV travel by providing financial incentives and benefits that support reduced automobile dependence in order to reduce the need to expand automobile-oriented transportation infrastructure, such as roads and parking facilities. Research indicates that reduced public and private spending on such transportation infrastructure, with investments redirected to transit, bicycle, and pedestrian-supportive travel, reduce the demand for vehicle travel (Newman and Kenworthy 1999; Litman 1997a; Litman 1998b; Litman 1999). This indicator thus encourages the use of least cost planning (LCP) and full cost accounting (FCA) techniques, where alternative transport investments (e.g. transit versus road investment) are assessed based on the inclusion of all internal and external costs (i.e. FCA), and investment decisions are based on the optimisation of economic, ecological, and social returns (i.e. LCP). The following table summarises the cost difference between SOV and transit travel, indicating that transit investments are more economical than automobile-oriented infrastructure investments.

Table 6-6. Full Cost Accounting Comparison Between Single-Occupant Vehicle and Transit Travel (Litman 1997a, 11)[41]

[illegible]	[illegible]	[illegible]	[illegible]
Accidents	0.035	0.008	0.027
Parking	0.12	0	0.12
Congestion	0.17	0.014	0.156
Roadway facilities	0.016	0.003	0.013
Roadway land	0.024	0.001	0.023
Municipal services	0.015	0.001	0.014
Air pollution	0.082	0.015	0.067
Noise pollution	0.01	0.002	0.008
Resource consumption	0.029	0.004	0.025
Water pollution	0.013	0.001	0.012
Total Savings			**0.465**

This FCA analysis indicates that for every mile shifted from SOV to transit travel, 46.5 US cents are saved. Therefore, using LCP principles, transit investments would be a more economical and sound use of public finances.

With respect to this case study, automobile-oriented infrastructure investments should be compared to those of pedestrian, bicycle, and transit-oriented infrastructure investments. For example, if the BMCD is developed to be a low-density, single-use community that encourages vehicle travel, the following costs may be incurred: increased land costs; increased municipal service infrastructure costs (e.g. water, sewage, roads); increased vehicle use and ownership costs (e.g. automobile ownership costs approximately $7,000 per year); increased parking facility costs; increased air, water, and noise pollution costs; increased accident costs; and increased congestion costs. On the other hand, the development of a moderate to high-density, mixed-use, pedestrian, bicycle and transit-oriented community may be more cost effective, as land and municipal infrastructure costs alone could save the BMCC and the City of Burnaby significant public capital. Given that these costs will not be borne solely by the BMCC, the City of

[41] Note that not all externalities are included in this example.

Burnaby, nor the future residents of the BMCD (i.e. some of these externalities will be shared with local and global citizens), investments in unsustainable land use and transportation plans are considered to be an unwise use of both public and private finances, and should therefore be minimised.

This indicator is thus a measure of the potential public and private savings from the development of a sustainable community on Burnaby Mountain, one where automobile travel is de-emphasised. The target is therefore based on the study's overall objective of reducing SOV travel by 20%, where it is assumed that a 20% reduction in SOV travel – based on the introduction of 'smart' land use and TDM measures – may result in a 20% net savings in public and private transportation and land use spending. To measure this target, public and private savings must first be evaluated for the alternative community design options (i.e. FCA analysis). Therefore, a FCA analysis will provide the basis for determining whether or not this 20% target is achieved (i.e. through comparing total net costs for all alternatives and using the 'automobile-oriented' design option as the basis for this comparison).[42] The FCA analysis, however, does not fall within the scope of this study.

It is therefore recommended that the City of Burnaby and BMCC invest in development plans that reduce the demand for SOV travel, and thus the need to expand automobile-oriented transportation infrastructure, and provide public/private transportation and land use savings of no less than 20%. Full cost accounting and least-cost planning techniques are recommended for the evaluation of alternative community design schematics and the assessment of this 20% target.

[42] The following formula should be applied to determine whether or not the 20% target is achieved:

$$\text{Percentage Saved (Lost)} = \frac{\text{FCA (Auto-Oriented Development)} - \text{FCA (Sustainable Community Development)}}{\text{FCA (Auto-Oriented Development)}}$$

To achieve this target, the following TDM strategies are highly recommended:

1. *Apply Full Cost Accounting, and Least Cost Planning and funding measures/principles.*
2. *Develop higher density and mixed-use communities, such as traditional neighbourhood and transit-oriented developments.*
3. *Improve transit/cycling/pedestrian facilities, environments, and services.*
4. *Apply traffic calming measures.*
5. *Increase and marginalise parking prices, restrict parking supply, and reduce development requirements for parking.*
6. *Develop a voluntary traffic reduction program (see Tables 6-2 and 6-3 for highlights).*
7. *Develop a central co-ordinating management body to implement TDM programs, establish ETAs, and monitor progress.*
8. *Develop and introduce transportation- and location-efficient mortgages.*

6.3 Sustainable Transportation and Land Use Policy Recommendations

The land use and transportation policies recommended for SFU's *Sustainable Transportation Plan* are outlined in Table 6-7 below. Note that though the 1st and 2nd priority indicators and targets identified above form the basis of these policies, not all of them are represented in Table 6-7 as direct policy. Table 6-8 outlines the TDM and land use strategies, measures, and programs that should be implemented to achieve the policies of the *Sustainable Transportation Plan*.

Table 6-7. Recommended Sustainable Transportation and Land Use Policies for SFU's Burnaby Mountain Campus

[illegible]	
1.	100% of the residential units developed on Burnaby Mountain should be within 400 meters of transit service (i.e. station, loop, or stop) and the commercial node(s).
2.	100% of the future Burnaby Mountain community should be zoned for mixed-use and transit-oriented/traditional neighbourhood development
3.	100% of the future Burnaby Mountain community should be developed to a minimum average density of 30 dwelling units per acre (gross).
4.	50% (minimum) of the future SFU/Burnaby Mountain community should be inhabited by members of the SFU, Discovery Park, and BC Hydro communities (this includes both market and student housing/residence), with a minimum of 30% of the BMCD units being occupied by members of the SFU, Discovery Park, and BC Hydro communities.
5.	SFU should develop, co-ordinate, and manage a voluntary traffic reduction program for its students, staff, and faculty.
6.	100% of the future Burnaby Mountain community should include strong pedestrian and bicycle infrastructure and circulation plans/facilities within the existing SFU campus should be improved to encourage bicycle travel.
[illegible]	
1.	No more than 10% of the residential units developed in the future Burnaby Mountain community should be single-family homes, and that a highly diverse mix of housing and funding types, tenures, tenants, and income levels should be represented in this community.
2.	60% (minimum) of the total street area in the future Burnaby Mountain community should be dedicated to pedestrian, cyclist, and transit uses.
3.	50% (minimum) of the future Burnaby Mountain community should be pervious to water.
4.	The future Burnaby Mountain community should be designed to enhance the 'sense of community' experienced by its residents and to maximise "spontaneous exchange" opportunities.
5.	SFU, the Burnaby Mountain Community Corporation, and the City of Burnaby should reduce the need to expand automobile-oriented infrastructure and provide public/private savings to SFU and the residents of the Burnaby Mountain community.

Table 6-8. Recommended Transportation Demand Management and Land Use Strategies for SFU's *Sustainable Transportation Plan*

1. Develop higher density and mixed-use communities, such as traditional neighbourhood and transit-oriented developments. • investigate the development of a single-neighbourhood community in the East Neighbourhood area, with the majority of the development 'footprint' covering the east parking facilities (lots B, C, and E) due to its proximity to the transit station and current P1 1e zoning (Figure 4-3). • introduce sensitive-ecosystem policies for the entire South Neighbourhood area. • Commit to an minimum average density of 30 upa (gross). • commit to quadrupling student residence beds (i.e. 4,200 beds). • integrate University recreational, cultural, and educational facilities into the overall community design (i.e. provide opportunities for non-SFU community residents to use facilities). • amend 'horizontal' P1 1e zoning to 'vertical' P1 1e zoning. • increase allocation of commercial floor area to a minimum of 30,000 $feet^2$ per 1,000 residents (i.e. from 110,000-220,000 ft^2 to 450,000 ft^2 of total commercial floor space – based on the 15,000 person increase of on-campus residents (both BMCD and student residence). • amend "maximum" lot coverage standards and replace with minimum standards greater than 0.35. • reduce yard and building setbacks. • provide density bonus incentives. • develop grid-like street patterns and short block lengths. • orient buildings to provide pedestrians and cyclists with direct access to streets. • develop 'live/work' suites. • allow and encourage secondary suites in development. • investigate opportunities for 'car-free' residential clusters. • introduce community design solutions that minimise impervious areas, such as narrow roads and reduced parking stall sizes (see Table 6-4). • investigate and introduce permeable pavements (see Table 6-5).	**20 - 50% reduction, with jobs-housing balance making up 2.5 - 14%.**

Table 6-8. Recommended Transportation Demand Management and Land Use Strategies for SFU's *Sustainable Transportation Plan* – continued

2. **Develop a voluntary traffic reduction program including:** • ridesharing privileges (e.g. subsidised fees and preferential parking), services/co-ordinated programs, and access to vehicles; • transportation allowance and discounted transit programs (e.g. UPASS); • guaranteed ride home service; • flexible work and student course schedules (e.g. telecommuting; 'flex time,' compressed work weeks); • car sharing co-ops and discounted car rentals; • 'Walking school bus' programs; • community-based shuttle service for on-campus (i.e. feeder and connector service) and off-campus travel (e.g. "*StudentMover*" concept); • 'public bikes' or bike sharing co-ops; and • non-motorised home delivery services and 'Buy Local & Save' programs.	**10 - 50% reduction**
3. **Develop a central co-ordinating management body to implement TDM programs, establish ETAs, and monitor progress.**	**Uncertain, but provides the foundation for the delivery of TDM programs.**
4. **Improve transit/cycling/pedestrian facilities, environments, and services.** • develop and promote end-of-trip facilities in both SFU and the BMCD. • develop direct pedestrian and bicycle links within campus. • improve 'connector' bike lanes between SFU, the existing GVRD bikeways, and local communities/regional centres. • integrate the climatic conditions of Burnaby Mountain into infrastructure and facility design. • develop minimum amenity standards for alternative modes (e.g. bike facility bylaws).	**Up to 35% for on-campus residents; 1-5% for off-campus residents. Progressive end-of-trip and intermodal treatment programs could have moderate to high impacts for off-campus commuters.**

Table 6-8. Recommended Transportation Demand Management and Land Use Strategies for SFU's *Sustainable Transportation Plan* – continued

5. Increase and marginalise parking prices, restrict parking supply, and reduce parking lot development requirements. • amend Schedule VIII parking bylaws for residential parking requirements to 1.25 spaces/unit and 1 space/3 residence beds. • reduce commercial and institutional parking requirements. • reduce parking stall-to-population ratio from 1:1.2-1:2 to 1:3 or 1:4. • prohibit, or minimise, the development of surface parking and single-use car washing stalls. • if surface parking is developed, locate at back of building (residence, commercial). • increase parking fees to match transit fares, GVRD market rates, and for SOV parking. • increase proportion of parking to short-term (i.e. hourly/daily) versus long-term (i.e. monthly/semester).	**High impacts (5% minimum), particularly when combined with UPASS and car-sharing programs.**
6. Develop and introduce transportation- and location-efficient mortgages. • investigate and introduce opportunities for "equity-sharing" and other 'green' mortgage incentive programs.	**Moderate impacts – an important strategy in encouraging a jobs-housing balance.**
7. Apply traffic calming measures: • sidewalks, narrow streets, bicycle lanes, street trees, chicanes, speed bumps, traffic circles, street furniture, alternative road surfaces (e.g. cobblestones), curb blow-outs and sidewalk extensions, landscape islands, bus bulges, and other "street reclaiming" activities, such as "block parties" and street re-design.	**Low to moderate impacts over the short-term (1-2%), larger impacts over the long-term.**
8. Apply Full Cost Accounting, Least Cost Planning, and other funding measures/principles. • prohibit road development in the entire South Neighbourhood area (including Naheeno Park) and minimise any other road development plans. • apply FCA and LCP tools to Gaglardi Way, University Drive, and Burnaby Mountain Parkway intersection expansion proposal.	**Uncertain, but provides the foundation for implementing sustainable land use and transportation policies.**

6.4 Conclusions

This study started out with a simple question – *"How can Simon Fraser University reduce single-occupant vehicle trips to and from its Burnaby Mountain campus?"* A simple question, but a complex and dynamic issue given the land use and transportation paradigms that exist at this time. The literature review uncovered that the primary objective of modern transportation management is to simply move *more vehicles*. However, academics and urban planners are now awakening to the fact that prioritising vehicle travel over 'person-travel' is not in the best interests of society, as not only the objectives of reducing congestion and increasing *vehicle* transportation efficiencies are not achieved, but significant ecological, economic, and social costs are incurred at the same time. This 'paradigm shift' has enlightened public policy to the synergies that exist between land use and transportation planning. Based in principles of sustainable development, *Integrated Planning* and *Smart Growth Management* have emerged as the key ideologies of this new paradigm, a philosophy where land use and transportation plans are developed simultaneously in a vision of long-term *sustainable* growth management. From this field the concept of *Transportation Demand Management (TDM)* has emerged – a land use and transportation management strategy that focuses on improving transportation efficiencies by influencing *when people travel*, *how they travel*, and *how far they travel* to reach major destinations. TDM and integrated growth management planning are thus considered to be the modern-day 'toolbox' for urban planning.

The *Sustainable Transportation and Land Use Planning Framework* was developed in this study in order to evaluate TDM and land use measures and recommend effective land use and transportation policies for SFU's *Sustainable Transportation Plan*. This sustainability planning process, however, is not only applicable to SFU and other university communities, but can be applied as a model to any neighbourhood, community, municipal or regional planning process. This framework is based on identifying the potential categories (e.g. transportation and accessibility), goals (e.g. minimise SOV travel), objectives (e.g. increase car-free living opportunities), indicators (e.g. percentage of city/community that is zoned for mixed-use and transit-oriented/traditional neighbourhood development), and targets (e.g. 100% of the BMCD) that may be identified by the SFU community. An *Indicators Menu* was developed in Chapter 3 and evaluated against the following sustainability criteria: transportation efficiency, land use efficiency, environmental impact, human livability, and economic efficiency. High priority indicators were then selected from this evaluation and separated between 1st and 2nd priority master indicators. This evaluation was based on each indicator's achievement of the sustainability criteria, where the achievement of three or more criteria designated those indicators as '1st priority,' and two or less were designated as '2nd priority.' Targets were then established for each indicator and supporting TDM strategies recommended. These 1st and 2nd priority indicators, and their associated targets, thus form the basis of the land use and transportation policy formation and development of the *Sustainable Transportation Plan* for SFU's Burnaby Mountain campus.

It is believed that these recommended policies and strategies – *if adopted, supported, and implemented at SFU's Burnaby Mountain campus* – will be successful in reducing single-occupant vehicle trips by a minimum of 20% from that of both 1998 traffic volumes and post-BMCD/student population growth transportation demands. These land use and transportation management strategies should help the University manage its challenging growth management issues, reduce dependence on automobile travel, reduce its ecological impacts to both local and global ecosystems (e.g. air pollution), and enhance the University's opportunities for creating a 'sense of place' and 'sense of community' on Burnaby Mountain. If these plans are adopted, the University should make it a *priority to integrate* the perspectives and needs of its community into the planning process, as this is a critical step in building not only plans that work, but in also nurturing SFU's sense of community and ownership. SFU, the Burnaby Mountain Community Corporation, and the City of Burnaby are strategically positioned to champion the development of a 'model' sustainable urban neighbourhood. This represents the ideal opportunity to achieve SFU's goals of developing a community of "international acclaim" and enhancing the University's sense of community. As well, the application of sustainable development principles and design guidelines at both SFU and the Burnaby Mountain community project should provide significant economic benefits to the University's Endowment Fund.

This research project is by no means completely comprehensive. Research opportunities abound in areas surrounding the community development on Burnaby Mountain and many transportation-related areas. For example, given that the University community (i.e. the general public) was not consulted on this project, there exists an opportunity to study public input, participation, and community-based land use planning at SFU. Furthermore, opportunities exist to study the application of full cost accounting to this study's proposed transportation and land use plan, as well as to the land use plans initially developed for the BMCD project (i.e. the Official Community Plan and Development Plan Concept). The integration of SFU's Harbour Centre campus and the extension of SkyTrain to Lougheed Mall were also not investigated in this study and could form the basis of a more comprehensive transportation plan. Finally, other issues surrounding sustainable urban development, such as housing and affordability, wildlife and habitat impacts, water management, and community energy planning, would complement this study and should thus be investigated.

It is now time for action. The transportation and land use policies prescribed in Tables 6-7 and 6-8 have been proven effective in reducing automobile dependence. Given this, SFU and the BMCC should now incorporate these tools into their growth management plans to mitigate short-term transportation problems, as well as to shape and enhance the future livability of its Burnaby Mountain campus.

Epilogue

This project has *changed my life*. My initial objective was to "*get as many people out of their cars as fast as possible by whatever means available*!" At that time I felt a sense of urgency – and I still do – but was focusing my energy in the wrong place. Given the transport economics of today (i.e. a litre of bottled water is more expensive than a litre of gas), I now feel that transportation behaviours may be more successfully influenced by creative and convenient services and smart land use planning that make it so elementary to walk, cycle, or take transit that driving a car would be considered nonsensical. Community-based shuttle programs – like the "*StudentMover*" concept – UPASS travel cards, and compact, complete community designs are examples of incentive-based strategies that could shape transportation behaviours without much conscious attention. And what better place for implementation – Simon Fraser University – an institution that prides itself on innovation and leadership. I urge SFU to start looking at 'not only the trees but the forest as well,' as I believe this would be the first step towards a healthier environment, stronger economy, and a more livable and dynamic community. SFU – you're literally *in the drivers seat!*

Appendix 1. Inventory of Discounted Transit Pass/UPASS Programs at Universities and Colleges across North America (Poinsatte and Toor 1999; Graves 1993; Brown, Hess, and Shoup 1998; Shoup 1998; N.D. Lea Consultants 1997; BC Transit 1998; Lovegrove 1998)

[illegible]	[illegible]	[illegible]
United States		
University of Washington	19% decrease in peak a.m. vehicle trips (8% overall), 35% in transit, 20% in car/vanpool	$7 (students) $9.75 (staff/faculty)
Cornell University – Ithaca	22% decrease in SOV trips, 26% decrease in all vehicle trips	$16.70 (1993)
University of California –Los Angeles	22% decrease in SOV trips, 50% increase in carpool and transit	$2.70
University of Minnesota – Minneapolis	n/a	$27 (1993)
University of Kansas – Lawrence	n/a	$9.15
University of Illinois – Urbana/Champaign	370% transit increase	$5.10
University of Wisconsin – Madison	n/a	$2.60
University of Wisconsin – Milwaukee	28% decrease in SOV trips, 100% transit increase	$5.15
University of California – San Diego	n/a	$0.42
University of California – Santa Cruz	n/a	$8.25
University of Georgia – Athens	n/a	$0.75
Cal Poly State University	n/a	$0.85
Appalachian State University	n/a	$1.60
University of Pittsburgh	n/a	$1.75
University of California – Santa Barbara	6% transit increase	$1.90
Santa Barbara City College	36% transit increase	$1.90
University of Massachusetts – Amherst	n/a	$2.10
Ohio State University	n/a	$2.40
Virginia Polytechnic Institute and State Univ.	n/a	$2.85
Auraria High Education Centre (Univ. of Colorado – Denver and 2 Denver Colleges)	n/a	$3.15
University of California – Davis	255% transit increase	$3.25
San Jose State University	n/a	$3.25
University of Colorado – Boulder	400% transit increase	$3.40
Marquette University	n/a	$5
University of Utah	n/a	n/a
University of Arizona	n/a	n/a
University of Michigan	n/a	n/a
University of Indiana	n/a	n/a

[43] Results shown may not be fully attributed to the UPASS program, as other TDM programs in existence at these particular universities/colleges may have also contributed to these results. However, UPASS is believed to be the primary factor that has influenced these results at the majority of these universities/colleges. Furthermore, monthly user fees are approximate, based on the above literature.

Appendix 1. Inventory of Discounted Transit Pass/UPASS Programs at Universities and Colleges across North America (Poinsatte and Toor 1999; Graves 1993; Brown, Hess, and Shoup 1998; Shoup 1998; N.D. Lea Consultants 1997; BC Transit 1998; Lovegrove 1998) – continued

University/C[illegible]	[illegible]	[illegible]
United States – continued		
University of Iowa	n/a	$5
Michigan State University	n/a	n/a
University of Texas	n/a	$3.65
Washington State University	n/a	n/a
Penn State College	n/a	n/a
Duke University	n/a	n/a
Western Michigan University	35% transit increase	n/a
University of Florida	n/a	$5.85
University of Chicago and other Chicago Universities (12 in total)	n/a	$15
University of Oregon – Eugene	n/a	n/a
Yale University	n/a	n/a
University of California – Berkeley	n/a	n/a
Harvard University	n/a	n/a
Portland State University	n/a	n/a
Canada		
University of Victoria	40% decrease in demand for parking permits (i.e. overall vehicle traffic)	$11
University of BC	To start in September 2000	n/a
Camosun College – Victoria	n/a	$11
Queens University	n/a	n/a
McMaster University	n/a	n/a
Trent University	n/a	n/a
Lakehead University	n/a	n/a
Univ. of Western Ontario	n/a	n/a
University of Guelph	n/a	n/a
University of Waterloo	n/a	n/a
University of Ottawa, Carleton, and other Ottawa-based colleges	n/a	n/a
University of Regina	n/a	n/a
University of Calgary	n/a	n/a
University of Alberta	n/a	n/a
University of Lethbridge	n/a	n/a
Quebec Transit Systems – all universities and colleges	n/a	n/a

Appendix 2. Transit-Oriented Development Design Guidelines (Calthorpe 1993)

1. **Site Size**: new growth areas may consist of 40-160 acres of land that are wholly undeveloped or have some minor amount of existing uses.
2. **Walkability**: a maximum 2,000-foot radius (10-minute walk) generally represents a comfortable walking distance for the majority of people.
3. **Core Commercial Area**: located adjacent to the transit stop and providing convenience retail, supermarkets, restaurants, entertainment, recreation, second-floor residential, employment opportunities and office and other general services. Its location is key in encouraging foot and bicycle travel and should be visible from the main transit station. Mixed-use core commercial areas are the primary link between transit and land use. Sufficient retail and commercial space within walking distance of most residents is crucial in reducing non-work auto trips and maintaining the incentive to use transit. Typical core commercial centres include:
    - Minimum of 10% of the total development site:
        - Minimum of 10,000 ft^2 next to the transit station.
        - Minimum of 10,000 ft^2 of convenience shopping and retail (up to 25,000 ft^2).
        - Minimum of 80,000 ft^2 for a neighbourhood centre with a supermarket, drugstore and supporting uses (up to 140,000 ft^2).
        - Minimum of 60,000 ft^2 of specialty retail stores (up to 120,000 ft^2).
        - Minimum of 120,000 ft^2 for a community centre with convenience shopping and department stores.
4. **Residential Areas**: housing is within a convenient walking distance (2,000 feet maximum) from core commercial areas and transit stops. Furthermore, it provides a mix of housing types, including small lot single-family units, townhomes, condominiums, apartments and secondary (ancillary) units within an average residential density of 18 dwelling units per net acre (ranging from 10 to 25 dwelling units per net acre). A minimum of 10 upa is required to support local bus service and commercial-retail services.
5. **Feeder Bus Service**: neighbourhood TODs should provide feeder bus service to the main trunk line or transit station, thereby increasing accessibility and convenience for transit users.
6. **Mix of land Uses**: neighbourhood TODs should aim to achieve the following mix of land uses:
    - Public = 10-15%
    - Core/Employment = 10-40%
    - Housing = 50-80%
7. **Street and Circulation System**: the local street system should be recognisable, formalised and interconnected, converging to transit stops, core commercial areas, schools and parks. Multiple and parallel routes should be provided between the core commercial area, residential and employment uses so that local trips are not forced onto auto-oriented arterial streets. Streets should be pedestrian-friendly; sidewalks, street trees, and building entries must shelter and enhance the walking environment.

8. **Street Dimensions and Design Speeds**: street widths, design speeds and the number of travel lanes should be minimised without compromising automobile safety, on-street parking and bicycle access. Streets should be designed for travel speeds of 25 km/hr. Travel lanes should be 8-10 feet wide. Total lane-width, with 2-way parking, should not be wider than 26 feet.
9. **Street Vistas**: where possible, streets should frame vistas of the core area, public buildings, parks and natural features.
10. **Sidewalks and Street Trees**: sidewalks are required on all streets and should provide an unobstructed path at a width of at least 5 feet. Larger sidewalk dimensions are desirable in core commercial areas where pedestrian activity will be greatest and where outdoor seating is encouraged. Shade trees are required along all streets. Street trees should be spaced no further than 30 feet apart on the centre of planter strips or tree wells located between the curb and sidewalk. Local tree species and planting techniques should be selected to create a unified image for the street, provide an effective canopy, avoid sidewalk damage and minimise water consumption.
11. **General Design Criteria**: buildings should address the street and sidewalk with entries, balconies, porches, architectural features and activities which help create safe, pleasant walking environments. Parking should be placed to the rear of buildings. Elementary schools should be carefully placed within a TOD, such as the periphery of the community with direct links for walking, cycling, transit and auto travel.
12. **Bicycle Parking**: bicycle parking facilities should be provided throughout core commercial areas, in office developments and at transit stops, schools and parks. Furthermore, other end-of-trip facilities, such as showers and locker rooms, are key in encouraging cycling. Given the weather conditions typical of this area, some parking facilities should be covered to shelter the rain and make cycling more comfortable.
13. **Transit Stop Facilities**: comfortable waiting areas, appropriate for year-round weather conditions, should be provided at all transit stops. All stops should include a service schedule for the convenience of passengers. Passenger drop-off zones should be located close to the stop, but should not interfere with pedestrian access.
14. **Access to Transit Stops**: streets should be designed to facilitate safe and comfortable pedestrian crossings to the transit stop. Street design should recognise the need for easy, safe and fast pedestrian access, by providing sufficient auto and pedestrian visibility distances, stop signs or manually operated traffic signals, handicapped access and clearly marked pedestrian-crossings. Park-and-ride lots, "kiss-n-ride," and major bus drop-off areas should not isolate the station from local pedestrians.

Appendix 3. City of Burnaby's Official Community Plan, Schedule VIII Parking Policies (Zoning Bylaw 511.12) (City of Burnaby 1999)

- Senior citizens housing: 1 space/5 units where established bus route[44] and commercial facilities[45] are located within 400 meters of unit; 1 space/4 units where development is located at a greater distance from an established bus route and commercial facilities.
- Child care facilities: 1 space/2 employees + 1 space/10 spaces licensed for the facility.
- Churches: 1 space/10 seats + 1 space/204.52 ft.^{2} (19 m^2) of gross floor area used for assembly within a church building or hall.
- Kindergartens, elementary and junior high schools: 1 space/staff member.
- Hotels: 1 space/2 sleeping units.
- Places of public assembly (e.g. community centres): 1 space/96.88 ft.^{2} (9 m^2) of floor area in areas without fixed seats (or 1 space/10 seats).
- Recreational uses (e.g. swimming pools): 1 space/495.16 ft.^{2} (46 m^2) of gross floor area + 1 space/10 seats.
- Banks, business administrative, and professional offices: 1 space/495.16 ft.^{2} (46 m^2) of gross floor area.
- Medical or dental offices and clinics: 1 space/301.40 ft.^{2} (28 m^2) of gross floor area.
- Restaurants: 1 space/5 seats (50 seats or more, pubs, drive-ins); 1 space/495.16 ft.^{2} (46 m^2) of gross floor area (50 seats or less).
- Retail stores and personal service establishments: 1 space/495.16 ft.^{2} (46 m^2) or gross floor area.
- Shopping centres and supermarkets exceeding a retail floor area of 2002.15 ft.^{2} (186 m^2): 1 space/150.70 ft.^{2} (14 m^2) of retail floor area.
- Discotheques: 1 space/10 seats + 1 space/96.88 ft.^{2} (9 m^2) of gross floor area.

[44] "Established bus route" shall mean a bus route providing service with no more than 30 minutes between buses travelling in the same direction (City of Burnaby 1999, 3 - Parking Zoning Bylaw).
[45] "Commercial facilities" shall mean commercial-retail establishments in a group of 4 or more within a one-block length of a roadway (City of Burnaby 1999, 3 - Parking Zoning Bylaw).

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