THE CAR IN CANADA: A STUDY OF FACTORS INFLUENCING AUTOMOBILE DEPENDENCE IN CANADA'S SEVEN LARGEST CITIES, 1961-1991

by

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ABSTRACT

Automobile dependence is defined as a series of convergent land use and transportation conditions in a city that leave people with few non-car options for urban travel. This dependence is compromising the environmental, social and economic health of cities in Canada. Furthermore, it appears as though automobile dependence is increasing in Canada, as are its attendant impacts. A fuller understanding of the primary relationships affecting this trend is needed if its impacts are to be adequately mitigated. However, there is little quantitative knowledge of the relative importance of factors contributing to automobile dependence in Canadian cities.

A review of the literature identifies a multitude of mutually reinforcing factors that contribute to the creation of automobile dependent cities. The factors are both cause and effect and exhibit 'feedback,' which results in a cycle of intensification of the original condition. While there are many feedback relationships that contribute to automobile dependence, some may be stronger than others. Mitigating the many adverse impacts of automobile dependence requires reducing the need for both automobile ownership and automobile use by reversing these feedback relationships.

This thesis identifies the relative importance of factors influencing automobile dependence in Canada's major cities through a comparative analysis of transportation, land use and population and employment distribution trends and patterns. This involves the collection and analysis of an extensive set of data from Canada's seven largest cities (Vancouver, Calgary, Edmonton, Winnipeg, Toronto, Ottawa-Hull and Montreal). To provide context and supplementary information, selected data from thirty-four additional global cities are also used. A correlation analysis of the data collected identifies the strength of correlation between factors involved in automobile dependence feedback.

The data reveal commonalities between cities: those cities with higher urban densities, higher transit service provision and lower automobile infrastructure provision exhibit lower levels of car ownership and use as well as higher levels of transit use. These cities also have better utilized transit systems, have higher walking and cycling mode shares and consume less fuel.

The quantitative findings are used in tandem with the qualitative findings of the literature review to identify and rank eight possible points for policy intervention in changing auto dependence feedback. Of the factors examined, metropolitan and outer area density, transit supply and CBD parking supply appear to exert the strongest relative influence on auto dependence. These are followed in importance by inner area density and car ownership, which are followed by road supply and non-motorized transport share.

While the auto dependence factors ranked require further study, clarification and confirmation, they provide a preliminary basis for directing policy analysis.

A policy evaluation framework is developed that enables policies prescribed in each intervention area to be assessed against a series of travel, environmental, social and economic impact criteria as well as their implementation potential. This framework can be used by policymakers to identify high leverage policies for reducing auto dependence.

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GLOSSARY OF COMMON ACRONYMS AND TERMS

ALC	(see BCALC)
ALR	Agricultural Land Reserve
ATED	Access to Exchange Disadvantaged. A term coined by David Engwicht (1993) to describe those who do not have access to an automobile, where auto dominance precludes other travel options for them.
BC Lower Mainland	British Columbia Lower Mainland. Includes the GVRD and the Fraser, Dewdney-Alouette, Fraser Cheam, Squamish Lillooet and Sunshine Coast regional districts.
BCALC	British Columbia Agricultural Land Commission
BCTFA	British Columbia Transportation Financing Authority
CAAD	Cities and Automobile Dependence: An International Sourcebook (see bibliographic reference to Newman and Kenworthy, 1989).
CBD	Central Business District
Commutershed	The geographical range from which a metropolitan area draws substantial commuter traffic.
CUTA	Canadian Urban Transit Association
GTA	Greater Toronto Area. Includes the five regional municipalities of York, Durham, Peel, Halton and Metro Toronto.
GVRD	Greater Vancouver Regional District
ha	Hectares (1 ha=2.47 acres)
HOV	High Occupancy Vehicle
ISTP	The Institute for Science and Technology Policy at Murdoch University in Perth, Western Australia
LOS	Level of service. The degree to which traffic flows without interruptions, measured by average traffic speeds.
LRT	Light Rail Transit
Metro	Metropolitan Toronto (City of Toronto post-1998)
MOTH	British Columbia Ministry of Transportation and Highways
MUC	Montreal Urban Community
NMT	Non-motorized transportation (typically referring to walking and cycling, but includes other non-motorized modes).
OGTA	Office of the Greater Toronto Area. Provincial agency acting as a coordinating body for municipalities and regional municipalities in the GTA.
Quad	Quadrillion Btu (10^{15} Btu)
RMOC	Regional Municipality of Ottawa-Carleton
SOV	Single Occupant Vehicle
SOV	Single Occupancy Vehicle
TDM	Transportation Demand Management
TTC	Toronto Transit Commission
UniCity	City of Winnipeg (metropolitan government)
VKT or VKmT	Vehicle Kilometres Travelled
VMT	Vehicle Miles Travelled
VPD	Vehicles Per Day

PREFACE

In June 1996, I had the privilege of being invited to work with Jeff Kenworthy and Peter Newman of the Institute of Science and Technology Policy (ISTP) at Murdoch University in Perth, Australia on the update of Cities and Automobile Dependence: An International Sourcebook (Newman and Kenworthy 1989a). Between June 1996 and February 1997, I worked with a team of researchers at ISTP to help update Cities and Automobile Dependence and expand the number of cities surveyed from 32 to 46.

I specifically worked with Jeff Kenworthy and Felix Laube on the collection of comparative urban data for the seven Canadian cities in the update, six of which were new additions to the study. The comparative data that appear in this thesis are drawn from this research, by permission of ISTP. The full data set, including all the international cities, will be published in the Spring of 1999 under the title An International Sourcebook of Automobile Dependence in Cities, 1960-1990 by Jeff Kenworthy and Felix Laube, with Peter Newman, Paul Barter, Tamim Raad, Chamlong Poboon and Benedicto Guia Jr.

Any subsequent use of the raw or standardized data items in this thesis (Appendices 2 and 3) should cite Kenworthy and Laube et al (1999) as the data source. Where specific work has been done extending the analyses or data beyond that which is contained in the above book, this thesis should be cited as the source.

ACKNOWLEDGEMENTS

I would first of all like to thank Peter Newman, Director of the Institute of Science and Technology Policy (ISTP), who made this research possible by inviting me to spend 8 months in Perth working on CAAD II. I would also like to thank everyone of what is know as the "ISTP family" for welcoming and supporting me while I was in Perth. Thanks to Felix Laube and Paul Barter for all the ideas and friendship and to William Ross and Barrie the Cat for the hospitality, laughs and cool digs. Most of all, a special thanks to Jeff Kenworthy for all the help, encouragement and mentorship over the past two years. ISTP not only manages to produce innovative research, but also a warm and inviting community.

My thesis committee has also been a tremendous help. Thanks to Professor Peter Boothroyd of the School of Community and Regional Planning (SCARP) at UBC for his clarity, his demonstrated commitment to teaching and for constantly challenging my thinking over the past five years. Thanks to Clive Rock, the GVRD's transportation guru and Adjunct Professor at SCARP for his insights and witticisms and for fielding my relentless call. Thanks also to Mark Roseland, Director of Simon Fraser University's Community Economic Development Centre for taking the time to be the external examiner and for his continuing commitment to community-based change.

There are many others who kindly provided their time and expertise throughout the project including: Brendon Hemily of CUTA, Todd Limtan of the Victoria Transport Policy Institute, Clark Lim of the GVRD, Brian Hollingworth of IBI Group and Wendy Sarkissian of University of Sydney. Thanks to Karim Dossa, statistics and SPSS wizard, who generously offered many free hours of help in making sense out of a big pile of numbers, even though he didn't know me. Thanks also to Terry Sunderland and Carmen Mills of Emerald City Communications for helping me make my Macintosh map files look pretty.

Many thanks to my friends, the good people at Better Environmentally Sound Transportation and to my Vancouver 'Bikeshevik' cohort (especially, the cycling dinos of Fossils Against Fossil Fuels) for their friendship, support and respite from writing. Special thanks to Gavin Davidson for sharing my perverse obsession with things transportation.

Finally, thanks to my mother, father and brothers for their motivation and support (especially Samer, who let me mooch off him for so long) and to Karen Peachey for inspiring me and putting up with my paper sprawl.

CHAPTER 1 - INTRODUCTION

1.0 PURPOSE AND CONTEXT

The purpose of this thesis is to identify the relative importance of factors that affect automobile dependence in Canadian cities through a comparative analysis of transportation patterns.

Although the post-war increase in the ownership and use of automobiles has brought tremendous mobility to Canadians, it has also brought tremendous costs. Over the past five decades, public decision-making has overwhelmingly favoured and facilitated automobile use and sprawling land uses such that few viable alternatives are available to meet travel needs. This "automobile dependence" (Newman and Kenworthy 1989a) imposes considerable social, ecological and economic costs that are of significance at the local, regional and global scales.[1]

To date, there have been few studies that have provided comprehensive and comparable information about the complex interactions between transportation, land use and related urban development factors that influence automobile dependence at the regional scale in the Canadian urban context. Often, Canadian information on transportation trends and patterns is temporally limited, anecdotal, not comparable between cities and years, or simply not available. Canadians often depend on data from the United States to inform much of our transportation analysis as it is the country with transportation and urban development patterns most closely resembling ours. However, the transportation, land use, political and cultural realities of the two countries are still so demonstrably different that we cannot meaningfully use the American experience as a proxy for our own (for examples of such differences Frisken 1986; Goldberg and Mercer 1986; Kenworthy and Newman 1994b; Linteau 1990; Pucher 1994; Raad and Kenworthy 1998; Schimek 1996). Therefore, reliable standardized information about how the complex interrelationships of automobile dependence are manifest in the Canadian context would be valuable for urban transport policy analysis.

In their landmark study, Cities and Automobile Dependence (CAAD), Peter Newman and Jeff Kenworthy analyzed trends in transportation and land use in 32 global cities in 1960, 1970 and 1980 (1989a). Although CAAD took 9 years to compile and publish, it made an invaluable contribution to the debate on automobile dependence in a global context when it was finally released. The study revealed commonalities between cities with lower levels of automobile dependence. The less car-oriented cities displayed higher urban densities, higher per capita provision and use of public transportation and lower per capita ownership of automobiles. While other key studies provided quantitative evidence of some of the key variables influencing car and transit use (most notably, Pushkarev and Zupan 1977), CAAD was the first quantitative study to reveal, on a comprehensive basis, the inextricable link between sprawling land uses and increasing automobile dependence. It also provided a standardized database of urban transportation, land use and demographic data which had not previously been compiled. CAAD provides a compendium of data that is today considered one of the seminal works in the study of urban transportation and land use trends in global cities.

Newman and Kenworthy (1989a) note that one of the regrets of the initial study was the inclusion of only one Canadian city. Toronto was the only Canadian city studied and attracted much interest. The data in the 1989 study indicate Toronto's transportation and land use patterns are an anomaly in the North American context. "Toronto seems to sit neatly between the land use and transportation patterns of the automobile-oriented US and Australian cities and the very public transport-oriented European cities. In this way it provides a very useful model for policy development, especially for the automobile cities" (Newman and Kenworthy 1989a, p. 11). The data show that until 1980, Toronto had much higher public transportation patronage, lower levels of car ownership and use and significantly higher urban densities than its automobile-oriented American and Australian counterparts.

In their book The Myth of the North American City (1986), Michael Goldberg and John Mercer's more generalized comparison of urban realities in Canadian and American cities support the Newman and Kenworthy findings. Goldberg and Mercer supported the thesis that Canadian cities, in general, did display transportation and urban settlement patterns that are distinct in the North American context. Updated transportation data compiled by Jeff Kenworthy in the early 1990's confirmed that Toronto is indeed unique in its transportation and land use patterns (Kenworthy and Newman 1994b).

Other studies have also supported the need for relevant Canadian urban transportation information. In his Master's thesis examining the implications of land use on automobile dependence in Canada, Anthony Parker says of the lack of Canadian data: "there is a particular need for better information, and quantitative data in particular, on the relationship between urban form and design characteristics and automobile use. It would be useful to have more data on travel behaviour...and on what factors affect this...an extension of Newman and Kenworthy's analysis to include Canadian cities in addition to Toronto would be valuable" (1993, p. 147).

This study attempts to fill this gap in the knowledge of transportation patterns in the Canadian context. From May 1996 until February 1997, I worked as part of a research team led by Jeff Kenworthy that was working on updating and expanding CAAD to An International Sourcebook of Automobile Dependence in Cities, 1960-1990 (Kenworthy et al. 1999). I was responsible for coordinating the

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[1] A more complete discussion of definitions and measures of 'automobile dependence' is available in Chapter 2.

research and data collection for the six additional Canadian cities to be included in the update (Vancouver, Edmonton, Calgary, Winnipeg, Ottawa-Hull and Montreal were being added to Toronto) for four study years (1961, 1971, 1981 and 1991). The data used for each region fall into the following broad categories: population and employment distribution, size of urbanized area, transport infrastructure supply, vehicle ownership, transport energy consumption and public and private transportation usage. I have used the data compiled from the CAAD update project as the basis for this thesis.

1.0.0 Why Compare Transportation in Canada?

The comparative approach to urban policy analysis can be useful for both theorists and practitioners to learn lessons from the experience of other regions. The approach allows for the testing of both dependent and independent variables between cities to yield insights into what is unique and what is commonplace (Artibise 1990; Goldberg and Mercer 1986). These tests provide a starting point for analysis of factors that account for differences.

The comparative approach can contribute to an understanding of the key forces that contribute to higher or lower levels of automobile dependence. Newman and Kenworthy (1989a) showed that cities that are more automobile dependent demonstrate particular characteristics that set them apart from less automobile dependent cities. In this thesis, I attempt to identify key factors that may account for these differences and key policies that could be instituted to facilitate favourable (i.e., less auto dependent) outcomes.

Comparing transportation trends and patterns amongst Canadian cities is particularly valuable because they are relatively homogenous. While lessons can be derived from comparing a city like Toronto to those in the U.S. and others globally, as much relevant information can be gleaned by comparing differences and similarities within Canada. Since there is a broader common denominator of economic, social, political and cultural forces influencing urban processes amongst these cities, there are fewer "intervening" variables. Studying the forces responsible for lower levels of auto use within a similar socio-economic, political and cultural context can help to better focus policy analysis.

1.1 OTHER KEY STUDIES

The comprehensiveness of the parameters and the rigorous methodology employed in the surveying and compilation process makes the data set an important and unique contribution to the understanding of urban transportation in Canada. Although other studies have recorded some of the various relationships between transportation, urban activity and land use, none have been able to achieve an acceptably accurate level of inter-city comparability. Key problems with these various studies include:

- the lack of trend data (most studies report on one specific year);

- some studies have missing parameters key to the understanding of the inter-relationships of urban activity; and
- poor data comparability due to imprecise definitions of land areas, poor matching of populations, urban areas and parameters, inaccurate or unclear reporting on parameters and soft estimations that all render the validity of comparisons questionable.

The earliest of these studies to offer a comprehensive survey of transportation and land use trends in Canada was ND Lea's 1966 study, Urban Transportation Developments in Eleven Canadian Metropolitan Areas (N.D. Lea and Associates 1966). This study provided a series of indicators regarding population, urban structure, transit service, motor vehicle traffic and transportation facilities in 11 Canadian metro areas. It also complemented these with corresponding demographic, economic and infrastructure indicators. However, from a comparative perspective, the study has several flaws and omissions that make standardization and meaningful analysis difficult. For example:

- definitions of urbanized areas are unclear or poorly defined;
- often, it is not clear whether other data correspond to the stated "urbanized area";
- the "urbanized area" and associated populations seem understated. One possible reason for this could be that only areas with population densities over 1000 people per square mile were included. However, many large tracts of industrial and institutional land that are urban in nature would likely have lower "population" densities;
- fuel consumption figures lack consistency between municipalities and are based on very soft estimations;
- there are no region-wide total vehicle travel (vehicle miles travelled, or VMT) estimates for the entire urban areas. Only traffic volumes for arterial roads with over 10,000 vehicles per day of traffic are counted;
- road network data lack completeness and are therefore not comparable; and
- while urban structure data corresponds to 1931, 1951 and 1961, the population, transit and motor vehicle data correspond to 1945 and 1965. In an age of extremely rapid motorization and suburbanization, such inconsistencies make accurate comparisons difficult.

Nonetheless, the study was a formidable achievement, particularly given the difficulty in accessing such data at that time. It provided a picture of the general relationships between sprawling land use, motorization and transit decline.

Later studies also attempted to develop a series of indicators on transportation and land use patterns with mixed success. In 1979, Transport Canada performed an extensive study of many aspects of urban transportation in Canada with The Role of the Automobile Study (Transport Canada 1979). Although extensive data were provided, they were often sourced from Statistics Canada publications and were often not disaggregated to the metropolitan level (i.e., they were either provincial or national figures). Of course, such reporting can do little for city-specific policy making and can only communicate the most macroscopic trends. Where transportation data were provided on a metropolitan level, no historical trends were offered, nor were they standardized or linked to other comparable land use, transit, population or demographic data.

Two studies in the 1990's presented a series of raw and standardized indicators to describe the urban structure, population and employment and transportation supply and demand characteristics of Canadian cities. The IBI Group report for the Canadian Mortgage and Housing Commission (CMHC), Urban Travel and Sustainable Development: The Canadian Experience, detailed travel patterns for ten Canadian cities (IBI Group 1993). Then, the Transportation Association of Canada (TAC) produced Urban Transportation Indicators in Eight Canadian Urban Areas, a survey of transport patterns in Canada's largest cities in 1991 (TAC 1996). Since comprehensive data on transportation and land use in Canadian cities are rare, these studies both provided a wealth of needed data. However, both also had some methodological challenges that affected the reliability and comparative value of some of the data.

The IBI report, for example, uses retail gasoline sales to estimate several other transportation activity, energy use and pollution parameters. Since vehicle kilometres travelled (VKT), energy consumption and pollution data in the IBI study are solely a function of (and vary directly with) gasoline sales, they will simply measure retail gasoline sales, expressed in different units (i.e., they will co-vary). Many factors other than gasoline consumption explain VKT, energy use and pollution. For example, local peculiarities such as climate, topography, fleet vehicular efficiency and age and average traffic speed all have an impact on fuel consumption (Kenworthy 1986; NDRC 1997). One city's fleet may have a higher proportion of older, heavier vehicles that consume more gas and pollute more on a per kilometre basis. Another city may have lower vehicle occupancies or fewer hills resulting in less gas consumed per kilometre. Winnipeg's winter cold-starts consume more gas and pollute more than Vancouver's. Theoretically, gasoline sales can provide a ballpark estimate of other parameters, however, most of the data necessary to do this (such as city-specific vehicular fleet fuel efficiencies) are not widely available. Therefore, such estimations are of marginal use for comparative purposes. The best way to achieve comparability is to obtain independent estimations of each parameter in each city.

Also, the range of parameters surveyed does not give a full enough picture of the urban activity patterns that characterize Canadian cities. For example, there are no parameters measuring road and parking infrastructure provision, job and population distribution or the relative proportion of passenger travel by car or transit.

The TAC study that followed IBI's report (which was completed with the assistance of IBI) was more thorough and provided a more comprehensive picture of transportation and urban structure. It even provided highly valuable and difficult to obtain transportation cost and finance data outlining consolidated capital and operating expenses for each urban area. However, although great pains were taken to explicitly define parameters in the survey, the survey responses reveal inconsistencies in reporting between municipalities. This likely reflects poor data availability and different data reporting conventions at the municipal level.

For example, although the study year was 1991, years for source data varied from 1987 to 1994. In fact, of the eight cities surveyed only Toronto and Ottawa were able to consistently provide 1991 data. Other key parameters were missing for many cities (such as freeway and arterial vehicle kilometres), while others were poorly reported and/or vague (such as transit usage data) or not requested (such as transit supply and total VKT). TAC is attempting to address many of these issues for future updates to the study. However, the inconsistencies and omissions make it difficult to benchmark the data and derive reliable performance indicators for the time being.

There are several methodological issues common to both the IBI and TAC reports that merit attention. Firstly, none of the surveys subsequent to the 1966 ND Lea study provided trend data on the evolution of transportation in Canadian cities. Understanding how land use, urban activity and transportation interact over time provides valuable lessons about the forces that contribute to or mitigate against auto dependence. Secondly, both the IBI and TAC reports excluded Hull, Quebec from their surveys. Hull is an important part of the contiguous and functional area of metropolitan Ottawa. It represents 25% of the region's population base (see Ottawa-Hull data table) and is a signification trip generator in the region.

Thirdly, both reports provide values for "urbanized area" that are internally inconsistent and defined differently on a region-by-region basis. The TAC recognizes this, stating that noticeably different conventions for defining the urbanized area were used in each region's reporting (TAC 1996, p. 7). Most often, these differences overstate the size of the urbanized land as the estimates include much non-urban land (e.g., water, regional parks, farmland, etc.). The degree to which this is overstated varies depending on the amount of non-urban land included in each administrative boundary. This overstatement results in a distortion of varying degrees in the true values of urban densities[2].

Urbanized land figures are used to derive other performance indicators and also form the basis for the comparison of transportation data amongst cities. As much of the discourse in transportation policy revolves around its relationship with land use, and particularly compact development, an accurate assessment of urban density in Canada is needed for appropriate policy formulation.

1.1.0 Some Criticisms of CAAD

Although some criticisms have been levied on the comparative work done by Newman and Kenworthy (see Brindle 1993; Gomez-Ibañez 1991; Gordon and Richardson 1989; Lave 1992), most of this critique focusses on issues of interpretation rather than methodology. Despite these criticisms, the approach taken in the compilation of the data is regarded as methodologically sound and the data set is

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[2] The issue of inaccuracies in calculating urban densities will be discussed in greater detail in Chapter 3: Methodology.

regarded as an excellent compendium of comparative urban transportation and land use data (Gomez-Ibañez 1991). Nonetheless, some of the key methodological and interpretative criticisms warrant some attention.

Gordon and Richardson (1989) offer several criticisms of Newman and Kenworthy's prelude to CAAD, their APA journal article "Gasoline Consumption and Cities: A comparison of U.S. cities with a global survey" (1989b). While many items of contention are those found in the normal course of debate on policy analysis, two in particular are of methodological significance and warrant attention.

Firstly, Gordon and Richardson assert that urban structure and the lack of transit service alone cannot explain differentials in transportation characteristics. Other factors such as lifestyle and travel behaviour need to be considered. While this assertion is true, the CAAD data is not meant to be exhaustive, but rather point to some key variables that influence travel characteristics. The data are not meant to imply singular causality between car use and urban structure and transit provision, but rather to provide a picture of some of the key influences in travel behavior. Indeed, while Newman and Kenworthy's qualitative analysis of the data suggests strong prescriptive measures that are open to debate, the real value in the data set is the amassing of a standardized set of data that can be complemented by the policy analyst with other independent data and qualitative information.

Gordon and Richardson's more relevant criticism is that "[Newman and Kenworthy] are pre-occupied by work trips" (Gordon and Richardson 1989, p. 343). While the criticism is overstated, many studies have confirmed that non-work car trips represent the bulk of regional travel in most North American cities (see, for example Altshuler 1980; Calgary 1993; Cervero 1989; GVRD 1993a). The exclusion of non-work modal share and trip length data stems mostly from a lack of availability of "all trips" numbers, particularly in earlier years. Most cities compile trip length and modal split data primarily for the journey to work. In most of the Canadian cities in this study, complementary data on "all trips" were also collected where possible. However, these data were only occasionally available. The inclusion of journey-to-work data is only a problem if the analysis of the data depends on it to the exclusion of other information. Again, complementary quantitative and qualitative information is needed for meaningful interpretation. Furthermore, these data only represent a small portion of indicators used and they are still useful as measures of work-trip car use and as anecdotal evidence of general car dependency.

Brindle (1992) criticized CAAD for using data from the much denser Metro Toronto (which contains only half the region's population), while leaving the more auto-dependent suburban areas of the Greater Toronto Area (GTA) out of the analysis. Brindle claims Toronto does not stand as a model of good transit-oriented planning, but rather is a "paradigm lost." Brindle claims that the Metro definition of Toronto is used to overstate its performance, and that when the outlying areas of the GTA are considered, Toronto is no better, or even worse, than many U.S. cities in automobile orientation. Brindle's assertion that a truly complete analysis of Toronto needs to include the entire GTA is a valid one. As mentioned section 3.3.0.0 below (Territorial Areas), in order to ensure 'apples to apples' comparisons, data need to be collected for the entire functional urban regions, not simply on the basis of arbitrary planning boundaries. This study therefore uses all areas within the functional urban region.[3]

However, Brindle's assertion that Toronto would be in the league of its more auto-dependent U.S. neighbours when the entire GTA was considered and then refuted by subsequent analysis of Toronto (Kenworthy and Newman 1994b). Although the GTA did show marginally higher automobile use, it was still very low by North American and Australian standards. Furthermore, Kenworthy and Newman they confirmed the link between higher density land use patterns and high transit use, even at that much larger regional scale.

Steiner (1994, p. 37) criticized CAAD, and other similarly regionally-oriented studies, for using "grossly aggregate data" and "a narrow definition of urban form that considered the density of both employment and housing but omitted the type of land uses and their spatial distribution within the region." This criticism does have some validity. Sub-regional spatial distributions of employment and population *are* provided within CAAD for the CBD, central (inner) city and outer area. While more detailed observations of the interaction of land use and transportation at the sub-regional scale (e.g., in polycentric regions, or at the neighbourhood level) are both necessary and laudable as complementary research, this is beyond both the scope and practicality of CAAD's research. The objective of CAAD (and this thesis) is not to conclusively solve the problem of auto dependence by collecting every possible piece of relevant data and establish absolute causality. Rather it is to describe general transportation trends and patterns so that macroscopic inter-urban comparisons of aggregate city performance can be made. Sub-regional data and studies are important complements to this effort. However, given the time required to assemble the data and the difficulties in standardizing them for meaningful comparison, such a task would be truly monumental.

Finally, Gomez-Ibañez (1991), Lave (1992) and Steiner (1994) have argued that CAAD is fundamentally flawed because it ignores the contribution of regional wealth and other economic factors in creating high levels of auto ownership and use. Higher incomes are argued to necessarily lead to high car ownership and use (Gomez-Ibañez 1991; Lave 1992). The impact of regional wealth on auto use is a key variable that would help to shed light on contributory factors to auto dependence. While there has been little proof of Lave's and Gomez-Ibañez's assertions, they have been held as conventional wisdom. However, subsequent studies (Aschauer and Campbell 1991; Kenworthy et al. 1997; Laube 1998) have debunked the myth that auto ownership and use are necessary by-products of increasing wealth.

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[3] See section 3.3 (Territorial areas) in Chapter 3 for a complete definition of "urbanized area" used for each region.

Kenworthy et al. (1997) showed that there is no strong correlation between auto use and wealth and that amongst many developing and developed cities, gross regional product (GRP) actually begins to decline in the most automobile-oriented regions. That is, after certain levels of ownership and use, there are substantial *diseconomies* associated with further auto dependence.

1.2 THESIS SCOPE

This thesis attempts to describe some of the general transportation trends and patterns in Canadian cities such that some key factors contributing to automobile dependence can be identified. An extensive review of the literature examining causes and impacts of automobile dependence will inform the analysis of the data in this thesis. There is also a large body of literature that examines policy prescriptions that address these impacts. Prescribing policy based on the data analysis would be a substantial project unto itself if it were to be meaningful. Therefore, rather than prescribe policy based on the data interpretation, this thesis will simply lay out a framework for policy analysis that reconciles the findings with possible points for intervention.

The scope of this thesis is also defined by the following:

- the data analysis will concentrate on the major Canadian cities, however data from the larger global cities sample will be used to contextualize the results and provide a larger sample size for correlations;

- the data and analysis in this thesis is limited to the four study years of 1961, 1971, 1981 and 1991. While there have been notable transportation developments in Canadian cities since 1991, it is difficult to collect current data that is comprehensive and comparable between cities. As a result, I will limit discuss of post-1991 developments to occasional references where appropriate. The thesis is therefore more an exercise in 'learning from history' than a description of current performance;

- the transportation data will primarily consist of private transportation (automobile) and transit data. This limitation is due mainly to data availability. Only limited modal split data indicating non-motorized travel (walking and cycling, or NMT) are available and only for work trips. These data, plus some additional modal split data for some cities, will be assumed to be representative of basic relative conditions for pedestrians and cyclists;

- sub-regional comparisons and data will be limited to the CBD and inner area. Some complementary data may be drawn on from other quantitative studies. While additional information would useful, it would be too time consuming to collect it for the purpose at hand;

- by its nature, this thesis focusses on the quantitative aspects of urban transportation and urban morphology, however, many qualitative aspects (e.g., culture, physical design, etc.) also influence travel choices. This thesis recognizes this and will draw on these perspectives where possible. However, more detailed qualitative analyses are beyond the scope of this thesis; and

- this thesis will orient discussion around the goal of making cities "less automobile dependent" rather than making them "sustainable." My review of the literature indicates that there is substantial debate as to what constitutes "sustainability" in general. Furthermore, there is not enough consensus as to what constitutes "sustainable transportation" to make such a concept operationally meaningful. I will simply define automobile dependence in Chapter 2 and assume reducing it is a means to better transportation.

1.3 THESIS OBJECTIVES AND STRUCTURE

As mentioned at the beginning of this chapter, the purpose of this thesis is to identify the relative importance of factors that can reduce automobile dependence in Canadian cities through a comparative analysis of transportation patterns. Towards this purpose, the objectives of the thesis are:

1. to discuss the value of comparative urban policy analysis and establish the need for such an analysis of transportation in the Canadian context;

2. to conduct a thorough review of the literature to define automobile dependence and to identify its major causes and impacts;

3. to detail the methodology employed for collecting meaningful and reliable comparative urban transportation data in Canada;

4. to analyze the data collected and identify the relative importance of factors influencing auto use in Canada; and

5. to develop a framework for directing policy based on the data results.

This thesis is divided into five additional chapters, as follows. **Chapter 2** consists of a major review of the literature. It provides an operational definition of automobile dependence to frame the analysis in the thesis. It then surveys the major literature to identify the key factors governing urban travel patterns in general and automobile ownership and overuse in particular. The social, economic and ecological implications of automobile dependence are identified and discussed and a critique on conventional policy is offered.

The methodology employed in the collection of the data use in this thesis is given in **Chapter 3**. Area and data definitions are also provided and discussion of data quality and limitations provides important background information for interpreting the data. City maps and the data survey sheets can be found in **Appendix 1**.

The data are analyzed in **Chapter 4** and key findings of Canadian transportation trends and patterns are presented and discussed. The relative importance of key factors making regions more, or less, auto dependent are identified. Comprehensive raw and standardized data tables for each of the Canadian cities are in **Appendix 2**, a summary "master sheet" of data for all the world cities referred to in the Chapter are in **Appendix 3** and the detailed correlation tables are in **Appendix 4.**

Chapter 5 sets out criteria and a framework for prescribing policy based on the literature as reviewed in Chapter 2 and the relative importance of factors influencing auto dependence identified in Chapter 4.

Chapter 6 concludes with a summary of the thesis findings, directions for policy analysis and some suggestions for further research.

CHAPTER 2 - AUTO DEPENDENCE: DEFINITIONS, CAUSES, IMPACTS AND FUTURE DIRECTIONS

2.0 INTRODUCTION

An understanding of automobile dependence, including its causes and its consequences, is required to develop policy that is appropriate and effective. There is a broad and extensive range of literature highlighting the many complex relationships and implications of the car's role in urban transportation. In an attempt to contextualize the thesis data and make recommendations based on them, this chapter identifies and characterizes some of the key issues surrounding the use and overuse of automobiles through a review and synthesis of the literature.

This chapter provides the following:

1. a working definition of 'automobile dependence' and discussion of the goal of transportation (what is the problem?);
2. a discussion of the causes of automobile dependence (what causes the problem?);
3. an assessment of the range of ecological, social and economic implications of auto dependence (why should we care about the problem?); and
4. a critique of some conventional reductionist approaches in solving transportation problems (why many certain types of solutions do not work).

2.1 PERSPECTIVES ON AUTOMOBILE DEPENDENCE

The term 'automobile dependence' was coined and popularized by Peter Newman and Jeff Kenworthy in their 1989 book Cities and Automobile Dependence and describes a series of convergent land use and transportation conditions in cities that leave people few non-car options for urban travel. In examining transportation and land use patterns, Newman and Kenworthy found that while some cities displayed a robust mix of travel modes (car use, transit, cycling and walking) others displayed a much stronger orientation towards the automobile. Some of the more automobile-oriented cities are effectively mono-modal, with as much as 93% of trips being made by car. These most 'automobile dependent' cities display low density, dispersed and uniformly zoned land uses and high priority for car use. Robert Cervero's observations of transportation and land use patterns in America's suburban centres supports this finding: "the *low density, single use,* and *non-integrated* character of many suburban office-commercial centers and corridors has compelled many workers to become dependent on their automobiles for accessing work and circulating within projects" (1989, p. 3). Increasingly development on the periphery of Canada's cities demonstrate these same qualities (Perl and Pucher 1995; Raad and Kenworthy 1998). These land use and infrastructure characteristics effectively preclude the availability or viability of non-car modes. Cities with such limited transportation choice are dependent on automobiles to meet urban travel needs. High levels of car ownership and use result.

Newman and Kenworthy (1989a) categorized the cities of their study into five classes from very high levels of auto dependence (Class I) to very low levels of auto dependence (Class V). These city classes appear in Table 1 below. One of the key defining features of these cities is an inverse relationship between urban densities and automobile dependence.

Table 1 - Classification of cities by degree of automobile dependence

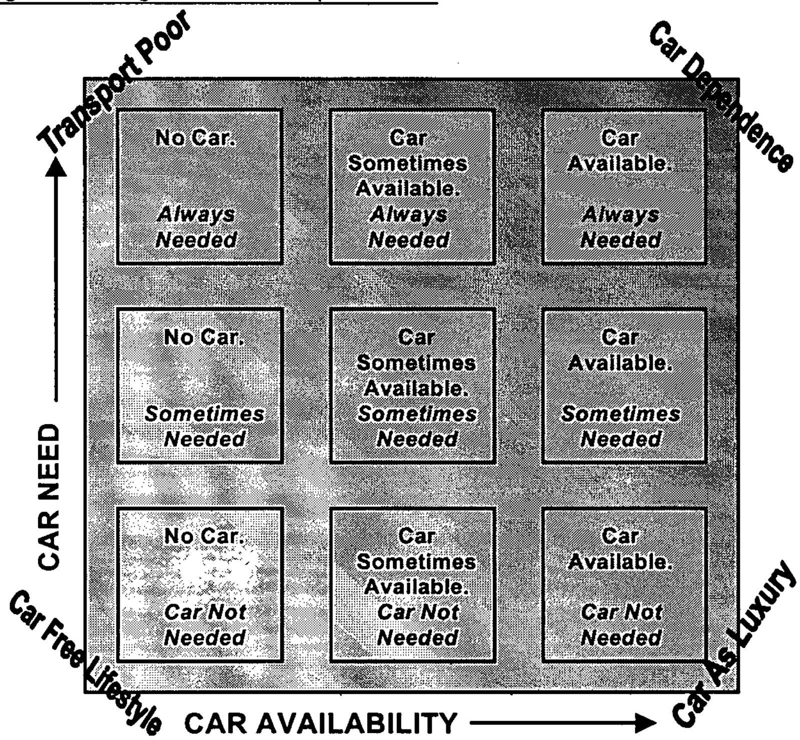
Class I	Class II	Class III	Class IV	Class V
Very High Auto Dependence – almost no role for transit, walking, cycling; very high gas use	**High Auto Dependence –** minor though significant role for transit, walking, cycling; high gas use	**Moderate Auto Dependence –** important role for transit, walking, cycling; moderate gas use	**Low Auto Dependence –** transit, walking, cycling equal with cars; low gas use	**Very Low Auto Dependence –** transit, walking, cycling more important than cars; very low gas use
Phoenix Houston Denver Detroit Perth Adelaide Los Angeles Brisbane	Washington Melbourne Boston Chicago San Francisco Sydney	Toronto New York Copenhagen Hamburg Zurich Brussels	Amsterdam Frankfurt West Berlin Vienna London Stockholm	Munich Singapore Paris Hong Kong Tokyo

Source: (Newman and Kenworthy 1989a)

The regional scale dimensions of automobile dependence have important implications for individual transportation choice. The degree to which one is dependent on the car for transportation varies with the degree to which non-car transportation options exist (car need) and the access some one has to an automobile (car availability). Figure 1 below describes how captive the individual may be to the automobile given the relative need for and availability of a car. Many factors, such as proximity to destinations, availability of alternative modes and age, may affect need, while income is the primary determinant of availability. Individuals who may need a car to access employment because they cannot afford more central housing, but also cannot afford a car, would be "transport poor." Those with high car need and high car access will be completely dependent on the car for transport. For example, an affluent CBD-employed business person who lives in an ex-urban area with no commuter rail will likely use their car for most trips. People at the other end of the spectrum have low car need because of location, greater transportation choice, or other factors, and therefore are either "car free" or lucky enough to have the "luxury" of a car.

Need, of course, is relative. Many people who drive frequently would claim that they "need" their car. However, virtually every large city in the world has a public transportation system. Likewise, most people have the ability to walk or cycle. An appropriate gauge for "need" would be whether the person would frequently forfeit the opportunity to meet basic economic and social necessities in the absence of a car (i.e., they would not walk, bike or take transit even if possible). For example, in Perth, Australia, some bus routes run at frequencies of only 2-3 times per day and there is no bus service after 8 p.m. on Sundays. Few alternatives to the car exist for longer distance journeys in these cases.

Figure 1 - Degrees of car dependence



Source: (Adapted from Pharoah 1996)

If one is poor and/or disabled, they simply would not be able to make the journey. Similarly, a homemaker in a single-car, low-density subdivision whose partner is at work will have few opportunities to take advantage of education, social or shopping opportunities and will therefore be isolated. Sometimes, transit service does not exist, and other times, it does not go where or when one wishes to travel. Other times, ability or distances are prohibitive for cycling or walking. Clearly, these are cases where a car is "needed."

It is useful to take Pharoah's typology for individual levels of auto dependence and apply Newman and Kenworthy's metropolitan-scale classification to it. Clearly, certain cities would fall neatly into certain categories. Detroit's citizens might waver between "transport poor" and "car dependence." In Zurich, where car ownership is moderately high, but need and use is low, citizens have cars "as luxury." Many in cities such as Amsterdam, Tokyo and Hong Kong may be lucky enough to live "car free" and still meet all their travel needs through transit, walking and cycling.

2.1.0 Redefining the Goal of Transportation

According to many transportation critics, one of the fundamental reasons transportation outcomes tend towards auto dependence in North America lies in how we define 'transportation.' Traditionally, planning has viewed the goal of transportation as *mobility*: the maximization of the free movement as measured by the speed and volume of traffic (Altshuler 1979). The automobile is often regarded as a perfect solution to challenges to mobility as it offers drivers control, comfort, freedom and convenience in going anywhere at anytime. In promoting mobility, the efficient and quick movement of traffic has become a singular objective of traffic planners in many cities. This free movement is traditionally measured by level of service (LOS) on roadways, or the degree to which traffic flows without interruption (i.e., average travel speeds) (Ewing 1993). The higher the LOS and the higher the vehicle ownership levels, the greater the level of mobility. Therefore, as a means of promoting mobility, public policy has focussed on increasing LOS and personal car ownership.

However, many authors have also argued that there is a profound irony in the fact that the quest for total mobility has resulted in the increasing *immobility* of many, often including those able to drive (Altshuler 1979; Ewing 1993; Freund and Martin 1993; Lowe 1990; Newman and Kenworthy 1989a; Schwartz 1971; Whitelegg 1993; Zielinski 1994). Maintaining high LOS (i.e., preventing congestion) has proven illusive (Freund and Martin 1993; Hart and Spivak 1993; Newman and Kenworthy 1988b) and car ownership will likely never be universal. While some continue to be unable to meet their basic needs (e.g., the young, old, poor and disable unable to afford cars), others are simply stuck in traffic. As will be discussed later, the pursuit of high levels of mobility through private motorized transportation also results in substantial social, economic and ecological costs to the individual and society.

Transportation is a *means* of facilitating social and economic interaction for urbanites, not an *end* in itself. Lewis Mumford (1953) and Jane Jacobs (1961) warn that unfettered mobility is actually antithetical to the purpose of the city in that it interrupts the basic city functions of proximity for contact and production as well as multiplicity of choice. In <u>The Death and Life of Great American Cities</u> Jane Jacobs states: " Good transportation and communication are not only among the most difficult things to achieve; they are also a basic necessity...But multiplicity of choice and intensive city trading depend also on immense concentrations of people, and on intricate minglings of uses and complex interweaving paths" (1961, p. 339-340). In <u>The Highway and the City</u>, Mumford writes: "The paradoxical result of this concentration on motorcars is a curbing of freedom of movement, a removal of alternate choices of transportation, the steady reduction of the speed of local travel, and the total defeat of the city itself as a place that offers the maximum possibilities for face-to-face meeting, social cooperation, and transactions of every kind" (1953, p.222). The single-minded pursuit of individual mobility can actually serve to undermine the basic urban functions it aims to enhance.

Little has changed since then. In his critique of the time and space dimensions of auto use, John Whitelegg argues for a paradigm that reflects the still-illusive values espoused by Jacobs and Mumford four decades ago. "The ability to make contact with places and other people is the central organizing feature of human activity and that it is ease of access to other people and facilities that determines the success of a transportation system, rather than the means or the speed of transport. It is relatively easy to increase the speed at which people move around, much harder to introduce changes that enable us to spend less time gaining access to the facilities that we need" (Whitelegg 1993, p. 131). The systemic biases towards auto dependence are still entrenched today.

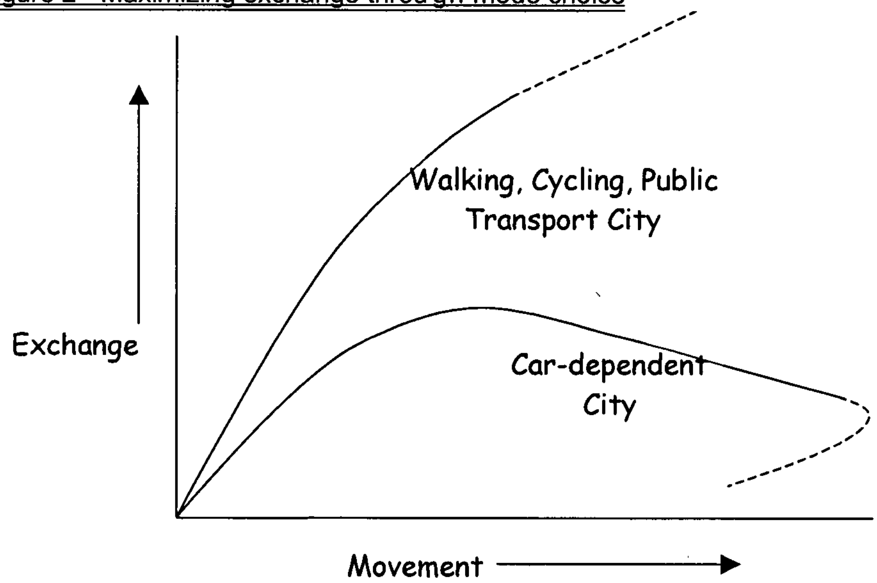
A more holistic way of defining transportation to provide a more appropriate framework for transportation policy formulation is needed. Focussing on *access* rather than *mobility*, it is argued, would result in more equitable, efficient and socially responsible satisfaction of travel needs (Altshuler 1979; Engwicht 1993; Ewing 1993; Litman 1995; Whitelegg 1993; Zielinski 1994). Rather than maximizing movement and speed for its own sake, access-based transportation seeks to maximize the contact that is the very reason for 'clustering' human activity in cities. Access requires proximity in destinations, but also choice in reaching them. This contrasts with the mobility-focussed, auto-centric paradigm that deprives people of access because it is mono-modal and assumes people can travel great distances. By promoting access, it is possible to reduce the "car need" of individuals and cities (see Figure 1 above) that is responsible for varying degrees of transport poverty or car dependence.

David Engwicht (1993) provides a passionate and persuasive argument for a transportation system that access-based rather than mobility-based. Engwicht argues that goal of a city, and therefore the transportation system, is to facilitate ease of "exchange." The greater the diversity and proximity of land uses and the greater the number of options for accessing them, the more likely the opportunities for planned and spontaneous exchange.

Figure 2 below demonstrates the tradeoffs between movement and exchange. Cities with exchange friendly transport offer more opportunities for social and economic exchange for similar amounts of "movement" and therefore offer greater access. Movement (through automobility) is good up to a certain extent, however it offers diminishing marginal benefits to exchange. Auto-dependent cities begin to limit exchange since much of the potential exchange space (e.g., shops, homes, parks, and paths) is actually occupied by movement space (e.g., roads, parking lots and freeways). The mere presence of this vast amount of movement space, and the landforms that accompany it, effectively precludes exchange-friendly transport. It also creates what Engwicht terms the "access-to-exchange disadvantaged"

(ATED) (Engwicht 1993). The ATED are those who do not have access to an automobile, where auto dominance precludes other travel options. In more automobile dependent cities, where movement is favoured over exchange, the gap between those who are ATED and those who are not is larger than in non-car dependent cities.

Figure 2 - Maximizing exchange through mode choice



Source: (Adapted from Engwicht 1993)

Lewis Mumford provides perhaps the most cogent articulation of the goal of transportation. "The purpose of transportation is to bring people or good to places where they are needed, and to concentrate the greatest variety of goods and people within a limited area, in order to widen the possibility of choice without making it necessary to travel. A good transportation system minimizes unnecessary transportation; and in any event, it offers a change of speed and mode to fit a diversity of human purposes" (Mumford 1953, p. 236).

2.1.1 Measuring Auto Dependence

The degree to which a city is automobile dependent (or, conversely, is accessible) can be measured as a function of the spatial distribution of destinations, the availability of choices in getting there and the level of car use. While some detailed performance measures of accessibility have been proposed and used (Barter 1998; Laube 1998; Pirie 1979), there are no widely accepted conventions for measuring it (Handy 1994). There are, however, basic proxy indicators of accessibility that can provide anecdotal evidence of relative levels of car dependence.

For example, urban activity densities can provide basic information about the proximity of people and activities and the levels of "exchange" possible. Modal splits, transit service levels and average trip lengths can provide information about the practical range of non-car options available to urban residents in accessing these. While these convey information about level of "car need" and, by extension, accessibility, other indicators such as vehicle kilometers travelled (VKT), parking and road supply and motor vehicles on register provide a gauge of the priority and need for private transport to meet travel needs. Of course, all these individual measures should be analyzed with consideration to some of the more qualitative variables that influence access such as the quality of urban design.

Newman and Kenworthy (Newman and Kenworthy 1989a) used "cluster analysis" techniques to assess levels of auto dependence based on a variety of land use and transportation data collected for their study. They then assigned each city a composite score ranking relative levels of auto dependence. For the purposes of this thesis, I will simply highlight the relationships between the various parameters identified as being good "proxies" for measuring car dependence and access.

2.2 CAUSES OF AUTOMOBILE DEPENDENCE

The literature identifies a range of causes of automobile dependence such as road building, urban sprawl and the decline of transit, as well as economic, demographic and lifestyle factors. In reality, there is no singular cause of automobile dependence. Rather, there are multiple contributing factors, many of which are both cause and consequence. Furthermore, these display "positive feedback" which reinforces the various contributing problems making it seemingly intractable.

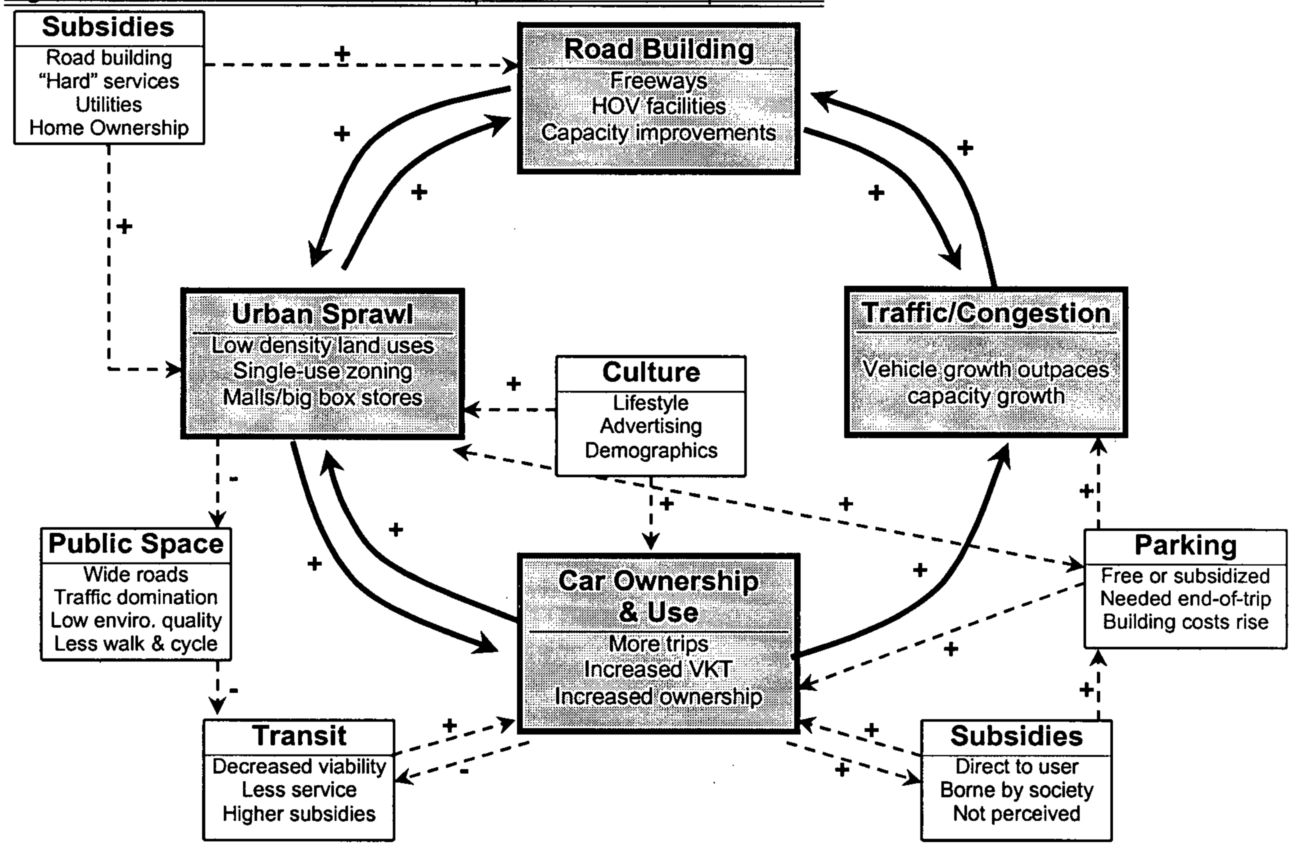
Figure 3 below highlights some of the basic factors influencing increasing levels of car use.[4] Changes in transportation technology provided the initial catalyst for widespread car ownership and use. The widespread availability of automobiles, particularly in wealthy countries in the post-war period, provided the mobility necessary to travel greater distances at relatively high speeds (Illich 1974; Mumford 1953). Convergent factors such as immigration, the baby boom and changing lifestyle preferences increased demands to open up new tracts of land to accommodate population increases. The availability of the automobile afforded planners the opportunity to accommodate much more dispersed settlement patterns than previously possible. With automobiles available, road building made suburbanization possible. Low-density suburbs proliferated throughout the developed world, but particularly in North America. Manufacturing and retail activities were able to free themselves from the locational constraints of rail and streetcar lines. Roads offered a new accessibility option to residences and industry.

While roads make these low-density development patterns possible, they also make automobiles a necessity as transit services are unable to support themselves. Transit servicing costs vary inversely with

[4] Of course, this diagram of influences can be placed in the context of more macroscopic social and economic dynamics.

density (Altshuler 1979; Newman and Kenworthy 1989a; Pucher 1988). Furthermore, the curvilinear roads characteristic of many suburbs makes these areas difficult to access and service by transit. Single use zoning means that travel distances are usually long. Increased subsidies are therefore required to service transit in low-density areas. Consistent and high subsidies usually result in pressures to curtail or eliminate transit services in low-density areas. These pressures have been particularly acute in Canada in recent years (Pucher 1998).

Figure 3 - Positive feedback relationships in automobile dependence



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

Not all suburbs are created equal. For example, Canadian outer areas (i.e., suburbs) are more than twice as dense as outer areas in the United States. The result has been much higher levels of transit use (and much lower levels of car use) in Canadian versus U.S. cities (Raad and Kenworthy 1998). The more methodical, planned suburbanization of Metro Toronto, with a linear street network, bus-rail integration and planned transit catchment areas, has resulted in high transit ridership even in Metro's suburbs (Frisken 1991). However, more recent transit-hostile land use decisions outside of municipalities outlying Metro have resulted in negligible levels of transit usage in the newest generation of suburban office parks. Perl and Pucher (1995) report that up to 25% of workers arrived by bus in Toronto's first generation of office sites, whereas the figure is now down to nearly zero in the newest sites. The location and surrounding uses of these sites (usually, vast ground-level parking) precludes any viable use of transit.

Monetary and nonmonetary subsidies for infrastructure, and directly to individuals, also influence development patterns in substantial ways (Frisken 1994a; Litman 1995; OECD 1994; Peat Marwick Stevenson & Kellogg 1993). In North America, governments subsidies (in the form of tax relief, cheap loans and grants) at the state, provincial and federal levels encouraged residential sprawl (Goldberg and Mercer 1986).

The construction of roads, trunk sewer and water lines and utilities, and the provision of higher cost public services (such as schools and hospitals) to service low-density land uses, encourages sprawl by opening up tracts of seemingly "cheap" land for development. This sprawl, in turn, requires automobile use for access. Similarly, there are a whole host of financial costs (such as road maintenance and construction, traffic enforcement and free or subsidized parking) as well as non-financial costs (such as congestion, environmental and social impacts) not borne directly by the driver (Litman 1995).[5] Since the driver does not perceive many of these costs, they merely serve to encourage a cycle of inefficient location and increased driving.

Table 2 - Comparison of relative price changes and transit ridership in Canada, 1980-95

	CPI -- all Goods	Auto Operating Costs	Urban Transit Fares	Transit Ridership
1980-1990	+77.8%	+108.4%	+113.1%	+16.3%
1990-1995	+11.7%	+12.2%	+34.5%	-11.4%

Source: (Pucher 1998)

The low and dropping real and perceived costs of driving, combined with the rising transit operating costs and reduced transit subsidies, has resulted in dropping transit patronage and increasing car use. Table 2 above highlights some of the basic relationships between relative transit and auto costs and transit ridership levels. While transit fares rose only slightly greater than auto operating costs between 1980-1990, they rose substantially greater than the CPI and auto costs between 1990-1995. Furthermore, the RMOC (1995) reports that automobile purchasing costs and gasoline prices have dropped by 11 and 12%, respectively (inflation adjusted) since 1981. Pucher (1994; 1998) and Perl and Pucher (1995) attribute much of the decline in transit ridership in Canada to decreasing service and the growing gap in between transit ticket price and car operating costs.

[5] The issue of subsidies to driving will be discussed in greater detail in section 2.3.2 below.

Durning (1996) describes some of the other relationships between relative car costs and car use in British Columbia, Washington, Oregon and Idaho in Table 3 below. While there are many other intervening factors that influence car use, the table below charts some clear relationships between car use, gasoline price and insurance costs. Litman (1997b) reports that the underpricing and cross-subsidies insurance premiums encourages driving and is inequitable. This flat price structure for insurance may also encourage inefficient locational decisions.

Table 3 - Car costs and car use in the U.S. Pacific Northwest and British Columbia

	Gasoline Consumption per Capita (gallons)	Vehicle Travel per Capita (miles)	Net Fuel Tax (US$/gallon)	Average Insurance Premium (US$/year)
British Columbia	294	~6,000	0.59	~$700
Washington	462	8,880	0.32	$588
Oregon	457	9,540	0.42	$535
Idaho	466	10,230	0.33	$402

Adapted from: (Durning 1996)

Some institutional practices also provide financial incentives for sprawl and increased driving. For example, bank-lending practices for home mortgages applied equally to prospective buyers, regardless of location, effectively discriminate against inner city home ownership. Currently mortgage assessments do not take into account locational choices that require substantially lower expenditures on car ownership and use. Goldstein (1996) estimates that accounting for lower transportation costs in certain locations (such as lower car ownership and operating needs) can provide an additional margin of affordability of up to US$40,000 on a house and lead to a higher demand for location efficient housing.

The increased levels of driving, both in terms of the number of trips and vehicle kilometres travelled (VKT), leads to congestion conditions in the absence of increased LOS (i.e., road capacity). The phenomenal growth in vehicle ownership and use in Canada has generated a substantial demand for automobile infrastructure. New roads, freeways and capacity enhancement measures (such as HOV lanes, light sychronization and left-turn bays) have been traditional tactics to improve vehicle flow and speeds, ostensibly with the longer-term goal to reduce congestion. However, this strategy of trying to "relieve" congestion though comprehensive capacity additions and enhancements is widely recognized to be a futile task (Freund and Martin 1993; Gordon 1991; Lowe 1990; Renner 1988). There is a direct relationship between road provision levels and VKT (Kenworthy and Newman 1994a; Newman and Kenworthy 1989a). Furthermore, free flowing traffic has a strong association with sprawl and higher levels of driving and energy consumption on a regional scale (Newman and Kenworthy 1988a; Newman and Kenworthy 1988b).

More recently, empirical research has found substantial evidence that road transportation improvements actually derive greater demand for automobile travel (Goodwin 1996; Hansen 1995; Johnston and Ceerla 1996; SACTRA 1994; Williams et al. 1991). In other words, these improvements do not actually relieve traffic congestion, they "generate" or "induce" additional amounts of traffic in the short and long term. Since there is a substantial 'latent demand' for automobile travel in most urban areas (constrained in many cases by congestion), any short-term improvements in congestion conditions are eroded by new (induced) travel over the long term. In an analysis of the aggregate effects of road improvement projects, Hanson (1995) estimates that every 1% increase in lane miles induces a 0.9% increase (i.e., a 90% net growth) in VKT within 5 years. Where travel demand is strong, the effects of generated traffic will ensure that predicted congestion relief will be illusive. Furthermore, additional capacity catalyzes longer term changes in land use, public transport viability and parking demand which will have further generative effects on road traffic well into the future (Goodwin 1996; Newman and Kenworthy 1988b; SACTRA 1994; Williams et al. 1991). However, most transportation models do not consider the long run implications of generated traffic and do not generally incorporate generated traffic costs, particularly "external" ones, into economic analysis of projects (Litman 1997a; Williams et al. 1991).

The effects of generated traffic are not limited to large road projects. The cumulative effect of many minor efficiency improvements (e.g., left turn bays, one way streets, signal enhancements) can also serve to induce more traffic if their cumulative effect is to raise the overall LOS for automobiles relative to other modes. Bill Curtis of the Sierra Legal Defence Fund captures the problem of induced traffic quite well. He likens building extra capacity for automobiles to "drilling holes in the bottom of a leaky boat to let the water out" (Berger 1993, p.153).

There is a growing body of evidence shows that reductions in road capacity can actually induce a *net* reduction in total traffic. Such measures can include the conversion of lanes for transit or parking use or the complete pedestrianization of roads. A major study recently completed for London Transport and the Department of Environment in the UK concluded that, taking into account traffic diversions to other roads, cases of capacity reductions have resulted in net traffic reductions of 25-50% original levels (Bates et al. 1998). Such evidence provides strong support to the theory that reducing auto capacity will not necessarily increase traffic congestion and may increase accessibility.

Free or subsidized parking also provides an incentive for automobile use (Litman 1998a; Shoup 1996; Shoup 1997). Most cities have ample free or underpriced parking at roadsides, shopping malls and places of employment. These are subsidized or provided by retailers, employers or municipalities. Occasionally, residential parking will be incorporated into the cost of the dwelling.

Ample parking is institutionalized. Most municipalities have minimum parking requirements, which dictate a (usually generous) ratio of parking to square footage or number of building occupants/users. These minimum parking standards are usually a response to political pressures to provide places to park cars. Donald Shoup calls minimum parking requirements "a fertility drug for cars" that in some places has become "the arbiter of urban form" (1997, p.7). Shoup indicates that high parking requirements raise housing costs, reduce urban density and reduce land values. Often, costs for providing the spaces are not borne directly by users. The massive subsidies therefore encourage the overuse of cars. Furthermore, planners usually set minimum parking requirements to meet the peak demand for free parking, thereby deriving and inflating demand for parking at other times. Again, the ample supply of automobile infrastructure generates demand for car use, encouraging sprawl and reducing transit viability in the long run.

The various by-products of the cycle of auto dependence serve to undermine non-motorized travel (e.g., walking and cycling) and transit. For example, sprawling land uses undermine the financial viability of public transportation by driving up the costs of providing service while simultaneously decreasing the size of the population catchment from which it can draw. Lower ridership leads to less service, which leads to increasing car ownership and use, and so on, through the cycle. Similarly, longer distances and more dispersed land uses make cycling and walking to shops, schools, work and entertainment less viable. Wider streets, priority to cars, traffic domination and safety concerns undermine the 'public realm' making these environments even less attractive, even hostile to non-drivers. The prevalence of malls and 'big box' stores oriented towards serving motorists further weakens the urban fabric. Again, this feeds into a cycle of increasing car use, congestion, more road building, more sprawl to get away from it all, and less walking, cycling and transit use.

2.2.0 Feedback in Transportation

The 'cycle of dependence' described above depends on 'positive feedback.' Positive feedback is a well-recognized phenomenon in environmental and social problems in general (Berry 1977; Dubos 1970; Ehrenfeld 1978; Hardin 1968; Hardin 1985; Schwartz 1971) as well as in transportation behaviour and planning specifically (Altshuler 1979; Engwicht 1993; Freund and Martin 1993; Illich 1974; Litman 1995; Mumford 1953; Newman and Kenworthy 1989a; Pushkarev and Zupan 1977). Jacobs (1961) describes positive feedback as a process whereby an action leads to a reaction which in turn intensifies the condition responsible for the initial action. The need for repeating the initial action is amplified and a cycle is set in motion. Positive feedback loops can have positive consequences or negative consequences. In the case of urban transportation in the developing nations context, most cities are caught in positive feedback of socially *negative* consequence as is demonstrated in Figure 3 above. There is no single feedback loop responsible for the downward spiral, but rather a web of mutually reinforcing feedback loops that, left alone, create an seemingly intractable cycle of dependence on automobiles.

Jane Jacobs describes the cycle of "erosion of cities by automobile":

> *Erosion of cities by automobiles entails so familiar a series of events that these hardly need describing. The erosion proceeds as a kind of nibbling, small nibbles at first, but eventually hefty bites. Because of vehicular congestion, a street is widened here, another is straightened there, a wide avenue is converted to one way flow, staggered-signal systems are installed for faster movement, a bridge is double-decked as its capacity is reached, an expressway is cut through yonder, and finally whole webs of expressways. More and more land goes into parking, to accommodate the ever increasing numbers of vehicles while they idle. No one step in this process is, in itself, crucial. But cumulatively the effect is enormous. And each step, while not crucial in itself, is crucial in the sense that it not only adds its own bit to the total change, but actually accelerates the process(Jacobs 1961, p. 349-350).*

Jacobs goes on to describe a series of attendant reactions that set in motion a series of complicating feedbacks and self-defeating palliatives with respect to transit use, pedestrians presence and intensity of districts.

There are a variety of other perspectives on positive feedback in transportation. For example, Freund and Martin focus on road building, using the "black hole theory" of highway building to describe the problem: highway congestion begets added capacity, which causes sprawl and auto dependent spaces which leads to more car use and congestion, which leads to calls for renewed rounds of road building (1993, p. 20). Pushkarev and Zupan (1977) focus on land use as both "cause and consequence" of auto dependence and the decline of transit, walking and urban vitality. David Engwicht takes a broader view, incorporating many of the feedback loops shown in Figure 3 in a description of what he calls "burning down the house to stay warm" (1993, p. 55). He also implicates the death of the corner store, fear of crime and the atomization of society in the perpetuation of this cycle. Litman (1995) touches on many of the aspects of feedback described in Figure 3, including induced traffic, however he frames his analysis in terms of behavioural queues provided in the way transportation costs and benefits are distributed (i.e., whether the users pays).

Reversing the problem is a matter of reversing the positive feedback such that it yields *positive* outcomes. Jacobs claims the "attrition of automobiles *by* cities" [emphasis added] can serve to reverse the erosion of cities by cars (1961, p. 359). For example, one way of doing this is to renew districts with vitality such that congestion develops and using an automobile is inconvenient and other modes more attractive. Over time, district activity can intensify further for locational reasons. Engwicht (1993) suggests a broad range of measures that move a city towards exchange-friendly transportation. More exchange opportunities are afforded individuals for the same amount of movement (Figure 2 above) because the feedback effects do not undermine the gains to the same extent. Litman (1995) prescribes a realignment of the distribution of cost and benefits such that positive or negative (action suppressing) feedback yield more positive social outcomes. While Susan Handy offers many of the same land use and accessibility remedies suggested by others for reversing the cycle of dependence, she warns that, as a result of entrenched practice and patterns, "we may, in fact, be beyond redemption" (1993, p. 40).

2.2.1 Common Property Problems

Many of the behavioural responses in transportation that elicit positive feedback are rooted in problems of common property. That is, where there is common property (e.g., public air, water and land) there is often no direct responsibility for the consequences of an action and the benefits are high and the costs diffuse.

In his essay, Tragedy of the Commons, Garrett Hardin popularized the notion that the unregulated pursuit of self-interest in the management of common property (e.g., public air, water, land) leads to collective ruin (1968). In Filters Against Folly, Hardin builds on his critique of the unmanaged commons by identifying the "distributional paths" of benefits and costs (profits and losses) are the types of responsibilities that accompany each (1985). In **privatism**, both profits and losses in the use of common property accrue to the individual. This is said to involve *intrinsic* responsibility because there is a direct negative or positive impact as a result of one's actions. In **Socialism,** profits and losses are differentially distributed by bureaucrats amongst the group that owns the common property (this is different from privatism in that the actor and the acted upon is the community). **Commonism** privatizes all profits while all losses are indiscriminately distributed to the population as a whole, or are "commonized." These "unmanaged commons" are characterized by what Hardin terms *negative* responsibility: it pays for the individual to make the wrong decision. While Hardin recognizes that no distributional path is best in all circumstances, combinations of both socialism and privatism are preferable to unfettered commonism. Currently, transportation decisions can be characterized as practicing a form of commonism: benefits accrue mostly the driver (internalized), while costs are commonized to society (externalized).[6]

Many of the diffuse costs of transportation decisions do not enter into the feedback equation and responsibility is not assumed because there is no direct adverse consequence to the action (i.e., responsibility is negative). Therefore, from a social perspective, the omission of these "common" factors from the feedback equation results in feedback that is 'incomplete.'

Transportation behaviour in Bangkok, Thailand provides an outstanding example of incomplete and positive feedback. Bangkok has some of the world's worst transportation-induced urban air quality (Faiz 1993). However, it is not uncommon for people to avoid walking for even short trips of 4-5 blocks

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[6] I discuss "internal" and "external" costs in detail in section 2.3.2.0 below.

because the air is so noxious. Instead, many will get in their cars and drive, thereby making their own contribution to the problem.

From an individual perspective, feedback is incomplete. The individual does not perceive their additional contribution to air pollution and therefore does not adjust their behaviour. There is 'negative responsibility' because each person is rewarded with clean(er) air at the expense of others. At the societal level, the aggregate effect of such decisions leads to positive feedback: more pollution leads to more driving, leads to more pollution, and so on.

Similar scenarios are played out in many other cities and in other circumstances to varying extremes. For example, public opinion studies in the GVRD indicate that although people recognize the main contribution they can make to improve air quality is to drive less, 9 out of 10 people still use their cars all or most of the time. Furthermore, although most say they would take public transit if it was convenient, most are unsure of just how convenient or inconvenient it is, and 38% of people have not even tried public transportation in the recent past (GVRD 1995b). Although transit may well be inconvenient for some, it is still a viable and convenient option in many Canadian cities. But clearly, many will not sacrifice their own total mobility for the benefits of one sacrificed trip divided by 1.8 million Vancouverites. The marginal impact off the individual's decision to drive is perceived as negligible and there is a 'negative' responsibility.

Lack of cooperation also creates a major challenge in dealing with common property problems where there exists positive feedback and rewards for self-interested action. Political scientists and economists describe the decision-making processes that characterize the "Tragedy of the Commons" in the field of 'game theory' with a decision simulation called The Prisoner's Dilemma. The Prisoner's Dilemma (Figure 4a below) is a classic problem of conflict and cooperation that is used to predict economic, political, military and personal responses. In its simplest and most popular form, each of the two players (e.g., two captured criminals) has a choice of cooperating with the other or defecting to minimize their potential sentence. Depending on the two players' decision, each receives payoff (e.g., number of years in jail) according to a payoff matrix.

When both players cooperate by refusing to fink on the other they are both rewarded at an equal, intermediate level (reward, R), such as a light sentence of 2 months. When only one player defects, they receive the highest level of payoff of no sentence (temptation, T), while the other player gets the fool's punishment of 10 months (fooled, F). When both players defect they each receive a high prison sentence. The dilemma demonstrates the difficulty of achieving cooperative behaviour when rewards are available for the successful defector. The ultimate result of failing to cooperate is a lose-lose situation for both.

Figure 4 - The prisoner's dilemma

a) Generic Dilemma

		Prisoner A	
		Co-operate	**Defect**
Prisoner B	**Co-operate**	**R=2, R=2 (win, win)**	**F=10, T=0 (lose, win)**
	Defect	**T=0, F=10 (win, lose)**	**P=8, P=8 (lose, lose)**

R = Reward
T = Temptation
F = Fooled
P = Punishment

b) Big Box Dilemma

		Vancouver	
		No Big Box	**Big Box**
Burnaby	**No Big Box**	**R=6, R=6 (win, win)**	**F=0, T=10 (lose, win)**
	Big Box	**T=10, F=0 (win, lose)**	**P=-1, P=-1 (lose, lose)**

Multi-player individual and municipal decision-making matrices often exhibit the similar outcomes. In the Prisoner's Dilemma model, Cooperate/Defect can be replaced with Walk/Drive, or a whole host of other individual decisions. At the municipal level, Cooperate/Defect can be replaced Big Box/No Big Box – in other words, the decision of whether to allow the construction of a big box store (see "Big Box Dilemma" in Figure 4b).[7] It is well recognized that big box stores have tremendous

[7] Big box stores are also referred to a 'megastores' or 'superstores' (e.g., Costco, Real Canadian Superstore, Home Depot). They are typically located in industrial areas that have been rezoned commercial. They have a large amount of floorspace are usually able to offer relatively cheap prices because they can engage in bulk buying and selling and can accommodate a large amount of on-site storage. They are typically car oriented establishments surrounded by large ground-levels parking lots and are reported to each generate up to 1 million car trips a year (Seelig 1998).

potential negative consequences for cities. While they do offer cheap goods, they offer relatively low marginal gains to property tax bases, they undermine local business, they destroy the urban fabric and they are almost completely automobile dependent. However, if the City of Vancouver does not allow Price-Costco to set up in its boundaries, the City of Burnaby almost surely will. So there is a 'temptation' for each city to pre-empt the other in order to capture a bigger piece of the proverbial 'pie.' If both begin a cycle of attrition to win the most of this type of development, it will almost certainly have adverse effects for both in terms of transportation, the loss of local small-scale business, decreased tax revenues, urban vitality and so on. Again, the individual actor (the municipality) perceives high personal gain and diffuse losses, and so acts with self-interest to the detriment of all.

Completing feedback loops and **facilitating cooperation** amongst individuals and organizations can help overcome common property problems. Distributing seemingly indivisible costs and benefits such that they are perceived in the feedback equation helps develop intrinsic responsibility. Since it is difficult for people to perceive the incremental pollution that may result from an action, building in other feedback responses, for example through pricing, may provide appropriate behavioural queues.[8]

Reducing "temptation" responses in common property management such that individuals work together for the common good requires "mutual coercion, mutually agreed upon" (Hardin 1968, p. 1247). The lack of cooperation and coordination between municipalities in dealing with the challenges of transportation and land use has been identified as a major aggravation to sprawl and automobile dependence (Freilich and White 1994; Frisken 1991; Frisken 1994b; Frisken et al. 1996; Goldberg and Mercer 1986; Linteau 1990; Mumford 1953; Yago 1983). In a comparative assessment of transportation and planning in the U.S. and Canada, Raad and Kenworthy (1998) argue that institutional structures aimed at achieving cooperation and coordination between municipalities was an important factor in controlling automobile dependence in Canada relative to its neighbour. However, the systematic deterioration of means to manage matters of common interest among municipalities is leading to increased sprawl and car use in Canadian cities. Municipalities increasingly face "temptations" to appropriate many of the benefits of sprawl, while commonizing its many costs to the public at large. Clearly, a means of managing common property and indivisable costs and benefits (Franklin 1990) is necessary in order to rein in the positive feedback, privatization of benefits and commonization of costs that characterize auto dependence.

[8] See section 2.3.2.1 below for more discussion marginal cost pricing of externalities as a means of modifying transportation behaviour.

2.3 SYMPTOMS AND EFFECTS OF AUTOMOBILE DEPENDENCE

Transportation impacts our lives in many ways. The range of urban transportation options available can make getting around the city easy or difficult. The transportation choices we make as individuals and as a society are a key determinant of whether our urban environments are ecologically sensitive, equitable, lively and efficient. However, those transportation choices we have made, and increasingly make, in Canada are compromising the well being of our cities.

Automobile dependence characterizes major Canadian cities (Perl and Pucher 1995; Raad and Kenworthy 1998). There are few options available for urban dwellers, particularly outside the inner cities, for meeting their accessibility needs. The result is very high levels of urban automobile ownership and use, with tremendous ecological, social and economic impacts.

However, the "problem" of transportation is invariably expressed in narrow terms, particularly amongst policy-makers. For example, transportation policy typically seeks to address singular and compartmentalized problems such as congestion, air pollution and, to a lesser extent, sprawl (for example, see Calgary 1995b; GVRD 1995a; Reynolds 1971; Transport Canada 1979). However, many of these are merely "symptomatic" of larger problems (Altshuler 1979; Schwartz 1971), and myriad other problems go unnoticed or ignored.

Figure 5 - Ecological, social and economic dimensions of auto dependence

Many impacts of auto dependence are inter-related. While many impacts fall neatly into one of the 3 dimensions of auto dependence, many clearly have dual or multiple dimensions.

The various symptoms of auto use are extensive, complex, inter-related and, often, mutually dependent (Figure 5 above). If policy is to effectively address the many complex ecological, social and economic dimensions of automobile dependence, then these various symptoms and their relationships first need to be identified.

The following sections provide an analysis of these ecological, social and economic dimensions of auto dependence identified in the review of the literature, with a special focus on the Canadian context.[9] While the list of impacts discussed is comprehensive, it is by no means exhaustive. It is also import to note that there are many ways in which one "problem" impacts many areas. For example, air pollution occurs throughout a vehicle's life cycle (from resource extraction to disposal) and effects water, air and soil quality. Similarly, sprawl has distinct environmental, social and economic elements. Some symptoms of auto dependence may be discussed in several of the subsections, however, the discussion will touch on different dimensions of the symptom and a such will not "double count."

2.3.0 Ecological Impacts of Auto Dependence

There are a whole host of ecological problems associated with the ownership and use of private automobiles. The following sub-sections touch on six broad areas of ecological impacts: water-related, land-related, resource consumption, vehicle disposal, air pollution and emissions, and "other" impacts.

Many of the impacts discussed are not well recognized in the general literature, nor are they traditionally directly attributed to automobile use. I have attempted to take a "life cycle" approach to identifying the impacts so that their full extent can be revealed.

2.3.0.0 Water related impacts

Water-related impacts are perhaps the least recognized of the environmental consequences associated with automobile dependence. Impacts on water range from disruptions of natural hydrology systems, to contamination of waterways from road runoff, to spill-related impacts of oil extraction and transport.

Of all land uses, sprawling urbanization has the greatest adverse impact on water hydrology and quality (MacKenzie 1987). Impacts include modifications to the local climate, increased erosion and sedimentation, increased precipitation and flooding potential, effects on groundwater recharge rates, and reduced water quality. These effects result from the paving over of soils which previously served to absorb rain and snow and keep water cycles and flows in balance with ecological needs. Paving causes a channeling of higher volume and higher speed water that leads to the above mentioned impacts. Also of importance with respect to water-related impacts is the contamination of water associated with this runoff.

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[9] The literature regarding the impact of transportation in Canada is limited and not well-recognized in the larger body of transportation literature. However, I have attempted to draw on the Canadian experience wherever possible in order to enhance the relevance of future policy discussions.

The United States Environmental Protection Agency suggests that urban runoff may rival agriculture as the worst contributor of non-point pollution, and may be a far more serious polluter in many areas (Hall and Anderson 1988). However, the general public does not perceive that urban runoff problem to be a major concern (McConnell 1991).

A significant portion of urban runoff pollution stems from automobile-related activities (NDRC 1997; Newman 1994; OECD 1995). Table 4 below details some of the sources of water pollution and hydrological disruptions associated with vehicle use. Most of the sources are non-point, except where they originate from oil and gas related industry and storage facilities. Motor vehicles, roads, auto-related industry and parking facilities all release contaminants that are then washed into stormwater drains, soils and water tables with each successive rainfall. For example, in the U.S. each year, a total of 1.4 billion gallons of lubricating oils are used. Of that total, 600 million gallons are burned or spilled in leaks and 180 million gallons are disposed of improperly (poured onto the ground or into sewers). Furthermore, an estimated 46 per cent of all cars on the road leak hazardous fluids, including - transmission fluid, crankcase oil, hydraulic fluid, and antifreeze onto the roadways, which are then washed down storm sewers and into soils (Bein, Litman, and Johnson 1994).

Table 4 - Sources of water pollution and hydrological disruptions due to auto-related activity

Water Pollution	Hydrological Impacts
• 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)

In British Columbia, urban runoff is considered a potentially larger source of toxic contaminants than sewage discharge (BC Environment and Environment Canada 1993). In the GVRD, urban runoff accounts for 32% of all wastewater discharges into the Fraser River Estuary and Boundary Bay (Environment Canada and BC Environment 1992). Although this problem is acute and persistent, urban runoff has not been monitored and there are few regulations controlling discharges in British Columbia.

Table 5 below indicates the many constituent pollutants of road runoff and their many sources. The primary sources are directly related to various aspects of automobile operation and the infrastructure dedicated to it. The sheer scale and complexity of the problem precludes any one effective technological solution to solve it.

Atmospheric deposition of pollutants is another source of contamination (namely, hydrocarbons) to aquatic environments (UNEP 1993). These contaminants eventually find their way from water sources into the ecosystems as they are assimilated in marine life, agricultural products and drinking water (Miller 1993).

Table 5 - Summary of road runoff constituents and their primary sources

Constituents	Primary Source
Particles	pavement wear, vehicles, atmospheric deposition, highway maintenance
Nitrogen, phosphorous	atmosphere, road fertilizer
Lead	leaded gas, tire wear, lubricating oil, grease, bearing wear, road paints
Zinc	tire wear, motor oil, grease
Iron	autobody rust, steel highway structures, automobile parts
Copper	metal plating, bearing wear, engine wear, brake lining, fungicides, insecticides
Cadmium	tire wear, insecticides
Chromium	metal plating, moving engine parts, brake lining wear
Nickel	gas, diesel, lubricating oil, metal plating, bushing wear, brake linings, asphalt
Manganese	moving engine parts
Bromide	auto exhaust
Cyanide	anti-cake compound for de-icing salts
Sodium, Calcium	de-icing salts, grease
Chloride	de-icing salts
Sulphate	roadway beds, fuel, de-icing salts
Petroleum	spills, leaks, engine blow-by, antifreeze and hydraulic fluids, asphalt leachate
PCB's	pcb catalyst in synthetic tires, atmospheric deposition
Rubber	tire wear

Source: (Bein, Litman, and Johnson 1994)

Finally, the exploration and transport of oil result in significant water-related impacts.[10] For example, the exploration of oil and gas results in substantial leaking of petrochemical products and by-products from improperly sealed wells and pipelines (Miller 1993; NDRC 1997; Schwartz 1971). In addition, accidental spills resulting from the marine transport routinely dump vast amounts of oil into the sea. Between, 1972 and 1992 there were 437 significant oil spills (i.e., over one tonne) in British Columbia's Georgia Straight, mostly in ecologically sensitive areas (BC Environment and Environment Canada 1993).[11] On a global basis, nearly 2.9 million barrels are spilled into the sea every year (Lowe 1990).[12]

[10] Similar water impacts can be traced for the many other aspects of life cycle of cars from the mining of materials through to disposal. For example, mill tailings from mines leak heavy metals and acids into water and soils as does the seepage of effluents from the production of lubricants and petrochemical products used for automobile operation.
[11] The number of spills decreased dramatically after new tanker technologies, stiff penalties and improved harbour traffic management was introduced. However, the frequency of accidents increased steadily since. BC Environment (1993) suggests this may be due to increased tanker traffic.
[12] This is over 10 times the volume of the *Exxon Valdez* oil spill off the coast of Alaska in 1989.

Lowe also estimates that an additional six times this amount of oil is dumped into the oceans through the routine flushing of carrier tanks, road runoff and other petroleum by-products. Often, chemical dispersants used to break up oil spills do more harm than good (Schwartz 1971). While the chemicals themselves are harmful to marine life, the breakup of oil into tiny particles makes it easier for the oil to be assimilated.

Again, all of the pollutants of these activities enter the cycle of marine and terrestrial life impacting the entire food chain. The complexity of treating these by-products of auto use and their many residual impacts precludes effective action.

2.3.0.1 Land related impacts

The consumption of semi-rural and rural lands for urban uses is noted as a serious environmental problem in most urban areas in the world (BCALC 1996a; OECD 1995; Wackernagel and Rees 1996). This is particularly in the case in North America and Australia where low-density patterns of peripheral urban development prevail (Altshuler 1979; BCALC 1993; Durning 1996; Freund and Martin 1993; Newman and Kenworthy 1996; OECD 1995). A review of the literature indicates that impacts of urban expansion fall into three general categories:

- the consumption and loss of land used for food production and vital ecological functions;
- secondary impacts associated with the loss of non-urban land and urban encroachment; and
- the aggravation of auto-related impacts resulting from sprawling, low-density development.

Loss of lands serving agricultural and ecological functions

Urban growth is particularly problematic because many of the world's cities are located on, or in close proximity to, the earth's most fertile and ecologically productive lands such as low-lying tidal zones, river basins and the like. This is certainly the case for Canada's major urban centres. For example, the BC Lower Mainland region's agricultural productivity is the highest in Canada and twice the global average (Wackernagel and Rees 1996). Similarly, the most highly arable farmlands in Canada are situated just on the periphery of the country's major urban centres (Statistics Canada 1994). As urban encroachment consumes these lands, large portions are covered with impervious surfaces (roads, sidewalks, parking lots, buildings) while much of the rest is converted to uses such as lawns that are of marginal ecological or productive value.

Urban growth in Canada in the post-war period has been characterized for the most part by urban sprawl: new low-density development on previously rural land on the periphery of the urban envelope (IBI Group 1993; Linteau 1990). The development of the Vancouver region is an excellent case in point. The following accounting of land use trends and impacts is drawn mostly from experience in the Lower Mainland, however the trends are similar, and perhaps more acute, in other regions in Canada.

Between 1961 and 1981 the GVRD's urbanized area grew at twice the rate of population growth (see Vancouver data table in Appendix 2). Today, the GVRD stands as the lowest density major urban region in Canada (Raad and Kenworthy 1998). While the inner area population of the GVRD has remained relatively stable, most of this new growth since 1961 has been accommodated on previously rural and agricultural land. By the early 1970's, prime agricultural land in the Lower Mainland was being converted to urban uses at a rate of approximately 6000 hectares a year, mostly within the Lower Mainland of BC (BCALC 1996b).

In response to this massive loss of arable land, the Province of BC enacted the *Agricultural Land Commission Act* in 1973. The Commission created a bank of land known as the Agricultural Land Reserve and regulated the subdivision and development of agricultural lands within it. However, lands are still sub-divideable by application to the Commission requesting an 'exclusion' from the ALR.

Much land has still been lost to development from the ALR since, particularly in the Lower Mainland. Since 1974, over 15,000 hectares have been converted from the ALR to urban uses (BCALC 1996b). Countless other hectares of rural land not registered in the ALR have also been converted. Of the land 'excluded' from the ALR since its inception, it is estimated that 60-65% was rated as "prime" or "prime dominant"[13] agricultural land (Lew 1997). This loss of highly productive land from the ALR is not being replaced with similarly capable land. For example, for every 3.5 hectares of "prime" or "prime dominant" land removed from the ALR in 1994 only one hectare of land with similar agricultural capability was included in the reserve (BCALC 1997).

Estimates from elsewhere in Canada confirm similar patterns. In Ontario, over 17,000 ha was lost to non-farm uses between 1981 and 1986 alone (Harcourt 1993) and substantial losses have continued since (Swainson 1998). Manitoba continues to lose an average of 1,215 ha of farmland each year due to subdivision on Winnipeg's periphery (Manitoba Environment 1995). Overall, it estimated that that up to 60% of urban growth in Canada's major urban centres has been onto high quality farmland (Zielinski 1994).

There are many other ways in which a loss of agricultural capability affects Canadians:

- **reduced food security** (Harcourt 1993; Wackernagel and Rees 1996). In 1990, 60% of BC's food supply came from BC producers (BCALC 1993). Assuming land productivity remains the same, an increasing population and a shrinking arable land base means that BC must import increasing amounts of food to meet it's local needs. Meanwhile, BC's existing out-of-province suppliers of agricultural products are facing even more severe pressures on their agricultural land base. California, BC's largest supplier, is losing over 20,000 ha of prime farmland to urban use every year (Harcourt 1993). Such trends threaten to reduce food self-

[13] The Canadian Land Inventory classification system for agriculture rates agricultural land according to its soil quality and agricultural capability. "Prime" and "prime dominant" are the most capable, followed by "prime subordinate" and "secondary."

sufficiency and increase vulnerability to vagaries of the global food market (i.e., price and quality uncertainties);

- **higher "ecological footprint"** as a result of increased demand for imported food and commodities. Increasing imports of food requires energy for transport and distribution;
- **higher food costs;**
- **loss of farm capital investment** as land owners anticipate the sale and conversion of land for urban uses;
- **increased competition for surface and ground water resources** (BCALC 1993); and
- **reduced viability of agricultural services sector** as farms fall below a 'critical mass' (BCALC 1993).

Despite losses of land since the ALR's creation in 1974, the ALR has proven to be successful relative to other provinces and American states in providing some level of protection for agricultural land. From the high of 6000 ha in losses of arable land in the years before the ALR, and the thousands of hectares lost in exclusions from the ALR since, conversions from the land reserve have diminished in the Lower Mainland to only 15.6 ha in 1994 and 357 ha in 1995 (BCALC 1997). Although BC's ALR is beginning to stabilize and show results, few other provinces, with the exception of Quebec, have agricultural land preservation regimes as comprehensive or successful.

Notwithstanding the stabilization of agricultural stock in the Lower Mainland, pressures still exist to convert other non-urban land currently excluded from the ALR to urban uses. For example, substantial pressure has been building to develop the Burns Bog in Delta, the largest undeveloped urban landmass in Canada. Only 5% of Burns Bog is held in the Delta Nature Reserve, while most of the rest is privately owned. Proposals ranging from residential subdivisions to industrial complexes to golf courses have been brought forward for large portions of the site. This 4000 ha wetland serves many important ecological functions. It is habitat for a substantial and diverse population of flora and fauna. It is also an important stopover for migratory birds. Peatlands like Burns Bogs serve important regulatory functions in the environment. The sphagnum moss found in the bog can hold up to 30 times its weight in water (BBCS 1997), assisting in floodpeak reduction. Finally, Burns Bog and other peatlands are also important greenhouse gas sinks, providing long term storage for methane and CO_2 which contribute to global warming (BBCS 1997; Miller 1993). It is estimated that peatlands hold up to twice as much undecomposed organic carbon than forests (BBCS 1997).

Secondary impacts associated with land loss to urbanization

There are many secondary impacts associated with this loss of land and concomitant low-density development. The following is a selected inventory of some of the secondary impacts:

- ecological impacts from land coverage with impervious surfaces (i.e., roads, buildings, etc.). Alan Thein Durning estimates that just 15 percent of impervious coverage on watershed land is required to dramatically alter waterflow regimes and ecosystem balance (1996). For example, coho salmon are seldom found in streams when coverage exceeds this amount as delicate food chains are disrupted and only the most hardy plants and insects remain (Durning 1996; Miller 1993). Large portions of the GVRD are built in the Fraser River catchment area and upon wetlands in both Richmond and Delta;

- increased water consumption due to watering of large lawns (Durning 1996);
- increased energy consumption and costs for heating and cooling of low density building (Durning 1996; Newman 1991; Pagani 1997). Newman (1991) estimates that heating higher density developments can use as little as 50% of the energy for heating as dispersed housing. Wackernagel and Rees (1996) estimate that choosing medium density housing over low-density suburban housing, combined with driving a compact rather than standard-size car, can reduce a household's housing and transport "ecological footprint" by a factor of three.
- higher material and energy needs for the construction of infrastructure and buildings in low density development (Altshuler 1979; Miller 1993; Newman, 1989 #29 and 1996; Pagani 1997; Pushkarev and Zupan 1977; Wackernagel and Rees 1996). For example, road infrastructure in low-density developments is underutilized. Newman and Kenworthy (1991) estimate that up to three quarters of streets in North American cities are minor and local streets, while Cervero (1991) and Kenworthy (1986) have found that only 15-28% of travel occurs on these roads. In Ottawa, 71% of road network accommodates only 26% of vehicle kilometrage (RMOC 1994). Provision of sewers, utilities, poles, pipes and other infrastructure all have similarly high material and energy requirements per household in low density developments (Miller 1993); and
- poor recycling rates in low density areas due to high collection costs (Newman 1991).

<u>Impacts due to increased auto use and dependence</u>

Many studies have shown that car use (Durning 1996; IBI Group 1993; Newman and Kenworthy 1989a; Pushkarev and Zupan 1977) and car ownership (GVRD 1996; JPINT 1996; Newman and Kenworthy 1989a; OECD 1995; Winnipeg 1995) exhibit an inverse relationship to urban density. As density decreases and land uses become segregated, transit provision becomes less viable and invariably falls. Automobiles are then required to meet accessibility needs and private automobile ownership increases. Lower densities also force longer and more frequent trips (BTS 1990?; Lowe 1990; Newman and Kenworthy 1996; Renner 1988; Yago 1983). Therefore, the environmental, social and economic impacts associated with increased motor vehicle operation and ownership are all aggravated by falling urban densities.

2.3.0.2 Resource consumption

Meeting the resource needs for automobile production and use through the entire cycle (from resource extraction to assembly) results in substantial degradation to the environment (see Freund and Martin 1993; Greenpeace 1992; Miller 1993). Generally, the impacts include:

- degradation of landscapes and loss of ecologically productive lands due to mining;
- pollution in the process of material extraction and processing;
- energy consumption and pollution in transporting materials for manufacture;
- energy consumption and pollution in the production automobiles;
- disposal problems of spent automobiles.

Table 6 below details the breakdown of materials needed to manufacture an automobile. Many of the inputs in car production require the mining and processing of primary resources, while others depend on manufacturing processes (rubber and plastics, for example). Greenpeace (1992) estimates that 10% of plastics production of industrialized countries is attributed to automobiles production. Metal requirements in cars require substantial mining of coal, iron ore, limestone, bauxite, copper, platinum zinc and lead. In 1990, the U.S. motor vehicle industry's national share of material consumption in the nation for various inputs was: 13% of steel, 16% of aluminum, 69% of lead, 36% of iron, 36% of platinum, and 58% of natural and synthetic rubber (Freund and Martin 1993). Ores are all non-renewable resources whose stocks are finite (Goodland, Daly, and El Serafy 1992; Wackernagel and Rees 1996; WCED 1987) and the known reserves of many of these are expected to be depleted within 25 to 100 years current rates of consumption (Freund and Martin 1993; Jacobs 1991).

Table 6 - Composition of the average automobile (1990)

Material	Weight (kg)	Weight (% of vehicle)
Low carbon steel	530	46.3
Alloy steel	91	7.9
Cast iron	91	7.9
Aluminum	136	11.9
Copper, brass	6	0.6
Zinc	4	0.3
Lead	8	0.7
Other metals	16	1.4
Rubber	58	5.0
Glass	32	2.8
Plastics	105	9.2
Other non-metals	68	6.0
Totals	1145	100

Source: (Greenpeace 1992). From Henstock, 1988. Design for Recyclability. Institute of Metals: London.

Furthermore, the mining, processing and refining of ore resources necessary for automobile production generate substantial environmental impacts. Abandoned mines not decommissioned properly can also leave a legacy of environmental problems for areas far removed from the source, well into the future (Manitoba Environment 1995). Table 7 below highlights some of the potential impacts of mining activities. With Canadian production of automobiles typically 15% of U.S. production levels (see Renner 1988), per capita consumption of natural resources devoted to automobile production is even higher in Canada than the United States.[14]

[14] This estimate assumes car inputs and Canadian fleet production require the same average inputs as in the U.S.. Using estimated 1995 population of 263,437,000 (U.S.) and 28,537,000 (Canada), Canada's population is roughly 11% that of the U.S.

The automobile manufacturing process follows the materials extraction process with substantial pollution and energy consumption of its own (Miller 1993; Moriguchi, Kondo, and Shimizu 1993). The US EPA estimates that transportation manufacturing is the fourth largest source of toxic chemical releases into the environment in the USA (in UNEP 1993).[15] From materials extraction, to material transport, to manufacture, to the showroom, the automobile acquires much 'embodied' energy. The OECD (1995) estimates that one quarter of the energy consumption in the life cycle of a car occurs before it leaves the showroom.

Table 7 - Environmental impacts of minerals extraction

Activity	Potential Impacts
Excavation and Ore Removal	• destruction of plant and animal habitat, human settlements and other surface features (open pit) • land subsidence (underground) • increased erosion • waste generation (overburden) • changes in river regime and ecology due to siltation and flow modification • acid drainage and heavy metals contamination of lakes, streams and groundwater
Ore Concentration	• waste generation (tailings) • organic chemical contamination from tailings • acid drainage
Smelting/Refining	• air pollution (including sulfur dioxide, arsenic, lead, cadmium and other toxic substances) • waste generation (slag) • impacts related to producing energy for smelter operation (depends on power source)
Mine Abandonment	• abandoned equipment, plant and buildings • release of methane from mine • leaching of pollutants

Source: (UNEP 1993; Young 1992)

The actual use of automobiles is the next stage in the life cycle where considerable resources are consumed and concomitant environmental impacts are experienced. The provision of infrastructure, such as roads and parking, to service the automobile requires the mining of gravel (to produce concrete), the production of asphalt (which requires oil), the manufacture of construction vehicles (with similar impacts as noted above for cars) and the consumption of non-renewable energy. All of these are material and energy intensive as well as polluting. Gordon (1991) estimated that one-third of all transportation energy

[15] This estimate does not include toxic chemicals released from other industries that supply the auto-manufacturing complex and for servicing auto use (e.g., machinery, plastics, petroleum, metals, chemicals, electrical, etc.).

(or 14% of all energy) in the US is consumed in these ancillary activities. Table 8 below demonstrates the relative energy intensity of various transportation-related activities.

Table 8 - Energy use of transportation related activities in the U.S., 1985

Activity	Energy (Quads)
Automobile use[a]	8.8
Light truck/van	4.1
Infrastructure repair	1.7
Infrastructure construction	4.8
Producing, refining and distributing fuel	3.4
Transit bus use[a]	0.07

Source: (Gordon 1991)
Note: a. 1987 data

Of course, the use of internal combustion engines for transport also necessitates direct consumption of fossil fuels. This is perhaps the most recognized resource consumed by transportation activities. Transportation is 97% dependent on petroleum as its source of energy (Gordon 1991). In Canada, 68% of all transportation energy used is gasoline, primarily for the operation of private vehicles (Gordon 1991).[16] In all OECD countries, petroleum consumption is rising by an average of 1.5% annually (OECD 1995).

While there are important implications of fuel consumption in terms of pollution (see section 2.3.0.4 below), there are other significant implications in terms of resource scarcity and geo-political and economic instability (Fleay 1995). Oil and gas are fossil fuels and, as a result, cannot be regenerated within a human-time scale. They are therefore considered finite, non-renewable resources. While the finite-nature of oil resources is not contested, the relevant supply is (The Economist 1997). Over the past few decades, the reserve supply of oil has been constantly revised upward to account for new discoveries. However, much research has pointed to a sharp decline in the frequency, size and economical viability of new oil discoveries. Fleay (1995) estimates that at current rates of exploitation, reserves of oil will be depleted within 50 years. While it has been argued that new discoveries may continue to extend this depletion deadline (The Economist 1997), these resources nonetheless almost certainly face exhaustion in the foreseeable future at current consumption rates.

Continued dependency on oil brings economic and geo-political uncertainty. Most OECD countries are currently net importers of oil and therefore various sources are not secure. In recent years, this uncertainty has resulted in economic instability (Kenworthy et al. 1997) as well as wars (Greenpeace 1992). Fleay (1995) and Hart and Spivak (1993) argue that the real concern in the medium term is not

[16] Private vehicles primarily use gasoline. Diesel and LPG fuel is primarily used for commercial transport (trucks, buses, trains, taxis and ferries). Therefore, gasoline consumption can almost entirely be attributed to private vehicle

that all oil stocks will be depleted, but that the surplus extractive capacity will disappear.[17] When the 'consumption' curve meets the 'supply' curve (expected within 25 years), oil-consuming nations will be 'captive' markets. The perpetuation of geo-political and economic uncertainty is likely to be aggravated as this production surplus is depleted and dependence on imported oil increases.

Comparative evaluations of various transportation modes demonstrate the high resource intensity of automobile production and use. Pendakur, Badami and Lin (1995) describe costs and benefits of non-motorized travel in terms of "bicycle equivalents." They show that the single occupant vehicle has 48 times the material requirements, 20 times the space requirements and 60 times the energy consumption[18] of the bicycle or bicyclist on a per unit basis. The much higher use and weight loads of automobiles on roadways have considerable implications in terms of secondary materials and energy consumption.

Whitelegg (1993) also shows that the SOV has inordinately high space requirements. Whitelegg estimates pedestrian, cyclist, rail transit and SOV space requirements at 0.8, 3, 1.5-4.6 and 60 M^2 per person, respectively. While per unit resource costs are extremely high for automobiles, their disproportionate share of use in absolute terms makes these figures even more concerning. Clearly, motorized transportation requires the consumption of substantial resources for the manufacture and servicing of the automobile.

2.3.0.3 Vehicle disposal

The disposal of vehicles and vehicle parts has substantial environmental impacts. These impacts include space consumed for dumps, toxic leachates from automobile parts and residual fluids, and impacts due to accidents. Automobile dumping represents a serious problem globally (Ginley 1994; Greenpeace 1992). Currently, in the United States, approximately 10 million cars are retired every year. Of this amount, approximately 71% of an automobile's gross vehicle weight is recycled (AAMA 1997).[19] This translates into the rough equivalent of 3 million cars, by gross vehicle weight, still being disposed of in landfills annually. In places such as British Columbia, where per capita vehicle ownership approaches U.S. levels (Raad and Kenworthy 1998) and where 60% of the province's landfills will reach capacity by 2000 (BC Environment and Environment Canada 1993), such waste is of serious concern.

Environmental pollutants resulting from vehicle and vehicle component disposal are also a problem. Leachates from metals, batteries and plastics (Beaumont 1993; Greenpeace 1992) elevate concentrations of lead, zinc, cadmium and other heavy metals and toxins. The disposal of tires also

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use. In 1986, this consumption amounted to more than 28 billion litres of gasoline out of 42 billion litres of petroleum.

[17] They examine the famed "Hubbert Curve" which traces oil discovery and production levels since the early 1900s. The Hubbert Curve indicates oil discoveries have peaked and that we are now in an era of declining reserves.

[18] Furthermore, the energy consumed by the bicyclist is human energy and therefore non-polluting.

results in toxic leachates entering the soil and water as well as the threat of potentially toxic emissions from tire fires. These all pose a threat to local human and ecosystem health. Day *et al* (1993) show that leachates from tires can be lethally toxic to aquatic biota.[20] Tire stockpile fires emit a large amount of semi-volatile organic compounds as well as zinc and lead (Lemieux and Ryan 1993). In 1990, a dump of 14 million tires in Hagersville, Ontario burned for over two weeks resulting in the release of high levels of toxic organic contaminants to the air, soil and water runoff (Environment Canada 1991; Steer et al. 1995)[21].

Some argue that recycling automobile parts "saves energy and conserves resources" (AAMA 1997).[22] While this may be true from a limited perspective, it is not true from a more holistic one. First, the recycling of automobile componentry (namely, metals) involves yet further energy intensive and polluting processes to reintroduce them for commercial uses. Second, substantial amounts of virgin material are still required in addition to the recycled material to make complete products. Third, many recycled materials are only suitable for lower-grade uses and repeated recycling can undermine the structural integrity of certain metals.

Finally, in the same way that pollution abatement technologies and improvements in vehicle efficiency can be overcome by growth in VKT (Freund and Martin 1993; Hart and Spivak 1993; Lowe 1990; Renner 1988), gains from the more efficient utilization of resources can be overwhelmed by increasing growth in auto sizes and ownership levels. For example, since the early 1990s, the trends in new vehicle ownership have tended towards larger vehicles such as small trucks and sport utility vehicles (Gordon 1991; Renner 1988), which require greater resources in production and use. If developing nations were to develop an appetite for automobile similar to levels found in Canada, any gains from efficiency would quickly be overwhelmed by total increase in material demand for new cars. For example, in 1990, China's had about 1.6 million buses and cars available for passenger use, or about two vehicles for every 1000 people (Hook 1998). If car ownership were to rise to Canadian levels, China's vehicle fleet would grow by over *six hundred million* vehicles, roughly equivalent to the entire current global car fleet.

Although the recycling of vehicles and the more efficient use of resources is desirable, they offer no panacea for the impacts incurred in through production, use and disposal. In order to truly realize the efficiency benefits that recycling offers (i.e., lower consumption of energy and resources), efficiency

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[19] 75% of the average vehicle is recovered, however 5% of total retired vehicles are not recycled at all.
[20] Used tires demonstrated the highest levels of toxicity.
[21] Over 12.6 million tires were consumed and there was substantial ground and surface water contamination (Environment Canada 1991).
[22] *Our Common Future* (WCED 1987) also calls for increases in efficiency as a means of achieving "sustainability."

savings must be "captured" (Wackernagel and Rees 1996) through stabilized or reduced car ownership levels. Says Jane Jacobs of the squandered efficiencies offered by cars:

> *"Automobiles are hardly the inherent destroyer of cities...[they were] potentially an excellent instrument for abetting city intensity, and at the same time for liberating cities from one of [the horse-and-buggy's] noxious liabilities...We went awry by replacing, in effect, each horse on the crowded city streets with half a dozen or so mechanized vehicles, instead of using each mechanized vehicle to replace half a dozen horses"* (1961, 343).

2.3.0.4 Airborne vehicular pollutants and emissions

The operation of vehicles results in vehicular emissions that harm the environment in many ways both at the local and global levels. Some pollutants are directly due to the internal combustion process, others are due to other aspects of vehicle operation (such as air conditioner operation) and others are the result of the reactions between vehicle emissions in the atmosphere.

Emissions and pollutants that result from vehicle use that are of local concern[23] include particulates (PM10, PM 2.5), sulfur dioxide (SO_2), carbon monoxide (CO), oxides of nitrogen (NO_x), volatile organic compounds (VOCs) (also known as hydrocarbons, or HCs), tropospheric (ground level) ozone, total suspended particulates (TSPs) and lead (though lead is no longer a major auto tailpipe pollutant in North America). Local scale air pollutants have implications for air, water and soil pollution and, therefore, human and ecosystem health (French 1990).

Emissions of global significance are greenhouse gases (GHGs) which include carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and chlorofluorocarbons (CFCs), all of which contribute to global warming (BC Environment 1995b; IPPC 1990). In addition to being a GHG, CFCs also contribute to ozone depletion (Bovard-Concord and ARA 1994; Vancouver 1990). Automobile air conditioners are the largest single source of CFCs in British Columbia (BC Environment 1995a) and account for 23% of all CFC releases in Canada (Environment Canada 1993).

Table 9 below shows the proportion of selected emissions in the GVRD that are attributable to mobile sources,[24] with a breakdown of the road motor vehicle share. Over 76% of total emissions in the GVRD come from private vehicles alone. Similar shares of motor vehicle pollution levels can be found in other North American and OECD cities (Gordon 1991; OECD 1995). Table 10 below outlines the causes of various vehicular emissions, their environmental and health implications, and the spatial scale at which the implications are experienced[25]. Most of the pollutants result from the internal combustion

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[23] Some local pollutants also have global significance. For example, ground-level ozone (formed by the reaction of NMHCs and oxides of nitrogen) also aggravates, and is aggravated by, global warming.
[24] All transportation including motor vehicles, trains, aircraft, marine vessels, off-road equipment.
[25] Health implications will be discussed in subsequent sections.

process. The environmental implications of these are well documented in the literature. They include smog, acid rain, ozone depletion and the enhanced greenhouse effect and many associated secondary impacts.

Table 9 - Emissions from transportation in the GVRD (% of total, 1991)

Transportation Source	Contaminant Emissions NO_x	VOC	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)

Many of the impacts confound one another and preclude, or are aggravated by, technical fixes (Gordon 1991; Lowe 1990; Schwartz 1971). While technologies serve to reduce certain emissions, the primary determinant of absolute motor vehicle pollution levels in a city is the amount of vehicle kilometers travelled (Gordon 1991; Newman and Kenworthy 1988a). Newman and Kenworthy (1988a) show that those cities with the freest flowing traffic actually have the highest gasoline consumption. Ironically, Many of these cities also have some of the strictest emissions standards in the world. The higher fuel consumption and emission levels result from longer and more frequent trips as well as induced traffic effects, which far outstrip any gains from increased fuel efficiency or temporary congestion relief.

Just as previous gains in efficiency were squandered by VKT increases in the 1970s and 1980s, so too will future advances. ORTEE (ORTEE 1992) estimates that despite improvements in vehicular fuel efficiencies, transportation emissions of SO_2, PM, and CO_2 are all expected to rise 60, 50 and 29 percent, respectively between 1988 and 2005 in Ontario. While NOx, CO and VOC are all expected to decline between 1988 and 2000, they are expected to begin rising again after 2000.

Table 10 - Air pollution and emissions from urban transportation

Emission/ Pollutant	Cause/ source	Environmental Impact	Health Impact	Spatial Scale of Impact
Nitrogen Oxides (namely NO_2)	Internal combustion process; malfunctioning catalytic converters; up to 80% from motor vehicles	• ozone precursor; reacts with nonmethane HCs 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
Carbon Monoxide (CO)	Internal combustion process; over 90% from vehicles in GVRD	• may contribute to global warming at 2.2 times the rate of CO_2 through tropospheric reactions • increases methane (a powerful GHG) levels	• exacerbates heart disease; causes drowsiness; compromises brain function; threatens fetal development	Local Regional Global
Sulfur Dioxide (SO_2)/Acid Rain[a]	Internal combustion process	• acid rain precursor; reacts with NO_x & leads to acid rain; changes soil and water chemistry • increases solubility of heavy metals in waters • harms vegetation and aquatic biota; enters food chain; damages buildings	• sulfate particles are carriers for toxic metals and gases; responsible for 2% of annual mortality in US • contaminates drinking water • respiratory ailments	Local Regional
Hydrocarbons (HCs)	Internal combustion (incomplete); fuel vapors; up to 50% from vehicles	• ozone precursor (see tropospheric ozone below)	• drowsiness, eye irritation and coughing	Local
Total Suspended Particulates (TSP)	Incomplete combustion; diesel; road dust	• reduces visibility	• contributes to human morbidity and mortality; lung damage	Local
Tropospheric Ozone (smog)[a]	Reactions of HCs and NO_x in sunlight	• inhibits photosynthesis; loss of agricultural productivity; crop damage • contributes to global warming	• temporary breathing difficulty; long-term lung damage; reduced immunity • young, old and those with respiratory ailments especially susceptible	Local Regional Global
Lead	Internal combustion w/ leaded gas; fuel additives	• enters soils, water and plants; leads to toxicity throughout the food chain	• extremely toxic; impairs nervous system mental development	Local (where gas is leaded)
Carbon Dioxide (CO_2)	Internal combustion process; cars and 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 warming; potential of increased disease	Global
CFCs	Operation and leaking of car air conditioners	• stratospheric ozone depletion; increases ultraviolet radiation; inhibits photosynthesis • global warming (see CO_2)	• skin cancers; represses immune system	Global
Nitrous Oxides (N_2O)	Internal combustion process; aging catalysts	• global warming: contributes 270 GWP of CO_2 • 70% of N_20 in GVRD is from vehicles	• see CO_2 above	Global

Sources: Flavin and Tunali 1996, GVRD 1994, EC 1994, UNEP 1993, EC 1992, Greenpeace 1992, City of Vancouver 1990, French 1990 and Prakash 1990
Note: Acid rain and smog are both formed as a result of reactions between other pollutants in the atmosphere.

2.3.0.5 Other environmental impacts

There are several other significant environmental impacts associated with automobile dependence that warrant mention. These include:

- **heritage and architectural and loss and damage.** Buildings, monuments and heritage sites incur substantial structural and surface damage due to pollution and vibration (Gratz 1993; Miller 1993; Newman, Kenworthy, and Vintilla 1995).
- **noise pollution.** Road traffic is regarded as the most common source of unwanted noise (Morton-Williams *et al.* 1978 in OECD 1995). The Canada Mortgage and Housing Corporation (CMHC) maximum acceptable outdoor noise level is 55 decibels.[26] However, traffic noise in medium and large cities routinely exceeds this level (OECD 1995). The effects of noise are for the most part subjective (Miller 1993). Noise results in a loss of environmental amenity and psychological well-being. This, in turn, can result in health, sleep and productivity losses. Excessive transportation noise is cited as a major factor in the decision not to walk to a destination (Energy Probe 1989). Traffic noise can is also a major disturbance to wildlife. Reijnen *et al.* (1997) indicate that traffic noise is the most critical factor in reduced wildlife densities and bird breeding in broad zones adjacent to busy roads. Substantial reductions in engine and transmission noise emissions are unlikely to significantly mitigate total noise due to increasing vehicle volumes, increased stop-starts and because a considerable portion of the noise attributable to driving is due to tire contact with the road surface (OECD 1995).
- **wildlife deaths.** Every year in North America alone, millions of large mammals and countless lower order species are killed by motor vehicle collisions. The 1991 U.S. "road-kill" total just for deer is conservatively estimated at half a million (Romin and Bissonette 1996).
- **habitat disruptions and loss due to roads.** Disruptions to wildlife habitat are substantial. For example, large carnivores are often 'keystone' species on which ecosystem balance depends. However, roads are a major threat to carnivores, particular endangered species in recovery, because of road barrier effects, vehicle collisions and increased accessibility to poachers (Noss et al. 1996). Fragmentation of habitat threatens many species that depend on a large range. Reed *et al.* (1996) examined fragmentation in over 30,000 ha of Rocky Mountain habitat and found that fragmentation from roads was 1.5-2 times worse than forest clearcuts in terms of converting interior habitat into edge habitat. As mention in sectioned 2.3.0.1 above, road construction and urbanization also result in substantial wetland loss and disruption. Wetlands play vital ecological roles in terms of diverse species habitat, shoreline stabilization, groundwater recharge, food/nutrient production, and toxin/pathogen retention (De Santo and Flieger 1995).

2.3.1 Social Impacts of Auto Dependence

2.3.1.0 Health

Auto dependence impacts the human health through: fatalities and injuries attributable to collisions involving motor vehicle; increased sickness and death due to pollution; and a more sedentary lifestyle which results in increased risks of illness and a loss of productivity.

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[26] See Barron Kennedy Lyzun & Associates. 1991. LRT SYSTEM NOISE STUDY: Sound Level Measurements Made along the Existing SkyTrain Guideway. Prepared for BC Transit: October 21, 1991.

Injuries and deaths resulting from motor vehicles are so commonplace that their magnitude is often forgotten. In Ontario, over 1,200 people are killed and 120,000 are injured annually in collisions involving motor vehicles (Zielinski 1994). In British Columbia, the statistics are equally grave. In 1995, 493 people were killed and 47,472 were injured (ICBC 1997). While total collisions have been in decline in British Columbia in recent years, pedestrian and cyclist collisions with motor vehicles have been on the rise.

OECD (1995) indicates that although many countries with high traffic volumes have low fatalities when expressed in terms of deaths per vehicle kilometre, pedestrian traffic fatalities per capita are lower in countries with less vehicle travel.[27] Furthermore, they indicate that while cyclists are 9 times more likely to be killed than a car driver, car drivers are 13 times more likely to be involved with a traffic fatality.[28] Therefore, rather than encourage modes that pose the largest threat to the general public, policy should focus on encouraging modes that pose the least threat to other road users (Hillman 1992 in OECD 1995). These less threatening modes include cycling and walking.

Air pollution is another source of morbidity and mortality related to auto use. Table 10 above highlights some of the health impacts associated with various pollutants. The health impacts range from direct illness and death from pollutants to lowered immunity, which results in *indirect* illness and death. The old, young and those with pre-existing medical conditions are particularly vulnerable. There has been extensive research establishing a strong causal link between air quality and health. For example, Delfino *et al* (1994) found a positive relationship between photochemical smog levels and hospital admissions for respiratory illnesses. A broader based study of 16 Canadian cities by Burnett *et al* (Burnett et al. 1997) found a similarly strong positive relationship with photochemical smog and respiratory hospitalizations as well as between particulate matter and CO concentrations and hospitalization. Proximity to traffic and therefore exposure to higher levels of ground-level pollutants can result in chronic respiratory ailments (van Vliet et al. 1997).

Finally, transportation-induced stress can have significant impacts on the health, quality of life and employment productivity of an individual. Raymond Novaco, a psychologist at the University of Californ ia, has done the most extensive research in this area (for example, see Novaco 1989; Novaco 1992; Stokols and Novaco 1981). Novaco's work focuses on measuring the dimensions of physical travel impedance.[29] High levels of impedance are associated with high blood pressure, low tolerance for

[27] This applies to developed (OECD) countries. Litman (1997b) also reports that accident rates and fatality risk highly correlate to distance travelled.
[28] This indicates that although a motorist may be less likely to die from an accident, they are more likely to cause a fatality.
[29] Physical impedance measures the distance and time spent on a journey, as well as the number of roads and freeways travelled on a trip.

frustration, family tensions, negative moods and illness. The symptoms are especially acute in women. Many of the effects on health and wellbeing are realized over time and repeated exposure to high levels of physical impedance reinforce and aggravate them. Furthermore, these impacts spill over to employers and are manifest in illness-related absence from work, high employee turnover and reduced productivity and morale.

2.3.1.1 Equity

Transportation infrastructure planning and funding in Canada favours automobiles disproportionately over transit and non-motorized modes. Few transportation users, with the exception of pedestrians and cyclists, actually pay an amount close to the full cost of their transportation choice.[30] This results in an inequitable distribution of transportation costs and benefits between users. In most developed cities, automobile users generally receive the highest subsidies of any transportation system user. A heavy bias towards subsidized automobile travel for leads to 'irrational' consumer choices and an aggravation of auto dependence. The lack of funding for viable alternatives means that those unable to afford automobiles enjoy lower levels of accessibility to services and economic opportunities (Altshuler 1979; Litman 1997c; Yago 1983). In some cities (such as Detroit and Houston), this bias altogether eliminates transportation choice, effectively forcing the use of cars despite affordability (Newman and Kenworthy 1989). In these situations, the users least able to afford transportation services or are forced to spend higher proportions of their disposable income to meet their basic access needs.

The imbalance between subsidies for automobiles, transit and non-motorized transportation is well documented and quantified in the literature (Altshuler 1979; Delucchi 1996; Kenworthy et al. 1997; Litman 1995; Litman 1998a; MacKenzie, Dower, and Chen 1992; Miller 1993; Yago 1983).[31] Todd Litman (1997c), has done perhaps the clearest work in the area of defining transportation costs as well as their distribution and equity implications. Litman identifies three types of equity well known to economists as being relevant to transportation:

1. **Horizontal Equity** – equity between individuals who have comparable wealth and ability to pay.
2. **Vertical Equity with Regard to Income and Social Class** – focusses on the allocation of costs between different income and social classes.
3. **Vertical Equity with Regard to Mobility Need and Ability** – focusses on whether an individual is relatively transportation disadvantaged.

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[30] Transportation decision involve two broad categories of costs: internal (those imposed and paid for directly by the individual) and external (those imposed by the individual, but paid for by society at-large). These will be discussed at length in section 2.3.2.

[31] This section is primarily concerned with the *distribution* of transportation costs and benefits. The actual economic costs and benefits of various modes will be discussed in section 2.3.2.

Horizontal inequities result between users of the same mode as well as between users of different modes, regardless of income. In the case of auto use, many costs are fixed and shared amongst users, regardless of distance travelled or size of the vehicle. Those who drive less or drive smaller vehicles, for example, effectively "cross-subsidize" those who drive more. The same phenomenon occurs with transit systems that have fixed or semi-fixed fare structures.[32] Suburban bus riders who make longer trips on buses with relatively low loads are effectively cross subsidized by urban riders on denser routes paying the same fare. Recent attempts at fare reform in Vancouver have alleviated these inequity to a certain extent (Bohn 1997), however suburban and longer-distance travellers still underpay.

The more substantial horizontal inequities lie in the degree to which the various modes are subsidized *vis a vis* one another. For example, cyclists and pedestrians pay almost all of the costs of their transportation out-of-pocket. Meanwhile, all of the motorized modes have 'external' costs not paid for by the user, but shared by society at-large (Bohn 1997; Litman 1998a; MacKenzie, Dower, and Chen 1992; Peat Marwick Stevenson & Kellogg 1993). Litman (1995) notes that while the average cyclist tends to *overpay* for transportation infrastructure, motorists in similar socioeconomic circumstances will tend to *underpay*. The GVRD estimates that motorists received $2.7 billion in subsidies[33] in 1991, while transit received $360 million and non-motorized transportation received just $2 million (see Table 11 below). Furthermore, the report estimates that cars accounted for 76, 87, 96, 98 and 99 percent of time, social, infrastructure, sprawl and parking costs, respectively. In terms of horizontal equity, motorists, transit users and pedestrians and cyclists of similar socioeconomic standing all impose different degrees of external costs.

Table 11 - Subsidies to transport in th e BC Lower Mainland, 1991

	Total Subsidy (millions)	Subsidy per capita	Subsidy per pass. km	Subsidy % of total cost
Automobile	$2,654	$1,507.00	$0.15	23%
Transit	$360	$204.00	$0.24	37%
Non-motorized	$2	$1.13	--	8%

Source: Adapted from (Peat Marwick Stevenson & Kellogg 1993)

While the imbalances in the allocation of subsidies between modes leads to horizontal equity, they also lead to **vertical inequities with respect to income and class**. Non-drivers tend to earn less money and therefore spend a higher proportion of their disposable income on transportation (Altshuler

[32] Some exceptions are made on some transit systems for "youth" and "seniors" fares.
[33] Many external costs attributable to automobile use and ownership are not included in this estimate. Despite this, automobile transportation accounts for 85% of all non-operating costs for transport in the GVRD.

1979; Blumenberg and Ong 1997; Haines 1978; Schrecker 1996; Yago 1983). Typically those who earn less and have minimal access to a car (the transit and non-motorized "captive," including the young, disabled, elderly, poor and women) are most greatly impacted (CUTA 1991). In this way, the distribution of transportation costs is quite regressive. Not only do cyclists, pedestrians and transit users pay a disproportionate share of costs, they pay even more as a portion of their income.

Table 12 - Auto ownership in Ontario, by household income, 1993

Household Income Range	Automobiles % Owning One	% Owning Two +
Under $10,000	39.6	7.0
$10,000-14,999	40.8	5.0
$15,000-19,999	55.1	6.3
$20,000-24,999	63.2	9.1
$25,000-29,999	61.9	13.7
$30,000-34,999	60.9	15.7
$35,000-44,999	63.0	21.0
$70,000 & over	46.2	46.9

Source: (RMOC 1995)

While auto operating costs have increased 12.2% between 1990 and 1995, transit fares have risen over 34.5% (Pucher 1998). This persistent underpricing of auto use also leads to longer term changes in urban structure that preclude other transport options and exacerbate auto dependence (Newman and Kenworthy 1989a). With transit and non-motorized modes not viable or unavailable, many households effectively *require* an automobile to access basic services and economic opportunities. The Regional Municipality of Ottawa-Carleton (1995) estimates motor vehicle operating costs at approximately $3,000 (excluding capital costs and depreciation) per household per year. Table 12 above shows that automobile ownership is still very high amongst lower income households. Obviously, auto ownership for these households is a considerable financial hardship.

Vertical inequities extend beyond hard financial costs. One way this is manifest is in the disproportionate cost of environmental impacts borne by those on lower incomes. Urban property values are generally inversely related to air quality, noise and traffic volumes (Schrecker 1996), therefore those who drive less (and make less) are also more likely to be subjected to higher levels of these external costs.

Impacts are also disproportionately distributed through systemic biases towards motorists (generally, higher income earners) in transportation system design. For example, Coffin and Morall (1995) attribute substantial difficulties for the elderly in crossing roads in Calgary to poorly designed crosswalks, insufficient crossing times on signals and the barrier effects of traffic. Also, transit system scheduling provides the highest level of service for peak period CBD inbound and outbound trips. This favours commuters who tend to have higher incomes and secure employment. Meanwhile, lower income individuals (who have lower labour force participation rates), the disabled and the elderly, whose trips are generally non-CBD focussed, all tend experience less convenient and less frequent transit services (Altshuler 1979).

Finally, **vertical inequities with regard to mobility need** result because those marginalized by exclusive transportation planning have difficulty accessing the employment, services and social opportunities necessary to live productive lives. Those most typically affected include the young, poor, disabled, elderly and women, who all have low car ownership rates (Altshuler 1979; Calgary 1994a; Engwicht 1993; Schrecker 1996; Yago 1983). These groups have been called the transport disadvantaged (Litman 1997c), the transport deprived (Altshuler 1979) and the access-to-exchange disadvantaged (Engwicht 1993). Women are especially disadvantaged with respect to access and mobility (Mensah 1995; Schrecker 1996). Schrecker indicates that women, particularly single mothers, have particularly demanding transport needs between child-care responsibilities and employment, however, they are especially likely to be transit captive. Altshuler (1979) asserts that transport deprivation is a cause of unemployment and poverty since securing affordable housing often means locating in areas with low access to services and economic opportunity. Recent research from highly auto-dependent regions in the U.S. has found that welfare recipients are confined to labour market areas that are one quarter the size of labour-market areas available to the general population due to poor housing location, poor transit service and low car ownership (Blumenberg and Ong 1997). Philp (1997) reports that the lack of access to, and affordability of, public transit in Toronto increases the hardships imposed on the homeless and actually aggravates homelessness itself. The homeless in Toronto spend two hours a day walking in order to secure basic shelter and food, with foot problems being a critical health issue. Furthermore, the large portion of time spent securing basic needs and the lack of access to transit means that there is simply not the time or ability to access the more advanced health and social services necessary to make a permanent move from the streets.

2.3.1.2 Decaying urban fabric

> *"Traffic arteries, along with parking lots, gas stations and drive-ins, are powerful and insistent instruments of city destruction. To accommodate them, city streets are broken down into looses sprawls, incoherent and vacuous for anyone afoot. Downtowns and other neighbourhoods that are marvels of close-grained intricacy and compact mutual support are casually disembowelled...City character is blurred until every place becomes more like every other place, all adding up to Noplace"* (Jacobs 1961 p.338).

Domination of traffic and spaces given over to the car for roads and parking reduces the quality and amount of space dedicated as 'public realm' for human exchange and interaction (Appleyard 1981; Engwicht 1993; Kunstler 1993; Newman, Kenworthy, and Vintilla 1995; Yago 1983).

The evisceration of neighbourhoods by freeways and major road projects to service car use has been most acute in the United States, where inner cities were blighted by a retreat to the suburbs (Leavitt 1970). However, neighbourhoods in several Canadian cities such as Montreal, Ottawa, Toronto and Calgary have also experienced similar damage accompanying major road projects. These projects usually cut through poorer neighbourhoods and bring visual intrusion, pollution, noise and unsafe streets (Appleyard 1981; Engwicht 1993).

In Canada, the high costs of freeway projects brought major protest movements in most Canadian cities in the 1960s and 1970s. For example, communities mobilized against the Spadina Expressway in Toronto and the Strathcona Freeway in Vancouver, preventing their construction (Newbury 1989; Nowlan and Nowlan 1970; Pendakur 1972). Few central city freeway projects have been completed in Canada since. However, major road expansions still routinely occur within central cities in Canada, as do major freeway projects on the urban periphery. The expansion of Pacific Boulevard in central city Vancouver and the construction of Highway 407 on the outskirts of Toronto are examples.

The amount of urban space and the intensity of auto traffic on roads reduces the amount of social space available in a city and constrains what David Engwicht calls "access to exchange" opportunities (Engwicht 1993). Wide streets and ample parking lots consumes land that could otherwise be used for socially productive purposes. Not only do cars consume "exchange" space, they have a "zone of influence" that increases with the speed and volume of traffic, reducing the effectiveness of the exchange space that remains (Engwicht 1993). In Donald Appleyard's studies of traffic on residential streets, he found a strong inverse relationship between traffic volumes and the amount of social interactions on the street, particularly amongst the young and the elderly (Appleyard 1981). Essentially, higher volumes of traffic on the street forced a continuing rollback in residents' perception of their home territory range, thereby reducing social exchange.

2.3.1.3 Isolation

Many authors have commented on the impact of segregated land uses on the isolation and alienation for those who lack the mobility that the automobile offers (Jacobs 1961; Newman and Kenworthy 1989a; Whitelegg 1993; Yago 1983). As previously mentioned, those who are transportation disadvantaged are relatively immobile and are only able to access services and social opportunities within walking distance. Within many suburban subdivisions this leaves little opportunity for human interaction within the community. Furthermore, large amounts of time spent commuting means fewer opportunities for social exchange within families (Whitelegg 1993).

Fear of crime and assault is another concern associated with transportation, particularly for women. Walking to, and waiting at, public transportation stops is a major concern where public visibility is low. Low density and isolated developments ensure wait and walk times are long, thereby increasing perceived vulnerability. Rosenbloom and Burns (Rosenbloom and Burns 1994) show that safety is a major influencing factor in womens' decisions to drive alone rather than take transit.

2.3.1.4 Dysfunctional social behaviors

One emerging social concern that has received only cursory academic attention is the relationship between anger and aggression and their relationship to driving. As congestion increases, so too does driver frustration (Novaco 1991). One manifestation of this frustration is a phenomenon called "road rage" – behaviours ranging from vehicle obstruction, to obscene gestures, to physical assault. Of course, the latter is of greatest concern. One survey in the UK found that 90% of drivers had experienced road rage incidents, while 1% of drivers claim to have been physically assaulted by other motorists (Joint 1995). Many of the assaultive behaviours exhibited with road rage are traceable to "disinhibitory" factors unique to driving an automobile (Novaco 1991). These include mass media imagery popularizing automobile machismo, the anonymity of highways, the protection offered by cars and the opportunity to escape quickly. Novaco indicates that, combined with these aggression disinhibitors, higher blood pressure, increases in negative moods and lower tolerance for frustration, all conspire to trigger driver aggression (Novaco 1990; Novaco 1991).

2.3.2 Economic Impacts of Auto Dependence

Typically, individuals are only aware of a limited range of the costs of driving such as vehicle price, fuel, repairs, insurance, registration and parking. For example, the Canadian Automobile Association estimates the annual out-of-pocket cost of owning and operating the average vehicle in Canada to be over $7,300 annually (CAA 1997). However, there are many more monetary and nonmonetary costs borne both by drivers themselves and by society at-large. Furthermore, many of the costs that are borne directly by motorists are not perceived as immediate and therefore do not influence the decision to drive (Litman 1998a).

This failure to account for the full cost of transportation, as well as the lack of clarity and efficiency in transportation pricing, means that the magnitude of the costs of driving is underestimated. This skews transportation decision-making. On one hand 'irrational' decisions are made regarding individual transportation choice. On the other hand, public policy is misdirected. Unless the full cost dimensions of automobile ownership and use are recognized and incorporated into decision-making processes at the individual and societal levels, the problems of auto dependence cannot be fully addressed.

The monetary costs of auto use include those paid for out of pocket by drivers (such as fuel, repairs, insurance and fees) as well as those financed by society (such as road construction and maintenance, parking, congestion and highway services). However, there are also a wide range of costs that have distinct "economic" dimensions that are not typically ascribed dollar values. These include many of the social and environmental costs described in some detail in the preceding sections.

Many authors have attempted to comprehensively quantify the full range of financial, social and environmental costs of transportation (Delucchi 1996; IBI Group 1995; Litman 1995; MacKenzie, Dower, and Chen 1992; Miller 1993; Peat Marwick Stevenson & Kellogg 1993). Also, much work has also been done examining the costs on a sectoral basis (e.g., congestion, agriculture, accident loss, sprawl, air pollution and the like), though they are too many to enumerate here. Although most of the authors listed offer a range of perspectives on the categorization of costs,[34] there is a great deal of congruence in the identification of various cost elements. Two authors, Todd Litman and Mark Delucchi, provide the clearest and most comprehensive identification, estimation and categorization of transportation costs. They also offer insight into two different approaches to, and applications of, transportation costing.

2.3.2.0 Total costing

Delucchi is primarily concerned with simply identifying and calculating the aggregate costs associated with motor vehicle use. Although Delucchi's estimates indicate motor vehicle use costs more than most people realize, he offers no evaluation of which transportation mode is 'better' or any judgement of whether these costs exceed the benefits (1996). Rather, he is interested in identifying the 'opportunity cost' of motor vehicle use (that is, what society as a whole gives up, or would otherwise save, as a result of auto use). In this respect, Delucchi's "social cost analysis" informs general discourse on transportation decisions and offers a framework for analyzing costs.

[34] For example, Ketcham and Komanoff (1992) classify costs as direct costs borne by users, direct costs borne by non-users, externality costs borne by users and externality costs borne by non-users (in Murphy and Delucchi 1996). Miller and Moffet (1993) categorize transportation costs as personal, government subsidies, societal and unquantified and MacKenzie *et al.* (1992) categorize them simply as market costs and external costs.

Table 13 below provides Delucchi's classifications of a wide range of transportation costs of motor vehicle use according to how explicitly they are priced and allocated in the economy. Delucchi's framework is useful in that it determines whether the cost is monetary or nonmonetary, who the payer is and, where prices exist, whether prices are explicit or implicit. Accordingly, he identifies costs that are:

- **personal nonmonetary costs inflicted upon oneself** (generally, these are not fully recognized and therefore inefficiently incurred);
- **private sector goods and services** (generally, these are the most efficiently allocated of all the costs, as they are borne directly by the users, however many are not perceived explicitly);
- **"bundled" private-sector goods** (these costs, such as condominium parkades, are large costs that are inefficiently allocated because they are priced implicitly in the cost of a package of other goods, such as condominiums);
- **public infrastructure** (these are incurred by government and are price inefficiently or simply not priced); and
- **monetary and nonmonetary externalities** (which are rarely priced).

Table 13 - Motor vehicle (MV) cost categories (Delucchi)

Personal Nonmonetary costs of MV's (unpriced)	Explicitly priced private-sector MV goods and services	"Bundled" private-sector goods (implicitly priced)	Public infrastructure and services for MV use	Monetary externalities (unpriced)	Nonmonetary externalities (unpriced)
Nonmonetary	Monetary				Nonmonetary
Uncompensated personal travel time Accidental pain and suffering and death upon self Noise inflicted on self Personal time spend working on MVs Air pollution inflicted on self	Usually included in GNP accounts: Purchase of MVs Fuel, lube oil, except costs due to travel delay Maintenance, repair, washing, renting, storage and towing Finance charges on purchases of MV Parts, tires, tubes and accessories Automobile insurance Accident costs paid by insurance, lost productivity, medical and legal services, victim restitution Parking away from residence Usually not included in GNP accounts: Compensated time of travellers Overhead expenses of business fleets Accident costs paid by responsible party Vehicle inspection by private garages Legal services, security devices due to MV-related crime	Nonresidential offstreet parking included in the price of goods and services or offered as employee benefit Home garages and other residential parking included in the price of housing Roads provided or paid for by the private sector and recovered in the price of structures	Public highway construction and maintenance, including on-street parking Municipal off-street parking not priced at marginal cost Highway patrol Environmental regulation, protection and cleanup, including landfills and sewerage treatments plants Energy and technology R&D	Costs of travel delay imposed by others, including fuel oil, maintenance and compensated travel time Probabilistic loss of GNP due to sudden changes in oil prices Accident costs not paid for by responsible party: productivity, medical, legal, property Price effect of using fuels for MVs: increased payments to other countries for oil used in other sectors Losses for MV thefts and robberies	Air pollution inflicted on others: effects on human health, crops, materials and visibility Accidents: pain and suffering and death not paid for by responsible party Extra uncompensated time due to delay Global warming due to fuel-cycle emissions Noise inflicted on others Price effect of using fuels for MVs: loss of consumer surplus Water pollution: health and environmental effect of leaking storage and waste sites, spills and road runoff Pain, suffering and inconvenience costs due to MV crime Not estimate here: Land use damage, species loss Socially divisive effects of roads Vibration damages Aesthetic impacts
			Police protection, court and prison system Military expenditures to secure oil supply Fire protection MV related costs of other agencies		

Source: (Delucchi 1996)

Table 14 below presents low and high estimates Delucchi has made of the various costs associated with motor vehicles. Delucchi's estimates indicate that the total social cost of motor vehicle transportation may be as high as US$3 trillion annually in the U.S. and that per vehicle costs are in the range of US$9,900-15,000. Using Delucchi's data, I have estimated the total social subsidy (costs shared by society, including externalities) to be roughly US$4,300-8,400 annually, while the direct monetary subsidy (excluding externalities) to be in the range of $880-2,100 per vehicle. This estimate seems consistent with Peat Marwick *et al.* (1993) figures which put the total social cost of motor vehicles in the BC Lower Mainland to be C$2.64 billion annually, or C$2,590 per vehicle in 1991.[35]

The main utility in Delucchi's work is in the thoroughness of identifying 'opportunity costs,' the precision of classifying them and in the detailed estimates of many of the costs.[36] Many of the costs previously hidden or unrecognized are now made plain for analysis.

Table 14 - Summary of the annualized social costs of motor vehicle use, 1990

COST ITEM	COST FOR U.S. (Billion $/year)		COST PER VEHICLE ($/year)	
	Low	High	Low	High
1) Personal nonmonetary costs	411	601	2,180	3,189
2) Private-sector	947	1,067	5,020	5,659
3) Bundled	71	223	337	1,181
4) Public infrastructure	125	207	662	1,099
5) Monetary externalities	80	147	423	780
6) Nonmonetary externalities	246	593	1,305	3,145
Total social cost	**1,880**	**2,839**	**9,967**	**15,054**
Subtotal: Monetary costs (2,3,4,5)	1,222	1,645	6,482	8,720
Subtotal: Payments by MV users	109	173	580	918
Total social subsidy[a]	**824**	**1,599**	**4,367**	**8,477**
Total monetary subsidy[a]	**166**	**400**	**882**	**2,143**

Source: Adapted from (Delucchi 1996)

Note: a. To calculate these, I subtracted 'payments by MV users' and 'private sector' costs from the total social costs and the monetary cost subtotals. None of the other costs were subtracted because they are not directly paid for by users (i.e., internalized) and are "socialized." Bundled prices are more directly paid for by MV users, by these costs are still shared by non-MV users to a great extent.

2.3.2.1 Incremental costing

Todd Litman's approach to assessing, evaluating and interpreting transport costs differs from that of Delucchi in that Litman's primary concern is rooting out the inefficiencies endemic in current transportation pricing schemes. While Delucchi inventories the total costs of motor vehicle transportation, Litman examines the marginal costs of many modes in order to determine the extent to which various modes are 'priced' and how this pricing influences transportation equity and efficiency and land uses. Litman's basic thesis is that many transportation costs are either ignored, subsidized or not perceived as immediate, particularly for motor vehicle users. Auto use is therefore 'underpriced' or priced ineffectively, leading to inefficient transportation choices by individuals and decision-makers (Litman 1995).

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[35] The Peat Marwick *et al* estimate is less exhaustive and includes fewer external cost items than Delucchi's and are therefore lower.

[36] Some of the nonmonetary externalities I have identified in the previous sections are not identified or costed in Delucchi's framework.

In order to make transportation more efficient and equitable, Litman presents and categorizes transportation costs according to how they influence modal choice. Three categories of transportation costs are identified in Litman's framework: internal and external, variable and fixed and market and non-market. These categories and some constituent costs are identified in Figure 6 below. **Internal (user) costs** are those borne directly by the user. **External (social) costs** are those uncompensated costs that are borne by society at-large. External costs are similar in nature to what Garrett Hardin refers to as "commonized" costs (1985), or costs shared by everyone, regardless of their contribution to that cost.

Figure 6 - Motor vehicle cost categori es (Litman)

	Variable	**Fixed**
Internal (User)	Fuel Short term parking Vehicle maintenance (partly) ***User time & stress*** ***User accident risk***	Vehicle purchase Vehicle registration Insurance payments Long-term parking facilities Vehicle maintenance (partly)
External (Social)	Road maintenance Traffic law enforcement Insurance disbursements ***Congestion delays*** ***Environmental impacts*** ***Uncompensated accident risk***	Road construction "Free" or subsidized parking Traffic planning Street lighting ***Land use impacts*** ***Social inequity***

Source: Adapted from (Litman 1995)
Note: ***Bold italicized items=non-market costs***

The diffuse nature of external cost and individual imposes on society means that it is not factored into the individual's cost calculation (Baumol and Oates 1988). For example, most drivers do not consider the external costs such as noise, pollution and congestion that their driving imposes on others. This practice primarily stems mostly from the fact that motorists do not pay directly for these costs, but also from the fact that the impacts they experience as a result of their own actions are diffuse and shared by many (often millions) of others. **Variable costs** (such as fuel and parking) are those that change according to the level of use, whereas fixed costs (such as insurance and vehicle purchases) are 'sunk' costs that do not vary with use. Variable costs offer immediate feedback to user behaviour, whereas fixed costs have already been incurred and therefore do not inhibit driving. In fact, these "sunk" costs may further encourage driving (Hart and Spivak 1993). For example, a person may conclude that since they have already spent $20,000 on a vehicle and insurance, they will get full value for their cash outlay by driving as often as they like. Finally, **market costs** are those which involve a monetary transaction (either explicitly or implicitly), while **non-market costs** are those costs which generally go unpriced (indicated in bold in Figure 6). Users do not directly pay for many of the market and non-market costs they impose, which effectively constitute a subsidy. This makes car use artificially cheap.

In order to address the equity and efficiency dimensions of transportation pricing and reduce the amount of motor vehicle use, two-pronged approach is required. First, the costs of driving need to reflect the full cost of driving. Underpricing results in 'irrational' individual decisions at the consumer level and policies skewed toward auto dependence at the institutional level. The omission of market subsidies and social and environmental costs from the transportation cost equation distorts the true costs of automobile use. Secondly, the pricing structure for automobile use needs to be restructured such that it precisely aligns the perceived costs of travel with actual costs.

Currently, travellers consider only a narrow range of internal variable costs (Figure 6) in their decision to drive or take the bus. The equation in Figure 7 below is a basic representation of the perceived costs of transportation to the user. Like the transit user, the automobile user presently perceives the full cost of transport to be out of pocket expenses (ticket or gas) and the value of time (V*T). These variable costs are often all that is considered in the modal choice cost equation. Not surprisingly, the automobile often seems to be cheaper. Fixed costs such as insurance, repairs, purchase price and external costs not considered, and therefore, are not part of the decision-making criteria for most users.

Figure 7 - Perceived full price of travel

$$PP = F + V*T$$

where:
PP = perceived full price of travel
F = fare (bus) or out of pocket variable expenses of travel (auto)
T = travel time (including waiting time)
V = value of time (what one is willing to pay for an hours time)

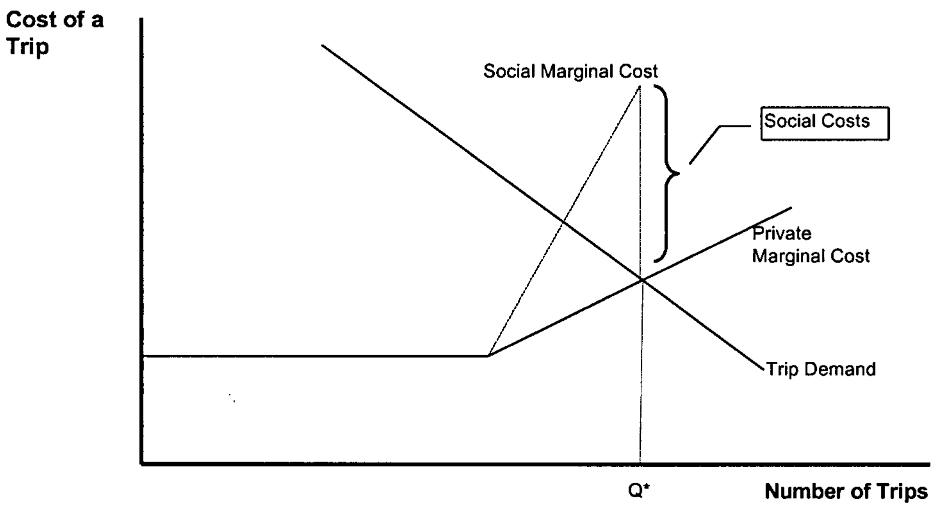
Ideally, the optimal pricing structure would have all costs which are external and fixed converted to costs which are internal and variable (see arrows in Figure 6). Among these costs, those which are non-market, or unpriced, should be assigned a price equal to their social marginal cost (i.e., incorporated into the full price equation). This is an often talked about (but seldom practiced) principle in transportation economics called "marginal cost pricing."[37]

Figure 8a represents the pricing problem in a simplified manner. Since drivers are only aware of the marginal private costs of using their car, they consume Q* trips. However, because the social marginal costs far outstrip the variable ones paid by the driver, she or he remains blind to the social cost that they exact. The economist solves this problem in Figure 8b by pricing trips at their social marginal cost. This effectively "rationalizes" the pricing of transport by changing travel demand, while passing on

[37] See Frankena (1979) for some early 'textbook' discussions of transportation economics that consider social marginal costs.

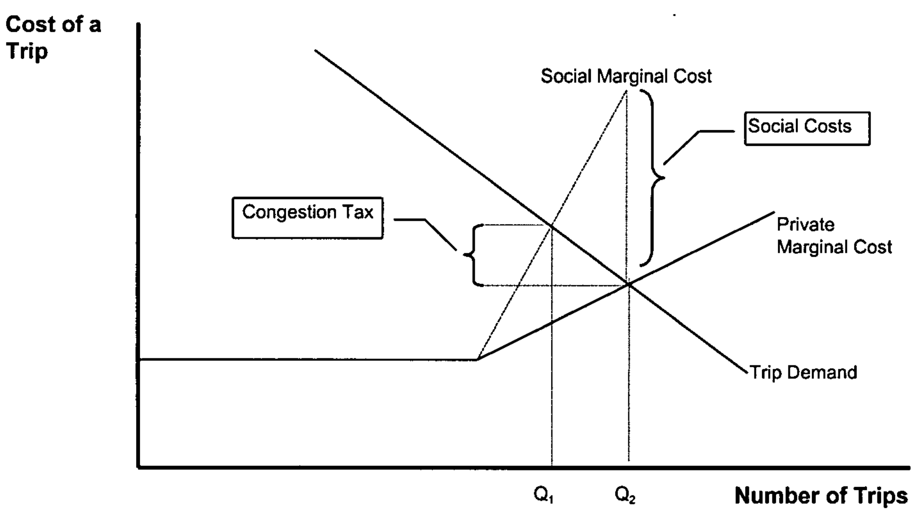
the remaining social costs through a "congestion tax" type of measure[38]. This model, of course, assumes that these costs are recoverable through money (for environmental degradation and urban sprawl, for example) and also assumes that people will actually act rationally and consume at Q_1. Consuming at Q_2, while only paying the outlined congestion tax, may still result in a social loss, albeit of a lesser amount than at Q* in Figure 8a.

Figure 8 - The pricing problem – an economist's perspective
a) Status quo – subsidies and hidden costs



Q* = Private Trips

b) The pricing approach – marginal cost pricing



Q_1 = Socially Optimal # of Trips
Q_2 = Private Solution

[38] These taxes for external costs imposed on society should be redirected towards mitigative efforts (or compensation) for those who bear the costs (usually society as a whole).

External costs currently account for 32% the cost of driving, while internal fixed costs account for 23% (Litman 1998a). An optimal pricing solution would see these 55% of external and fixed costs converted to internal-variable costs. While it may not be practical or possible to convert all of these costs, there are a variety of measures that could see many fixed costs converted to variable ones, with good results on travel demand (see, for example, Calgary 1994b; Litman 1995; Litman 1997b; OECD 1995; Shoup 1996, as well as the wide body of literature on TDM). Litman (1998a) estimates that the elimination of subsidies for motor vehicle use and the implementation of marginal cost pricing can reduce private motor vehicle travel by 30-50%. While some direct transportation costs may substantially increase for some motorists, Litman asserts these will be more than offset by savings in vehicle ownership expenses, housing costs, taxes, healthcare and environmental degradation.

2.3.2.2 Are the benefits worth the cost?

One argument forwarded by those justifying diseconomies in external costs of private motor vehicle transportation is that its external benefits (or positive externalities) outweigh the external costs. For example, it is often argued that automobiles offer substantial benefits to users in terms of increased mobility or that road investment and motor vehicle maintenance expenditures generate substantial economic activity. While Mark Delucchi does not perform cost-benefit analysis in his full social costing of transportation, he does acknowledge motorized transportation to have "social" (read, "external") benefits stating "motor-vehicle use provides enormous social benefit and, in our view, probably exceeds the social cost" (Delucchi 1996 p. 9).

However, many authors have criticized this claim, showing that many of the benefits cited are, in fact, not "external," that external benefits rarely exist in transport and that many of the benefits attributed to auto use can otherwise be achieved.

The argument of whether benefits such as increased access and economic spin-offs are indeed "external" rests on the definition of what an external effect is. The basic features of an external effect that they result an unintended consequence of an activity that is shared by society at large (see Rothengatter 1994; Verhoef 1994). However, Rothengatter (1994), Litman (1995) and OECD (1995) indicate that most of these benefits facilitate, or result in, market transactions which allow external benefits to be internalized by individuals over the long term. Benefits are essentially competed away (Litman 1995). Rothengatter shows that road transport subsidies involve the creation of consumer or producer surpluses (e.g., by lowering consumer or producer costs). This benefit, however, is one that is internalized and not realized by society at-large. Consumers and producers will continue to extract these surpluses and "internalize" them until no more benefits are available. Rothengatter concludes that "most of the effects mentioned such as the improvement of economic efficiency or development of new consumption/production structures are basically not external but normal consumer's or producer's surpluses induced by market interactions" and that "the number and the relevance of positive externalities is low" (Rothengatter 1994 p. 321).

As mentioned in Chapter 2 (section 2.2.1), this phenomenon of internalizing benefits and externalizing costs is a well-known social and ecological dilemma. Marginal social cost pricing essentially converts **commonized** transportation costs to **privatized** ones in Hardin's framework. The application of intrinsic responsibility through these market instruments allows transportation users to respond directly to gains and losses by adjusting transportation choices.

Litman (1998b) also argues that the important questions with respect to assessing auto benefits is not whether there are benefits to auto use, but whether:

- you (the individual or society) would benefit if your neighbour drove?
- you would benefit if your neighbour drove *more*? and
- any of the benefits of driving could be accrued by using different modes?

Litman argues that driving is rarely inherently good for society and that the benefits of others *driving more* rarely extend beyond those accrued to the individual. Most of the benefits are capture by individuals and businesses, while the external costs are shared by all (and some more than others). Furthermore, many of the benefits enjoyed from driving can often be met (and exceeded) by utilizing other modes. For example, British Columbia Treasury data indicate that the economic development benefits of transit exceed those of auto spending: every million dollars of transit spending yields 21 full-time jobs, while one million dollars spent on autos yields just 7 full-time jobs (1998a).

Aschauer and Campbell (1991) also find that investment in transit in the U.S. has greater potential as an economic stimulant than does highway spending (in Kenworthy et al. 1997). Much of the spending that is dedicated to automobiles and their use simply transfers money (capital) elsewhere in the economy that could be used for other productive investment. Or worse, these monies are often transferred *outside* the local and national economy removing any longer-run domestic economic benefits. Pricing correctly, Litman argues, will provide users with appropriate feedback when driving is reduced and eventually correct these inefficient transfers.

Finally, it has also been shown that transportation infrastructure and modal choices have much more profound impacts that extend beyond sectoral economic development. Research completed in 1997 for a World Bank commissioned report the relationships between land use, transportation and regional productivity, found weak overall correlations between auto dependence and gross regional product (GRP) (Kenworthy et al. 1997).[39] This study built on earlier research that produced only anecdotal evidence that auto dependence may impede regional economic productivity (Newman, Kenworthy, and Vintilla 1995).

[39] GRP is defined as the gross domestic product (GDP) contribution of the functional urban region.

However, Kenworthy *et al* (1997) were able to examine a larger sample of 37 cities in a more rigorous fashion and identify broad global patterns. They found that excessive car use and ownership does not necessarily confer substantial economic benefit (or what some would call an "external" benefit). Rather, they found that amongst developed cities, regional productivity actually declines after certain levels of car ownership and use and that external costs (such as energy depletion, sprawl, emissions and transport deaths) actually grow. That is, there are potentially *dis*economies associated with excessively high levels of car use. Key reasons for these diseconomies include the high cost of servicing suburban sprawl[40], the cost of deaths and injuries, time lost in congestion, higher transport expenditures and inefficient housing patterns.

The excessive personal and societal spending on transportation also ties up capital that could otherwise be used for economic development. Walter Hook (1994) attributes much of Japan's economic success over the past four decades to its low levels of car ownership and use. Not only was energy saved and urban systems made more efficient, but monies saved from car ownership and operation created a larger pool of potential investment capital critical for economic development. Today, Japan has some of the highest levels of NMT use in the developed world (Hook 1994).

2.3.2.3 Summary: ecological, social and economic impacts

There is a multitude of ecological, social and economic impacts associated with automobile use. Many of these impacts display tremendous complexity in terms of their multi-dimensionality, their scope and their mutually reinforcing relationships. While a wide range of impacts is recognized in a broad survey of the literature examining the implications of automobile dependence, few references provide a comprehensive inventory of these impacts. This problem is particularly acute in the government literature where policy prescriptions are formulated based on a limited understanding of the full, life-cycle costs of automobile dependence. Since documents typically assess only a narrow range of the most explicit impacts, the policies prescribed will necessarily be incomplete. It is quite clear that addressing these many "symptoms" of automobile dependence individually is a complex, and perhaps futile task.

In assessing the impacts inventoried and discussed above, they seem to fall in to two broad categories amenable to clear policy analysis. Those which are "fixed" and those which are "variable." **Fixed impacts** are those that are incurred regardless of vehicle kilometers driven (i.e., by virtue of ownership). Examples of fixed impacts include those incurred in the vehicle production process, those

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[40] Sprawling cities necessitate higher costs for the provision and servicing of fixed infrastructure such as roads, sewers, cables and electrical wires. They generally also have lower per capita utilization of public facilities such as schools and hospitals, and higher capital and operating costs for the provision of distance-sensitive public services such as transit, fire, police, ambulance, garbage collection, snow plowing, road de-icing and the like. See Calgary

associated with minimal fixed infrastructure and services to accommodate cars and those associated with automobile disposal. **Variable impacts** fall or rise (not necessarily proportionately) with the number of cars and their level of use. Examples of variable impacts include local pollution, health costs, accidents, maintenance, infrastructure and the like, which are incurred after vehicle purchase.

This dichotomy provides a useful starting point for policy analysis since it addresses the complexity of transportation symptoms with a great deal of simplicity and clarity: by addressing the root source of auto-related impacts. Those policies which reduce vehicle ownership will necessarily reduce the fixed costs, and any variable costs that vehicle would otherwise have produced throughout its life cycle. Those policies that reduce the number of kilometres driven will necessarily reduce the preponderance of variable impacts associated with driving.

2.4 REDUCING AUTO DEPENDENCE

In the previous sections, I have reviewed some of the conventional approaches to transportation planning, presented some of the key relationships between various causes of auto dependence and discussed some of the resultant impacts. I have argued that transportation planning is primarily rooted in a paradigm that focusses on mobility over access, effectively deriving demand for automobile use. A series of mutually dependent and mutually reinforcing positive feedback relationships lead to the aggravation and seeming intractability of auto dependence. The impact of this over dependence on cars has profound implications for the ecological, social and economic wellness at a local and global scale. These are basically rooted in the need to own and use cars.

However, many conventional approaches designed to deal with auto dependence tend to focus on narrow efficiency-focussed goals and technological fixes that often aggravate auto dependence rather than reduce ownership and use. These approaches are reductionist in nature isolating singular causes and impacts such that they are amenable to easy treatment. By merely "nibbling at the margins" (Hart and Spivak 1993), these technology and efficiency-oriented palliatives ignore the tremendous complexity of the issue at hand and tend away from more holistic approaches. Scholars such as David Ehrenfeld (1978), Ursulu Franklin (1990), Lewis Mumford (1934) and Rene Dubos (1970) have all argued that technology and efficiency alone are no panacea for problems wrought by technology. They merely offer refuge from treating root problems and often make them worse.

Traditionally, transportation policy has focussed on resolving the problems of congestion and air pollution as most the visible problems associated with car use (Freund and Martin 1993; Gordon 1991;

(1995c), Miller and Moffet (1993), MacKenzie *et al.* (1992), Newman and Kenworthy (1989a) and Altshuler (1979) for some discussion of the impact of sprawl on infrastructure capital and servicing costs.

Lowe 1990; Renner 1988; Schwartz 1971). Even today, much transportation policy in Canada and the U.S. focusses on treating congestion and air pollution as the primary problems requiring treatment (BC Environment 1995c; BC Transit 1996; BCTFA 1996; Gordon 1991; ORTEE 1992). More effective strategies for dealing with the problem are effectively forgone since policy efforts are directed at micro- and meso-level policy rather than macroscopic, holistic policies which consider a wider range of criteria. Defining problems in such narrow terms means the prescriptions for affecting them will necessarily be incomplete.

2.4.0 The Quasi-Solution – Seeing the Trees, Missing the Forest

Author Eugene Swartz characterizes incomplete solutions as *quasi-solutions*. In his book, Overskill: The Decline of Technology in Modern Civilization, Swartz provides a critique of technology-oriented solutions and their inability to provide a long-term fix for problems. Swartz asserts that a technological solution is always a quasi-solution because it gives rise to a residue of unsolved problems. He outlined three sources of this residue:

1. the incompleteness of the technological solution;
2. the augmentation of the original problem; and,
3. secondary effect

Furthermore, residual problems result in the creation of future generations of problems which drive the endless cycle of positive feedback technological solution-seeking (Schwartz 1971).

The first residue problem, *incompleteness*, is mainly an extension of the original problem. Many technologies, for example, are not 100% efficient. The problem is therefore never completely solved, require further iterations of the process of technological refinement to perfect the process. Reducing vehicle emissions is an example such an iterative process that does not seem to resolve itself. The drive for completeness creates new problems through *augmentation* and *secondary effects*. Augmentation occurs when the initial problem is aggravated, or a higher-level problem is created, that requires the development of a new technology to address it. Secondary effects are other foreseen or unforeseen effects that result from the treatment of the original problem. For example, the quasi-solution of developing higher performance fuels to reduce pollution has reduced some pollutants, but increased others, such as hydrocarbons and carbon monoxide (augmentation). Meanwhile, the quasi-solution to the local pollution problem, emission control devices, has resulted in higher CO_2 emissions and the secondary effect of global warming.

Schwartz argues that the residue of a multitude of quasi-solutions becomes so compounded that technological solutions become increasingly difficult. The difficulty is attributable to the increasing complexity of the problem, the dynamics of technology, decreased resources, increased costs and the inertia of political institutions. New problems multiply at such a rapid rate such that real solutions can no longer be found to address them each individually. Schwartz's argues that most of what we actually perceive as *problems* in transportation (as well as in other areas) are actually *symptoms* of larger, more significant problem. This assessment is also shared by Alan Altshuler (1980) in his seminal critique of transportation policy.

Transportation policy developments in the United States (that in some respects mirror Canada's experience) demonstrate how the application of quasi-solutions fail to address the root problem, aggravate the original problem and spawn new ones.

In the early 1960's, residents in cities such as Los Angeles and San Francisco began to lobby heavily to have the congestion and air pollution impacts of the automobile mitigated. The response of policy-makers was two-fold: the first was to require that vehicle manufacturers develop more fuel efficient vehicles (cleaner engines and catalytic converters) and oil companies develop cleaner burning fuels; the second was to increase capacity and roadway efficiency to allow for freer flowing traffic. However, both strategies failed to either decrease emission or reduce congestion.

The first California air pollution law in 1960 was followed by the federal Motor Vehicle Air Pollution and Control Act in 1965. Both of these set out guidelines and for vehicle efficiency and, in subsequent amendments, required the use of catalytic converters to reduce the amount of certain tailpipe emissions. The Clean Air Act of 1970 and the Arab oil embargo of 1973 prompted yet more stringent regulations on tailpipe emissions and fuel quality to be in place by 1975. The result was that, from 1975 to 1987, the fuel economy of new cars in America increased nearly twofold – an impressive technological achievement. However, these gains in fuel efficiency were completely erased by the increased fleet sizes and vehicle miles travelled (VMT) of these, now more "environmentally friendly," cars (Freund and Martin 1993; Gordon 1991). The cheaper capital and operating costs offered by newer, more efficient cars further increased the demand for auto trips. The sheer increase in vehicle miles travelled from increased demand caused a net increase of air-borne pollutants (Renner 1988).

Furthermore, like most technologies, pollution control devices are not perfect. At low speeds, and in cold conditions, catalytic converters experience dramatically lower efficiency. They also do not age very well. Unless pollution checks are in place, a catalytic converter can be inoperable or inefficient for the life of the car without being noticed. When they do operate properly, catalytic converters only eliminate some pollutants, but create others, namely greenhouse gases such as CO_2. These newer greenhouse gas emissions are now of great global consequence.

With increasing automobile use came congestion. From 1970 to 1987 the number of automobiles in the U.S. increased at a rate of 2.4% per year, while highways financing increased at a rate of 15% (Gordon 1991). Despite the added capacity, VKT has increased dramatically since the early 1960s (Lowe

1990; Newman and Kenworthy 1996; Newman and Kenworthy 1989a), while congestion continues and has worsened in many cases (Lowe 1990; Renner 1988).

Many transportation policies pursued today in Canada can also be categorized as quasi-solutions. For example, a strategy of encouraging HOV use through the provision of HOV lanes[41] suffers from incompleteness and may actually result in substantial augmentation and secondary effects. Conventional wisdom has it that HOV is desirable because it gets more people into fewer cars for commuting purposes. It therefore is purported to reduce the demand for auto travel and reduce emissions (BCTFA 1996; ORTEE 1995). However, it has been shown that HOV facilities may actually derive greater demand for auto travel in the long run by inducing travel (Johnston and Ceerla 1996; Vuchic et al. 1995; Vuchic et al. 1997).

HOV provision essentially amounts to a freeing of existing capacity (and, in some cases, the creation of new capacity), thereby encouraging longer distance travel and sprawling land uses. Ultimately, these magnify the ecological, social, economic impacts highlighted in section 2.3 above. Although HOV conversions are traditionally characterized as TDM measures, their effect is to increase supply and they therefore derive greater demand for trips.

HOV provisions are viewed as demand measures because they serve to reduce the demand for SOV trips. However, because "encouraging" HOV measures necessitates additional infrastructure and leads to less traffic in mixed-use lanes, it effectively results in a greater supply of road for SOVs. In the short run, this trip reduction and greater supply of capacity will no doubt lower the trip times for HOVs, while reducing pollution and congestion on other roads. However, the initial euphoria of such a strategy will eventually be dampened as the sobering reality of an auto-focused, supply-oriented solution takes hold.

There is a substantial latent demand for automobile travel in most urban centres (Litman 1995). For every car-pool,[42] at least two additional SOVs will be eliminated, providing cleaner air and less congested streets. However, as the congestion on the roads is reduced and a free-flow of traffic is restored, this newly created capacity for cars will merely act to satisfy an existing latent demand for SOV trips. Failing restrictions or a dampening of demand on new SOV use, this vacated capacity will attract new users and those previously deterred by congestion. Furthermore, a modal switch from those using "greener" modes (e.g., public transit, bicycles, walking, and even carpools themselves) now attracted to SOVs may compound this problem. Cars will continue to fill the free flow until congestion again is a deterrent and a new *congestion equilibrium* is reached. However, this new equilibrium operates at a

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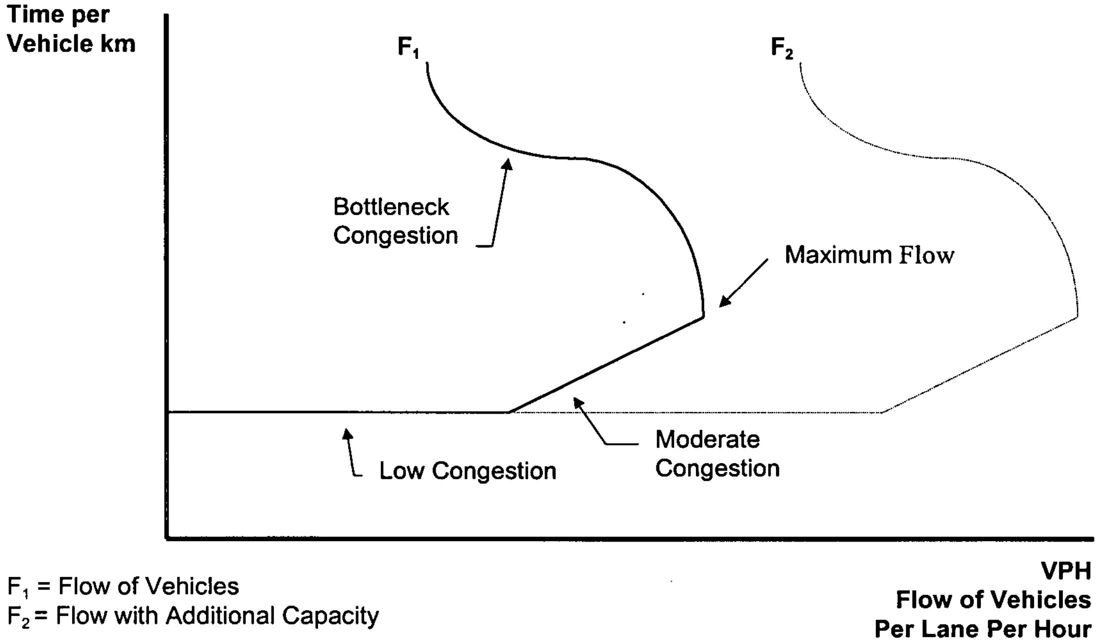
[41] HOV lanes can be provided by either constructing new lanes, converting general purpose lanes to HOV use only, or opening curb parking lanes for HOV use.
[42] Assuming 3+ occupancy.

higher state: the increase in total capacity means there are now even more vehicles congesting and polluting and that some of this new car travel may been switched from "greener" modes.

Figure 9 - Road congestion: the "capacity myth"



Adapted from (Frankena 1979)

Figure 9 above demonstrates the phenomenon I will term the "capacity myth." F_1 refers to the flow of vehicles for a road of a given capacity. Initially, there is little congestion and a relatively unconstrained flow of traffic. As the lane approaches capacity, cars begin to slow down, thereby creating moderate congestion. Once maximum flow is reached, gridlock sets in and cars move at very low rates of speed, if at all. Position F_2 describes the flow of vehicles once transport supply measures, such as new road and HOV lane infrastructure construction, are implemented. These measures serve to push the curve outward from F_1 to F_2, effectively increasing an artery's vehicle flow capacity. Here, the same phenomenon of congestion equilibrium sets in, but with a greater number of vehicles and vehicle trips. Similar phenomena have been documented in the construction of new capacity throughout North America and elsewhere (see previous discussion of induced traffic in section 2.2 above). In the longer run, HOV policies may have the effect of encouraging sprawling land uses and creating "future latent demand" for car travel (Hart and Spivak 1993).

HOV strategies suffer from incompleteness. They focus on mitigating a narrow range of problems such as vehicle emissions, low vehicle occupancies and high peak period demand for car travel. However, in supplying easier automobile access, HOV strategies lead to augmentation of the original problems it sought to address (emissions, occupancy and peak demand). Furthermore, other secondary effects such as sprawl, increased off-peak demand for car travel and other related impacts of auto dependence may ensue.

2.5 HOLISTIC DIRECTIONS

A more holistic approach to reducing auto dependence is necessary. Nibbling at the margins offers no panacea and often makes matters worse. In order to affect substantive change, our prescriptions for addressing auto dependence must address the fundamental root causes. Quasi-solutions at best offer temporary reprieve from the symptoms of car dependence and are most often self-defeating in the long run.

More holistic solutions address the fundamental problems of auto dependence identified in this chapter. They:

- promote exchange and access over mobility and speed;
- reduce car ownership and use;
- provide a counterweight to the positive feedback relationships that feed auto dependence; they either provide 'negative feedback' (suppress unwanted action) or set in motion desirable positive feedback loops; and
- engender intrinsic responsibility or mutual cooperation in using and managing common property.

Of course, any measures that meet these criteria must also be considered within a wider context of time required for implementation, cost effectiveness and political/public acceptability. Chapter 5 sets out a more detailed framework for evaluating measures based on the policy directions suggested in Chapter 4.

CHAPTER 3 – METHODOLOGY

3.0 INTRODUCTION

This analysis in this thesis uses comparative data on transportation and land use patterns in seven major Canadian urban regions for four years (1961, 1971, 1981 and 1991). The data used for each region fall into the following broad categories: population and employment distribution, developed area, transport infrastructure supply, vehicle ownership, transport energy consumption and public and private transportation usage.

This chapter provides an overview of the methodology employed in the data collection process and a discussion of some of the issues relevant to data interpretation. It builds on the discussion in Chapter 1 of the need for comparative transportation data for Canadian cities and provides a rationale for the selection of data items, cities studied and years surveyed. I follow with a description of the data surveyed and of the collection process. The indicators collected from the survey are then defined and issues relevant to their collection and interpretation are discussed. Finally, I end with some notes regarding the use and interpretation of the data and an assessment of their reliability.

3.1 ORIGINS OF THE RESEARCH

The data collection methodology used in this thesis was initially developed by Peter Newman and Jeff Kenworthy in their landmark 1989 study, *Cities and Automobile Dependence* (CAAD). This initial study was based on a sample of 32 global cities (13 European, 10 American, 5 Australian, 3 wealthy Asian and 1 Canadian) and covered 3 study years (1960, 1970 and 1980). In early 1996, I was invited to work on assisting with the collection of the Canadian cities data for this update to CAAD (CAAD II) titled An International Sourcebook of Automobile Dependence in Cities, 1960-1990 (Kenworthy et al. 1999).

Table 15 - Stages in the research program

Research Activity	Location	Time Frame
1. General survey of relevant literature	Australia	May – August 1996
2. Learning data collection and processing techniques	Australia	July – August 1996
3. Collection of transportation and land use data	Australia	August 1996 – January 1997
4. Collection of missing data items	Canada	March 1997 – May 1997
5. Detailed literature review	Canada	May 1997 – August 1997
6. Analysis and thesis writing	Canada	July 1997 – April 1998

I worked with Jeff Kenworthy and a team of PhD students at the Institute for Science and Technology Policy (ISTP) at Murdoch University in Perth, Australia from June 1996 until February 1997 on CAAD II. The project also involved several months of follow-up work in Vancouver to finalize and correct various data items (see Table 15- Stages of the Research Program). Each student was charged with responsibility for a particular geographical area (e.g., Asia, Europe and North America), however the collection and processing of data was very much a collaborative effort. Table 16 lists all the cities of study by region. Table 17 indicates the researcher(s) who made the primary contribution for the collection of data.

Table 16 - Global cities included in CAAD II

American cities	Australian cities	Canadian cities	European cities	Wealthy Asian Cities	Developing Asian cities
Boston	Adelaide	Calgary	Amsterdam	Hong Kong	Bangkok
Chicago	Brisbane	Edmonton	Brussels	Singapore	Jakarta
Denver	Canberra	Montreal	Copenhagen	Tokyo	Kuala Lumpur
Detroit	Melbourne	Ottawa-Hull	Frankfurt		Manila
Houston	Perth	Toronto	Hamburg		Seoul
Los Angeles	Sydney	Vancouver	London		Surabaya
New York		Winnipeg	Munich		
Phoenix			Paris		
Portland			Stockholm		
Sacramento			Vienna		
San Diego			Zurich		
San Francisco					
Washington					

Table 17 - Researchers' contribution to the data collection process

City/City Group	Main data collector(s)
Australian cities	Jeff Kenworthy
US cities	Kenworthy, Felix Laube and Tamim Raad
Canadian cities	
Calgary	Kenworthy, Laube and Raad
Edmonton	Kenworthy, Laube and Raad
Montreal	Kenworthy, Laube and Raad
Ottawa-Hull	Raad and Laube
Toronto	Kenworthy, Laube and Raad
Vancouver	Kenworthy, Laube and Raad
Winnipeg	Raad
European cities	Laube and Kenworthy
Wealthy Asian cities	
Hong Kong, Tokyo	Kenworthy
Singapore	Kenworthy and Paul Barter
Developing Asia	
Bangkok	Chamlong Poboon
Beijing	Hu Gang
Jakarta, Kuala Lumpur, Seoul, Surabaya	Barter
Manila	Jun Guia and Barter

The data collection process was at various stages of completion when I began work on this project. The data collection for Toronto was almost complete. Vancouver, Calgary and Montreal had much of the 1991 data collected, so most of the work in these cities involved obtaining the 1961, 1971 and 1981 data. Edmonton required significant work for all years. Winnipeg and Ottawa-Hull were added when I joined the project, so these required all data for all four study years.

3.1.0 Rationale for Cities, Study Years and Data Items Selected

Seven Canadian metropolitan areas were surveyed in this study: Vancouver, Edmonton, Calgary, Winnipeg, Toronto, Ottawa-Hull and Montreal. Section 3.3 below provides a detailed description of how the metropolitan areas, inner cities and CBDs of each of the regions were defined for survey purposes.[43]

The seven regions were chosen mainly because they are Canada's major population centres. From a comparative perspective, the selection also illuminates differences in the urban transportation experience within Canada. The cities represent a range of urban density levels, public transit services (bus only or with combinations of bus, busway, LRT, ALRT, subway and commuter rail) and private transportation infrastructure supply levels (e.g., freeways, parking, etc.). Initially, Winnipeg and Ottawa-Hull were not included in the study. However, they were added because they are unique in the context of other large Canadian cities: both have bus-based systems (Ottawa has a segregated busway) with no urban rail provision.

The years used in the survey are 1961, 1971, 1981 and 1991.[44] For the most part, most data items were obtained for these study years. Where data were not available for these study years, data within 1-2 years of them were obtained and the appropriate population base was used to standardize them. Otherwise, best-guess approximations were made in concert with local planning staff. The base year of 1961 was chosen as it marks the beginning of the period of rapid motorization and suburbanization in Canadian cities and is the earliest date for which any of the data required in the survey are widely and accurately available. Data for subsequent years trace the evolution of urban transportation and land use in the face of continuing motorization and suburbanization.

Each of the years of the study was selected to correspond to census years to enhance data availability and the usefulness of results for planning purposes. Data for many other cities in the CAAD study (the American cities, for example) used 1960, 1970, 1980 and 1990 data to correspond with their respective census years. The one-year difference is not highly significant because of the large time frame necessary to see meaningful changes in urban form and transport. Therefore, there is still a high degree of

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[43] Throughout the thesis the use of the city name alone refers to the entire metropolitan area as defined in Table 19. For example, the use of 'Vancouver' refers to the GVRD, 'Toronto' to the GTA and 'Ottawa' to Ottawa-Hull (or RMOC, MRCCO and CUO combined). Where reference to a specific municipality within these regions bearing the same name is made, it will be qualified with reference to the City of Vancouver, the City of Toronto, etc.

[44] The only exception is the City of Winnipeg. As comprehensive database of transportation, land use and demographic data already existed for 1962, 1971, 1981 and 1992, these were used as the study years for Winnipeg.

comparability between various countries. The 10-year spread between survey years is used also because of the time lag necessary to see substantive changes in urban form and infrastructure. Although it would be desirable to have an updated set of 1996 data for Canadian cities, it would not be realistic to begin collecting and collating comprehensive data until at least mid-1998 as census data take from 1-3 years to be processed and fully available.

The data items in the study were selected to describe the basic relationships between urban land use patterns and transportation use, supply and transportation efficiency over time. The 'raw' data items needed to describe these basic relationships, but also needed to be universally collected and reported to allow for standardization and comparison.

To track the movement and dispersal of population and jobs each region was divided into three distinct sectors: the CBD, the inner city, and the outer area. The inner city includes the CBD and describes the pre-World War II (pre-automobile) city. The outer area is simply the remainder of the metropolitan area. Urbanized area, population and jobs data were collected for each of these three sectors. Parking and road length data provide a basic picture of infrastructure supply dedicated to car use. Meanwhile, motor vehicle registrations, vehicle travel, energy use and trip lengths data are all standard transportation planning indicators measuring the use of private automobiles in urban areas. Modal split data measure the balance between car, transit and non-motorized travel in a region. Finally, the public transport data used are widely indicators used to describe the levels of use and supply of transit in a city.

While the raw data provide information regarding the absolute levels of car dependency, standardizing these raw data (e.g., per person, hectare, kilometre, etc.) provide insights into transport and land use efficiency, intensity of use and supply. Standardizing also allows for comparative assessment between regions.

3.2 DATA COLLECTION PROCESS

The data collection process involved 3 steps:

1) **The selection of parameters and distribution of the survey forms.** As mentioned earlier, the parameters were selected to provide insights into the basic relationships between urban form and transportation service, infrastructure and use. These parameters were the same as those used in CAAD, with some refinement of certain parameters. The surveys were distributed to officials at relevant planning agencies in each city along with an explicit definition of each parameter requested. Typically, the initial surveys were sent to a regional planning body or municipality in each city as well as the regional transit operator(s). Table 18 below shows the primary and secondary agencies that supplied the requested information. Appendix 5 (Data Sources) provides detailed source agency information.

2) **Follow up work to collect missing data items.** Only in rare cases, such as Winnipeg, was high quality and relatively complete data immediately available. Substantial additional follow-up work with other departments with the agencies, as well as contact with other agencies (such as Statistics Canada, provincial ministries, central city municipalities and CUTA) was required to complete the data set. Visits to each city, faxing and telephone calls were required to follow-up with each agency.

3) **Crosschecking and confirming of data to ensure consistency and reliability**. On occasion, data supplied by agencies were clearly in error. However, intense scrutiny of each data item supplied usually ferreted out errors. Data were crosschecked so that dramatic trends or inconsistencies were identified and confirmed. For example, transportation data were compared with one another to ensure they corroborated one another. Very high vehicle ownership levels and low transit use would be inconsistent with low VKT. Such inconsistencies are investigated and confirmed with local agencies. If aberrant were found, they were either confirmed or corrected with local planning staff.

Table 18 - Data source agencies

Data type	Primary data source	Secondary data source
POPULATION/AREA		
Total pop.	• Cities of Edmonton, Calgary, and Winnipeg • GVRD, Metro, OGTA, RMOC and CUM	• Statistics Canada
Urbanized area	• Cities of Edmonton, Calgary, and Winnipeg • GVRD, Metro, OGTA, RMOC and CUM	• Detailed planometer measurements
CBD/Inner City pop.	• Central city governments (all cities)	• Statistics Canada
CBD/Inner City area	• Central city governments (all cities)	• Detailed planometer measurements
EMPLOYMENT		
Region	• Cities of Edmonton, Calgary, and Winnipeg • GVRD, Metro, OGTA, RMOC and CUM	• Statistics Canada
CBD/Inner city	• Central city governments (all cities)	• Statistics Canada
Parking	• Central city governments (all cities)	
Road Network	• Cities of Edmonton, Calgary, and Winnipeg • GVRD, Metro, OGTA, RMOC and CUM	• BC Ministry of Municipal Affairs
Vehicles Registered	• Cities of Edmonton, Calgary, and Winnipeg • BC MoTH, Metro, RMOC and CUM	• Statistics Canada • TAC (1996); JPINT (1996)
PRIVATE TRANSPORT	• Cities of Edmonton, Calgary, and Winnipeg • GVRD, Metro, OGTA, RMOC and CUM	• ND Lea (1966) • Quebec Ministry of Transport
Private Energy	• GVRD, Metro, OGTA, RMOC and CUM • City of Calgary • Kent Marketing, Inc.	
Mode split/Trip Length	• Cities of Edmonton, Calgary, and Winnipeg • GVRD, Metro, OGTA, RMOC and CUM	
TRANSIT	• City/Regional transit agency in each city • RMOC in Ottawa • Detailed cross-checking with CUTA	• RMOC provided Hull data

There was rarely "one stop shopping" in collating the data. This process at a minimum required contact with several departments in one regional agency. In most cities, it was necessary to liaise with several departments and agencies at the local, regional and provincial level, as well as others.

3.3 DEFINITIONAL ISSUES

There are two forms in which that data in this study appear: "raw" and "standardized". These data are located in Appendix 2.

The raw data are basically the unadjusted absolute measures for each parameter. The standardized data provide indicators derived from the raw data. These measure the efficiency of public and private transportation, the intensity of urban activity and infrastructure use and the per capita performance of transportation and land use. So long as the raw data inputs are collected on a consistent basis for each city, standardizing the data allows for accurate comparison between metropolitan areas.

Since the purpose of the thesis is to come to a better understanding of the factors accounting for differences in auto dependence in Canadian cities, I will rely primarily on the standardized data for the analysis. This is not to understate the value of the raw data. They are the base from which the standardized data are derived. Also, from a 'sustainability' perspective they provide important information regarding absolute changes in urban characteristics and auto dependence. For this reason, I will infuse the analysis with information regarding the absolute changes as well. However, for comparative purpose the analysis will revolve primarily around the standardized data.

To ensure that these comparisons are accurate and meaningful, it is important to be precise in defining the parameters used, the methodology employed in collecting them and any difficulties encountered with specific items.

3.3.0 Raw Data Definitions and Issues

The raw data were chosen to represent the broad range of factors that affect the evolution of urban transportation. The parameters were chosen to allow for the analysis of the relationships between land use, demographic change, and public and private transport supply and use on a regional scale. Below are definitions of each data item as well as (where appropriate) discussion of specific problems and difficulties encountered in their collection and processing.

3.3.0.0 Territorial areas

Data were collected for three geographical areas for each city: the metropolitan area, inner area and central business district (CBD). A fourth area, the outer area, was derived from the data provided. Appendix 1 contains maps outlining the relationship of these geographical areas to one another. For accurate comparisons, raw data items correspond to these geographical definitions in every case. In rare cases where raw data items correspond to a different geographical regions or year, the appropriate (corresponding) population and land area data are used to standardize them. Only the Canadian cities in the study are described below. Specific definitions for data from the other 40 cities in CAAD can be found in Kenworthy and Laube, et al. (1998).

Metropolitan area

The metropolitan area is defined as the functional urban area of a city, or what is commonly referred to as the 'city-region.' The city region can be defined as agglomeration of urban units that share a common social, environmental and economic destiny (Golden et al. 1996; Jacobs 1969; Sancton 1994). The individual municipalities of a metropolitan area display economic and spatial interconnectedness, typically manifest in a common 'commutershed.' The urbanized area is generally contiguous, with occasional "satellite" communities on the periphery. The metropolitan areas, as defined here, may or may not have a single corresponding administrative unit.

How closely this definition is followed depends to a large extent on data availability. In the case of the Canadian cities included in the study, it was possible to get fairly comprehensive data for the entire metro regions as defined. Some cities, such as Edmonton, have smaller satellite communities with poor data availability (e.g., St. Albert). In cases such as these, these areas were simply omitted. Data reliability remains high as these omissions are generally small in population and size and the remaining data items are kept internally consistent.

In several cases (most notably Toronto, Montreal and Ottawa), the regional governing bodies lack territorial comprehensiveness. Metro in Toronto and MUC in Montreal each have roughly half their regions' populations. Meanwhile, RMOC is territorially comprehensive on the Ontario side, but does not include the Hull on the Quebec side that accounts for roughly one third of the region. Therefore data from outlying areas that are essentially part of the functional urban area, but are not included in a single regional jurisdictional unit, had to be sought out and included.

Table 19 below defines the functional metropolitan areas of the seven Canadian cities, as used in this study. Maps of the metro regions are found in Appendix 1.

The City of Calgary encompasses the entire functional **Calgary** region. Its boundaries have been and still are progressively expanded through annexations to include new development on the city's periphery. Calgary's 1991 population was 710,677. **Edmonton's** functional region is somewhat larger than the City of Edmonton. However, the City of Edmonton contains the majority of the region's population. The satellite communities of St. Albert, Fort Saskatchewan and Sherwood Park roughly total 90,000 people. Due to extraordinary difficulty in obtaining data for these cities, the City of Edmonton, with a 1991 population of 614, 665, was chosen to represent the region. The travel patterns of these satellite communities are not expected to impact the overall metropolitan averages significantly.

In **Montreal**, the Montreal Urban Community (MUC) is the official regional planning agency for the area. However, even at its inception, it lacked territorial comprehensiveness. Today, less than half the region's population is located in MUC. The Quebec Ministry of Transportation, however, defines the total region based on its functional area and commuter shed. This area, Région de Montréal (RM), includes Laval and all or part of eleven municipalities to the north and south of Montreal Island and has a 1991 population of 3,119,570.

Table 19 - Canadian city metropolitan area definitions (1991)

City	Metro area definition
Calgary	City of Calgary
Edmonton	City of Edmonton
Montreal	Région de Montréal(RM). This includes the Montreal Urban Community (MUC) plus Laval and all or part of eleven surrounding suburban Regional Municipalities.
Ottawa-Hull	Regional Municipality of Ottawa-Carleton (RMOC) on the Ontario side and bodies Municipalité Régionale de Comté Collines-de-l'Outaouais (MRCCO) and the Communauté Urbaine de l'Outaouais (CUO) on the Quebec side.
Toronto	The Municipality of Metropolitan Toronto (Metro) for most data. Where the Greater Toronto Area (GTA) is used in 1981 and 1991, it includes Metro as well as the outlying Regional Municipalities of Durham, Halton, Peel and York.
Vancouver	The Greater Vancouver Regional District (GVRD).
Winnipeg	City of Winnipeg (UniCity).

Ottawa consists of two distinct parts, a larger area in the Province of Ontario called the Regional Municipality of Ottawa-Carleton (RMOC), and population about one third its size in the Province of Quebec with the two administrative bodies, Municipalité Régionale de Comté Collines-de-l'Outaouais (MRCCO) and the Communauté Urbaine de l'Outaouais (CUO). This is a large area in size that corresponds roughly to the National Capital Region. Much of the land within the RMOC, MRCCO and CUO are rural; the actual urbanized area of these jurisdictions is small and mostly contiguous. The 1991 population of Ottawa-Hull was 907,919.

The Municipality of Metropolitan Toronto (Metro; 1991 population 2.2 million) collects high quality data for **Toronto.** Upon inception in 1954, Metro was territorially comprehensive, but has been significantly outgrown since the 1970s by peripheral urban development. A more appropriate definition for the region is what is now known as the Greater Toronto Area (GTA), with a 1991 population of 4,235,756. The GTA includes the Regional Municipalities of Durham, Halton, Peel and York in addition to Metro. Since there has been no single jurisdictional unit corresponding to this definition, data collection has been difficult and has required the collation of data from multiple agencies. Some data are available for the GTA for 1981 and 1991, however earlier years are much patchier. For the purposes of this study, 1981 and 1991 Toronto data used will generally refer to Metro Toronto, unless otherwise noted. Additional 1981 and 1991 data for the GTA are used where available to supplement these data and provide a broader region-wide perspective. Only Metro data are used for 1961 and 1971, however this is not deemed to be a problem for comparative purposes as the functional regional area corresponded closely to Metro in this period[45]. Furthermore, when standardized indicators are calculated, data items are matched with their geographical equivalent (e.g., Metro population is divided by Metro urbanized area to determine densities), thereby ensuring 'per unit' consistency and 'apples to apples' comparisons.

On January 1, 1998, the Province of Ontario amalgamated Metro Toronto and all its constituent municipalities into one "megacity" now called the City of Toronto. The structure of the remaining regions and municipalities outside Metro remains largely unchanged. To eliminate confusion throughout the thesis, all references to cities and regions in the Toronto region will be in pre-1998 nomenclature, unless otherwise noted[46].

Most of **Vancouver**'s functional region is included in the Greater Vancouver Regional District (GVRD; 1991 population of 1.5 million), although it could be argued that some satellite communities such as Abbotsford and Chilliwack are part of the commutershed and should be included. The GVRD, however, is considered to be territorially comprehensive and has expanded to include newly developed suburban precincts throughout the years. The GVRD keeps regular, consistent and reliable data.

In **Winnipeg,** the City of Winnipeg (UniCity; 1992 population 641,850) is used to define the region. This is includes almost all of the functional urban region and excellent data are readily available. Winnipeg had excellent data availability for 1962, 1971, 1981 and 1992. Since Winnipeg had excellent data availability for these years, 1962 and 1992 were used as the study years for that city in lieu of 1961 and 1991 for all the other cities). Since few dramatic changes occur in urban transportation and land use patterns within the span of one year (especially in low-growth cities), these were taken as a good approximation for 1961 and 1991.

<u>Inner area</u>

The inner area (or, alternatively, inner city) is defined as the part of the metropolitan area that was contiguously developed by the 1940s (that is, the pre-automobile era). Fewer complementary data items

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[45] Metro represented 77, 72, 63 and 54% of the GTA's population in 1961, 1971, 1981 and 1991, respectively (see Toronto in Appendix 2, Data Tables). In 1961 and 1971, outlying population centres were not considered part of the functional regional area, and commuting patterns there reflected this.

[46] For example, if a reference is made to the larger, post-January 1, 1998 City of Toronto, it will be referred as post-1998 Toronto, post-amalgamation Toronto, or the Megacity.

are required for this area, so complete data were easy to obtain in most cases. Furthermore, because the area definitions were highly precise (down to the intersecting streets) and the area usually fell within the jurisdiction of the central-city municipality, data reliability is quite high.

Table 20 - Canadian inner area definitions (1991)

City	Administrative Unit	Names
Calgary	Community District	Altadore, Banff Trail, Bankview, Bridgeland/Riverside, Britannia, Cambrian Heights, Capitol Hill, Canadian Forces Base Currie, Chinatown, Cliff Bungalow, Connaught, Crescent Heights, Downtown East, Downtown West, Eau Claire, Elbow Park, Elboya, Hilton, Highland Park, Highwood, Hillhurst, Hounsfield Heights/Briar Hill, Inglewood, Killarney/Glengarry, Lincoln Park Redevelopment, Mayland Heights, Mission, Mount Royal Lower, Mount Royal Upper, Ogden, Parkdale, Parkhill/Stanley Park, Queens Park Village, Ramsay, Renfrew, Richmond, Rideau Park, Rosedale, Rosemont, Roxboro, Rutland Park, Scarboro, Scarboro/Sunalta West, Shaganappi, South Calgary, Spruce Cliff, St. Andrews Heights, Sunalta, Sunnyside, Triwood, Tuxedo Park, University of Calgary, University Heights, Victoria Park, Vista Heights, West Hillshurst, West Mount Pleasant, Windsor Park, Winston Heights Mountview
Edmonton	Zone	1-12, 20, 21, 28, 42-46, 60, 61, 69-72, 74, 82, 83
Montreal	Secteur	1 Montréal: Centre-Ville, 2 Montréal: Centre-Ville périphérique, 3 Montréal: Sud-Ouest, 4 Montréal: Notre-Dame-de-Grâce, 5 Montréal: Côte-des-Neiges, 6 Montréal: Plateau-Mont-Royal, 7 Montréal: Villeray, 9 Montréal: Saint-Michel, 10 Montréal: Rosemont, 11 Montréal: Sud-Est, 20 Mont-Royal, 21 Outremont, 22 Westmount, 23 Hampstead, 24 Côte-Saint-Luc, 25 Montréal-Ouest, 26 Saint-Pierre, 27 Verdun
Ottawa		Ottawa Inner Area, Hull CBD
Toronto	Minor Planning District	1a-1h, 2a-2l, 3c, 3e, 3g-3i, 4b-4d, 4g, 4h, 6a-6c, 6e-gh, 7b-7d, 14a
Vancouver	Local Area	Arbutus-Ridge, Central Business District, Dunbar-Southlands, Fairview, Grandview-Woodland, Hastings-Sunrise, Kensington-Cedar Cottage, Kerrisdale, Kitsilano, Marpole, Mount Pleasant, Oakridge, Renfrew-Collingwood, Riley Park, Shaughnessy, South Cambie, Strathcona, Sunset, Victoria-Fraserview, West End, West Point Grey
Winnipeg	Traffic Superzone	1, 7, 12, 13, 22, 26, 30, 33, 36

The definitions of the inner city were usually arrived at in concert with local planning staff who had knowledge of the development history of the city. Table 20 above details the inner city definitions for the Canadian cities in the study. Maps outlining the inner city are found in Appendix 1. Each city's inner area usually described as an agglomeration of neighbourhoods, districts or traffic zones as shown in the table.

Central Business District (CBD)

The Central Business District is defined as the area with the most significant employment concentration in the metropolitan area. The CBDs are usually defined by the central-city planning department and data availability and reliability is high. Table 21 below provides the CBD definitions for the Canadian cities in the study. Maps outlining the CBDs are found in Appendix 1.

Table 21 - Canadian central business district definitions (1991)

City	Administrative unit	Names
Calgary	Community District	Chinatown, Downtown East, Downtown West, Eau Claire
Edmonton	District	1 CBD
Montreal	Secteur	1 Montréal: Centre-Ville, 2 Montréal: Centre-Ville périphérique
Ottawa		Ottawa CBD and Hull CBD
Toronto	Minor Planning District	1e
Vancouver	Local Area	Central Business District
Winnipeg	Traffic Superzone	36

Outer area

The outer area is simply defined as the difference between the inner area and the metropolitan area. This area captures post-automobile era development and transportation patterns. Data items for the outer area are calculated as the difference between the metropolitan area and the inner area.

3.3.0.1 Population

The population data are collected for the metro area, inner area and CBD, and are derived for the outer area. The accuracy of this item is important as it is used to standardize many of the other data items for comparative purposes. The population data are considered highly reliable as the study years fall on census years. Municipal governments typically have special reporting done from Statistics Canada (Statscan) to disaggregate data by the administrative units used locally. The matching of population to area is therefore quite precise. In some cases, notably in **Vancouver** (inner area 1961) and **Edmonton** (inner area for all years), census tract boundaries may not have corresponded perfectly to area definitions. In these cases, estimations were made based the proportion of the census tract falling within the boundary (with allowances for undeveloped land, etc.). Since these adjustments represented a small proportion of the population counts for the areas in each case, the accuracy of the estimates remains quite good. Furthermore, as Statscan uses the same data collection methodology in each city, comparability is again considered high.

3.3.0.2 Employment

The employment figures collected are for "jobs" or "place of work," rather than "labour force." The distinction is crucial as the former measure how many jobs are located in a particular area, while the latter measures how many people living in an area have jobs. For example, the CBDs of most cities will have a very high number of jobs located there (with people commuting in), while its labour force (the number of people living there that have jobs) will be quite small. Moreover, the jobs of the CBD-dwellers may lie outside the CBD.

Employment data are obtained through city planning departments. These data have either been obtained through Statistics Canada or through municipal surveys and censuses. Employment data are collected for the CBD, inner area and metro area and are derived for the outer area.

3.3.0.3 Urbanized area

Urbanized areas measure the total amount of urbanized land in metropolitan region as defined for this study. The areas used in this study are net areas, as opposed to gross areas. Net areas measure all urban land in the region (residential, commercial, industrial, institutional, transportation, utilities, local parks and open spaces and abandoned urban land), less all the non-urban land (such as undeveloped land, regional scale open spaces, land zoned urban but not yet developed, forests, agricultural land, and waterways). Gross areas will include all land within an administrative boundary such as a census metropolitan area (CMA) or a regional district, regardless of the use of lands within it. Areas are also calculated on the same basis for the inner city and CBD as defined in the preceding sections.

The data were mostly obtained from detailed land use inventories provided by planning authorities with non-urban land excluded. Where local land inventories did not exist for certain years (particularly 1961 and 1971 in some cities), I measured the areas manually with a planometer[47] from detailed land use maps of the appropriate year. This measuring process was a very labour intensive task and took up to one day for each map. Both the land inventory and planometered land area data are of high quality.

Since urban land areas are used to derive urban densities, its appropriate measurement is critical for the formulation of meaningful urban policy. With the ratio of urban to non-urban included in administrative boundaries varying dramatically from region to region, the use of gross densities renders comparisons meaningless. In these cases, urban density has little utility as an indicator of the actual intensity of activity. For example, generous administrative boundaries (such as in Edmonton and Vancouver) will understate densities, while more constrained administrative boundaries (such as in Toronto and Montreal) will overstate them. The implications of over- or understated urban densities are profound for policymaking, particularly in the case transportation and land use planning.

Unfortunately, much of the planning literature using urban areas and densities do not to discriminate adequately between gross and net measures, or are not clear about methodology. Table 22 below compares the density figures found in a three studies, each ranked relative to density published in

Raad and Kenworthy (1998). In all cases, noteably different rankings are found. In some cases, namely Rothblatt (1994), differences in urban density calculations are dramatic. For example, Rothblatt's density for Edmonton (presumably calculated on regional administrative boundaries) yields a density of 2 p/ha, a figure that is essentially rural. Such statistics are clearly an unsound basis for policy analysis and formulation.

Table 22 - Comparison of urban density measures

	IBI Group (1994)[48]		Raad and Kenworthy (1998)		TAC (1996)[49]		R/ K '98	Rothblatt (1994)		R/K '98
	Urban Density[50]	Rank	Urban Density	Rank	Urban Density	Rank	Rank	Urban Density	Rank	Rank
Toronto (GTA)	26.8	1	25.9	4	24.7	2	4	10.4	2	3
Montreal (RM)	22.6	2	33.8	1	25.2	1	1	11.9	1	1
Vancouver (GVRD)	12.5	7	20.8	6	6.2	5	5	6.1	3	4
Edmonton	15.2	4	29.9	3	9.0	4	3	2.0	4	2
Calgary	13.4	5	20.8	6	-	-		-	-	
Winnipeg	13.3	6	21.3	5	-	-		-	-	
Ottawa (RMOC)	20.8	3	31.3	2	19.4	3	2	-	-	

3.3.0.4 Parking supply

Parking supply data are collected for the CBD area only. These data are usually easy to obtain through the central city government as parking inventories are updated regularly. These numbers include both private lots as well as and municipally owned lots and on-street spaces and are counted through surveys or taxation records.

The spaces are disaggregated to show the number of on-street and off-street spaces. This classification is useful as it gives an indication of the degree to which a municipality is willing to control travel demand and vehicular flow. For example, ample provision of on-street parking (in proportion to off-street) may indicate a willingness to sacrifice vehicular flow to accommodate parking needs. Meanwhile, a high number of off-street spots indicate loose parking controls and a willingness to accommodate long-term commuter parking.

Although inner area parking data would also be useful, these data are not widely collected or regularly updated by municipalities.

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47 A planometer is an electronic measuring device that when moved on a flat surface accurately calculates areas.
48 IBI Group's densities are based on 1990 figures. The remaining authors quote 1991. Because temporal variation in urban density is quite small, the figures provide satisfactory comparability for illustrative purposes.
49 Although TAC's base year was 1991, some cities have provided data for years other than 1991; Edmonton is 1994, Montreal is 1993 and GVRD's urban area is 1991, while its population is 1992. Urban density was calculated for the TAC report using the figures provided for urbanized area and population.
50 All urban densities are in persons per hectare (p/ha).

3.3.0.5 Road supply

Road supply is a measure of the total number of kilometres of all classes of paved roads in the metropolitan region, from freeways down to local collectors. These are measured in centre-line kilometres. As a result, this measure does not give an indication of the total capacity of a city's road system. For example, two cities may have the same number of centre-line kilometres of roadway, but one may have many more 4 and 6 lane arterials, and therefore more capacity. A more a appropriate measure of capacity is lane kilometres (centre-line kilometres on a roadway multiplied by the number lanes). However, this measure is not widely available and is provided only for selected cities for 1991.

The measure of centreline kilometres is still useful as it gives a rough idea of general infrastructure requirements to service its land use pattern (this figure can also be generalized to water and sewer line requirements).

The road supply data have been disaggregated by road class, providing data users with a rough idea of the capacity mix of the roadway system. Because of inconsistencies in the classification of roads between municipalities, road classes are generally not comparable. For example, some municipalities may only have two classes of roads whereas others may have as many as five, or more.

3.3.0.6 Vehicles on register

Vehicles on register measure the total number of motor vehicles registered in a metropolitan area, less commercial and utility trailers. Generally high quality data broken down by municipality and class of vehicle are available from the various provincial ministries responsible for motor vehicles. Statistics Canada also compiles annual motor vehicle statistics in its annual publication titled Motor Vehicle Registrations, which also breaks data down by municipality. In some cases it is easy to get data that correspond to the metro area definitions. Where data were not available from the provincial sources for a particular year, the Statscan publications were used (this was usually necessary for 1961 and 1971 in most cities). The Statscan publication is drawn from provincial sources and a comparison of the Statscan publication with the provincial sources indicate no great discrepancies. Data accuracy is therefore considered high.

Over time, sub-classifications of vehicle registrations have changed from city to city. For example, some cities lump trucks and buses into one category, some disaggregate them, some have one catch-all label for commercial vehicles and some have yet other classifications for vehicles. These categories often change over time. However, passenger cars are always classified separately. For the purposes of this study, two grouping of vehicles are used to overcome this confusion: **passenger cars**, which simply refer to private automobiles (cars, pickups, vans, sport utility vehicles) and **total vehicles**, which refers to the total of passenger cars and all other vehicle classes (buses, trucks, commercial vehicles).

3.3.0.7 Private transportation

Private transportation indicators were obtained from the regional government agencies in Vancouver, Toronto, Ottawa and Montreal and the city governments in Edmonton, Calgary and Winnipeg. These data are usually obtained through:

- computer traffic models (e.g., for VKT, fuel consumption and average network speed);
- household surveys (e.g., for average vehicle occupancy);
- roadside/screenline counts (e.g., for average vehicle occupancy and vehicle.kms. travelled);

Data for the private transportation indicators, where available, is generally quite good, with the exception of fuel consumption in many Canadian cities (see Private Transport Energy Use below). Data items such as VKT and vehicle occupancies were not widely collected prior to 1981 in some cities. In general, data availability and reliability for all private transportation indicators is best for 1981 and 1991. Therefore, comparative analysis between data items and cities is best for these years.

Total annual vehicle kilometres travelled (VKT)

Total annual VKT refers to the cumulative number of kilometres travelled on all roads by all vehicles (trucks, cars, commercial vehicles) within the metropolitan area during the study year. VKT provides an indication of private motorized vehicle use, in aggregate, in each city.

VKT is derived from computer models in most metropolitan areas. In Winnipeg, transportation planning staff provided data based on extrapolation from screenline counts and road volumes. VKT data were difficult to obtain for most cities prior to 1981. Most notably, Toronto, Montreal, and Vancouver were not able to provide any pre-1981 data. Edmonton was not able to provide data pre-1991.

In some cities (namely Ottawa and Winnipeg), total VKT and car VKT are not modelled or calculated separately. In these cases, car VKT (see below), which is more widely available, was used to estimate total VKT. Using data available on commercial vehicle traffic and volumes, traffic engineers can make fairly accurate estimations of total VKT. Total VKT is usually 10-15% higher than car VKT in most cities.

Total annual VKT in cars

Total annual VKT in cars simply indicates the amount of kilometres travelled by private cars (that is, total VKT less commercial vehicles, trucks and buses). Private car VKT is more widely used than total VKT in analyses in this study as car VKT represents the bulk of VKT travelled and is usually more accurate. It is also a more useful and relevant indicator for the purposes of this thesis: formulating urban transportation policies related to dependence on cars for personal travel needs.

Average vehicle occupancy

Average vehicle occupancy measures the average number of occupants in private cars over a 24 hour period, 7 days a week. Occupancy is usually measured from random surveys conducted by municipal and regional agencies on the driving patterns of residents. Vehicle occupancy is useful as an indicator of the occupancy intensity of cars.

Car occupant kilometres

Vehicle occupancy is also useful to calculate car occupant kilometres. Car occupant kilometres is the average car occupancy multiplied by car VKT and measures the total amount of passenger travel done by private cars in one year. The car occupant kilometres measure is useful in comparing the amount of passenger travel done by car versus the amount of passenger travel done by transit.

Average road network speed

The average road network speed measures the average speed of motorized vehicles in a region over a 24 hour, 7 day period. This figure is usually generated from transportation models. However, in Canada, it is not widely available. Generally, only peak-hour speeds are available.
Since road network speeds are not widely available on a consistent basis for the Canadian cities, they will not be widely used in this study. However, they are useful as complementary pieces of data for individual metropolitan areas and are therefore provided in the data sheets for reference.

Transport energy use

Transportation energy use measures the amount of fuel (gasoline and diesel) consumed by private transportation within the metropolitan area. In the Canadian cities, this data is not widely available. While some modelling has been done in 1991 for some urban areas (Toronto, Vancouver and Montreal), accurate modelled data were simply not available from any planning agencies for other cities or other years.

I was able to obtain fuel sales data for each of the individual cities for 1973, 1981 and 1991 for all the Canadian cities through Kent Marketing Ltd.[51] Kent collects fuel sales data from retail sales records of gasoline vendors in each city. However, these sales do not necessarily measure fuel consumed in the metropolitan region accurately for several reasons. While sales are a relatively accurate reflection of

[51] The only exception was 1973 data for the City of Calgary.

demand for fuel in some metropolitan areas, it is not an accurate measure of *consumption* within a designated area. For example, some fuel may be bought within the metro area and consumed outside the metro area, or vice versa. Some areas, such as the GVRD, experience a significant amount of cross-border refuelling from residents in southern municipalities going to the U.S. to purchase cheaper gasoline.

While the fuel sales data provide acceptable anecdotal evidence of fuel consumed, they should be used with a degree of caution.

3.3.0.8 Journey to work data

The modal split for the journey to work measure the proportion of people travelling to work in each mode (car, transit, walking and cycling). Trip lengths measure the average length of trips for work as well as other purposes. In most other countries, this information is collected from census data.[52] Ideally, this provides for highly consistent data. However, Statistics Canada has only starting collecting these data as of the 1996 census. Therefore, transportation surveys are the primary source of this information.

3.3.0.9 Public transport indicators

Public transit data were collected from two sources: the individual transit operators in each city and the Canadian Urban Transit Association (CUTA). CUTA is the association of Canadian transit operators and, among its many functions, serves as a research body and clearinghouse of information for them.

In Vancouver, Edmonton, Calgary and Winnipeg, there is only one agency responsible for the management and operation of transit services in the region making the collection of transit data relatively straightforward. However, in Toronto, Ottawa-Hull and Montreal multiple transit companies operate within the region. The Ottawa-Hull region has two transit operators: O-C Transpo on the Ontario side and Societe Transport Outaouais (STO) on the Quebec side. In the Greater Toronto area, data were collected from the Toronto Transit Commission (TTC), which covers Metro, as well as from GO Transit (regional commuter transit) and 14 transit agencies operating outside of Metro.[53] In Montreal, transit data were collected for STCUM (Société de Transport de la Communauté urbaine de Montréal), which serves the MUC, as well as for the two off-island operators in Laval and the South Shore. Both Canadian Pacific (CP) and Canadian National (CN) provided data for commuter rail operations in the region.

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[52] Questions on the census will typically ask the mode of transportation used and the work address, which are then used for making mode type and distance calculations.

[53] For Toronto's 1961 and 1971 data, only TTC statistics were used. This is because data were only available for Metro in these years, as opposed to the entire GTA. See "territorial area definitions" on page 74 for a discussion of the use of Metro data for 1961 and 1971 versus GTA data for 1981 and 1991.

In most cities, accurate records of transit system performance have been kept for all study years (back to 1961) as part of the regular reporting of operations. However, some data were compiled using different methodologies, particularly in earlier years (1961, 1971) where data collection standards were not as detailed. Research staff at CUTA assisted by reviewing the data, filling in gaps and providing corrections as necessary. The data for Canadian transit operators were rigorously review and are considered accurate and reliable.

Two data items, passenger boardings and trip length, are considered to be "softer" data. The implications are discussed below.

Vehicle kilometres travelled

Transit vehicle kilometres travelled are the total number of kilometres travelled in revenue operation by a transit operator in one year. The data typically provide a the transit vehicle kilometres by mode (motor bus, trolley bus, LRT, subway, commuter rail, ferry, etc.). This is a standard reporting item for transit operators. Data are considered accurate as operators have detailed knowledge routing and service. Some transit operators include what are known as "deadhead" kilometres (non-revenue driving such as going back to the garage empty), however data screening ensured these kilometres were excluded.

Passenger boardings

Passenger boardings are the total number of *unlinked* trips taken by passenger in one year. An "unlinked" trip refers to any boarding of a transit vehicle. A "linked" trip refers to one trip, origin to destination. In many cities, passengers may "transfer" from one vehicle to another to complete a trip, using only a paper transfer. Therefore, calculating unlinked trips precisely is not possible. To calculate "unlinked" trips, transit operators will provide an estimation of the 'transfer rate' (usually approximately 70%) which is then used to "delink" the trip numbers provided. Some transit agencies will automatically report both linked and unlinked trips.

The use of linked trips would be simpler in the Canadian context, however, the majority of the transit operators in the global CAAD study report unlinked trips because of the nature of their fare structures (for example, some systems charge a fare upon each boarding or have automated fare systems). To ensure comparability and standardization between all cities the convention of using "unlinked" trips was adopted.

Brendon Hemily, Research Manager at CUTA, notes that transit operators in Canada are asked to record the "estimated percentage of revenue passengers transferring on regular service" as part of their annual reporting to CUTA. Hemily indicates that transit systems believe that, on average, their boardings estimates are 93% accurate. However, since the transfer rate probably does not include second or third transfers by revenue passengers, boardings are likely underestimated and "no better than 90%" accurate (Hemily 1998).

Average trip length

Average trip lengths by public transit are reported by transit agencies and are estimated through regular trip surveys conducted by transit operators of ridership travel characteristics. Sometimes average trip lengths are also reported by regional government agencies collecting information on regional travel.

Passenger kilometres travelled

Transit passenger kilometres provides an estimation of the total amount of passenger travel on transit. It is calculated by multiplying the number of unlinked trips taken by transit by the average trip lengths of these trips. Since this number involves the multiple of these two estimates, it is considered a "soft" indictor. While passenger kilometres are not highly precise, the estimates of trip lengths and 'unlinked' trips provide an acceptable degree of accuracy for analysis.

Transit passenger kilometres is a particularly useful indicator when used in conjunction with car occupant kilometres. Taken together, they indicate the proportions of regional passenger travel taken by car and by transit.

Average speed

The average speed of transit is simply the total number of revenue kilometres travelled by all vehicles while in revenue service, divided by the total number of hours logged (that is, total distance in kms. divided by total time required hours). These speeds are disaggregated by mode where possible. Average speed of transit is useful as an indicator of transit priority in cities and can be compared to car speeds to determine speed competitiveness.

Energy consumption

Energy is a major operational cost for transit agencies, therefore its usage is closely tracked for financial reporting. Energy data are supplied by transit agencies in total litres of diesel, gasoline or compressed natural gas (CNG) or in kilowatt-hours (KWh) for trolleys and rail. For ease of use, these are all converted and expressed as joules of energy.

3.3.1 Standardized Data

The standardized data appear after the raw data for each city in Appendix 1. These data provide indicators of activity intensity, per capita use, relative infrastructure and service supply, intensity of infrastructure use and transport efficiency. The standardized data combine raw data items to calculate per unit expression of a parameter. This standardization is achieved by normalizing data based on population, jobs, vehicle kilometers, hectares, etc. All data items in the 'numerator' are matched with data corresponding to the same year and geographical area in the 'denominator,' ensuring indicators are internally consistent and comparable. Where data items were provided for non-study year because of data availability problems, the corresponding population, jobs or area were used for that year (for example, if 1962 vehicle registrations were provided, the 1962 population would have been used for standardization).

3.3.2 Use of Data and Data Reliability

There are several issues one should be aware of in using and interpreting the data presented in this thesis.

Firstly, caution should be exercised in the interpretation of raw and standardized data. Standardized data merely allow for comparative analysis of trends and patterns amongst cities. However, in terms assessing quality of life and sustainability, it is the raw data that provide the most useful information about absolute changes in transportation and urban structure. Standardized data can also be deceptive if caution is not employed in its interpretation. For example, a city may experience a levelling, or even decrease, of per capita VKT between two study years. However, VKT may still have increased dramatically in absolute terms. A per capita increase will only result if the growth rate of the data item is greater than that of the population.

Growth rates and averages also require caution in interpretation. A growth rate of 10% in VKT in Toronto results in roughly 1 billion extra vehicle kilometers a year, whereas a 10% growth rate in Los Angeles results in 10 billion extra vehicle kilometers driven. The average of Canadian cities, for example, will refer to city averages rather than weighted city averages. This means that Winnipeg (population, 640,000) is given the same weight as Toronto (population, 4.2 million). Again, this provides a picture of the performance of policy in the average city in a country rather than an indication of their overall 'sustainability.'

Secondly, relying on quantitative data alone as an assessment of the performance of land use and transportation in a city is insufficient. Qualitative assessments of city characteristics and policies must also be used for a more complete and accurate understanding. For example, two areas with similar and high population densities may not be "equal" in their pedestrian and cycling friendliness. Several other intervening qualitative factors, such as the concentration of densities, the quality of the pedestrian environment, the width of road and availability of traffic calming will also influence pedestrian friendliness. The quantitative data in this thesis only provide a limited range of the information necessary and should be complemented with qualitative information.

Finally, while the data used in this thesis are of a high quality for comparative purposes, they do vary in degrees of reliability. Table 23 below provides an assessment of the general quality and reliability of the data items by city and year. Some data in this study are 'hard', while others are 'soft.' Hard data come from census materials, detailed inventorying, registration databases and the like. Meanwhile, soft data are usually those that come from transportation models (in the case of private transportation) and surveys (in the case of trip lengths and transfer rates). While there is a larger margin of error in modelled and surveyed transportation data than in the hard data, they still provide reasonable estimates of the parameters. In the case of surveys, the sample sizes are usually large enough to provide reliable data. Though some modelled data are 'soft,' they may be considered reliable based the relative quality of the modelling and acceptable as they represent a well-informed "best guess" estimate (Litman 1995). Furthermore, most of the models and methodologies used are similar from city to city, maintaining internal consistency.[54] Therefore, the indication of error provided for the soft data reflects the quality of the modelling, the degree of internal consistency and the level of trust afforded them as reasonable and confident estimations.

Where softer data are used, only notable differences are highlighted. For example, while 5-10% increase in VKT from study year to study year may be within the realm of error, a 10-20% or greater increase may indicate notable change, particularly if such growth persists over time.

Other potential errors with data include false accuracy and the multiplication of error. False accuracy involves indicating an unrealistic level of precision from imprecise data sources. For example, vehicle occupancies and transit transfer rates involve surveying and averaging. Indicating a precise result implies precision is possible. Where false accuracy is a concern, data are rounded. Multiplication of error occurs when two parameters with some degree of error are used in conjunction with one another (Hardin 1986). The combined error is larger than those items used as multiples. A level of confidence equal to the multiple of these errors should be place on such derived data.

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[54] For example, the EMME II transportation model is used in every major region in Canada to model transportation use.

Table 23 - Data quality and reliability

Data Item	Data Quality/Reliability																											
	Vancouver				Edmonton				Calgary				Winnipeg				Toronto				Ottawa-Hull				Montreal			
	1961	1971	1981	1991	1961	1971	1981	1991	1961	1971	1981	1991	1962	1971	1981	1992	1961	1971	1981	1991	1961	1971	1981	1991	1961	1971	1981	1991
Population/Area																												
Total pop.	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5	5	3	5	5	5	5	5	5	5
Urbanized area	4	4	5	5	-	4	3	5	5	5	5	5	5	4	5	5	5	5	4	5	4	5	4	5	5	5	5	5
CBD pop.	4	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
CBD area	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Inner city pop.	4	5	5	5	5	5	5	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Inner city area	5	5	5	5	5	5	5	5	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Employment																												
Region	5	5	5	5	-	-	5	4	5	5	5	5	5	5	5	5	5	5	5	5	3	5	5	5	-	5	5	5
CBD	-	5	5	5	5	4	5	5	4	5	5	5	5	5	5	5	5	5	5	5	3	5	5	5	-	5	5	5
Inner city	-	5	5	5	-	-	-	-	3	5	3	5	5	5	5	5	5	5	5	5	3	5	5	5	-	5	5	5
Parking	5	5	5	5	5	4	4	5	4	5	5	5	5	5	5	5	5	5	5	5	-	-	-	5	-	-	4	4
Road Network	5	5	5	5	-	-	-	5	5	5	5	5	-	-	-	5	5	5	-	5	-	-	4	5	-	-	-	5
Vehicles Registered	5	5	5	5	5	5	5	4	5	5	5	5	4	5	5	5	5	5	4	4	3	3	4	5	3	3	5	5
Private Transport																												
Total VKT	-	-	5	5	-	-	-	3	4	5	5	5	4	4	4	4	-	-	5	5	2	-	5	5	-	-	5	5
Car VKT	-	-	5	5	-	-	-	3	4	5	5	5	4	4	4	4	-	-	5	5	2	-	5	5	-	-	5	5
Car occupant km.	-	-	4	4	-	-	-	3	4	4	4	4	3	3	3	3	-	-	5	5	2	-	4	4	-	-	5	5
Avg. road speed	-	-	4	4	-	-	-	3	3	4	4	4	3	-	3	3	-	-	-	4	-	-	3	3	-	-	4	4
Private Energy	-	2	4	4	-	-	-	2	-	-	2	4	-	2	3	3	-	-	4	4	-	2	3	3	-	-	-	5
Mode Split	-	-	-	5	-	-	-	5	-	5	5	5	5	5	5	5	5	-	5	5	3	3	5	5	-	3	5	5
Trip Length	-	-	-	4	-	-	-	4	-	-	-	3	-	-	-	4	4	4	5	5	-	-	3	3	-	-	5	5
Transit																												
VKT	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	?	5	4	5	5	5	5	5	5	5
Pass. Boardings	3	3	3	3	3	3	3	4	3	3	3	3	4	4	4	4	4	4	?	4	3	4	4	4	4	4	4	4
Avg. trip length	-	-	4	4	3	3	3	3	3	3	4	5	3	3	3	4	5	5	?	5	3	4	4	4	4	4	4	4
Passenger km.	-	-	4	4	3	3	3	4	3	3	4	4	3	3	4	4	5	5	?	5	4	4	4	4	4	4	4	4
Avg. Speed	-	5	5	5	-	-	5	5	5	5	5	5	5	5	5	5	5	5	?	5	-	-	5	5	-	-	5	5
Energy Used	3	3	4	5	3	3	4	5	4	4	5	5	3	5	5	5	5	5	?	5	4	5	5	5	4	5	5	5

Key: 5=Excellent (<5-10% error), 4=Good (<~10% error), 3= (<~15% error), 2=not reliable, -=not available/not entered

3.4 METHODS OF ANALYSIS

The data collected for this thesis will be analyzed to determine the extent to which the variables studied influence car use, car ownership and transit use (i.e., manifestations of car dependence). The analysis in the following chapter will consist of a trend and pattern analysis that will identify some of the basic relationships between the variables studied. A correlation analysis will then be used to determine how strongly the variables influence, or are influenced by car use, car ownership and transit use.

Correlation analysis serves to measure how well two variables vary together, or how strongly they are related (Gujarati 1988; Kenkel 1984). Of course, no causal relationships can be determined, but knowing the strength of the association between these factors can help to reconcile quantitative findings with theory help and provide some initial directions for policy interventions. While a multiple regression analysis would be preferable in terms of its explanatory and predictive value,[55] it would require a much more rigorous statistical treatment that is beyond the scope of this thesis.

Issues related to the findings of the correlation analysis will be discussed in greater detail in Chapter 4.

3.5 CONCLUSIONS

Compiling useful comparative urban data is a difficult task. It requires much time, intense scrutiny and a sound methodology. The availability of comprehensive and standardized transportation and urban form data can be extremely useful in policy analysis. However, the compilation and analysis of such comprehensive information has not yet been done in Canada. Where partial data are available, the methodology in collecting them and their comparability are often questionable. A more rigorous process of collecting and screening data can provide reliable data for urban transportation policy analysis.

The methodology outlined in this chapter provides a means for collecting data that are reliable and highly comparable. The data judicious use of these data can aid an understanding of some of the

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[55] For example, one variable, such as car ownership, could be held as dependent and a series of other independent variables (density, transit supply, parking supply) can be simultaneously tested against car ownership for their explanatory value. The resultant regression equation can be used to 'predict' the dependent variable, car ownership, given changing values in density, transit supply or parking supply.

major forces contributing to higher or lower levels of car use and ownership. They can also be a useful adjunct to a policy analysis determining which public policies relieve or exacerbate auto dependence.

CHAPTER 4 – FINDINGS: TREND, PATTERN AND CORRELATION ANALYSIS

4.0 INTRODUCTION

This chapter provides an analysis of the data collected for this thesis. It draws on the larger sample of cities (46 in total) included in the CAAD update for context, but focusses on developments in the Canadian cities. This chapter has four main components:

1. a general overview of the urban development and transportation trends in Canada from 1961 to 1991;
2. a more detailed analysis of how these urban development trends are manifest in each of the seven Canadian cities;
3. an analysis, focussing on the 1991 standardized variables, of the factors that are correlated with higher or lower levels of automobile dependence; and
4. a summary of the key findings of the trend and correlation analyses.

Again, the raw and standardized data referred to in this thesis can be found in Appendix 1, for reference.

4.1 OVERVIEW OF THE TRENDS 1961-1991

Urban development in Canada's seven largest cities in the 1961-91 period has been marked by rapid population increases, urban sprawl, the decentralization of population and employment and inner city decline. These trends have been accompanied by increasing car ownership, use and infrastructure provision, as well as transit decline. While car ownership and use have increased in real terms relative to population increases, transit use has dropped. Furthermore, this decline in transit use came despite the fact that transit service per capita (as measured by transit VKT per capita) has increased in most Canadian cities over this period. One 'bright spot' in the evolution of transportation over this period was a marked revival in transit use between 1971 and 1981 because of a substantial transit investment in most cities. However, transit continued its decline thereafter, and Canadian cities have since continued along the path of increasing automobile dependence.

4.1.0 Urban Growth Trends – Inner City Decline and Sprawl

The post-war suburbanization of Canadian cities into exclusively zoned residential sub-divisions was well underway by 1961 (Linteau 1990). Therefore, the 1961 to 1991 data in this study only capture part of this post-war suburbanization picture. However, these data do reveal the continued and accelerated pace of population and employment dispersal throughout Canadian urban regions.

Figure 10 below shows the distribution of population growth between the inner and outer areas of the 7 Canadian cities in this study between 1961 and 1991. During this 30-year period, inner city populations declined in most cities to varying extents, while outer area population increased dramatically. Some cities did enjoy moderate inner city growth between 1961 and 1971. However, there was a universally dramatic drop in inner city population in all cities between 1971 and 1981. In this period alone, the decline amounted to 21% of the total inner city population of the study cities. Not only did the outer areas absorb the population losses of the inner areas, they also absorbed most of the residential population increase that resulted from urbanization, immigration and natural population growth.

Figure 10 - Inner and outer area population in the Canadian cities, 1961-91

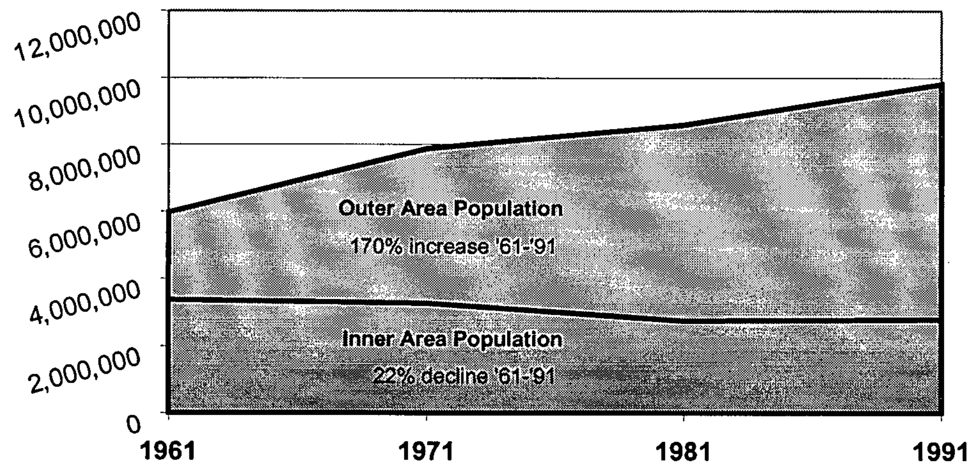


Figure 11 below demonstrates how inner cities have declined in regional importance in the 1961-91 period. Inner areas contained a substantial 74.8% of these cities' populations in 1961. This share of regional population declined in each successive study year to represent roughly one quarter of regional populations by 1991. Despite the losses in inner city population during this period, Canadian cities still have inner cities that are relatively well populated and vibrant compared to their U.S. counterparts (Raad and Kenworthy 1998) and some seem to be experiencing a healthy 'reurbanization' post-1981 (though modest compared to outer-area growth).

Employment, too, has been increasingly decentralized in Canadian cities, as indicated in Figure 11 below. Unlike inner area population, inner area jobs[56] grown in absolute terms in most Canadian cities

[56] 'Employment' as a term, differs from 'jobs' in the context of this thesis. Employment refers to the number of people that are employed within a specified area. However, these people may or may not be employed within that same area they live in (e.g., they could live in the inner area and be employed, but that employment may be in the outer area). 'Jobs' refers to the number of jobs *located* in a specified area (i.e., place of work). For example, the 'number of jobs in the inner area' refers strictly to the number of jobs located within that area, regardless of how many people in that area are "employed".

from 1961 to 1991 (some cities saw declines in 1981). However, outer area jobs growth has continued to outpace inner area growth.

Figure 11 - Inner area share of regional population and jobs in the Canadian cities, 1961-91

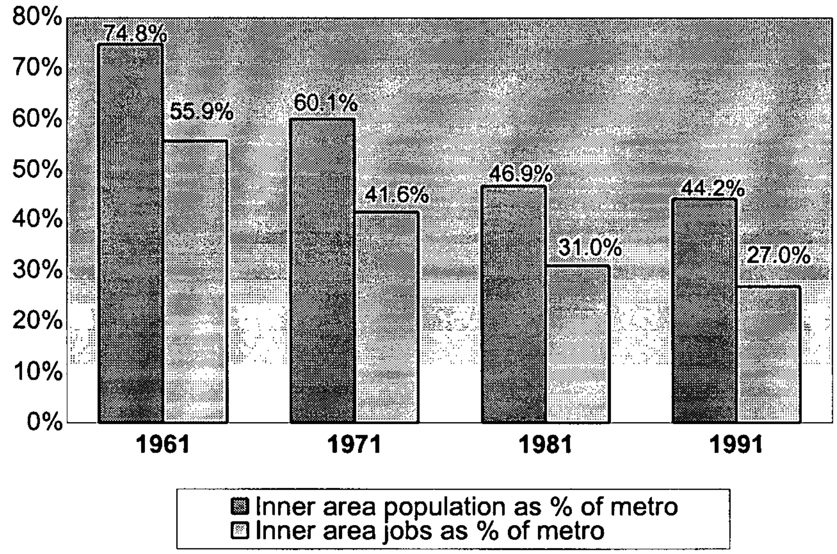
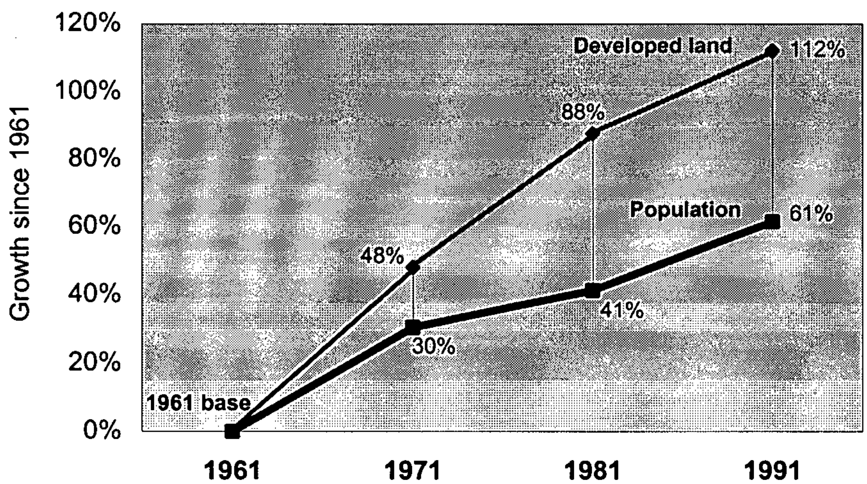


Figure 12 - Growth in developed land vs. population in the Canadian cities, 1961-91[57]



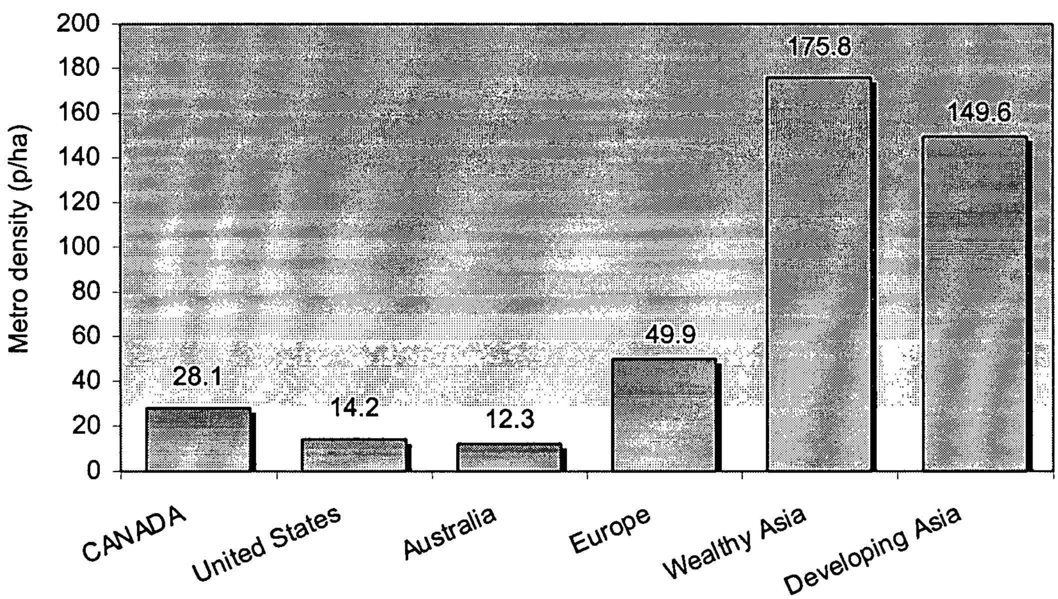
The main concern with the declining importance of inner areas in terms of population and jobs is that the outer area shares are increasingly accomodated at very low densities, thereby consuming land and making developments difficult to service by transit. Canadian urban growth in the 1961-91 period has consumed ever increasing amounts of undeveloped land (Figure 12 above). In fact, during this period the growth in land consumption outpaced the growth in population by over a factor of two. Much of this land

[57] These figures exclude Edmonton.

consumed for urban growth has been prime capability agricultural land (Environment Canada 1981; Manitoba Environment 1995; Warren, Kerr, and Turner 1989).

The faster growth in developed urban land versus population resulted in declining population densities. Between 1961 and 1991, the average urban population density of the cities in this study dropped from 36.1 to 25.5 persons per hectare (p/ha). Outer areas (where most growth was concentrated) continued developing at average densities as low as 14.6 p/ha. Furthermore, this development was often exclusively zoned, formless and difficult to serve by transit. Perl and Pucher (1995) indicate that the urban decentralization and suburban development characteristic of much of this outer area development preclude the viability of virtually any mode but the car. The decline in total urban densities and continued spread of low-density outer areas is particularly worrisome given empirical studies showing transit ridership and viability, as well as the suppression of car ownership levels, are greatly diminished at densities below roughly 30 p/ha (Newman and Kenworthy 1989a; Pushkarev and Zupan 1977). As will be pointed out later in this chapter, the decline in urban density has been more accute in some cities than others. Even in cases where density is increasing, sprawl continues unabated.

Figure 13 - Average urban densities in 46 World cities, 1990/91



In the international context, Canadian cities sits atop a league of low-density cities (Figure 13 above). Canadian urban densities pale in comparison to those in wealthy and developing Asia. However, Canadian densities are still more than twice as high as their U.S. and Australian counterparts, which followed similar car-based urban development models in the post-war years. In turn, the European cities are nearly twice as dense as the Canadian ones. The density profile of Canadian cities midway between its transit-oriented European and auto-oriented U.S. and Australian counterparts provides an interesting positioning for comparative purposes. As I will show shortly, in terms of transportation, the European cities offer an urban model to aspire to while the U.S. and (to a certain extent) Australian cities offer ones to avoid.

4.1.1 Transportation Trends – Increasing Car Dominance and Transit Decline

A phenomenon that parralels developments in urban growth in Canada is the increasing dominance of the car's role in urban transportation and transit's declining role. Private car ownership, use and infrastructure provision have all grown faster than population in the 1961 to 1991 period. Meanwhile, transit use in Canadian cities has transit has been declining in real terms, failing to keep pace with population growth. This decline comes despite the fact that transit service provision (in terms of transit vehicle kilometres (VKT) per capita) has increased almost universally in every year since 1961.

Similar to the manner in which the growth in developed land outstripped population growth, so too did car ownership. During the 1961-91 period, car ownership growth was 2.5 times the growth in population, rising from 1.3 million vehicles in the seven study cities in 1961 to just over 3.3 million in 1991. Growth was particularly strong in the 1971 to 1981 period, coinciding with the inner city decline and outer area boom mentioned earlier.

Figure 14 - Growth in car registrations versus population in the Canadian cities, 1961-91

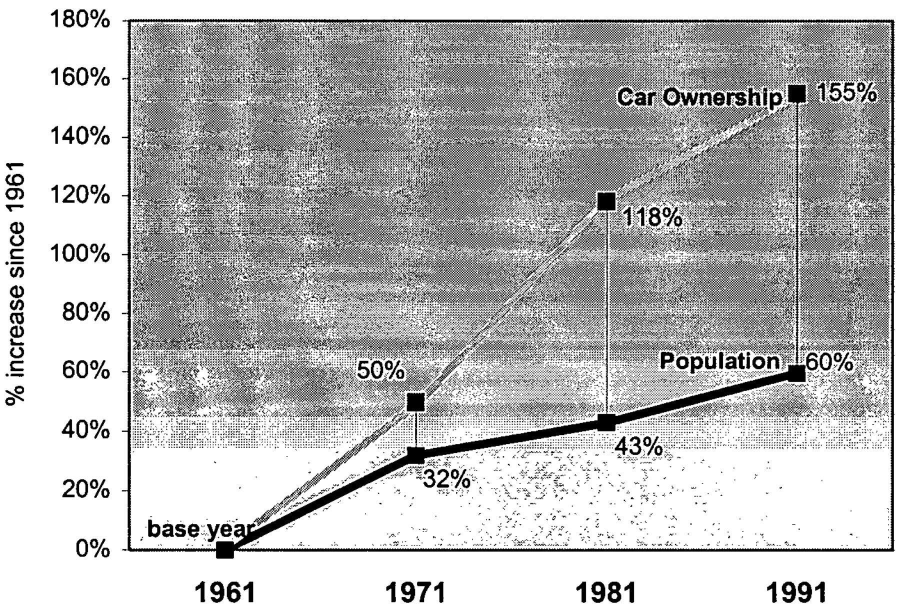
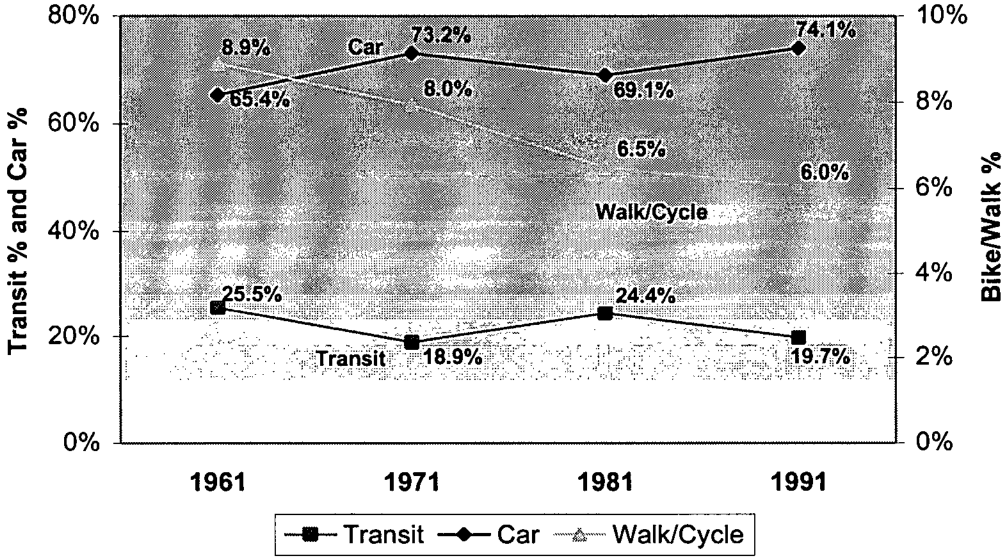


Figure 15 - Average modal split in the Canadian cities, 1961-91



The changing modal shares for cars, transit and walking and cycling (or non-motorized transportation – NMT) reveal an overall decline in transit and NMT shares and an overall increase in the share of car use.[58] One particularly worrisome trend is the continued decline of NMT as a share of total travel. One possible explanation for this trend is that roadway severence, automobile priority and traffic domination lead to the deterioration of pedestrian and cycling environments (Appleyard 1981; Calgary 1994a; Moudon et al. 1997; Perkins 1993; Sarkar, Nederveen, and Pols 1997; Zein et al. 1997). Since transit requires high quality pedestrian and cycling environments to improve its catchment potential, this development does not bode well for transit's long-term viability.

Again, the bright spot for transit in the 1961-91 period was the ridership gains made between 1971 and 1981, and the concomitant reduction in car use share.[59] During this period, provincial governments throughout Canada were able to head off the major financial and ridership hemorraging of transit services experienced in the U.S. by extending healthy subsidies to transit systems to keep fares low and expand services (Perl and Pucher 1995; Pucher 1994; Pucher 1998). However, these gains proved unsustainable. As will be shown in the next section, transit continued its decline in per capita ridership and in per kilometer utilization post-1981, despite the fact that transit service provision is higher than 1961 levels in absolute terms in every Canadian city (as well as in per capita terms in most Canadian cities). Demographic forces have been responsible for part of the shift from transit to cars (CUTA 1991).

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[58] These modal split figures represent the modal split for the journey to work. All-day modal splits usually reveal higher car shares and lower transit and NMT shares.

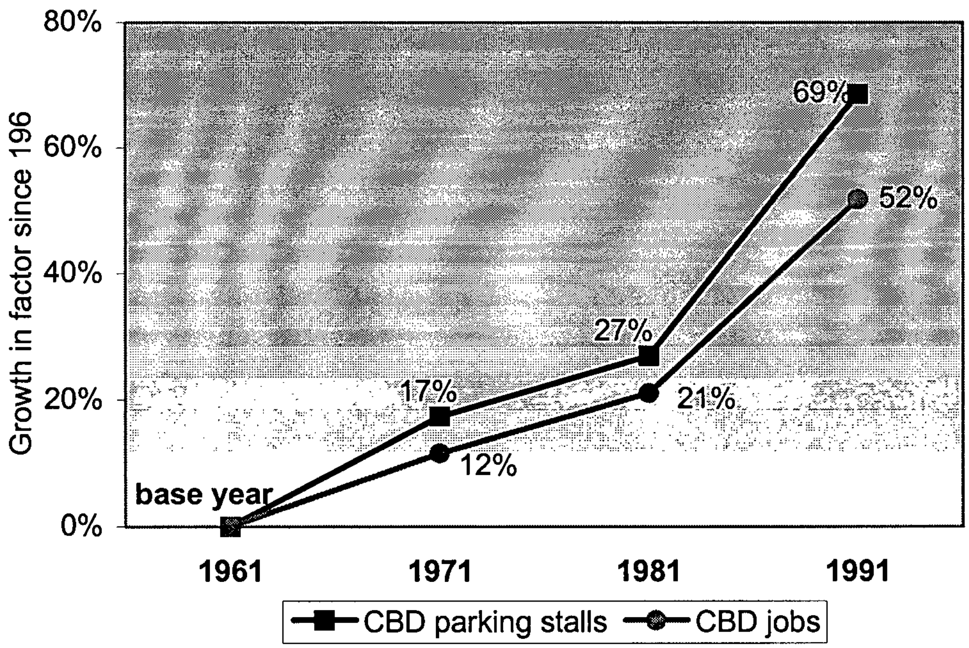
[59] This trend is somewhat of a mixed blessing. Although transit shares increased, the total demand for travel increased, and this increase tended entirely towards motorized modes (public and private). So while transit captured a larger share of the increase in travel, car travel still increased in total.

However, much of the decline in transit ridership and performance, despite the service increases, can also be can be attributed to the higher servicing needs (Perl and Pucher 1995) and the lower ridership returns characteristic of newer low-density suburban services.

Transportation infrastructure geared towards automobile use has also increased over the last 30 years. For example, parking supply growth has consistently outstripped jobs growth in the CBDs of the Canadian cities (Figure 16 below)[60]. The effect of this has been to make it increasingly easier (and cheaper) for CBD-bound travellers to drive and park their vehicles. Generous parking supply guidelines in many cities have been effectively demand-driven, responding to commercial demands for easy car access to properties.

Many Canadian cities have have generous minimum parking standards, while relatively few have parking ceilings (Calgary 1995a). Where ceilings do exist, they are frequently exceeded. Only a select few cities actively enforce tight CBD parking supply. This high supply of CBD parking may actually have the effect of deriving demand for more auto trips (Shoup 1997).

Figure 16 - Growth in CBD parking supply versus CBD jobs in four Canadian cities,[61] 1961-91



Road infrastructure provision has also increased along with the outward spread of the Canadian cities. Though the use of centre-line kilometers is an admittedly crude measure of car capacity, the data

[60] The graph understates the degree to which parking supply growth has outstripped jobs growth since it includes Toronto (which has tightened its supply and represents a large proportion of the jobs and parking) and excludes Montreal and Vancouver (which have had parking supply expanding faster than jobs).
[61] These cities are Calgary, Edmonton, Winnipeg and Toronto. Vancouver, Ottawa and Montreal were left out because of a lack of comprehensive time series data.

in this thesis show roughly a doubling of road length per capita in most cities. For example, lane kilometre data, which more accurately measure road supply, show substantially higher road provision in Ottawa and Winnipeg (RMOC 1994; Winnipeg 1995). The increasing ease of access by automobile to the CBDs, and throughout the regions at-large, has likely produced in many of the synergic side effects on land use and environmental quality discussed in Chapter 2.

Figure 17 below captures the basic problem with transsportation developments in the Canadian cities in this study over the last 30 years. While automobile ownership (cars per 1000 people) and automobile use have grown faster than population since 1961, transit use has consistently lagged behind. Furthermore, the increase in car use is accompanied by dropping average vehicle occupancies (Figure 18 below). While this relative loss in the importance of transit is of concern, it is even more significant given the large increases in private motor-vehicle ownership and use in absolute terms.

Figure 17 - Growth in car ownership, car use and transit use versus population in the average Canadian city, 1961-91

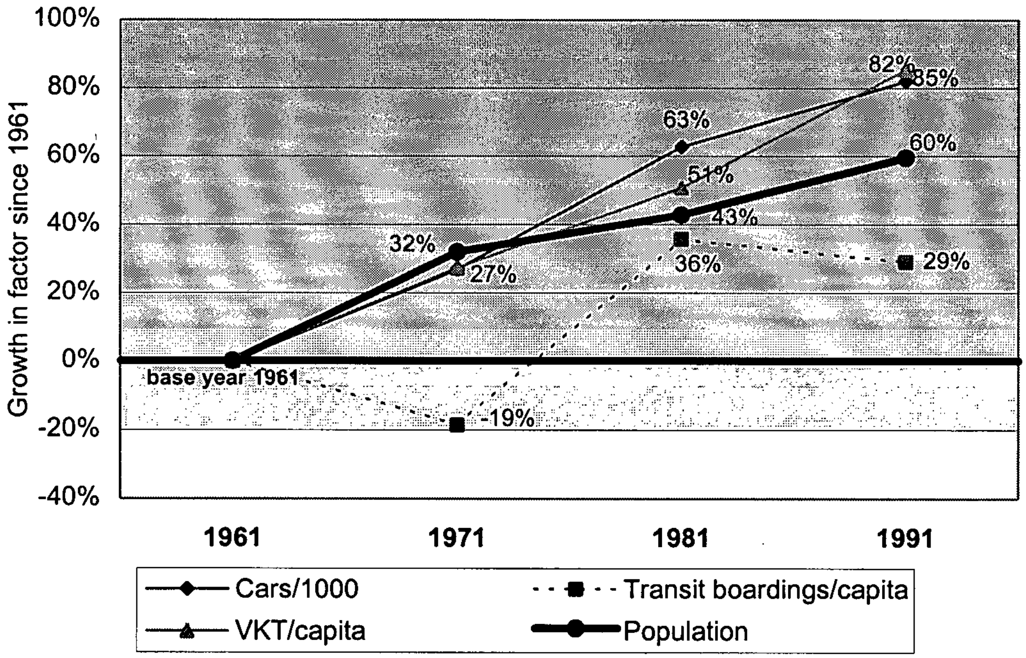


Figure 18 - Average vehicle occupancies in the Canadian cities, 1961-91

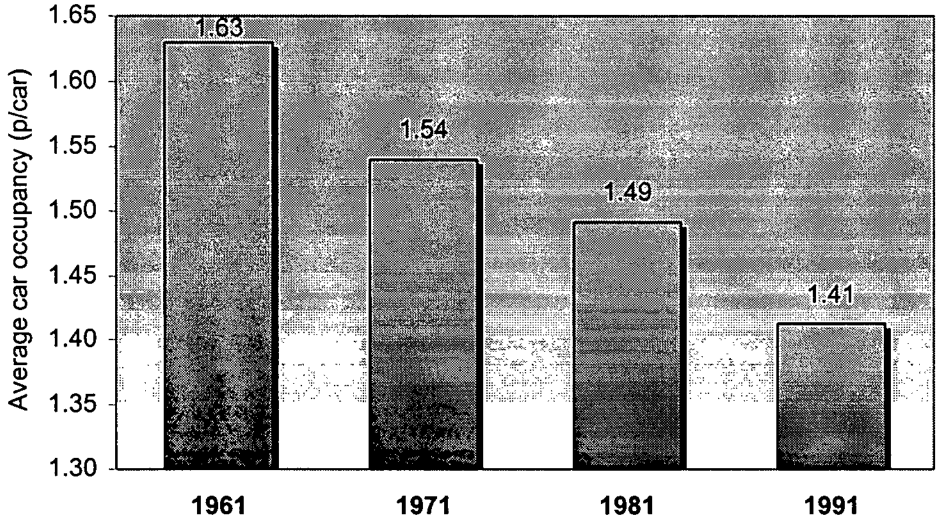
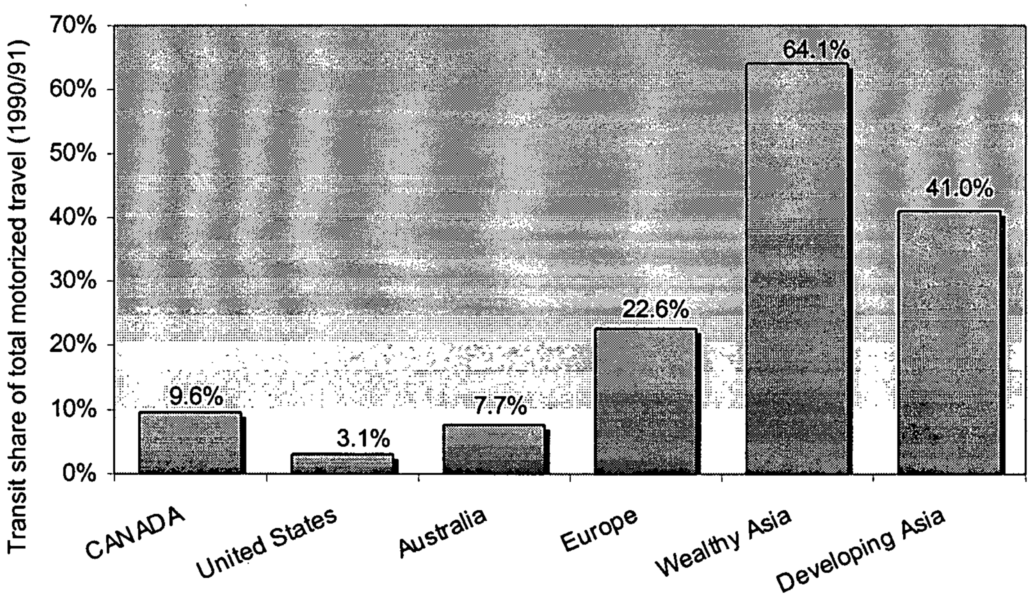


Figure 19 - Average transit share of motorized travel in 46 World cities, by region 1990/91



In the international context, Canada is relatively automobile dependent. Canada's position in terms of transportation orientation mirrors its position in terms of land use. For example, its transit use is among the lowest in the world as a proportion of total motorized urban travel (Figure 19 above). Canada outperforms the U.S. and Australia, falls well behind the European cities and is nowhere near the very high levels of transit use found in Asia. In terms of automobile use, similar patterns arise. U.S. and Australian cities drive an average of 67% and 8% more VKT per capita than Canada, respectively. Meanwhile, the Canadian cities drive 50% more on average than the European cities. Some indicators further describing Canada's relative position in terms of urban transportation performance are presented in Table 24 below. As will be discussed in subsequent sections, these same distinct transportation patterns emerge for cities depending on their urban density, transit supply and provision of automobile infrastructure.

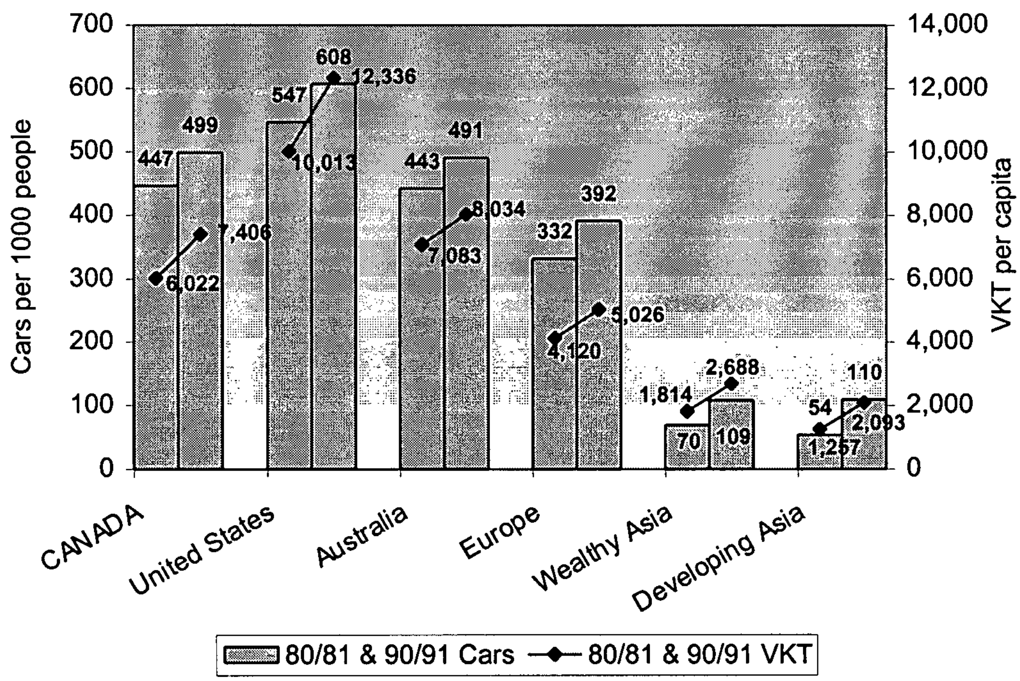
Table 24 - Land use and private and public transportation indicators in World regions, 1990/91

Region	Land Use Intensity	Car Use	Cars Owned	CBD Parking	Transit Use	% of workers using[a]		
	pop. + jobs/ha	VKT/ capita	cars/ 1000 pop.	stalls/ 1000 jobs	boardings/ capita	car	transit	NMT
United States	22.3	12,336	608	468	63	86.3	9.0	4.9
Australia	17.5	8,034	491	483	92	80.4	14.5	5.0
Canada	42.9	7,406	499	408	161	74.0	20.0	6.0
Europe	81.4	5,026	392	230	318	42.8	38.8	18.4
Wealthy Asia	275.1	2,688	109	72	487	20.2	59.6	20.2
Dev'ping. Asia	215.9	2,093	110	240	356	41.5	31.8	26.8

Note: Modal splits may not total 100% due to rounding.

In terms of trends, Canada, like Australia and the United States, experienced relatively low growth (11-12%) in vehicle ownership per capita between 1981 and 1991 (see Figure 20 and Table 25 below). However, these growth rates understate the true extent of the expansion in vehicle ownership as they added to already high levels of car ownership (in both per capita and absolute terms). For example, developing Asia's per capita increase of 104% yielded 56 additional cars per 1000 people whereas Canada's much lower 12% growth yielded an additional 52 cars per 1000. During this same period,

Figure 20 - Change in car ownership and use in the World cities, by region, 1981-91



Canadian cities experienced strong growth in car use relative to other regions. Average car VKT in Canadian cities grew by 23% from an average of 6,022 VKT to 7,406 VKT. While Europe and the U.S. also experience the same level growth, Canada's performance was worse than Europe's, since theirs grew from relatively low level, and better than the U.S., since the U.S. grew from already very high levels of VKT.

Table 25 - Change in average car own ership and car use in World cities, by region, 1981-91

	Car Ownership			Car Use		
	1981	1991	% change	1981	1991	% change
United States	547	608	11%	10,013	12,336	23%
Australia	443	491	11%	7,083	8,034	13%
CANADA	447	499	12%	6,022	7,406	23%
Europe	332	392	18%	4,120	5,026	22%
Wealthy Asia	70	109	56%	1,814	2,688	48%
Developing Asia	54	110	104%	1,257	2,093	67%

4.2 A CLOSER LOOK AT THE CITIES

While the preceding overview of urban developments paints of general picture of how Canada has developed as a nation, a disaggregated look at Canadian urban realities reveals distinctiveness of trends and patterns in individual cities that can lay the foundation for policy analysis. This section provides a comparative analysis of the development of individual Canadian cities. The comparisons clearly show that regions with lower urban densities, higher infrastructure provision for automobiles and lower levels of transit service have higher car ownership and use, as well as lower transit patronage.[62]

4.2.0 Urban Growth Trends

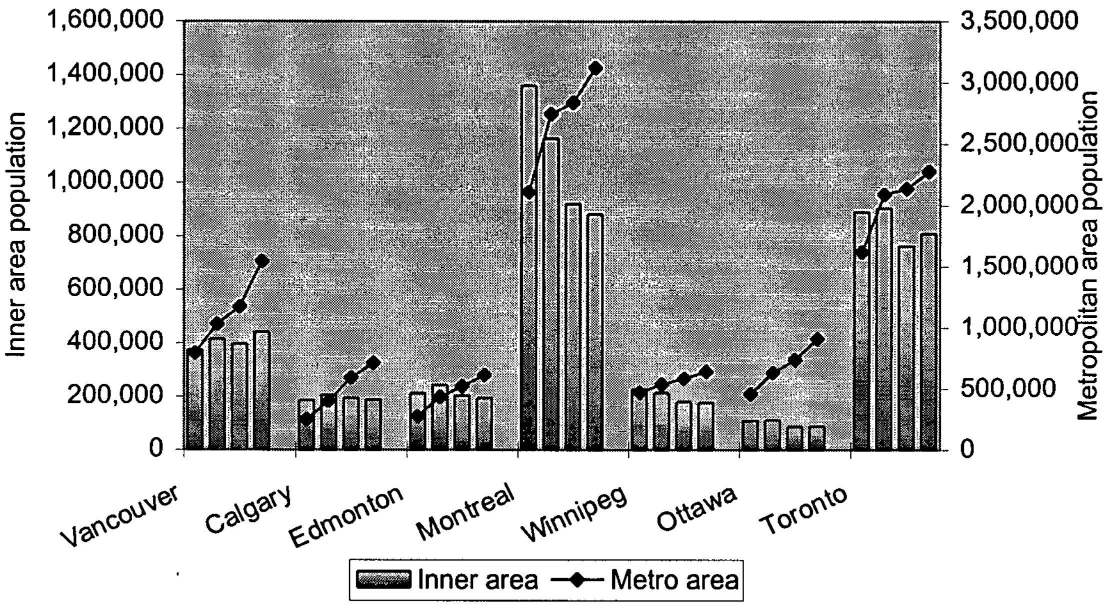
The decline in the relative importance of inner areas combined with strong outer area growth has been characteristic of most Canadian cities. This is particularly the case in Calgary, Edmonton, Montreal and Ottawa. However, Canadian cities on the whole still have quite well populated inner areas. Some cities, such as Toronto and Vancouver, actually seem to be experiencing a notable 'reurbanization' of their inner areas. Between 1981 and 1991, they each experienced inner area population increases of over 47,000 and 43,000 people, respectively. However, despite such gains (and the general stabilization of

[62] No discernible relationships between these factors and NMT use could be determined because of the lack of availability of NMT data beyond course modal split data.

inner area populations throughout Canada), the relative importance of inner areas continue to diminish amid low-density sprawl on the periphery.

Figure 21 below traces the growth in population of both the inner areas and total metropolitan areas of the Canadian cities in this study. While all the cities have faced various degrees of inner area decline, all have experienced a burgeoning of their outer areas. Calgary and Edmonton continued to experience losses in inner area population up until 1991, while Winnipeg and Ottawa seem to have witnessed a stabilization of their inner area populations. Montreal continues to see a substantial bleeding of its inner area population in the face of an explosive growth in its suburbs.

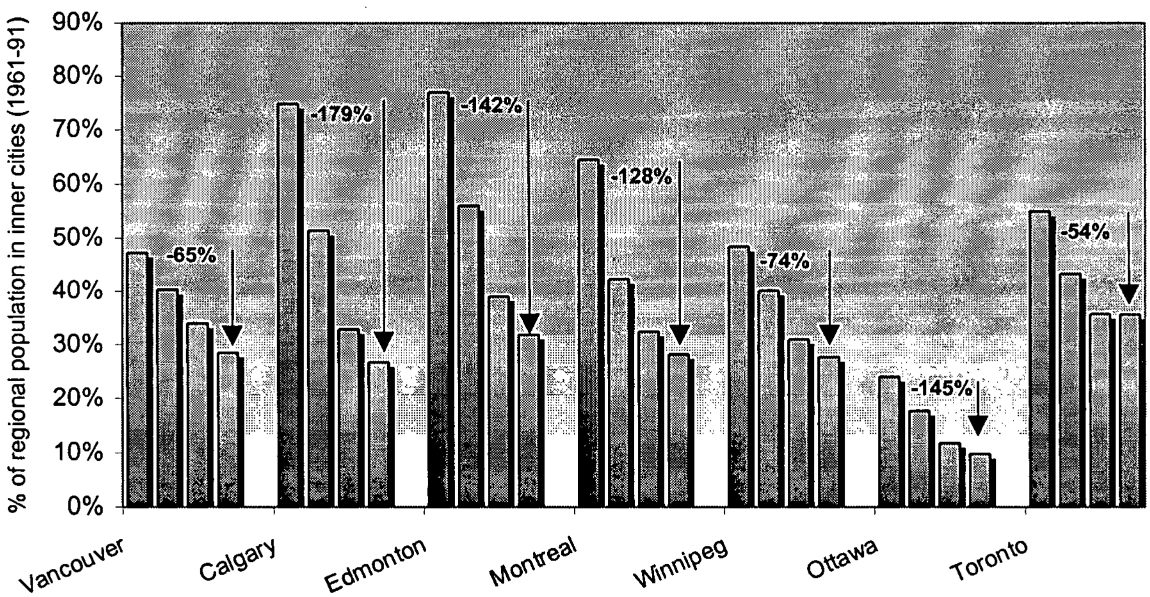
Figure 21 - Inner and metro area populations in 7 Canadian cities, 1961-91



The increasing concentration of population growth into outer areas, means that the importance of centralized activity in inner areas is declining (Figure 22 below). In Edmonton and Calgary, this declining importance of the inner areas has partly been due to inner city population losses. But most of this loss has been a function of rapid metropolitan growth, with the majority of the population increase settling in outer areas. Their metropolitan populations increased by 2.2 and 2.8 times, respectively, and almost all of this increase settled in the outer areas. While Edmonton's inner city population declined from 213,000 to 196,000 people between 1961 and 1991 (a drop of 8.7%), its outer area increased from 63,000 to 418,500 (an increase of 565%). Calgary's pattern of suburban settlement is even more unbalanced with an outer area growth of 731%.

While Calgary and Edmonton's declining inner area importance is almost singularly accounted for by metropolitan growth, Montreal's large decline is a dual function of massive hemorrhaging of their inner city population base *and* the suburbanization of new settlement. Between 1961 and 1991, Montreal's inner area population declined from 1.361 million to 883,000 (a drop of 54%). It is difficult to pinpoint precisely what ails Montreal in that there are many complex forces at play. For example, the loss of inner city population and economic importance has been attributed to political uncertainty due to separatism (Jacobs 1980) as well as economic restructuring and industrial obsolescence (Barber 1995; Coffey 1994). However, metropolitan population in Montreal still increased significantly between 1961 and 1991 and most of this increase settled in relatively low-density suburbs in Laval and on the South Shore. Significant enabling factors that facilitated this dramatic outer area growth in Montreal were political fragmentation, significant regional highway investments, the extension of trunk sewers lines and the relaxation of regulations governing the subdivision of rural land (Frisken 1994b; Sancton 1994; Trepanier 1994).

Figure 22 - Proportion of regional population living in Canadian inner areas, 1961-91



Vancouver and Toronto provide interesting cases in that have both experienced a notable process of 'reurbanization' in their inner areas. Vancouver's inner city experienced a net growth in population of 18% between 1961 and 1991, the largest gain of any city. While much of the post-1981 growth in Vancouver has been driven by immigration, conscious policies by successive civic administrations since the mid-1960s have encouraged significant densification and infill in areas such as the West End and False Creek. Additionally, densification was encouraged throughout city neighbourhoods by encouraging the conversion of single family dwellings to multi-unit dwellings. Nonetheless, this inner area population increase pales in comparison to the 165% increase in Vancouver's outer area that brought an additional 685,000 people into the region at very low densities.

Toronto, too, has been able to reverse its inner city decline since the mid-1970s through conscious policy and the benefits of immigration (Bourne 1992). However, like Vancouver, its outer areas have also experienced rapid growth far exceeding that of the inner city. In fact, this growth (and the decline in inner city share of regional population) is even more pronounced when the entire GTA is considered.[63]

Figure 23 - Metro, CBD, inner and outer area densities in the Canadian cities, 1961-91

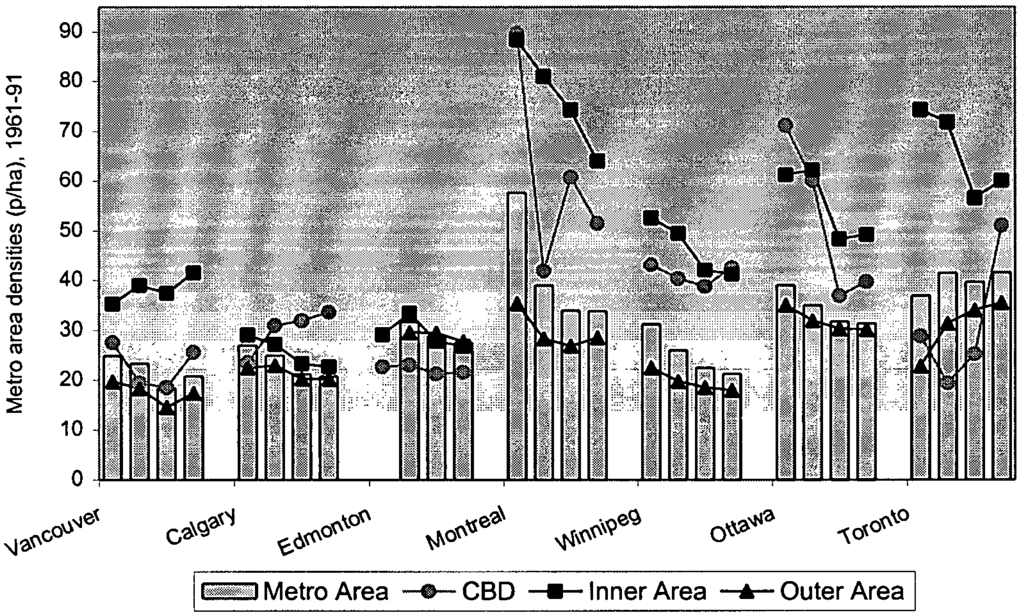


Figure 23 above shows the relative densities of the Canadian cities between 1961 and 1991. Metro Toronto and Montreal are by far the most dense Canadian cities (41.5 and 33.8 p/ha, respectively),[64] followed by Ottawa and Edmonton in the 30 p/ha range and Winnipeg, Calgary and Vancouver in the 20 p/ha range. Toronto and Montreal have the highest inner area densities in the 60 p/ha range. Ottawa, Vancouver and Winnipeg follow them in the 40 p/ha range, with Edmonton and Calgary having relatively low density inner areas in the mid-20 p/ha range. In terms of outer area density, Metro Toronto is the most dense at 35.4 p/ha. Edmonton, Ottawa and Montreal fall in at the 30 p/ha range and Calgary, Winnipeg and Vancouver have lowest density outer areas.

[63] Since Metro Toronto has been largely built-out since 1981, outer area growth and some transportation data for Metro will understate GTA-wide developments to some extent. Again, the lack of availability of comprehensive data for the GTA precludes their use in lieu of Metro data for the comparative and statistical analysis in this chapter. Metro data alone should therefore be interpreted with caution as they only provide a partial picture of regional developments. Instead, I will discuss GTA-wide developments throughout this chapter, where GTA data are available. Nonetheless, since the boundaries of Metro are fixed, they do provide useful information about how a transportation system may perform given a degree of urban containment.

[64] The GTA has a population density of 26.9 p/ha.

As mentioned in the previous section, the outward spread of cities with developed land growth exceeding population growth has resulted in dropping urban densities (Figure 23 above). A common thread in the density profile of all the Canadian cities is the decline of inner area densities and the proliferation of lower density outer areas. The most precipitous drop in urban densities was experienced in Montreal between 1961 and 1971 (dropping from a very high 57.6 p/ha down to 39.0 p/ha, with the decline stabilizing by 1981). Again, this decline is largely due to a depopulation of the inner area and the accompanying spread in the growth of the outer areas.

Only Vancouver and Toronto have experienced rising metro-wide urban densities. In Toronto, the increases in density are the result of infill development and redevelopment. In Vancouver, inner area density has similarly increased due to redevelopment and infill, as mentioned earlier. However the outer area density increases seem to be coming on the heels of restrictions of the conversion of agricultural land (due to the creation of the ALR in 1974) as well as policies aimed at concentrating significant amounts of new higher density development around 'regional town centres.'

Figure 24 - Metro densities in the Canadian cities, 1981-1991

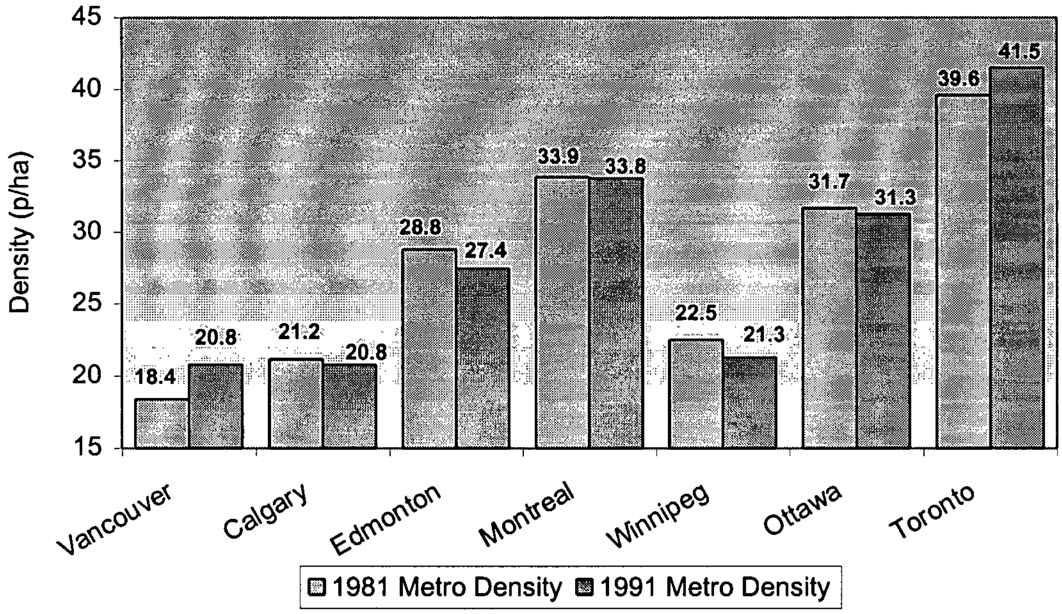


Figure 24 above shows that although the densities of Canadian cities are no longer dropping as dramatically (at least between 1981 and 1991), they are still dropping nonetheless. This trend is more worrisome than may first appear. Firstly, many urban densities are decreasing from already low levels (e.g., Calgary and Winnipeg) and the low-density spread of outer areas is accounting for the majority of the decline. Secondly, moderately declining densities still indicate sprawl – substantially so in rapidly growing cities. For example, Figure 25 below shows that in Winnipeg, Ottawa and Calgary, the spread of the urban envelope continued to be quite dramatic despite only moderate drops in urban density. For example, Calgary's density decreased by less than 2% while its urbanized area grew by more than 22% (see Table 26 below).

Figure 25 - Urbanized areas in Calgary, Ottawa and Winnipeg, 1961-91

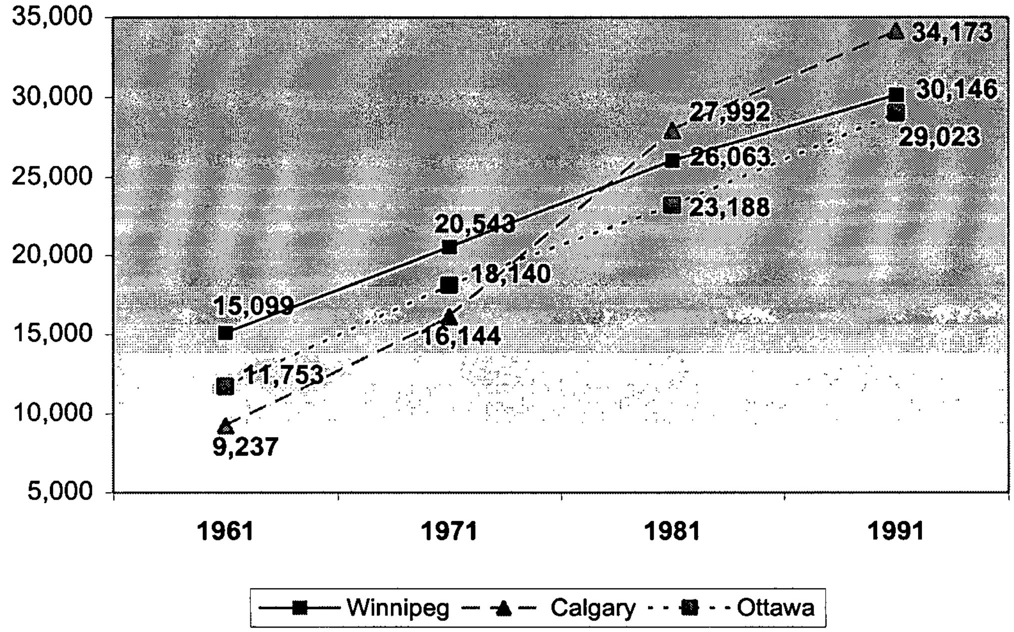


Table 26 - Effect of density changes on developed areas in three cities between 1981 and 1991

City	Decrease in density (p/ha)	% decrease in density	Increase in urban area (ha)	% increase in urban area
Winnipeg	-1.2	-5.6%	+4,083	+15.7%
Calgary	-0.4	-1.9%	+6,181	+22.1%
Ottawa	-0.4	-1.3%	+5,835	+25.2%

Cities such as Vancouver, where urban densities have actually increased, provide an even more dramatic example. Even with moderately *increasing* average densities, the prevalence of low-density development can still result in substantial sprawl. Vancouver's average density increased by 13% between 1981 and 1991. However, it's developed area continued along its three decade long growth path and increased by 17% (Figure 26 below). Although population growth in Vancouver finally outstripped developed land growth on average, its outer areas continue to sprawl at low densities.[65]

[65] It is difficult, given the data to determine the average density of new development in Vancouver from 1981-1991. A rough calculation of the average density that this new population settled at (outer population increase divided by outer area increase) yields an average density of 31.3 p/ha. However, much of the population increase (and density increase) settled in land previously considered outer area 'developed' land, but which was subsequently redeveloped (e.g., Metrotown and New Westminster). Thus, one can safely assume that the majority of 10,532 ha of new urban land in Vancouver between 1981 and 1991 developed at densities well below 20 p/ha.

Figure 26 - Metro density versus developed area in the GVRD, 1961-91

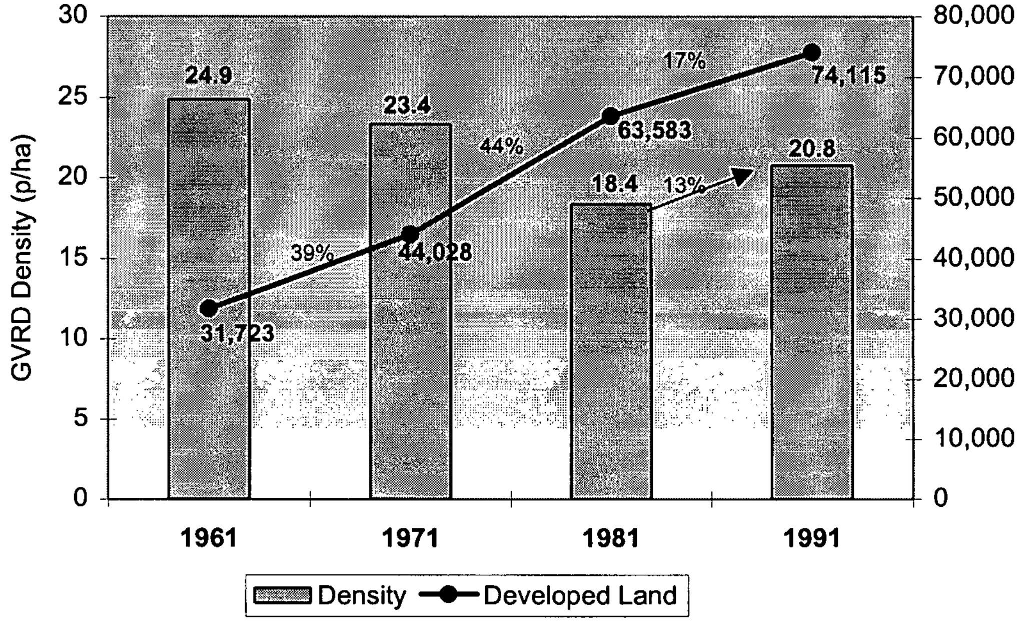
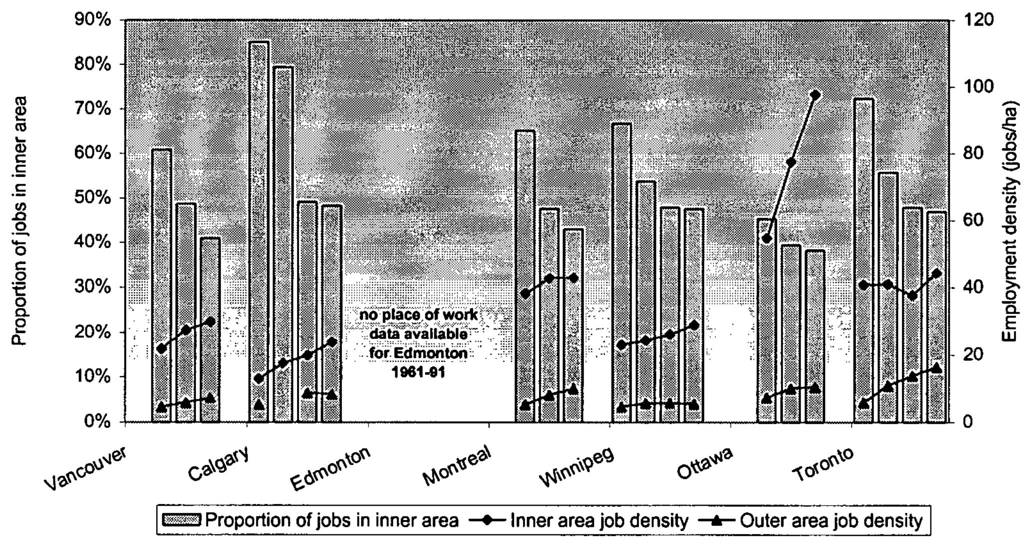


Figure 27 - Inner and outer area employment trends in the Canadian cities, 1961-91



Finally, employment distribution in the sample of Canadian cities has followed a pattern similar to population in terms of declining concentration in inner cities and dispersal into lower density outer areas (Figure 27 above). Although the inner city share of employment also decreased over the 1961-91 period, most cities appear to have stabilized their inner city proportions of population since 1981, or have declined only slightly. One positive note is that inner area employment densities (including the CBD) continued to increase due to continued jobs growth, making these areas more serviceable by transit. In absolute terms, though, outer area employment growth continued to be strong in all cities and these jobs were invariably accommodated at low, or extremely low, densities. With the exception of Toronto and Ottawa, all of the cities had outer area densities of less than 10 jobs/ha.[66]

4.2.1 Transportation Trends

All of the Canadian cities in this study show increasing levels of car ownership coupled with increasing levels of car use over the 1961-91 period (Figure 28 below). These increases were strongest in Vancouver, Calgary and Montreal, particularly between 1981 and 1991.[67] For example, these cities each showed per capita increases in car VKT driven of 23%, 30% and 45%, respectively. Ottawa, Winnipeg and Toronto, on the other hand, seem to have experienced relatively moderate growth in car ownership and use.[68]

4.2.1.0 Car ownership and use

As at 1991, Vancouver, Calgary, Edmonton and Winnipeg stand out as cities that display the highest overall levels of car ownership and use. This generally corresponds with a combination of lower densities, lower transit service provision and greater infrastructure dedicated to the automobile. Meanwhile, Toronto, Montreal and Ottawa have lower levels of car ownership and use as well as correspondingly higher levels of transit provision and use. These cities also have generally higher population and employment densities and a relatively lower level of auto infrastructure provision.

The per capita data presented in Figure 28 below present only a partial picture of the real growth in motorization in Canadian cities. Although it communicates the increase in driving done by the average person, it does not communicate the total (absolute) increase. Table 27 below shows the increase in per capita VKT, as well as absolute levels of population and VKT growth in the Canadian cities from 1981-91. While there were substantial per capita increases in Vancouver, Calgary and Montreal, the absolute increase in car VKT are even stronger. Each of these cities showed increases in the neighbourhood of

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[66] Outer area densities do not always provide a complete picture of employment dispersal, particularly in regions where significant poly-nucleation (i.e., sub-centres) exists. For example, Toronto and Vancouver stand out as two cities that have managed to create concentrated sub-centres of activity. However, even the largest of these sub-centres pale in comparison to the CBDs. Therefore, the low average outer area densities serve as sufficient indicators of dispersal for most cities, especially those without notable poly-nucleation.

[67] Edmonton appears to have experienced a strong increase in car orientation, however poor data availability pre-1991 precludes accurate trend analysis.

[68] The apparent drop in car ownership levels (per 1000 population) in Toronto between 1981 and 1991 is due in large part to changes in the collection of vehicle registration data during this period. During this period, the Ontario Ministry of Transportation (MTO) went from bi-annual to annual reporting of "inactive" vehicles. This substantially increased the number of vehicles deemed "inactive". It is therefore not possible to make accurate comparisons of vehicle ownership levels between these years, though it may be possible to assume 1981 vehicle registrations are overestimated.

60% -- even greater than the very strong 52% growth found in Los Angeles, one of the most auto-oriented cities in the United States.

Figure 28 - Change in car ownership and use in the Canadian cities, 1961-91

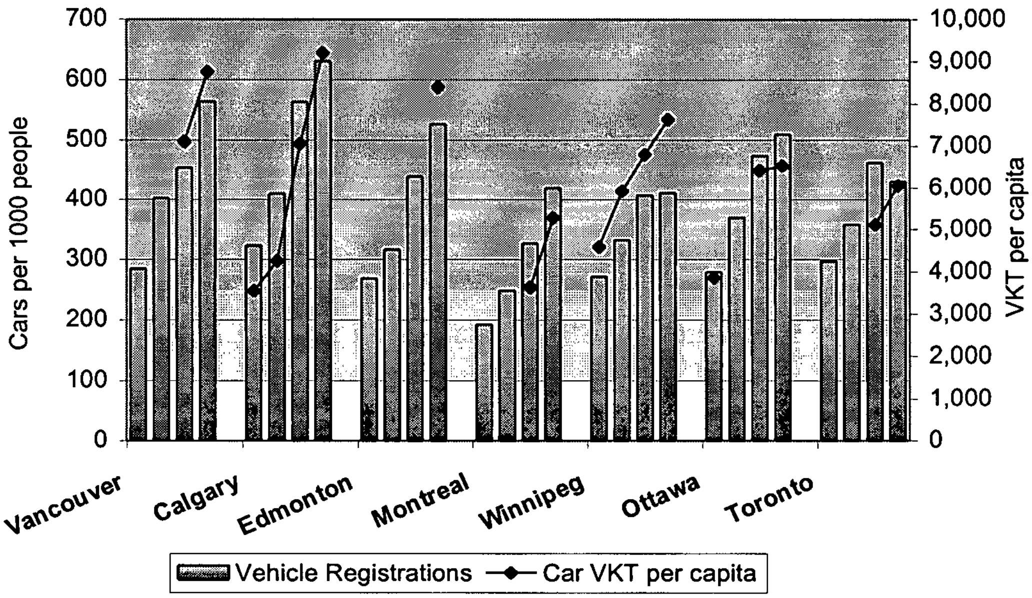

Table 27 - Increases in VKT/capita, population and VKT between 1981 and 1991

	% Increase Between 1981-1991		
	car VKT/capita	population	car VKT
Vancouver	23%	32%	63%
Calgary	30%	20%	56%
Edmonton	?	18%	?
Montreal	45%	10%	64%
Winnipeg	12%	9%	23%
Ottawa	2%	23%	26%
Toronto	18%	6%	26%

While all the cities have experienced car VKT growth far outstripping population growth, nowhere was this more acute than in Montreal. Their population only grew by 10%, while driving increased 64%. In fact, the increase in car VKT in Montreal of 6.2 billion car kilometres was the greatest of any city in Canada and exceeded the *total* 1991 kilometrage in either of Edmonton, Calgary, Winnipeg or Ottawa. Vancouver's total growth in VKT amounted to 5.0 billion VKT. This too was greater than the *total* VKT clocked in several of the medium sized Canadian cities, and is in some respects of greater concern than Montreal's increase given Vancouver's population is less than half of Montreal's.

Of course, such strong growth in motor vehicle use increases the many externalities associated with car use mentioned in chapter 2. This is particularly the case since technological improvements to mitigate these impacts can rarely keep up with such strong growth.

One final interesting aspect of driving patterns in Canadian cities is the difference between VKT clocked in the outer areas, versus VKT driven region-wide. VKT driven in the outer areas is well above the annual regional per capita VKT in the GTA, Montreal and Vancouver, as indicated in Table 28 below. Likewise, the inner areas of these cities are responsible for far less than the regional average of VKT.

Table 28 - Outer area VKT and other transport variables in 3 Canadian and 3 U.S. cities, 1991

	Metropolitan Region			
	Toronto (GTA)	Montreal	Vancouver	USA three city Avg.[69]
Car VKT/capita				
Metro	5,680	4,746	8,361	11,155
Inner area[70]	5,019	3,130	5,673	?
Outer area	6,448	7,443	9,509	13,033
Urban density (persons/ha)				
Metro	25.9	33.8	20.8	19.7
Inner area	41.5	43.2	40.9	60
Outer area	18.1	28.5	17.4	15.9
Transit VKT/capita				
Metro	65	60	50	28
Inner area	98	78	?[71]	?
Outer area	49	37	?	?
Transit boardings/capita				
Metro	210	222	117	63
Inner area	350	351	?	?
Outer area	48	50	?	?
% of regional pass. kms. on transit	15%	12.8%	6.5%	6%

69 These cities only include San Francisco, Los Angeles and New York as inner/outer area VKT splits are not available for other cities. New York is by far the most transit-oriented and dense city in the U.S., therefore, the averages tend to overstate San Francisco and Los Angeles' performance as well as that of the U.S. in general. For example, New York's percent of passenger travel on transit is 11%, while San Francisco and Los Angeles manage just 5% and 2%, respectively.

70 Because of limitations with transit data and of the models generating the VKT estimates, the definition of inner areas differs somewhat for this analysis than that used in the rest of the thesis. Vancouver's inner area includes a slightly larger area incorporating the Killarney neighbourhood, which is usually considered outer area in this study (in total, the area modelled is equivalent to the entire City of Vancouver proper). The impact of the inclusion of this small neighbourhood is likely very small. Its exclusion would likely drive Vancouver's inner area estimated VKT down by only a very marginal amount. The inner areas of Toronto and Montreal are simply Metro and MUC, respectively. Their outer areas are simply the difference between these and the regional totals.

71 Vancouver's estimated inner area boardings were provided by BC Transit (Rees 1998).

For example, Vancouver's inner area shows only 5,673 VKT/capita, well below the regional average of 8,361 VKT/capita. This contrasts sharply with the 9,722 VKT/capita driven in Vancouver's outer area which is well above the regional average and 80% higher than inner area VKT.

This inner-outer area dichotomy is also reflected in the relative standing of each city in terms of density gradient and public transport use. The higher densities of inner areas appear to be a significant enabling factor for achieving higher levels of transit use, while the lower density, more auto-dependent nature of outer areas reflects itself in terms of lower transit ridership there. Toronto's ex-Metro suburbs (i.e., the surrounding "905" region of the GTA) has only 48 boardings per capita in contrast to Metro's 350, thus pulling down the regional average down to 210 boardings. In Montreal and Vancouver as well, the same inner/outer area patterns are evident.

The Montreal-Toronto inner-outer area comparison is particularly interesting since Montreal is able to attain higher levels of ridership in both it's inner and outer areas, despite markedly lower levels of transit service. In each of these three Canadian cities, it appears as though transit service has much higher returns per transit VKT in inner areas than outer and that density plays a crucial role in this.
The higher levels of car use and lower levels of boardings per VKT in inner versus outer areas have tremendous implications for transit productivity and viability. These issues will be discussed in greater detail in section 4.2.1.4 below (Transit demand, service and utilization).

4.2.1.1 Auto infrastructure: roads and parking

Increasing use of private motor vehicles has accompanied increasing infrastructure provision for motor vehicles in most Canadian cities. All cities have experienced continued growth in their road network lengths, most notably Vancouver, Calgary and Edmonton[72]. However, the inability of road construction to keep pace with strong growth in motor vehicle ownership and use has led to decreasing road length per capita and increasing vehicles per kilometre of road in all cities. Congestion has also risen with VKT use. For example, in Vancouver, the number of vehicle kilometres per kilometre of road[73] increased 40% between 1981 and 1991.

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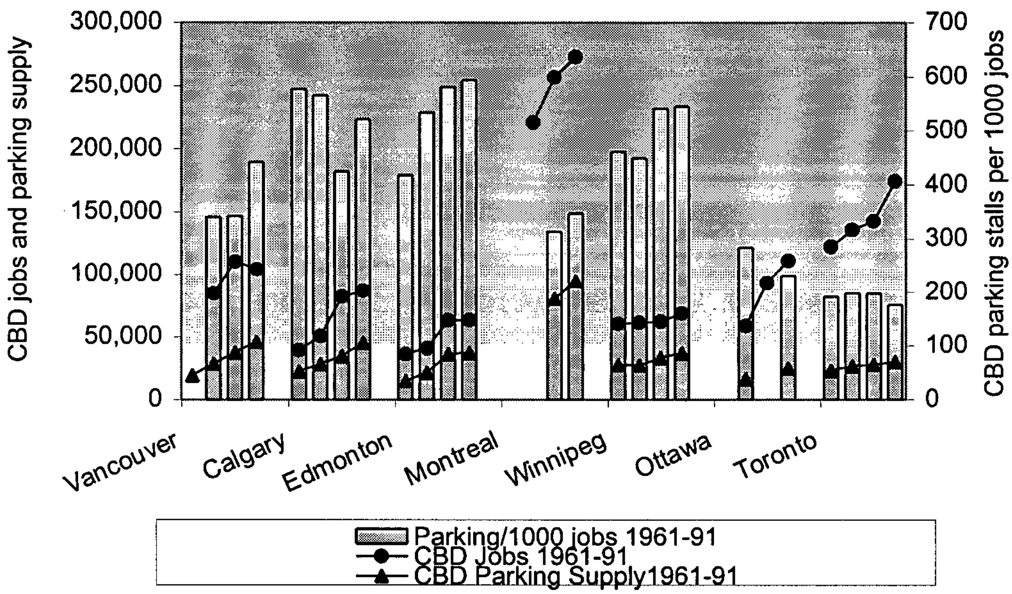
[72] Time series data are unavailable for Winnipeg and Montreal.
[73] Since this study measures road network length rather than lane kilometres (which is a better gauge of capacity) vehicle kilometres per kilometre of road is only a crude measure of congestion. Vehicle kilometres remaining constant, cities with wider roads (more lanes) and higher traffic priority will have less congestion and intensity of road infrastructure use. In the case of Vancouver, where there are fewer freeways and wide roadways than Calgary, traffic intensity will be higher.

Figure 29 - CBD parking supply and employment in the Canadian cities, 1961-91



Most Canadian cities have also experienced net increases in CBD parking supply (as expressed in CBD parking stalls per 1000 CBD jobs) during the 1961-91 period (Figure 29 above). Out of all the Canadian cities in the study, Toronto, Ottawa and Montreal are the cities show relatively low (sub-350 stalls per 1000 jobs) and only Toronto and Ottawa have experienced net declines in parking supply. Toronto has managed to keep an exceptionally low parking supply, tightening it over the decades to its current low level of 176 stalls per 1000 jobs. Toronto's low supply has been the result of a decades long policy of accommodating 'essential' drivers and discouraging discretionary, non-essential commuting by car (Calgary 1995a). In Ottawa, conscious policies aimed at controlling the supply and price of parking have also been actively pursued. In 1975, the federal government, in cooperation with provincial and municipal governments, eliminated free parking for employees and began efforts to rein in supply explicitly as a means of increasing transit use and enhancing equity (De Leuw 1976).[74] As a result parking supply decreased from 284 stalls/1000 workers in 1971 to 230 stalls in 1991 and transit use increased dramatically.

Vancouver, Calgary, Edmonton and Winnipeg have the most generous CBD parking supplies in Canada. In contrast with Toronto and Ottawa, Vancouver has moved from a relatively tight supply of parking at 343 stalls per 1000 jobs to a much more generous supply of 443 stalls. Part of this is accounted for by a slight decline in CBD employment through a regional redistribution in jobs over the

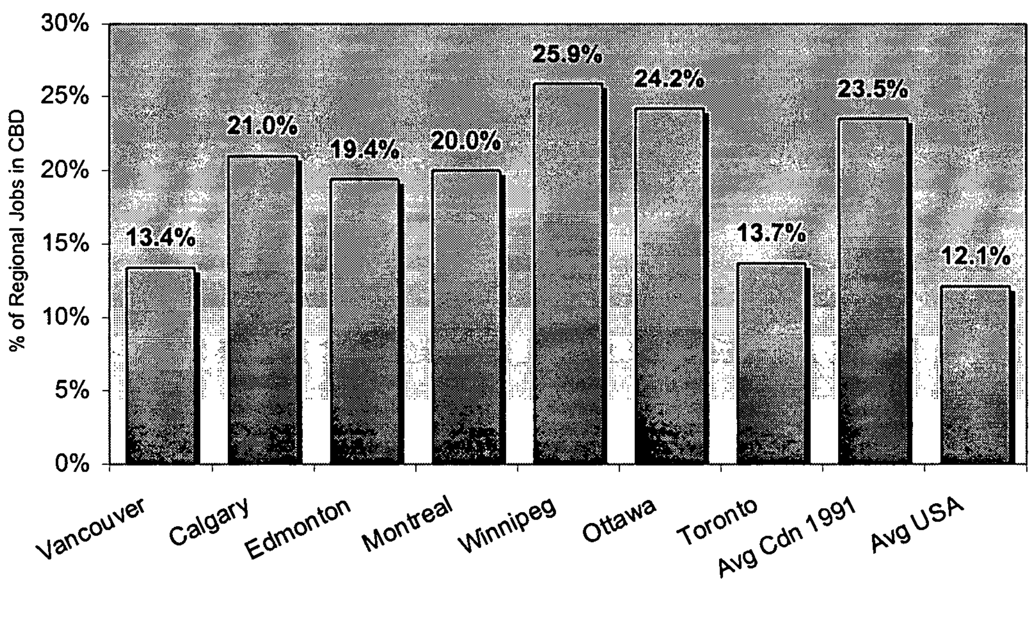
[74] As the largest employer in the Ottawa-Hull region federal government employees are responsible for the majority of travel demand in the region.

period, however much is due to a large expansion in parking supply – from 33,617 stalls in 1981 to 41,915 stalls in 1991.

The regional significance of CBD parking supply in regulating travel choices can be inferred by determining the level of regional employment concentrated in the CBD. Figure 30 below shows the proportion of regional workers that would be subjected to given level of parking supply in each city. For example, Winnipeg and Calgary have relatively large portions of their regional workforce subject to generally ample parking supply conditions. Ottawa and Montreal, on the other hand, have significant shares of their regional workforce subject to tight parking supply conditions.

Vancouver and Toronto indicate relatively low shares of regional employment in their CBDs. However, this somewhat understates the importance of their CBD parking supplies as both cities have significant concentrations of employment in areas just outside their officially designated CBDs (or what each refer to as their "central area") and both have polynucleated regions with significant concentrations of employment located in regional sub-centres.[75] For example, Toronto's parking supply is even tighter looking at its 'central area' rather than just the CBD alone. A paltry 120 spots are provided per 1000 workers bound for this area, yet it contains over 405,000 jobs – 32% of all the jobs in Metro. While Vancouver's central area parking supply is unknown, its proportion of jobs in its central area is lower than Toronto's at 15%.

Figure 30 - Proportion of regional employees working in CBDs in Canadian cities, 1991



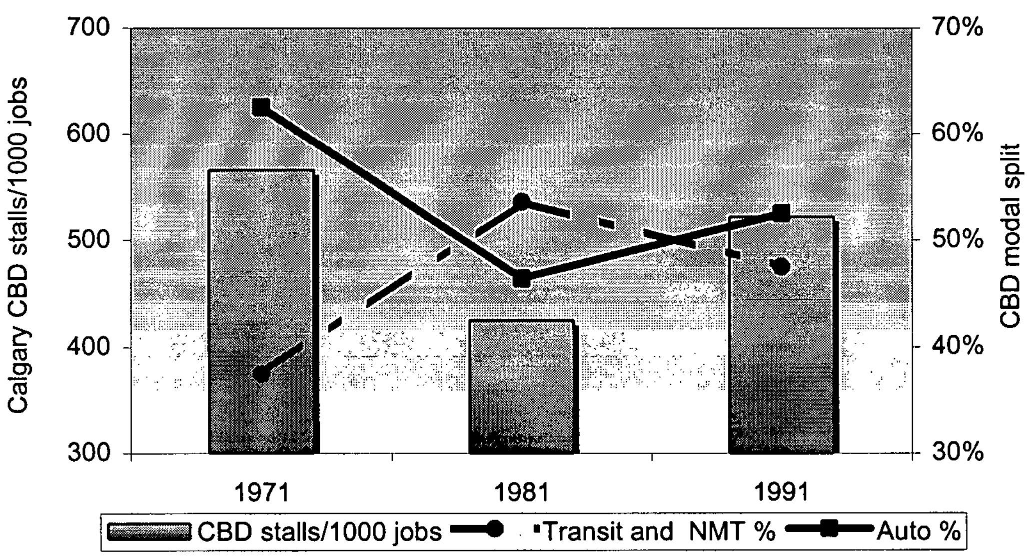
[75] Parking supply in these sub-centres was not counted in this study. The supply is likely tight relative to other cities' outer areas in general since land is more scarce and stricter parking policies cap their supplies.

4.2.1.2 Parking and transit

There appears to be a strong link between parking supply and the degree to which automobiles are used for commuting purposes. For example, Canadian regions with parking supplies in the 400-600 stalls per 1000 workers range are able to achieve journey to work modal splits in the range of 11-20%. Meanwhile, the European cities, with an average of 230 stalls/1000 workers obtain an average transit share of 39%. Some of the most car-oriented cities in the U.S., such as Phoenix and Detroit have very generous parking supplies (906 and 706 stalls per 1000 workers, respectively) and virtually negligible transit shares (2.1% and 2.6%, respectively).

Calgary's decline in parking supply per employee in 1981 provides an excellent case study explaining the strong possible link between parking supply and transit use. Figure 31 below shows the available supply of parking per 1000 jobs in Calgary in 1971, 1981 and 1991, as well as the corresponding share of commuters driving or taking transit/nonmotorized modes to work in the CBD[76]. The sharp decline in parking supply between 1971 and 1981 (from 565 to 425 stalls per 1000 jobs) came on the heels of a booming economy and sharp growth employment. While the parking supply did grow during this period in absolute terms, it did so at a rate far below jobs growth. This tightening of parking supply in 1981 corresponds with a sharp decline in the proportion of people driving to the CBD (from 62.5% to 46.4%) and a sharp increase in people taking transit and nonmotorized modes (from 37.5% to 53.6%).

Figure 31 - Parking supply and modal split in Calgary, 1971-1991



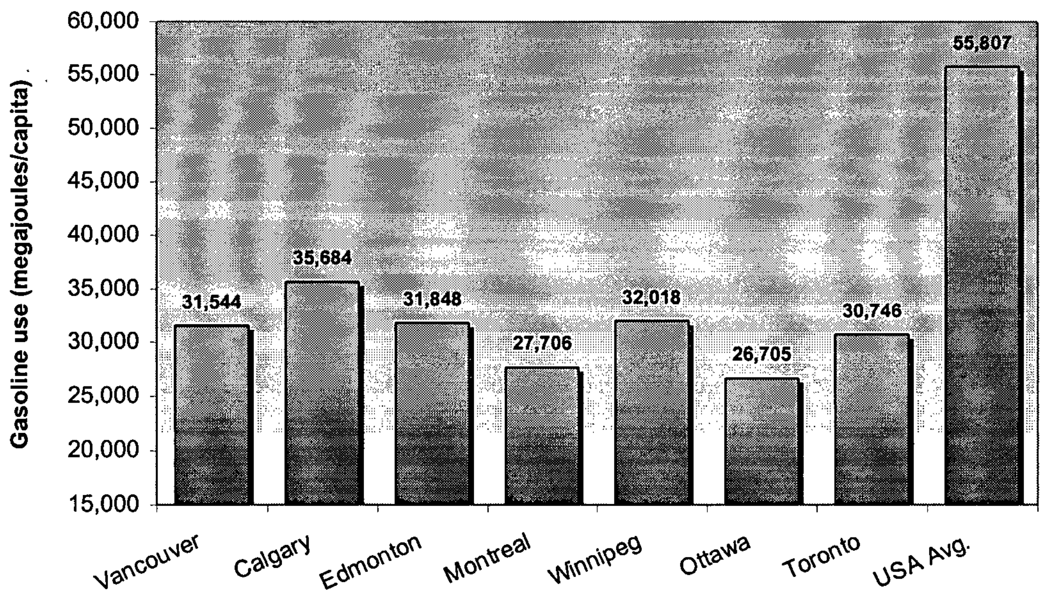
[76] Also see Figure 29 for additional CBD data for Calgary.

This positive trend reversed itself in the 1981 to 1991 period as stall growth outstripped employment growth by over 2.3 times,[77] bringing the parking supply back up to 522 spots per 1000 jobs from 425 in 1981.[78] In other words, for every 1000 new jobs in the CBD, 2341 additional parking stalls were added. Transit use declined amid this increase in parking supply, despite the expansion of LRT and higher levels of transit service (in absolute and per capita terms) available by 1991.[79] During this period, Calgary also had one of the strongest region-wide VKT growth figures in Canada for this same period. Furthermore, during the 1981-1991 period, the decentralization of employment continued in Calgary (as it did elsewhere), subjecting those periphery-bound commuters to an even less stringent parking supply than that found in the CBD.

4.2.1.3 Energy use

Not surprisingly, those regions with the most regional travel by car, the greatest infrastructure provision afforded to the automobile and the lowest public transit patronage, have the highest levels of gasoline use in the country (Figure 32 below). With nearly half the driving and three times the transit use the average U.S. city, Canadian cities consume much less gasoline.

Figure 32 - Gasoline use in seven Canadian cities and the U.S., 1991



[77] The Alberta "oil boom" slowed in the early 1980's and as a result many developers were unable to develop downtown land profitably. Some of the initial growth in parking supply came in the form of ground level lots that were converted to parking in order for land owners to cover holding costs on their land. However, a substantial number of new stalls remained by 1991, despite a rebound in the economy.

[78] To maintain a parking ratio of 425 spots per 1000 jobs, the parking supply should have increased by only 1864 stalls. Instead it increased by 10,262 stalls, 5.5 times what it should have.

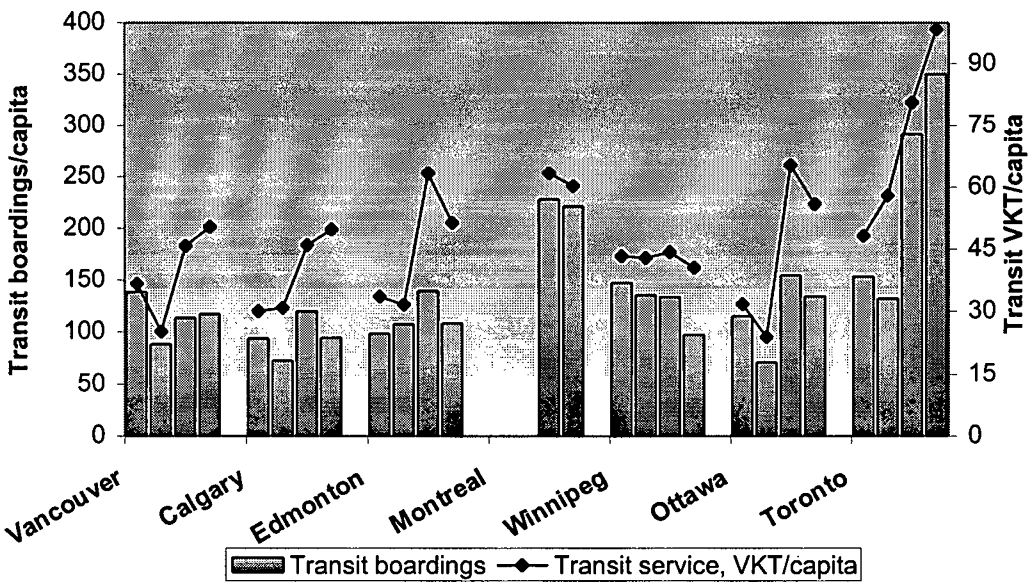
[79] Additionally, much of the service increase was heavily CBD focussed.

4.2.1.4 Transit service, demand and utilization

Most Canadian cities show a pattern of transit decline between 1961 and 1971, revival between 1971 and 1981 and decline once again between 1981 and 1991. This is reflected in terms of boardings[80] per capita (demand) and transit VKT per capita (service) in Figure 33 below. In most cities throughout this period, transit demand and service move in the same direction. (Tables 29-30 below highlight some of the changes in the transit service, demand and utilization discussion that follows.)

Only Vancouver and Toronto actually showed increases in transit travel demand between 1981 and 1991, while all other cities faced declining demand. Vancouver's transit demand increased nominally from 114 boardings per capita to 117 boardings (or 3%) between 1981 and 1991, while its transit service increased 10%, mostly because of the introduction of SkyTrain and a realignment of bus routes. Toronto's increase was more substantial. Between 1981 and 1991 transit demand in Metro Toronto increased by 20%, from 292 to 350 boardings per capita. This demand was accompanied by a 22% increase in transit VKT per capita,[81] while population increased only nominally.

Figure 33 - Transit demand and supply in 7 Canadian cities, 1961-91



Overall, Toronto and Montreal have the highest per capita transit ridership in North America.[82] Both cities have relatively high urban densities and transit friendly urban forms, particularly in their inner

[80] The terms "boardings" and "trips" will be used interchangeably in reference to transit travel demand.
[81] Transit demand GTA-wide is obviously lower, but still very high by Canadian, and North American, standards. Available data indicated GTA-wide transit demand also increased during the 1981 to 1991 period from 198 boardings to 210 boardings per capita. Although Metro's surrounding suburbs (GTA less Metro) also increased their transit usage, they did so from relatively low levels 41 boardings per capita in 1981 to 49 boardings in 1991.
[82] Montreal's transit use is actually higher than Toronto's if one considers the entire GTA as the region. The Montreal Region managed 222 boardings per capita region-wide in 1991 while the GTA garnered 210 boardings.

cities. Both cities also invested heavily in subway systems in the 1950's and 60's to serve as "spines" for their transit systems. In addition, Toronto has maintained an extensive network of streetcars (trams) that have served the dual function of maintaining high levels of transit service and visibility as well as limiting automobile capacity on arterial roads.

Ottawa has also been a transit leader in Canada. As at 1991, it had the fourth highest ridership levels per capita in North America, after Toronto, Montreal and New York. Between 1971 and 1981 Ottawa managed to double its transit boardings (from 75 to 155 annual boardings per capita). This increase coincided with a 116% in transit service VKT. Ottawa managed this impressive rebound in transit ridership using an entirely entirely bus-based system. In fact, Ottawa's high of 155 boardings per capita in 1981 came even before the completion of the Ottawa-Carleton Transitway.[83] Ottawa's transit ridership actually declined between 1981 and 1991 (by 13%), well after major portions of the busway were complete. Whether these declines would have been even greater without the busway, or whether they were aggravated by a 14% decline in system-wide service VKT is not easily discernable from the data at hand.

Overall, transit service kilometers have increased in both absolute and per capita terms in most Canadian cities between 1961 and 1991.[84] Table 29 below indicates that the biggest increases in service kilometres over this period were observed in Toronto, Ottawa and Calgary,[85] with most of the growth coming between 1971-81. Between 1981 and 1991, service increased substantially yet again in Toronto, increased marginally in Vancouver and Calgary and dropped in Montreal, Winnipeg, Ottawa and Edmonton.

However, few cities were able to parlay these increases in service kilometres into lasting gains in transit demand (Table 30 below). Despite substantial expansion in service since 1961, demand has actually decreased, or increased only nominally, in most cities. Only Toronto experienced a strong growth in transit demand since 1961, with an increase of 127%.[86] A look at the more recent changes in boardings per capita between 1981-91 reveals a drop in demand in all cities except Vancouver and Toronto. The declines in Montreal, Winnipeg, Ottawa and Edmonton all correspond to declines in transit service VKT per capita during that period. Meanwhile, the sizeable drop in ridership in Calgary (-22%)

[83] In the early-1980's, Ottawa began construction of the Transitway, a busway network which uses mostly articulated buses in exclusive rights of way, grade separated from general traffic as most rail rapid transit systems operate. By 1991, the busway carried 210,000 passengers per day, more than almost any light rail system in North America (McCallum and Beere 1997). However, Ottawa's busway has not been able to attract higher density development similar to that found in along Vancouver and Toronto's rail lines, despite effort to encourage it.
[84] Only Winnipeg had a net decline in transit service VKT over this period.
[85] Although figures are not available for the Montreal region back to 1961, transit service VKT in the MUC increased 79%. Meanwhile, boardings per capita increased by 42% while utilization declined by 21%.
[86] Again, while metro-wide figures are not available for Montreal, the MUC showed a gain in transit patronage of 42%.

came despite and a notable increase in transit service (8%) and the expansion of LRT, indicating that other forces were strongly influencing transit demand there.

Table 29 - Change in transit service levels (VKT/capita) in seven Canadian cities, 1961-91

	Transit VKT per capita				% change 1961-71			
	1961	1971	1981	1991	1961-71	1971-81	1981-91	1961-91
Toronto	48	58	81	98	20%	39%	22%	104%
Montreal			63	60			-5%	
Winnipeg	43	43	44	40	-1%	3%	-9%	-7%
Vancouver	37	25	46	50	-31%	82%	10%	37%
Ottawa	32	24	65	56	-25%	174%	-14%	76%
Edmonton	33	31	63	51	-6%	101%	-19%	53%
Calgary	30	31	46	50	3%	49%	8%	66%

Table 30 - Change in transit demand (boardings/capita) in seven Canadian cities, 1961-91

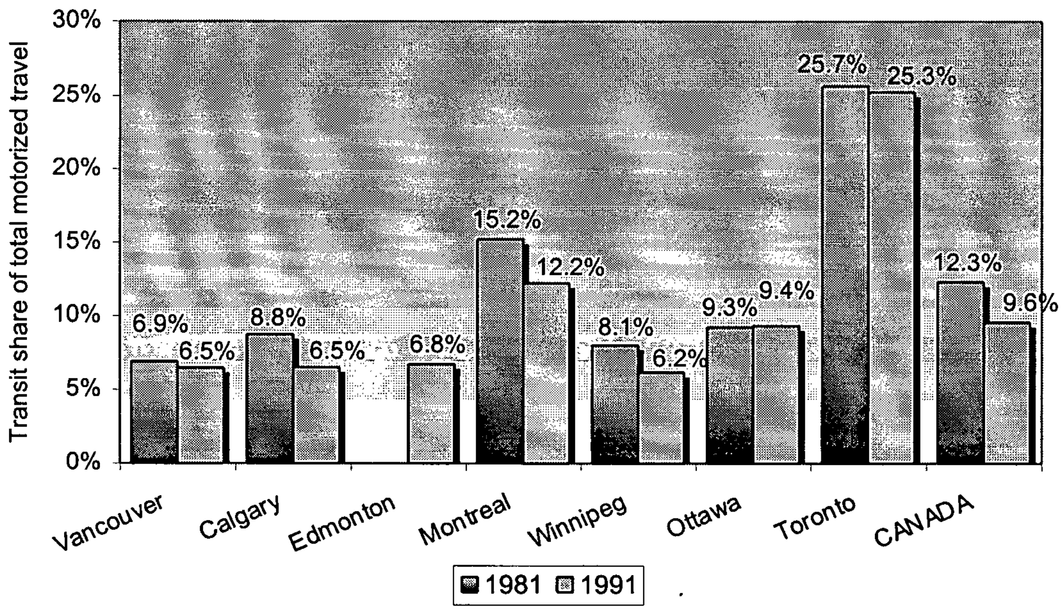
	Transit boardings per capita				% change			
	1961	1971	1981	1991	1961-71	1971-81	1981-91	1961-91
Toronto	154	132	292	350	-14%	120%	20%	127%
Montreal			228	221			-3%	
Winnipeg	148	136	134	98	-8%	-1%	-27%	-34%
Vancouver	138	88	114	117	-36%	29%	3%	-15%
Ottawa	115	72	155	135	-38%	116%	-13%	17%
Edmonton	98	108	140	109	9%	30%	-22%	10%
Calgary	94	73	120	94	-23%	65%	-22%	0%

Table 31 - Change in transit utilization (boardings/VKT) in seven Canadian cities, 1961-91

	Transit boardings per VKT				% change			
	1961	1971	1981	1991	1961-71	1971-81	1981-91	1961-91
Toronto	3.3	2.3	3.6	3.5	-28%	56%	-5%	6%
Montreal[87]			3.6	3.7			2%	
Winnipeg	3.4	3.2	3.0	2.4	-7%	-4%	-20%	-29%
Vancouver	3.8	3.5	2.5	2.3	-7%	-29%	-6%	-38%
Ottawa	3.6	3.0	2.4	2.4	-17%	-21%	1%	-34%
Edmonton	2.9	3.4	2.2	2.1	16%	-35%	-4%	-28%
Calgary	3.1	2.4	2.6	1.9	-25%	11%	-27%	-39%

Not surprisingly, the cities that lost transit patronage in this period also experienced a declining importance of transit relative to the car (Figure 34 below). One development that is of particular interest is that even where transit demand has risen (i.e., Toronto and Vancouver), the transit share of total motorized transportation has actually declined. In other words, in real 'inflation adjusted' terms, transit use is declining. The increase in transit demand in these cities was more a function of an increased demand for travel of which transit took a smaller share relative to the automobile.[88]

Figure 34 - Transit share of motorized travel



Another pattern that is evident in examining these changes in transit supply and demand is that where transit supply has dropped, the percentage decline in transit demand dropped at a rate greater than supply. Furthermore, where transit supply increased, the percentage increase in transit demand grew at a rate less than supply. For example, Winnipeg's service VKT dropped by 9% between 1981-91, while its ridership dropped by 27%. Meanwhile, Vancouver's expansion in VKT per capita of 10% only yielded an increase of 3% in boardings per capita. In other words, transit is getting 'less bang for the buck.' There have been, for the most part, declining marginal gains in ridership for service increases.

This contrast in increasing service provision (Table 29) with demand failing to keep pace (Table 30) is manifest itself in poor or declining "utilization" (boardings per VKT) in most Canadian transit systems (Table 31). Although Table 29 indicates expanding service per capita between 1961 and 1991, Table 31 indicates this increase in service was poorly used. The reason for the declining utilization in transit appears to be that most of the increase in service VKT was provided to lower density suburban areas. This increase in service VKT often served a more sparsely populated catchment, therefore

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[87] Trend data are not available for the entire Montreal area for 1961 and 1971. However, the MUC's change in boardings between 1961 and 1991 was 42%.

[88] Total "travel" is measured measured by passenger kilometres (i.e., number of passengers in a vehicle x kilometres travelled). The strong increase in car passenger kilometres is likely related to an increase in sprawl-induced long haul urban travel, the preponderance of which is done by automobile.

ridership potential is much lower. This supports the general axiom of transit planning that relatively high densities are required to deliver accessibility to transit services, which can then be translated into ridership.

Table 32 - Land use and transit service in 7 Canadian cities, 1991

	Density	Service intensity	Demand	Utilization
	p/ha	VKT/ha	Boardings/cap	Boardings/VKT
Montreal (MUC)	43.2	3361	351	4.5
Montreal (Region)	33.8	2034	222	3.7
Toronto (Metro)	41.5	4378	350	3.5
Toronto (GTA)	25.9	1685	210	3.4
Ottawa	31.3	1750	135	2.4
Vancouver	20.8	1046	117	2.3
Edmonton	27.4	1409	109	2.1
Winnipeg	21.3	862	98	2.4
Calgary	20.8	1033	94	1.9

The strong role density plays in determining ridership levels and service viability was demonstrated in Table 28 above. The higher density areas of both MUC (Montreal) and Metro (Toronto) have substantially higher levels of service and ridership than their outlying areas. Table 32 above provides a comparative overview of land use and transit service and performance in various Canadian regions. The more dense cities are able to offer higher levels of service intensity (VKT per hectare of developed land) and in so doing can provide more frequent service to a greater number of people.[89] In general, the more compact cities also have higher transit utilization: for every kilometer of revenue service provided, more people get on the bus.

Declining transit utilization has tremendous implications in terms of productivity, subsidies and overall system sustainability. The servicing of vast tracts of suburban land has meant declining service intensity and a diminished ability to attract patronage. In the short run, having to travel more kilometres to attract fewer passengers (low system utilization) means ever increasing operating subsidies are required (for labour, fuel and maintenance) in order to keep the system running. In the long run, these services

[89] The use of transit VKT per capita as a measure of service only paints a partial picture of true service levels. In a comparative sense, it tends to overstate the level service in low density cities, since transit services travel greater distances to service the existing population base. Furthermore, higher density cities are more like to have rail services. Since each rail car (which is the basis for rail VKT figures) carries more passengers, and since rail services are typically operated in dense corridors, cities with rail VKT actually deliver higher levels of service, and are more accessible, per VKT, than buses. Therefore, given two cities with equal transit service VKT, the higher density city likely offers more frequent and accessible service per VKT. Using VKT/ha normalizes for density and provides a crude estimation of how 'intense' service is.

prove unsustainable and become vulnerable to cuts when purse strings tighten. In many cities, service expansion into sprawling areas has heavily taxed the resources of transit systems (Perl and Pucher 1995). BC Transit's expansion in the 1980's, for example, focussed heavily on extending new and more frequent services low-density areas. The resulting decline in system utilization has drained resources away from improvements to already viable transit services within higher density areas.

Toronto's gains in ridership and utilization since 1971 were due in large part to the fact that service increases were fortified within a fully developed boundary (i.e., Metro). Since the TTC's service area was constrained by Metro's largely built out urban boundary, service expansion was not diluted by the low density spread of serviceable area that has compromised transit performance in Metro itself pre-1971, and in the GTA and other Canadian cities today. The intensification of land uses within Metro has helped Toronto to reap dividends from service expansion.[90]

Although the level of transit service is an important, even critical, *enabling* factor in increasing transit patronage, the data presented above indicate increases to transit service alone will not guarantee ridership. Decreasing transit provision is just one of the factors influencing declining transit patronage and utilization. While transit decline has surely been influenced by other factors such as the declining operating and capital costs of the car (Perl and Pucher 1995; RMOC 1995), sharp increases in transit fares (Pucher 1998) and demographic change (CUTA 1991),[91] the data presented here indicate that auto availability, auto infrastructure provision, land use and transit supply also play important roles.
In the case of Ottawa, it seems cuts in service since 1981 and lower-density urban growth may be key contributors to lower demand. In the case of Calgary where transit supply increased dramatically, it seems road and parking infrastructure supply, in addition to outward urban growth has contributed to the loss of transit share. In Metro Toronto, land use intensification and controlled parking supply may have been the key catalysts that allowed the expansion of transit service to truly reap rewards by building a strong transit catchment base and by controlling ease of access by car.

4.2.1.5 The cities summarized

The transport and land use characteristics of the cities discussed thus far reveal a web of factors that influence levels of auto dependence. The factors appear to act as levers, serving to increase or decrease auto use, and likewise for transit. Some of the key characteristics defining the transport and land

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[90] Of course, the trends outside of Metro are still of concern, however, the gains in Metro provide an interesting cas study of the potential urban containment policies may have for encouraging transit use.

[91] Certain 'demographic' changes and sprawl are in many ways proxies for one another. For example, the increasing affluence and aging of baby-boomers leads to higher car ownership and less transit use. However, high car ownership and use may simply reflect preferences for single family suburban dwellings, which in many cases are automobile dependent.

use patterns of Canadian cities are placed in the context of some of the global cities and are summarized in Table 33 below.

Table 33 - Land use and transportation characteristics of selected World cities, 1990/91

City	Land Use Intensity pop+jobs/ ha	Cars Owned cars/ 1000 pop.	Car Use VKT/ capita	Parking Supply stalls/ 1000 jobs	Transit Use Boardings/ Capita	Transit Service VKT/ Capita
Phoenix	16	644	11,608	906	15	10
Detroit	19	693	11,239	706	24	14
Portland	20	764	10,114	403	46	27
San Francisco	25	604	11,933	137	112	49
Perth	15	522	7,203	631	54	47
Vancouver	31	564	8,361	443	117	50
Calgary	33	630	7,913	522	94	50
Edmonton	42	527	7,062	594	109	51
Winnipeg	30	412	6,871	546	98	41
Ottawa	47	510	5,883	230	135	56
Toronto (GTA)	40	515[a]	5,680	176	210	65
Toronto (Metro)	65	431	5,019	176	350	98
Montreal	49	420	4,746	347	222	60
Copenhagen	45	283	4,558	223	164	121
Amsterdam	71	319	3,977	354	325	60
Stockholm	92	409	4,638	193	348	133
Munich	91	468	4,202	266	404	91
Vienna	106	363	3,964	187	422	73
Tokyo	178	225	2,103	43	461	89
Hong Kong	440	43	493	33	570	140

Note: a. Estimated from "Transportation Today and Tomorrow Survey." Joint Programme in Transportation, University of Toronto, 1991.

Various degrees of car orientation are evident upon examining the data and clear patterns emerge. The cities with the highest car use also have relatively low land use intensity, high car availability, abundant CBD parking, low transit use and sparse transit service.

Since each of these factors represent 'policy intervention points' and may influence auto dependence to various degrees, one of the key questions for transportation planning is: what is the relative importance of these each of these factors in determining auto dependence? Knowing which factors most strongly influence, and are influenced by, a city's car orientation can help to steer planning towards policies that offer the greatest marginal benefits in reducing car dependence and improving access.

4.3 DATA CORRELATION ANALYSIS

The analysis above reveals certain factors associated with higher and lower levels of automobile dependence in Canadian cities and this section follows with a basic correlation analysis of some of the key variables examined in this thesis. It is particularly focussed on identifying the factors most strongly correlated with **car ownership** (cars/1000 people), **car use** (car VKT/capita) and **transit use** (boardings/capita).[92] I will refer to these three indicators as the "auto dependence indicators."

The basic correlation analysis presented in this section takes car ownership, car use and transit demand and assesses the degree to which they are positively or negatively associated with other variables. For example, I will determine how strongly transit use is associated with such factors as density, transit supply and parking supply. The strength of correlation for the data items presented are given a qualitative designation and are then discussed. These correlations are also used to reconstruct the auto dependence feedback diagram (presented earlier in Chapter 2), showing the strength of correlation between various factors identified as being involved in auto dependence feedback. The correlation analysis, as with the previous discussion in this chapter, focusses on Canada, but uses the world cities for context.[93]

4.3.0 Correlations of Key Factors

Table 34 and Table 35 below provide a summary of the correlations between some of the key factors studied in this thesis.[94] The full correlation tables, including levels of significance, the number of cases for each factor and a key defining variable short forms are found in Appendix 4.

4.3.0.0 Using the correlation charts

Table 34 presents the correlations for the 7 Canadian cities in the study and Table 35 presents the correlations for 41 world cities.[95] Thirty-two variables in the tables are compared to car ownership, car

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[92] Since boardings per capita focussed only on region-wide transit, and some explanatory factors have a more narrow geographical scope (e.g., CBD, inner area and parking variables), journey to work modal split on transit is also used as a supplementary transit indicator. Since much of the transit demand in these areas is journey to work oriented, correlations between parking supply and employment, for example, can help to explain why transit mode share may be higher or lower. It must be cautioned, however, that since the transit mode split data is only focussed on the journey to work, it is not useful in its explanatory function for any of the region-wide variables. Therefore, low levels of correlation with region-wide variables, particularly for cities where transit is heavily work oriented (e.g., North America and Australia), are not meaningful.

[93] The sample of World cities used in the correlation analysis excludes those in developing Asia. These cities have a dramatically different economic environment (for example, infrastructure decisions are much more constrained by lack of resources), so removing them and comparing only developed-nations cities will provide more meaningful correlation data.

[94] The large volume of data collected precludes the detailed analysis of each factor. Furthermore, many of the factors are co-related or are proxies for one another. Therefore, the most relevant variables have been chosen for analysis.

use, transit use and transit mode split to work. The resultant correlations have been rounded to the nearest hundredth and are expressed as positive or negative values.[96]

The tables, and their more detailed counterparts in Appendix 4, should be used carefully. Many of the variables compared in the table co-vary, are surrogates for one another or result in correlations that are meaningless.

For example, metropolitan areas with high population densities are also likely to have high employment densities. Likewise, activity density, which describes the total employment *and* population density, will also be high. Therefore, each of these three variables will likely have similar correlations to car use. On the other hand, certain related variables can provide different dimensions on factor relationships. Inner area employment densities do not seem to bear as strong a relationship to car ownership, car use, transit use as for inner area population densities. However, the relationship strengthens for the journey to work transit modal split.

Various levels of statistical significance have been attached to the correlation data and these are indicated in Appendix 4. While many of the strong correlations that will be discussed are also "statistically significant" (particularly in the case of the larger 41 cities sample), I have not screened for statistical significance for two reasons. Firstly, because the Canadian cities are fewer (and therefore have fewer data "cases"), the data are less likely to establish correlations that are "significant" in the statistical sense, unless the correlation is extremely strong. Many of these relationships are just shy of being "statistically significant" by the slightest margin by virtue of the small sample size. The larger sample of 41 cities (or cases) show most of these same relationships to be similarly strong and statistically significant to the 0.01 level (meaning there is a 99% chance the relationship is not a random occurrence).

Secondly, while the 41 world cities are a 'sample' of the world's many large cities, the 7 Canadian cities sampled, for the most part, comprise the large Canadian cities (population over 600,000). Therefore, establishing statistical significance is irrelevant since the sample is the entire 'population' of large Canadian cities. Any correlations that result are therefore "significant" by definition since they include all possible large Canadian cities. While sampling further World cities may result in changing correlations, sampling other large Canadian cities is not possible. The World cities provide a large enough sample size to make inferences that bear greater statistical significance.

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[95] This includes all the Canadian, Australian, U.S., European and Wealthy Asian cities. It excludes all the Developing Asia cities (see note 93).

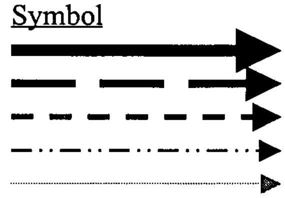
[96] A positive correlation means the two variables move in the same direction – an increase in one variable leads to an increase in the other, and vice versa. A negative correlation means the two variables move in opposite directions – an increase in one variable leads to a decrease in the other, and vice versa.

4.3.0.1 Giving meaning to the correlations

Managing and interpreting the large volume of correlation data generated can be unwieldy and confusing. Furthermore, given that there is a range of error with the various data items (see Data Quality and Reliability, Chapter 3), discussing minor differences in correlation does not contribute to a greater understanding of the relative of importance of factors influencing auto dependence. In order to make the large volume of correlation data useful for guiding discussion and policy analysis, qualitative descriptions will be given to correlations that fall within designated ranges.

By assembling and sorting all the correlation data, it is possible to identify clear groupings of data, making the assignment of qualitative designations to them a relatively straightforward task.[97] The correlations grouped and described as follows:

Correlation range	Descriptor	Symbol
0.83 – 1.00	very high correlation	
0.74 – 0.82	high correlation	
0.67 – 0.73	significant correlation	
0.60 – 0.66	moderate correlation	
< 0.60	weak correlation	



These descriptors, and the accompanying symbols, will be often used in lieu of the actual correlation numbers in discussion and analysis that follows.

For simplicity, this classification will be used for both the Canadian and World cities. However, it is recognized that since the taxonomy is based on the correlation results from the smaller Canadian cities sample, a lower threshold for each data range would be more appropriate for the World cities. For example, data deemed to have a "very high correlation" may more appropriately fall between 0.75 and 1.00 correlation coefficients, rather than the existing 0.83 – 1.00, and the threshold for the correlations deemed to be "weak" may fall below 0.60. Using one conservative classification system for both the Canadian and World cities allows the analysis to be both statistically sound, yet straightforward for the purpose at hand.

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[97] While the correlation ranges identified for designation are arbitrary to some extent, they do reflect apparent "clusters" of correlation data. The use of all correlation coefficients greater than 0.65 for the Canadian cities sample is supported by statistical tables which hold that values over 0.65.

Table 34 - A sample of correlations between transport, land use and demographic factors in 7 Canadian cities

	CAR_1000	CARKM_P	CBDEMDEN	CDBACDEN	CDBDENSI	GAS_P	INNACDEN	INNDENSI	INNEMDEN	METACDEN	METAREA	METDENSI	METEMDEN	OUTACDEN	OUTDENSI	OUTEMDEN
CAR_1000	1.00	0.76	-0.20	-0.23	-0.72	0.55	-0.43	-0.75	-0.13	-0.47	-0.26	-0.56	-0.29	-0.38	-0.40	-0.26
CARKM_P	0.76	1.00	-0.44	-0.46	-0.83	0.70	-0.71	-0.83	-0.45	-0.83	-0.31	-0.89	-0.70	-0.81	-0.82	-0.67
TOTBRDPP	-0.55	-0.76	0.85	0.87	0.71	-0.34	0.40	0.76	0.11	0.91	0.45	0.91	0.88	0.88	0.77	0.92
PROPTRAN	-0.54	-0.77	0.68	0.70	0.84	-0.51	0.73	0.71	0.62	0.73	0.07	0.75	0.68	0.88	0.67	0.79

	PKG_1000	PRJOBCBD	PRJOBINN	PROPCARS	PROPNMT	PROPTRAN	PRPOPCBD	PRPOPINN	ROAD_P	TOTBDPKM	TOTBRDPP	TOTEN_P	TOTPKPP	TOTTRSPD	TRANEN_P	TTRVKTPP
CAR_1000	0.36	-0.15	-0.08	0.59	-0.49	-0.54	-0.41	-0.18	0.43	-0.75	-0.55	0.60	-0.35	0.45	-0.50	-0.34
CARKM_P	0.70	-0.05	0.08	0.76	-0.13	-0.77	-0.09	0.02	0.26	-0.87	-0.76	0.64	-0.55	-0.04	-0.81	-0.63
TOTBRDPP	-0.77	-0.53	0.13	-0.64	-0.27	0.71	-0.39	0.39	-0.63	0.86	1.00	-0.59	0.94	0.37	0.84	0.96
PROPTRAN	-0.87	0.08	-0.04	-0.99	0.30	1.00	-0.01	-0.25	-0.16	0.62	0.71	-0.71	0.66	0.23	0.87	0.68

Notes: **CAR_1000** = Car ownership per 1000 population
CARKM_P = Car VKT per person
TOTBRDPP = Total annual transit boardings per person
PROPTRAN = Journey to work modal split on transit
The variables in the columns are defined in Appendix 4.

Table 35 - Sample of correlations between transport, land use and demographic factors in 41 World Cities

	CAR_1000	CARKM_P	CBDEMDEN	CDBACDEN	CDBDENSI	GAS_P	INNACDEN	INNDENSI	INNEMDEN	METACDEN	METAREA	METDENSI	METEMDEN	OUTACDEN	OUTDENSI	OUTEMDEN
CAR_1000	1.00	0.84	-0.36	-0.42	-0.53	0.83	-0.64	-0.67	-0.62	-0.78	0.18	-0.76	-0.78	-0.76	-0.75	-0.76
CARKM_P	0.84	1.00	-0.26	-0.31	-0.42	0.97	-0.53	-0.53	-0.52	-0.66	0.33	-0.63	-0.70	-0.62	-0.61	-0.62
TOTBRDPP	-0.81	-0.84	0.40	0.45	0.52	-0.83	0.63	0.64	0.62	0.76	-0.23	0.72	0.80	0.71	0.69	0.75
PROPTRAN	-0.84	-0.86	0.46	0.52	0.59	-0.86	0.70	0.69	0.70	0.81	-0.21	0.77	0.85	0.76	0.75	0.79

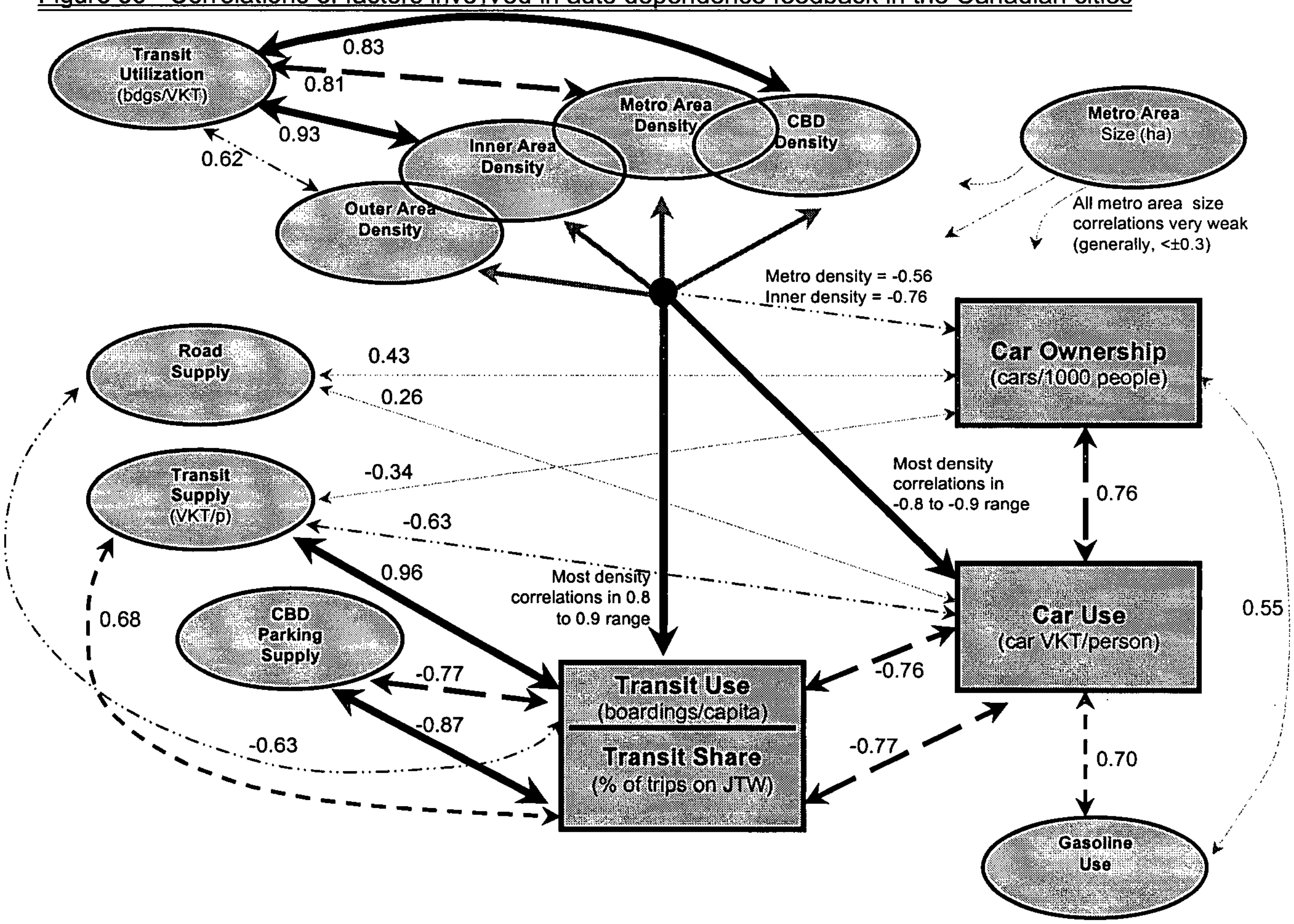
	PKG_1000	PRJOBCBD	PRJOBINN	PROPCARS	PROPNMT	PROPTRAN	PRPOPCBD	PRPOPINN	ROAD_P	TOTBDPKM	TOTBRDPP	TOTEN_P	TOTPKPP	TOTTRSPD	TRANEN_P	TTRVKTPP
CAR_1000	0.59	-0.32	-0.36	0.87	-0.70	-0.84	-0.30	-0.18	0.69	-0.58	-0.81	0.84	-0.79	-0.21	-0.62	-0.76
CARKM_P	0.62	-0.54	-0.54	0.87	-0.66	-0.86	-0.37	-0.26	0.67	-0.62	-0.84	0.97	-0.79	-0.30	-0.66	-0.81
TOTBRDPP	-0.71	0.36	0.51	-0.94	0.69	0.93	0.38	0.34	-0.80	0.76	1.00	-0.84	0.90	0.33	0.67	0.84
PROPTRAN	-0.76	0.41	0.50	-0.97	0.61	1.00	0.38	0.26	-0.79	0.69	0.93	-0.84	0.87	0.39	0.70	0.83

Notes: **CAR_1000** = Car ownership per 1000 population
CARKM_P = Car VKT per person
TOTBRDPP = Total annual transit boardings per person
PROPTRAN = Journey to work modal split on transit
The variables in the columns are defined in Appendix 4.

4.3.1 Relative Strength of Factors Influencing Auto Dependence

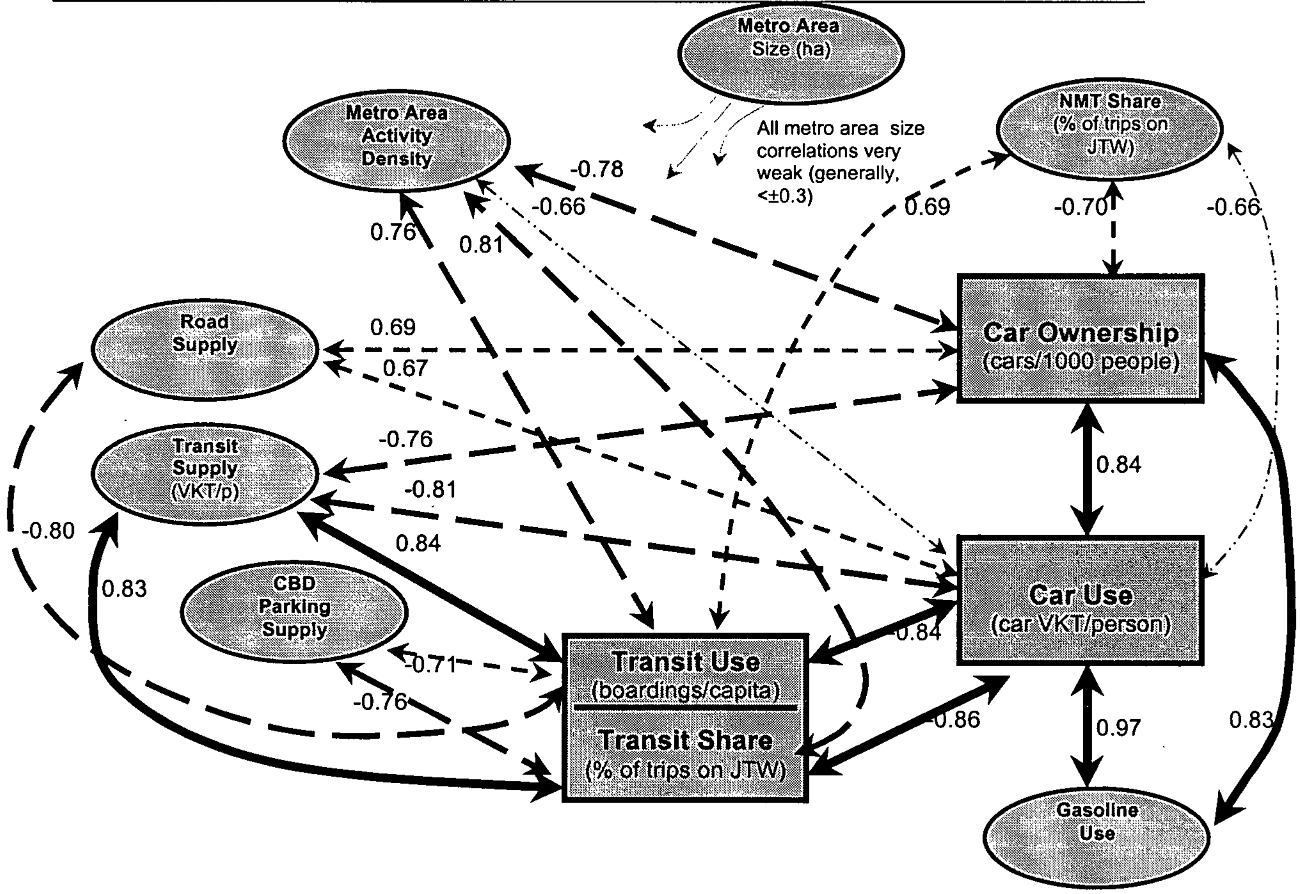
Analysis of the correlation data in Table 34 and Table 35 reveals several key factors associated with higher and lower levels of automobile dependence. By excluding various data items because they covary with others, are surrogate measures of one another, or are not relevant to the analysis, a core set of influencing factors are identified. These factors, their relative strength of correlation and their relationships between one another are mapped out for the Canadian and World cities in Figure 35 and Figure 36 below.[98]

Figure 35 - Correlations of factors involved in auto dependence feedback in the Canadian cities



[98] Some additional factors not summarized in Table 34or Table 35, but included in Appendix 4, will be drawn in the analysis on occasion.

Figure 36 - Correlations of factors involved in auto dependence feedback in the World cities



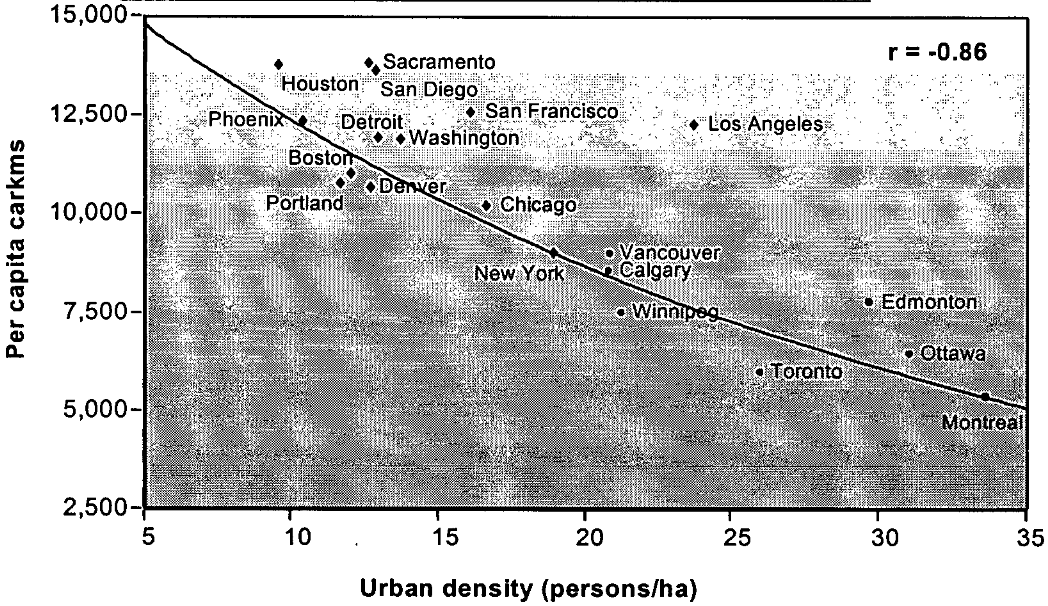
Of the factors studied, urban density, transit supply and CBD parking supply are most strongly correlated with the variables of interest: transit use, car use and car ownership.

4.3.1.0 Urban density

Urban density appears to exert the strongest and broadest influence on the three auto dependence indicators. Much of the correlation data for the density variables[99] in the Canadian cities fall in the –0.8 to –0.9 range for car use and the 0.8 to 0.9 correlation coefficient range for transit use. Figure 37 below shows the relationship between density and car use in the Canadian and U.S. cities for 1991 (-0.86 correlation coefficient; -0.89 for Canadian cities only). Montreal, Ottawa and Toronto lead the North American cities in terms of relatively low levels of car use per capita. Not coincidentally, these cities also have the highest level of transit use. The "outlying" cities on this graph (sitting further from the curve) are of particular interest and some will be discussed in greater detail below.

[99] These include all the employment, population and activity density variables for the CBD as well as the inner, outer and metro areas (see Appendix 4).

Figure 37 - Density and car use in the Canadian and U.S. cities, 1990/91[100]

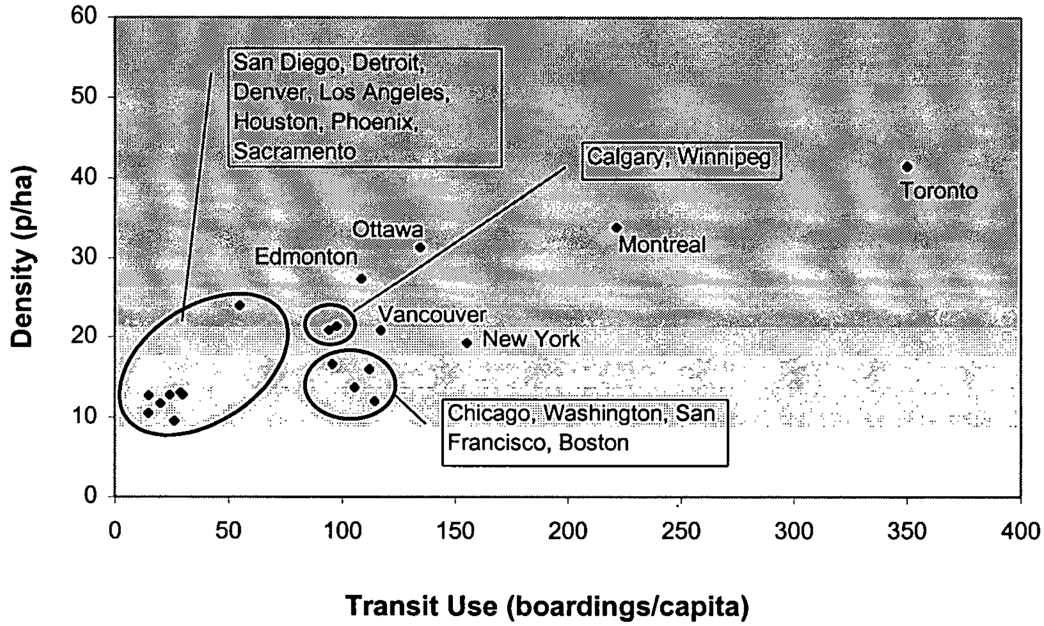


The axiom that higher urban densities facilitate higher transit ridership appears to hold true for Canadian cities. The Canadian cities demonstrate both high (0.76) and very high (0.91) correlations between inner area and metro-wide population densities, respectively. This confirms the observations presented earlier in this chapter, and noted by other authors (Newman and Kenworthy 1989a; Patterson 1993; Perl and Pucher 1995; Pushkarev and Zupan 1977), that higher urban densities are strongly associated with higher transit use. Indeed, density appears to be a key enabling factor for higher transit use.

0 below plots the relationship between density and transit use for the Canadian and U.S. cities. Montreal and Toronto far outperform all other North American cities in transit use. Transit use in these two cities appears to "take off" after the next closest city, New York, managing transit ridership levels approximately 50% and 230% greater, respectively. Much of this higher transit demand can be attributed to the relatively higher urban densities in those two cities. The much higher transit ridership levels in these two cities seems to support the assertion by other authors (Newman and Kenworthy 1989a, for example; Pushkarev and Zupan 1977) that sharp increases in transit ridership are observed in cities where densities are over 30 p/ha. This theory would suggest that several Canadian cities, particularly Ottawa, Edmonton and Vancouver, are under-performing in transit use given their metro and inner area densities.

[100] Toronto's density and car use are for the GTA.

Figure 38 - Density and transit use in the Canadian and U.S. cities, 1990/91



At the lower end of the urban density gradient, the seven U.S. cities hovering in the 8-13 p/ha density range have transit ridership levels of between 15 and 30 boardings/capita annually. Chicago, Washington, San Francisco and Boston all manage to achieve high transit ridership relative to the other U.S. cities, and even relative to some of the Canadian cities. Several factors appear to account for this difference. Unlike the U.S. cities with low transit use, Chicago, Washington, San Francisco and Boston all have extensive rail networks upon which their systems are based (very few of the other cities have any rail whatsoever). Public transport is therefore faster and more accessible. These cities also have somewhat higher metropolitan population densities compared to the other seven U.S. cities as well as very dense inner areas which account for a large proportion of the transit ridership. Finally, and perhaps most importantly, these cities all have extremely tight CBD parking supplies, even by Canadian standards. Since significant regional employment in these cities is still located in the CBDs, many commuters have relatively constrained modal choice options (parking will be discussed further below).

Outer area densities also demonstrate a high degree of correlation with car use and transit use. Outer area density is highly negatively correlated with car use (-0.82). Conversely, density has a high positive correlation with transit use.

Outer area *employment* density also exhibits a very high positive correlation (0.92) with transit use. This does not mean that people in outer areas use transit often for work. Rather, it indicates that where employment densities in outer areas are high enough, transit can provide viable service such that it can attract ridership. Areas with higher density outer areas, such as Toronto, Montreal and Ottawa, are able to attract notable ridership, thereby boosting region-wide ridership relative to other cities.

Higher urban densities not only make car use less necessary and transit more accessible, they also make transit more viable, as discussed in section 4.2.1.4 above. There is a high positive correlation between transit utilization (boardings/km) and metro area population density (0.81 correlation coefficient). This relationship is even stronger between transit utilization and inner area density (0.93 correlation coefficient). Transit systems operating within cities of higher densities will likely have lower servicing requirements, or will be able to deliver higher levels of service to a greater number of people. Density therefore appears to have important implications for transit cost-effectiveness.

One area where correlations with density are not particularly strong is with car ownership. Although there is a high negative correlation with car ownership and inner area density (-0.76), there is a weak negative correlation with metro density (-0.56). This implies that, in the Canadian context, metro-wide changes in density do not affect car ownership to a great extent. One possible explanation is that metro-wide densities are fall with in a comparatively narrow (and low) range. Therefore, urban densities in Canada may not have passed a sufficiently high threshold such that car ownership is not as necessary and accessibility needs can be satisfied to a significant extent by other modes. This is particularly the case for lower density cities like Vancouver and Calgary, where car ownership approaches U.S. levels.

A comparison with the World cities sample, where there is greater upward density variation, supports this observation. These cities (which include the Canadian cities) show a high negative correlation (-0.78) between metro activity density and car ownership. At the higher density end of the spectrum, relatively high degrees of accessibility means that car ownership, or multiple car ownership, is not a necessity. Since most Canadian cities seem to fall short of the "threshold" density for realizing low levels of car ownership like those found in Europe and Asia, owning a car is still necessary to meet some access needs. This is particularly the case at off-peak times where transit service in many Canadian cities can be poor to non-existent. The fact that there is a high correlation between inner area density, where densities reach or surpass European levels, and region wide car ownership does give some credence to the assertion that increases in density in the Canadian context could result in a declining need for car ownership.

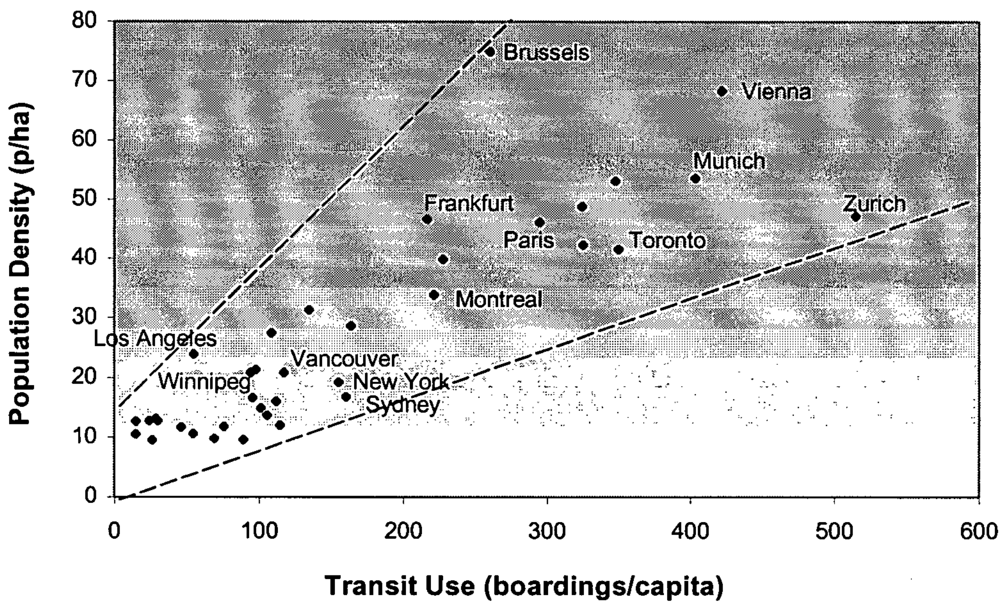
There are likely many other qualitative aspects of urban form not studied here that greatly affect the levels of car and transit use in a city. These may include land use mix, the quality of the urban fabric and the basic walkability and cyclability of the streets. However, at first glance, the net density of a city does appear to act as a suitable barometer in the Canadian context to measure the degree to which a city is auto-oriented.

4.3.1.1 Transit service

While density is a critical enabling factor for cities to achieve lower levels of auto use and higher levels of transit use, it alone is not sufficient. Transit service levels are also critically important (see Figure 33 above). After all, if transit service is widely available, transit use is unlikely to be high, regardless of the density. Amongst the Canadian and World cities, transit supply is very highly, positively correlated with transit use at 0.96 and 0.84, respectively.

Figure 39 below demonstrates that there is a wide range of transit potential ridership levels at various levels of density. It is clear that as density increases, higher levels of transit ridership become possible.

Figure 39 - Density and transit use in Europe, Australia, Canada and the U.S., 1990/91



It is instructive to compare the transit use outcomes of various cities at similar levels of service or similar levels of density. Table 36 below shows the influences of both density and transit service on transit ridership levels in fifteen cities. The shaded areas provide reference points for groupings of cities.

In examining the table, it becomes clear that both density and transit use exert strong influences on ridership. In the first grouping of cities, Los Angeles has the highest urban density of the four cities, but less than 50% of the transit boardings of Vancouver and roughly 1/3 the transit boardings of New York. Winnipeg, Vancouver and New York all have similar densities and ridership increases with higher transit supply. In the second grouping of cities, Montreal is slightly denser than Ottawa. Yet the slightly higher VKT yields many more trips per capita. Frankfurt and Montreal have similar ridership levels although Montreal provides 25% more service VKT. Frankfurt's higher density appears to lower servicing requirements to deliver the same ridership. On the other hand, San Francisco and Frankfurt have similar service levels, yet San Francisco's much lower urban density yields few rides per VKT.

Table 36 - Influence of transit service and density on transit use in 15 World cities, 1990/91

City	Transit Use (boardings/capita)	Transit Service (VKT/capita)	Metro Density (p/ha)	Transit Utilization (boardings/VKT)
Los Angeles	55.0	19.8	23.9	2.8
Winnipeg	97.7	40.5	21.3	2.4
Vancouver	117.2	50.3	20.8	2.3
New York	155.2	62.8	19.2	2.5
Ottawa	134.6	55.9	31.3	2.4
Montreal	221.5	60.2	33.8	3.7
Frankfurt	216.6	47.9	46.6	4.5
San Francisco	112.0	49.3	16.0	2.3
Sydney	160.3	94.0	16.8	1.7
Toronto	350.0	98.4	41.5	3.6
Zurich	514.9	148.1	47.1	3.5
Amsterdam	324.5	60.3	48.8	5.4
Paris	295.0	71.0	46.1	4.2
Vienna	421.8	72.6	68.3	5.8
Munich	403.5	91.4	53.6	4.4

In the third grouping of cities, Toronto and Sydney are similar in population and in service VKT. Yet, Toronto's transit ridership is 118% greater than Sydney's. Again, Sydney's much lower urban density figures appear to explain much of the difference.[101] In the final group of European cities, Zurich, Amsterdam and Paris all have similar population densities, yet the much higher transit service levels in Zurich deliver much higher ridership levels.[102] Paris and Vienna have similar service VKT, yet Vienna's ridership is appreciably higher. Vienna and Munich both have similar ridership levels, balancing inversely related service and density levels.

While adding service can do much to boost transit ridership in cities, it is not sufficient unto itself. Cities at the lower end of the density spectrum have ridership levels that fluctuate only within a narrow and low range. This is especially true of the sub-15 p/ha cities. Only those with relatively high transit service levels (and tight parking supplies to add inducements) are able to attain ridership nearing 100 boardings/capita. However, these cities reach an upper limit of ridership potential, which is only surpassed by cities with higher densities. Density appears to be the condition without which high levels of ridership are not attainable.

[101] Toronto also has better bus-rail service balance and integration which helps to boost its ridership relative to Sydney's.

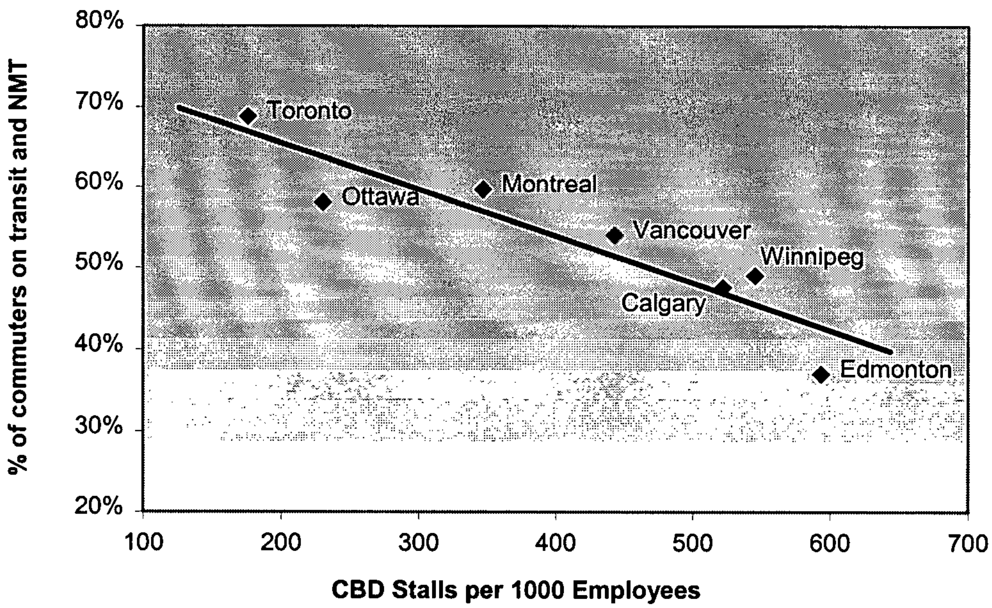
The very high correlation (0.96) between transit use and transit service in the Canadian cities supports the observation made earlier in the chapter that simply providing adequate levels of service translates into higher ridership. It also suggests that many Canadian cities are underserviced given their densities relative to similarly performing cities elsewhere in the world.

4.3.1.2 Parking supply, transit and cars

CBD parking supply exerts a very strong influence on the use of transit. There is a very high correlation (-0.87) between CBD parking supply and transit mode share for the journey to work. This relationship is even stronger when the CBD mode split is examined.[103]

CBD-bound modals splits for the Canadian cities reveal a negative correlation coefficient of -0.92 for the relationships between CBD parking supply and both the transit and the combined transit-NMT mode splits. Not only is the relationship between parking supply and CBD modal split very strong, but transit use and NMT use are also very responsive changes in parking supply, as demonstrated with the case of Calgary parking (see Figure 31 above).

Figure 40 - CBD parking supply and CBD mode split in Canadian cities, 1991[104]



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[102] Since, Frankfurt has a similar density, it is also useful to include it in a comparison with this group.
[103] The journey to work modal split data collected in this studied are to region-wide totals. However, since most Canadian cities have transit systems that heavily cater to CBD-bound trips for the journey to work, this measure is a suitable barometer for transit use to the CBD. However, additional data regarding journey to work modal split *to the CBD* were obtained to confirm this relationship.
[104] CBD-bound transit and NMT mode share data were obtained for Edmonton, Montreal, and Ottawa from TAC (1996).

The CBD parking supply also shows a high (-0.77) and significant (0.70) correlation between transit use (boardings) and car use. Since the parking supply data only cover one small (albeit important) portion of the urban area, it cannot reflect the true impact of regional transport demand. The strong correlations with these other factors, however, may also indicate that: the impact is significantly strong enough in the CBD to affect total regional travel over the year; cities with tight CBD parking supply may also have relatively tight parking supply elsewhere in the city; or tight parking supply in the CBD may have synergetic impacts on transit supply and transportation demand region-wide.[105] Better collection of disaggregated parking and transportation demand data for the region would provide insights about the dynamic of these relationships region-wide. Such disaggregated data would also help describe the relationship between parking supply and car ownership. Currently, the CBD focussed parking data and region-wide ownership data yield no useful information on these dynamics.

Nonetheless, the relationships presented here do confirm the strong association between parking supply and transportation behaviour observed by others (Calgary 1995a; Moore and Thornes 1994; Morall 1996; Shoup 1997). Adjusting parking supply may be an extremely effective, quick, low cost policy lever for boosting transit ridership and NMT use, while reducing car use and ownership.

4.3.1.3 Other factors of importance

Several other factors can be identified as having a moderate to high correlation with the auto dependence variables in the Canadian cities. These are as follows:

1. **Car ownership and car use have a high positive correlation (0.76).** This relationship is even stronger when the larger world cities sample is used (0.84). This may suggest that car availability is a key determinant of use. Since car ownership is expensive and car use is cheap (Litman 1998a), cars will be used once available as a means of extracting value from the sunk, or fixed, costs. This is particularly the case where low densities or lack of transit service require car ownership to meet basic access needs. In the case of high auto dependence cities (e.g., those in Canada, Australia and the U.S.) transit and NMT can rarely meet all of the access needs of residents, thereby requiring the high levels of car ownership (availability) that feed the cycle of auto dependence.

2. **Transit supply and car use have a moderate negative correlation (-0.63).** This relationship is more pronounced when the larger World cities sample is used (-0.81). Again, the stronger correlation found when a larger group of higher density cities is included may indicate that increasing transit supply plays a greater role in reducing traffic at higher densities.

[105] Interestingly, parking supply also has strong correlations with density. This, of course, may simply describe other phenomena for which parking supply is a proxy. For example, cities with low parking supply could have high land costs, which makes low-density development and the building parking expensive. Or, perhaps the cumulative effect of tight parking supply over time has spurred investment in transit, which in turn has shaped land uses.

3. **Road supply and transit use have a moderate negative correlation (-0.63).** However, no clear relationships can be identified between road supply and car ownership and car use (0.43 and 0.26, respectively), although the correlations move in the expected direction. This unexpected result could mean that the road-transit relationship is a chance one. It could also likely stem from the low number of cases, the relatively poor quality of Canadian road supply data and the use of centre-line kilometre instead of lane kilometre data. The use of the World cities data to identify road supply relationships helps to clear up some of the confusion (see below).

Since the Canadian cities results are limited by data quality, have a small sample size and reflect only a narrow range of urban densities (i.e., they are relatively homogenous), the World cities correlation data help to identify additional relationships not clear from the Canadian sample alone. These additional correlations of interest from the World cities sample[106] are:

4. **Road supply is significantly correlated with car ownership and car use (0.69 and 0.67, respectively) and is highly correlated with transit use (-0.80).** These data highlight the relationship between road infrastructure supply and auto dependence. The axiom 'build it and they will come' seems to hold true when the larger sample is considered. Since road length figures are only centreline kilometres, they do not completely reflect roadway capacity. It is expected that these relationships would be stronger using lane kilometres. As was pointed out with several other correlations, road supply appears to have synergetic effects with other factors. The causality is uncertain, but it is clear that many of these effects are mutually reinforcing.

5. **NMT modal share is significantly correlated with transit use and car ownership (0.69 and -0.70) and is moderately correlated with car use (-0.66).** One likely explanation for these correlations is that lower levels of car ownership and use also have other complementary conditions (such as higher densities and better pedestrian and cycling environments) that facilitate more walking, cycling and transit. Better transit services also appear to facilitate (and require) more walking and cycling. The cities with the highest NMT modal splits are those in Europe and Wealthy Asia that have higher densities, better public transport systems and less need for cars to meet basic access requirements.

One final finding of interest is that city size (metropolitan area in hectares) demonstrates very weak correlations with all of the variables studied (generally, less than ±0.3) in both the Canadian and World sample. This dispels the myth that increasing auto dependence is a necessary by-product of urban growth.

4.4 CONCLUSIONS

The trend data presented in this chapter indicate that Canadian cities are becoming increasingly automobile dependent.

Canadian cities are sprawling. While most inner areas remain healthy, or are enjoying a revival, their relative importance in terms of metropolitan activity is declining in all cases and growth is increasingly being accommodated in low-density suburbs.

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[106] Again, the world sample includes the seven Canadian cities.

Most often, these outlying suburban areas are difficult to service by transit and car ownership is virtually a necessity to meet basic transportation needs. Even where transit use has grown in absolute terms, such as in Toronto and Vancouver, it is declining in real terms relative to population, car use and car ownership growth.

At the same time, this cycle of auto dependence is being exacerbated by increasing infrastructure provision for the automobile (in terms of road space and CBD parking provision) and declining transit service. Low-density sprawl sends transit into an economic tailspin. Transit service areas increase while the passenger catchment areas decrease. This reduces ridership, requires increased subsidies and puts further pressure on transit operators to cut services.

The data presented and analyzed in this chapter add a quantitative dimension to the "cycle of dependence" illustrated in Chapter 2. Increasing sprawl requires increasing car ownership that leads to more driving. Transit, walking and cycling drop as the urban fabric cannot support them. More driving results, which leads to increased demands for automobile infrastructure, which increases sprawl. Transit viability is again reduced. The cycle repeats itself, in many cases resulting in almost complete capitulation to the automobile.

Comparative analysis within Canada, and between Canadian and other World cities, reveal commonalities that define levels of automobile dependence. Those cities with higher urban densities, higher transit service provision and lower automobile infrastructure provision all have lower levels of car ownership and use and higher levels of transit use. These cities also have better utilized transit systems, have higher walking and cycling mode shares and burn less gas. Canadian cities sit between the U.S. and European cities in their auto and transit orientation. They appear to have the potential of achieving much higher levels of transit use and lower levels of car use given their land use characteristics and infrastructure.

Given that many of the variables examined in this study appear to exert some degree of influence on transportation patterns, it is important to identify those factors most strongly associated with auto dependence factors (car use, car ownership and transit use) in order to direct policy.

A Pearson correlation analysis provided some initial results that can be used for developing a policy framework to address auto dependence. The correlations do not indicate causality. Rather, they describe a web of interrelationships that must be reconciled with theory and other analyses. More complex statistical analysis can address issues of covariance and proxy variables. However given the task at hand, using the correlation findings in concert with the previous trend analysis and the theory reviewed in Chapter 2 has provided sufficient information for preliminary identification of the relative strength of factors influencing, and being influenced by, auto dependence.

The correlation analysis provided the data necessary to map out the strength of correlation between key auto dependence factors. These are illustrated in Figure 35 and Figure 36 above.

Among the factors examined, urban density has the strongest and broadest correlation with the auto dependence factors. Among the density correlations, inner area density is most strongly associated with high transit utilization. The other factors demonstrating very high correlations with the auto dependence factors are transit supply, followed by CBD parking supply.

The auto dependence factors, too, demonstrate influences worthy of note and amenable to the application of policy. Car ownership (availability) is highly correlated with car use, while transit supply has a moderate to high correlation with car use.

Road supply has a moderate correlation with transit use in the Canadian cities. However, examination of correlations in the larger World city sample reveals road supply has a significant correlation with car ownership and use, and a high correlation with transit use. While these relationships are unclear in the Canadian cities alone, the international data provide valuable information on the role of road supply. However, these relationships require further clarification in the Canadian context. Finally, putting Canada in the context of the larger World cities sample also reveals that NMT is moderately to significantly correlated with the auto dependence factors.

There is no one defining factor that determines whether a region will be auto dependent. Rather a series of associated factors act in concert to deliver a given level of auto orientation. A review of the literature, combined with the trend and correlation analysis on the data collected for this thesis suggests some factors bare a greater relative influence.

Identifying the relative importance of these factors, as has been done above, is an important first step in prescribing policy to mitigate auto dependence. Clearly, policies to increase density and transit supply and restrict parking supply are needed. However, prioritizing policies best suited to mitigating auto dependence is not simply a function of the strength of relationship between two factors. Equally important from a policy perspective are matters such as the breadth of impact on social, economic and environmental effects, the ease of implementation, the time required for impact, political acceptability and financial cost. The following chapter develops a framework for prescribing policies that reconcile priority policy intervention points with these dynamics.

CHAPTER 5 – POLICY FRAMEWORK DEVELOPMENT

5.0 INTRODUCTION

There are a variety of factors that influence the degree to which a city is dependent on the automobile to meet access needs. These factors were identified through a review of the literature in Chapter 2 and many of the key factors were quantified in Chapter 4 through an analysis of data collected for seven Canadian and thirty four European, Wealthy Asian, Australian and U.S. cities. The relationships between these mutually reinforcing factors were expressed in a qualitative "feedback diagrams" (Chapter 2) and an quantitative iteration of this diagram which showed the strength of correlation between factors involved in auto dependence feedback (Chapter 4).

Identifying factors most strongly correlated with auto dependence does not in itself provide adequate information about how feedback occurs or how best to intervene with policy to create desirable feedback. Reconciling the quantitative findings with theory helps to order the strength of influence these factors have on levels of auto dependence. Knowing the relative strength of influencing factors provides a starting point for introducing both positive and negative feedback that is of positive consequence. This feedback can induce countervailing effects on the current cycle of auto dependence and help mitigate its many social, economic and environmental impacts.

This Chapter sets out criteria and a framework for prescribing policy based on the literature reviewed in Chapter 2 and the relative importance of factors influencing auto dependence identified in Chapter 4. This chapter will not prescribe policy, rather it will provide the basis for choosing from policies that offer the most leverage in reducing auto dependence and associated impacts. Towards this end, this chapter will:

1. identify and summarize key 'policy intervention points' for introducing feedback that mitigates auto dependence;
2. develop criteria and a framework for assessing various policies, using selected policies as examples; and
3. discuss some of the dynamics that influence policy choices stemming from the findings.

5.1 POLICY INTERVENTION: INTRODUCING VIRTUOUS FEEDBACK

Reversing the cycle of dependence on automobiles requires the introduction of countervailing feedback that increases the intensity of urban activity, walking, cycling and transit, while reducing car ownership and use (Jacobs 1961; Mumford 1953). Introducing such feedback allows a transportation system to turn the spiral of "vicious" cycles that characterize auto dependence into "virtuous" ones

(Badami 1995). For example, increasing density may lessen the need for car ownership and increase transit ridership. This increase in transit demand may spurn increased transit services, which again facilitate density increases, and so on.

Figure 41 - Possible policy intervention points in creating "virtuous" feedback

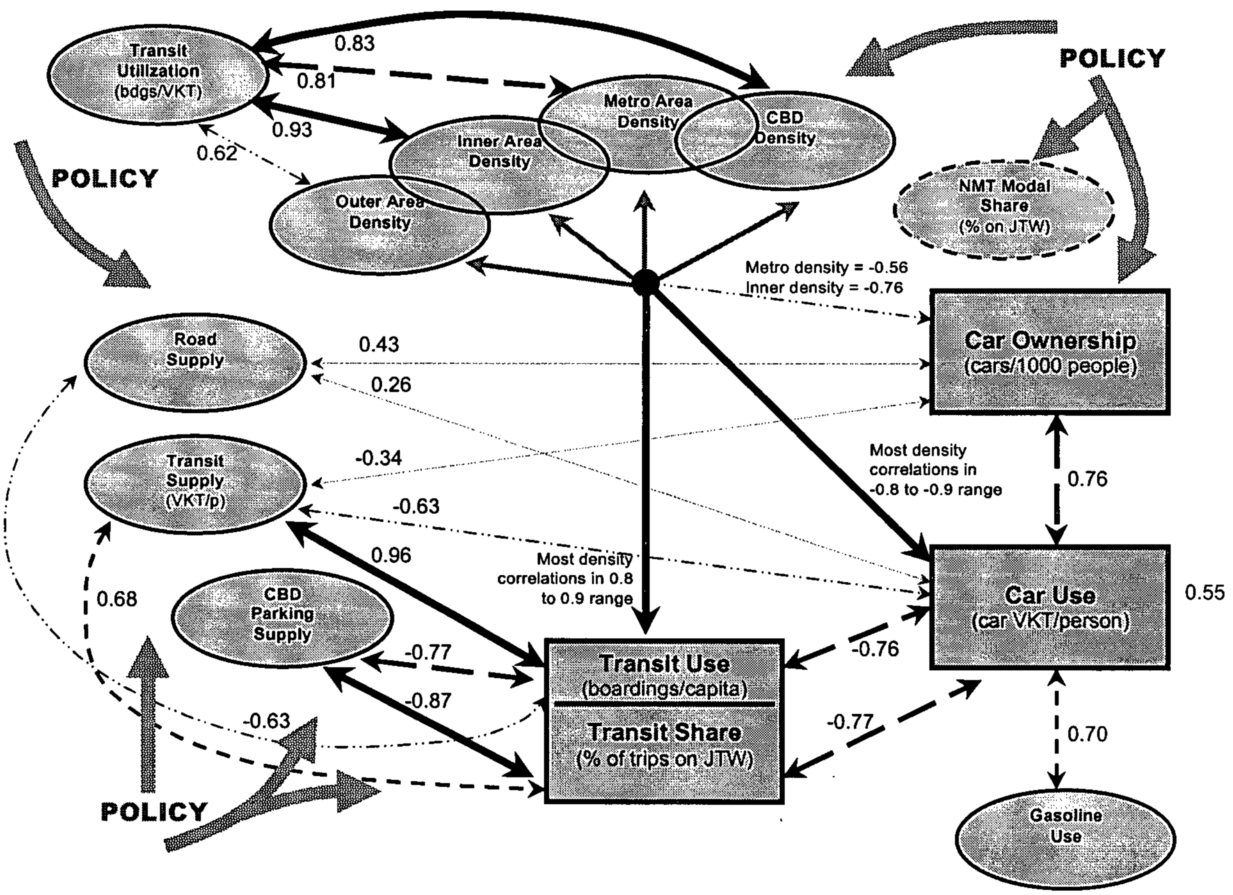

Figure 41 above duplicates the diagram indicating correlation relationships of factors involved in auto dependence feedback, highlighting possible intervention points for policy in reversing current transport feedback cycles. Based on the data analyzed, it appears high leverage intervention points could include:

- land use policies;
- road, transit and parking supply policies;
- NMT encouragement policies; and
- car ownership suppression policies.

Applying policy in these any of these areas will potentially have the effect of reducing car ownership, reducing car use or increasing transit use. Based on the correlation analysis, the relative importance of the various factors are summarized as follows, in descending order of correlation:

Variables very highly correlated

1. Metro density
2. Transit supply
3. CBD parking supply
4. Outer area density

Variables highly correlated

5. Inner/CBD area density
6. Car ownership

Variables significantly-moderately correlated

7. Road supply
8. NMT modal share

Using this hierarchy of factors influencing auto dependence provides a useful starting point for applying specific policies. Clearly, those factors most strongly impacting auto dependence are ones that would be likely candidates for policy intervention. However, the application of transport policy does not operate within a vacuum, and other issues need to be considered in choosing which policies are most appropriate and which should be implemented first.

5.2 DECISION MAKING FRAMEWORK

Potential policies aimed at effecting the variables ranked above need to be evaluated against some standardized criteria in order to determine which are most appropriate for implementation. There has been extensive study of the range of policies available to reduce auto use and their relative effectiveness in changing travel behaviour (Davidson 1997; Downs 1992; IBI Group 1993; OECD 1995; Zupan 1992). Furthermore, Davidson (1997), IBI Group (1993) and Downs (1992) have developed frameworks for assessing the merits of these policies against a series of transportation, social, economic, environmental, feasibility and political criteria.

This study uses the policies and criteria examined by these authors in concert with the findings of the literature review to inform policy analysis of the data. Since the goal of this chapter is to establish a working framework that can be used to assess policy rather than prescribe policy, only selected measures will be examined for illustrative purposes. The potential effectiveness of each policy in meeting stated criteria will be based on a combination of objective and subjective information gleaned from the studies mentioned above and from the literature reviewed in this thesis. As much of the evaluation of TDM measures is based on the U.S. experience, assessments will be adjusted to reflect the Canadian context, particularly when evaluating the acceptability and feasibility of measures. While some of the assessment requires personal judgement, it will be largely based on the extensive findings of many authors on the outcomes of the measures as practiced. Nevertheless, since policy will not be prescribed, and the policies given are merely illustrative, the actual outcomes of each policy are not immediately relevant.

What is of greater interest for the task at hand is the selection of criteria that lead to the most effective policies. In Chapter 2, it was suggested that a "holistic" approach to transportation policy is needed. Such an approach needs to treat the root causes of auto dependence rather than offer mere palliatives that generate "quasi-solutions." These more holistic policies treat a broad range of social, economic and environmental ills associated with automobile dependence by reducing its variable (use related) and fixed (ownership related) impacts. Incorporating such criteria in a policy evaluation framework will help to weed out policies that "see the trees while missing the forest," as suggested in Chapter 2.

In addition, there are criteria that govern the feasibility and potential for implementation. Amongst these criteria that can influence the selection of policies are cost of the measure, ease of implementation, political acceptability and the amount of time required for implementation (Davidson 1997; Downs 1992; GVRD 1993b; Zupan 1992). Ideally, all of the criteria should be weighted. However, given that weighting criteria is typically a political decision, and given that policy is not being prescribed, I will not weight criteria here.

The criteria selected fall into three broad categories: travel impacts; environmental, social and economic impacts; and implementation potential. These are described in Table 37 below. Of course, these criteria can be further disaggregated for a more complete evaluation[107], but also to ensure relevance to local circumstance and regional goals.

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[107] A broader range of impacts of auto dependence was identified in Chapter 2. These impacts could represent additional criteria. While additional criteria could be added to further focus policy evaluation, the criteria presented represent an appropriate summary.

Table 37 - Criteria for evaluating transportation policy

Criteria	Description
Travel Impacts	**These criteria describe the extent to which a measure reduces car dependence and promotes alternatives that are more "exchange" oriented (see Chapter 2).**
Less car use	The relative reduction in car VKT.
Less car ownership	The relative reduction in car ownership levels.
More Transit	The relative increase in transit ridership or mode share.
More NMT	The relative increase in the use of non-motorized travel modes.
Environmental, Social and Economic Impacts	**These criteria are manifestations of the travel impacts noted above. They describe the extent to which a measure improves or detracts from environmental, social and economic well being.**
Resource conservation	The extent to which a measure reduces primary (e.g., gas) and secondary (e.g., construction, housing) energy use, land consumption (e.g., farms, greenspace) and non-renewable resource extraction.
Improved environmental quality	The extent to which a measure reduces air, water and noise pollution.
Improved economic efficiency	The extent to which a measure reduces market and non-market costs. The extent to which a measure supports local economic development.
Improved social welfare	The extent to which the measure improves community cohesion (e.g., neighbourhood connectivity), reduces personal stress (e.g., travel induced) and enhances horizontal and vertical equity.
Enhanced livability	The extent to which the measure enhances safety and the urban fabric/aesthetic and creates people-friendly places.
Implementation Potential	**These criteria measure the feasibility and potential for easy implementation of a measure.**
Cost	The relative cost needed to implement the measure. Measures with low costs are preferred as they take less time to implement.
Ease	Whether legislation, new agencies or extensive administration and coordination are required to implement the measure widely.
Political acceptability	How much public acceptance (and, by extension, political will) there is to implement the measure.
Time required	The relative time required to plan, implement and begin taking effect.

5.2.0 Reconciling Quantitative Findings with Criteria and Potential Policy

Applying policy to each of the correlated factors ranked above yield travel impacts. In turn, these travel impacts manifest themselves in terms of improvements, or deterioration, in the social, environmental and economic criteria. Introducing policy measures to each of these factors allows for the introduction of "virtuous" feedback.

Table 38 below presents a decision-framework for assessing transportation policies aimed at effecting the ranked factors. For each factor studied and ranked, a series of potential policies and measures have been sampled to test their performance in the evaluation scheme. The factors studied in this thesis appear in descending order, according to rated importance, in the far-left column. The policies associated with each of these factors do not appear in any particular order of preference or feasibility. Any range of policies or criteria can be inserted into this framework to allow for an even broader approach to policy evaluation and selection.

The sample policies selected to test this framework were evaluated using the qualitative scale presented in the legend of Table 38. These policies were ascribed qualitative values of effectiveness based on the assessment other authors have provided of these measures[108] and based information gleaned from the literature review. The assessment of these policy measures is therefore subjective and is based on my evaluation of a synthesis of information from various sources.

While the selection of policies is arbitrary for this exercise, it is clear that applied to the criteria developed, some policies are superior to others in terms of travel benefits (in grey shading) and their associated impacts (appearing in the following columns). This is particularly the case with the highly rated factors that tend to affect a wider range of criteria to a greater extent.

[108] The works referred to specifically include: (Altshuler 1979; De Leuw 1976; Downs 1992; Durning 1996; Frank and Pivo 1994; GVRD 1993b; Hart and Spivak 1993; IBI Group 1993; Johnston and Ceerla 1996; Kenworthy and Newman 1994a; Litman 1995; MacKenzie, Dower, and Chen 1992; Newman and Kenworthy 1988b; OECD 1995; Pucher 1998; Rothengatter 1994; Shoup 1997; Williams et al. 1991; Zupan 1992), however many others have informed the evaluation of the policies vis · vis the criteria.

Table 38 - Decision making framewor k for potential policies impacting the variables studied

Criteria for evaluating measures / Potential measures relevant to ranked factors	TRAVEL IMPACTS				RESOURCE CONSERVATION				IMPROVED ENVIRONMENTAL QUALITY			IMPROVED ECONOMIC EFFICIENCY		IMPROVED SOCIAL WELLNESS/ WELFARE			ENHANCE LIVABILITY		IMPLEMENTATION POTENTIAL			
	Less Car VKT	Fewer Cars Owned	More Transit	More NMT	Less fossil fuel	Less sec. energy	Less land used	Extract fewer resources	Air	Water	Noise	Lower mkt. costs	Lower non-mkt. costs	Cohe-sion	Stress	Equity	Urban Fabric	Safety	Cost	Ease	Accept-ability	Time req'd
1. DENSITY POLICIES																						
⇒ Compact mixed land use	●	●	●	●	●	●	●	●	●	●	≈	●	●	●	•	•	●	●	≈	·	·	·
⇒ Transit oriented development	•	•	●	●	●	•	•	•	●	●	•	•	•	●	•	·	●	●	•	•	•	·
⇒ Coordinated transport/land use	●	●	●	●	●	●	●	●	●	●	•	●	●	●	●	•	●	●	•	·	•	·
⇒ Density minimum, new suburbs	●	•	●	•	●	·	●	•	•	•	·	●	●	•	•	·	·	•	•	●		•
2. TRANSIT SUPPLY POLICIES																						
⇒ Add additional bus VKT	●	·	●	·	●	?	·	•	●/≈	●/≈	•	●	•	•	•	●	•/≈	●	•	●	●/≈	●
⇒ Build street-grade LRT	●	•/≈	●	•	●	●	●	•	●	●	●	•	●	●/≈	●	●	●	●	·	•	●	·
⇒ Build RapidBus (curb lane parking removed)	•/–	•/–	●	•/–	•/–	•/–	•/–	•/–	•/–	•/–	•/–	?	?	•/–	•	•	·	•	•	•	●/–	•
3. PARKING SUPPLY POLICIES																						
⇒ Cash in lieu of parking	•	●/•	●	•	•		•	·	•	•	·	•	•/·		•			•	●	●	●	●
⇒ Parking ceilings	•	●/•	●	•	•		•	·	•	•	·	•	•/·		•			•	●	●	•/–	•
⇒ On-street parking restrictions	≈/-	·	≈/-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	●	●	●/–	●
4. INNER AREA DENSITY POL.																						
⇒ Residential infill	●	●	●	●	●	●	●	●	●	●	≈	●	●	●	●	·	●/•	•	●/·	●	●/•	•
⇒ Density bonusing	●	●	●	●	●	●	●	●	●	●	≈	●	●	●	●	•	●	•	●	●	●	·
5. CAR OWNERSHIP POLICIES																						
⇒ Increase urban densities	●	●	●	●	●	●	●	●	●	●	≈	●	●	●	•	•	●	●	≈	·	•	·
⇒ Purchase tax (e.g., Singapore's)	●/≈	●	●/≈		●/≈	•/≈	•/≈	●/•	·	·	·	·	•			•/–			●	•		●
6. ROAD SUPPLY POLICIES																						
⇒ Build HOV lanes	–	–	•/≈	–	–	–	–	–	–	–	–	–	–	–	–	–	–	?	·	•	●	•
⇒ Convert general purpose lanes to HOV	•/≈		•/≈		•/≈	•/–	•/–	•/–	•/≈	•/≈	•/≈	·	·		·			?	●	•	·	•
7. NMT POLICIES																						
⇒ Build cycle routes and install or widen sidewalks	●/•	•/·	•	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
⇒ Traffic calming	•/·	·	·	●	•	•		•	•	•	●	·	•	●	●	•	●	●	●	●	●	●

LEGEND: For travel, environmental, economic and social impacts of proposed measure	
●	Large Impact
•	Moderate Impact
·	Modest Impact
≈	Variable Impact
	Negligible Impact
-	Negative Impact

LEGEND: For implementation potential of proposed measure	
●	High potential (i.e., high feasibility)
•	Moderate potential
·	Modest potential
≈	Variable potential
	No potential

5.3 SOME DYNAMICS OF POLICY EVALUATION

Evaluating and choosing policies for implementation is not as simple as choosing the policies with the strongest and broadest impact on the transport, social, economic and environmental criteria. Often, effective policies do not get implemented because there is much public resistance or because the institutional and cultural barriers are too entrenched (Downs 1992; Moore 1994; Newman, Kenworthy, and Vintilla 1995; Zupan 1992). Policy is not implemented in a vacuum. There are other dynamics that profoundly effect the implementation potential of a particular measure.

Four criteria (cost, ease of implementation, public acceptability and time required for implementation) were added to the evaluation framework to reflect these policy selection dynamics[109].

To see how the "implementation potential" dynamics may affect policy decisions it is instructive to compare the policies evaluated for the top three factors cited as influence auto dependence: density, transit supply and parking supply. Table 38 shows density to have predominantly large effects on the travel impact criteria and its associate impacts in the following columns. Providing more bus service or building LRT (transit supply) has predominately large and moderate effects. Meanwhile, parking ceilings and cash in lieu of parking produce predominately moderate effects on the criteria. These measures have a large impact only on transit ridership.

However, the evaluation of the implementation potential of these policies reveals the opposite pattern. The parking policies have highest implementation potential by most of the criteria. The transit supply measures, then the density measures follow this. The density measures in particular show modest to moderate potential for implementation by most criteria. This reflects the long lag time require to realize appreciable density increases and the intense resistance there is to density increases in many single-family neighbourhoods. On the other hand, residential infill and density bonusing offer high impacts as well as high implementation potential. Residential infill can result in considerable cost savings from the utilization of existing infrastructure (unless site remediation is necessary and costly). Moreover, since infill is typically located on vacant disused industrial, there is rarely community opposition, and, often, there is substantial support. This is precisely the strategy the City of Vancouver has used for densifying and revitalizing many areas of that city.

Building cycle and pedestrian routes and traffic calming roads have mixed travel impacts, yet substantial social, economic and environmental benefits. The lower auto travel reductions reflect the fact that most car trips replaced by cycling and walking will typically be shorter trips. These travel reductions

[109] These are described in Table 37 above. Again, other criteria can be added. However, those presented are representative of key criteria.

can become more substantial if there is an attendant trend towards densification. However, these measures have high implementation potential because they are relatively cheap, straightforward to design, desired by the public and quick to build. Therefore, despite lower initial travel impacts, NMT policies could be high priorities for implementation.

Policies should not be selected or abandoned based strictly on their implementation potential alone. Rather, criteria assessment information could prove useful in instituting certain effective measures (albeit, ones that are less effective) until such time that other measures become acceptable, there is money to implement them, institutional issues can be resolved or they begin to take effect. Or, criteria assessment information can be used to evaluation the many trade offs typical of policy selection. Effective policy analysis means ensuring these trade-offs should be known and understood, combining technical knowledge with policy insights and skills (Morgan and Henrion 1990). It also means ensuring that the criteria are weighted according to the values driving their selection (McDaniels 1994). Sometimes this weighting flows from public consultation processes. However, most often it occurs at the bureaucratic or political level, one or two more steps removed from the public. In the final analysis, selection and timing of policy prescriptions rests on much more than the efficacy of the policies alone.

5.4 CONCLUSION – EFFECTIVENESS OF THE FRAMEWORK

The literature review in Chapter 2 concluded that 'holistic' policies designed to address the fundamental problems of auto dependence would need to accomplish several objectives. Policy measures that are more holistic by nature will:

- promote exchange and access over mobility and speed;
- reduce car ownership and use;
- provide a counterweight to the positive feedback relationships that feed auto dependence; they either provide 'negative feedback' (suppressing unwanted action) or set in motion desirable positive feedback loops; and
- engender intrinsic responsibility or mutual cooperation in using and managing common property.

The policy evaluation framework developed in this chapter provides a highly effective means of reconciling the quantitative findings in the previous chapter with the holistic policy approach argued for in Chapter 2. It helps to discern policy approaches that make broad and significant contributions to reducing automobile dependence.

Using the criteria developed, it is possible to determine policies that result in large impacts on modes that are more access and exchange oriented. For example, many of the land use policies enhance the urban fabric, facilitate the creation of 'people places' and lead to a natural tendency towards local transit and NMT over long haul car-based travel. Likewise, policies that reduce car ownership and use while still facilitating access, such as NMT and certain transit supply measures likewise contribute to the holistic objective described.

Many of the measures described also represent policy interventions that help introduce 'virtuous' feedback and the many synergies that flow from it. Moreover, it is possible to identify quasi-solutions that do not make appreciable contributions to reducing auto dependence, and may in fact aggravate it by introducing "vicious" feedback. Building new HOV lanes and removing curbside parking to introduce a "RapidBus" service may be two such measures with variable or negative impacts that may introduce such feedback.

Finally, many of the factors examined are amenable to treatment by policies that facilitate mutual cooperation and decision-making in managing common property, or the "mutual coercion, mutually agreed upon" proposed by Hardin (1968). For example, coordinated regional transportation land use planning requires cooperative planning and management by municipalities, regional and provincial governments and the private sector. Many competing objectives must be traded off and many localized costs must be borne, or benefits forgone, in order to protect assets of common interest.

One important objective in holistic policy evaluation that is not reflected given the factors examined is "intrinsic responsibility" (i.e., giving individuals appropriate queues to assume personal responsibility for their costs imposed on society so that they alter their choices accordingly). There do not appear to be many factors of the examined that are amenable to the introduction of market based measures, for example, that offer individual actors a mechanism for response to their actions. Some factors may be amenable to such measures. For example, an automobile licensing tax, paid at the time of vehicle purchase, may be sufficiently large to reflect many of the market and non-market costs incurred in the production of the vehicle, but external to the buyer. Such a tax would be a signal to the buyer that there are many fixed costs associated with the production of the automobile that are otherwise imposed on society. A decision reflecting this reality will more likely be made than if the buyer is a "free rider" in the economic sense of the term.

A major reason why many of the measures that engender intrinsic responsibility can not be confidently recommended is that the factors studied were primarily limited to transportation supply and demand. Relevant market and regulatory factors that generate intrinsic responsibility, and noted as eliciting potentially strong travel behaviour responses (IBI Group 1995; Litman 1995; MacKenzie, Dower, and Chen 1992), and were not surveyed in the study. For example, although it may be reasonable to expect that increases in parking surcharges may have effects similar to constricting supply, such policies cannot be recommended with full confidence unless the behavioural response to parking price increases are fully examined. Since parking price and taxing data were not collected, their relationships with the other factors cannot be explored or reasonably assumed.

Notwithstanding the limitations with respect to the "intrinsic responsibility" objective of holistic policy evaluation, the policy evaluation framework proposed provides a useful starting point for assessing potential transportation measures. It provides a basis from which to examine other factors as they are identified and add or tailor criteria as necessary. The policy prescriptions that flow from this framework may offer some hope of addressing some of the fundamental factors that feed auto dependence.

CHAPTER 6 - CONCLUSIONS

6.0 SUMMARY

The relative importance of factors influencing automobile dependence in Canada's major cities have been identified through a comparative quantitative analysis of factors correlated with auto dependence in Canadian and World cities. The findings of such a quantitative analysis can be used to inform and direct the development of an evaluation framework that helps assess the relative merits of various policies' breadth and extent of impact on reducing auto dependence and its associated symptoms. A comparative approach to urban policy analysis is useful for both theorists and practitioners to learn lessons from the experience of other regions. In this thesis, the comparative approach was used in conjunction with a quantitative analysis of the key forces that contribute to higher and lower levels of automobile dependence as well as to develop the evaluation framework.

6.0.0 Auto Dependence in a nutshell

Chapter 2 consisted of an extensive review of the literature to help guide the analysis of the data collected and provide a basis for developing a policy evaluation framework. In that chapter, automobile dependence was defined as a series of convergent land use and transportation conditions in a city that leave people few non-auto options for urban travel. Such conditions included sprawling, segregated land uses, poor transit service and ridership, low NMT use, ample auto-related infrastructure and high car ownership and use. Reducing automobile dependence requires a refocussing of policies to promote access and exchange over mobility and speed. In doing so, the quality and intensity of activity can be heightened such that they complement walking, cycling and transit.

The literature identified a multitude of mutually reinforcing factors that contribute to the creation of automobile dependent cities. Among these factors are urban sprawl, road building, transit decline, decaying urban fabric, underpricing of market and non-market transport costs (e.g., subsidies), auto infrastructure supply increases, cultural attitudes and demographics. These factors cannot be neatly characterized as 'causal.' Rather, they are both cause and effect. The contributing factors listed above display a phenomenon well known to environmental and social problems called "feedback." That is, one action leads to a reaction that in turn intensifies the condition responsible for the initial action. The need for repeating the initial action is amplified and a cycle is set in motion. Some of the feedback relationships were sketched out in Figure 3 of Chapter 2. There is no single feedback loop entirely responsible for auto dependence, however some feedback relationships may play larger roles than others.

Collectively, these feedback loops create a "vicious" cycle of automobile dependence that is seemingly intractable.

Another perspective on the intractability of the problem can be found in common property theory. With common property (e.g., air, water and land), there is often no direct responsibility assumed by an individual actor for their actions. Usually, the benefits of an action are high and the negative consequence are diffuse resulting in the plundering of a common asset, or the "tragedy of the commons" (Hardin 1968). The individual, for example, does not directly feel the negative consequences of their marginal contribution to air pollution from driving. Yet, the benefits they receive are perceived to be quite high. The individual possesses a "negative responsibility" (Hardin 1985) where 'it pays' to make the wrong transportation choice (from society's point of view, at least).

Many of the diffuse costs of transportation decisions do not enter into the feedback equation. Therefore, responsibility is not assumed because there is no direct adverse consequences. The omission of these "common" factors from the feedback equation results in feedback that is incomplete for the individual. At the societal level, the aggregate effect of such decisions leads to repeating and intensifying positive feedback loops: more pollution, leads to less walking, leads to more driving, leads to more pollution, and so on. Moreover, there are few mechanisms or incentives that bring individual actors together such that the commons can be cooperatively managed.

From society's perspective, the key to overcoming common property problems is to facilitate cooperation and create intrinsic responsibility (that is, direct positive or negative responses to individual action).

The feedback mechanisms that drive automobile dependence are manifest in many ways. Table 39 below summarizes the key environmental, economic and social impacts associated with the automobile life cycle. These impacts exhibit tremendous complexity in terms of their multi-dimensionality, their scope and their mutually reinforcing relationships. The impacts inventoried seem to fall in to two broad categories amenable to clear policy analysis. Those which are "fixed" and those which are "variable." Fixed impacts are those that are incurred regardless of vehicle kilometers driven (i.e., by virtue of ownership). Such impacts include those incurred in manufacture, in the construction of parking or in vehicle disposal. Variable impacts fall or rise (not necessarily proportionately) with the number of cars and their level of use. Variable impacts include pollution, health costs, accidents, maintenance, infrastructure and the like, which are vehicle use related.

This dichotomy is a useful perspective for policy analysis since it addresses the complexity of transportation symptoms with a great deal of simplicity and clarity: by addressing the root sources of auto-related impacts. Moreover, fixed impacts are externalities typically ignored by policy analysis. While many impacts are both fixed <u>and</u> variable by source, many are just fixed. For example, reducing

CO_2 emissions by reducing vehicle use does not eliminate the auto-related CO_2 problem. One quarter of a car's life cycle energy is embodied in the vehicle itself (OECD 1995). Much of a car's global CO_2 contribution is made before it is even driven. In a perfect world where people just owned cars and did not drive them, numerous problems would remain.

Table 39 - Impacts of auto dependence summarized

Environmental			Economic			Social		
	Impact Type[110]			Impact Type			Impact Type	
	Fixed	Var.		Fixed	Var.		Fixed	Var.
Foodlands loss	✓	✓	Sprawl	✓	✓	Health	✓	✓
Wetland loss	✓	✓	Housing affordability	✓	✓	Noise		✓
Wildlife loss/disrupt'n	✓	✓	Congestion (time)		✓	Accessibility	✓	✓
Sprawl	✓	✓	Vehicle ownership	✓		Liveability		✓
Severance	✓	✓	Vehicle operating		✓	Equity	✓	
Water (hydrology)	✓		Parking	✓	✓	Isolation	✓	
Water (runoff)		✓	Road facilities	✓		Dysfunction	✓	✓
Smog		✓	Opportunity cost	✓		Public realm	✓	✓
Acid rain	✓	✓	Accidents		✓	Safety	✓	✓
Air pollution	✓	✓	Property loss		✓			
Global warming	✓	✓	Public services	✓	✓			
Energy use	✓	✓	Other ext. non-mkt	✓	✓			
Resource extract'n	✓	✓						
Vehicle disposal	✓							

The tendency to overlook the fixed impact highlights a problem endemic in transportation policy. Only a very narrow range of variable/environmental impacts listed in the table above are typically recognized in transportation decision-making. For example, transportation policy overwhelmingly focussed on addressing the variable environmental impacts of transportation, most noteably air pollution and smog. Meanwhile the many other fixed and variable environmental impacts, in addition to the social and economic ones, are largely not attended to.

Since many "solutions" to the transportation problem only focus on a narrow range of symptoms, the prescriptions are usually incomplete. These "quasi-solutions" often lead to a worsening of the symptom being treated or the creation of secondary impacts (Schwartz 1971). Furthermore, defining problems in such narrow terms means that more effective strategies for dealing with the problem are essentially forgone since policy efforts are directed at micro- and meso-level policy rather than macroscopic, holistic policies which consider a wider range of criteria. Defining problems in such narrow terms means the prescriptions for affecting them will necessarily be incomplete.

[110] Fixed impact are impacts that are incurred regardless of vehicle kilometres driven (e.g., by virtue of ownership). Variable impact are impacts that fall or rise (not necessarily proportionately) with vehicle kilometres driven (e.g., by virtue of use).

From a policy perspective, it would appear that greater and broader benefits could be realized by addressing the many symptoms through the two primary sources of impacts, car ownership and car use (the columns), rather than by addressing each individual symptom (the rows). That is, by intervening at the root causes rather than the many symptoms, it is possible to hit many birds with the proverbial stone. Given the limited range of criteria considered by traditional transport policy in treating automobile dependence or its related symptoms, there is a real need for a more holistic approach. Holistic policies are ones that promote exchange and access over mobility and speed, reduce car ownership and use, create responses that introduce "virtuous" feedback, engender intrinsic responsibility and facilitate mutual cooperation in managing common property. Transportation policies proposed can be tested for their 'holism' using their mitigative potential on the impacts listed above as evaluation criteria.

6.0.1 Data: The Good, the Bad and the Ugly

The methodology employed for this study was rigorous and thorough to ensure a high degree of comparability between the various urban centres. The experience that Jeff Kenworthy and Peter Newman have acquired in collecting this type of data over the past 18 years in Canada and globally has been invaluable in ensuring a high degree of data consistency and integrity. While there is some degree of error associated with some of the data items (particularly, the modelled data), the patterns and correlations are so consistent and strong[111] that, overall, reliability can be assumed to be quite high.

There are, however, limitations in the data. Many data items were difficult to obtain for the 1971 and 1961 study years. This made conducting some of the trend analysis difficult. There were also certain data items that were difficult to obtain reliable estimates of, particularly pre-1991. Gasoline use and vehicle occupancy data are two such examples.

Often, data might have been collected for certain parameters, but not for the study years requested. The study years were chosen because the coincide with census years, making data availability for most items high and making standardization easier. Many cities, however, do not consistently collect data to coincide with the census. This is surprising considering the data would be much more useful in concert with the census.

Finally, there were some difficulties in collecting data for certain cities, namely Toronto and Edmonton. The main difficulty with Toronto is that since 1971 its functional regional area began to expand significantly beyond Metro Toronto's borders. By 1991 nearly half the GTA's population lived in communities outlying Metro Toronto. However, there was no agency charged with collecting consistent data for the region. For this reason, it was necessary to use Metro Toronto data consistently for multi-

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[111] Furthermore, the data identified as having notable correlations with auto dependence factors are also generally statistically significant, particularly within the larger World Cities sample.

year comparison. Some selected data were available for the GTA for 1991 (and 1981, to a much lesser extent) and these were used where appropriate. In the future, it is expected full data would be available for the GTA making trend analyses for the entire region easier.

Edmonton was a data nightmare. It is surprising that the city is able to plan effectively for itself given the dearth of information available. Planning staff could not provide even some of the most basic of information for 1991, such as the number of jobs in the inner area. Much of the remaining data was only available for 1994. This made pursuing some of the potentially interesting findings difficult. For example, the density of the outer areas in Edmonton is marginally higher than the inner area density. This pattern was not observed in any other North American city. However, given the questionable quality of some of Edmonton's data, it was not clear whether this was simply a reporting error by the city of Edmonton[112] or an anomaly worth investigating.

Overall, data collection and availability in most Canadian cities is relatively poor by international standards. There appears to be a widespread sentiment at the political and, to a certain extent, bureaucratic levels that data collection is not important or is expendable. There is no central agency in Canada that collects transportation data and there is no clear or established methodological convention for the regions or municipalities that do. Furthermore, as indicated above, the utility of data is not as high as could otherwise be since they most often do not coincide with other data collection projects. This contrasts with the U.S., where there is extensive data collection at the regional, state and federal levels, particularly in conjunction with the census.

The Transportation Association of Canada has recognized the lack of quality data as a transportation planning barrier that needs to be addressed. For several years now, it has been trying to develop standards and conventions for collecting periodic transportation data. However, it is unclear how much buy-in there is from its member municipalities and agencies or how long it will take for such conventions to be adopted.

6.0.2 Findings: Crunching the Numbers

A large volume of data for seven Canadian and thirty-five other World Cities were condensed and analyzed. The first stage of this analysis consisted of identifying and discussing major trends and patterns. This stage informed the subsequent correlation analysis, which identified and ranked those factors most highly correlated with auto dependence.

The trend data indicate that Canadian cities are becoming increasingly automobile dependent. Canadian cities are sprawling. Increasingly, this growth is being accommodated in rings of low density

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[112] I was unable to satisfactorily clarify the issue of outer area densities with Edmonton planning staff. There did not seem to be an awareness of the pattern nor a real sense of whether it reflected reality.

suburbs surrounding relatively dense inner cores. These outlying suburban areas are difficult to service by transit and car ownership is virtually a necessity to meet basic transportation needs.

Increasing infrastructure provision for the automobile and declining transit service is exacerbating this resulting cycle of auto dependence. Low-density sprawl compromises the viability of transit services. Attempting to service these areas results in transit service kilometres being spread over areas with low catchment potential. This sends transit into a cycle of decline, whereby low levels of service beget low levels of ridership, thereby increasing subsidies and the attendant pressures for operators to cut service.

The trends presented point to a "cycle of dependence" whereby increasing sprawl requires increasing car ownership which leads to more driving. Alternative modes faced reduced viability, which results in more driving, and increased demand for auto infrastructure, which increases sprawl.

There are common threads defining cities at various points on the auto dependence spectrum. Cities with higher urban densities, higher transit service provision and lower automobile infrastructure provision all have lower levels of car ownership and use and higher levels of transit use. These cities also have better utilized transit systems, have higher walking and cycling mode shares and burn less gas.

Canadian cities sit between the U.S. and European cities in their auto and transit orientation. Toronto and Montreal appear to be the least auto-dependent cities in Canada. They have extensive transit systems with high ridership, relatively low levels car ownership and use and relatively dense metro (particularly inner) areas. Their transit ridership levels are the highest in North America and approach some of the 'lesser' European cities. However, the outer areas of Toronto and Montreal are developing at very low densities and levels of car ownership, car use and transit use trends are reflecting this pattern. Ottawa has in the past managed to maintain high levels of transit ridership, however this appears to be declining amid transit service cuts. Given its high urban density, it appears Ottawa's transit is relatively underserviced. Edmonton and Winnipeg, too, have witnessed dramatic declines in transit ridership due to service cuts.

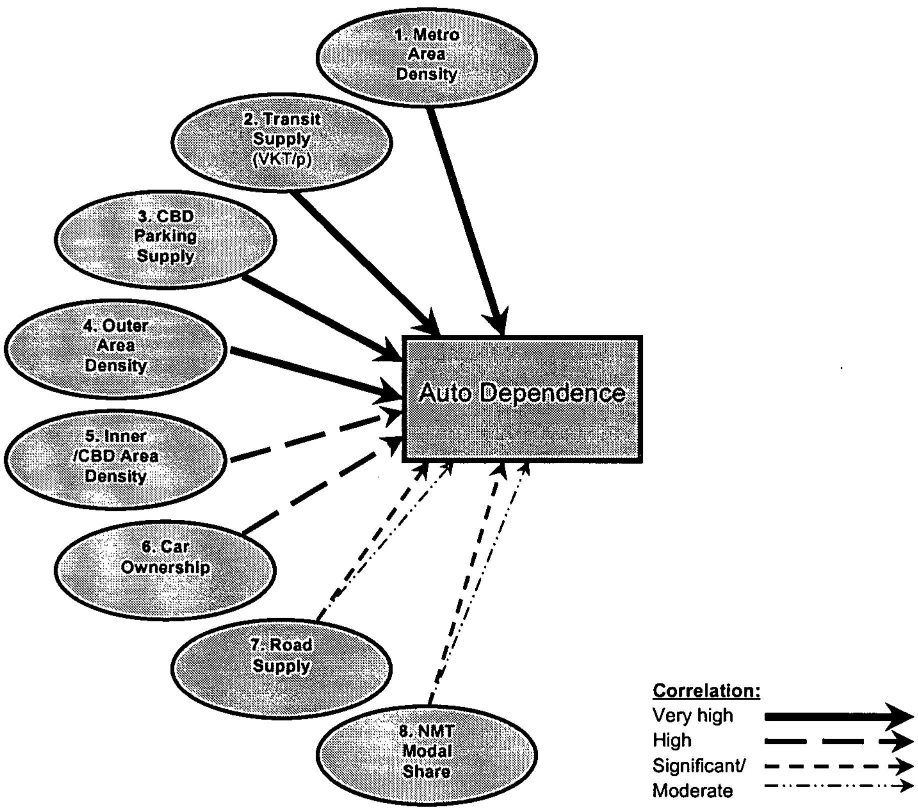
Calgary and Vancouver are the most automobile dependent cities in Canada. They exhibit the lowest overall urban densities, the highest car ownership levels (approaching U.S. cities) and high levels of car use. Calgary is an interesting case because it clearly demonstrates the responsiveness parking supply has with transit use. A sharp increase in 1981 and then precipitous drop by 1991 in CBD transit mode share corresponded inversely with CBD parking supply changes. An overall region-wide drop in transit ridership from 1981 – 1991 also corresponded with sprawling peripheral development and service cuts to transit. Vancouver is an interesting case because there appear to be two solitudes. A very dense, transit-oriented inner area, and a very low-density auto-dependent suburban ring. While transit use increased in Vancouver between 1981 and 1991, most of the gains came from within the inner core, while service expansion to the periphery yielded low gains. Moreover, this growth in ridership trailed population growth substantially and there was a strong growth in auto use.

One common theme amongst the Canadian cities, though, is that despite current trends, they all appear to have the potential of achieving much higher levels of transit use and lower levels of car use given their land use, infrastructure and institutional characteristics.

* * *

A correlation analysis of the data was conducted to make a preliminary determination if any of the feedback responses, as expressed by the variables studied, were most strongly correlated with the auto dependence factors (car ownership, car use and transit use). A diagram was constructed (Figure 35 in Chapter 4) describing the strength of correlation between various factors involved in auto dependence. It describes in quantitative terms, the web of interrelationships, highlighting the strongest ones.

Figure 42 - Factors most strongly correlated with automobile dependence



An analysis of the data indicated that certain factors consistently exhibit the strongest correlation on the automobile dependence factors. These are summarized in Figure 42 above. These indicate that some factors may indeed play a larger relative role. This provides very valuable preliminary information for guiding further analyses of the data and directing transportation policy.

While the results obtained to confirm certain relationships and provide insights on new ones, more rigorous statistical and qualitative analysis is needed. Such analyses could include regression or multiple-regression analysis that can take into account covariance and proxy variables and have more statistically significant explanatory value. It can also include case studies of patterns before and after various policies have been instituted. The findings of the correlation analysis are valuable in that it presents a number of questions to pursue in these future analyses.

Nonetheless, the initial correlation findings, used in concert with the trend and pattern analysis and the literature reviewed, allow for the preliminary identification of the relative strength of influence of various contributing factors.

6.0.3 Policy Directions: From Reductionism to...at Least a Bit More Holistic

There are scores of transportation policies to choose from in addressing auto-related impacts, but the key question is, which policies are best?

Ranking the relative importance of factors involved in auto dependence feedback is useful because it can identify possible high-priority intervention points for the introduction of virtuous feedback. When the intervention points are known, various interventions can be formulated and their relative effectiveness measured against criteria that capture a wider range of impacts than those typically considered. It is in this way that policies can be tested for their net effectiveness in reducing the impacts of auto dependence on individuals and communities and that the quasi-solutions can be identified and weeded out.

Those policies that meet objectives of reducing car ownership and use, promoting exchange and access over speed and mobility, introducing virtuous feedback, facilitating cooperation and creating intrinsic responsibility are likely to show the most broad and extensive impacts on the criteria. It is possible for policies associated with the ranked factors to meet many of these "holistic transportation policy" objectives.

Policies may have a large impact on many of these objectives and many criteria, however their implementation potential may be low. For example, certain measures may be too expensive, require heavy administration, may take a long time or may be politically unacceptable. The "best" policies, therefore, are ones which achieve a broad array of objectives and impact many criteria, but are also feasible. Some high impact policies may take several years or even decades to yield results, meaning other measures will need to be taken in the interim. The ideal package of policy measures selected must balance timing, cost, implementation and political constraints to deliver maximum impact on the factors.

One element not reflected in the policy evaluation framework developed is the weighting of criteria. It may be desirable to impact certain criteria more than others. For example, acute air pollution may be a more pressing problem than noise. Weighting can also be extended to factors influencing implementation potential. For example, it is likely that "political acceptability" is one of the most highly weighted decision criteria. Indeed, Downs (1992) notesthat it is unlikely any effective measures will be taken until the citizenry (and therefore decision-makers) feel that the problem is more painful than the solution.[113]

The policy evaluation framework is not a panacea for transportation decision-making. It likely does not cover every effect of auto dependence. It is meant simply to help move beyond reductionist problem solving to a more integrated approach to policy-making. It is therefore meant to be dynamic and adaptable.

6.1 AREAS FOR FURTHER RESEARCH

This study involved the compilation and analysis of a large volume of data. It also identified many of the key factors that contribute to automobile dependence in Canadian cities and developed a framework for prescribing transportation policy. There are several areas for further research that are recommended based on my experience of the process of collecting and analyzing the data as well as on the substance of the findings.

Knowledge

1. There needs to be a more rigorous statistical analysis of the data. This should include a regression analysis of the data so that the relationships between factors contributing to auto dependence can be better understood. Regression analysis would lend greater explanatory value to the data as it would be possible to estimate how much of the variance in the model is explained by the variable examined. It would also be useful in developing an equation of some nominal predictive value. Perhaps there are some basic "rules" by which urban transportation systems operate.

2. There needs to be a more detailed examination of the relationship between parking and transportation behaviour. The parking data collected for the thesis show very strong relationships between CBD parking and CBD mode split. While these findings have specific application withing the CBD, where activity is relatively concentrated, these relationships should be tested elsewhere in urban regions to see the degree to which parking supply is relevant. Furthermore, additional information regarding parking, such as price and taxation, could be collected to help explain behavioral responses to parking cost.

3. A more broad set of NMT measures need to be collected to further explore its role in regional transportation. Currently, only a.m. peak trip modal split data were collected which only capture a small portion of NMT trips by purpose, time and origin. The level of all trip NMT use 24 hours a day, 7 days a week would help to define its relationship to the auto and transit use data collected for the year. While this may be a difficult task requiring extensive surveying, it is necessary so that the role and potential of NMT is not over or underestimated. For example, effective least-

[113] From Moore and Thornes (1994).

cost strategies may not be pursued because the *potential* role of NMT is not fully understood and therefore underestimated (Hillman 1996). Instead, more expensive and capital intensive public transport solutions may be offered.

4. Market-based and regulatory variables that induce individual behavioral responses need to be more fully explored. This study mostly examined elements of transport supply and demand. However, a major reason for inefficient transport choices is that pricing mechanisms distort true costs and therefore lead to perverse behavior (Litman 1995). Understanding how fuel, parking and transit costs, for example, induce "intrinsic responsibility" and interact with the other variables studied will greatly expand our understanding of the dynamics at play.

5. A set of conventions for collecting standardized data needs to be developed. There are many lessons to learn from comparing the transportation performance of urban centres, however the lack of quality comparative data, particularly in the Canadian context, makes this process exceeding difficult and time consuming. The Transportation Association of Canada has made preliminary attempt at developing such conventions for Canadian municipalities (TAC 1996), however there are many methodological problems that still need to be resolved.

6. There are many interesting questions particular to each of the cities that arise, but were not possible to explore within the scope of this thesis. Why are Edmonton's outer area densities higher than the urban average? Does the responsiveness of transit use to the parking supply changes observed in Calgary hold true of other cities? Why has Montreal's recent car ownership and use growth been so strong? There are many more questions. Clearly, each city has more lessons to offer and unique "stories" to tell.

<u>**Action**</u>

7. Many of the policies that can reduce policies are widely known, but not so widely implemented. Why are some cities better at moving from rhetoric to action? A preliminary comparative examination of the institutional underpinnings of better transportation policymaking was made in an article published based on the data presented here (Raad and Kenworthy 1998). However, a better understanding of the factors that facilitate common good policies can help regions to enact policies that will reduce auto dependence.

8. An understanding of how different stakeholders (e.g., advocates, academics, government and constituents) perceive the problem of auto dependence can help in developing a common basis for prescribing policy. It is difficult to develop consensus on solutions if the problems are perceived to be different. Reviewing the literature to identify impacts that are of concern to each group can be used mediate differences. For example, Table 39 above can be further disaggregated by stakeholder group to gain information about their respective perspectives on the issues. It will then likely become apparent where challenges exist in moving to a more holistic policy approach.

6.2 CLOSING REMARKS

Automobile dependence is compromising the environmental, social and economic health of cities in Canada. Automobile dependence is increasing in Canada as are it attendant impacts. We need to understand some of the primary relationships affecting this trend if we are to adequately mitigate its impacts. There is hope, though. Some cities are successfully addressing auto dependence by implementing progressive transportation policies. Much can be learned from the experience of these cities.

The findings in the study are important because it presents a comprehensive overview and quantification of the trends, patterns and key factors influencing automobile dependence in Canada's major urban centres. Many of the comparative relationships identified, quantified and discussed have not been presented prior to this study. The auto dependence factors identified therefore help identify areas for further study and clarification and provide a preliminary, but sound, basis for directing policy analysis.

We need to move from knowledge to action. However, transportation decision-making criteria are chronically myopic. The problem of auto dependence is exceedingly complex and cannot be distilled to a simple problem of air pollution, sprawl or mobility. The use of a more holistic framework that considers a broad range objectives and criteria, offers advocates, academics, the public and decision-makers a tool for turning knowledge of factors influencing auto dependence into effective action.

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APPENDIX 1 – MAPS AND TERRITORIAL BOUNDARIES

Calgary

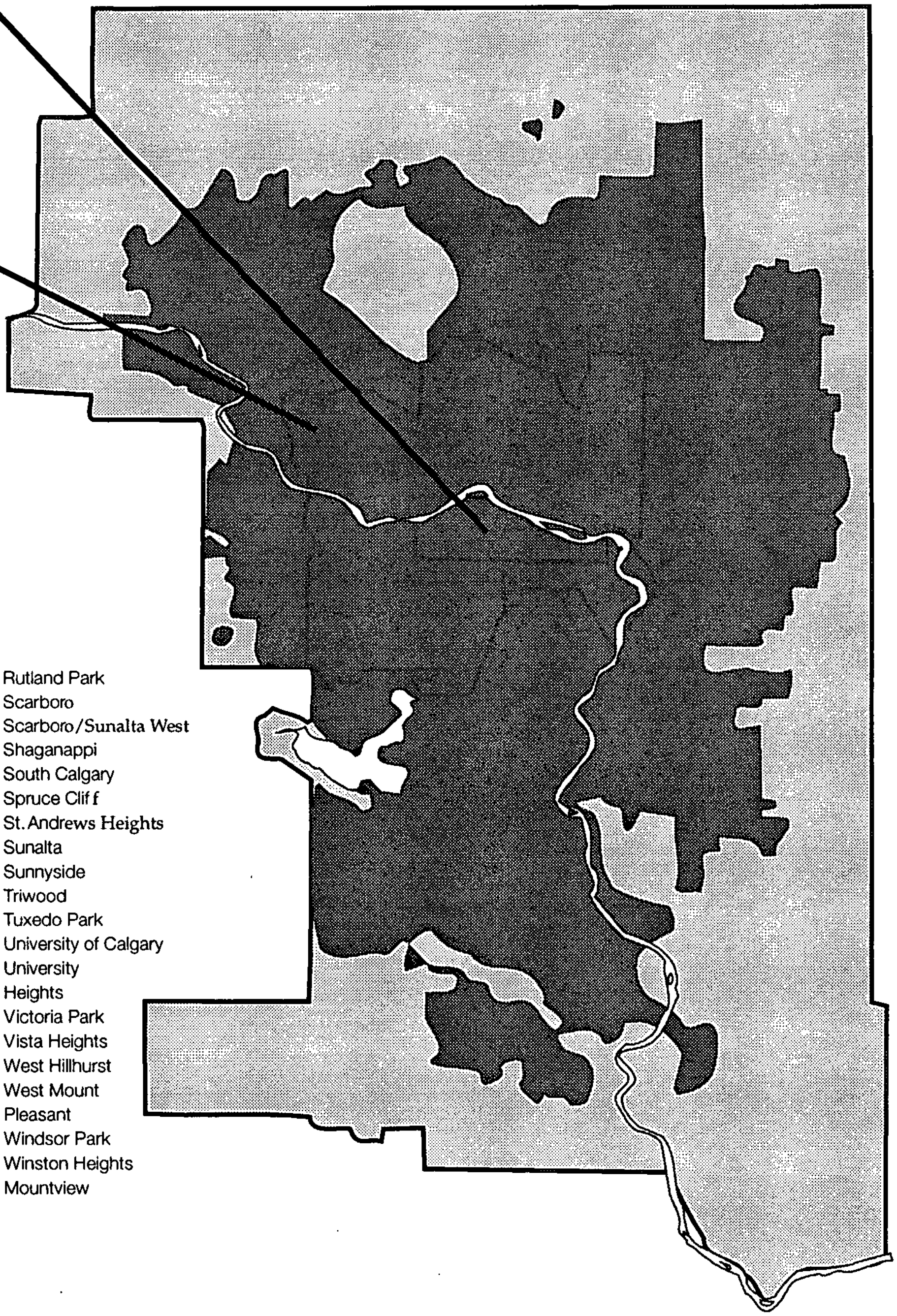
0 5 10km

Legend
- Green Space & Undeveloped Land
- Urbanized Area

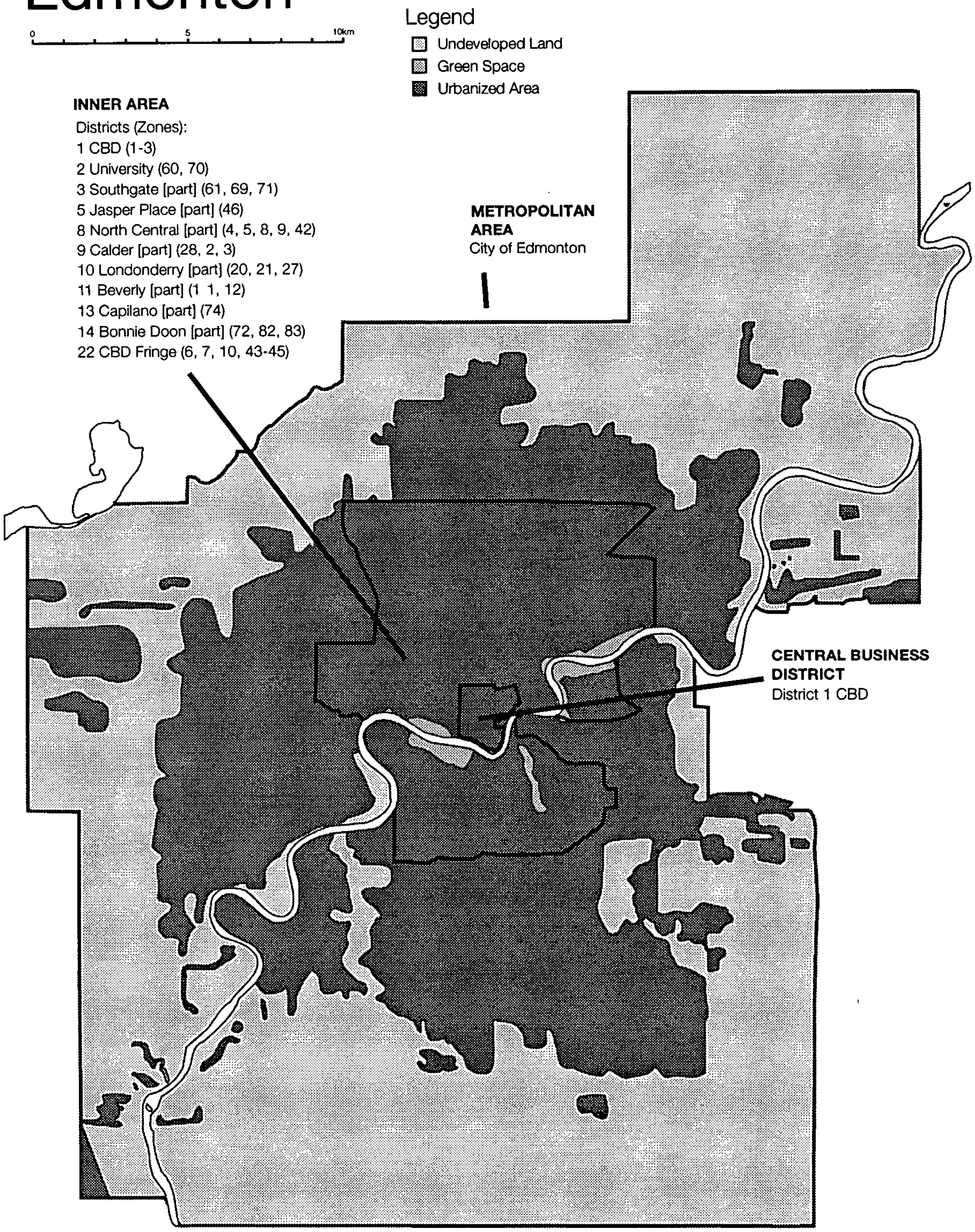
METROPOLITAN AREA
City of Calgary

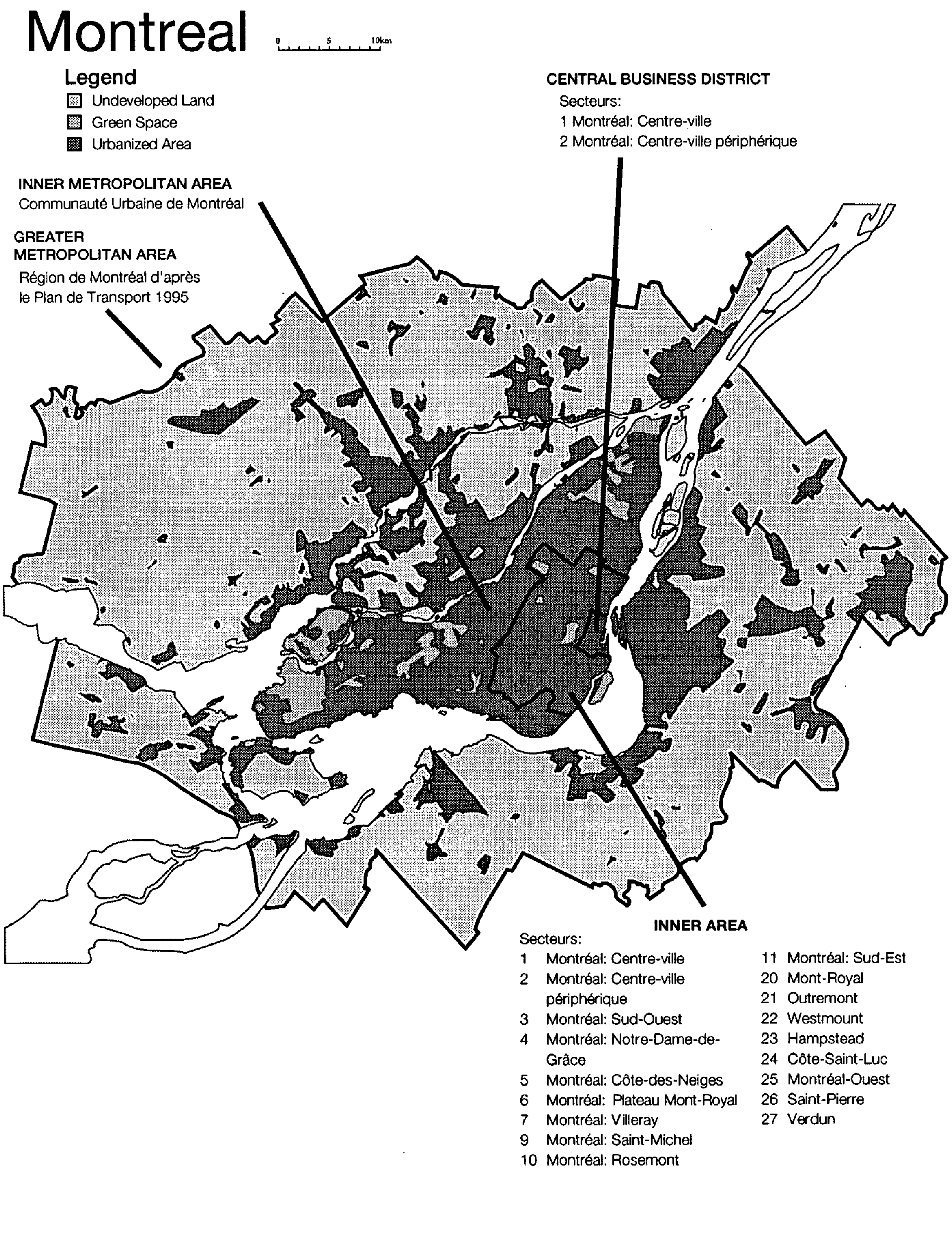
CENTRAL BUSINESS DISTRICT
Community Districts:
Chinatown
Downtown East
Downtown West
Eau Claire

INNER AREA
Community Districts:
Altadore
Banff Trail
Bankview
Bridgeland/Riverside
Britannia
Cambrian Heights
Capitol Hill
Canadian Forces Base Currie
Chinatown
Cliff Bungalow
Connaught
Crescent Heights
Downtown East
Downtown West
Eau Claire
Elbow Park
Elboya
Erlton
Highland Park
Highwood
Hillhurst
Hounsfield Heights/Briar Hill
Inglewood
Killarney/Glengarry
Lincoln Park Redevelopment
Mayland Heights
Mission
Mount Royal Lower
Mount Royal Upper
Ogden
Parkdale
Parkhill/Stanley Park
Queens Park Village
Ramsay
Renfrew
Richmond
Rideau Park
Rosedale
Rosemont
Roxboro
Rutland Park
Scarboro
Scarboro/Sunalta West
Shaganappi
South Calgary
Spruce Cliff
St. Andrews Heights
Sunalta
Sunnyside
Triwood
Tuxedo Park
University of Calgary
University Heights
Victoria Park
Vista Heights
West Hillhurst
West Mount Pleasant
Windsor Park
Winston Heights
Mountview



Edmonton


0
5
10km
Legend
Undeveloped Land
Green Space
Urbanized Area
INNER AREA
Districts (Zones):
1 CBD (1-3)
2 University (60, 70)
3 Southgate [part] (61, 69, 71)
5 Jasper Place [part] (46)
8 North Central [part] (4, 5, 8, 9, 42)
9 Calder [part] (28, 2, 3)
10 Londonderry [part] (20, 21, 27)
11 Beverly [part] (1 1, 12)
13 Capilano [part] (74)
14 Bonnie Doon [part] (72, 82, 83)
22 CBD Fringe (6, 7, 10, 43-45)
METROPOLITAN AREA
City of Edmonton
CENTRAL BUSINESS DISTRICT
District 1 CBD

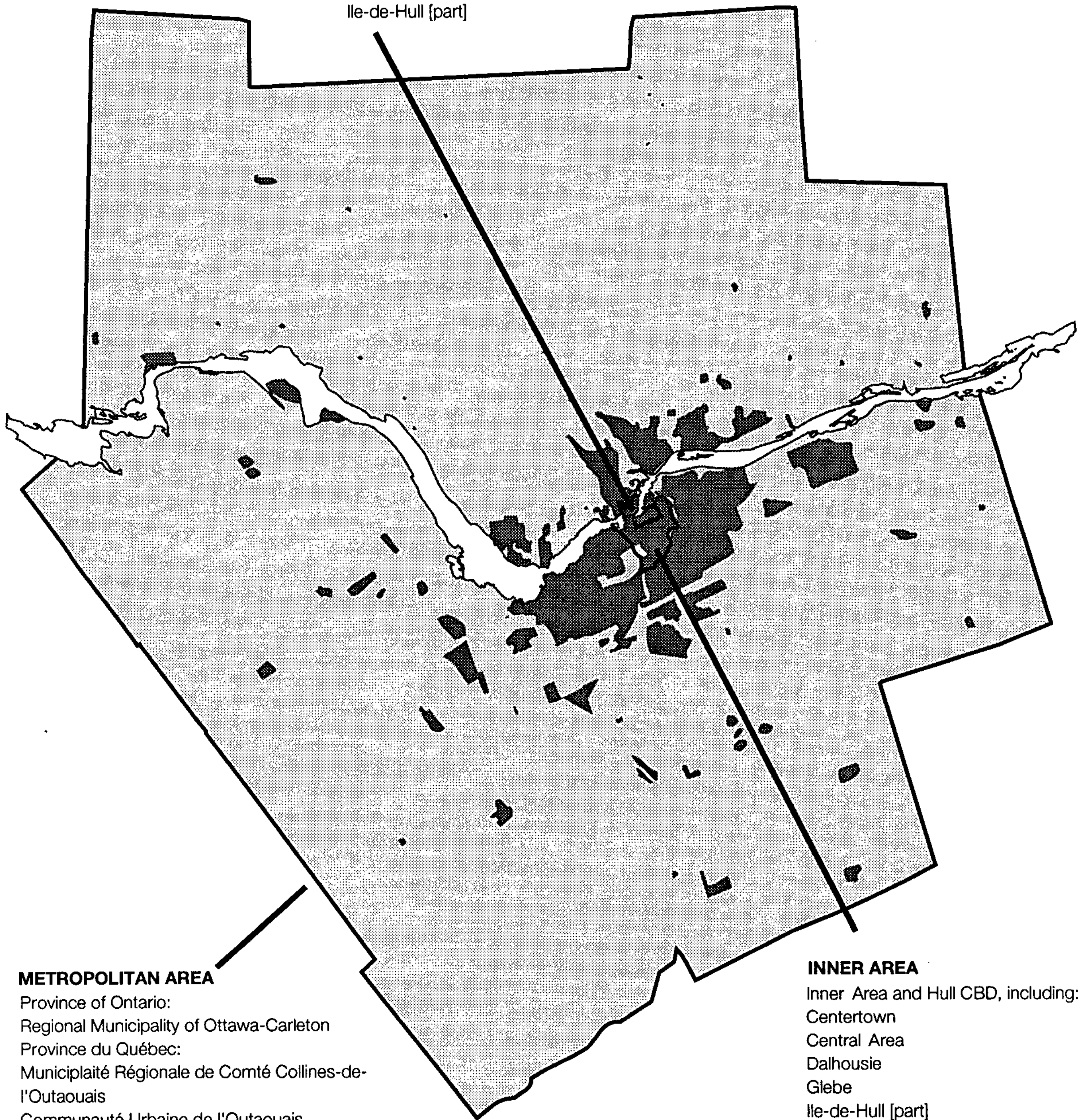

Montreal
0
5
10km
Legend
Undeveloped Land
Green Space
Urbanized Area
CENTRAL BUSINESS DISTRICT
Secteurs:
1 Montréal: Centre-ville
2 Montréal: Centre-ville périphérique
INNER METROPOLITAN AREA
Communauté Urbaine de Montréal
GREATER METROPOLITAN AREA
Région de Montréal d'après le Plan de Transport 1995
INNER AREA
Secteurs:
1 Montréal: Centre-ville
2 Montréal: Centre-ville périphérique
3 Montréal: Sud-Ouest
4 Montréal: Notre-Dame-de-Grâce
5 Montréal: Côte-des-Neiges
6 Montréal: Plateau Mont-Royal
7 Montréal: Villeray
9 Montréal: Saint-Michel
10 Montréal: Rosemont
11 Montréal: Sud-Est
20 Mont-Royal
21 Outremont
22 Westmount
23 Hampstead
24 Côte-Saint-Luc
25 Montréal-Ouest
26 Saint-Pierre
27 Verdun

Ottawa

0 5 10km

Legend
Green Space & Undeveloped Land
Urbanized Area

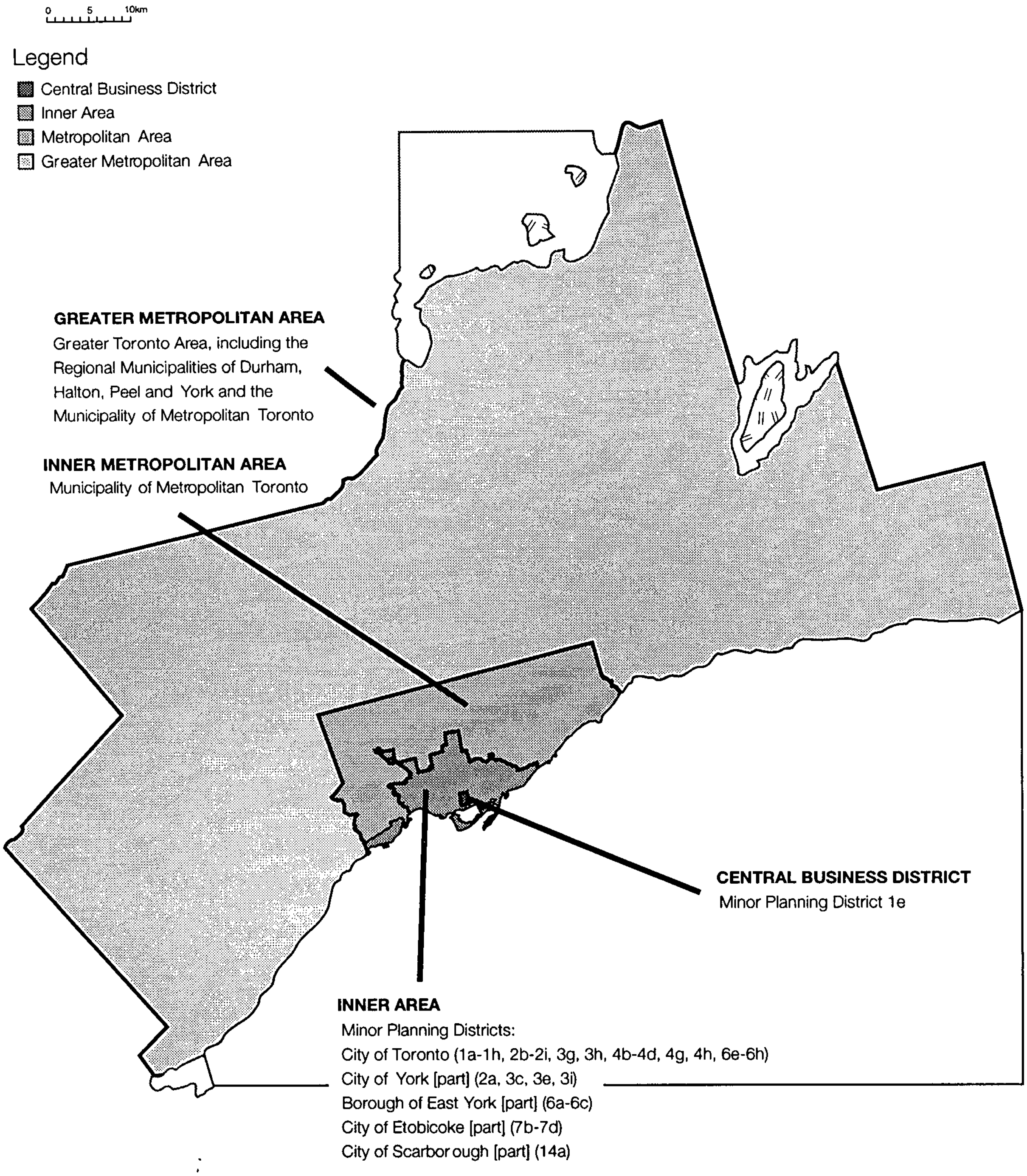
CENTRAL BUSINESS DISTRICT
Ottawa and Hull CBD, including:
Central Area
Ile-de-Hull [part]



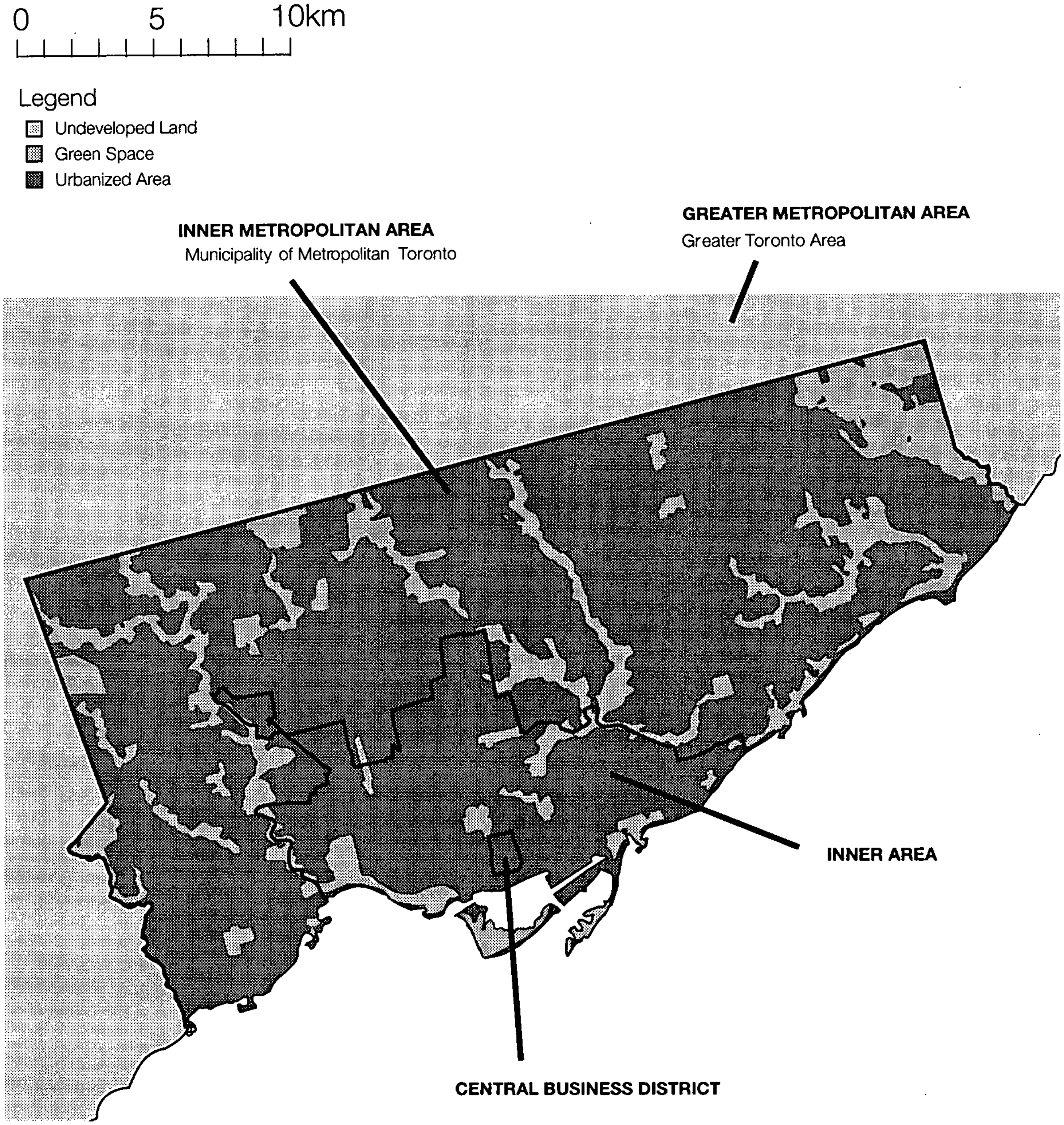
METROPOLITAN AREA
Province of Ontario:
Regional Municipality of Ottawa-Carleton
Province du Québec:
Municiplaité Régionale de Comté Collines-de-l'Outaouais
Communauté Urbaine de l'Outaouais

INNER AREA
Inner Area and Hull CBD, including:
Centertown
Central Area
Dalhousie
Glebe
Ile-de-Hull [part]
Lower Town East
Lower Town West
Ottawa East
Ottawa South
Sandy Hill

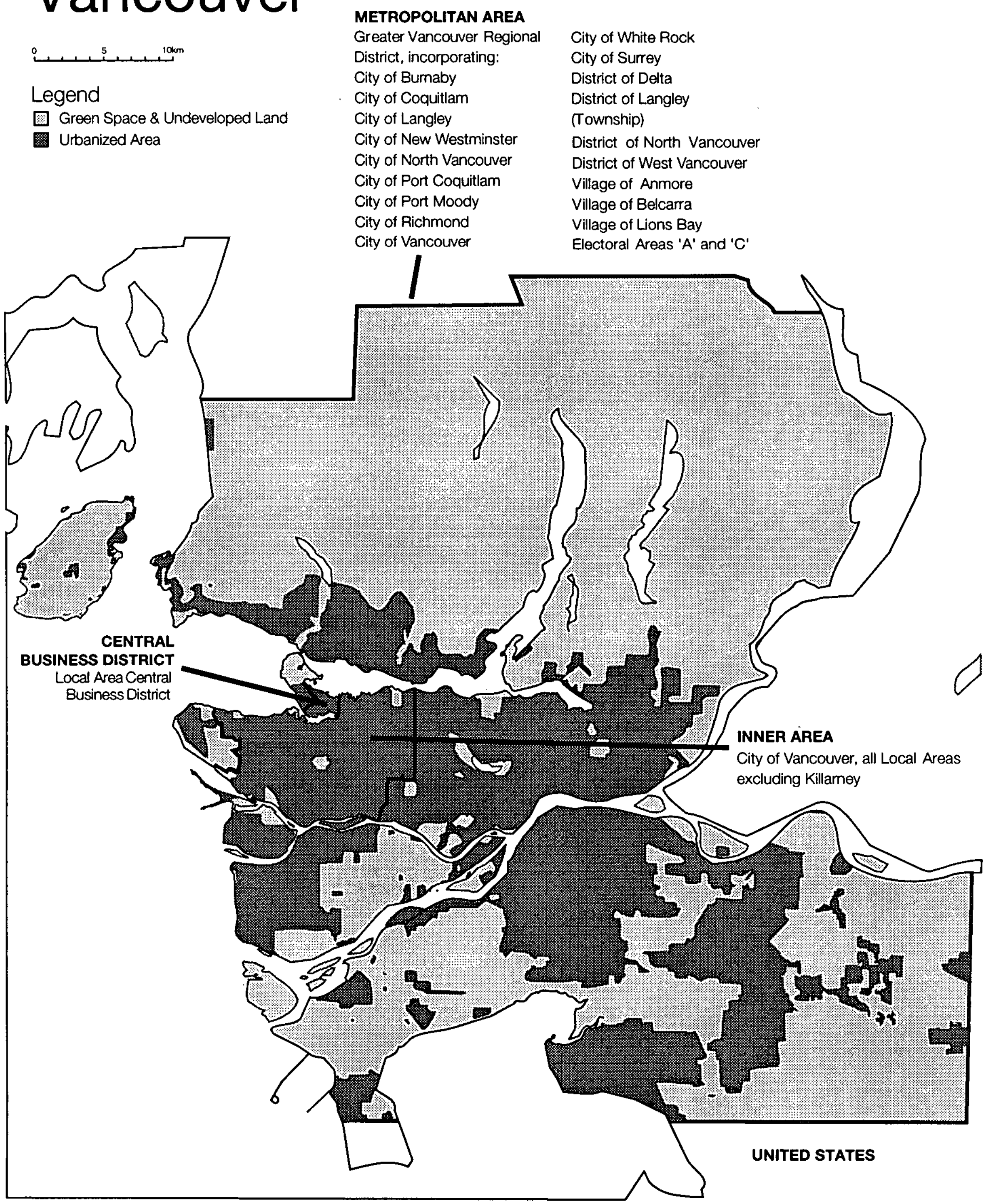
Toronto (GTA Administrative Boundaries)



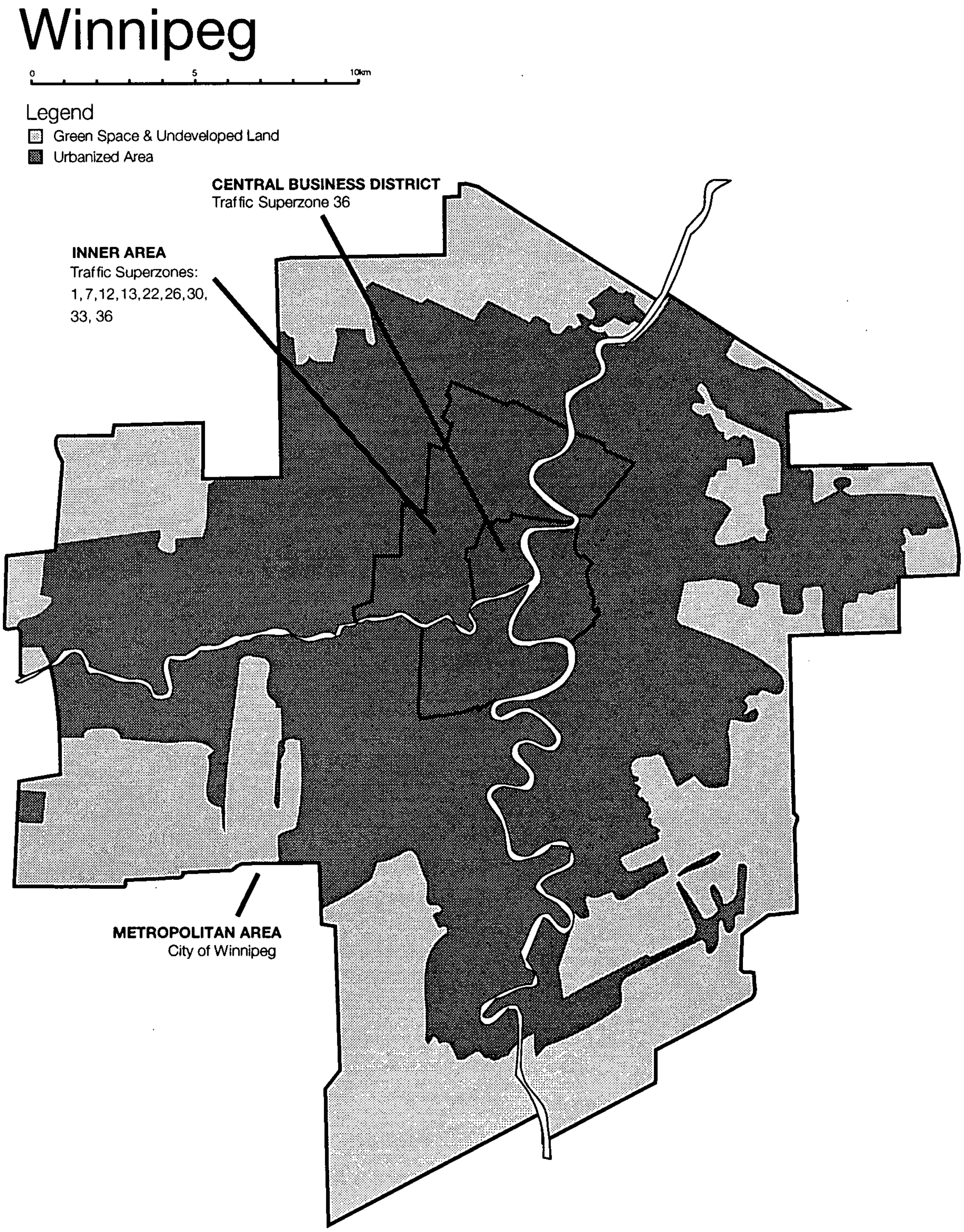
Toronto


0
5
10km
Legend
Undeveloped Land
Green Space
Urbanized Area
INNER METROPOLITAN AREA
Municipality of Metropolitan Toronto
GREATER METROPOLITAN AREA
Greater Toronto Area
INNER AREA
CENTRAL BUSINESS DISTRICT

Vancouver

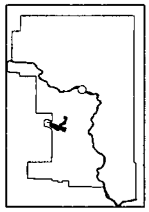


0 5 10km
Legend
Green Space & Undeveloped Land
Urbanized Area
METROPOLITAN AREA
Greater Vancouver Regional District, incorporating:
City of Burnaby
City of Coquitlam
City of Langley
City of New Westminster
City of North Vancouver
City of Port Coquitlam
City of Port Moody
City of Richmond
City of Vancouver
City of White Rock
City of Surrey
District of Delta
District of Langley (Township)
District of North Vancouver
District of West Vancouver
Village of Anmore
Village of Belcarra
Village of Lions Bay
Electoral Areas 'A' and 'C'
CENTRAL BUSINESS DISTRICT
Local Area Central Business District
INNER AREA
City of Vancouver, all Local Areas excluding Killarney
UNITED STATES


Winnipeg
0
5
10km
Legend
Green Space & Undeveloped Land
Urbanized Area
CENTRAL BUSINESS DISTRICT
Traffic Superzone 36
INNER AREA
Traffic Superzones:
1, 7, 12, 13, 22, 26, 30,
33, 36
METROPOLITAN AREA
City of Winnipeg

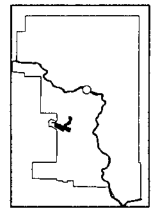
APPENDIX 2 – CANADIAN CITIES RAW AND STANDARDIZED DATA

CALGARY



CALGARY

	1961	1971	1981	1991
POPULATION AND AREA				
Total population				
City of Calgary	249,641	403,320	592,743	710,677
Metropolitan Calgary	279,062	-	-	-
Urbanised area (ha)	9,237	16,144	27,992	34,173
Population of the CBD	7,026	9,216	9,492	10,023
Area of the CBD (ha)	298	298	298	298
Population of the inner city	187,000	207,406	195,228	190,247
Area of the inner city	6,454	7,627	8,365	8,365
EMPLOYMENT				
Number of jobs in the CBD	39,503	50,595	82,316	86,700
Number of jobs in the inner city	82,000	133,035	166,000	199,280
Number of jobs in the outer area	14,371	34,390	171,190	213,725
Total jobs	96,371	167,425	337,190	413,005
PARKING SUPPLY IN THE CBD				
Off-street parking spaces	19,800	25,800	32,491	42,990
On-street parking spaces	3,000	2,800	2,507	2,270
Total parking spaces	22,800	28,600	34,998	45,260
ROAD NETWORK (km)				
Freeway	0	0	21	40
Expressway	47	60	156	203
Major	58	161	334	389
Collector	109	188	512	608
Residential/Local	475	1,119	1,954	2,220
Total roads	689	1,528	2,977	3,460
MOTOR VEHICLES ON REGISTER				
Passenger Cars	80,795	165,258	334,000	447,906
Commercial vehicles	17,523	33,880	-	-
Trucks and Vans	-	-	43,700	49,700
Total vehicles on register	98,318	199,138	377,700	497,606
PRIVATE TRANSPORT INDICATORS				
Total annual V. K. T.	1.0840E+09	1.7155E+09	4.1829E+09	6.5388E+09
Total annual V. K. T. in cars	8.6720E+08	1.3896E+09	3.5973E+09	5.6234E+09
Average vehicle occupancy	1.76	1.58	1.50	1.40
Car occupant kilometres	1.5263E+09	2.1956E+09	5.3960E+09	7.8728E+09
Average road network speed (km/h)	35.6	38.9	43.0	47.1
TRANSPORT ENERGY USE				
Private Passenger (Joules)	?	?	1.9966E+16	2.5360E+16
Non-passenger (Joules)	?	?	5.4935E+15	7.4868E+15
Total fuel consumption (Joules)	?	?	2.5460E+16	3.2847E+16

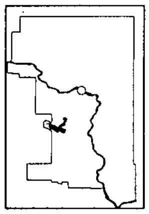


CALGARY

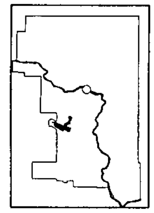
	1961	1971	1981	1991
MODE SPLIT: JOURNEY-TO-WORK (%)				
Journey-to-Work				
Public transport	?	15.3	20.2	16.5
Private transport	?	78.9	73.4	78.2
Walking and cycling	?	5.8	6.4	5.3
Non-Work Trips (excludes school trips)				
Private	?	91.8	90.5	95.6
Public	?	8.2	9.5	4.4
CBD-Bound Work Trips				
Public transport	?	29.2	43.2	38.8
Private transport	?	62.5	46.4	52.5
Walking and cycling	?	8.3	10.4	8.7
AVERAGE TRIP LENGTHS (km)				
Journey to work	?	?	?	11.9
Other trip purposes	?	?	?	?

PUBLIC TRANSPORT INDICATORS

	1961	1971	1981	1991
VEHICLE KILOMETRES				
- Buses				
Trolley bus (CT)	3,981,057	2,978,500	0	0
Motor bus (CT)	3,500,382	9,457,071	26,225,964	29,042,354
Total	*7,481,439*	*12,435,571*	*26,225,964*	*29,042,354*
- Trains				
Light Rail (CT)	0	0	1,038,036	6,259,279
- Trams	*0*	*0*	*0*	*0*
- Ferries	*0*	*0*	*0*	*0*
Grand Total	*7,481,439*	*12,435,571*	*27,264,000*	*35,301,633*
PASSENGER BOARDINGS				
- Buses				
Trolley bus (CT)	16,453,888	9,773,838	0	0
Motor bus (CT)	7,018,330	19,547,678	64,420,614	38,891,195
Total	*23,472,218*	*29,321,516*	*64,420,614*	*38,891,195*
- Trains				
Light Rail (CT)	0	0	6,879,386	28,127,925
- Trams	*0*	*0*	*0*	*0*
- Ferries	*0*	*0*	*0*	*0*
Grand Total	*23,472,218*	*29,321,516*	*71,300,000*	*67,019,120*



	1961	1971	1981	1991
AVERAGE TRIP LENGTH (km)				
- Buses				
All buses	3.1	5.4	9.4	11.5
- Trains				
Light Rail (CT)	0.0	0.0	9.4	11.5
- Trams	*0.0*	*0.0*	*0.0*	*0.0*
- Ferries	*0.0*	*0.0*	*0.0*	*0.0*
PASSENGER KILOMETRES				
- Buses				
All buses (CT)	60,524,090	128,944,202	468,815,826	319,463,388
Total	*60,524,090*	*128,944,202*	*468,815,826*	*319,463,388*
- Trains				
Light Rail (CT)	0	0	50,064,174	231,050,813
- Trams	*0*	*0*	*0*	*0*
- Ferries	*0*	*0*	*0*	*0*
Grand Total	*60,524,090*	*128,944,202*	*518,880,000*	*550,514,200*
AVERAGE SPEED (km/h)				
- Buses				
All Buses	19.2	21.0	22.6	24.6
- Trains				
Light Rail (CT)	0.0	0.0	32.0	32.0
- Trams	*0.0*	*0.0*	*0.0*	*0.0*
- Ferries	*0.0*	*0.0*	*0.0*	*0.0*
All modes average	*19.2*	*21.0*	*23.5*	*27.7*



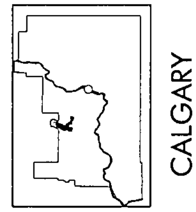
	1961	1971	1981	1991
ENERGY CONSUMPTION				
- Buses				
Motor bus (CT)				
Diesel (litres)	1,842,251	4,981,039	14,623,000	14,995,474
Trolley bus (CT)				
Electricity (kWh)	9,952,642	7,580,282	0	0
Total (Joules)	*1.0637E+14*	*2.1801E+14*	*5.5991E+14*	*5.7418E+14*
- Trains				
Light Rail (CT)				
Electricity (kWh)	0	0	7,000,000	20,959,461
Total (Joules)	*0.0000E+00*	*0.0000E+00*	*2.5200E+13*	*7.5454E+13*
- Trams	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*
- Ferries	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*
Grand Total	*1.0637E+14*	*2.1801E+14*	*5.8511E+14*	*6.4963E+14*

NOTES:

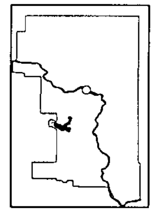
(1) All public transport in Calgary is operated by Calgary Transit (CT).

(2) The VKT shown for 1961 are actually for 1964 and for standardisation the following parameters were used: Population 305,170; Total vehicles: 124,400; Cars: 104,400 and a road network of 1130 km.

CALGARY



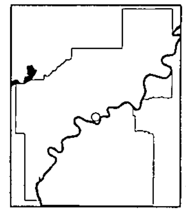
	1961	1971	1981	1991
POPULATION PARAMETERS				
Urban density (persons/ha)	27.0	25.0	21.2	20.8
Inner area density (persons/ha)	29.0	27.2	23.3	22.7
Outer area density (persons/ha)	22.5	23.0	20.3	20.2
CBD density (persons/ha)	23.6	30.9	31.9	33.6
Proportion of population in CBD	2.8%	2.3%	1.6%	1.4%
Proportion of population in inner area	74.9%	51.4%	32.9%	26.8%
EMPLOYMENT PARAMETERS				
Job density (jobs/ha)	10.4	10.4	12.0	12.1
Inner area job density (jobs/ha)	12.7	17.4	19.8	23.8
Outer area job density (jobs/ha)	5.2	4.0	8.7	8.3
CBD job density (jobs/ha)	132.6	169.8	276.2	290.9
Proportion of jobs in CBD	41.0%	30.2%	24.4%	21.0%
Proportion of jobs in inner area	85.1%	79.5%	49.2%	48.3%
ACTIVITY INTENSITY PARAMETERS				
(Population and Jobs/ha)				
CBD activity density	156.1	200.7	308.1	324.6
Inner area activity density	41.7	44.6	43.2	46.6
Outer area activity density	27.7	27.0	29.0	28.4
City-wide activity density	37.5	35.4	33.2	32.9
VEHICLE OWNERSHIP PARAMETERS				
Total vehicles/1000 people	393.8	493.7	637.2	700.2
Passenger cars/1000 people	323.6	409.7	563.5	630.3
PRIVATE MOBILITY PARAMETERS				
Total per capita vehicle kilometres	3,552	4,253	7,057	9,201
Per capita car kilometres	2,842	3,445	6,069	7,913
Total per capita occupant kilometres	6,252	6,720	10,585	12,881
Per capita car occupant kilometres	5,001	5,444	9,103	11,078
Total vehicle kilometres per vehicle	8,714	8,615	11,075	13,141
Car kilometres per car	8,307	8,409	10,770	12,555
TRAFFIC RESTRAINT PARAMETERS				
Parking spaces / 1000 CBD workers	577.2	565.3	425.2	522.0
Length of road per person (m)	2.8	3.8	5.0	4.9
Total vehicles per km of road	142.7	130.3	126.9	143.8
Total vehicle kilometres per km of road	959,292	1,122,709	1,405,072	1,889,827
Car kilometres per km of road	767,434	909,424	1,208,364	1,625,260
PER CAPITA TRANSPORT ENERGY PARAMETERS (MJ)				
Private passenger transport energy	?	?	33,685	35,684
Total private energy use/person	?	?	42,953	46,219
Public transport energy use/person	426	541	987	914
Total energy use/person	?	?	43,940	47,133



PUBLIC TRANSPORT PARAMETERS

	1961	1971	1981	1991
Vehicle kilometres per person				
Buses	30.0	30.8	44.2	40.9
Rail	0.0	0.0	1.8	8.8
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Total	*30.0*	*30.8*	*46.0*	*49.7*
Passenger boardings per person				
Buses	94.0	72.7	108.7	54.7
Rail	0.0	0.0	11.6	39.6
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Total	*94.0*	*72.7*	*120.3*	*94.3*
Passenger boardings per vehicle km				
Buses	3.1	2.4	2.5	1.3
Rail	0.0	0.0	6.6	4.5
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Overall	*3.1*	*2.4*	*2.6*	*1.9*
Passenger kilometres per person				
Buses	242.4	319.7	790.9	449.5
Rail	0.0	0.0	84.5	325.1
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Total	*242.4*	*319.7*	*875.4*	*774.6*
Average public transport speed (km/h)				
Buses	19.2	21.0	22.6	24.6
Rail	0.0	0.0	32.0	32.0
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Overall	*19.2*	*21.0*	*23.5*	*27.7*
Vehicular energy efficiency (MJ/km)				
Buses	14.2	17.5	21.3	19.8
Rail	0.0	0.0	24.3	12.1
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Overall	*14.2*	*17.5*	*21.5*	*18.4*
Modal energy efficiency (MJ/pass km)				
Buses	1.76	1.69	1.19	1.80
Rail	0.00	0.00	0.50	0.33
Trams	0.00	0.00	0.00	0.00
Ferries	0.00	0.00	0.00	0.00
Overall	*1.76*	*1.69*	*1.13*	*1.18*

EDMONTON



EDMONTON

	1961	1971	1981	1991
POPULATION AND AREA				
Total population				
Edmonton CMA	360,327	496,597	740,882	837,418
Metropolitan Edmonton	333,786	518,144	704,471	823,163
City of Edmonton	276,018	436,264	521,205	614,665
Urbanised area (ha)	?	13,795	18,094	22,393
Population of the CBD	6,746	6,847	6,322	6,417
Area of the CBD (ha)	297	297	297	297
Population of the inner city	212,868	244,235	203,354	196,109
Area of the inner city	7,310	7,310	7,310	7,310
EMPLOYMENT				
Number of jobs in the CBD	36,700	41,000	63,000	63,200
Number of jobs in the inner city	?	?	?	?
Number of jobs in the outer area	?	?	?	?
Number of jobs in the Edmonton CMA	?	?	363,350	392,500
Number of jobs in the City of Edmonton	**?**	**?**	**316,525**	**325,100**
Number of jobs in Metropolitan Edmonton	?	?	376,600	?
PARKING SUPPLY IN THE CBD				
Off-street parking spaces	10,944	17,581	33,972	34,994
On-street parking spaces	4,413	4,319	2,668	2,518
Total parking spaces	**15,357**	**21,900**	**36,640**	**37,512**
ROAD NETWORK (km)				
Arterials	?	?	?	832
Collectors/Local	?	?	?	2,110
Total roads	**713**	**1,679**	**2,523**	**2,942**
MOTOR VEHICLES ON REGISTER				
Passenger cars	89,930	163,867	309,637	333,900
Commercial vehicles	20,355	39,689	-	33,200
Trucks and buses	-	-	81,611	-
Total vehicles on register	**110,285**	**203,556**	**391,248**	**367,100**
PRIVATE TRANSPORT INDICATORS				
Total annual V. K. T.	?	?	?	5.1613E+09
Total annual V. K. T. in cars	?	?	?	4.3409E+09
Average vehicle occupancy	?	?	?	1.42
Car occupant kilometres	?	?	?	6.1641E+09
Average road network speed (km/h)	?	?	?	40.0
TRANSPORT ENERGY USE				
Private Passenger (Joules)	?	?	?	1.9576E+16
Non-passenger (Joules)	?	?	?	6.8324E+15
Total fuel consumption (Joules)	?	?	?	2.6408E+16

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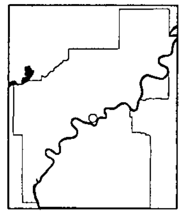


MODE SPLIT: JOURNEY-TO-WORK (%)

	1961	1971	1981	1991
Public transport	?	?	?	11.0
Private transport	?	?	?	83.0
Walking and cycling	?	?	?	6.0

AVERAGE TRIP LENGTHS (km)

	1961	1971	1981	1991
Journey to work	?	?	?	10.3
Other trip purposes	?	?	?	6.0

PUBLIC TRANSPORT INDICATORS

VEHICLE KILOMETRES

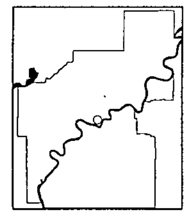
	1961	1971	1981	1991
- Buses				
Motor bus (ET)	4,781,064	10,086,581	30,904,675	27,953,130
Trolley bus (ET)	4,462,633	3,651,916	801,702	1,600,000
Total	*9,243,697*	*13,738,497*	*31,706,377*	*29,553,130*
- Trains				
Light Rail (ET)	0	0	1,321,876	1,999,724
- Trams	*0*	*0*	*0*	*0*
- Ferries	*0*	*0*	*0*	*0*
Grand Total	*9,243,697*	*13,738,497*	*33,028,253*	*31,552,854*

PASSENGER BOARDINGS

	1961	1971	1981	1991
- Buses				
Motor bus (ET)	9,341,712	25,848,619	?	?
Trolley bus (ET)	17,819,658	21,069,214	?	?
Total	*27,161,370*	*46,917,833*	*67,330,109*	*60,132,642*
- Trains				
Light Rail (ET)	0	0	5,540,000	6,637,544
- Trams	*0*	*0*	*0*	*0*
- Ferries	*0*	*0*	*0*	*0*
Grand Total	*27,161,370*	*46,917,833*	*72,870,109*	*66,770,186*

AVERAGE TRIP LENGTH (km)

	1961	1971	1981	1991
- Buses				
All buses (ET)	5.0	5.5	6.1	6.7
- Trains				
Light Rail (ET)	0.0	0.0	6.1	6.7
- Trams	*0.0*	*0.0*	*0.0*	*0.0*
- Ferries	*0.0*	*0.0*	*0.0*	*0.0*



	1961	1971	1981	1991
PASSENGER KILOMETRES				
- Buses				
Motor bus (ET)	46,708,560	142,167,405	-	-
Trolley bus (ET)	89,098,290	115,880,677	-	-
Total	*135,806,850*	*258,048,082*	*410,713,665*	*402,888,701*
- Trains				
Light Rail (ET)	0	0	33,794,000	44,471,545
- Trams	*0*	*0*	*0*	*0*
- Ferries	*0*	*0*	*0*	*0*
Grand Total	*135,806,850*	*258,048,082*	*444,507,665*	*447,360,246*
AVERAGE SPEED (km/h)				
- Buses				
All buses (ET)	?	?	18.7	19.5
- Trains				
Light Rail (ET)	0.0	0.0	32.0	32.0
- Trams	*0.0*	*0.0*	*0.0*	*0.0*
- Ferries	*0.0*	*0.0*	*0.0*	*0.0*
All modes average	*?*	*?*	*19.7*	*20.7*
ENERGY CONSUMPTION				
- Buses				
Motor bus (ET)				
Diesel (litres)	2,516,274	5,312,602	17,772,112	16,479,342
Trolley bus (ET)				
Electricity (kWh)	11,156,583	9,294,126	3,148,521	5,244,513
Total (Joules)	*1.3651E+14*	*2.3688E+14*	*6.9183E+14*	*6.4987E+14*
- Trains				
Light Rail (ET)				
Electricity (kWh)	0	0	5,191,399	6,554,737
Total (Joules)	*0.0000E+00*	*0.0000E+00*	*1.8689E+13*	*2.3597E+13*
- Trams	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*
- Ferries	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*
Grand Total	*1.3651E+14*	*2.3688E+14*	*7.1052E+14*	*6.7347E+14*

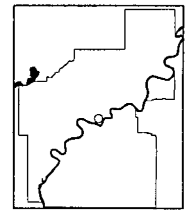
NOTES:

(1) All public transport within the City of Edmonton is operated by Edmonton Transit (ET). Minor operators exist outside.

(2) The 1990 vehicle data refers to 1994 and the corresponding population is 633,750.

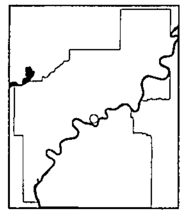
(3) To calculate vehicles per kilometre of road, vehicle numbers had to be trended. The figure used for total vehicles to match up with road length data is 476,818.

EDMONTON



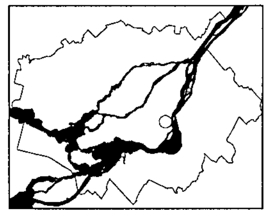
EDMONTON

	1961	1971	1981	1991
POPULATION PARAMETERS				
Urban density (persons/ha)	?	31.6	28.8	27.4
Inner area density (persons/ha)	29.1	33.4	27.8	26.8
Outer area density (persons/ha)	?	29.6	29.5	27.8
CBD density (persons/ha)	22.7	23.1	21.3	21.6
Proportion of population in CBD	2.4%	1.6%	1.2%	1.0%
Proportion of population in inner area	77.1%	56.0%	39.0%	31.9%
EMPLOYMENT PARAMETERS				
Job density (jobs/ha)	?	?	18.4	15.8
Inner area job density (jobs/ha)	?	?	?	?
Outer area job density (jobs/ha)	?	?	?	?
CBD job density (jobs/ha)	123.6	138.0	212.1	212.8
Proportion of jobs in CBD	?	?	19.9%	19.4%
Proportion of jobs in inner area	?	?	?	?
ACTIVITY INTENSITY PARAMETERS				
(Population and Jobs/ha)				
CBD activity density	146.3	161.1	233.4	234.4
Inner area activity density	?	?	?	?
Outer area activity density	?	?	?	?
City-wide activity density	?	?	46.3	42.0
VEHICLE OWNERSHIP PARAMETERS				
Total vehicles/1000 people	330.4	392.9	555.4	579.3
Passenger cars/1000 people	269.4	316.3	439.5	526.9
PRIVATE MOBILITY PARAMETERS				
Total per capita vehicle kilometres	?	?	?	8,397
Per capita car kilometres	?	?	?	7,062
Total per capita occupant kilometres	?	?	?	11,924
Per capita car occupant kilometres	?	?	?	10,028
Total vehicle kilometres per vehicle	?	?	?	14,060
Car kilometres per car	?	?	?	13,001
TRAFFIC RESTRAINT PARAMETERS				
Parking spaces / 1000 CBD workers	418.4	534.1	581.6	593.5
Length of road per person (m)	2.6	3.8	4.8	4.8
Total vehicles per km of road	154.7	121.2	155.1	162.1
Total vehicle kilometres per km of road	?	?	?	1,754,351
Car kilometres per km of road	?	?	?	1,475,493
PER CAPITA TRANSPORT ENERGY PARAMETERS (MJ)				
Private passenger transport energy	?	?	?	31,848
Total private energy use/person	?	?	?	42,964
Public transport energy use/person	495	543	1,363	1,096
Total energy use/person	?	?	?	44,060



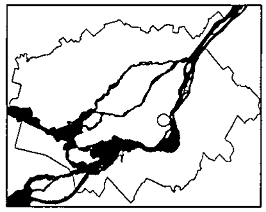
	1961	1971	1981	1991
PUBLIC TRANSPORT PARAMETERS				
Vehicle kilometres per person				
Buses	33.5	31.5	60.8	48.1
Rail	0.0	0.0	2.5	3.3
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Total	*33.5*	*31.5*	*63.4*	*51.3*
Passenger boardings per person				
Buses	98.4	107.5	129.2	97.8
Rail	0.0	0.0	10.6	10.8
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Total	*98.4*	*107.5*	*139.8*	*108.6*
Passenger boardings per vehicle km				
Buses	2.9	3.4	2.1	2.0
Rail	0.0	0.0	4.2	3.3
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Overall	*2.9*	*3.4*	*2.2*	*2.1*
Passenger kilometres per person				
Buses	492.0	591.5	788.0	655.5
Rail	0.0	0.0	64.8	72.4
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Total	*492.0*	*591.5*	*852.8*	*727.8*
Average public transport speed (km/h)				
Buses	?	?	18.7	19.5
Rail	0.0	0.0	32.0	32.0
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Overall	*?*	*?*	*19.7*	*20.7*
Vehicular energy efficiency (MJ/km)				
Buses	14.8	17.2	21.8	22.0
Rail	0.0	0.0	14.1	11.8
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Overall	*14.8*	*17.2*	*21.5*	*21.3*
Modal energy efficiency (MJ/pass km)				
Buses	1.01	0.92	1.68	1.61
Rail	0.00	0.00	0.55	0.53
Trams	0.00	0.00	0.00	0.00
Ferries	0.00	0.00	0.00	0.00
Overall	*1.01*	*0.92*	*1.60*	*1.51*

MONTREAL



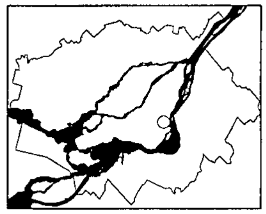
	1961	1971	1981	1991
POPULATION AND AREA				
Total population				
Montreal Urban Community (CUM)	1,747,696	1,959,143	1,760,122	1,775,915
Metropolitan region	2,109,509	2,743,208	2,835,759	3,119,570
Urbanised area (ha)				
Montreal Urban Community (CUM)	28,228	32,398	36,530	41,117
Metropolitan region	36,610	70,280	83,576	92,390
Population of the CBD	99,994	46,887	61,161	63,054
Area of the CBD (ha)	1,113	1,118	1,006	1,224
Population of the inner city	1,361,230	1,161,183	920,529	882,829
Area of the inner city	15,404	14,353	12,392	13,770
EMPLOYMENT				
Number of jobs in the CBD	?	221,260	256,923	273,203
Number of jobs in the inner city	?	548,258	529,072	589,296
Number of jobs in the outer area	?	293,172	578,990	776,633
Number of jobs in the CUM	?	747,030	816,886	995,037
Total jobs	?	841,430	1,108,062	1,365,929
PARKING SUPPLY IN THE CBD				
Off-street parking spaces	?	?	65,998	76,779
On-street parking spaces	?	?	14,492	17,966
Total parking spaces	?	?	80,490	94,745
ROAD NETWORK (km)				
Major roads	?	?	?	4,078
Collectors	?	?	?	1,103
Locals	?	?	?	8,804
Total roads	?	?	?	13,985
MOTOR VEHICLES ON REGISTER				
Passenger cars	406,145	487,659	662,387	878,390
Trucks and vans	58,020	69,665	83,135	33,454
Buses	-	-	10,474	3,405
Motorcycles	-	-	13,319	10,716
Motor assisted bicycles	-	-	5,247	2,263
Restricted	-	-	22,530	22,661
Other	-	-	23,019	-
Total vehicles on register	464,165	557,324	820,111	950,889

	1961	1971	1981	1991
PRIVATE TRANSPORT INDICATORS				
Total annual V. K. T.				
CUM	?	?	4.4936E+09	6.1764E+09
Metropolitan region	?	?	1.0511E+10	1.7289E+10
Total annual V. K. T. in cars				
CUM	?	?	4.0442E+09	5.5588E+09
Metropolitan region	?	?	9.4599E+09	1.5560E+10
Average vehicle occupancy				
CUM	?	?	1.47	1.40
Metropolitan region	?	?	1.48	1.37
Car occupant kilometres				
CUM	?	?	5.9450E+09	7.7823E+09
Metropolitan region	?	?	1.4001E+10	2.1317E+10
Average road network speed (km/h)				
CUM	?	?	38.3	?
Metropolitan region	?	?	40.3	43.3
TRANSPORT ENERGY USE				
Private Passenger (Joules)				
CUM	?	?	?	3.4050E+16
Suburbs Only	?	?	?	5.2380E+16
Metropolitan region	?	?	?	8.6430E+16
Non-passenger (Joules)				
CUM	?	?	?	?
Suburbs Only	?	?	?	?
Metropolitan region	?	?	?	?
Total fuel consumption (Joules)	?	?	?	8.6430E+16
MODE SPLIT: JOURNEY-TO-WORK (%)				
CUM				
Public transport	?	?	34.5	31.8
Private transport	?	?	57.2	59.9
Walking and cycling	?	?	8.2	8.3
Metropolitan region				
Public transport	?	?	26.0	21.3
Private transport	?	?	67.4	72.6
Walking and cycling	?	?	6.6	6.1
AVERAGE TRIP LENGTHS (km)				
Journey-to-work				
CUM	?	?	?	10.2
Metropolitan region	?	?	?	17.5
All trips (CUM)				
Public transport	?	?	?	?
Private transport	?	?	?	?
Walking and cycling	?	?	?	?



PUBLIC TRANSPORT INDICATORS

	1961	1971	1981	1991
VEHICLE KILOMETRES				
- Buses				
Motor bus (STCUM)	72,891,348	74,650,571	85,411,731	77,564,952
Trolley bus (STCUM)	3,012,569	0	0	0
Motor bus (STL)	-	10,971,000	15,765,000	13,046,336
Motor bus (STRSM)	-	-	13,905,691	18,635,631
Motor bus (others)	-	-	-	14,370,397
Total	*75,903,917*	*85,621,571*	*115,082,422*	*123,617,316*
- Trains				
Metro (STCUM)	0	29,147,350	62,715,792	60,632,276
Commuter rail (CN & CP)	?	?	2,083,330	3,640,842
Total	*?*	*?*	*64,799,122*	*64,273,118*
- Trams	*0*	*0*	*0*	*0*
- Ferries	*0*	*0*	*0*	*0*
Grand Total	*?*	*?*	*179,881,544*	*187,890,434*
PASSENGER BOARDINGS				
- Buses				
Motor bus (STCUM)	410,968,646	310,536,893	381,521,945	358,355,618
Trolley bus (STCUM)	21,184,029	0	0	0
Motor bus (STL)	?	12,188,000	18,763,000	21,427,097
Motor bus (STRSM)	?	?	23,083,408	27,599,017
Motor bus (others)	-	-	-	9,015,925
Total	*432,152,675*	*322,724,893*	*423,368,353*	*416,397,657*
- Trains				
Metro (STCUM)	0	117,526,800	220,191,037	265,748,887
Commuter rail (CN & CP)	?	?	4,178,000	8,700,000
Total	*?*	*?*	*224,369,037*	*274,448,887*
- Trams	*0*	*0*	*0*	*0*
- Ferries	*0*	*0*	*0*	*0*
Grand Total	*?*	*?*	*647,737,390*	*690,846,544*



	1961	1971	1981	1991
AVERAGE TRIP LENGTH (km)				
- *Buses*				
Motor bus (STCUM)	3.1	3.1	3.2	3.3
Trolley bus (STCUM)	3.1	0.0	0.0	0.0
Motor bus (STL)	0.0	4.0	4.0	4.0
Motor bus (STRSM)	0.0	0.0	4.0	4.0
Motor bus (others)	0.0	0.0	0.0	11.1
- *Trains*				
Metro (STCUM)	0.0	4.9	4.9	5.1
Commuter rail (CN & CP)	?	?	14.8	15.0
- *Trams*	*0.0*	*0.0*	*0.0*	*0.0*
- *Ferries*	*0.0*	*0.0*	*0.0*	*0.0*

	1961	1971	1981	1991
PASSENGER KILOMETRES				
- *Buses*				
Motor bus (STCUM)	1,273,996,603	962,664,368	1,205,609,346	1,178,989,983
Trolley bus (STCUM)	65,670,490	0	0	0
Motor bus (STL)	-	48,752,000	75,052,000	85,708,388
Motor bus (STRSM)	-	-	92,333,632	110,396,068
Motor bus (others)	-	-	-	100,076,768
Total	*1,339,667,093*	*1,011,416,368*	*1,372,994,978*	*1,475,171,207*
- *Trains*				
Metro (STCUM)	0	575,881,320	1,083,339,902	1,363,291,790
Commuter rail (CN & CP)	?	?	61,834,400	130,500,000
Total	*?*	*?*	*1,145,174,302*	*1,493,791,790*
- Trams	0	0	0	0
- *Ferries*	*0*	*0*	*0*	*0*
Grand Total	*?*	*?*	*2,518,169,280*	*2,968,962,997*

MONTREAL

	1961	1971	1981	1991
AVERAGE SPEED (km/h)				
- Buses				
Motor bus (STCUM)	?	?	16.3	18.9
Trolley bus (STCUM)	?	-	-	-
Motor bus (STL)	-	28.0	25.0	25.0
Motor bus (STRSM)	-	-	25.6	22.2
Motor bus (others)	-	-	-	34.0
Overall bus speed	*?*	*?*	*17.4*	*20.5*
- Trains				
Metro (STCUM)	0.0	?	28.9	28.6
Commuter rail (CN & CP)	0.0	0.0	38.6	40.8
Overall train speed	*?*	*?*	*29.4*	*29.7*
- Trams	*0.0*	*0.0*	*0.0*	*0.0*
- Ferries	*0.0*	*0.0*	*0.0*	*0.0*
All modes average	*?*	*?*	*22.9*	*25.1*
ENERGY CONSUMPTION				
- Buses				
Motor bus (STCUM)				
Diesel (litres)	51,541,472	52,785,419	60,398,781	54,277,826
Trolley bus (STCUM)				
Electricity (kWh)	7,531,422	0	0	0
Motor bus (STL)				
Diesel (litres)	0	4,996,000	9,067,087	7,758,751
Motor bus (STRSM)				
Diesel (litres)	0	0	9,945,402	12,056,503
Motor bus (others)				
Diesel (litres)	0	0	0	8,987,859
Total (Joules)	*2.0006E+15*	*2.2125E+15*	*3.0407E+15*	*3.1812E+15*
- Trains				
Metro (STCUM)				
Electricity (kWh)	0	78,166,675	168,189,730	173,000,000
Commuter rail (CN & CP)				
Mixed diesel and electricity	?	?	1.0883E+14	1.9020E+14
Total (Joules)	*?*	*?*	*7.1431E+14*	*8.1300E+14*
- Trams	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*
- Ferries	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*
Grand Total	*?*	*?*	*3.7550E+15*	*3.9942E+15*

NOTES:

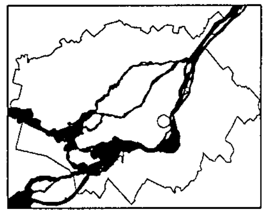
(1) Most public transport on Montreal Island is operated by the Société de transport de la Communauté Urbaine de Montréal (STCUM). Heavy rail service is provided by Canadian National (CN) and Canadian Pacific (CP) for STCUM. The Société de transport de Laval (STL) operates bus services on Laval Island, and the Société de transport de la Rive Sud de Montreal (STRSM) operates in the area immediately south of Montreal. The wider Montreal region is serviced by a multitude of small bus operators, mostly strongly commuter-oriented operations.

(2) The vehicle data for 1991 refer to the CUM area plus Laval only with a population of 2,090,300, and likewise for 1981 when the population was 2,028,818.

(3) The V.K.T. data for private transport for 1991 refer to 1993 with a population of 3,278,442, and for 1981 they refer to 1982 with a population of 2,895,899.

(4) As vehicle kilometre data and the vehicle registration data don't match, an adjustment was made to make the two items comparable.

MONTREAL



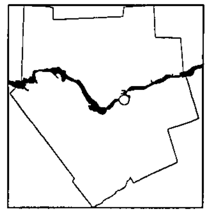
MONTREAL

	1961	1971	1981	1991
POPULATION PARAMETERS				
Urban density (persons/ha)	57.6	39.0	33.9	33.8
Inner area density (persons/ha)	88.4	80.9	74.3	64.1
Outer area density (persons/ha)	35.3	28.3	26.9	28.5
CBD density (persons/ha)	89.8	41.9	60.8	51.5
Proportion of population in CBD	4.7%	1.7%	2.2%	2.0%
Proportion of population in inner area	64.5%	42.3%	32.5%	28.3%
EMPLOYMENT PARAMETERS				
Job density (jobs/ha)	?	12.0	13.3	14.8
Inner area job density (jobs/ha)	?	38.2	42.7	42.8
Outer area job density (jobs/ha)	?	5.2	8.1	9.9
CBD job density (jobs/ha)	?	197.9	255.4	223.2
Proportion of jobs in CBD	?	26.3%	23.2%	20.0%
Proportion of jobs in inner area	?	65.2%	47.7%	43.1%
ACTIVITY INTENSITY PARAMETERS				
(Population and Jobs/ha)				
CBD activity density	?	239.8	316.2	274.7
Inner area activity density	?	119.1	117.0	106.9
Outer area activity density	?	60.5	58.8	38.3
City-wide activity density	?	51.0	47.2	48.5
VEHICLE OWNERSHIP PARAMETERS				
Total vehicles/1000 people	220.0	284.5	404.2	454.9
Passenger cars/1000 people	192.5	248.9	326.5	420.2
PRIVATE MOBILITY PARAMETERS				
Total per capita vehicle kilometres	?	?	3,630	5,274
Per capita car kilometres	?	?	3,267	4,746
Total per capita occupant kilometres	?	?	5,372	7,225
Per capita car occupant kilometres	?	?	4,835	6,502
Total vehicle kilometres per vehicle	?	?	8,979	11,593
Car kilometres per car	?	?	10,005	11,294
TRAFFIC RESTRAINT PARAMETERS				
Parking spaces / 1000 CBD workers	?	?	313.3	346.8
Length of road per person (m)	?	?	?	4.5
Total vehicles per km of road	?	?	?	101.5
Total vehicle kilometres per km of road	?	?	?	1,236,288
Car kilometres per km of road	?	?	?	1,112,652
PER CAPITA TRANSPORT ENERGY PARAMETERS (MJ)				
Private passenger transport energy	?	?	?	27,706
Total private energy use/person	?	?	?	?
Public transport energy use/person	?	?	1,324	1,280
Total energy use/person	?	?	?	?

MONTREAL

PUBLIC TRANSPORT PARAMETERS	1961	1971	1981	1991
Vehicle kilometres per person				
Buses	36.0	31.2	40.6	39.6
Rail	?	?	22.9	20.6
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Total	*?*	*?*	*63.4*	*60.2*
Passenger boardings per person				
Buses	204.9	117.6	149.3	133.5
Rail	?	?	79.1	88.0
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Total	*?*	*?*	*228.4*	*221.5*
Passenger boardings per vehicle km				
Buses	5.7	3.8	3.7	3.4
Rail	?	?	3.5	4.3
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Overall	*?*	*?*	*3.6*	*3.7*
Passenger kilometres per person				
Buses	635.1	?	484.2	472.9
Rail	?	?	403.8	478.8
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Total	*?*	*?*	*888.0*	*951.7*
Average public transport speed (km/h)				
Buses	?	?	17.4	20.5
Rail	?	?	29.4	29.7
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Overall	*?*	*?*	*22.9*	*25.1*
Vehicular energy efficiency (MJ/km)				
Buses	26.4	25.8	26.4	25.7
Rail	?	?	11.0	12.6
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Overall	*?*	*?*	*20.9*	*21.3*
Modal energy efficiency (MJ/pass km)				
Buses	1.49	2.19	2.21	2.16
Rail	?	?	0.62	0.54
Trams	0.00	0.00	0.00	0.00
Ferries	0.00	0.00	0.00	0.00
Overall	*?*	*?*	*1.49*	*1.35*

OTTAWA



OTTAWA

	1961	1971	1981	1991
POPULATION AND AREA				
Total population				
RMOC	358,410	471,931	546,849	678,147
CUO & MRC	?	161,512	189,005	229,772
Total Metropolitan Ottawa	?	633,443	735,854	907,919
Urbanised area (ha)				
RMOC	9,753	13,400	17,288	21,404
CUO & MRC	2,000	4,740	5,900	7,619
Total Metropolitan Ottawa	11,753	18,140	23,188	29,023
Population of the CBD				
RMOC	6,689	4,230	3,550	4,895
CUO & MRC	15,022	14,065	7,685	7,202
Total Metropolitan Ottawa	21,711	18,295	11,235	12,097
Area of the CBD (ha)				
RMOC	175	175	175	175
CUO & MRC	130	130	130	130
Total Metropolitan Ottawa	305	305	305	305
Population of the inner city				
RMOC	95,085	97,880	79,189	81,360
CUO & MRC	15,022	14,065	7,685	7,202
Total Metropolitan Ottawa	110,107	111,945	86,874	88,562
Area of the inner city				
RMOC	1,670	1,670	1,670	1,670
CUO & MRC	130	130	130	130
Total Metropolitan Ottawa	1,800	1,800	1,800	1,800

EMPLOYMENT

	1961	1971	1981	1991
Number of jobs in the CBD				
RMOC	36,000	47,205	68,140	82,307
CUO & MRC	?	11,500	25,000	28,724
Total Metropolitan Ottawa	?	58,705	93,140	111,031
Number of jobs in the inner city				
RMOC	?	86,970	114,524	147,219
CUO & MRC	?	11,500	25,000	28,724
Total Metropolitan Ottawa	?	98,470	139,524	175,943
Number of jobs in the outer area				
RMOC	?	91,020	175,921	235,690
CUO & MRC	?	28,000	37,500	47,993
Total Metropolitan Ottawa	?	119,020	213,421	283,683
Total jobs				
RMOC	138,031	177,990	290,445	382,909
CUO & MRC	?	39,500	62,500	76,717
Total Metropolitan Ottawa	?	217,490	352,945	459,626

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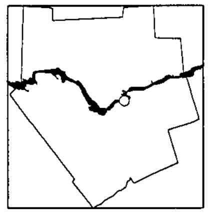
PARKING SUPPLY IN THE CBD (Ottawa only)

	1961	1971	1981	1991
Off-street parking spaces	?	?	?	24,200
On-street parking spaces	?	?	?	1,365
Total parking spaces	?	16,655	?	25,565



OTTAWA

	1961	1971	1981	1991
ROAD NETWORK (km - Ontario only)				
RMOC	?	?	-	1,100
Local	?	?	-	3,437
Provincial	?	?	-	216
N.C.C.	?	?	-	67
Total roads	?	?	**4,600**	**4,820**
MOTOR VEHICLES ON REGISTER				
Passenger Cars	132,696	234,182	348,718	463,254
Commercial vehicles	15,670	24,017	-	-
Trucks and Buses	-	-	35,308	46,599
Total vehicles on register	**148,366**	**258,199**	**384,026**	**509,853**
PRIVATE TRANSPORT INDICATORS				
Total annual V. K. T.	1.8575E+09	?	4.7250E+09	5.9320E+09
Total annual V. K. T. in cars	1.6886E+09	?	4.2500E+09	5.3410E+09
Average vehicle occupancy	1.51	1.43	1.4	1.4
Car occupant kilometres	2.5498E+09	?	5.9500E+09	7.4774E+09
Average road network speed (km/h)	?	?	42.0	40.0
TRANSPORT ENERGY USE				
Private Passenger (Joules)	?	1.8229E+16	2.4070E+16	2.4246E+16
Non-passenger (Joules)	?	?	4.4560E+15	4.9219E+15
Total fuel consumption (Joules)	?	?	2.8526E+16	2.9168E+16
MODE SPLIT: JOURNEY-TO-WORK (%)				
Public transport	?	?	22.0	27.0
Private transport	?	?	73.0	66.0
Walking and cycling	?	?	5.0	7.0
AVERAGE TRIP LENGTHS (km)				
Journey-to-work	?	?	11.0	12.0
Other trip purposes	?	?	6.0	7.0
All Trips	?	?	10.0	10.0
PUBLIC TRANSPORT INDICATORS				
VEHICLE KILOMETRES				
- Buses				
Motor bus (OC Transpo)	11,362,005	13,947,827	39,410,921	42,323,933
Motor bus (STO)	?	1,158,696	8,607,831	8,455,000
Total	*11,362,005*	*15,106,523*	*48,018,752*	*50,778,933*
- Trains	*0*	*0*	*0*	*0*
- Trams	*0*	*0*	*0*	*0*
- Ferries	*0*	*0*	*0*	*0*
Grand Total	*11,362,005*	*15,106,523*	*48,018,752*	*50,778,933*

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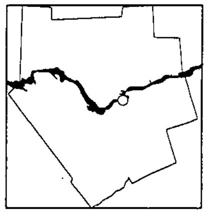
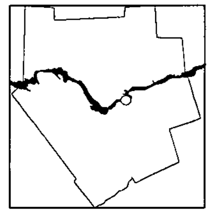


	1961	1971	1981	1991
PASSENGER BOARDINGS				
- Buses				
Motor bus (OC Transpo)	41,357,171	43,149,380	102,076,133	110,917,800
Motor bus (STO)	?	2,250,000	11,973,922	11,328,584
Total	*41,357,171*	*45,399,380*	*114,050,055*	*122,246,384*
- Trains	*0*	*0*	*0*	*0*
- Trams	*0*	*0*	*0*	*0*
- Ferries	*0*	*0*	*0*	*0*
Grand Total	*41,357,171*	*45,399,380*	*114,050,055*	*122,246,384*
AVERAGE TRIP LENGTH (km)				
- Buses				
Motor bus (OC Transpo)	3.7	4.6	5.2	6.3
Motor bus (STO)	?	6.4	6.4	6.4
- Trains	*0.0*	*0.0*	*0.0*	*0.0*
- Trams	*0.0*	*0.0*	*0.0*	*0.0*
- Ferries	*0.0*	*0.0*	*0.0*	*0.0*
PASSENGER KILOMETRES				
- Buses				
Motor bus (OC Transpo)	153,021,533	198,487,148	530,795,892	698,782,140
Motor bus (STO)	?	14,400,000	76,633,101	72,502,938
Total	*153,021,533*	*212,887,148*	*607,428,992*	*771,285,078*
- Trains	*0*	*0*	*0*	*0*
- Trams	*0*	*0*	*0*	*0*
- Ferries	*0*	*0*	*0*	*0*
Grand Total	*153,021,533*	*212,887,148*	*607,428,992*	*771,285,078*
AVERAGE SPEED (km/h)				
- Buses				
All Buses	?	?	21.4	24.0
- Trains	*0.0*	*0.0*	*0.0*	*0.0*
- Trams	*0.0*	*0.0*	*0.0*	*0.0*
- Ferries	*0.0*	*0.0*	*0.0*	*0.0*
All modes average	*?*	*?*	*21.4*	*24.0*



	1961	1971	1981	1991
ENERGY CONSUMPTION				
- Buses				
Motor bus (OC Transpo)				
Diesel (litres)	5,979,823	7,346,320	23,900,000	31,192,903
Motor bus (STO)				
Diesel (litres)	?	610,285	4,424,425	4,988,122
Total (Joules)	***2.2897E+14***	***3.0466E+14***	***1.0845E+15***	***1.3854E+15***
- Trains	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*
- Trams	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*
- Ferries	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*
Grand Total	*2.2897E+14*	*3.0466E+14*	*1.0845E+15*	*1.3854E+15*

NOTES:

(1) Public transport in the Ontario portion of the Ottawa region is operated by Ottawa-Carleton Transport (OC Transpo). The Quebec side is serviced by the Société de Transport de l'Outaouais (STO).

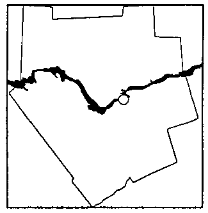
(2) RMOC stands for Regional Municipality of Ottawa-Carleton. CUO is the abbreviation for Communauté Urbaine de l'Outaouais. MRC stands for Municipalité Régionale de Comté Collines-de-l'Outaouais.

(3) As there is no total population available for the Quebec part of the Ottawa Region in 1961, only the Ontario vehicles were used for standardisation. In 1961, there were 100,279 cars in the RMOC and a total of 112,266 vehicles.

(4) The 1961 private vehicle kilometre data refers to 1965 with a population of 482,000.

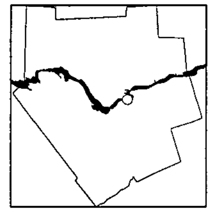
(5) For the vehicles per kilometre of road only, the Ontario registrations were used as there were no road length data for Quebec. The respective vehicle populations are: 243,141 (1981) and 320,284 (1991).

OTTAWA



OTTAWA

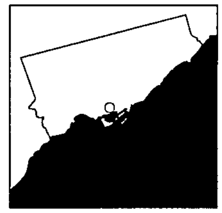
	1961	1971	1981	1991
POPULATION PARAMETERS				
Urban density (persons/ha)	?	34.9	31.7	31.3
Inner area density (persons/ha)	61.2	62.2	48.3	49.2
Outer area density (persons/ha)	?	31.9	30.3	30.1
CBD density (persons/ha)	71.2	60.0	36.8	39.7
Proportion of population in CBD	?	2.9%	1.5%	1.3%
Proportion of population in inner area	?	17.7%	11.8%	9.8%
EMPLOYMENT PARAMETERS				
Job density (jobs/ha)	?	12.0	15.2	15.8
Inner area job density (jobs/ha)	?	54.7	77.5	97.7
Outer area job density (jobs/ha)	?	7.3	10.0	10.4
CBD job density (jobs/ha)	?	192.5	305.4	364.0
Proportion of jobs in CBD	?	27.0%	26.4%	24.2%
Proportion of jobs in inner area	?	45.3%	39.5%	38.3%
ACTIVITY INTENSITY PARAMETERS				
(Population and Jobs/ha)				
CBD activity density	?	252.5	342.2	403.7
Inner area activity density	?	116.9	125.8	146.9
Outer area activity density	?	39.2	40.3	40.5
City-wide activity density	?	46.9	47.0	47.1
VEHICLE OWNERSHIP PARAMETERS				
Total vehicles/1000 people	313.2	407.6	521.9	561.6
Passenger cars/1000 people	279.8	369.7	473.9	510.2
PRIVATE MOBILITY PARAMETERS				
Total per capita vehicle kilometres	3,854	?	6,421	6,534
Per capita car kilometres	3,503	?	5,776	5,883
Total per capita occupant kilometres	?	?	8,990	9,147
Per capita car occupant kilometres	?	?	8,086	8,236
Total vehicle kilometres per vehicle	12,520	?	12,304	11,635
Car kilometres per car	12,725	?	12,187	11,529
TRAFFIC RESTRAINT PARAMETERS				
Parking spaces / 1000 CBD workers	?	283.7	?	230.3
Length of road per person (m)	?	?	8.4	7.1
Total vehicles per km of road	?	?	52.9	66.4
Total vehicle kilometres per km of road	?	?	763,343	919,244
Car kilometres per km of road	?	?	686,605	827,661
PER CAPITA TRANSPORT ENERGY PARAMETERS (MJ)				
Private passenger transport energy	?	28,778	32,710	26,705
Total private energy use/person	?	?	38,766	32,126
Public transport energy use/person	?	481	1,474	1,526
Total energy use/person	?	?	40,240	33,652



OTTAWA

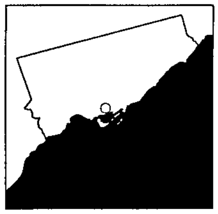
	1961	1971	1981	1991
PUBLIC TRANSPORT PARAMETERS				
Vehicle kilometres per person				
Buses	31.7	23.8	65.3	55.9
Rail	0.0	0.0	0.0	0.0
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Total	*31.7*	*23.8*	*65.3*	*55.9*
Passenger boardings per person				
Buses	115.4	71.7	155.0	134.6
Rail	0.0	0.0	0.0	0.0
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Total	*115.4*	*71.7*	*155.0*	*134.6*
Passenger boardings per vehicle km				
Buses	3.6	3.0	2.4	2.4
Rail	0.0	0.0	0.0	0.0
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Overall	*3.6*	*3.0*	*2.4*	*2.4*
Passenger kilometres per person				
Buses	426.9	336.1	825.5	849.5
Rail	0.0	0.0	0.0	0.0
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Total	*426.9*	*336.1*	*825.5*	*849.5*
Average public transport speed (km/h)				
Buses	?	?	21.4	24.0
Rail	0.0	0.0	0.0	0.0
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Overall	*?*	*?*	*21.4*	*24.0*
Vehicular energy efficiency (MJ/km)				
Buses	20.2	20.2	22.6	27.3
Rail	0.0	0.0	0.0	0.0
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Overall	*20.2*	*20.2*	*22.6*	*27.3*
Modal energy efficiency (MJ/pass km)				
Buses	1.50	1.43	1.79	1.80
Rail	0.00	0.00	0.00	0.00
Trams	0.00	0.00	0.00	0.00
Ferries	0.00	0.00	0.00	0.00
Overall	*1.50*	*1.43*	*1.79*	*1.80*

TORONTO



TORONTO

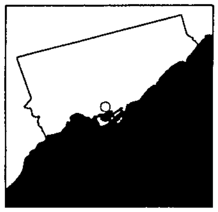
	1961	1971	1981	1991
POPULATION AND AREA				
Total population				
Municipality of Metropolitan Toronto	1,620,861	2,089,729	2,137,395	2,275,771
Metropolitan region	2,105,792	2,910,250	3,417,701	4,235,756
Urbanised area (ha)				
Municipality of Metropolitan Toronto	43,989	50,447	53,970	54,868
Metropolitan region	?	?	?	163,388
Population of the CBD	5,413	3,650	4,742	9,615
Area of the CBD (ha)	188	188	188	188
Population of the central area	124,983	121,165	121,093	143,650
Area of the central area (ha)	2,697	2,716	2,775	2,775
Population of the inner city	890,174	904,325	762,921	810,240
Area of the inner city	12,000	12,594	13,500	13,500
EMPLOYMENT				
Number of jobs in the CBD	122,179	135,815	142,645	174,267
Number of jobs in the central area	297,179	318,430	335,739	405,662
Number of jobs in the inner city	488,205	514,468	508,418	597,740
Number of jobs in the outer area	186,495	407,016	553,773	674,331
Total jobs	**674,700**	**921,484**	**1,062,191**	**1,272,071**
Number of jobs in the GTA	?	?	1,830,000	2,290,000
PARKING SUPPLY IN THE CBD				
Off-street parking spaces	22,436	25,913	27,187	29,408
On-street parking spaces	1,000	1,000	1,006	1,236
Total parking spaces	23,436	26,913	28,193	30,644
Off-street parking spaces in central area	?	?	?	13,890
On-street parking spaces in central area	?	?	?	4,546
Total parking spaces in central area	?	?	?	**18,436**
ROAD NETWORK (km)				
Highways and arterials	615	?	824	851
Municipal streets and roads	2,157	?	4,991	4,991
Total roads in Metro Toronto	**2,772**	**4,875**	**5,815**	**5,842**
Total roads in the GTA area	?	?	?	**19,026**
MOTOR VEHICLES ON REGISTER				
Cars and station wagons	482,705	748,521	975,658	980,729
Trucks	75,913	95,089	167,845	124,913
Motor cycles and mopeds	?	?	21,026	15,612
Buses	?	?	4,770	4,228
Total vehicles on register	**558,618**	**843,610**	**1,169,299**	**1,125,482**
PRIVATE TRANSPORT INDICATORS				
Total annual V. K. T.	?	?	1.0922E+10	1.3771E+10
Total annual V. K. T. in cars	?	?	9.0580E+09	1.1422E+10
Average vehicle occupancy	1.5	1.6	1.4	1.4
Car occupant kilometres	?	?	1.2681E+10	1.5991E+10
Average road network speed (km/h)		?	?	35.0



TORONTO

	1961	1971	1981	1991
TRANSPORT ENERGY USE				
Private passenger (Joules)	?	?	5.5492E+16	6.9971E+16
Non-passenger (Joules)	?	?	1.9110E+15	2.4078E+15
Total fuel consumption (Joules)	?	?	5.7403E+16	7.2379E+16
MODE SPLIT: JOURNEY-TO-WORK (%)				
Metro Toronto				
Public transport	22.9	?	31.7	30.1
Private transport	70.3	?	62.8	64.6
Walking and cycling	6.3	?	5.5	5.3
Greater Toronto Area (GTA)				
Public transport	?	?	22.9	20.1
Private transport	?	?	72.4	75.8
Walking and cycling	?	?	4.8	4.1
AVERAGE TRIP LENGTHS (km)				
Journey-to-work	8.5	10.7	13.2	14.4
School	?	?	6.2	6.5
Other home-based	?	?	8.2	8.0
Non home-based	?	?	9.3	9.8
GTA overall	?	?	9.9	6.3
Metro				
Journey-to-work	?	?	10.5	11.2
School	?	?	5.5	6.2
Other home-based	?	?	7.5	7.1
Non home-based	?	?	8.7	8.4
Metro overall	?	?	?	?
PUBLIC TRANSPORT INDICATORS				
VEHICLE KILOMETRES				
- Buses				
Motor bus (TTC)	24,472,000	52,969,000	79,373,000	112,383,608
Trolley bus (TTC)	6,601,000	6,601,000	6,601,000	5,462,981
Motor bus (GO Transit)	0	4,000,000	6,206,000	15,925,000
Total	***31,073,000***	***63,570,000***	***92,180,000***	***133,771,589***
- Trains				
Subway (TTC)	11,431,000	36,547,000	62,146,000	74,199,635
Commuter rail (GO Transit)	0	5,000,000	8,156,835	19,102,000
Total	***11,431,000***	***41,547,000***	***70,302,835***	***93,301,635***
- Trams				
Tram (TTC)	35,581,000	18,354,000	15,134,000	13,131,237
- Ferries	*0*	*0*	*0*	*0*
Grand Total	***78,085,000***	***123,471,000***	***177,616,835***	***240,204,461***

	1961	1971	1981	1991
PASSENGER BOARDINGS				
- Buses				
Motor bus (TTC)	66,500,000	119,000,000	266,247,000	351,596,000
Trolley bus (TTC)	22,600,000	17,700,000	23,562,000	27,882,000
Motor bus (GO Transit)	0	5,000,000	8,803,589	11,317,322
Total	*89,100,000*	*141,700,000*	*298,612,589*	*390,795,322*
- Trains				
Subway (TTC)	31,300,000	84,200,000	235,280,000	317,166,000
Commuter rail (GO Transit)	0	7,000,000	13,282,839	25,974,537
Total	*31,300,000*	*91,200,000*	*248,562,839*	*343,140,537*
- Trams				
Tram (TTC)	134,300,000	55,600,000	98,956,000	98,788,000
- Ferries	*0*	*0*	*0*	*0*
Grand Total	*254,700,000*	*288,500,000*	*646,131,428*	*832,723,859*
AVERAGE TRIP LENGTH (km)				
- Buses				
All TTC buses	8.5	9.8	6.5	5.5
Motor bus (GO Transit)	0.0	6.0	6.6	19.8
- Trains				
Subway (TTC)	8.5	9.8	6.2	5.4
Commuter rail (GO Transit)	0.0	26.0	27.9	29.8
- Trams				
Tram (TTC)	8.5	9.8	6.2	5.9
- Ferries	*0.0*	*0.0*	*0.0*	*0.0*
PASSENGER KILOMETRES				
- Buses				
Motor bus (TTC)	565,250,000	1,166,200,000	1,660,581,000	1,945,920,000
Trolley bus (TTC)	192,100,000	173,460,000	209,326,000	154,560,000
Motor bus (GO Transit)	0	30,000,000	58,137,000	224,117,600
Total	*757,350,000*	*1,369,660,000*	*1,928,044,000*	*2,324,597,600*
- Trains				
Subway (TTC)	266,050,000	825,160,000	1,467,440,000	1,726,080,000
Commuter rail (GO Transit)	0	182,000,000	370,917,008	774,535,000
Total	*266,050,000*	*1,007,160,000*	*1,838,357,008*	*2,500,615,000*
- Trams				
Tram (TTC)	1,141,550,000	544,880,000	617,188,000	581,760,000
- Ferries	*0*	*0*	*0*	*0*
Grand Total	*2,164,950,000*	*2,921,700,000*	*4,383,589,008*	*5,406,972,600*



TORONTO

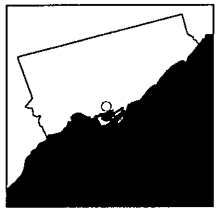
	1961	1971	1981	1991
AVERAGE SPEED (km/h)				
- Buses				
Motor bus (TTC)	18.2	19.0	20.3	20.0
Trolley bus (TTC)	15.8	15.5	14.8	14.3
Motor bus (GO Transit)	0.0	?	?	32.5
Overall bus speed	*17.6*	*18.5*	*19.7*	*20.3*
- Trains				
Subway (TTC)	24.2	30.8	32.4	31.3
Commuter rail (GO Transit)	0.0	50.0	55.1	52.6
Overall train speed	*24.2*	*33.4*	*35.5*	*35.4*
- Trams				
Tram (TTC)	16.1	16.3	15.8	14.3
- Ferries	*0.0*	*0.0*	*0.0*	*0.0*
All modes average	*17.6*	*23.1*	*25.5*	*26.1*
ENERGY CONSUMPTION				
- Buses				
Motor bus (TTC)				
Diesel (litres)	12,880,000	27,900,000	40,800,000	59,898,000
Trolley bus (TTC)				
Electricity (kWh)	16,502,500	16,800,000	18,300,000	14,851,451
Motor bus (GO Transit)				
Diesel (litres)	0	1,869,000	2,900,000	6,020,000
Total (Joules)	*5.5258E+14*	*1.2003E+15*	*1.7392E+15*	*2.5775E+15*
- Trains				
Subway (TTC)				
Electricity (kWh)	35,436,100	157,000,000	232,100,000	271,824,553
Commuter rail (GO Transit)				
Diesel (litres)	0	11,770,000	19,200,000	24,748,000
Total (Joules)	*1.2757E+14*	*1.0159E+15*	*1.5707E+15*	*1.9262E+15*
- Trams				
Tram (TTC)				
Electricity (kWh)	113,859,200	58,100,000	51,800,000	44,091,279
Total (Joules)	*4.0989E+14*	*2.0916E+14*	*1.8648E+14*	*1.5873E+14*
- Ferries	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*
Grand Total	*1.0900E+15*	*2.4254E+15*	*3.4964E+15*	*4.6624E+15*

NOTES:

(1) Public transport within Metro Toronto is provided by the Toronto Transit Commission (TTC). Commuter services from the adjoining areas are provided by Government of Ontario Transit (GO Transit).

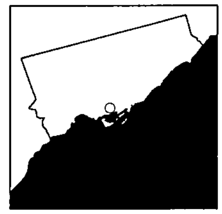
(2) GTA stands for the Greater Toronto Area.

TORONTO



TORONTO

	1961	1971	1981	1991
POPULATION PARAMETERS				
Urban density (persons/ha)	36.8	41.4	39.6	41.5
Inner area density (persons/ha)	74.2	71.8	56.5	60.0
Outer area density (persons/ha)	22.8	31.3	34.0	35.4
CBD density (persons/ha)	28.8	19.4	25.2	51.1
Proportion of population in CBD	0.3%	0.2%	0.2%	0.4%
Proportion of population in inner area	54.9%	43.3%	35.7%	35.6%
EMPLOYMENT PARAMETERS				
Job density (jobs/ha)	15.3	18.3	19.7	23.2
Inner area job density (jobs/ha)	40.7	40.9	37.7	44.3
Outer area job density (jobs/ha)	5.8	10.8	13.7	16.3
CBD job density (jobs/ha)	649.9	722.4	758.8	927.0
Proportion of jobs in CBD	18.1%	14.7%	13.4%	13.7%
Proportion of jobs in inner area	72.4%	55.8%	47.9%	47.0%
ACTIVITY INTENSITY PARAMETERS				
(Population and Jobs/ha)				
CBD activity density	678.7	741.8	784.0	978.1
Inner area activity density	114.9	112.7	94.2	104.3
Outer area activity density	28.7	42.1	47.6	51.7
City-wide activity density	52.2	59.7	59.3	64.7
VEHICLE OWNERSHIP PARAMETERS				
Total vehicles/1000 people	344.6	403.7	547.1	494.5
Passenger cars/1000 people	297.8	358.2	456.5	430.9
PRIVATE MOBILITY PARAMETERS				
Total per capita vehicle kilometres	?	?	5,110	6,051
Per capita car kilometres	?	?	4,238	5,019
Total per capita occupant kilometres	?	?	7,154	8,472
Per capita car occupant kilometres	?	?	5,933	7,027
Total vehicle kilometres per vehicle	?	?	9,179	8,566
Car kilometres per car	?	?	9,163	8,283
TRAFFIC RESTRAINT PARAMETERS				
Parking spaces / 1000 CBD workers	191.8	198.2	197.6	175.8
Length of road per person (m)	1.7	2.3	2.7	2.6
Total vehicles per km of road	201.5	173.0	204.6	275.2
Total vehicle kilometres per km of road	?	?	1,878,246	2,357,241
Car kilometres per km of road	?	?	1,557,696	1,955,152
PER CAPITA TRANSPORT ENERGY PARAMETERS (MJ)				
Private passenger transport energy	?	?	25,962	30,746
Total private energy use/person	?	?	26,857	31,804
Public transport energy use/person	673	1,090	1,487	1,809
Total energy use/person	?	?	28,344	33,613



TORONTO

PUBLIC TRANSPORT PARAMETERS

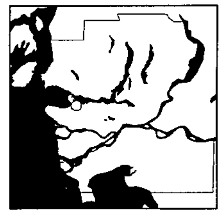
	1961	1971	1981	1991
Vehicle kilometres per person				
Buses	19.2	29.9	42.0	55.5
Rail	7.1	19.2	31.5	37.1
Trams	22.0	8.8	7.1	5.8
Ferries	0.0	0.0	0.0	0.0
Total	*48.2*	*57.9*	*80.6*	*98.4*
Passenger boardings per person				
Buses	51.8	63.0	131.5	161.1
Rail	19.3	42.7	114.0	145.5
Trams	82.9	26.6	46.3	43.4
Ferries	0.0	0.0	0.0	0.0
Total	*153.9*	*132.3*	*291.7*	*350.0*
Passenger boardings per vehicle km				
Buses	2.9	2.2	3.2	2.9
Rail	2.7	2.2	3.5	3.7
Trams	3.8	3.0	6.5	7.5
Ferries	0.0	0.0	0.0	0.0
Overall	*3.3*	*2.3*	*3.6*	*3.5*
Passenger kilometres per person				
Buses	467.3	651.4	891.9	975.9
Rail	164.1	457.4	795.1	941.3
Trams	704.3	260.7	288.8	255.6
Ferries	0.0	0.0	0.0	0.0
Total	*1,335.7*	*1,369.5*	*1,975.7*	*2,172.8*
Average public transport speed (km/h)				
Buses	17.6	18.5	19.7	20.3
Rail	24.2	33.4	35.5	35.4
Trams	16.1	16.3	15.8	14.3
Ferries	0.0	0.0	0.0	0.0
Overall	*17.6*	*23.1*	*25.5*	*26.1*
Vehicular energy efficiency (MJ/km)				
Buses	17.8	18.9	18.9	19.3
Rail	11.2	24.5	22.3	20.6
Trams	11.5	11.4	12.3	12.1
Ferries	0.0	0.0	0.0	0.0
Overall	*14.0*	*19.6*	*19.7*	*19.4*
Modal energy efficiency (MJ/pass km)				
Buses	0.73	0.88	0.90	1.11
Rail	0.48	1.01	0.85	0.77
Trams	0.36	0.38	0.30	0.27
Ferries	0.00	0.00	0.00	0.00
Overall	*0.50*	*0.83*	*0.80*	*0.86*

VANCOUVER

VANCOUVER

	1961	1971	1981	1991
POPULATION AND AREA				
Total population				
GVRD	791,450	1,028,320	1,170,015	1,542,933
Vancouver CMA	827,335	1,082,185	1,268,197	1,602,502
Urbanised area (ha)	31,723	47,653	63,583	74,115
Population of the CBD	9,290	6,585	6,260	8,635
Area of the CBD (ha)	337	337	337	337
Population of the Central Area (West End + CBD)	33,497	44,100	43,210	45,825
Area of the Central Area	531	531	531	531
Population of the inner city	374,455	414,685	397,535	440,810
Area of the inner city	10,632	10,632	10,632	10,632
EMPLOYMENT				
Number of jobs in the CBD	?	84,597	110,245	104,000
Number of Jobs in the Central Area	?	94,758	124,239	116,800
Number of jobs in the inner city	?	232,238	292,907	317,650
Number of jobs in the outer area	?	148,917	306,722	457,855
Number of jobs in the Vancouver CMA	294,759	394,204	632,191	792,485
Number of jobs in the GVRD	**294,759**	**381,155**	**599,629**	**775,505**
PARKING SUPPLY IN THE CBD				
Off-street parking spaces	15,532	24,681	33,617	41,915
On-street parking spaces	4,138	4,138	4,138	4,138
Total parking spaces	**19,670**	**28,819**	**37,755**	**46,053**
ROAD NETWORK (km)				
Major/secondary highways	489	781	903	1,192
Local roads/lanes	5,028	5,283	5,815	6,670
Total roads	**5,517**	**6,064**	**6,718**	**7,862**
MOTOR VEHICLES ON REGISTER				
Passenger cars	225,805	413,034	531,053	871,013
Commercial vehicles	33,274	65,397	112,320	178,888
Motorcycles	-	-	16,010	20,554
Utility Trailers	-	-	39,837	53,430
Commercial Trailers	-	-	12,033	18,151
Total vehicles on register	**259,079**	**478,431**	**711,253**	**1,142,036**
Total vehicles without trailers	-	-	**659,383**	**1,070,455**
PRIVATE TRANSPORT INDICATORS				
Total annual V. K. T.	?	?	8.3202E+09	1.3500E+10
Total annual V. K. T. in cars	?	?	7.9042E+09	1.2900E+10
Average vehicle occupancy	?	?	1.67	1.50
Car occupant kilometres	?	?	1.3200E+10	1.9350E+10
Average road network speed (km/h)	?	?	?	38.0
TRANSPORT ENERGY USE				
Private passenger (Joules)	?	3.0577E+16	4.6068E+16	4.8670E+16
Non-passenger (Joules)	?	?	6.5859E+15	7.3134E+15
Total fuel consumption (Joules)	?	?	5.2654E+16	5.5983E+16

	1961	1971	1981	1991
MODE SPLIT: JOURNEY-TO-WORK (%)				
Public transport	?	?	?	12.4
Private transport	?	?	?	81.9
Walking and cycling	?	?	?	5.7
AVERAGE TRIP LENGTHS (km)				
Journey-to-work	?	?	?	14.0
Post-secondary school	?	?	?	12.6
Shopping	?	?	?	7.5
All Purposes	?	?	?	9.8
Other trip purposes	?	?	?	?
PUBLIC TRANSPORT INDICATORS				
VEHICLE KILOMETRES				
- Buses				
Motor bus (BC Transit)	12,693,739	12,763,534	-	45,315,632
Trolley bus (BC Transit)	16,288,793	13,045,500	-	13,344,576
Total	*28,982,532*	*25,809,034*	*53,363,216*	*58,660,208*
- Trains				
SkyTrain (BC Transit)	0	0	0	18,734,113
- Trams	*0*	*0*	*0*	*0*
- Ferries				
Seabus (BC Transit)	0	0	135,684	140,834
Grand Total	*28,982,532*	*25,809,034*	*53,498,900*	*77,535,155*
PASSENGER BOARDINGS				
- Buses				
Motor bus (BC Transit)	33,606,252	40,500,792	-	97,861,978
Trolley bus (BC Transit)	75,768,666	50,502,000	-	49,308,442
Total	*109,374,918*	*91,002,792*	*130,000,000*	*147,170,420*
- Trains				
SkyTrain (BC Transit)	0	0	0	29,285,281
- Trams	*0*	*0*	*0*	*0*
- Ferries				
Seabus (BC Transit)	0	0	3,195,801	4,299,665
Grand Total	*109,374,918*	*91,002,792*	*133,195,801*	*180,755,366*



VANCOUVER

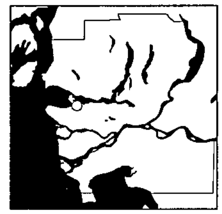
	1961	1971	1981	1991
AVERAGE TRIP LENGTH (km)				
- Buses				
All buses	?	?	7.5	6.9
- Trains				
SkyTrain (BC Transit)	0.0	0.0	0.0	11.1
- Trams	*0.0*	*0.0*	*0.0*	*0.0*
- Ferries				
Seabus (BC Transit)	0.0	0.0	2.1	2.1
PASSENGER KILOMETRES				
- Buses				
Motor bus (BC Transit)	?	?	?	?
Trolley bus (BC Transit)	?	?	?	?
Total	*?*	*?*	*975,000,000*	*1,010,266,065*
- Trains				
SkyTrain (BC Transit)	0	0	0	325,066,619
- Trams	*0*	*0*	*0*	*0*
- Ferries				
Seabus (BC Transit)	0	0	6,711,182	9,029,297
Grand Total	*?*	*?*	*981,711,182*	*1,344,361,981*
AVERAGE SPEED (km/h)				
- Buses				
All Buses	?	20.8	19.9	20.1
- Trains				
SkyTrain (BC Transit)	0.0	0.0	0.0	41.7
- Trams	*0.0*	*0.0*	*0.0*	*0.0*
- Ferries				
Seabus (BC Transit)	0.0	0.0	13.9	13.5
All modes average	*?*	*20.8*	*19.9*	*25.3*

	1961	1971	1981	1991
ENERGY CONSUMPTION				
- *Buses*				
Motor bus (BC Transit)				
Diesel (litres)	6,680,715	6,722,553	23,031,144	28,839,635
Natural gas (litres)	0	0	0	16,001,000
Trolley bus (BC Transit)				
Electricity (kWh)	40,721,982	33,200,797	41,762,705	33,746,730
Total (Joules)	*4.0240E+14*	*3.7693E+14*	*1.0322E+15*	*1.2264E+15*
- *Trains*				
SkyTrain (BC Transit)				
Electricity (kWh)	0	0	0	44,926,600
Total (Joules)	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*	*1.6174E+14*
- *Trams*	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*
- *Ferries*				
Diesel (litres)	0	0	1,051,395	1,117,498
Total (Joules)	*0.0000E+00*	*0.0000E+00*	*4.0258E+13*	*4.2789E+13*
Grand Total	*4.0240E+14*	*3.7693E+14*	*1.0725E+15*	*1.4309E+15*

NOTES:

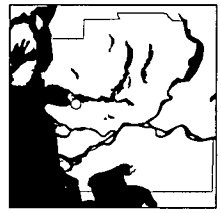
(1) All public transport in Vancouver is provided by British Columbia Transit (BC Transit).

VANCOUVER



VANCOUVER

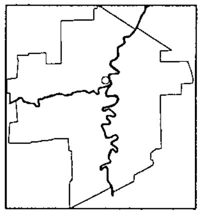
	1961	1971	1981	1991
POPULATION PARAMETERS				
Urban density (persons/ha)	24.9	21.6	18.4	20.8
Inner area density (persons/ha)	35.2	39.0	37.4	41.5
Outer area density (persons/ha)	19.8	16.6	14.6	17.4
CBD density (persons/ha)	27.6	19.5	18.6	25.6
Proportion of population in CBD	1.2%	0.6%	0.5%	0.6%
Proportion of population in inner area	47.3%	40.3%	34.0%	28.6%
EMPLOYMENT PARAMETERS				
Job density (jobs/ha)	9.3	8.0	9.4	10.5
Inner area job density (jobs/ha)	?	21.8	27.5	29.9
Outer area job density (jobs/ha)	?	4.0	5.8	7.2
CBD job density (jobs/ha)	?	251.0	327.1	308.6
Proportion of jobs in CBD	?	22.2%	18.4%	13.4%
Proportion of jobs in inner area	?	60.9%	48.8%	41.0%
ACTIVITY INTENSITY PARAMETERS				
(Population and Jobs/ha)				
CBD activity density	?	270.6	345.7	334.2
Inner area activity density	?	60.8	64.9	71.3
Outer area activity density	?	20.6	20.4	24.6
City-wide activity density	34.2	29.6	27.8	31.3
VEHICLE OWNERSHIP PARAMETERS				
Total vehicles/1000 people	327.3	465.3	563.6	693.8
Passenger cars/1000 people	285.3	401.7	453.9	564.5
PRIVATE MOBILITY PARAMETERS				
Total per capita vehicle kilometres	?	?	7,111	8,750
Per capita car kilometres	?	?	6,756	8,361
Total per capita occupant kilometres	?	?	11,876	13,124
Per capita car occupant kilometres	?	?	11,282	12,541
Total vehicle kilometres per vehicle	?	?	12,618	12,611
Car kilometres per car	?	?	14,884	14,810
TRAFFIC RESTRAINT PARAMETERS				
Parking spaces / 1000 CBD workers	?	341	342	443
Length of road per person (m)	7	6	6	5
Total vehicles per km of road	?	?	98	136
Total vehicle kilometres per km of road	?	?	1,238,494	1,717,120
Car kilometres per km of road	?	?	1,176,570	1,640,804
PER CAPITA TRANSPORT ENERGY PARAMETERS (MJ)				
Private passenger transport energy	?	29,735	39,374	31,544
Total private energy use/person	?	?	45,003	36,284
Public transport energy use/person	508	367	917	927
Total energy use/person	?	?	45,920	37,211



PUBLIC TRANSPORT PARAMETERS

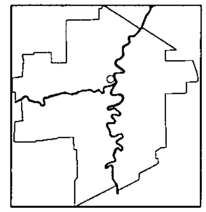
	1961	1971	1981	1991
Vehicle kilometres per person				
Buses	36.6	25.1	45.6	38.0
Rail	0.0	0.0	0.0	12.1
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.1	0.1
Total	*36.6*	*25.1*	*45.7*	*50.3*
Passenger boardings per person				
Buses	138.2	88.5	111.1	95.4
Rail	0.0	0.0	0.0	19.0
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	2.7	2.8
Total	*138.2*	*88.5*	*113.8*	*117.2*
Passenger boardings per vehicle km				
Buses	3.8	3.5	2.4	2.5
Rail	0.0	0.0	0.0	1.6
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	23.6	30.5
Overall	*3.8*	*3.5*	*2.5*	*2.3*
Passenger kilometres per person				
Buses	?	?	833.3	654.8
Rail	0.0	0.0	0.0	210.7
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	5.7	5.9
Total	*?*	*?*	*839.1*	*871.3*
Average public transport speed (km/h)				
Buses	?	20.8	19.9	20.1
Rail	0.0	0.0	0.0	41.7
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	13.9	13.5
Overall	*?*	*20.8*	*19.9*	*25.3*
Vehicular energy efficiency (MJ/km)				
Buses	13.9	14.6	19.3	20.9
Rail	0.0	0.0	0.0	8.6
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	296.7	303.8
Overall	*13.9*	*14.6*	*20.0*	*18.5*
Modal energy efficiency (MJ/pass km)				
Buses	?	?	1.06	1.21
Rail	0.00	0.00	0.00	0.50
Trams	0.00	0.00	0.00	0.00
Ferries	0.00	0.00	6.00	4.74
Overall	*?*	*?*	*1.09*	*1.06*

WINNIPEG

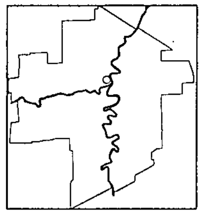


WINNIPEG

	1962	1971	1981	1991
POPULATION AND AREA				
Total population				
City of Winnipeg	470,619	534,822	586,205	641,850
Urbanised area (ha)	15,099	20,543	26,063	30,146
Population of the CBD	18,977	17,741	17,021	18,689
Area of the CBD (ha)	440	440	440	440
Population of the inner city	227,902	214,259	181,930	178,445
Area of the inner city	4,331	4,331	4,331	4,331
EMPLOYMENT				
Number of jobs in the CBD	60,429	61,478	62,036	68,593
Number of jobs in the inner city	99,996	105,762	114,065	125,974
Number of jobs in the outer area	49,768	90,660	123,505	138,462
Total jobs	149,764	196,422	237,570	264,436
PARKING SUPPLY IN THE CBD				
Off-street parking spaces	25,490	25,444	31,289	35,408
On-street parking spaces	2,395	2,200	2,299	2,011
Total parking spaces	27,885	27,644	33,588	37,419
ROAD NETWORK (km)				
Regional streets	?	?	?	426
District streets	?	?	?	2,242
Total roads	?	?	?	2,668
MOTOR VEHICLES ON REGISTER				
Passenger cars	128,108	177,749	238,749	264,365
Commercial vehicles	14,232	18,626	-	-
Trucks and buses	-	-	41,796	51,766
Total vehicles on register	142,340	196,375	280,545	316,131
PRIVATE TRANSPORT INDICATORS				
Total annual V. K. T.	2.1552E+09	3.1648E+09	3.9882E+09	4.9003E+09
Total annual V. K. T. in cars	1.9397E+09	2.8483E+09	3.5894E+09	4.4103E+09
Average vehicle occupancy	1.75	1.55	1.50	1.40
Car occupant kilometres	3.3944E+09	4.4149E+09	5.3841E+09	6.1744E+09
Average road network speed (km/h)	?	?	?	35.0
TRANSPORT ENERGY USE				
Private passenger (Joules)	?	1.7515E+16	2.0750E+16	2.0551E+16
Non-passenger (Joules)	?	?	3.7414E+15	4.0810E+15
Total fuel consumption (Joules)	?	?	2.4491E+16	2.4632E+16
MODE SPLIT: JOURNEY-TO-WORK (%)				
Public transport	28.1	22.5	22.3	19.9
Private transport	60.4	67.4	68.7	72.2
Walking and cycling	11.5	10.1	9.0	8.0



	1962	1971	1981	1991
AVERAGE TRIP LENGTHS (km)				
Journey-to-work	?	?	?	6.6
Other trip purposes	?	?	?	?
PUBLIC TRANSPORT INDICATORS				
VEHICLE KILOMETRES				
- Buses				
Motor bus (WT)	13,679,796	22,944,321	25,955,447	25,969,676
Trolley bus (WT)	6,714,445	0	0	0
Total	*20,394,241*	*22,944,321*	*25,955,447*	*25,969,676*
- Trains	*0*	*0*	*0*	*0*
- Trams	*0*	*0*	*0*	*0*
- Ferries	*0*	*0*	*0*	*0*
Grand Total	*20,394,241*	*22,944,321*	*25,955,447*	*25,969,676*
PASSENGER BOARDINGS				
- Buses				
Motor bus (WT)	43,302,500	72,595,000	78,574,000	62,739,000
Trolley bus (WT)	26,190,000	0	0	0
Total	*69,492,500*	*72,595,000*	*78,574,000*	*62,739,000*
- Trains	*0*	*0*	*0*	*0*
- Trams	*0*	*0*	*0*	*0*
- Ferries	*0*	*0*	*0*	*0*
Grand Total	*69,492,500*	*72,595,000*	*78,574,000*	*62,739,000*
AVERAGE TRIP LENGTH (km)				
- Buses				
All buses	4.6	5.3	6.0	6.5
- Trains	*0.0*	*0.0*	*0.0*	*0.0*
- Trams	*0.0*	*0.0*	*0.0*	*0.0*
- Ferries	*0.0*	*0.0*	*0.0*	*0.0*

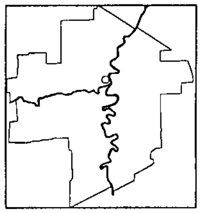


	1962	1971	1981	1991
PASSENGER KILOMETRES				
- Buses				
Motor bus (WT)	199,191,500	384,753,500	471,444,000	407,803,500
Trolley bus (WT)	120,474,000	0	0	0
Total	*319,665,500*	*384,753,500*	*471,444,000*	*407,803,500*
- Trains	*0*	*0*	*0*	*0*
- Trams	*0*	*0*	*0*	*0*
- Ferries	*0*	*0*	*0*	*0*
Grand Total	*319,665,500*	*384,753,500*	*471,444,000*	*407,803,500*
AVERAGE SPEED (km/h)				
- Buses				
All Buses	16.7	17.5	18.5	19.0
- Trains	*0.0*	*0.0*	*0.0*	*0.0*
- Trams	*0.0*	*0.0*	*0.0*	*0.0*
- Ferries	*0.0*	*0.0*	*0.0*	*0.0*
All modes average	*16.7*	*17.5*	*18.5*	*19.0*
ENERGY CONSUMPTION				
- Buses				
Motor bus (WT)				
Diesel (litres)	7,199,677	13,211,292	15,718,239	16,584,830
Trolley bus (WT)				
Electricity (kWh)	16,786,113	0	0	0
Total (Joules)	*3.3611E+14*	*5.0586E+14*	*6.0185E+14*	*6.3503E+14*
- Trains	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*
- Trams	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*
- Ferries	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*	*0.0000E+00*
Grand Total	*3.3611E+14*	*5.0586E+14*	*6.0185E+14*	*6.3503E+14*

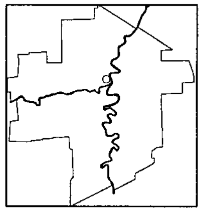
NOTES:

(1) All public transport in Winnipeg is operated by Winnipeg Transit (WT).

WINNIPEG



	1962	1971	1981	1991
POPULATION PARAMETERS				
Urban density (persons/ha)	31.2	26.0	22.5	21.3
Inner area density (persons/ha)	52.6	49.5	42.0	41.2
Outer area density (persons/ha)	22.5	19.8	18.6	18.0
CBD density (persons/ha)	43.1	40.3	38.7	42.5
Proportion of population in CBD	4.0%	3.3%	2.9%	2.9%
Proportion of population in inner area	48.4%	40.1%	31.0%	27.8%
EMPLOYMENT PARAMETERS				
Job density (jobs/ha)	9.9	9.6	9.1	8.8
Inner area job density (jobs/ha)	23.1	24.4	26.3	29.1
Outer area job density (jobs/ha)	4.6	5.6	5.7	5.4
CBD job density (jobs/ha)	137.3	139.7	141.0	155.9
Proportion of jobs in CBD	40.3%	31.3%	26.1%	25.9%
Proportion of jobs in inner area	66.8%	53.8%	48.0%	47.6%
ACTIVITY INTENSITY PARAMETERS				
(Population and Jobs/ha)				
CBD activity density	180.5	180.0	179.7	198.4
Inner area activity density	75.7	73.9	68.3	70.3
Outer area activity density	27.2	25.4	24.3	23.3
City-wide activity density	41.1	35.6	31.6	30.1
VEHICLE OWNERSHIP PARAMETERS				
Total vehicles/1000 people	302.5	367.2	478.6	492.5
Passenger cars/1000 people	272.2	332.4	407.3	411.9
PRIVATE MOBILITY PARAMETERS				
Total per capita vehicle kilometres	4,580	5,917	6,803	7,635
Per capita car kilometres	4,122	5,326	6,123	6,871
Total per capita occupant kilometres	8,014	9,172	10,205	10,689
Per capita car occupant kilometres	7,213	8,255	9,185	9,620
Total vehicle kilometres per vehicle	15,141	16,116	14,216	15,501
Car kilometres per car	15,141	16,024	15,034	16,683
TRAFFIC RESTRAINT PARAMETERS				
Parking spaces / 1000 CBD workers	461.5	449.7	541.4	545.5
Length of road per person (m)	?	?	?	4.2
Total vehicles per km of road	?	?	?	118.5
Total vehicle kilometres per km of road	?	?	?	1,836,694
Car kilometres per km of road	?	?	?	1,653,025
PER CAPITA TRANSPORT ENERGY PARAMETERS (MJ)				
Private passenger transport energy	?	32,749	35,397	32,018
Total private energy use/person	?	?	41,779	38,377
Public transport energy use/person	714	946	1,027	989
Total energy use/person	?	?	42,806	39,366



PUBLIC TRANSPORT PARAMETERS

	1962	1971	1981	1991
Vehicle kilometres per person				
Buses	43.3	42.9	44.3	40.5
Rail	0.0	0.0	0.0	0.0
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Total	*43.3*	*42.9*	*44.3*	*40.5*
Passenger boardings per person				
Buses	147.7	135.7	134.0	97.7
Rail	0.0	0.0	0.0	0.0
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Total	*147.7*	*135.7*	*134.0*	*97.7*
Passenger boardings per vehicle km				
Buses	3.4	3.2	3.0	2.4
Rail	0.0	0.0	0.0	0.0
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Overall	*3.4*	*3.2*	*3.0*	*2.4*
Passenger kilometres per person				
Buses	679.2	719.4	804.2	635.4
Rail	0.0	0.0	0.0	0.0
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Total	*679.2*	*719.4*	*804.2*	*635.4*
Average public transport speed (km/h)				
Buses	16.7	17.5	18.5	19.0
Rail	0.0	0.0	0.0	0.0
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Overall	*16.7*	*17.5*	*18.5*	*19.0*
Vehicular energy efficiency (MJ/km)				
Buses	16.5	22.0	23.2	24.5
Rail	0.0	0.0	0.0	0.0
Trams	0.0	0.0	0.0	0.0
Ferries	0.0	0.0	0.0	0.0
Overall	*16.5*	*22.0*	*23.2*	*24.5*
Modal energy efficiency (MJ/pass km)				
Buses	1.05	1.31	1.28	1.56
Rail	0.00	0.00	0.00	0.00
Trams	0.00	0.00	0.00	0.00
Ferries	0.00	0.00	0.00	0.00
Overall	*1.05*	*1.31*	*1.28*	*1.56*

APPENDIX 3 – WORLD CITIES DATA USED FOR SPSS RUNS

World Cities Standardized Data, 1990/91

City	Year	AvgOcc	AvgRdSpd	PropTran	PropCars	PropNMT	BusSpeed	RaiSpeed	TotTrSpd	MetDensi	InnDensi	OutDensi	CDBDensi	PrPopCBD	PrPopInn	MetEmDen
Vancouver	1991	1.50	38.0	12%	82%	6%	20.1	41.7	25.3	20.8	41.5	17.4	25.6	0.6%	28.6%	10.5
Calgary	1991	1.40	47.1	17%	78%	5%	24.6	32.0	27.7	20.8	22.7	20.2	33.6	1.4%	26.8%	12.1
Edmonton	1991	1.42	40.0	11%	83%	5%	19.5	32.0	20.7	27.4	26.8	27.8	21.6	1.0%	31.9%	14.5
Montreal	1991	1.37	43.3	21%	73%	6%	20.5	29.7	25.1	33.8	64.1	28.5	51.5	2.0%	28.3%	14.8
Winnipeg	1992	1.40	35.0	20%	72%	8%	19.0		19.0	21.3	41.2	18.0	42.5	2.9%	27.8%	8.8
Ottawa	1991	1.40	40.0	27%	66%	7%	24.0		24.0	31.3	49.2	30.1	39.7	1.3%	9.8%	15.8
Toronto	1991	1.40	35.0	30%	65%	5%	20.3	35.4	26.1	41.5	60.0	35.4	51.1	0.4%	35.6%	23.2
Washington	1990	1.45	42.4	15.0	80.6	4.4	19.3	39.4	32.2	13.7	38.1	12.0	27.3	0.4%	17.0%	9.5
San Francisco	1990	1.36	44.3	14.5	80.0	5.5	20.1	46.6	33.2	16.0	59.8	13.6	111.1	1.2%	19.6%	8.5
San Diego	1990	1.44	55.7	3.4	90.8	5.8	26.7	35.0	28.9	13.1	32.1	10.9	27.2	0.6%	23.8%	
Boston	1990	1.69	52.3	14.7	77.8	7.4	20.1	33.2	29.5	12.0	43.1	9.8	71.2	2.2%	23.8%	7.1
Detroit	1990	1.41	56.3	2.6	95.4		22.5		22.5	12.8	28.6	10.5	16.5	0.2%	26.3%	6.1
Denver	1990	1.35	58.1	4.4	91.3	4.3	24.2		24.2	12.8	16.3	11.7	16.7	0.6%	26.2%	8.7
Chicago	1990	1.48	45.0	14.9	80.6	4.5	17.9	46.1	36.8	16.6	47.3	11.4	30.3	0.2%	38.3%	8.7
Los Angeles	1990	1.44	45.0	6.7	89.3		19.9		19.9	23.9	28.7	21.6	28.2	0.1%	30.6%	12.4
Houston	1990	1.46	61.2	4.1	93.3	2.6	23.6		23.6	9.5	18.4	8.8	17.9	0.2%	12.4%	5.7
Phoenix	1990	1.37	51.5	2.1	93.7	4.2	24.5		24.5	10.5	16.4	10.4	16.6	0.3%	2.3%	5.1
New York	1990	1.33	38.3	26.6	66.7	6.7	18.8	39.0	34.2	19.2	91.5	12.6	226.6	2.9%	39.8%	11.0
Sacramento	1990	1.46	63.9	2.5	92.7	4.7	22.7	30.7	25.2	12.7	19.4	10.8	26.6	0.9%	27.3%	6.8
Portland	1990	1.45	49.7	5.8	90.3	3.9	26.0	31.5	27.0	11.7	23.7	9.9	34.0	0.8%	26.4%	8.5
Brisbane	1990	1.73	50.1	14.5	80.4	5.1	28.7	44.0	38.8	9.8	20.3	8.9	11.8	0.1%	16.9%	
Adelaide	1990	1.67	46.4	11.5	83.1	5.4	22.1	27.0	23.0	11.8	18.7	11.3	10.2	0.2%	10.6%	5.1
Melbourne	1990	1.52	45.1	15.9	79.4	4.7	21.0	33.0	27.1	14.9	27.2	14.4	27.1	0.2%	7.5%	5.9
Perth	1990	1.67	45.0	9.7	86.2	4.1	24.6	34.0	26.3	10.6	16.3	9.8	9.5	0.6%	19.1%	4.4
Sydney	1990	1.60	37.0	25.2	69.3	5.5	19.0	42.0	33.5	16.8	39.2	15.3	20.8	0.2%	15.2%	7.2
Vienna	1990	1.33	27.5	43.9	44.1	11.9	19.1	36.3	25.1	68.3	128.6	56.5	60.4	1.2%	30.9%	37.4
Zurich	1990	1.48	36.0	39.8	36.0	24.2	21.1	54.7	44.7	47.1	73.5	36.1	37.3	0.7%	45.8%	35.2
Amsterdam	1990	1.64	35.0	25.0	40.0	35.0	16.3	38.6	22.5	48.8	89.3	29.7	93.2	9.5%	51.2%	22.2
Brussels	1990	1.40	37.9	35.3	45.5	19.1	19.1	36.0	28.8	74.9	91.0	62.7	50.3	1.6%	52.3%	46.8
Copenhagen	1990	1.70	50.0	25.0	43.0	32.0	24.2	59.2	47.1	28.6	53.9	22.6	74.8	2.0%	36.1%	16.0
Frankfurt	1990	1.41	45.0	42.1	49.4	8.5	19.6	52.2	45.8	46.6	61.0	39.7	65.5	2.5%	42.3%	43.3
Hamburg	1990	1.50	30.0	38.1	49.4	12.5	22.0	37.3	33.2	39.8	85.7	33.6	29.9	0.8%	25.7%	23.6
London	1990	1.45	30.2	40.0	46.0	14.0	19.0	48.3	43.4	42.3	78.1	33.2	63.0	2.5%	37.5%	23.6
Munich	1990	1.41	35.0	46.0	38.0	16.0	23.2	47.8	42.6	53.6	106.9	47.7	96.6	6.0%	19.8%	37.2
Paris	1990	1.40	25.7	36.2	48.9	14.9	19.3	41.8	38.0	46.1	96.8	27.0	179.7	3.9%	57.6%	22.1
Stockholm	1990	1.35	30.0	55.0	31.0	14.0	27.2	43.9	38.2	53.1	91.7	42.9	101.4	6.4%	36.1%	39.3
Tokyo	1990	1.51	24.4	48.9	29.4	21.7	12.0	39.6	38.5	71.0	132.1	61.2	63.2	0.8%	25.7%	73.1
Hong Kong	1990	1.65	25.7	74.0	9.1	16.9	18.4	41.4	27.9	300.5	803.9	258.0	113.8	0.2%	20.8%	140.0
Singapore	1990	1.70	32.5	56.0	21.8	22.2	19.2	40.0	25.7	86.8	124.2	80.5	82.8	2.2%	20.7%	49.3
Seoul	1990	1.70	24.0	59.6	20.6	19.8	18.8	39.8	25.7	244.8	298.8	235.7	203.7	2.5%	17.5%	101.6

World Cities Standardized Data, 1990/91

City	InnEmDen	OutEmDen	CBDEmDen	PrJobCBD	PrJobInn	CDBAcDen	InnAcDen	OutAcDen	MetAcDen	Veh_1000	Car_1000	VKT_p	CarKm_p	OccKm_p	CarOcK_p
Vancouver	29.9	7.2	308.6	13.4%	41.0%	334.2	71.3	24.6	31.3	693.8	564.5	8,750	8,361	13,124	12,541
Calgary	23.8	8.3	290.9	21.0%	48.3%	324.6	46.6	28.4	32.9	700.2	630.3	9,201	7,913	12,881	11,078
Edmonton			212.8	19.4%		234.4			42.0	579.3	526.9	8,397	7,062	11,924	10,028
Montreal	42.8	9.9	223.2	20.0%	43.1%	274.7	106.9	38.3	48.5	454.9	420.2	5,274	4,746	7,225	6,502
Winnipeg	29.1	5.4	155.9	25.9%	47.6%	198.4	70.3	23.3	30.1	492.5	411.9	7,635	6,871	10,689	9,620
Ottawa	97.7	10.4	364.0	24.2%	38.3%	403.7	146.9	40.5	47.1	561.6	510.2	6,534	5,883	9,147	8,236
Toronto	44.3	16.3	927.0	13.7%	47.0%	978.1	104.3	51.7	64.7	494.5	430.9	6,051	5,019	8,472	7,027
Washington	45.1		688.5	13.7%	31.0%	715.9	83.3	19.0	23.2	703.7	620.1	11,896	11,182	17,249	16,214
San Francisco	48.3	6.3	744.3	15.1%	30.3%	855.4	108.1	19.8	24.6	776.5	603.5	13,304	11,933	18,093	16,229
San Diego	19.6	5.5	128.0	5.9%	29.2%	155.2	51.7	16.5	20.1	739.2	559.0	14,557	13,026	20,962	18,757
Boston	34.1	5.2	297.5	15.8%	32.1%	368.7	77.2	15.0	19.1	609.2	520.7	11,422	10,280	19,304	17,373
Detroit	10.9	5.4	256.9	5.3%	22.2%	273.4	39.5	15.9	18.9	798.9	693.4	12,487	11,239	17,607	15,846
Denver	14.5	6.8	175.9	10.9%	40.3%	192.6	30.7	18.5	21.4	1036.9	752.6	10,511	10,011	14,189	13,515
Chicago	23.8	6.2	921.0	10.2%	39.3%	951.3	71.1	17.6	25.2	633.3	547.1	10,355	9,525	15,325	14,096
Los Angeles	15.6	10.9	506.1	4.5%	41.2%	534.3	44.3	32.4	36.3	689.9	543.6	13,054	11,587	18,798	16,686
Houston	21.6	4.3	303.3	6.9%	29.3%	321.2	40.0	13.1	15.2	803.9	607.7	14,117	13,016	20,610	19,004
Phoenix	31.1	4.7	89.7	3.6%	9.4%	106.3	47.6	15.0	15.5	747.4	643.9	13,049	11,608	17,878	15,903
New York	52.4	7.2	989.1	21.9%	39.8%	1215.7	143.9	19.8	30.2	557.0	483.5	9,181	8,317	12,211	11,062
Sacramento	12.7	5.2	117.1	9.2%	41.0%	143.7	32.1	16.0	19.5	786.9	563.0	15,194	13,178	22,184	19,239
Portland	23.5	6.3	371.0	13.8%	41.1%	405.0	47.2	16.1	20.2	848.7	763.5	11,238	10,114	16,295	14,665
Brisbane	20.7	2.5	528.6	11.4%	42.1%	540.4	41.0	11.4	13.8	580.7	463.0	8,309	6,467	14,374	11,188
Adelaide	26.0	3.6	408.1	16.7%	34.2%	418.3	44.8	14.8	16.8	633.3	536.7	7,956	6,690	13,286	11,173
Melbourne	43.0	4.3	530.6	10.6%	30.3%	557.7	70.1	18.6	20.8	613.5	518.3	7,924	6,436	12,045	9,782
Perth	15.9	2.7	131.5	21.3%	45.1%	141.0	32.2	12.6	15.0	678.2	522.9	8,861	7,203	14,798	12,029
Sydney	38.1	5.1	422.2	11.5%	34.3%	443.0	77.3	20.4	24.1	530.0	448.5	7,051	5,886	11,281	9,417
Vienna	110.4	23.0	378.4	13.4%	48.5%	438.8	239.0	79.5	105.7	433.7	363.2	4,587	3,964	6,101	5,272
Zurich	72.8	19.5	417.2	10.8%	60.7%	454.5	146.4	55.6	82.2	510.1	444.2		5,197		7,692
Amsterdam	43.1	12.4	98.0	25.2%	62.1%	191.2	132.3	42.2	71.1	363.1	319.1	4,420	3,977	7,249	6,522
Brussels	82.5	19.8	470.5	24.1%	75.9%	520.8	173.5	82.6	121.7	500.4	428.2	5,404	4,864	7,566	6,809
Copenhagen	35.2	11.4	269.8	12.8%	42.2%	344.6	89.1	34.0	44.5	341.0	283.0	5,201	4,558	8,841	7,749
Frankfurt	93.6	19.3	498.9	20.3%	69.8%	564.4	154.6	59.1	90.0	525.9	477.6	6,636	5,893	9,357	8,309
Hamburg	95.1	13.9	331.7	15.6%	48.1%	361.6	180.8	47.5	63.5	455.6	410.2	5,799	5,061	8,698	7,592
London	63.8	13.3	423.7	30.7%	54.9%	486.8	141.9	46.5	65.9	416.3	347.6	4,641	3,892	6,729	5,644
Munich	150.2	24.7	276.1	24.8%	40.1%	372.7	257.1	72.4	90.7	524.4	468.2	4,417	4,202	6,228	5,925
Paris	56.1	9.2	369.6	16.9%	69.7%	549.2	152.8	36.2	68.2	426.6	359.9	4,100	3,459	5,739	4,842
Stockholm	126.4	16.3	262.3	22.3%	67.1%	363.7	218.1	59.3	92.4	471.8	408.9	5,050	4,638	6,817	6,261
Tokyo	108.3	31.0	546.8	27.7%	80.7%	610.0	240.5	102.4	177.6	373.6	225.0	3,795	2,103	5,731	3,175
Hong Kong	775.1	86.5	1712.6	7.5%	43.0%	1826.3	1579.0	344.5	440.4	78.5	42.9	1,459	493	2,408	813
Singapore	132.9	35.2	386.2	18.2%	38.9%	469.0	257.0	115.7	136.1	200.5	101.5	3,597	1,864	6,116	3,169
Seoul	209.7	83.6	579.5	17.2%	29.5%	783.2	508.5	319.3	346.4	118.6	65.6	1,899	1,483	3,157	2,464

World Cities Standardized Data, 1990/91

City	VehKm_v	CarKm_c	Pkg_1000	Road_p	Veh_kmrd	Gas_p	TranEn_p	TotEn_p	BusVKTpp	Railvkpp	TtrVKTpp	Busbrdpp	Raibrdpp	Totbrdpp	Totbdpkm	TotPKpp
Vancouver	12,611	14,810	442.8	5.1	136.2	31,544	927	37,211	38.0	12.1	50.3	95.4	19.0	117.2	2.3	871.3
Calgary	13,141	12,555	522.0	4.9	143.8	35,684	914	47,133	40.9	8.8	49.7	54.7	39.6	94.3	1.9	774.6
Edmonton	14,060	13,001	593.5	4.8	162.1	31,848	1,096	44,060	48.1	3.3	51.3	97.8	10.8	108.6	2.1	727.8
Montreal	11,593	11,294	346.8	4.5	101.5	27,706	1,280		39.6	20.6	60.2	133.5	88.0	221.5	3.7	951.7
Winnipeg	15,501	16,683	545.5	4.2	118.5	32,018	989	39,366	40.5		40.5	97.7		97.7	2.4	635.4
Ottawa	11,635	11,529	230.3	7.1	66.4	26,705	1,526	33,652	55.9		55.9	134.6		134.6	2.4	849.5
Toronto	12,236	11,646	175.8	2.6	275.2	30,746	1,809	33,613	55.5	37.1	98.4	161.1	145.5	350.0	3.5	2172.8
Washington	16,904	18,034	252.9	5.2	136.0	49,593	1,129	60,454	21.1	16.2	37.3	53.5	52.1	105.6	2.8	773.8
San Francisco	17,133	19,774	136.6	4.6	169.3	58,493	1,210	65,890	28.4	18.7	49.3	75.7	22.1	112.0	2.3	899.3
San Diego	19,694	23,300	688.5	5.5	133.5	61,004	555	67,248	21.1	2.6	23.7	22.5	6.4	28.9	1.2	259.0
Boston	18,751	19,743	285.0	6.7	90.5	50,617	1,097	58,391	16.5	18.7	36.0	36.2	69.5	114.4		626.5
Detroit	15,630	16,208	705.7		132.8	54,817	405	62,744	14.0		14.0	24.3		24.3	1.7	171.3
Denver	10,136	13,303	605.6	7.6	137.0	56,132	594	68,286	21.2		21.2	30.0		30.0	1.4	198.6
Chicago	16,350	17,408	128.2	5.2	122.3	46,498	1,268	56,121	22.2	19.3	41.5	63.6	32.0	95.7	2.3	805.3
Los Angeles	18,923	21,317	520.4	3.8	191.7	55,246	643	62,167	19.8		19.8	55.0		55.0	2.8	351.6
Houston	17,561	21,418	612.3	11.7	68.4	63,800	499	71,624	16.7		16.7	26.2		26.2	1.6	215.0
Phoenix	17,461	18,029	905.6	9.6	77.8	59,832	301	64,641	9.9		9.9	14.8		14.8	1.5	123.7
New York	16,483	17,203	59.9	4.6	121.6	46,409	1,469	51,626	23.3	39.5	62.8	59.0	94.9	155.2	2.5	1334.3
Sacramento	19,309	23,408	777.1	8.8	89.6	65,351	324	76,673	8.3	1.6	9.9	10.8	4.2	15.0	1.5	116.8
Portland	13,217	13,222	403.0	10.6	79.6	57,699	641	70,698	25.4	1.8	27.2	40.7	5.5	46.2	1.7	285.8
Brisbane	14,308	13,969	321.7	8.2	71.0	31,290	916	39,277	28.3	26.8	55.1	37.6	31.5	69.1	1.3	899.8
Adelaide	12,563	12,466	580.2		79.4	31,784	959	37,103	39.1	6.6	46.4	63.6	9.7	75.8	1.6	572.2
Melbourne	12,915	12,417	337.3	7.7	79.7	33,527	749	38,890	21.7	20.8	49.9	30.2	35.3	101.1		843.8
Perth	13,066	13,775	631.1	10.7	63.2	34,579	851	41,395	42.2	4.8	47.0	47.0		54.4	1.2	544.4
Sydney	13,303	13,122	222.2	6.2	85.4	29,491	1,102	35,074	39.9	53.8	94.0	83.1	71.1	160.3	1.7	1769.4
Vienna	10,577	10,913	186.5	1.8	240.7	14,990	1,227	20,603	20.0	20.2	72.6	80.6	156.2	421.8	5.8	2430.3
Zurich		11,699	136.7		126.1	19,947	1,422	25,244	31.1	90.4	148.1	153.0	106.0	514.9	2.9	2459.4
Amsterdam	13,941	14,270	354.3	2.6	137.3	13,915	831	19,843	26.7	21.9	60.3	74.4	82.9	324.5	5.4	1060.8
Brussels	10,799	11,359	314.1	2.1	238.3	24,639	1,518	28,895	32.7	18.7	62.7	81.4	119.3	260.3	4.1	1427.5
Copenhagen	15,253	16,107	223.2	4.6	74.7	14,025	1,685	20,385	53.1	68.2	121.3	93.5	70.4	163.9	1.4	1606.8
Frankfurt	12,617	12,338	246.3		260.0	24,779	742	38,293	15.3	22.8	47.9	40.3	128.4	216.6	4.1	1148.9
Hamburg	12,728	12,338	177.3	2.6	177.6	20,344	908	36,716	26.9	44.0	71.0	101.1	126.3	227.8	3.2	1374.8
London	11,147	11,197			209.0	12,884	1,350	23,374	44.8	93.4	138.4	176.7	147.3	325.2	1.9	2405.1
Munich	8,424	8,974	266.2	1.8	295.4	14,224	1,376	18,197	18.5	65.6	91.4	87.2	279.0	403.5	4.2	2462.5
Paris	9,611	9,611	199.5	0.9	455.9	14,269	946	24,241	20.9	50.1	71.0	96.4	198.6	295.0	4.2	2120.6
Stockholm	10,702	11,343	193.2	2.2	212.2	18,362	1,819	26,817	66.4	66.3	133.2	145.0	199.8	347.6	2.6	2351.3
Tokyo	12,162	10,867	42.9	3.9	195.4	8,015	923	18,243	16.6	72.6	89.3	67.9	391.5	460.7	5.2	5500.8
Hong Kong	19,126	11,493	32.9	0.3	283.7	2,406	1,527	9,612	113.6	24.9	140.4	348.7	180.8	569.7	4.1	3784.2
Singapore	18,261	18,370	163.8	1.1	188.2	11,383	1,739	18,079	94.2	19.8	114.0	382.2	74.8	456.9		2775.2
Seoul	13,644	18,471	48.7	0.8	151.0	5,293	1,719	9,615	98.5	15.4	113.9	361.0	99.4	460.4		2890.0

APPENDIX 4 – CORRELATION RESULTS, CANADIAN AND WORLD CITIES

CANADIAN CITIES CORRELATION RESULTS, 1991 (7 cities)

		CAR_1000	CARKM_P	CBDEMDEN	CDBACDEN	CDBDENSI	GAS_P	INNACDEN	INNDENSI	INNEMDEN	METACDEN	METAREA	METDENSI	METEMDEN	OUTACDEN	OUTDENSI	OUTEMDEN	PKG_1000	PRJOBCBD	PRJOBINN	PROPCARS
Pearson Correlation	CAR_1000	1.000	.761*	-.205	-.232	-.722	.552	-.430	-.755*	-.130	-.466	-.262	-.559	-.294	-.381	-.402	-.258	.363	-.150	-.075	.592
	CARKM_P	.761*	1.000	-.437	-.465	-.832*	.699	-.708	-.831*	-.449	-.829*	-.309	-.891**	-.695	-.812*	-.818*	-.667	.700	-.054	.083	.764*
	CBDEMDEN	-.205	-.437	1.000	.999**	.437	-.085	.280	.452	.149	.803*	.115	.741	.875**	.814*	.667	.924**	-.745	-.590	.159	-.596
	CDBACDEN	-.232	-.465	.999**	1.000	.472	-.103	.293	.479	.154	.813*	.130	.755*	.878**	.827*	.674	.931**	-.759*	-.573	.166	-.621
	CDBDENSI	-.722	-.832*	.437	.472	1.000	-.440	.462	.811*	.194	.591	.394	.652	.472	.697	.478	.581	-.664	.115	.237	-.837*
	GAS_P	.552	.699	-.085	-.103	-.440	1.000	-.931**	-.761*	-.780	-.494	-.330	-.577	-.337	-.495	-.547	-.293	.648	-.119	.750	.546
	INNACDEN	-.430	-.708	.280	.293	.462	-.931**	1.000	.704	.921**	.642	.044	.685	.544	.674	.746	.494	-.830*	.123	-.691	-.752
	INNDENSI	-.755*	-.831*	.452	.479	.811*	-.761*	.704	1.000	.372	.671	.656	.746	.524	.691	.557	.580	-.793*	-.204	-.320	-.705
	INNEMDEN	-.130	-.449	.149	.154	.194	-.780	.921**	.372	1.000	.424	-.254	.441	.377	.501	.574	.327	-.686	.295	-.729	-.650
	METACDEN	-.466	-.829*	.803*	.813*	.591	-.494	.642	.671	.424	1.000	.206	.991**	.975**	.990**	.964**	.962**	-.801*	-.365	-.063	-.673
	METAREA	-.262	-.309	.115	.130	.394	-.330	.044	.656	-.254	.206	1.000	.265	.106	.138	.046	.152	-.342	-.526	-.223	-.022
	METDENSI	-.559	-.891**	.741	.755*	.652	-.577	.685	.746	.441	.991**	.265	1.000	.937**	.973**	.956**	.919**	-.805*	-.308	-.099	-.699
	METEMDEN	-.294	-.695	.875**	.878**	.472	-.337	.544	.524	.377	.975**	.106	.937**	1.000	.980**	.937**	.997**	-.764*	-.446	.000	-.606
	OUTACDEN	-.381	-.812*	.814*	.827*	.697	-.495	.674	.691	.501	.990**	.138	.973**	.980**	1.000	.991**	.965**	-.936**	-.313	-.102	-.808
	OUTDENSI	-.402	-.818*	.667	.674	.478	-.547	.746	.557	.574	.964**	.046	.956**	.937**	.991**	1.000	.921**	-.719	-.208	-.159	-.619
	OUTEMDEN	-.258	-.667	.924**	.931**	.581	-.293	.494	.580	.327	.962**	.152	.919**	.997**	.965**	.921**	1.000	-.880*	-.501	.023	-.687
	PKG_1000	.363	.700	-.745	-.759*	-.664	.648	-.830*	-.793*	-.686	-.801*	-.342	-.805*	-.764*	-.936**	-.719	-.880*	1.000	.282	.417	.830*
	PRJOBCBD	-.150	-.054	-.590	-.573	.115	-.119	.123	-.204	.295	-.365	-.526	-.308	-.446	-.313	-.208	-.501	.282	1.000	.027	-.183
	PRJOBINN	-.075	.083	.159	.166	.237	.750	-.691	-.320	-.729	-.063	-.223	-.099	.000	-.102	-.159	.023	.417	.027	1.000	.061
	PROPCARS	.592	.764*	-.596	-.621	-.837*	.546	-.752	-.705	-.650	-.673	-.022	-.699	-.606	-.808	-.619	-.687	.830*	-.183	.061	1.000
	PROPNMT	-.486	-.134	-.351	-.329	.347	-.359	.247	.240	.301	-.297	-.154	-.210	-.427	-.343	-.285	-.521	-.035	.723	-.163	-.419
	PROPTRAN	-.543	-.771*	.676	.699	.840*	-.514	.732	.712	.620	.735	.068	.750	.683	.884*	.669	.788	-.872*	.082	-.037	-.992**
	PRPOPCBD	-.411	-.092	-.636	-.610	.300	-.037	-.150	.002	-.140	-.447	-.115	-.353	-.584	-.480	-.404	-.633	.382	.823*	.256	-.087
	PRPOPINN	-.182	.020	.287	.282	.009	.496	-.565	-.016	-.810	.150	.268	.125	.185	.055	.010	.230	.257	-.581	.692	.307
	ROAD_P	.431	.258	-.525	-.532	-.384	-.351	.372	-.246	.634	-.373	-.258	-.358	-.384	-.274	-.193	-.413	.046	.471	-.742	.113
	TOTBDPKM	-.747	-.868*	.490	.517	.825*	-.565	.461	.926**	.093	.741	.692	.805*	.609	.701	.618	.638	-.666	-.304	-.007	-.585
	TOTBRDPP	-.547	-.763*	.854*	.868*	.706	-.344	.400	.764*	.106	.911**	.449	.910**	.879**	.884*	.771*	.915*	-.771*	-.528	.132	-.640
	TOTEN_P	.598	.642	-.568	-.575	-.567	.826*	-.828	-.958**	-.634	-.569	-.410	-.620	-.481	-.607	-.476	-.519	.839*	.215	.577	.720
	TOTPKPP	-.350	-.547	.974**	.978**	.536	-.129	.264	.565	.052	.848*	.262	.806*	.885**	.831*	.694	.930**	-.729	-.622	.216	-.585
	TOTTRSPD	.449	-.043	.460	.459	.193	.109	-.078	.155	-.052	.292	.448	.234	.382	.372	.188	.492	-.465	-.519	-.023	-.120
	TRANEN_P	-.500	-.813*	.804*	.815*	.631	-.592	.765	.702	.604	.950**	.088	.945**	.919**	.966**	.918**	.910*	-.894**	-.215	-.178	-.833*
	TTRVKTPP	-.344	-.631	.953**	.958**	.545	-.223	.369	.593	.155	.920**	.271	.883**	.948**	.905*	.799*	.974**	-.768*	-.595	.131	-.597

CANADIAN CITIES CORRELATION RESULTS, 1991 (7 cities)

Sig. (2-tailed)

	CAR_1000	CARKM_P	CBDEMDEN	CDBACDEN	CDBDENSI	GAS_P	INNACDEN	INNDENSI	INNEMDEN	METACDEN	METAREA	METDENSI	METEMDEN	OUTACDEN	OUTDENSI	OUTEMDEN	PKG_1000	PRJOBCBD	PRJOBINN	PROPCARS
CAR_1000	.	.047	.659	.616	.067	.199	.395	.050	.806	.292	.570	.192	.522	.456	.371	.622	.423	.748	.887	.161
CARKM_P	.047	.	.327	.293	.020	.081	.115	.021	.372	.021	.500	.007	.083	.050	.025	.148	.080	.908	.876	.046
CBDEMDEN	.659	.327	.	.000	.326	.856	.591	.308	.778	.030	.807	.057	.010	.049	.102	.009	.055	.163	.763	.158
CDBACDEN	.616	.293	.000	.	.284	.827	.573	.277	.771	.026	.782	.050	.009	.042	.097	.007	.048	.178	.754	.137
CDBDENSI	.067	.020	.326	.284	.	.324	.356	.027	.713	.163	.381	.113	.285	.124	.278	.227	.104	.807	.651	.019
GAS_P	.199	.081	.856	.827	.324	.	.007	.047	.067	.260	.469	.175	.460	.318	.204	.573	.115	.800	.086	.204
INNACDEN	.395	.115	.591	.573	.356	.007	.	.118	.009	.170	.935	.133	.264	.142	.089	.320	.041	.816	.129	.085
INNDENSI	.050	.021	.308	.277	.027	.047	.118	.	.468	.099	.110	.054	.228	.129	.194	.228	.033	.660	.537	.077
INNEMDEN	.806	.372	.778	.771	.713	.067	.009	.468	.	.403	.627	.381	.462	.311	.233	.527	.133	.570	.101	.162
METACDEN	.292	.021	.030	.026	.163	.260	.170	.099	.403	.	.658	.000	.000	.000	.000	.002	.031	.421	.906	.097
METAREA	.570	.500	.807	.782	.381	.469	.935	.110	.627	.658	.	.566	.821	.794	.921	.774	.452	.226	.671	.963
METDENSI	.192	.007	.057	.050	.113	.175	.133	.054	.381	.000	.566	.	.002	.001	.001	.010	.029	.501	.853	.080
METEMDEN	.522	.083	.010	.009	.285	.460	.264	.228	.462	.000	.821	.002	.	.001	.002	.000	.046	.316	1.000	.149
OUTACDEN	.456	.050	.049	.042	.124	.318	.142	.129	.311	.000	.794	.001	.001	.	.000	.002	.006	.545	.847	.052
OUTDENSI	.371	.025	.102	.097	.278	.204	.089	.194	.233	.000	.921	.001	.002	.000	.	.009	.069	.654	.764	.138
OUTEMDEN	.622	.148	.009	.007	.227	.573	.320	.228	.527	.002	.774	.010	.000	.002	.009	.	.021	.312	.965	.131
PKG_1000	.423	.080	.055	.048	.104	.115	.041	.033	.133	.031	.452	.029	.046	.006	.069	.021	.	.541	.411	.021
PRJOBCBD	.748	.908	.163	.178	.807	.800	.816	.660	.570	.421	.226	.501	.316	.545	.654	.312	.541	.	.959	.694
PRJOBINN	.887	.876	.763	.754	.651	.086	.129	.537	.101	.906	.671	.853	1.000	.847	.764	.965	.411	.959	.	.908
PROPCARS	.161	.046	.158	.137	.019	.204	.085	.077	.162	.097	.963	.080	.149	.052	.138	.131	.021	.694	.908	.
PROPNMT	.268	.775	.440	.471	.446	.429	.637	.604	.562	.518	.742	.651	.340	.506	.536	.289	.941	.066	.758	.350
PROPTRAN	.208	.042	.095	.080	.018	.238	.098	.073	.189	.060	.885	.052	.091	.019	.101	.062	.010	.862	.944	.000
PRPOPCBD	.360	.845	.125	.145	.513	.938	.777	.997	.792	.314	.806	.437	.169	.335	.369	.177	.398	.023	.625	.854
PRPOPINN	.696	.966	.532	.540	.984	.258	.243	.973	.051	.747	.561	.789	.691	.918	.984	.661	.578	.171	.127	.503
ROAD_P	.334	.576	.226	.219	.396	.441	.468	.594	.176	.410	.576	.430	.395	.599	.678	.416	.921	.286	.091	.809
TOTBDPKM	.054	.011	.264	.235	.022	.187	.358	.003	.860	.057	.085	.029	.146	.121	.139	.173	.102	.507	.989	.168
TOTBRDPP	.204	.046	.014	.011	.076	.450	.432	.046	.842	.004	.312	.004	.009	.019	.042	.010	.042	.223	.803	.122
TOTEN_P	.210	.170	.240	.233	.241	.043	.083	.003	.251	.239	.419	.190	.335	.278	.340	.370	.037	.683	.309	.107
TOTPKPP	.441	.204	.000	.000	.215.	.782	.613	.186	.922	.016	.571	.029	.008	.040	.084	.007	.063	.136	.682	.168
TOTTRSPD	.312	.927	.299	.300	.679	.817	.884	.741	.922	.526	.313	.613	.398	.468	.687	.322	.294	.233	.966	.798
TRANEN_P	.253	.026	.029	.025	.129	.162	.076	.078	.204	.001	.851	.001	.003	.002	.003	.012	.007	.644	.736	.020
TTRVKTPP	.450	.129	.001	.001	.206	.630	.471	.160	.769	.003	.556	.009	.001	.013	.031	.001	.044	.159	.805	.157

CANADIAN CITIES CORRELATION RESULTS, 1991 (7 cities)

		CAR_1000	CARKM_P	CBDEMDEN	CDBACDEN	CDBDENSI	GAS_P	INNACDEN	INNDENSI	INNEMDEN	METACDEN	METAREA	METDENSI	METEMDEN	OUTACDEN	OUTDENSI	OUTEMDEN	PKG_1000	PRJOBCBD	PRJOBINN	PROPCARS
	CAR_1000	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	CARKM_P	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	CBDEMDEN	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	CDBACDEN	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	CDBDENSI	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	GAS_P	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	INNACDEN	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	INNDENSI	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	INNEMDEN	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	METACDEN	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	METAREA	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	METDENSI	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	METEMDEN	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	OUTACDEN	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	OUTDENSI	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	OUTEMDEN	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
N	PKG_1000	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	PRJOBCBD	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	PRJOBINN	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	PROPCARS	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	PROPNMT	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	PROPTRAN	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	PRPOPCBD	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	PRPOPINN	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	ROAD_P	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	TOTBDPKM	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	TOTBRDPP	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	TOTEN_P	6	6	6	6	6	6	5	6	5	6	6	6	6	5	6	5	6	6	5	6
	TOTPKPP	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	TOTTRSPD	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	TRANEN_P	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7
	TTRVKTPP	7	7	7	7	7	7	6	7	6	7	7	7	7	6	7	6	7	7	6	7

CANADIAN CITIES CORRELATION RESULTS, 1991 (7 cities)

		PROPNMT	PROPTRAN	PRPOPCBD	PRPOPINN	ROAD_P	TOTBDPKM	TOTBRDPP	TOTEN_P	TOTPKPP	TOTTRSPD	TRANEN_P	TTRVKTPP
Pearson Correlation	CAR_1000	-.486	-.543	-.411	-.182	.431	-.747	-.55	.598	-.350	.449	-.500	-.344
	CARKM_P	-.134	-.771*	-.092	.020	.258	-.868*	-.76*	.642	-.547	-.043	-.813*	-.631
	CBDEMDEN	-.351	.676	-.636	.287	-.525	.490	.854*	-.568	.974**	.460	.804*	.953**
	CDBACDEN	-.329	.699	-.610	.282	-.532	.517	.868*	-.575	.978**	.459	.815*	.958**
	CDBDENSI	.347	.840*	.300	.009	-.384	.825*	.706	-.567	.536	.193	.631	.545
	GAS_P	-.359	-.514	-.037	.496	-.351	-.565	-.34	.826*	-.129	.109	-.592	-.223
	INNACDEN	.247	.732	-.150	-.565	.372	.461	.400	-.828	.264	-.078	.765	.369
	INNDENSI	.240	.712	.002	-.016	-.246	.926**	.764*	-.958**	.565	.155	.702	.593
	INNEMDEN	.301	.620	-.140	-.810	.634	.093	.106	-.634	.052	-.052	.604	.155
	METACDEN	-.297	.735	-.447	.150	-.373	.741	.911**	-.569	.848*	.292	.950**	.920**
	METAREA	-.154	.068	-.115	.268	-.258	.692	.449	-.410	.262	.448	.088	.271
	METDENSI	-.210	.750	-.353	.125	-.358	.805*	.910**	-.620	.806*	.234	.945**	.883**
	METEMDEN	-.427	.683	-.584	.185	-.384	.609	.879**	-.481	.885**	.382	.919**	.948**
	OUTACDEN	-.343	.884*	-.480	.055	-.274	.701	.884*	-.607	.831*	.372	.966**	.905*
	OUTDENSI	-.285	.669	-.404	.010	-.193	.618	.771*	-.476	.694	.188	.918**	.799*
	OUTEMDEN	-.521	.788	-.633	.230	-.413	.638	.915*	-.519	.930**	.492	.910*	.974**
	PKG_1000	-.035	-.872*	.382	.257	.046	-.666	-.77*	.839*	-.729	-.465	-.894**	-.768*
	PRJOBCBD	.723	.082	.823*	-.581	.471	-.304	-.53	.215	-.622	-.519	-.215	-.595
	PRJOBINN	-.163	-.037	.256	.692	-.742	-.007	.132	.577	.216	-.023	-.178	.131
	PROPCARS	-.419	-.992**	-.087	.307	.113	-.585	-.64	.720	-.585	-.120	-.833*	-.597
	PROPNMT	1.000	.304	.766*	-.519	.300	-.005	-.27	-.349	-.359	-.541	-.053	-.408
	PROPTRAN	.304	1.000	-.015	-.252	-.162	.617	.709	-.709	.665	.228	.870*	.681
	PRPOPCBD	.766*	-.015	1.000	-.194	.093	-.021	-.39	.245	-.560	-.547	-.370	-.582
	PRPOPINN	-.519	-.252	-.194	1.000	-.904**	.283	.390	.270	.419	.004	-.079	.358
	ROAD_P	.300	-.162	.093	-.904**	1.000	-.502	-.63	-.009	-.652	-.049	-.217	-.579
	TOTBDPKM	-.005	.617	-.021	.283	-.502	1.000	.863*	-.738	.649	.215	.664	.687
	TOTBRDPP	-.269	.709	-.390	.390	-.633	.863*	1.0	-.593	.940**	.373	.840*	.958**
	TOTEN_P	-.349	-.709	.245	.270	-.009	-.738	-.59	1.000	-.540	-.020	-.730	-.528
	TOTPKPP	-.359	.665	-.560	.419	-.652	.649	.940**	-.540	1.000	.423	.805*	.984**
	TOTTRSPD	-.541	.228	-.547	.004	-.049	.215	.373	-.020	.423	1.000	.216	.450
	TRANEN_P	-.053	.870*	-.370	-.079	-.217	.664	.840*	-.730	.805*	.216	1.000	.860*
	TTRVKTPP	-.408	.681	-.582	.358	-.579	.687	.958**	-.528	.984**	.450	.860*	1.000

CANADIAN CITIES CORRELATION RESULTS, 1991 (7 cities)

		PROPNMT	PROPTRAN	PRPOPCBD	PRPOPINN	ROAD_P	TOTBDPKM	TOTBRDPP	TOTEN_P	TOTPKPP	TOTTRSPD	TRANEN_P	TTRVKTPP
Sig. (2-tailed)	CAR_1000	.268	.208	.360	.696	.334	.054	.204	.210	.441	.312	.253	.450
	CARKM_P	.775	.042	.845	.966	.576	.011	.046	.170	.204	.927	.026	.129
	CBDEMDEN	.440	.095	.125	.532	.226	.264	.014	.240	.000	.299	.029	.001
	CDBACDEN	.471	.080	.145	.540	.219	.235	.011	.233	.000	.300	.025	.001
	CDBDENSI	.446	.018	.513	.984	.396	.022	.076	.241	.215	.679	.129	.206
	GAS_P	.429	.238	.938	.258	.441	.187	.450	.043	.782	.817	.162	.630
	INNACDEN	.637	.098	.777	.243	.468	.358	.432	.083	.613	.884	.076	.471
	INNDENSI	.604	.073	.997	.973	.594	.003	.046	.003	.186	.741	.078	.160
	INNEMDEN	.562	.189	.792	.051	.176	.860	.842	.251	.922	.922	.204	.769
	METACDEN	.518	.060	.314	.747	.410	.057	.004	.239	.016	.526	.001	.003
	METAREA	.742	.885	.806	.561	.576	.085	.312	.419	.571	.313	.851	.556
	METDENSI	.651	.052	.437	.789	.430	.029	.004	.190	.029	.613	.001	.009
	METEMDEN	.340	.091	.169	.691	.395	.146	.009	.335	.008	.398	.003	.001
	OUTACDEN	.506	.019	.335	.918	.599	.121	.019	.278	.040	.468	.002	.013
	OUTDENSI	.536	.101	.369	.984	.678	.139	.042	.340	.084	.687	.003	.031
	OUTEMDEN	.289	.062	.177	.661	.416	.173	.010	.370	.007	.322	.012	.001
	PKG_1000	.941	.010	.398	.578	.921	.102	.042	.037	.063	.294	.007	.044
	PRJOBCBD	.066	.862	.023	.171	.286	.507	.223	.683	.136	.233	.644	.159
	PRJOBINN	.758	.944	.625	.127	.091	.989	.803	.309	.682	.966	.736	.805
	PROPCARS	.350	.000	.854	.503	.809	.168	.122	.107	.168	.798	.020	.157
	PROPNMT	.	.508	.045	.232	.514	.991	.559	.498	.429	.210	.911	.363
	PROPTRAN	.508	.	.975	.586	.729	.140	.075	.115	.103	.622	.011	.092
	PRPOPCBD	.045	.975	.	.677	.843	.964	.387	.640	.191	.204	.415	.171
	PRPOPINN	.232	.586	.677	.	.005	.539	.388	.604	.350	.993	.866	.431
	ROAD_P	.514	.729	.843	.005	.	.251	.127	.986	.112	.918	.640	.173
	TOTBDPKM	.991	.140	.964	.539	.251	.	.012	.094	.114	.644	.104	.088
	TOTBRDPP	.559	.075	.387	.388	.127	.012	.	.215	.002	.410	.018	.001
	TOTEN_P	.498	.115	.640	.604	.986	.094	.215	.	.268	.970	.100	.281
	TOTPKPP	.429	.103	.191	.350	.112	.114	.002	.268	.	.344	.029	.000
	TOTTRSPD	.210	.622	.204	.993	.918	.644	.410	.970	.344	.	.642	.312
	TRANEN_P	.911	.011	.415	.866	.640	.104	.018	.100	.029	.642	.	.013
	TTRVKTPP	.363	.092	.171	.431	.173	.088	.001	.281	.000	.312	.013	.

CANADIAN CITIES CORRELATION RESULTS, 1991 (7 cities)

		PROPNMT	PROPTRAN	PRPOPCBD	PRPOPINN	ROAD_P	TOTBDPKM	TOTBRDPP	TOTEN_P	TOTPKPP	TOTTRSPD	TRANEN_P	TTRVKTPP
N	CAR_1000	7	7	7	7	7	7	7	6	7	7	7	7
	CARKM_P	7	7	7	7	7	7	7	6	7	7	7	7
	CBDEMDEN	7	7	7	7	7	7	7	6	7	7	7	7
	CDBACDEN	7	7	7	7	7	7	7	6	7	7	7	7
	CDBDENSI	7	7	7	7	7	7	7	6	7	7	7	7
	GAS_P	7	7	7	7	7	7	7	6	7	7	7	7
	INNACDEN	6	6	6	6	6	6	6	5	6	6	6	6
	INNDENSI	7	7	7	7	7	7	7	6	7	7	7	7
	INNEMDEN	6	6	6	6	6	6	6	5	6	6	6	6
	METACDEN	7	7	7	7	7	7	7	6	7	7	7	7
	METAREA	7	7	7	7	7	7	7	6	7	7	7	7
	METDENSI	7	7	7	7	7	7	7	6	7	7	7	7
	METEMDEN	7	7	7	7	7	7	7	6	7	7	7	7
	OUTACDEN	6	6	6	6	6	6	6	5	6	6	6	6
	OUTDENSI	7	7	7	7	7	7	7	6	7	7	7	7
	OUTEMDEN	6	6	6	6	6	6	6	5	6	6	6	6
	PKG_1000	7	7	7	7	7	7	7	6	7	7	7	7
	PRJOBCBD	7	7	7	7	7	7	7	6	7	7	7	7
	PRJOBINN	6	6	6	6	6	6	6	5	6	6	6	6
	PROPCARS	7	7	7	7	7	7	7	6	7	7	7	7
	PROPNMT	7	7	7	7	7	7	7	6	7	7	7	7
	PROPTRAN	7	7	7	7	7	7	7	6	7	7	7	7
	PRPOPCBD	7	7	7	7	7	7	7	6	7	7	7	7
	PRPOPINN	7	7	7	7	7	7	7	6	7	7	7	7
	ROAD_P	7	7	7	7	7	7	7	6	7	7	7	7
	TOTBDPKM	7	7	7	7	7	7	7	6	7	7	7	7
	TOTBRDPP	7	7	7	7	7	7	7	6	7	7	7	7
	TOTEN_P	6	6	6	6	6	6	6	6	6	6	6	6
	TOTPKPP	7	7	7	7	7	7	7	6	7	7	7	7
	TOTTRSPD	7	7	7	7	7	7	7	6	7	7	7	7
	TRANEN_P	7	7	7	7	7	7	7	6	7	7	7	7
	TTRVKTPP	7	7	7	7	7	7	7	6	7	7	7	7

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

WORLD CITIES CORRELATION RESULTS, 1990/91 (41 cities)

Pearson Correlation	CAR_1000	CARKM_P	CBDEMDEN	CDBACDEN	CDBDENSI	GAS_P	INNACDEN	INNDENSI	INNEMDEN	METACDEN	METAREA	METDENSI	METEMDEN	OUTACDEN	OUTDENSI	OUTEMDEN	PKG_1000	PRJOBCBD	PRJOBINN	PROPCARS
CAR_1000	1.000	.839**	-.358*	-.415**	-.530**	.831**	-.644**	-.666**	-.617**	-.780**	.181	-.762**	-.785**	-.756**	-.747**	-.762**	.587**	-.322*	-.361*	.869**
CARKM_P	.839**	1.000	-.265	-.312*	-.423**	.974**	-.529**	-.531**	-.521**	-.658**	.334*	-.627**	-.697**	-.616**	-.606**	-.624**	.620**	-.535**	-.543**	.871**
CBDEMDEN	-.358*	-.265	1.000	.990**	.394*	-.213	.694**	.701**	.681**	.573**	.313*	.574**	.560**	.552**	.553**	.558**	-.626**	-.122	.031	-.351*
CDBACDEN	-.415**	-.312*	.990**	1.000	.522**	-.261	.709**	.721**	.690**	.612**	.341*	.614**	.594**	.592**	.592**	.597**	-.677**	-.063	.061	-.418**
CDBDENSI	-.530**	-.423**	.394*	.522**	1.000	-.405**	.410**	.452**	.367*	.512**	.323*	.520**	.473**	.507**	.502**	.516**	-.611**	.317*	.209	-.585**
GAS_P	.831**	.974**	-.213	-.261	-.405**	1.000	-.505**	-.504**	-.499**	-.634**	.367*	-.601**	-.667**	-.589**	-.578**	-.599**	.627**	-.546**	-.563**	.888**
INNACDEN	-.644**	-.529**	.694**	.709**	.410**	-.505**	1.000	.996**	.995**	.904**	-.157	.911**	.881**	.881**	.886**	.862**	-.446**	-.027	.099	-.639**
INNDENSI	-.666**	-.531**	.701**	.721**	.452**	-.504**	.996**	1.000	.982**	.917**	-.116	.927**	.888**	.896**	.901**	.877**	-.459**	-.036	.100	-.642**
INNEMDEN	-.617**	-.521**	.681**	.690**	.367*	-.499**	.995**	.982**	1.000	.882**	-.189	.886**	.867**	.856**	.861**	.839**	-.432**	-.022	.097	-.632**
METACDEN	-.780**	-.658**	.573**	.612**	.512**	-.634**	.904**	.917**	.882**	1.000	-.192	.989**	.987**	.988**	.983**	.985**	-.519**	.102	.228	-.773**
METAREA	.181	.334*	.313*	.341*	.323*	.367*	-.157	-.116	-.189	-.192	1.000	-.216	-.209	-.214	-.221	-.202	-.138	-.116	-.169	.247
METDENSI	-.762**	-.627**	.574**	.614**	.520**	-.601**	.911**	.927**	.886**	.989**	-.216	1.000	.956**	.994**	.996**	.984**	-.483**	.051	.142	-.731**
METEMDEN	-.785**	-.697**	.560**	.594**	.473**	-.667**	.881**	.888**	.867**	.987**	-.209	.956**	1.000	.956**	.945**	.962**	-.551**	.125	.318	-.812**
OUTACDEN	-.756**	-.616**	.552**	.592**	.507**	-.589**	.881**	.896**	.856**	.988**	-.214	.994**	.956**	1.000	.999**	.995**	-.479**	.056	.112	-.722**
OUTDENSI	-.747**	-.606**	.553**	.592**	.502**	-.578**	.886**	.901**	.861**	.983**	-.221	.996**	.945**	.999**	1.000	.989**	-.461**	.041	.093	-.703**
OUTEMDEN	-.762**	-.624**	.558**	.597**	.516**	-.599**	.862**	.877**	.839**	.985**	-.202	.984**	.962**	.995**	.989**	1.000	-.513**	.063	.120	-.748**
PKG_1000	.587**	.620**	-.626**	-.677**	-.611**	.627**	-.446**	-.459**	-.432**	-.519**	-.138	-.483**	-.551**	-.479**	-.461**	-.513**	1.000	-.338*	-.403*	.733**
PRJOBCBD	-.322*	-.535**	-.122	-.063	.317*	-.546**	-.027	-.036	-.022	.102	-.116	.051	.125	.056	.041	.063	-.338*	1.000	.601**	-.437**
PRJOBINN	-.361*	-.543**	.031	.061	.209	-.563**	.099	.100	.097	.228	-.169	.142	.318	.112	.093	.120	-.403*	.601**	1.000	-.550**
PROPCARS	.869**	.871**	-.351*	-.418**	-.585**	.888**	-.639**	-.642**	-.632**	-.773**	.247	-.731**	-.812**	-.722**	-.703**	-.748**	.733**	-.437**	-.550**	1.000
PROPNMT	-.701**	-.657**	.001	.064	.404*	-.706**	.312	.339*	.286	.474**	-.229	.438**	.497**	.421**	.403*	.449**	-.450**	.327*	.491**	-.801**
PROPTRAN	-.838**	-.856**	.456**	.515**	.585**	-.857**	.699**	.694**	.700**	.808**	-.213	.769**	.849**	.764**	.748**	.785**	-.759**	.414**	.502**	-.966**
PRPOPCBD	-.304	-.370*	-.219	-.121	.523**	-.418**	.048	.057	.041	.123	-.148	.117	.117	.086	.081	.100	-.244	.576**	.408**	-.479**
PRPOPINN	-.180	-.260	.051	.106	.370*	-.298	-.012	.017	-.048	.064	.025	.040	.082	-.010	-.018	.000	-.324*	.314*	.729**	-.355*
ROAD_P	.690**	.672**	-.369*	-.434**	-.593**	.715**	-.501**	-.517**	-.478**	-.607**	.145	-.593**	-.618**	-.575**	-.565**	-.597**	.652**	-.336*	-.450**	.798**
TOTBDPKM	-.578**	-.616**	.266	.311	.452**	-.623**	.388*	.404*	.372*	.561**	-.086	.505**	.587**	.499**	.472**	.542**	-.590**	.369*	.610**	-.707**
TOTBRDPP	-.809**	-.836**	.399**	.451**	.521**	-.834**	.633**	.640**	.623**	.764**	-.233	.720**	.803**	.712**	.692**	.745**	-.712**	.358*	.508**	-.940**
TOTEN_P	.843**	.969**	-.228	-.278	-.420**	.987**	-.502**	-.504**	-.495**	-.635**	.348*	-.608**	-.662**	-.596**	-.586**	-.605**	.607**	-.512**	-.508**	.882**
TOTPKPP	-.785**	-.791**	.437**	.480**	.474**	-.786**	.582**	.590**	.570**	.723**	-.022	.642**	.777**	.651**	.622**	.682**	-.713**	.377*	.521**	-.861**
TOTTRSPD	-.212	-.297	.159	.185	.241	-.352*	.025	.022	.042	.052	.070	-.004	.169	-.015	-.029	.026	-.475**	.222	.417**	-.413**
TRANEN_P	-.622**	-.664**	.434**	.482**	.501**	-.647**	.384*	.382*	.380*	.462**	-.140	.464**	.460**	.463**	.460**	.480**	-.730**	.432**	.276	-.690**
TTRVKTPP	-.756**	-.809**	.357*	.398*	.425**	-.817**	.516**	.515**	.513**	.592**	-.248	.569**	.622**	.559**	.549**	.577**	-.687**	.358*	.417**	-.848**

WORLD CITIES CORRELATION RESULTS, 1990/91 (41 cities)

		CAR_1000	CARKM_P	CBDEMDEN	CDBACDEN	CDBDENSI	GAS_P	INNACDEN	INNDENSI	INNEMDEN	METACDEN	METAREA	METDENSI	METEMDEN	OUTACDEN	OUTDENSI	OUTEMDEN	PKG_1000	PRJOBCBD	PRJOBINN	PROPCARS
Sig. (2-tailed)	CAR_1000	.	.000	.022	.007	.000	.000	.000	.000	.000	.000	.258	.000	.000	.000	.000	.000	.000	.040	.022	.000
	CARKM_P	.000	.	.095	.047	.006	.000	.000	.000	.001	.000	.033	.000	.000	.000	.000	.000	.000	.000	.000	.000
	CBDEMDEN	.022	.095	.	.000	.011	.181	.000	.000	.000	.000	.046	.000	.000	.000	.000	.000	.000	.448	.851	.024
	CDBACDEN	.007	.047	.000	.	.000	.099	.000	.000	.000	.000	.029	.000	.000	.000	.000	.000	.000	.694	.708	.007
	CDBDENSI	.000	.006	.011	.000	.	.009	.009	.003	.020	.001	.040	.000	.003	.001	.001	.001	.000	.044	.196	.000
	GAS_P	.000	.000	.181	.099	.009	.	.001	.001	.001	.000	.018	.000	.000	.000	.000	.000	.000	.000	.000	.000
	INNACDEN	.000	.000	.000	.000	.009	.001	.	.000	.000	.000	.335	.000	.000	.000	.000	.000	.004	.870	.543	.000
	INNDENSI	.000	.000	.000	.000	.003	.001	.000	.	.000	.000	.470	.000	.000	.000	.000	.000	.003	.823	.538	.000
	INNEMDEN	.000	.001	.000	.000	.020	.001	.000	.000	.	.000	.243	.000	.000	.000	.000	.000	.006	.891	.552	.000
	METACDEN	.000	.000	.000	.000	.001	.000	.000	.000	.000	.	.230	.000	.000	.000	.000	.000	.001	.525	.158	.000
	METAREA	.258	.033	.046	.029	.040	.018	.335	.470	.243	.230	.	.174	.209	.184	.165	.218	.394	.471	.296	.120
	METDENSI	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.174	.	.000	.000	.000	.000	.002	.751	.382	.000
	METEMDEN	.000	.000	.000	.000	.003	.000	.000	.000	.000	.000	.209	.000	.	.000	.000	.000	.000	.454	.055	.000
	OUTACDEN	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.184	.000	.000	.	.000	.000	.002	.731	.491	.000
	OUTDENSI	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.165	.000	.000	.000	.	.000	.003	.797	.566	.000
	OUTEMDEN	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.218	.000	.000	.000	.000	.	.001	.703	.468	.000
	PKG_1000	.000	.000	.000	.000	.000	.000	.004	.003	.006	.001	.394	.002	.000	.002	.003	.001	.	.033	.011	.000
	PRJOBCBD	.040	.000	.448	.694	.044	.000	.870	.823	.891	.525	.471	.751	.454	.731	.797	.703	.033	.	.000	.004
	PRJOBINN	.022	.000	.851	.708	.196	.000	.543	.538	.552	.158	.296	.382	.055	.491	.566	.468	.011	.000	.	.000
	PROPCARS	.000	.000	.024	.007	.000	.000	.000	.000	.000	.000	.120	.000	.000	.000	.000	.000	.000	.004	.000	.
	PROPNMT	.000	.000	.994	.704	.012	.000	.060	.038	.086	.003	.166	.006	.002	.010	.012	.006	.005	.045	.002	.000
	PROPTRAN	.000	.000	.003	.001	.000	.000	.000	.000	.000	.000	.181	.000	.000	.000	.000	.000	.000	.007	.001	.000
	PRPOPCBD	.054	.017	.170	.452	.000	.007	.771	.725	.802	.442	.356	.465	.484	.598	.612	.543	.129	.000	.009	.002
	PRPOPINN	.259	.100	.750	.511	.017	.059	.940	.915	.771	.692	.875	.803	.626	.951	.910	.999	.041	.046	.000	.023
	ROAD_P	.000	.000	.027	.008	.000	.000	.002	.001	.004	.000	.400	.000	.000	.000	.000	.000	.000	.045	.007	.000
	TOTBDPKM	.000	.000	.111	.061	.005	.000	.019	.013	.025	.000	.613	.001	.000	.002	.003	.001	.000	.025	.000	.000
	TOTBRDPP	.000	.000	.010	.003	.000	.000	.000	.000	.000	.000	.142	.000	.000	.000	.000	.000	.000	.022	.001	.000
	TOTEN_P	.000	.000	.157	.083	.007	.000	.001	.001	.001	.000	.028	.000	.000	.000	.000	.000	.000	.001	.001	.000
	TOTPKPP	.000	.000	.004	.002	.002	.000	.000	.000	.000	.000	.889	.000	.000	.000	.000	.000	.000	.015	.001	.000
	TOTTRSPD	.184	.059	.321	.246	.128	.024	.879	.894	.799	.748	.663	.981	.312	.925	.858	.877	.002	.163	.008	.007
	TRANEN_P	.000	.000	.005	.001	.001	.000	.014	.014	.015	.002	.381	.002	.004	.003	.002	.002	.000	.005	.085	.000
	TTRVKTPP	.000	.000	.022	.010	.006	.000	.001	.001	.001	.000	.117	.000	.000	.000	.000	.000	.000	.021	.007	.000

WORLD CITIES CORRELATION RESULTS, 1990/91 (41 cities)

		CAR_1000	CARKM_P	CBDEMDEN	CDBACDEN	CDBDENSI	GAS_P	INNACDEN	INNDENSI	INNEMDEN	METACDEN	METAREA	METDENSI	METEMDEN	OUTACDEN	OUTDENSI	OUTEMDEN	PKG_1000	PRJOBCBD	PRJOBINN	PROPCARS
N	CAR_1000	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41
	CARKM_P	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41
	CBDEMDEN	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41
	CDBACDEN	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41
	CDBDENSI	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41
	GAS_P	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41
	INNACDEN	40	40	40	40	40	40	40	40	40	40	40	40	37	40	40	39	39	40	40	40
	INNDENSI	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41
	INNEMDEN	40	40	40	40	40	40	40	40	40	40	40	40	37	40	40	39	39	40	40	40
	METACDEN	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41
	METAREA	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41
	METDENSI	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41
	METEMDEN	38	38	38	38	38	38	37	38	37	38	38	38	38	37	38	36	37	38	37	38
	OUTACDEN	40	40	40	40	40	40	40	40	40	40	40	40	37	40	40	39	39	40	40	40
	OUTDENSI	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41
	OUTEMDEN	39	39	39	39	39	39	39	39	39	39	39	39	36	39	39	39	38	39	39	39
	PKG_1000	40	40	40	40	40	40	39	40	39	40	40	40	37	39	40	38	40	40	39	40
	PRJOBCBD	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41
	PRJOBINN	40	40	40	40	40	40	40	40	40	40	40	40	37	40	40	39	39	40	40	40
	PROPCARS	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41
	PROPNMT	38	38	38	38	38	38	37	38	37	38	38	38	36	37	38	36	37	38	37	38
	PROPTRAN	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41
	PRPOPCBD	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41
	PRPOPINN	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41
	ROAD_P	36	36	36	36	36	36	35	36	35	36	36	36	33	35	36	34	36	36	35	36
	TOTBDPKM	37	37	37	37	37	37	36	37	36	37	37	37	34	36	37	35	36	37	36	37
	TOTBRDPP	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41
	TOTEN_P	40	40	40	40	40	40	39	40	39	40	40	40	37	39	40	38	39	40	39	40
	TOTPKPP	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41
	TOTTRSPD	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41
	TRANEN_P	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41
	TTRVKTPP	41	41	41	41	41	41	40	41	40	41	41	41	38	40	41	39	40	41	40	41

WORLD CITIES CORRELATION RESULTS, 1990/91 (41 cities)

		PROPNMT	PROPTRAN	PRPOPCBD	PRPOPINN	ROAD_P	TOTBDPKM	TOTBRDPP	TOTEN_P	TOTPKPP	TOTTRSPD	TRANEN_P	TTRVKTPP
Pearson Correlation	CAR_1000	-.701**	-.838**	-.304	-.180	.690**	-.578**	-.809**	.843**	-.785**	-.212	-.622**	-.756**
	CARKM_P	-.657**	-.856**	-.370*	-.260	.672**	-.616**	-.836**	.969**	-.791**	-.297	-.664**	-.809**
	CBDEMDEN	.001	.456**	-.219	.051	-.369*	.266	.399**	-.228	.437**	.159	.434**	.357*
	CDBACDEN	.064	.515**	-.121	.106	-.434**	.311	.451**	-.278	.480**	.185	.482**	.398*
	CDBDENSI	.404*	.585**	.523**	.370*	-.593**	.452**	.521**	-.420**	.474**	.241	.501**	.425**
	GAS_P	-.706**	-.857**	-.418**	-.298	.715**	-.623**	-.834**	.987**	-.786**	-.352*	-.647**	-.817**
	INNACDEN	.312	.699**	.048	-.012	-.501**	.388*	.633**	-.502**	.582**	.025	.384*	.516**
	INNDENSI	.339*	.694**	.057	.017	-.517**	.404*	.640**	-.504**	.590**	.022	.382*	.515**
	INNEMDEN	.286	.700**	.041	-.048	-.478**	.372*	.623**	-.495**	.570**	.042	.380*	.513**
	METACDEN	.474**	.808**	.123	.064	-.607**	.561**	.764**	-.635**	.723**	.052	.462**	.592**
	METAREA	-.229	-.213	-.148	.025	.145	-.086	-.233	.348*	-.022	.070	-.140	-.248
	METDENSI	.438**	.769**	.117	.040	-.593**	.505**	.720**	-.608**	.642**	-.004	.464**	.569**
	METEMDEN	.497**	.849**	.117	.082	-.618**	.587**	.803**	-.662**	.777**	.169	.460**	.622**
	OUTACDEN	.421**	.764**	.086	-.010	-.575**	.499**	.712**	-.596**	.651**	-.015	.463**	.559**
	OUTDENSI	.403*	.748**	.081	-.018	-.565**	.472**	.692**	-.586**	.622**	-.029	.460**	.549**
	OUTEMDEN	.449**	.785**	.100	.000	-.597**	.542**	.745**	-.605**	.682**	.026	.480**	.577**
	PKG_1000	-.450**	-.759**	-.244	-.324*	.652**	-.590**	-.712**	.607**	-.713**	-.475**	-.730**	-.687**
	PRJOBCBD	.327*	.414**	.576**	.314*	-.336*	.369*	.358*	-.512**	.377*	.222	.432**	.358*
	PRJOBINN	.491**	.502**	.408**	.729**	-.450**	.610**	.508**	-.508**	.521**	.417**	.276	.417**
	PROPCARS	-.801**	-.966**	-.479**	-.355*	.798**	-.707**	-.940**	.882**	-.861**	-.413**	-.690**	-.848**
	PROPNMT	1.000	.610**	.566**	.473**	-.608**	.530**	.692**	-.718**	.591**	.347*	.440**	.646**
	PROPTRAN	.610**	1.000	.377*	.265	-.789**	.686**	.931**	-.844**	.870**	.385*	.703**	.831**
	PRPOPCBD	.566**	.377*	1.000	.468**	-.446**	.466**	.379*	-.416**	.210	.175	.276	.285
	PRPOPINN	.473**	.265	.468**	1.000	-.512**	.483**	.336*	-.263	.204	.317*	.242	.261
	ROAD_P	-.608**	-.789**	-.446**	-.512**	1.000	-.744**	-.804**	.709**	-.654**	-.163	-.648**	-.672**
	TOTBDPKM	.530**	.686**	.466**	.483**	-.744**	1.000	.761**	-.614**	.635**	.103	.312	.327*
	TOTBRDPP	.692**	.931**	.379*	.336*	-.804**	.761**	1.000	-.839**	.895**	.334*	.665**	.841**
	TOTEN_P	-.718**	-.844**	-.416**	-.263	.709**	-.614**	-.839**	1.000	-.783**	-.328*	-.679**	-.827**
	TOTPKPP	.591**	.870**	.210	.204	-.654**	.635**	.895**	-.783**	1.000	.415**	.579**	.789**
	TOTTRSPD	.347*	.385*	.175	.317*	-.163	.103	.334*	-.328*	.415**	1.000	.321*	.531**
	TRANEN_P	.440**	.703**	.276	.242	-.648**	.312	.665**	-.679**	.579**	.321*	1.000	.794**
	TTRVKTPP	.646**	.831**	.285	.261	-.672**	.327*	.841**	-.827**	.789**	.531**	.794**	1.000

WORLD CITIES CORRELATION RESULTS, 1990/91 (41 cities)

		PROPNMT	PROPTRAN	PRPOPCBD	PRPOPINN	ROAD_P	TOTBDPKM	TOTBRDPP	TOTEN_P	TOTPKPP	TOTTRSPD	TRANEN_P	TTRVKTPP
Sig. (2-tailed)	CAR_1000	.000	.000	.054	.259	.000	.000	.000	.000	.000	.184	.000	.000
	CARKM_P	.000	.000	.017	.100	.000	.000	.000	.000	.000	.059	.000	.000
	CBDEMDEN	.994	.003	.170	.750	.027	.111	.010	.157	.004	.321	.005	.022
	CDBACDEN	.704	.001	.452	.511	.008	.061	.003	.083	.002	.246	.001	.010
	CDBDENSI	.012	.000	.000	.017	.000	.005	.000	.007	.002	.128	.001	.006
	GAS_P	.000	.000	.007	.059	.000	.000	.000	.000	.000	.024	.000	.000
	INNACDEN	.060	.000	.771	.940	.002	.019	.000	.001	.000	.879	.014	.001
	INNDENSI	.038	.000	.725	.915	.001	.013	.000	.001	.000	.894	.014	.001
	INNEMDEN	.086	.000	.802	.771	.004	.025	.000	.001	.000	.799	.015	.001
	METACDEN	.003	.000	.442	.692	.000	.000	.000	.000	.000	.748	.002	.000
	METAREA	.166	.181	.356	.875	.400	.613	.142	.028	.889	.663	.381	.117
	METDENSI	.006	.000	.465	.803	.000	.001	.000	.000	.000	.981	.002	.000
	METEMDEN	.002	.000	.484	.626	.000	.000	.000	.000	.000	.312	.004	.000
	OUTACDEN	.010	.000	.598	.951	.000	.002	.000	.000	.000	.925	.003	.000
	OUTDENSI	.012	.000	.612	.910	.000	.003	.000	.000	.000	.858	.002	.000
	OUTEMDEN	.006	.000	.543	.999	.000	.001	.000	.000	.000	.877	.002	.000
	PKG_1000	.005	.000	.129	.041	.000	.000	.000	.000	.000	.002	.000	.000
	PRJOBCBD	.045	.007	.000	.046	.045	.025	.022	.001	.015	.163	.005	.021
	PRJOBINN	.002	.001	.009	.000	.007	.000	.001	.001	.001	.008	.085	.007
	PROPCARS	.000	.000	.002	.023	.000	.000	.000	.000	.000	.007	.000	.000
	PROPNMT	.	.000	.000	.003	.000	.001	.000	.000	.000	.033	.006	.000
	PROPTRAN	.000	.	.015	.095	.000	.000	.000	.000	.000	.013	.000	.000
	PRPOPCBD	.000	.015	.	.002	.006	.004	.014	.008	.187	.274	.081	.071
	PRPOPINN	.003	.095	.002	.	.001	.002	.032	.102	.202	.043	.127	.099
	ROAD_P	.000	.000	.006	.001	.	.000	.000	.000	.000	.342	.000	.000
	TOTBDPKM	.001	.000	.004	.002	.000	.	.000	.000	.000	.543	.061	.048
	TOTBRDPP	.000	.000	.014	.032	.000	.000	.	.000	.000	.033	.000	.000
	TOTEN_P	.000	.000	.008	.102	.000	.000	.000	.	.000	.039	.000	.000
	TOTPKPP	.000	.000	.187	.202	.000	.000	.000	.000	.	.007	.000	.000
	TOTTRSPD	.033	.013	.274	.043	.342	.543	.033	.039	.007	.	.041	.000
	TRANEN_P	.006	.000	.081	.127	.000	.061	.000	.000	.000	.041	.	.000
	TTRVKTPP	.000	.000	.071	.099	.000	.048	.000	.000	.000	.000	.000	.

WORLD CITIES CORRELATION RESULTS, 1990/91 (41 cities)

		PROPNMT	PROPTRAN	PRPOPCBD	PRPOPINN	ROAD_P	TOTBDPKM	TOTBRDPP	TOTEN_P	TOTPKPP	TOTTRSPD	TRANEN_P	TTRVKTPP
N	CAR_1000	38	41	41	41	36	37	41	40	41	41	41	41
	CARKM_P	38	41	41	41	36	37	41	40	41	41	41	41
	CBDEMDEN	38	41	41	41	36	37	41	40	41	41	41	41
	CDBACDEN	38	41	41	41	36	37	41	40	41	41	41	41
	CDBDENSI	38	41	41	41	36	37	41	40	41	41	41	41
	GAS_P	38	41	41	41	36	37	41	40	41	41	41	41
	INNACDEN	37	40	40	40	35	36	40	39	40	40	40	40
	INNDENSI	38	41	41	41	36	37	41	40	41	41	41	41
	INNEMDEN	37	40	40	40	35	36	40	39	40	40	40	40
	METACDEN	38	41	41	41	36	37	41	40	41	41	41	41
	METAREA	38	41	41	41	36	37	41	40	41	41	41	41
	METDENSI	38	41	41	41	36	37	41	40	41	41	41	41
	METEMDEN	36	38	38	38	33	34	38	37	38	38	38	38
	OUTACDEN	37	40	40	40	35	36	40	39	40	40	40	40
	OUTDENSI	38	41	41	41	36	37	41	40	41	41	41	41
	OUTEMDEN	36	39	39	39	34	35	39	38	39	39	39	39
	PKG_1000	37	40	40	40	36	36	40	39	40	40	40	40
	PRJOBCBD	38	41	41	41	36	37	41	40	41	41	41	41
	PRJOBINN	37	40	40	40	35	36	40	39	40	40	40	40
	PROPCARS	38	41	41	41	36	37	41	40	41	41	41	41
	PROPNMT	38	38	38	38	34	34	38	37	38	38	38	38
	PROPTRAN	38	41	41	41	36	37	41	40	41	41	41	41
	PRPOPCBD	38	41	41	41	36	37	41	40	41	41	41	41
	PRPOPINN	38	41	41	41	36	37	41	40	41	41	41	41
	ROAD_P	34	36	36	36	36	32	36	35	36	36	36	36
	TOTBDPKM	34	37	37	37	32	37	37	36	37	37	37	37
	TOTBRDPP	38	41	41	41	36	37	41	40	41	41	41	41
	TOTEN_P	37	40	40	40	35	36	40	40	40	40	40	40
	TOTPKPP	38	41	41	41	36	37	41	40	41	41	41	41
	TOTTRSPD	38	41	41	41	36	37	41	40	41	41	41	41
	TRANEN_P	38	41	41	41	36	37	41	40	41	41	41	41
	TTRVKTPP	38	41	41	41	36	37	41	40	41	41	41	41

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX 5 – DATA SOURCES

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Montreal

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Transportation Association of Canada (TAC) 2323 St. Laurent Blvd. Ottawa, Ontario K1G 4K6 Canada "Urban Transportation Developments in Eleven Canadian Metropolitan Areas" (1966)	Antoine Landry Directeur Service des Communications Société de transport de la Ville de Laval 1333, boulevard Chomedey, 7^{e} étage Laval Québec H7V 3Y1	Gerry Whillan Kent Marketing Services Ltd. 199 Queens Avenue London, Ontario N6A 1J1 Canada Fax (519) 672-3228
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Ottawa

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Brendon Hemily Canadian Urban Transit Association Suite 901, 55 York Street Toronto, Ontario M5J 1R7 Canada	Statistics Canada Statistical Reference Centre (NCR) R.H. Coats Building, Lobby Holland Avenue Ottawa, Ontario K1A 0T6 (Population and Housing Characteristics by Census Tracts)	Transportation Association of Canada (TAC) 2323 St. Laurent Blvd. Ottawa, Ontario K1G 4K6 Canada "Urban Transportation Developments in Eleven Canadian Metropolitan Areas" (1966)

Toronto

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Vancouver

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Monica Stekl, Cityplan, Community Services Group; Christina DeMarco, Planner City of Vancouver Planning Department City Hall 453 W. 12th Avenue Vancouver, British Columbia V5Y 1V4 Canada	Frances Woodward Special Collections & University Archives Division, Main Library University of British Columbia 1956 Main Mall Vancouver, British Columbia V6T 1Z1 Canada	Transportation Association of Canada (TAC) 2323 St. Laurent Blvd. Ottawa, Ontario K1G 4K6 Canada "Urban Transportation Developments in Eleven Canadian Metropolitan Areas" (1966)

Winnipeg

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Statistics Canada Statistical Reference Centre (NCR) R.H. Coats Building, Lobby Holland Avenue Ottawa, Ontario K1A 0T6 Canada	Transportation Association of Canada (TAC) 2323 St. Laurent Blvd. Ottawa, Ontario K1G 4K6 Canada "Urban Transportation Developments in Eleven Canadian Metropolitan Areas" (1966)	Frances Woodward Special Collections & University Archives Division, Main Library University of British Columbia 1956 Main Mall Vancouver, British Columbia V6T 1Z1 Canada
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