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The environmental impact of urban land use and transportation strategies in the City of Toronto

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THE ENVIRONMENTAL IMPACT OF URBAN LAND USE AND TRANSPORTATION STRATEGIES IN THE CITY OF TORONTO

by

Faisal Mahmood Siddiqui, B.Eng. (Civil), Toronto, June 2005

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Civil Engineering

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By

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Submitted to the Department of Civil Engineering at Ryerson University, Toronto, Ontario, on May 16th, 2007 in partial fulfillment of the requirements for the degree of Master of Engineering in Civil Engineering, 2007
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Abstract

The objective of researchers, planners and engineers is to present to society a viable infrastructure that is sustainable as well as environmentally friendly. Since the growing population, as well as the socio-economic growth of an urban landscape, creates greater and greater travel demands, the effects that these increases cause on our environment and social fabric can not be underestimated. It may appear impossible to devise a plan that will provide a sustainable system, but the crux of the matter is to recognize the importance of this vision as a process. Today, thousands of researchers worldwide are working to develop solid plans and a timeline to implement the many good ideas that have been brought forward.

The development of urban land increases demand for an extensive transportation infrastructure. The impact of land use on transportation, and vice-versa, eventually boils down to its impact on our environment. This project elaborates the inter-connected relationship of urban land use with transportation infrastructure and identifies the regions in the City of Toronto where land-use activities are not compatible with the transportation system. The analysis of this research is based on data from the Transportation Tomorrow Survey (TTS). This paper not only elaborates on these issues but also addresses the requisite improvements that could significantly enhance the quality of the environment for us all in a broader vision of a more sustainable society.

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I would like to thank my project supervisor, Dr. Mostafa Warith, for his guidance during this project and throughout my academic years. Dr. Warith has always been very supportive. I will make certain that his name is acknowledged in any future accomplishments of mine.

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1.0 Introduction

Research has demonstrated that there is a strong relationship between the total vehicle kilometers traveled and urban land use. The number of vehicles that travel in and around the city can be used to estimate the emission and pollution contributions to the urban land and the environment as a whole. One may argue that air pollution benefits from the limited outward growth of cities and by making urban land use denser and more compact. This ideology can be brought to a practical level by putting more emphasis on having a more compact city and on transportation planning. Land-use activities, a contributing factor to increasing traffic volume along with the lack of appropriate transportation facilities in the City of Toronto, form the central focus of this project.

Since the growing population of the GTA is creating higher and higher traffic demands, the significance of the marked increase in the use of vehicles cannot be underestimated. Alternatively, how this demand can be met without further compromising the environment is the goal of today's scientists, engineers and researchers, and will be addressed in this project. The mission to restrain the increasing trend towards greater air pollution from motor vehicle emissions should proceed on two parallel tracks: reducing our dependence on the motor vehicle and reducing emissions per motor-vehicle-kilometer traveled.

Both concepts are closely linked in transportation planning and land development. If a mass transit system is in place, this will obviously reduce automobile dependence and will result in the lesser use of vehicles with regard to less vehicle kilometers traveled, thereby producing fewer toxins in our environment. At the present time, motor-vehicle ownership continues to rise at a rate that is higher than the growth rate of the human population.

In the past, Toronto transit achieved significant growth in terms of ridership along rapid transit corridors where appropriate land-use activities enhanced overall transit ridership. However, the current land development pattern and the type of land-use activities do not conform to the existing transportation facilities. This project identifies the regions where significant population, employment and auto ownership growth have occurred. These realities require Toronto to develop a better transportation system in order to diminish auto dependence.

Well thought-out, ongoing plans for urban land are crucial for Toronto, as is a critical analysis of auto dependence and its load on the transportation system. Urban land use is intimately interconnected with the transportation system, and their combined impact places far more stress on the environment than on each other. Major remedial plans are currently either in place or under review to address this issue.

Across the country there is growing concern for urban land use and transportation issues. Both transportation professionals and lay people are seeking solutions to these pressing issues. In particular, the idea is to launch transit-oriented land development in those regions where mixed-use and higher density areas are built around effective transit systems. This would, in turn, reduce dependence on automobiles and enhance the overall quality of life within the urban structure.

A significant contribution must be made from each level of our society, from government, industry and the general public; only then can our society become a role model of sustainable development. However, the crux of the matter is to recognize the importance of this vision as a process. We, engineers are to address these issues and enhance awareness to the society in a hope to have environmentally friendly and sustainable city for us to live.

The contents of this report present the views of the author and also present the views discussed in the literature and in numerous research papers. Therefore, this report does not compose a standard, specification, or regulation.

1.1 Literature Review

This section of the report will review the critical points of current knowledge on the environmental impact of urban land use and transportation strategies in general and then further linked to the local bodies of the City of Toronto. The ultimate goal is to bring the readers up to date with the current literature relevant to the topic and to provide justification for future research in this area.

Urban land use, air toxics and public health

Land-use data can be used to indicate potential environmental health risks because actual air monitoring data rarely exists. This data can act as a good alternate for estimating air toxics at neighbourhood level; in addition, it can expand the reach of environmental impact assessment to analyze potential exposures to air toxics within urban structure. Hazardous air pollutants are known to have adverse health effects on urban populations and are alleged to play a significant role in the rapid increase in serious health problems. A series of studies suggests that chronic exposure to aldehydes, benzene, diesel particulate matter (from vehicle engines) and other volatile organic compounds can all aggravate respiratory disease and may be excessively concentrated in urban neighborhoods. As a result, environmental planners and public-health analysts are forced to either establish costly monitoring programs or rely on land-use-based models to estimates air toxins (*Corburn, 2007*).

Automobile Dominance and the Tragedy of the Land-Use/Transport System

Technological advancement has connected the invention of the automobile with more than 10 miles of paved road around the world, all in the name of "progress and development." What we have created has slanted our advancement against us. The widening of highways and the increase in the number of road networks has resulted in bringing about more and more traffic, thus reducing speed and the overall level of efficiency. As a result, massive land development has taken place in the suburban regions, in turn causing an adverse impact on the environment. Having higher and higher traffic volumes on the network for longer periods of time reflects an unbalanced incompatibility of land-use and transportation. The automobile is the least energy-efficient, least space-efficient and most expensive mode of transport out there. On the other hand, our cities face traffic congestion, air and noise pollution, increased fuel consumption and higher infrastructure cost—all due to the fact of automobile dependence. It is observed that these adverse consequences are either directly or indirectly related to the impaired land-use/transportation system. In contrast, most urban systems are planned in isolation. Ever since the automobile was invented as a feasible mode of transportation, policymakers have planned and operated the system with one goal in mind: to move people and goods into and around the city as rapidly as possible. In due course, a massive expansion in highways and road networks has taken place, which has resulted in an imbalanced infrastructure. The combined land-use/transportation system is just that, a system, but is seldom planned or managed under one umbrella (*Khisty and Ayvalik, 2003*).

Transportation-Land-use Interaction

In last three decades or so, various policies have been implemented around the globe to address problems based on land-use and the overwhelming growth in automobile ownership and use. There are, however, questions with respect to the effectiveness of such policies concerning the transportation/land-use interaction with respect to the impact land-use policies are likely to have on the urban system. Some studies conclude that urban densities, traditional neighborhood design schemes and land-use mix have an impact on auto ownership and use, whereas others find the impact of such variables to be relatively insignificant. Although, this interaction has to be identified, without such an integrated approach to analyze the transportation/land-use interaction, any study of the impact of urban form on travel behavior is likely to yield invalid results (*Badoe and Miller, 2000*).

There has been increased concern in metropolitan regions regarding deteriorating air quality, increased congestion and negative impact to the natural environment resulting from land development patterns that favour automobile dependence. To address these concerns and meet national air quality standards, more emphasis is being put forth to carry out research on the development and implementation of policies that exploit the relationship between urban form and travel behavior. However, the questions are as follows: What type of policies should be implemented? How effective might they be in addressing these issues? This idea has generated a fair amount of research relating to the transportation/land-use interaction.

Alternative Fuels in Transportation

In light of declining fossil-fuel supplies and their unfavorable environmental impact, research and development activities in the field of renewable energy sources and technologies has taken off. Alternative energy sources and technologies can play an important role in reducing our dependence on fossil fuels. As the urban population grows more rapidly, the energy demand will rise as well. The benefits of alternative fuels such as hydrogen and other liquid fuels in transportation industry are not minor. The transportation sector is currently consuming gasoline and diesel, mainly from crude oil, at a frightening rate to fulfill the demands of transportation industry. Energy demand in Canada will rise in the future, and it is time that all sectors should ponder this issue before society becomes unsustainable (*Kouroussis and Karimi, 2006*).

The energy demand in Canada for various sectors (Figure 1) has either remained stable or has had a slight upward shift since 1995. However, demand for the transportation sector continues to rise, reflecting the growing number of autos on the road and their dependence and use. Out of 72% of consumed energy, 28% and 44% (Figure 2) is consumed by trucks and autos respectively. It is evident to state that this rise in the demand and the resulting dependence require further analysis to observe the trends in auto ownership and how the dependence can be lowered in the context of the urban structure. What alternatives can be provided in those geographical regions where auto ownership and dependence continue to grow? All these issues need to be analyzed and addressed accordingly.

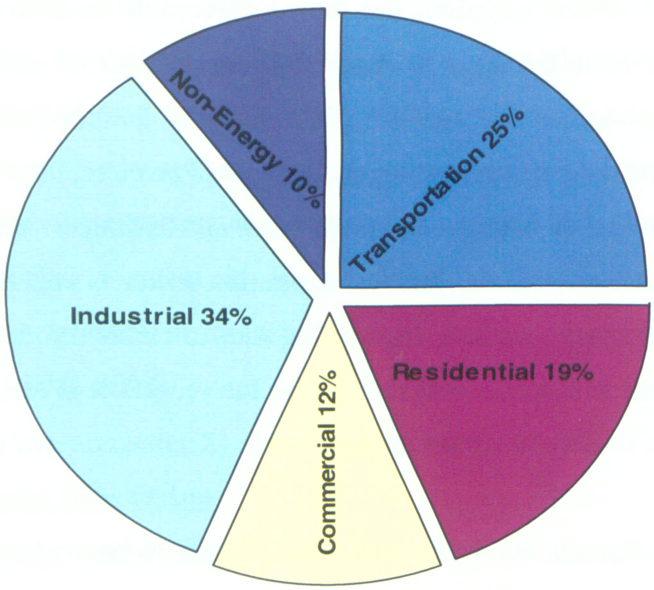


Figure 1: Canadian End-use Energy Demand by Sector (1995)

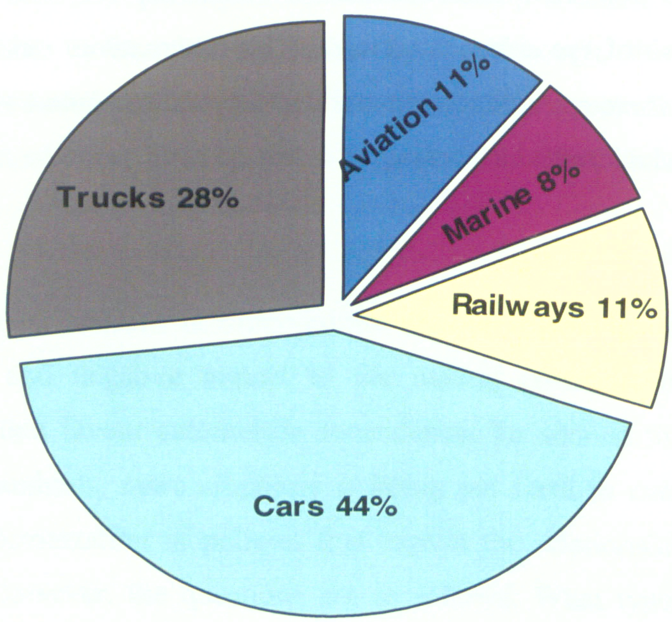


Figure 2: Canadian Transportation Energy Use by Sector (1995)

Land-use and Transport: Research and Policy Challenges

In the discussion of the impact of land use on transportation, two important questions need to be analyzed: (1) Does land use affect travel behaviour? (2) If land use affects travel behaviour, should land-use policies expected to be partly based on transportation requirements? (*Wee, 2002*).

There is sufficient evidence to conclude that land use can influence travel behaviour. On this account, future land-use and transport plans should be evaluated according to a broad range of factors. Transportation facilities are out there to fulfill people's desire to participate in different activities such as living, working, shopping and recreating in different places. Therefore, land-use patterns would appear to have significant impact on the need for transportation facilities. However, some researchers still argue that there is no consensus on the impact of land use on transportation. Instead, they prefer to place more emphasis on location-choice impact. For example, some people prefer to live in a lower density area, whereas others may prefer to live close to their workplace. This would, in turn, encourage the concept of encouraging a more compact city by having new offices built close to rapid-transit stations. Looking at this argument in the broader picture, it does appear that there is a very intimate relationship between land use and transportation.

The Land use-Transport connection: An Overview

Civil engineers or economists who become transportation planners tend to see transport as isolated patterns of origins and destinations as floating entities to be joined up by a straight line and be as fast moving as possible. However, our modern era has established a spirit of urbanism and has put planning, especially transportation planning, into the appropriate context. Cities are much more organic, living entities than the simplistic transport models of the past ever managed to express. Nowadays, cities are reasserting the fundamentals of the land-use/transportation connection. Likewise, the political will to overcome the negative aspects of automobile dependence is now coming to the fore in all cities worldwide. The United Nations and the World Bank have all begun to recognize this, and are emphasizing that transport funding needs to be more critically evaluated (*Newman and Kenworthy, 1996*).

The reduction of auto dependence and its association with energy use, greenhouse-gas emissions and air pollution is also the subject of many international agreements. Cities around the world are working towards establishing walking cores and building new walking-scale urban villages as people discover the joys of good pedestrian areas. There is likewise much talk about the need for transit-oriented development at the basis of any sustainable city. People throughout urban history have manifested one characteristic that has shaped the nature of our cities: they do not like to travel more than half an hour to major urban destinations. This has caused the development of three types of cities: namely, transit city (Figure 3); auto city and walking city. Technological advances have made this evolution towards greater speed and freedom possible. In the case of City of Toronto, the concept of the transit-oriented city was very successful in the past. The basis of this urbanism approach is a good transit system, and those in charge are now rediscovering the ways in which good planning and design can better incorporate less automobile-dependent land use (*Newman and Kenworthy, 1996*).

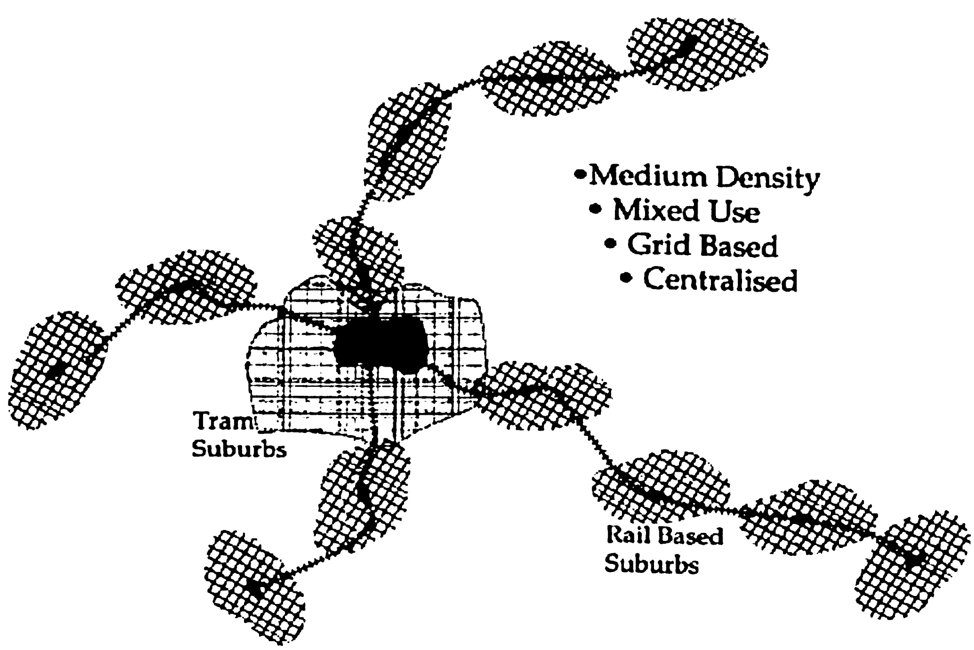


Figure 3: The Transit City, Dominant City Form in Industrial World

In an effort to quantify the above literature reviews, as an environmentalist, I have decided to provide and analyze additional factual data and figures in this paper. In order to do, this TTS data from 1986 and 2001 was used in my analysis. The survey is conducted in partnership between the Ministry of Transportation, 18 Greater Golden Horseshoe (GGH) municipalities, the Toronto Transit Commission and GO Transit, and is managed by the University of Toronto's Data Management Group. Over the next 25 years, The GGH population is expected to grow by about 35% to about 11.5 million people. In order to accommodate this impressive growth, it is important to understand travel patterns in the area. The purpose of this survey is to facilitate the work of the planners and decision-makers by providing them with the requisite date on growth trends so that better infrastructure and policies can be implemented in this region (*TTS Data Guide and Validation, 2001*).

The study also reveals how travel patterns and choices are changing throughout the region. The TTS methodology is to randomly select households within survey area and contact each household by letter, following up the letter with a telephone call. The collected information includes the type of residence, the number of members in each household, location, age, gender, number of licensed drivers, employed or student status, work location, purpose and destination of each trip taken the previous day and the mode of travel. All the information collected is kept in the strictest confidential fashion and cannot be traced to any given individual or household. Names, addresses and phone numbers are destroyed at the end of the survey. Following are some of the facts extracted from the 1986 and 2001 survey data. These facts provide the reader with an overview as to what kind of information can be made available upon the conclusion of this survey.

- Total travel in the GTA-Hamilton Area increased by 40% between 1986 and 2001.
- Almost one-quarter of total daily travel in the GGH occurs in the morning peak hours.
- Work trips accounts for 52% of total trips made in the morning peak period.
- In Toronto, one quarter of households do not have access to a car on a regular basis.
- In the Region of York 18% of households have 3 or more vehicles.
- In 2001, over a 24-hour period, transit accounted for 16% of total trips.
- The average length of trips taken by GO Rail is almost 30 km.
- The average length of trips taken on local transit is 5.5 km.
- The average commute to work by auto is 17.7 km.
- Shared car trips increased from 74% to 80% of total trips between 1986 and 2001.

- Walking and cycling account for almost 10% of total travel in the morning peak period.
- The portion of GTA peak period travel that takes place entirely within Toronto decreased from 48% in 1986 to 36% in 2001.
- 55% of the labour force living in York Region commutes to jobs outside the region.
- Single-person households account for more than 25% of total households in Toronto.
- In the Peel Region, 16% of households consist of 5 or more persons.

Although, the TTS survey of 1996 and 2001 also includes the GGH area (Figure 4), my analysis is restricted to identifying the regions in the Metropolitan Toronto area where significant growth in population, employment and auto ownership has occurred and where considerably less emphasis has been put forth towards the rapid-transit system.

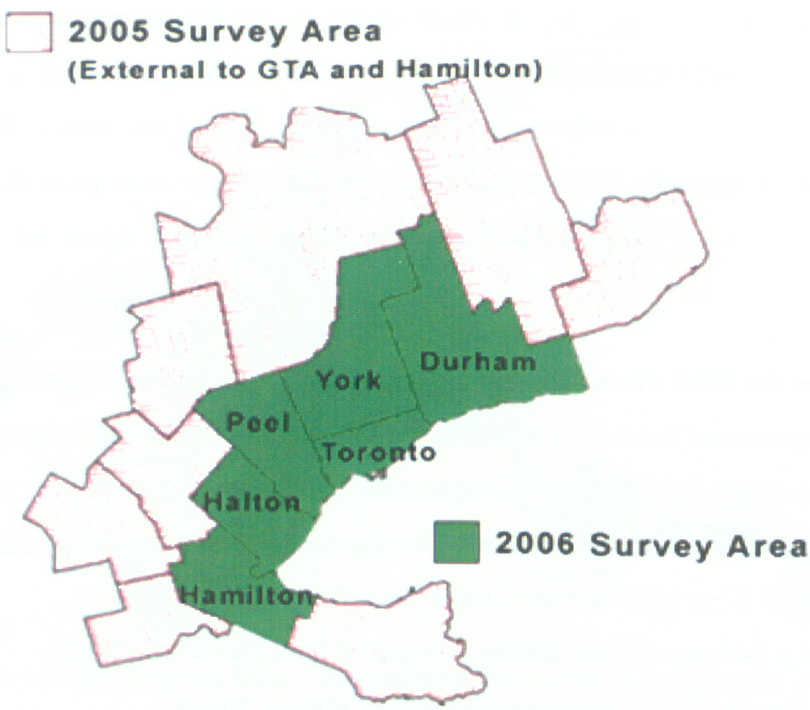


Figure 4: TTS 2005 and 2006 Survey Area

1.2 Report Organization

This report is organized in three different sections. Chapter one highlights the introduction of this project followed by detailed literature reviews. The contents of the literature review are organized in such a way that readers can easily establish a precise concept of the topic at hand. The concept of the environmental impact of transportation is not unique. However, its connection to land-use and development patterns is being argued worldwide, and is extensively discussed here.

Once the spirit of this connection is established, this report will indicate the environmental analysis on both fundamental factors in the urban context. How these factors, land-use and transportation, adversely impact the environment is addressed in the second chapter of this report. The constituents of hazardous particles, along with issues that are global in nature, are also discussed in this part. The necessity of involvement from all sectors—government, industry and the general public—as well as the policies and counter-measures that have been put into place to overcome environmental issues, are also outlined here. Moreover, this part delineates the existing control, management and contributions from the various sectors.

In chapter three, the land use/transportation interaction is discussed. Land use and development, along with population and employment growth in the city of Toronto—an integral part of the ever-increasing traffic-volume problem—is likewise described. These analyses are based on the TTS 1986 to 2001 survey data. Later, an analysis of local transportation facilities, of rapid transit in particular, is given. The sorts of enhancements in transit infrastructure that have either been brought into the picture or planned for the future are crucial to this discussion. Are these facilities compatible with current growth trends in urban land development? Can automobile dependence be curbed? Finally, a conclusion is presented and recommendations are on the land-use/transportation issues are suggested.

2.0 Environmental Analysis

Environmental issues must be addressed, and ignoring them no longer remains an option. Strong standards in this regard began to be set as early as 1992, during the Earth Summit in Rio de Janeiro, Brazil, where 98% of the world nations in attendance signed the document known as Agenda 21. Today, thousands of researchers worldwide are working to develop solid plans as well as a timeline to implement the many good ideas that have been brought forward.

In global terms, awareness of the need to address this issue goes back as far as the mid-19th century. The purpose of bringing so many nations together was based on the inescapable reality that environmental issues are not local but global in nature. International development—in particular, the socioeconomic growth of cities—has significantly impacted the environment, and the hard facts of this impact must concern every nation, region and municipality. Although this issue is global, this research is based on the situation in the City of Toronto, and, more particularly, is based on the impact of transportation on urban lands and vice-versa.

> *"Economies of agglomeration generate the growth of cities. As cities grow and become richer, vehicle ownership and use grow more rapidly than available road space, resulting in increased congestion and traffic-generated air pollution."* (*Gwilliam, 2002*).

Every time a vehicle engine starts, it releases emissions in the form of toxic pollutants into the environment, and it is essential to address the risks that come with that contribution. These risks pertain to the health of the general public (not exclusively or necessarily vehicle users) and to the environment as a whole. If a vehicle is used for traveling, how can it be made less polluting? Innovation in this field leads to the notion of the possible technical modification of the existing types of vehicles or to the source of the emissions. Simply put, the government must take control of vehicle emissions and enforce strict rules pertaining to them. Secondly, there must be an increased focus on the need to reduce toxic pollutants in manufacturing at the industrial level, the need to make technical modifications in vehicles and the need to provide a transportation network that fulfills the need of commuters and is more environmentally friendly than the status quo.

Lastly, and most importantly, public-sector leadership and legislation are crucial. The source of toxic pollutants from vehicles is based on the use of transportation facilities and is measured as a Vehicle Kilometer Traveled (VKT). Along with urban land development, having a well-connected, accessible transportation system can lead to a significant reduction in VKT and thus provide a less polluted environment. Far more than the wish for a better environment is at stake. There is a sense of urgency in addressing this matter, for the most significant source of environmental toxins comes from vehicles. How vehicular kilometers can be reduced and what kind of benefits can be gained from doing so call for urgent investigation and remediation.

Every city has different problems to solve in its efforts to promote a sustainable system. However, the major focus of this literature is to reduce the use of cars. One approach is to form a localized urban management plan based on a transit-oriented urban landscape. Another innovation in the Toronto area is the development of dense communities around transit lines. Although Toronto is far behind in meeting its goal for a sustainable system, the redevelopment of the city's core is another step towards meeting this goal. The suburban boundary of the City of Toronto has greatly extended over the past three decades, and this has contributed exponentially towards increased automobile dependency because the transit system has not been enhanced along with the new boundaries.

However, in the earlier stages of urban growth in Toronto, most development took place around the rapid transit line. This made other sustainability factors easier to manage, for example, issues pertaining to water treatment and supply. This has inhibited the strong nodal development characteristic of other parts of the subway system. This development is clearly visible from the air, as clusters of high-rise development abound above and around many subway stations.

As Toronto continues to thrive socially and economically, land development and travel demands increase. If the current land-development pattern continues to follow a path where fulfilling travel demands makes people become more and more auto-dependent, it will become an even greater challenge for planners and government bodies to establish sustainable infrastructure. Automobile use and dependency creates more and more air pollution, so reducing VKT would, of course, directly reflect on the betterment of our environment.

2.1 Vehicle Emissions

Air pollution can be described as any harmful gases or particles in the air. Although air pollution also exists in nature as a result of forest fires or wind-blown dust, human actions contribute the greatest percentage of pollutants into the environment. The major contributing factor is, of course, the ever-increasing use of automobiles. Emissions from motor vehicles and air pollution have become an inevitable reality of life in urban areas. However, there are several ways that different sectors such as government, industry, and the public can radically contribute towards reducing vehicle dependence and harmful emissions. An observant, informed society will help to ensure that air-pollution concerns are central to the ways in which we plan our cities and our transportation systems.

In an effort to achieve these goals, researchers, planners, engineers and decision-makers are facing the problems that accompany increasing traffic volume and its impact on health and the environment. Providing a sustainable system of road networks, mass transit and land use that reduces automobile dependence and provides a more environmentally friendly infrastructure has become a high priority in Toronto.

The urgency of addressing these issues comes from the enormous increase in vehicle ownership and use. On the other hand, a decline in transit rides per capita has been observed in the last twenty years. In 1950, there were about 53 million cars on the world's roads; 44 years later, the global private car fleet had grown to 460 million, a nine-fold increase (*Schwela, Zali, 1999*). This observation is directly linked to air pollution caused by vehicle emissions. In other words, an increase in vehicle ownership shows increased dependence on the automobile that, in turn, causes more vehicle kilometers traveled, translating to growing emissions and increased human exposure to pollutants.

Air pollution affects both urban and rural areas. Canada's largest sources of air pollution are power plants, industries and vehicle emissions. Canada's air quality is affected by numerous pollutants, which include ground-level ozone (O_3), particulate matter, sulphur dioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NO_x), volatile organic compounds (VOCs), hydrogen sulphide (H_2S), sulphates and nitrates. Additional air pollutants include toxic metals (lead, mercury, manganese, arsenic and nickel), benzene, formaldehyde, polychlorinated biphenyl

(PCB), dioxins and other chemicals. Every day, the average adult breathes about 15,000 to 20,000 litres of air [1]. These pollutants exist in the air and contain chemical and biological gases, droplets and particles, and are harmful to health. They can either be solid, liquid or exist in a form of gas. A significant percentage of them come from vehicles. Pollutants come from the tailpipes of vehicles and go straight into our lungs.

Even on the clearest of days, Environment Canada's Dr. Jeffrey Brook reports that the air is still heavy with pollution. Some of this pollution can be measured by researchers and scientists while the general public can also know, through personal exposure, which days are more pollution-ridden than others. The smog or haze is, in fact, a mixture of everything that creates a visual effect of particles. When a brown blanket hovers over the city, it is easy to feel the weight of the smog. One can see it, smell it and almost taste it [2].

It becomes a challenge for policy-makers and transportation engineers to evaluate the impact and control or limit the use of vehicles where traffic demand has dramatically increased. The public is also becoming more concerned about the impact that transportation has on air quality. Although rural areas are not exempt from vehicle pollution, urban land appears to be more seriously affected due to its greater population densities and overall development. The formation of greenhouse gases, such as CO_2 (that contribute to global warming), and emissions from vehicle exhaust such as carbon monoxide, nitrogen oxides and hydrocarbons (which have negative health consequences) have raised concerns among citizens in virtually every society. Following are some salient facts pertaining to vehicle use and the resulting consequences [3].

- Per-capita car ownership has increased by 300% in the last 40 years.
- Kilometres traveled by urban automobiles have increased five-fold while urban transit rides per person per year have declined from 250 to under 100.
- Greenhouse-gas emissions per kilometre traveled by new passenger vehicles have increased by 13% over the last decade.
- 25% of our urban space is devoted to pavement: parking lots, streets, and highways.
- At an average of 343 ppm, Canada's gasoline sulphur levels are among the highest in the industrialized world.
- It has been estimated that if Canada were to adopt a stringent sulphur standard, between 2000 and 2020 we could expect to avoid 2,100 premature deaths, 6,800 emergency-room visits, 3.3 million asthma-symptom days, and 11 million acute respiratory symptoms.

2.1.1 Health Issues

In order to obtain the bigger picture in terms of air pollution, scientists analyze the impact of smallest particles on human health. On the other hand, air-pollution measurement in cities can be compared with hospital admission records. Canadian scientists have been successful in establishing the relationship between cities having higher levels of air pollution and local hospital records by identifying the effects of pollution on human health in a variety of ways [1]:

- irritation of eyes, nose and throat
- wheezing, coughing and breathing difficulties
- worsening of existing lung and heart problems
- increased risk of heart attack and
- in especially sensitive people, premature death.

Each individual has different reactions to air pollution, depending on various factors such as location, the source of pollution, the duration of exposure, the quantity of pollutants, age, activity level and health status. As discussed earlier, as cities grow and become richer, vehicle ownership and use grows more rapidly than available road space, resulting in increased congestion and traffic-generated air pollution. Therefore, it can be stated without any doubt that the urban environment is exposed to greater air pollution than rural areas (with some exceptions), and one of the most significant sources remains vehicle emissions.

Recent findings published in the Canadian Public Health Association's *Canadian Journal of Public Health* indicate that approximately 8% of non-traumatic mortality in Canadian cities is attributable to air pollution caused by the burning of fossil fuels. There is no distinction as to who is more severely affected by air pollution. Seniors, children, individuals with special needs, and even healthy adults can have difficulty breathing under extreme conditions.

Children breathe much more quickly than a normal adult, thus inhaling more pollutants and becoming vulnerable to the negative effects of air pollution. Their lungs are not fully developed, and new tissue growing throughout childhood is acutely sensitive to irritants, including air pollutants. Many children's activities take place outdoors, in parks and schoolyards, and if such places are located near higher traffic zones, their exposure to air pollutants is increased.

Health Canada estimates that every year several thousand Canadians die prematurely due to air pollution. The Ontario Medical Association estimates that every year tens of thousand of people in Ontario visit emergency rooms or are admitted to hospital as a result of exposure to smog [1].

- The National Survey of Children and Youth shows that 15.2% of Canadian children between the ages of 4 and 11 have been diagnosed with asthma.
- Air pollution makes asthma symptoms worse. Symptoms include coughing, wheezing, chest tightness and shortness of breath.
- Seniors with chronic respiratory or heart conditions may find their conditions worsened by the inhalation of air pollutants.

These issues and facts cannot be simplified or resolved without stronger contributions and increased involvement from the various stakeholders. Government bodies should act in a stringent fashion to mitigate these effects at all levels, from planning to implementation, by providing physical infrastructure that is effective and environmentally friendly. As far as local urban bodies are concerned, land-use activities should be made compatible with transportation facilities so as to reduce automobile dependency—the major contributor to air pollution.

2.1.2 Global Warming and Ozone

The concept of global warming is not unique to this era. Air pollution and climate change are inherently linked. Smog pollutants and greenhouse gases (GHG) are often emitted from vehicle exhaust and industrial activities. Taking steps to reduce air pollution also helps to decelerate global warming. Greenhouse gases exist in the atmosphere that entraps heat from the sun. Some GHG are naturally present in the environment; these include water vapour, ozone, carbon dioxide, methane and nitrous oxide [1].

An excess amount of these gases in the atmosphere results in trapping too much infrared heat from the sun and causing "climate change"—now a concern of every nation in the world. Higher concentrations of GHG cause the average surface temperature of the earth to rise and, in turn, lead to "global warming." These GHG come from a variety of places, and their exposure to the environment has no boundaries. This is why concerns about global warming are not local in nature. A significant contribution of GHG occurs primarily in urban settings. In this era of technological advancement, socioeconomic growth, along with the use and dependency of auto vehicles alone, has significantly raised the level of GHG in the environment.

The ozone layer can be defined in two different terms, depending on the formation height in the atmosphere. The ozone layer occurs naturally in the upper atmosphere and protects life on earth from the ultraviolet radiation emanating from the sun. In the lower atmosphere, near the earth's surface, ozone is created by chemical reactions when nitrogen oxide gases from vehicle and industrial emissions react with volatile organic compounds. This is also known as smog. Human activity is responsible for this increase in ground-level ozone. About 95% of NO_x comes from the burning of gasoline, coal, gas and oil in motor vehicles, homes, industries and power plants [1]. On the other hand, VOC come mainly from gasoline combustion and from the evaporation of liquid fuels and solvents.

There are various tangible, feasible steps in place to curtail the surge of air pollution from motor vehicles. Although it is imperative for these practical goals to be recognized, consciousness about the intensely negative impacts of air pollution on our health and environment must continue to be spread.

2.2 Pollution Control and Management

This section concerns the effects of increasing auto traffic volume on our environment and looks at the possible involvement and remedial measures that could come from the different sectors, including industry, government and the public. Vehicle emissions, as everyone now knows, are the primary source of air pollution. As soon as a vehicle engine starts, a dose of toxic pollutants is delivered into the environment.

The federal government is trying to reduce some of those pollutants by improving gas quality. The plan is to lower the amount of sulphur in gasoline, and this should bring about enormous health benefits. Also, the benefits of alternative fuels that contain generic bio-components for spark-ignition engines hold great promise. At the same time, alternative fuel maintains all the advantages of ethanol by increasing the ability of the octane number of gasoline and to reduce the amount of harmful pollutants.

These alternative fuels do not increase the vapour pressure of gasoline, have a better tolerance to water and do not increase fuel consumption (*Kouroussis and Karimi 2006*). Such initiatives require a strong interaction between industry and government. For example, the government has offered tax exemptions for alternative fuels in an attempt to reduce emissions. At the same time, the government has improved the criteria for its vehicle inspection program, in which vehicle owners are required to have their cars and trucks tested for emissions.

Additionally, EPA has set up a pilot project in several school areas in order to educate parents and children regarding their safety and well-being. This program also encourages parents to walk their children to school instead of giving them a car ride. This will not only promote active and safe routes to schools, but will also help ease congestion around school areas. Also, it will reduce peak-hour traffic congestion and will prevent people from leaving their vehicles idling while waiting for their children.

Similarly, it is very common during the winter for people to leave their vehicles idling while they quickly run in and out of stores to pick up a few items. On account of this, the City of Toronto has banned vehicle idling to reduce not only car theft, but also to protect the environment.

According to Natural Resources Canada, if people refrained from idling, this would save about 1,356 litres of fuel a day—a financial savings of $1,031/day based on current gas prices [1].

On the industrial level, modification within vehicle technology is another virtuous step from the automobile industry. Solar-powered vehicles or hybrid vehicles are becoming common among all the major automobile manufacturers. An increase in the use of such vehicles would, of course, reduce the level of air pollution that comes from vehicle engines. However, lessening the impact on traffic congestion and reduction in VKT would require other alternatives combined with these types of advancements.

In order to meet the standards and commitments of the Kyoto Accord, the federal government is becoming more and more involved with local officials and planners, and as well with the representatives of industry. Also, in light of most people's awareness of greenhouse gas emissions, it now appears politically feasible to revive the concept of reducing greenhouse-gas emissions throughout our society. The federal government is putting $1.5 billion into alternative energy technologies. These include wind, solar, geothermal and other forms of renewable energy. In terms of greenhouse-gas reduction, Prime Minister Stephen Harper has stated, "That's the equivalent of taking one million cars off the road," and "That is real, practical, achievable action on climate change." (Heard on the CBC News)

3.0 Land Use—Transportation Interaction

An integrated land-use/transportation system reflects the set of transport infrastructures and modes that sustain the movements of people and goods. Normally, the transportation system articulates the level of accessibility to a given location whereas land use reflects the nature, extent, origins and destinations of such movements. This interaction accounts for the quality of the transportation system as well as the land-use factors that generate and attract these movements. This interaction supports effective decision-making for one while improvements are made to the other.

Travel within and among the regions outside Toronto has been increasing rapidly. The ever-rising travel pattern is observed in all types of movement: work, business, shopping, etc. Toronto and its surrounding regions have developed in a grid pattern, with streets intersecting at right angles and, therefore, providing a higher degree of consistency to the settlement pattern. Land-use decisions, such as the expansion of low density areas, intensely affect transportation choices and air quality. Similarly, sound decisions concerning the role of the transit service and land-use zoning laws will encourage more sustainable infrastructure. The prediction of travel demand based on land-use factors would solve the trip-generation and distribution problem by establishing well-planned, accessible residential and employment areas.

However, it should be noted that a massive development between Sheppard and Finch Avenues has become well established on Yonge Street. Very recently, large numbers of high-rise condominiums were erected in this area, and one of their main attractions and selling points is the easy access to transit stations—undermining the impact of new commuters on the Yonge transit corridor, which currently runs at capacity during peak hours.

At this stage, one may argue that population densification helps to reduce the number of longer trips and overall VKT more specifically—if this type of densification is increased along a rapid-transit corridor. The issue here is to provide such densification in areas where transportation systems can accept this type of massive land development, as in the case cited above. It would have been more beneficial had such development, for example, been built in the vicinity of the Downsview subway station as this would have, in turn, reduced the load on the Yonge transit line. Also, older development on urban land should be reused to benefit all stakeholders and to provide environmentally friendly infrastructure.

Planning has a crucial role in putting forward good design for new-housing plans, indicating the requirements for landscaping and identifying the points where higher densities would be suitable. As well, the characteristics of the different dwelling types, including such features as size and the number of rooms, must be taken into account. Builders and developers of new housing must consider all these aspects of land use in order to build new houses in the right places. Along with this comes the need for the city to enforce the current zoning by-laws while remaining flexible in terms of encouraging the type of development that will make the best use of the available land.

This phenomenon is widely observed in various major cities around the globe—especially in cities that are enforcing sustainable urban development (*Bockstaelb and Irwina, 2004*).

New housing should also be easily accessible by public transport and well integrated into cycling and walking networks. On this account, the City of Toronto has sixteen planning districts, namely: PD1-PD16. (Please see Figure 5.) (TTS, 2001) The next section provides the analysis and impact these planning districts have on travel demand.

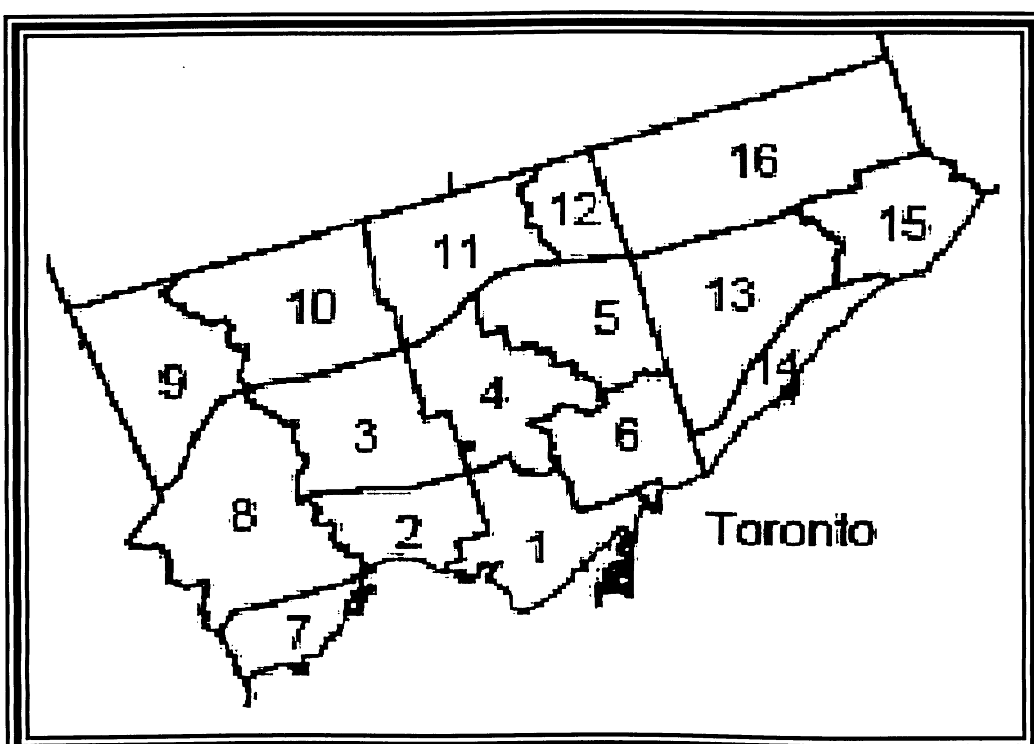


Figure 5: The City of Toronto Planning Districts (PD1-PD16)

The phrase "housing supply" not only represents the building of new residential houses but also includes the conversion process of turning old housing into new, multi-unit dwellings. A principal aim of urban planning is to provide good quality, well-located housing. In fulfilling these requirements, it is essential for planners and housing providers to work together in order to ensure quality residential environments. New housing should make a sound contribution to the environment and be designed in such a way that long-lasting benefits are attained. The interaction of the land-use/transportation system operates for different components such as land, built objects and activities. Each of these components has its own dynamics. For example, urban land use tends to remain unchanged for a long period of time. Objects also have a relatively long life, whereas the activities in a given developed environment are the most flexible component. This is where different factors and agents are analyzed before a space can be turned into housing supply.

One of the major components that planners and developers look at is the spatial distribution of the employed workforce as well as the number of economically inactive households where people are unemployed or retired. The next section will elaborate on the population, employment, labour force and vehicle ownership growth trends in the City of Toronto because these factors provide the greatest input into any land-use and transportation planning as they carry significant travel demand. In the case of Toronto, a very large proportion of urban land is allocated to housing the population (including employed members of the labour force) and employment areas (See Table 1-*Newman and Kenworthy,1996*).

Area	**Type**	**Density**
Urban	Population	40
	Jobs	20
Central	Population	25
	Jobs	757
Inner City	Population	57
	Jobs	38
Outer City	Population	34
	Jobs	14

Table 1: Land-Use Density
City of Toronto (1980)

3.1 Urban Land Use

Urban land use takes various different forms such as commercial, residential, recreational, natural, industrial, etc. The core elements of land use represent the activities taking place at particular spaces as well as the intensity of such activities which are identified as cultural, social or economic in terms of functional systems. Regardless of the type of activity, all have certain features that represent the impact of land use. In the formation of the urban structure, socioeconomic activities establish a relationship with other land-use types. Since all activities require mobility, transportation is the factor that is most closely associated with land use. The relationship between urban land use and transportation is not easy to understand, as it must be determined which of the two came first within a given context and which led to the development of the other. The urgent need to address the transportation/land-use interaction within the urban structure is based on the reality that environmental costs are becoming higher and higher due to rapid socioeconomic growth.

> *"Estimated cumulative HAP exposure is over 360 times greater than that which would result in a one-in-one-million risk of cancer ... HAP exposure is more than three times higher than the estimated national exposure, almost 2.5 times higher than estimated exposures in urban areas." (EPA, 1999)*

On the other hand, industrialization has caused a greater impact on the land-use/transportation relationship. Cities are not only expanding, but their land use is also altered to accommodate the growing economy and to move people within the urban boundary. In such a situation, the urban transportation system struggles to fulfill travel demands caused by the diversity of urban activities. Land use reflects the spatial collection of activities and their association with travel demand. It is usually linked with both the demographic of the human population and economic elements. Moreover, during last two decades, Toronto and its surrounding regions have experienced massive residential development. This trend is especially significant because Toronto remains the Central Business District (CBD)—a major component of attraction—as people generally want to live closer to their workplaces.

Spatial movements of people and goods have had a significant impact on existing transportation facilities. Therefore, having an integrated land-use/transportation system can help facilitate the human aspects of this reality and, in turn, can provide a more environmentally friendly infrastructure.

3.1.1 Population

In order to analyze the Urban Transportation Modeling System (UTMS) and work through it to counteract the problems involved in trip generation and distribution, one may need to look at the spatial distribution of population and employment respectively. On the other hand, the concept of modal split and trip assignment would require the analysis of existing transportation facilities along with trends in vehicle ownership.

This section analyzes the City of Toronto's population and its distribution along PD1 to PD16 (Table 2). Normally, population, employment and the employed labour force are the basic inputs used to calibrate trip generation and attractions. To do this, generation and attractions are classified at zonal and district levels. As well, population, employment and labour-force growth trends can be used to forecast future travel patterns of the given zones or districts under analysis and be compared with present trip generation, which becomes a tool for better transportation planning.

Location	**Year**			
	1986	**1991**	**1996**	**2001**
PD1	132023	130348	146644	164180
PD2	198359	201113	199591	199931
PD3	224513	227063	232683	230871
PD4	184152	184809	192125	202527
PD5	106854	105288	112235	115751
PD6	204196	210831	207286	209624
PD7	50856	53236	55044	55637
PD8	175975	168803	177910	177650
PD9	77027	79044	84725	91246
PD10	147975	130912	144539	140010
PD11	132192	131995	142836	147312
PD12	77706	75651	78665	76753
PD13	191228	191982	197646	210845
PD14	60853	60361	58575	65310
PD15	67795	78435	75577	77620
PD16	166500	184232	199475	203440
Total	**2198204**	**2214103**	**2305556**	**2368707**

Table 2: Population by Planning Districts City of Toronto (1986-2001)

In planning a better transportation system, population characteristics (such as age, gender, employed, retired) is the other factor that contributes to the overall trip production of a zone and planning district. Toronto experienced massive population growth (Figure 6) between 1991 and 1996. The population rose by over 63,000 between 1996 and 2001, reaching 2,368,707 people (*TTS, 2001*). Although the growth trend appeared to be overwhelming in 2001, it is observed that higher growth and settlement took place from 1991 to 1996. The more compact, higher density neighbourhoods remain an attraction for many, whereas old single-family housing stock that was built 50 years ago becomes home for younger families as older residents move out of their long-time homes (*Census, 2001*). However, this change is likely to continue in a few traditionally older areas of the city, but the transition will have an impact on the characteristics of communities, specifically on people's travel patterns. In turn, this will have an impact on overall trip productions in such zones and will require a new set of needs to fulfill people's travel demands. Population is the most important single component needed for the analysis of travel demand and pattern. Moreover, knowledge of the type of dwellings, the number of households and the size of dwelling units is also required in order to accurately forecast travel demands. Residential densities by housing type are an important factor in both trip generation and modal split (*Mekky, 2001*).

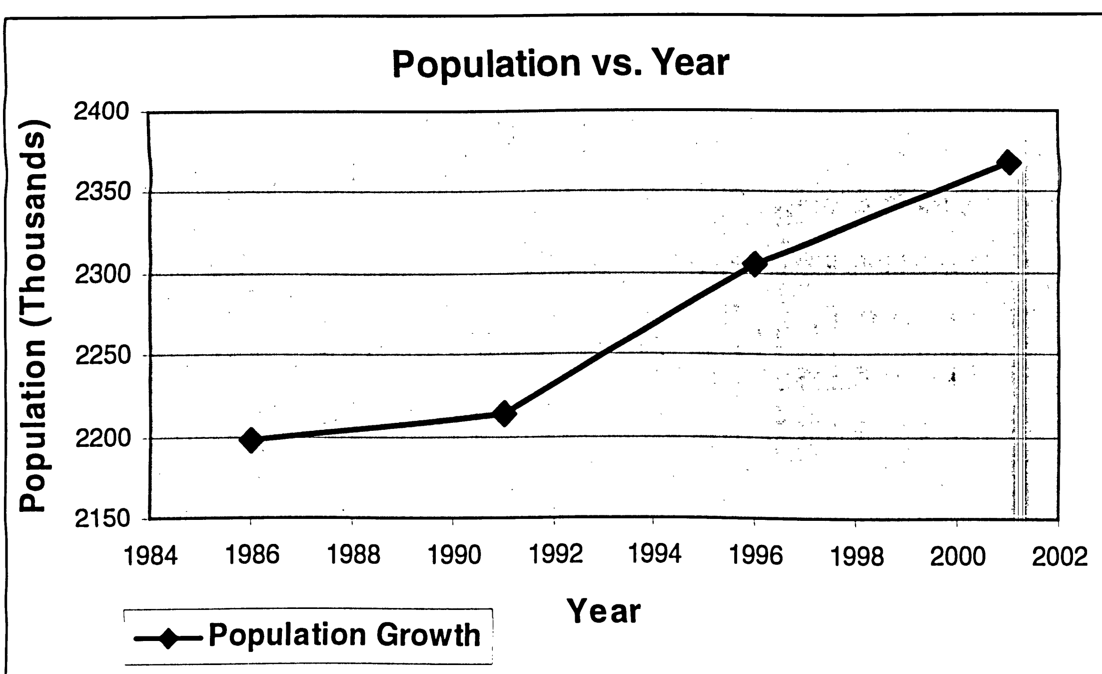


Figure 6: Population Growth, City of Toronto (1986-2001)

It is interesting to note that most of the planning districts saw an increase in population between 1996 and 2001, and some remained almost constant during this five-year (1996-2001) period, as in the case of PD7 and PD15 (Figure 7). Also, it should be noted that PD10 and PD12 have decreased in terms of population since 1996. Both these districts are on the outskirts of the northern part of the City of Toronto. This demonstrates that massive residential development in the northern regions surrounding Toronto has attracted more people, and this settlement has taken root in reshaping our population distribution and its characteristics.

Census Canada reports that all the outer GTA regions have experienced growth in the settlement of those less than 35 years of age. However, within the City of Toronto this group has declined by 16% since 1996. The outer regions of the GTA are experiencing enormous growth as younger families continue to avail themselves of the opportunity to purchase new, more affordable housing. At the same time, the City of Toronto is also growing because it remains the most attractive region for singles and newcomers, having the alternative of a substantial stock of rental housing on a larger scale compared to that available in the surrounding regions.

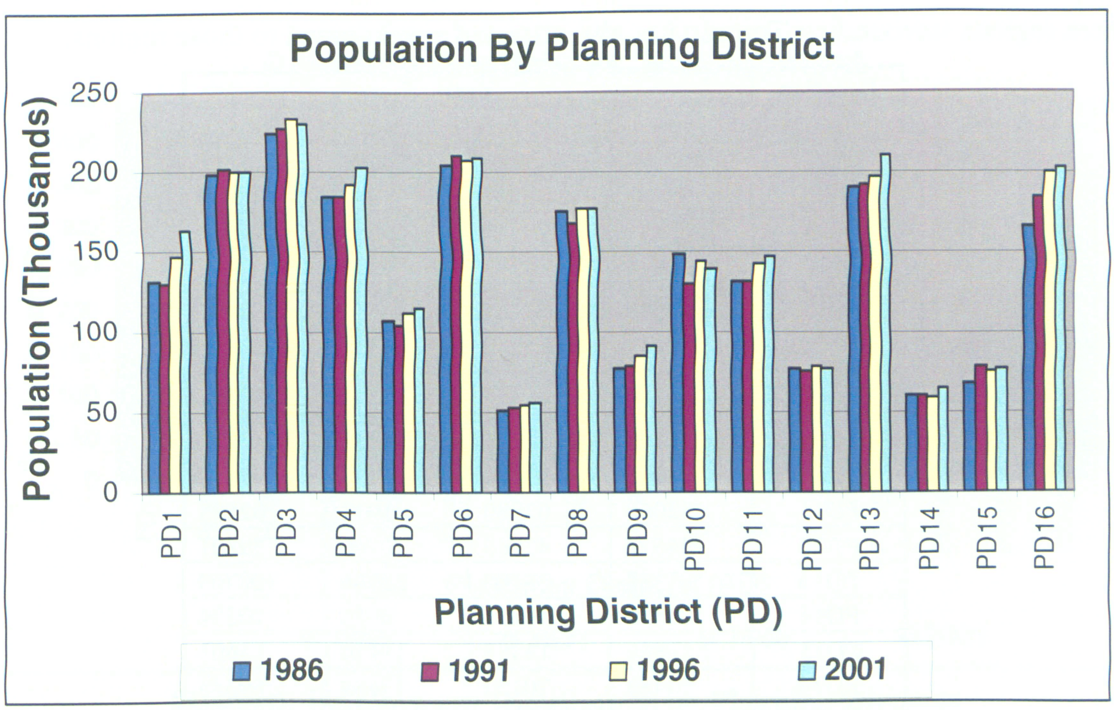


Figure 7: Population Distribution by Planning Districts City of Toronto (1986-2001)

3.1.2 Employment

Employment is a vital factor in the analysis of trip attractions. Normally, it is more difficult to estimate and forecast than population. Employment depends on economic forces at three levels—local, national and international—while population grows in a more orderly fashion (*Mekky, 2001*). However, the same statement can be true for the population variable in areas where major population growth is due to the settlement of new immigrants, which is the case in the City of Toronto. Figure 8 shows employment trends in the city for the period of 1986-2001. These trends reflect the reality that the recession of the late 1980s affected the overall employment figures in the region, whereas employment continued to rise in the surrounding regions of the city (*TTS, 2001*). Although the employment numbers of 2001 within PD1-PD16 are somewhat closer to what the city had in 1986 (Table 3), the growth trend has shown a steep peak since 1996 (Figure 8). Also, it should be noted that some districts have not yet achieved the same level of employment since 1986, which is the case in PD3, PD4, PD6, PD9 and PD 13. While analyzing the distribution of employment over the various planning districts, it is observed that total employment in PD16 has even gone lower since 1996 (Figure 9). This district is on the northern outskirts of the city and reflects the situation that the massive land development in the northern regions surrounding Toronto has also attracted employment to those regions.

Location	Year			
	1986	1991	1996	2001
PD1	400080	415937	394541	425227
PD2	53398	48307	51488	53839
PD3	83477	70548	69887	78616
PD4	101874	95912	91696	101650
PD5	64820	69953	60625	68589
PD6	50541	42638	45249	48633
PD7	29469	26363	22254	27384
PD8	77317	73929	74079	79162
PD9	65148	56194	56757	62548
PD10	92016	93002	92486	97510
PD11	52068	63980	61942	62575
PD12	34522	42063	36740	39801
PD13	107337	98009	82066	100793
PD14	9339	10854	9023	10254
PD15	11866	13355	13470	13603
PD16	53483	70153	73439	69355
Total	**1286755**	**1291197**	**1235742**	**1339539**

Table 3: Employment by Planning Districts City of Toronto (1986-2001)

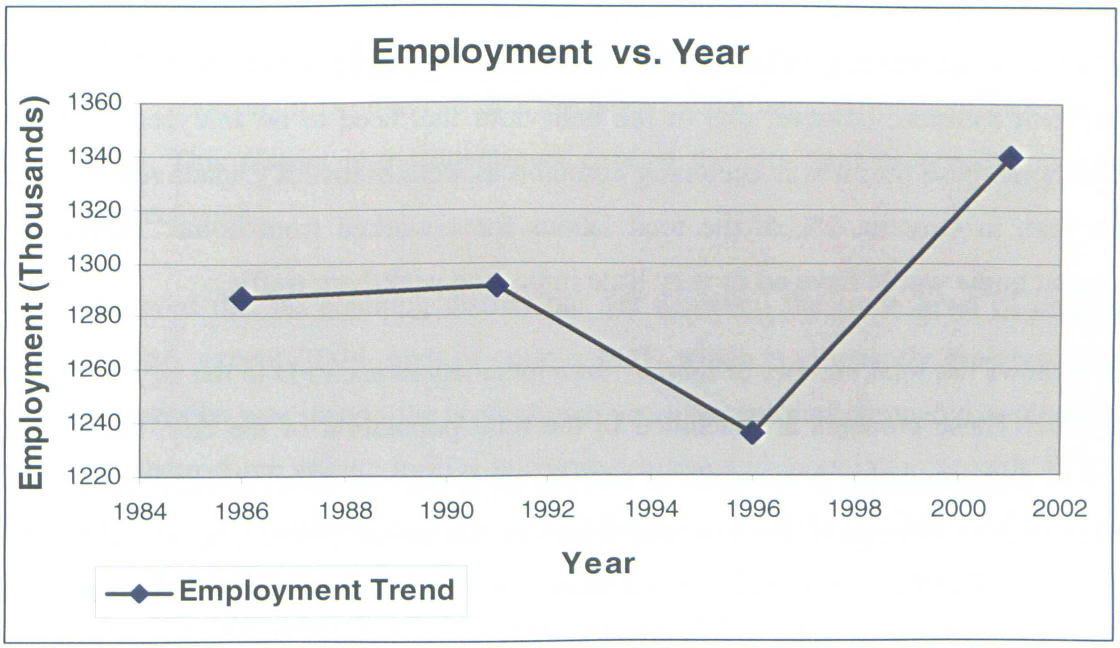


Figure 8: Employment Trends, City of Toronto (1986-2001)

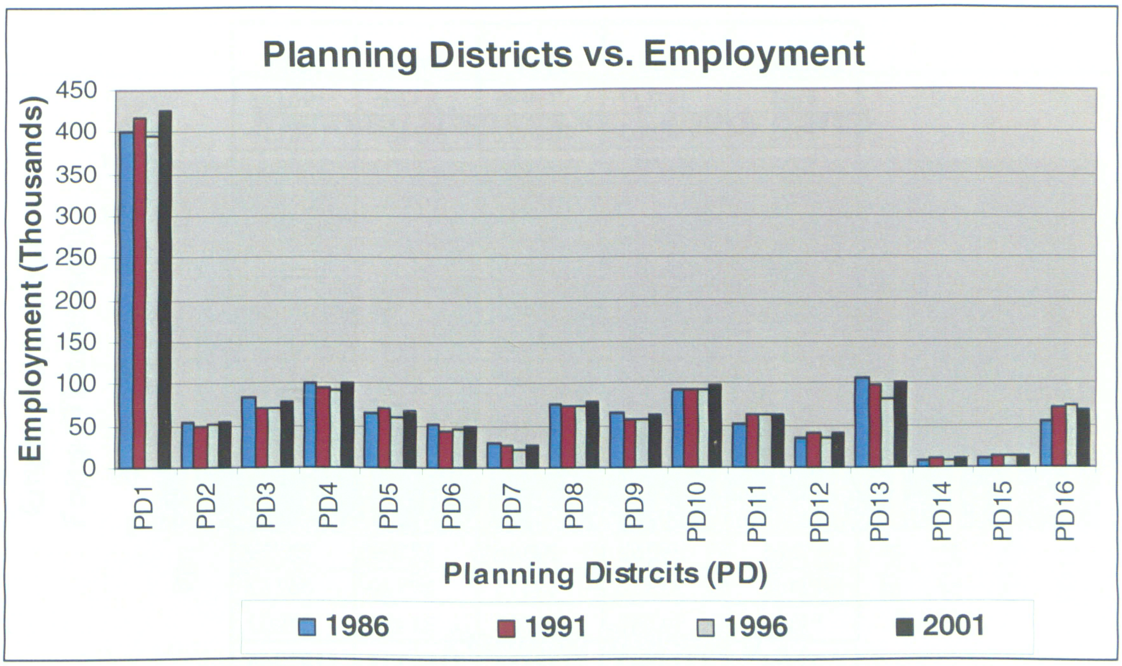


Figure 9: Employment Distribution by Planning Districts
City of Toronto (1986-2001)

3.1.3 Labour Force

Labour force is another factor that has an impact on travel demand and behaviour. For instance, if a district has an increase in labour force it would have higher travel demand to travel to their employment location, however one of the behaviour that need to be analyzed is the nature of work as home-base business is becoming common as well. Statistics Canada reports in the 2001 census that, in Ontario, 7% of the total labour force worked from home. Therefore, people working at home would have no or very little impact on peak-hour traffic.

Table 4 shows the total number of labour-force members in each PD in the city of Toronto from 1986-2001. These numbers are included in the total population of the city, but the employed portion of that population is extracted to analyze the impact on travel demand in each district. If a person lives in Brampton, Ontario, and works in downtown Toronto, he would be counted in the labour force of Brampton, not Toronto. However Toronto would be his employment location. Census 2001 reports that more people work in the City of Toronto than there are employed City of Toronto residents. Again, this is due to the fact that Toronto is the CBD and attracts labour-force participants from all the surrounding regions.

Location	1986	1991	1996	2001
PD1	80277	79996	83205	96418
PD2	108265	105832	103407	98113
PD3	120724	107750	105673	114368
PD4	106636	102321	103601	109851
PD5	58842	58186	51637	56414
PD6	114232	117622	106444	113102
PD7	29676	26845	27331	30033
PD8	99794	88664	79034	83522
PD9	42289	37804	38889	42773
PD10	79351	66623	63098	63155
PD11	66249	63476	65811	70291
PD12	44419	38576	36532	37927
PD13	100788	94433	87571	97125
PD14	29762	29446	27509	30759
PD15	38372	44473	37589	40112
PD16	94887	96508	92403	98902
Total	**1214563**	**1158555**	**1109734**	**1182865**

Table 4: Labour Force by Planning Districts City of Toronto (1986-2001)

As discussed in the employment section, Toronto has experienced a decline in employment trends after the recession that had an impact on the overall labour-force distribution in the City of Toronto. A large number of people became unemployed since 1986 in all districts, as can be seen from Figure 10. However, it is observed that the labour force has continued to increase in PD1 ever since 1986. This district is the downtown core of the city, and its population was least affected by the recession.

Also, it is observed that no planning district has yet achieved the same level of employment growth since 1986, except PD16, and, of course, PD1, which is constantly growing. The least impact of the recession was seen in the professional-services sector as compared to other types of employment. Labour-force growth in PD1 is commensurate with population growth. PD1, being the CBD, has a very distinctive impact on travel behaviour, and this co-relation will be analyzed later in this report. Aging is another factor that affects the labour force because people grow older and retire. On the other hand, however, the population itself is constantly growing in Toronto, and the labour force likewise grows. This also reflects that people who live and work in Toronto place less impact on the overall travel demand than people who commute from the surrounding regions to the City of Toronto.

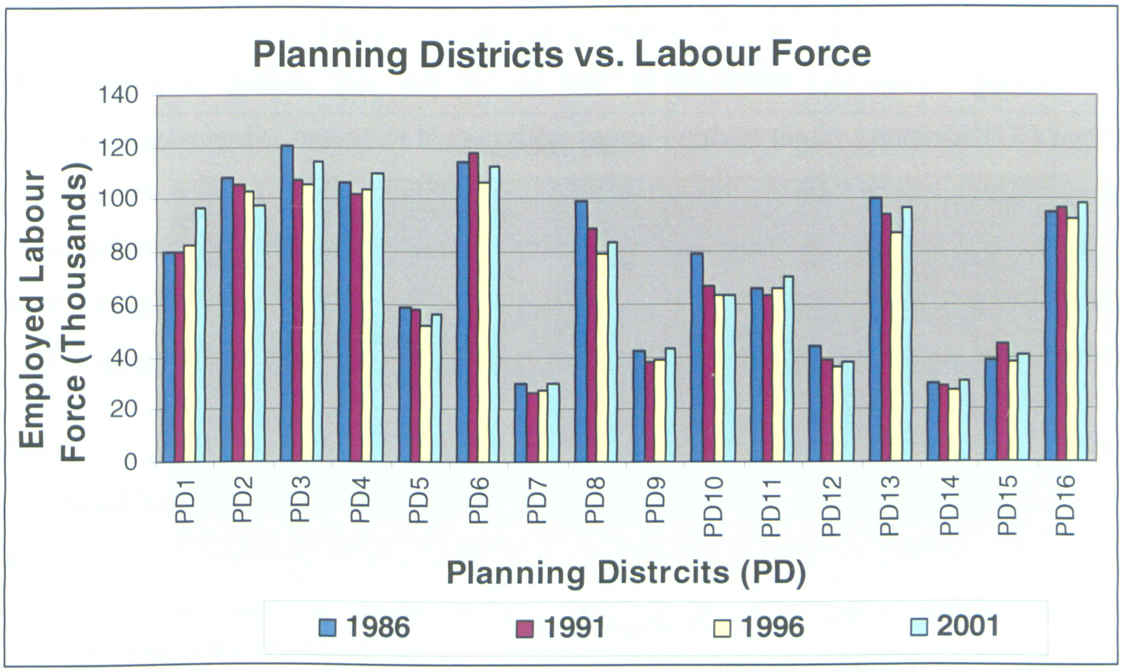


Figure 10: Labour-Force Distribution by Planning District City of Toronto (1986-2001)

3.2 Transportation

Transportation is one of the biggest industries of this era. It covers core areas of our daily lives and accounts for the smooth functioning—or not—of society. As engineers, we play an important role in this industry by designing, analyzing and managing this infrastructure. There are many ongoing issues that come up on a continuing basis, and it is to us to make the best possible choices and find solutions to ensure the best possible movement of people and goods.

Transportation is governed by laws and regulations that vary from place to place, depending on the situation and the surroundings. Transportation law includes federal and state laws pertaining to highways, mass transit, aviation, rail links, maritime and motor carriers. Also, certain standards are applied and complied globally, including the control of toxic emissions, on a local basis. These pollutants have an adverse effect on our environment and a great deal of pollution is caused by traffic on our local streets. Today's planners are hard at work in their attempts to solve the problems created by the ever-increasing traffic volume, particularly on urban land.

The Canadian Urban Transportation Association (CUTA) sets internal programs and actions to make transportation facilities more effective and environmentally friendly. As Toronto grows in size, so do its travel demands. On the other hand, massive land development in the surrounding regions puts extra pressure on the transit infrastructure, which is experiencing difficulty in accommodating commuters traveling in and out of the city during peak hours. Recently published CUTA reports target various issues with regard to transit infrastructure; these include investment needs, the federal gas-tax program and sustainable transportation. Paramount among these is the need to fulfill the people of the outlying regions' requirement of being able to gain smoother access to the downtown core of the City of Toronto in a far more efficient manner than is the case right now.

The aim of a sustainable transportation system is to reduce pollution, traffic congestion, auto dependence and the cost of maintaining the infrastructure. By achieving a good balance between socioeconomic growth and environmental concerns, goals can be achieved to a significant level. People use various modes of travel for their socioeconomic activities or, in some cases, a combination of two different modes.

For instance, a combination trip could be partial auto and partial transit. This is very common in cases where accessibility to transit corridors is not very effective or land development has not been kept compatible with transit infrastructure. It appears that Toronto has quite an effective transit system, but the issue of auto dependence has always been an obstacle towards sustainable transportation. In the past, Torontonians were among the highest transit users in all of North America in that 25% of total trips in the GTA were made through public transit (*Newman and Kenworthy, 1996*).

However, this trend of transit use has gone lower as compared to earlier transit-use patterns (Figure 11). As discussed in previous sections, planners are working hard to achieve sustainable transportation aims by reducing auto dependence and by providing an effective transit infrastructure. However, the modal split between auto and transit has stayed at the same level for the past three decades. One of the major factors contributing to auto dependence in the City of Toronto is the inconvenient accessibility to transit infrastructure, and Toronto has had no enhancement in this area.

On the other hand, most of the growth in the GTA is found in the surrounding regions of Toronto. The only rapid transit improvement the city has seen is the Sheppard East Rapid Transit (SRT) line, which offers little or no benefit to the commuters traveling to and from the surrounding regions. Further analysis on the SRT line is provided in the next section.

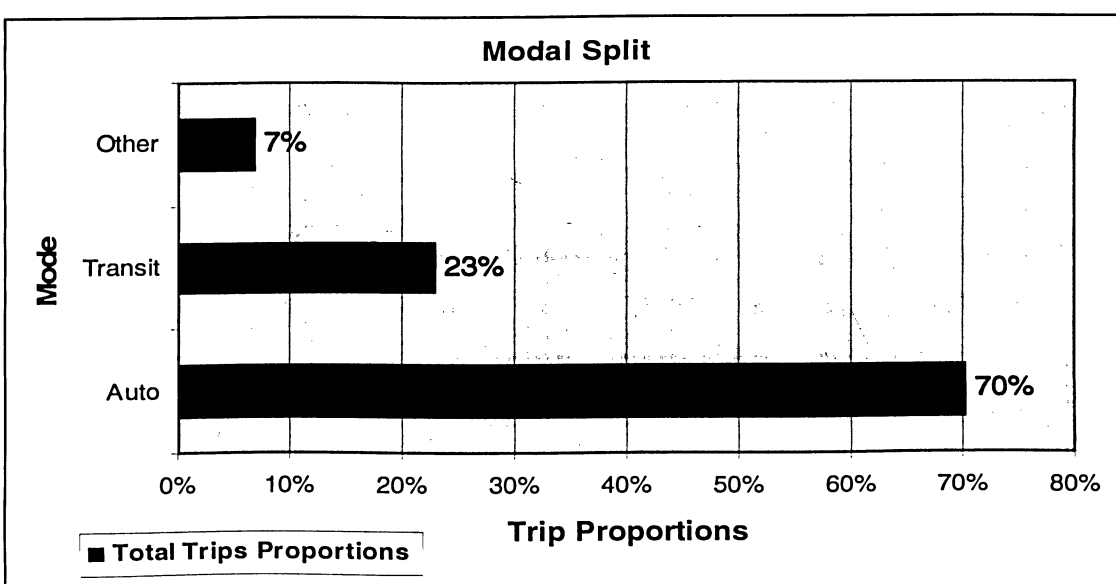


Figure 11: Modal Split, City of Toronto (2001)

Other modes include walking and bicycling, which happen to be very effective means of transportation in various cities around North America such as Phoenix, Arizona, and Vancouver, British Columbia. Although the implementation of such networks (walking/bicycling) requires an in-depth safety analysis, recognizing the importance of establishing such networks is the first step. Fortunately, it is part of the City of Toronto's master plan.

If the use of other and transit modes were to increase, dependence on automobiles would decrease commensurately. This would, in turn, result in fewer vehicles on the road, less pollution, less traffic congestion, less VKT and, of course, a healthier environment for us all. This is the aim of a sustainable transportation system, which would need an enhanced transit infrastructure along with a well thought-out interaction with land-use planning.

At present, the most-used mode of transportation in all PDs of Toronto is the auto, except PD1, where the transit mode prevails (Figure 12). PD1 is the downtown core, and, as was observed in the previous sections, this district has the highest employment rate and has demonstrated significant growth in population and in labour-force size since 1996. Also, PD1 is well connected with rapid transit (Yonge-Spadina) as well as with light rail (Spadina) transit facilities.

It is interesting to note that PD1 also has the highest number of auto trips among all districts, whereas other modes are relatively low compared to other districts. On the other hand, PD1 only has 5% of the total vehicles registered in PD1-PD16 (Figure 13). This indicates that although most people in the district prefer transit as their mode of commuting, auto dependency remains higher. An even lower proportion of vehicles than in the rest of the city is responsible for the highest number of auto trips among all districts.

One may argue at this point that if densification helps in the vicinity of rapid-transit infrastructure, which is the case in PD1, why is automobile usage the highest there? This is where the importance of the land-use/transportation interaction comes into play. It reflects an imbalance between population growth and, more specifically, the size of the labour force and employment.

If employment growth had remained at the same level as the population, or, in other words, if population growth had been less than it is in this district, there would have been more balance in the overall system. Since population growth is relatively higher than other district (See Appendix E for detail) and employment levels are not as such, people need to travel out of this district for employment and automobile usage becomes the only feasible travel mode for them.

Additionally, PD4, PD8, PD13 and PD16 are the districts with relatively higher auto-use compared to other districts. PD16 has experienced a very high population growth and a decline in employment since 1996. Also, this district does not have any rapid transit infrastructure in place. Therefore, auto use prevails as people need to travel out of this district for employment, which has declined within the district. All three other districts, PD4, PD8 and PD13, are well connected with rapid transit and, once again, reflect an imbalance between employment and population growth. It is also observed that PD4, PD8, PD13 and PD16 all have relatively higher vehicle ownership compared to other districts (Figure 13) which reflects that as number of vehicles grow so do the number of trips.

Also, the nature of employment should be analyzed for the districts that are well connected with the transit infrastructure. Still, in those areas, auto use is relatively higher compared to that in other districts. It is also important to note that the co-operation of citizens in terms of sustainable transportation is a crucial factor. If good transit infrastructure is in place and can be used to commute to and from work, using public transit should be preferred over automobile use with the goal of achieving an overall sustainable system.

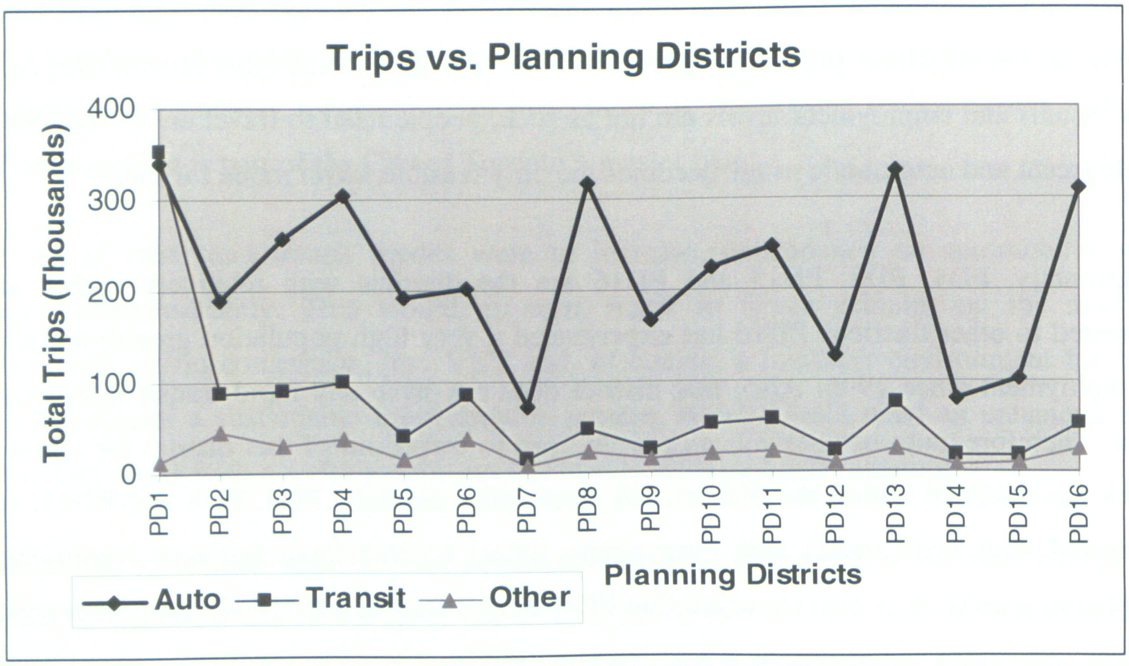
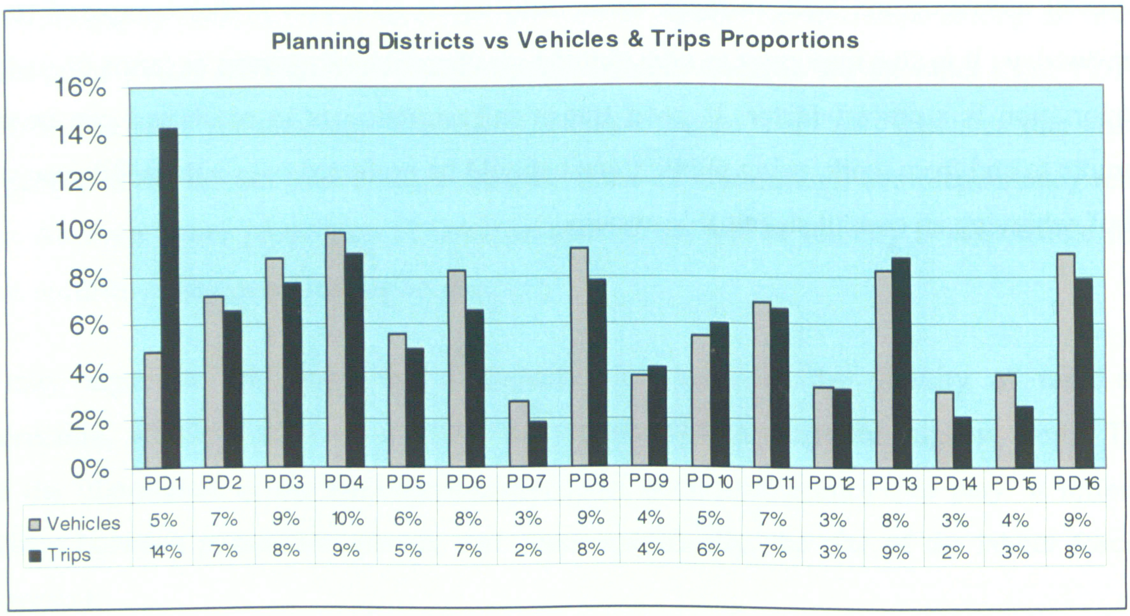


Figure 12: Modal Split by Planning District City of Toronto (2001)



	PD1	PD2	PD3	PD4	PD5	PD6	PD7	PD8	PD9	PD10	PD11	PD12	PD13	PD14	PD15	PD16
Vehicles	5%	7%	9%	10%	6%	8%	3%	9%	4%	5%	7%	3%	8%	3%	4%	9%
Trips	14%	7%	8%	9%	5%	7%	2%	8%	4%	6%	7%	3%	9%	2%	3%	8%

Figure 13: Proportions of Total Trips and Total Vehicles by Planning District City of Toronto (2001)

3.2.1 Vehicle-Use Trends

Issues related to air pollution, human health and global warming were discussed in previous sections, and it was observed that the problems caused by toxic pollutants emitted from vehicle emissions are being addressed all around the world. Toronto is no exception in this regard. Where Toronto has experienced very significant population growth, along with a commensurate growth in its employment and labour force rates, there has also been a corresponding increase in the total number of vehicles in PD1 to PD16. On the other hand, it has been discussed that although Toronto is growing, it has not yet reached the same level of 1986, for instance, in terms of the size of its labour force. However, vehicle ownership is the parameter along with population that grew beyond the 1986 level in 2001 (Table 5). Another relationship that has been observed is the decline in employment during the time of recession along with the number of vehicles during the same period (Figure 14). This reflects that although the population was growing, vehicle ownership declined along with employment levels. Similarly, employment growth shows a sharp peak since 1996, and so does the total number of vehicles.

Location	Year			
	1986	1991	1996	2001
PD1	42422	42417	45271	49749
PD2	68770	78219	68795	73530
PD3	89351	90800	84640	89597
PD4	90293	94158	91857	100721
PD5	56163	60919	52924	56899
PD6	79849	83199	77946	84336
PD7	25374	25398	26972	28516
PD8	101190	96272	92127	93822
PD9	37220	37869	36312	38598
PD10	62986	60056	56403	56320
PD11	65143	69759	68099	71052
PD12	38058	38753	34790	34441
PD13	84867	85171	81035	84853
PD14	28458	27840	29839	32251
PD15	37005	41484	36564	40089
PD16	82392	86941	86584	91544
	989541	**1019255**	**970158**	**1026318**

Table 5: Number of Vehicles by PD
City of Toronto (1986-2001)

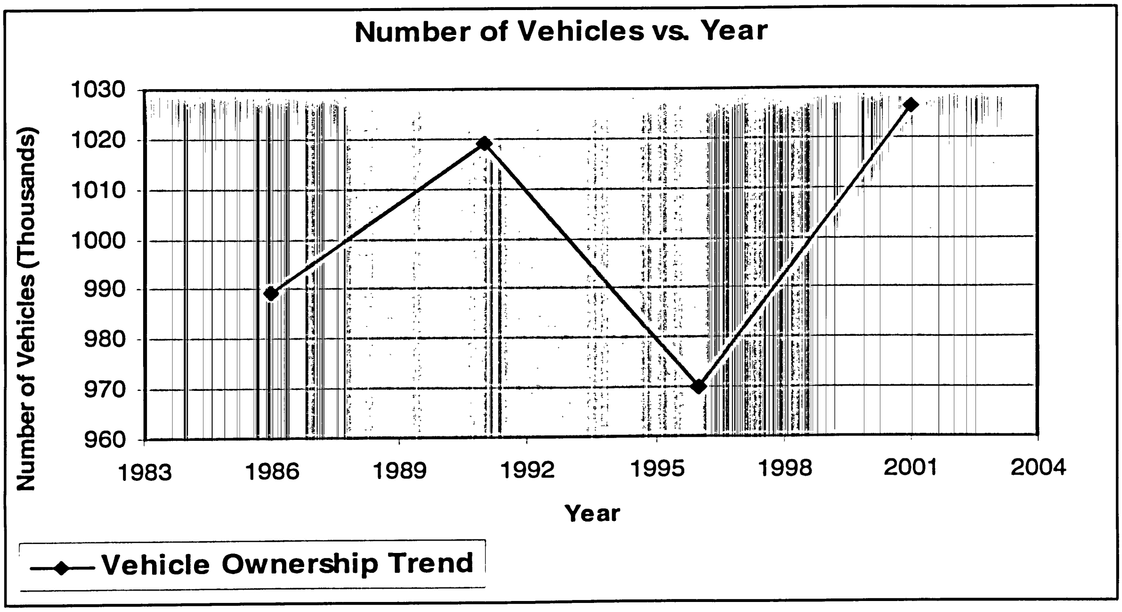


Figure 14: Vehicle Ownership Trends, City of Toronto (1986-2001)

At the same time, the growing number of vehicles in PD1 to PD16 has a directly proportional relationship with total trips made in the districts (Figure 15). As a sign of automobile use and dependence, districts that have higher numbers of vehicles have higher trip rates. And, as observed previously, the auto mode dominates all others. One exception is PD1 that appears as an outlier in this analysis because this district has relatively low proportion of vehicles but at the same time being the highest in making of total trips as well in auto use.

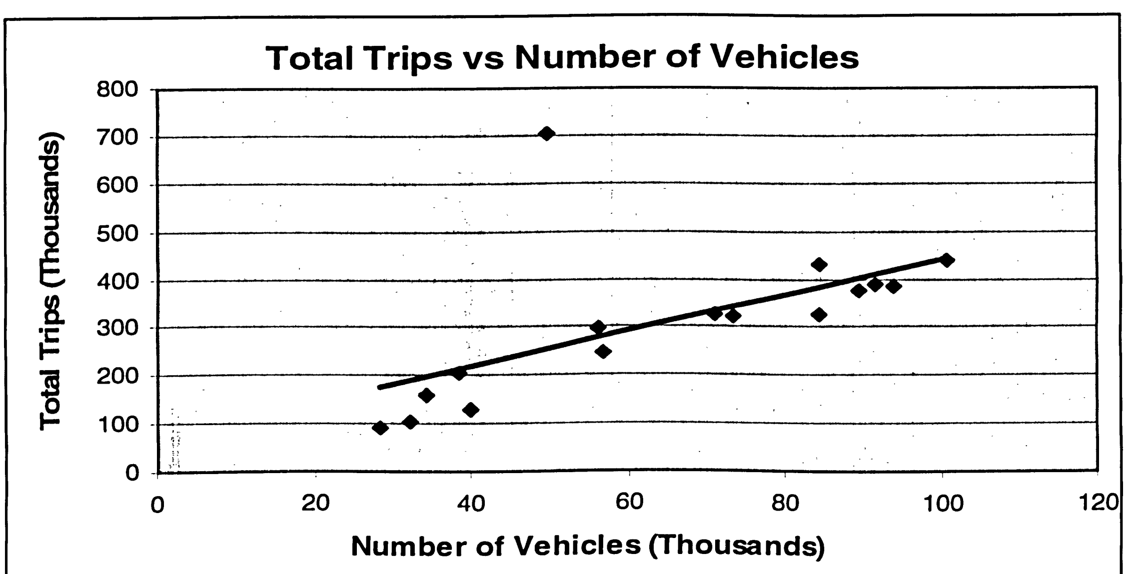


Figure 15: Total Trips vs. Total Vehicles, City of Toronto PD1-PD16 (2001)

3.2.1.1 Impact on Travel Behaviour

The impact of automobile use on travel behaviour can be analyzed under different characteristics. For instance, the use of autos also depends on the number of licensed drivers in households. If a household increases in size along with the number of licensed drivers, the household tends to acquire more than one vehicle. On this account, a combination of different factors needs to be analyzed to calibrate a trip rate for a specific zone or planning district.

In transportation planning, the calibration of trip rates becomes an essential tool in forecasting future travel demands. It predicts the number of trips generated (produced and attracted) for a given traffic-analysis zone. Trip productions are closely related to household characteristics, whereas trip attractions are related to land-use parameters (*Mekky, 2001*). Moreover, trip rate can also be classified in terms of the specific types of land uses that produce and attract trips. The analysis of trip attraction, for the most part, focuses on non-residential land uses. In trip generation, the main focus is to be found on residences, and the generation is considered as a function of the socioeconomic traits of households.

There are various methods to determine the trip rate of a traffic analysis zone. Since all methods have their pros and cons, two different methods, namely, Category and Multiple Classification Analysis are used to rationalize the results obtained for the City of Toronto. For a detailed tabulation of both methods, please see Appendix D. However, results for category and multiple classification analysis are summarized in Table 6 and Table 7 respectively. The reason for using such analyses is to identify the impact of the number of available vehicles along with household size on total trips made by all modes in PD1-PD16.

Category Analysis						
Trip Rate = Number of Trips/Number of Households						
HH Size	**Vehicles/HH**					
	0	**1**	**2**	**3**	**4**	**5+**
1	1.57	3.10	4.18	5.14	5.76	8.12
2	2.77	4.47	5.78	7.03	7.89	9.26
3	3.21	5.30	6.87	8.86	10.23	11.46
4	2.82	5.65	7.30	9.51	11.28	12.93
5	2.81	4.63	7.38	10.32	11.45	14.10
6+	4.00	5.98	8.78	10.15	13.48	17.19

Table 6: Trip Rate by Category Analysis, City of Toronto (2001)

Multiple Classification Analysis						
Trip Rate = U + αi + βj						
HH Size	**Vehicles/HH**					
	0	**1**	**2**	**3**	**4**	**5+**
1	-0.21	1.99	3.56	5.39	6.65	8.34
2	1.99	4.19	5.76	7.59	8.85	10.55
3	4.41	6.61	8.19	10.02	11.27	12.97
4	5.99	8.19	9.76	11.59	12.85	14.54
5	7.14	9.34	10.91	12.74	14.00	15.69
6+	8.01	10.21	11.79	13.61	14.87	16.57

Table 7: Trip Rate by MCA, City of Toronto (2001)

Although there is a variation in the pattern that these two methods show in Figure 16 and Figure 17, they both conform to the fact that as household size and the available number of vehicles increases, the trip rate increases as well. Therefore, greater the number of available vehicles in a household, higher the trip rate is. For instance, a household size of one, with two vehicles, would make more trips than same household size with one vehicle. Regardless, the fact that the household size is one, the availability of more than one vehicle contributes to a higher trip rate in the city.

In summary:

- The trip rate per household, taking total trips by all modes into account, shows a significant and direct correlation to household size, increasing from a rate of 1.57 for one-person households to 17.19 trips per household for households of six or more persons (Table 6).

- Household trip rates increase with vehicle availability. A household size of five with zero vehicles makes 7.14 trips per day by all modes, while the same household size with more than five vehicles available makes 15.69 trips per day by all modes (Table 7).

In the light of the earlier discussion of vehicle emissions and the accompanying hazards to the environment, the above analysis clearly indicates the trend in which automobile use and dependency are growing. If this trend continues, and there appears no contradiction to its doing so at the present time, it will become extremely challenging for planners to provide a sustainable infrastructure.

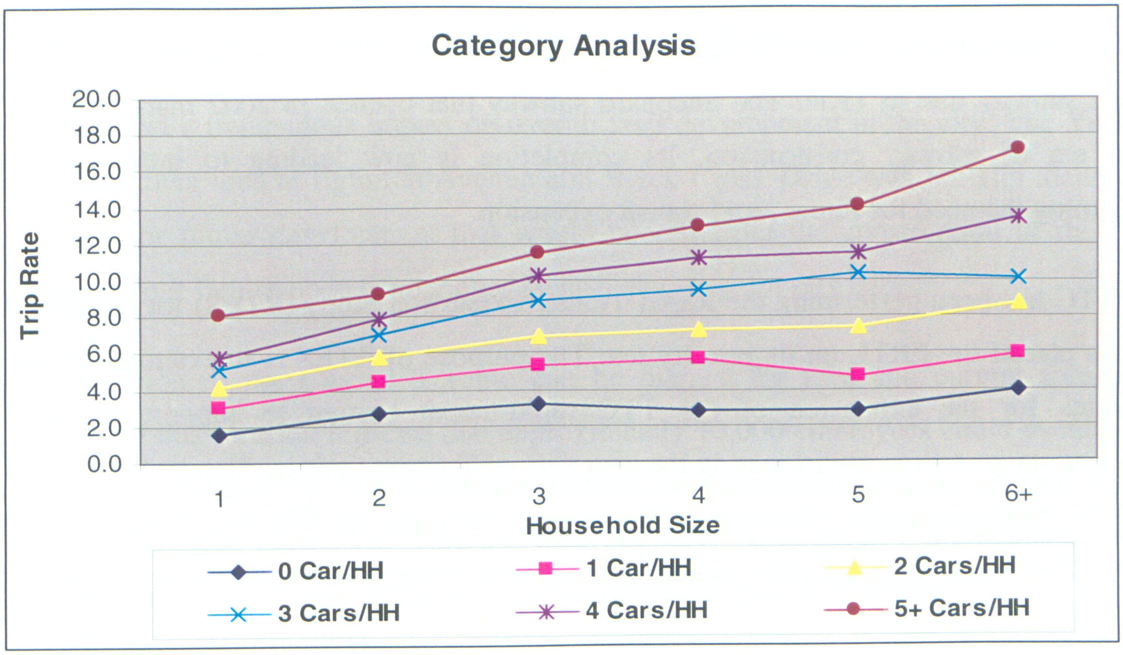


Figure 16: Trip Rate by Category Analysis, City of Toronto (2001)

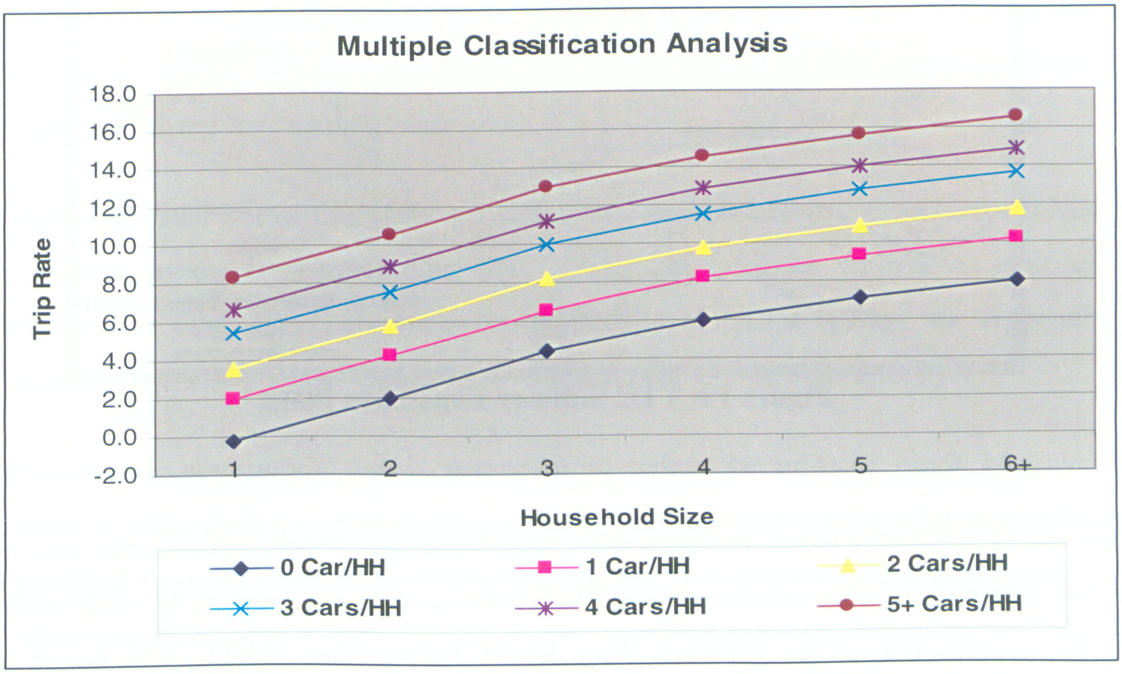


Figure 17: Trip Rate by MCA, City of Toronto (2001)

3.2.2 Transit Infrastructure

The TTC rapid transit system has grown through various stages since the opening of the initial Yonge subway line in 1954. The Sheppard subway that opened in 2002 marks the end of the latest era of subway construction. Its completion is now leading to inevitable questions concerning the need for future rapid-transit expansion.

The TTC has been performing the Rapid Transit Expansion Study (RTES) for decades, and has always placed the ERTL on its priority list. The purpose of RTES is to examine the needs and priorities for the expansion of the TTC rapid-transit system to support population and employment growth as envisioned in the new City of Toronto Official Plan and in recognition of GTA development trends. However, in the most recent study, the TTC has placed the ERTL as a proposal for future expansion but has not placed this extension on its priority list (Figure 18).

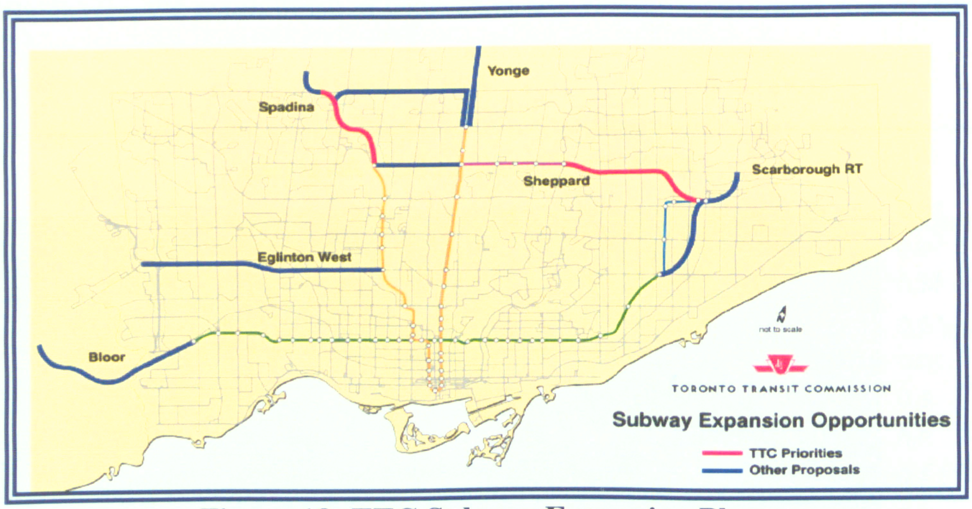


Figure 18: TTC Subway Expansion Plans

In some cases, politically-based decisions take precedence over people's real needs, and, as such, such decisions can impede social progress. This is the case, in my view, in the City of Toronto. When the construction of the Eglinton West Rapid Transit Line (ERTL) was halted and the decision taken to build the Sheppard East Rapid Transit Line (SRTL), Torontonians lost out. The cave that had been excavated for a future station was filled in, creating another unfinished subway station and costing the municipal and provincial governments a fortune.

This decision had a tremendous impact on overall land development in the city. The York City Centre development area at Eglinton Avenue and Black Creek Drive was initially identified as the key node for future development that would benefit from the construction of the ERTL. However, the York Centre node is no longer identified as a major city node.

The amalgamation of the City of Toronto can be blamed for this, and current forecasts of employment for this location indicate that approximately 10,000 employees could eventually be expected to work in this area. This is a reduction from the forecasts used in the original planning work done in the early 1990s. This figure is also less than the target of a minimum number of 20,000 employees, which is one of the criteria for success in the RTES report.

Building the Eglinton line would have had a positive impact by making the existing transit system work better: It would have provided relief to the Bloor-Danforth subway by 25%; provided direct ridership to the Spadina subway, which currently has spare capacity; and would reduce transfers at St. George station by 25%. The Sheppard line, however, will likely have a negative impact. It will increase the load on the already heavily loaded southbound direction of the Yonge line during the morning peak hours.

Regrettably, the addition of the Sheppard line overloads the Yonge line, which is already near capacity, And, in the broader picture, SRTL does not integrate with other regional transit systems. On the other hand, enormous residential development (please see Appendix E for population change along this corridor) has overloaded the Yonge line capacity.

On this account, automobile use is persistent in being the primary mode of traveling for commuters. It is interesting to note that households with zero vehicles have lower transit use than household that have one vehicle available (Figure 19). This reflects the combination of partial trips, where people either use their cars to access transit by availing themselves of TTC parking at subway stations or by using "kiss and ride" facilities to pick up and drop off other members of their households.

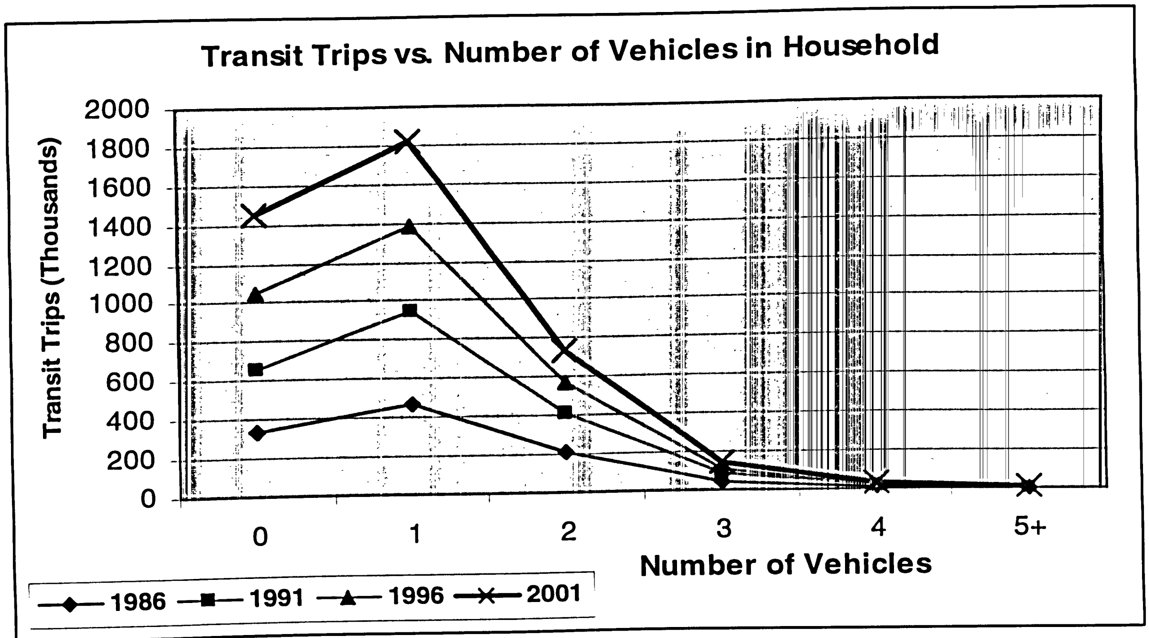


Figure 19: Transit-Use Trends with Increased Number of Vehicles in Household City of Toronto (1986-2001)

Additionally, it is observed that having a higher number of available vehicles reduces the overall use of transit. As the number of available vehicles per household increases, transit use shows a decline. Also, it was stated earlier that the modal split between auto and transit for the City of Toronto shows that the use of the auto mode has declined since 1980.

Table 8 shows the total transit trips made within PD1-PD16 from 1986 to 2001, and is classified by the available number of vehicles in households. For instance, it is observed that, in 1986, households having more than five vehicles made 3,710 transit trips whereas same category of household made only 823 transit trips in 2001, a decline of 82% in total transit trips for the specified category since 1986 (Table 8).

Number of Vehicles in Household						
	0	1	2	3	4	5+
Year	Total Transit Trips					
1986	333140	471966	207299	49391	11906	3710
1991	325944	472330	204566	34896	7026	630
1996	396148	438087	159116	27552	4867	1288
2001	400664	443618	169167	29467	4761	823

Table 8: Total Transit Trips by Number of Vehicles in Household City of Toronto (1986-2001)

Similarly, another relationship is observed among transit use and employment, and 1986 remains the highest transit-use period (Figure 20). Along with a decline in employment since the recession, transit-use trends have been affected as well. However, vehicle use has continued to increase. Although, transit use appears to have been increasing since 1996, the numbers have not yet achieved the same level as in 1986. At the same time, it is observed that employment has had a sharp peak since 1996, which is not the case in transit-use trends. This reflects that as more employment is created in the region, a lower ratio of people is using transit than was the case in 1986, when transit use made up 25% of total trips.

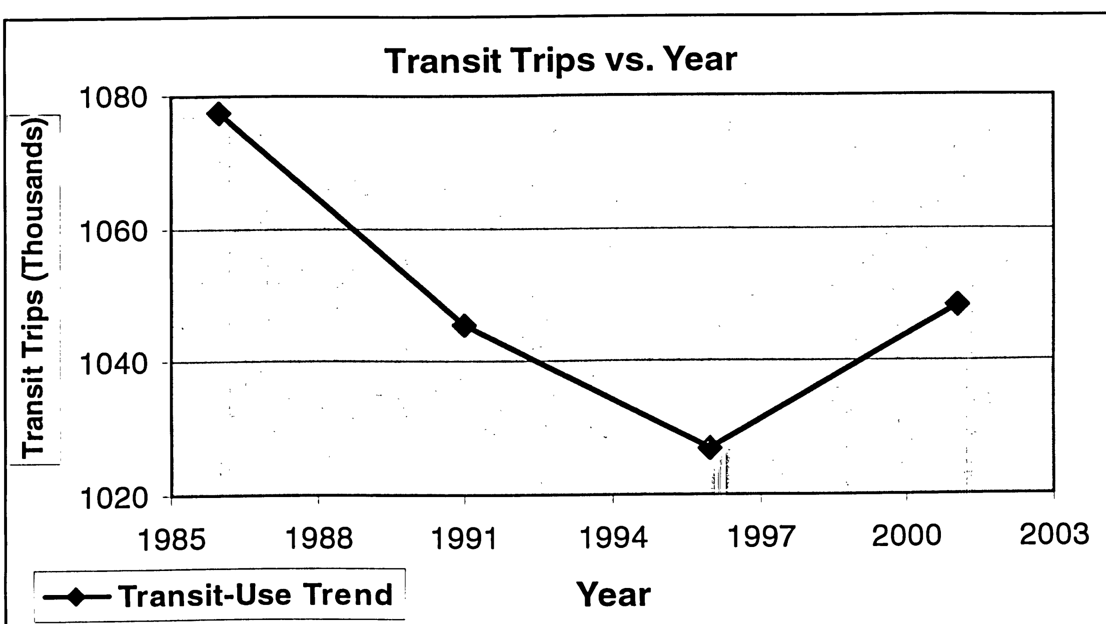


Figure 20: Transit-Use Trends, City of Toronto (1986-2001)

3.2.2.1 Compatibility with Land Use

Land use and transportation are closely interrelated. The existing layout and use of land greatly affect the choice of travel mode. In most situations, public transit in high-density areas and in more compact land use is most effective. A low-density land-use pattern promotes the use of the personal vehicle.

In order to elaborate the concept of land-use/transportation interaction, the proposed rapid transit corridor of ERTL is discussed as an example in terms of benefit and enhancement that better land use and an improved transit infrastructure can bring to the society. Urban density by traffic zone presented by a rapid-transit-expansion study (1996) shows that population density along Eglinton Avenue West from Allen Road to Keele Street is moderately dense at about 100 to 250 (persons + jobs) per hectare (Figure 21). The density reduces westward beyond Keele Street, which is fewer than 100 (persons + jobs) per hectare.

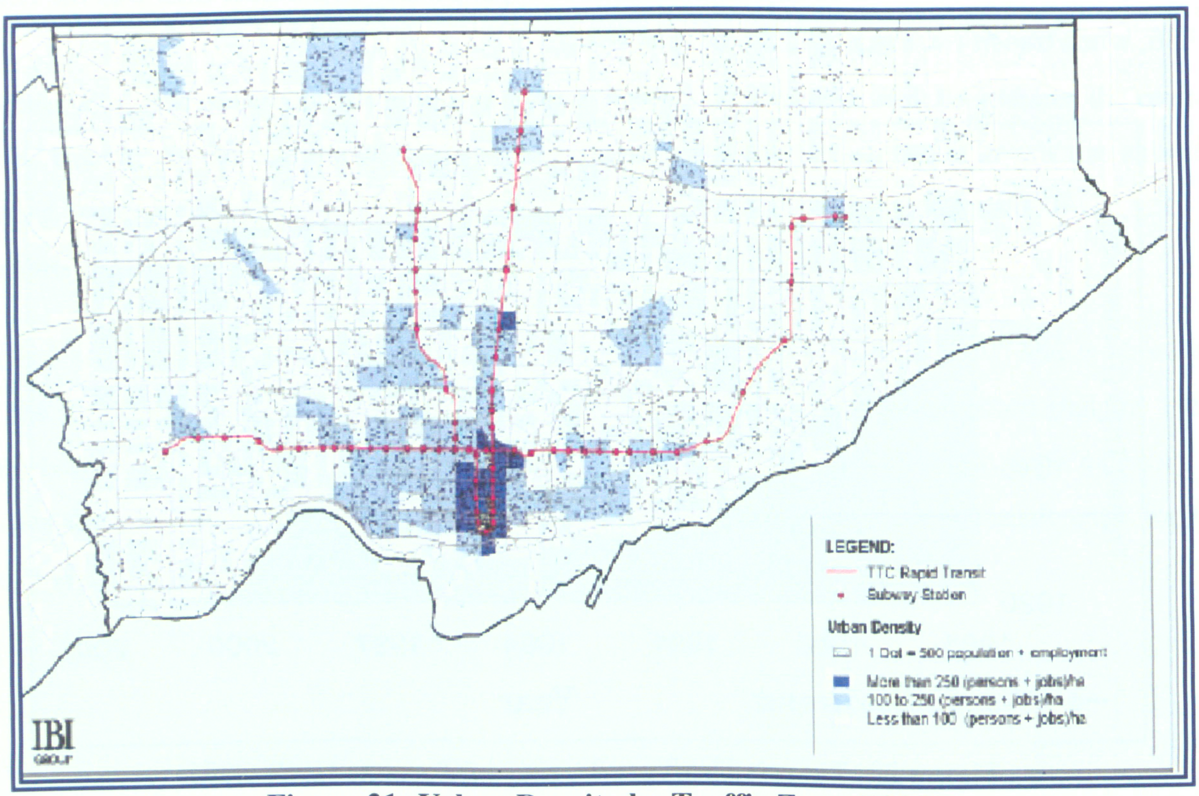


Figure 21: Urban Density by Traffic Zone (1996)

The land-use pattern of Eglinton West from Allen Road to Keele Street represents mostly mixed-use areas. There is a large employment area near Eglinton and Weston as well as near Eglinton and Caledonia. These employment areas would probably have developed in any case due to the intersection of major roads and railway lines in the vicinity. Therefore, there are more developmental attractions in these areas, and the public transport there is essential and effective. The land-use pattern and population density of Eglinton West represent different behaviors up to Weston Road. There the population is denser and is mixed with primary and secondary land uses from Allen Road to Weston Road (Figure 22).

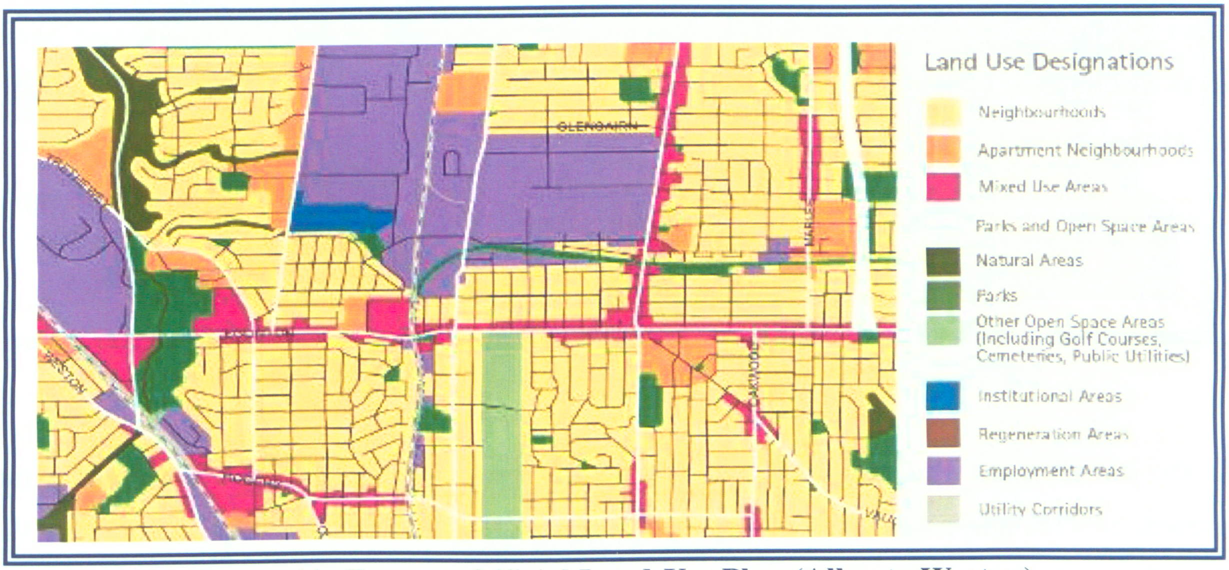


Figure 22: Toronto Official Land-Use Plan (Allen to Weston)

Land-use characteristics are different from west of Weston Road to Highway 427. Large parcels of natural or green areas and parks exist on both sides of Eglinton Avenue between Pearen Street and Scarlett Road. Beyond Scarlett Road most of the land areas are occupied by apartments, mixed-housing and small-business neighborhoods. Farther west of Scarlett Road to Highway 427, most land uses are residential. There are also some open natural lands with low-density buildings. Also, immediately to the northwest of the proposed ERTL at Renforth, there is a huge employment area that is, in fact, in the vicinity of Pearson International Airport (Figure 23).

Many reports from Peel Region, the City of Mississauga, the former City of York and the City of Etobicoke have demonstrated that increasing population and employment growth are significant reasons for the ERTL to be built. Population and employment growth in the Toronto region (1981-2011) is forecast to be concentrated outside Metropolitan Toronto and distributed 56% to the west.

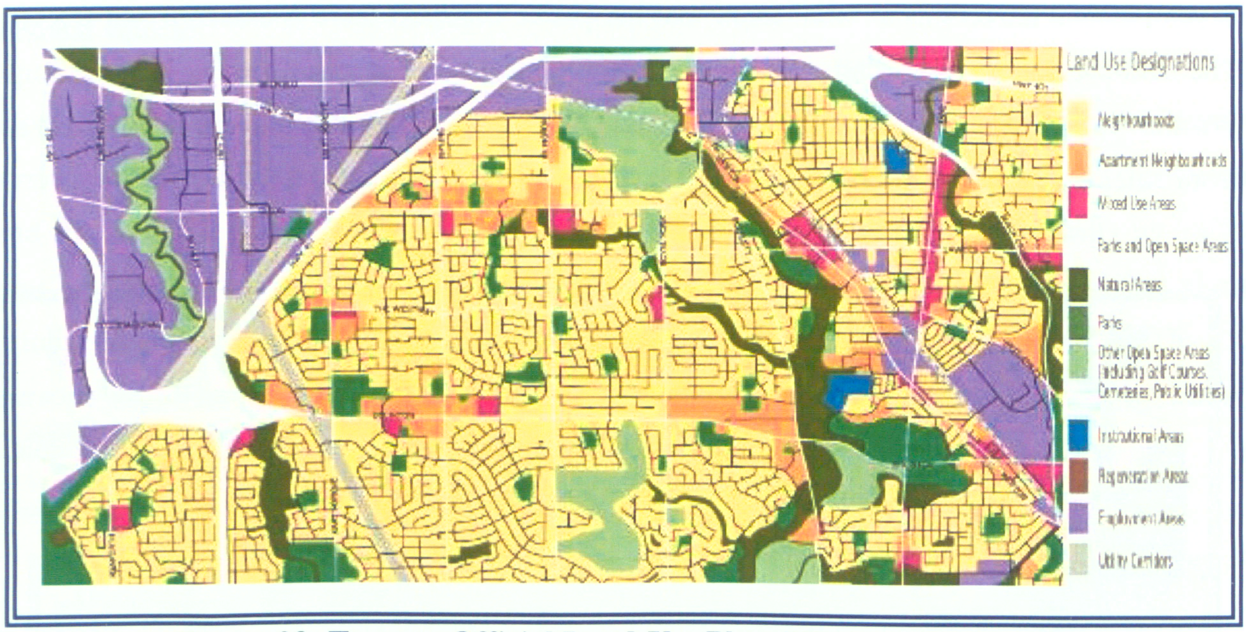


Figure 23: Toronto Official Land-Use Plan (Weston to Renforth)

In the last 10 years, Peel Region has experienced a population growth of 61%, an employment growth of 73% and a labour-force growth of 89%.Current annual ridership on Eglinton West from Renforth Drive to Weston Road is 4.4 million per year, as stated in Toronto's Official Plan, 2005. According to the metro cordon count of 1983, total person trips crossing the west-metro boundary during morning peak hours increased by 63% between 1975 and 1983. Peel Region noted that total eastbound person trips during the morning peak period increased by 76% between 1975 and 1985.

The Mississauga, Peel and Network 2011 Report acknowledges that both the Peel Region road network and the Etobicoke arterial roads are presently at or near capacity, and that there is very little opportunity to increase road capacity at the west-metro boundary. Eglinton Avenue, in the former City of York, is already congested at major intersections from Jane Street to Allen Road. It has been projected that there will be serious capacity deficiencies even with all the available road widening and additional transit capacity in place.

As a result of the current scenario, existing roadway and available transit facilities—along with the increasing rate of population and employment growth in the west metro region—will soon be deemed insufficient, and an accelerated demand for underground railway facilities across the west-metro boundaries is expected. The dominating factors in planning a transit infrastructure are population growth, employment growth, labour-force growth and existing facilities. In the case of the ERTL analysis, the importance of the land-use/transportation interaction has been more than adequately demonstrated.

On the other hand, the new SRTL stations have been ranked very low among 74 subway stations (Table 9).The TTC now has 69 subway stations. Five stations, including Sheppard-Yonge, are served by two subway routes. Passengers are counted entering and leaving each subway route, with 74 station platforms in total. One of the major factors to be noted here is that even at the two end-node stations, most of the volume consists of the replacement volume of former bus riders.

Stations	Passengers Entering/Leaving Each Weekday	Rank of 74 TTC Subway Station
Sheppard	32,600	23
Bayview	5,050	69
Bessarion	1,850	73
Leslie	4,150	71
Don Mills	25,740	32

Table 9: SRTL Ranking

Although the TTC is putting forward many good ideas in terms of rapid-transit expansion, these efforts appears to be progressing towards meeting intra-zonal travel demands rather than being at an inter-zonal level. The need to have an infrastructure that would provide a better link to the surrounding regions is greater, since Toronto is a CBD and more employment attraction lies within the city. Ever-increasing land development, however, is found in the surrounding regions. Therefore, to connect this new, huge development to the CBD, infrastructure that would not only meet the travel demands of the city but would also connect the developing regions to Toronto is essential.

Conclusion

The issue of environmental hazards contributed by urban land development and auto dependence is global in nature because pollution has no boundaries. However, looking at the specific situation of the City of Toronto, the population, employment and labour force are all growing, and their settlement has not been coordinated with the transit infrastructure. As a result, auto dependence dominates the major travel mode. With the increasing numbers in vehicle ownership, there has been a higher rate of trip generation within the City of Toronto, where 70% of all trips are made by cars. As a result, the risks pertaining to vehicle emissions are constantly with us. These risks pertain to the health of the general public and to the environment as a whole.

Although various remedial measures from different sectors have been taken to counteract the environmental issues, but the importance of land-use/transportation integration is still at midpoint. The concept of reducing auto dependence is vital and requires planners, decision makers and government bodies to rethink the way our communities are designed. Having absolute community structure or more complete urban development would not only reduce car dependence and use but would also provide better and improved transportation choices to society as a whole. Improved transportation planning along with land-use and development planning must be under one umbrella, and turning this concept into reality would be of incalculable benefit to society.

In the case of PD1, a relatively low proportion of vehicle owners is making the highest number of auto trips among all districts. On the other hand, the construction of the Sheppard Rapid Transit expansion, which was carried out in the lower-ranked corridor among all the subway stations in Toronto, and the massive residential development along Yonge Street between Finch and Sheppard Avenue, have belied the fact that most land development has taken root in the surrounding regions of the City. All these factors indicate the urgency of addressing the land-use/transportation integration from a sound planning standpoint. Toronto, of course, remains the CBD. The truth is, however, that people now living in the surrounding regions are not well served by the public-transit systems currently in place. The communities around Toronto urgently require a transit infrastructure that is well connected to it, and functional in practice so auto dependency can be reduced and so that people's transition to the city core can be facilitated.

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Glossary

AZ: State of Arizona, USA
BC: Province of British Columbia, Canada
CA: Category Analysis
CBD: Central Business District
CH4: Methane
CO_2: Carbon Dioxide
CUTA: Canadian Urban Transportation Association
DMG: Data Management Group
EPA: Environmental Protection Agency
ERTL: Eglinton Rapid Transit Line
GTA: Greater Toronto Area
GGH: Greater Golden Horseshoe
GHG: Greenhouse Gases
HAP: Hazardous Air Pollutants
HH: Household
IDRS: Interactive Data Retrieval System
MCA: Multiple Classification Analysis
NO_x: Nitrogen Oxides
O-D: Origin Destination
O_3: Ozone
PD: Planning Districts
RTES: Rapid Transit Expansion Study
SRTL: Sheppard Rapid Transit Line
TTS: Transportation Tomorrow Survey
TTC: Toronto Transit Commission
UTMS: Urban Transportation Modeling System
VKT: Vehicle Kilometer Traveled
VOC: Volatile Organic Compounds

Appendix A

	PD1	PD2	PD3	PD4	PD5	PD6	PD7	PD8	PD9	PD10	PD11	PD12	PD13	PD14	PD15	PD16
PD1	221131	69751	39092	74940	19976	66547	8954	26315	7126	12301	25142	11282	24598	9545	8584	21728
PD2	71071	109774	31791	12790	3289	7748	4862	21970	4315	6928	5145	1767	4166	957	874	2530
PD3	39390	32136	132514	30938	5777	4988	2693	16196	9905	27500	12479	2778	4564	1053	1131	3770
PD4	74555	12798	31238	156194	24555	20215	1574	6636	3088	9003	23177	6214	10550	2484	1790	7047
PD5	19465	3393	5664	23725	66946	13702	762	2677	1426	4713	12877	13750	24024	2427	3308	10753
PD6	67421	7894	4906	20538	13533	122460	1340	3754	1719	3259	4678	4113	25599	9708	1958	7121
PD7	9121	4827	2673	1519	720	1198	27212	18809	2231	1395	795	221	706	211	104	459
PD8	25994	22040	16580	6599	2641	4009	18210	169838	19118	8623	3652	1335	2725	576	598	2281
PD9	6943	4245	10096	3029	1394	1731	2391	18851	73225	15207	2767	1121	1840	467	468	2295
PD10	12040	6974	27640	8626	4691	3625	1313	9025	15235	99958	17442	4199	4425	596	1450	6141
PD11	25776	5016	12439	22792	12975	4711	652	3844	2786	17416	107330	15111	6486	1031	1399	10876
PD12	10828	1923	3007	6080	13581	4256	234	1313	1020	4126	14654	37623	8487	1128	1653	16958
PD13	24897	4301	4603	10920	23415	25399	666	2667	1895	4434	6840	8524	173796	22088	18270	44821
PD14	9389	956	1118	2529	2263	10189	225	575	477	595	1064	999	22091	31428	6456	5829
PD15	8372	929	1100	1797	3179	1991	129	638	446	1386	1521	1580	18488	6491	45992	14606
PD16	21220	2776	3561	7172	10773	7014	516	2346	2034	6001	10750	17583	45188	5554	14486	155894

O-D Matrix for Total Trips by Planning Districts of Toronto (2001)

Source: TTS

Appendix B

	PD1	PD2	PD3	PD4	PD5	PD6	PD7	PD8	PD9	PD10	PD11	PD12	PD13	PD14	PD15	PD16
PD1	62847	34203	22743	36348	8866	32679	3875	12983	3638	6576	15758	5973	13798	4407	4501	11941
PD2	33162	17566	8874	5222	1255	3201	1111	4197	1118	2110	1836	502	1603	294	221	465
PD3	22393	8693	26170	7259	1246	1882	544	3227	2186	6192	2825	378	1371	247	172	488
PD4	34954	5220	7350	16402	4665	5415	400	2040	879	2035	6078	1509	2659	617	526	1491
PD5	8636	1321	1356	4426	6943	2795	154	504	249	976	1782	2358	3577	466	442	1459
PD6	32518	3426	1832	5186	2854	22057	173	1073	414	1003	1638	734	5641	1357	609	1666
PD7	3763	1184	558	363	154	223	3271	2310	390	265	93	38	129	34	51	39
PD8	12807	4328	3095	2161	541	1164	2353	11055	2501	1420	643	152	595	105	59	207
PD9	3463	1079	2143	806	232	393	397	2765	6889	3226	310	186	227	38	67	116
PD10	6256	2246	6494	2057	965	1174	254	1520	3046	17329	4028	993	962	82	285	888
PD11	16005	1753	2726	5957	1925	1651	93	693	445	3850	10845	2427	1242	140	239	2470
PD12	5714	538	386	1538	2450	796	38	174	150	1087	2556	3183	1299	187	125	2024
PD13	13787	1610	1329	2821	3623	5700	103	580	269	1027	1340	1320	25506	3804	2487	7541
PD14	4250	251	276	559	439	1270	34	78	52	87	171	223	3867	2417	1020	766
PD15	4199	179	234	479	421	595	51	64	82	263	263	170	2943	1121	3072	1954
PD16	11499	455	494	1398	1418	1642	53	171	133	964	2391	2018	7287	938	2146	15742

O-D Matrix for Transit Trips by Planning Districts of Toronto (2001)

Source: TTS

Appendix C

	PD1	PD2	PD3	PD4	PD5	PD6	PD7	PD8	PD9	PD10	PD11	PD12	PD13	PD14	PD15	PD16
PD1	158284	35548	16349	38592	11110	33868	5079	13332	3488	5725	9384	5309	10800	5138	4083	9787
PD2	37909	92208	22917	7568	2034	4547	3751	17773	3197	4818	3309	1265	2563	663	653	2065
PD3	16997	23443	106344	23679	4531	3106	2149	12969	7719	21308	9654	2400	3193	806	959	3282
PD4	39601	7578	23888	139792	19890	14800	1174	4596	2209	6968	17099	4705	7891	1867	1264	5556
PD5	10829	2072	4308	19299	60003	10907	608	2173	1177	3737	11095	11392	20447	1961	2866	9294
PD6	34903	4468	3074	15352	10679	100403	1167	2681	1305	2256	3040	3379	19958	8351	1349	5455
PD7	5358	3643	2115	1156	566	975	23941	16499	1841	1130	702	183	577	177	53	420
PD8	13187	17712	13485	4438	2100	2845	15857	158783	16617	7203	3009	1183	2130	471	539	2074
PD9	3480	3166	7953	2223	1162	1338	1994	16086	66336	11981	2457	935	1613	429	401	2179
PD10	5784	4728	21146	6569	3726	2451	1059	7505	12189	82629	13414	3206	3463	514	1165	5253
PD11	9771	3263	9713	16835	11050	3060	559	3151	2341	13566	96485	12684	5244	891	1160	8406
PD12	5114	1385	2621	4542	11131	3460	196	1139	870	3039	12098	34440	7188	941	1528	14934
PD13	11110	2691	3274	8099	19792	19699	563	2087	1626	3407	5500	7204	148290	18284	15783	37280
PD14	5139	705	842	1970	1824	8919	191	497	425	508	893	776	18224	29011	5436	5063
PD15	4173	750	866	1318	2758	1396	78	574	364	1123	1258	1410	15545	5370	42920	12652
PD16	9721	2321	3067	5774	9355	5372	463	2175	1901	5037	8359	15565	37901	4616	12340	140152

O-D Matrix for Auto Trips by Planning Districts of Toronto (2001)

Source: TTS

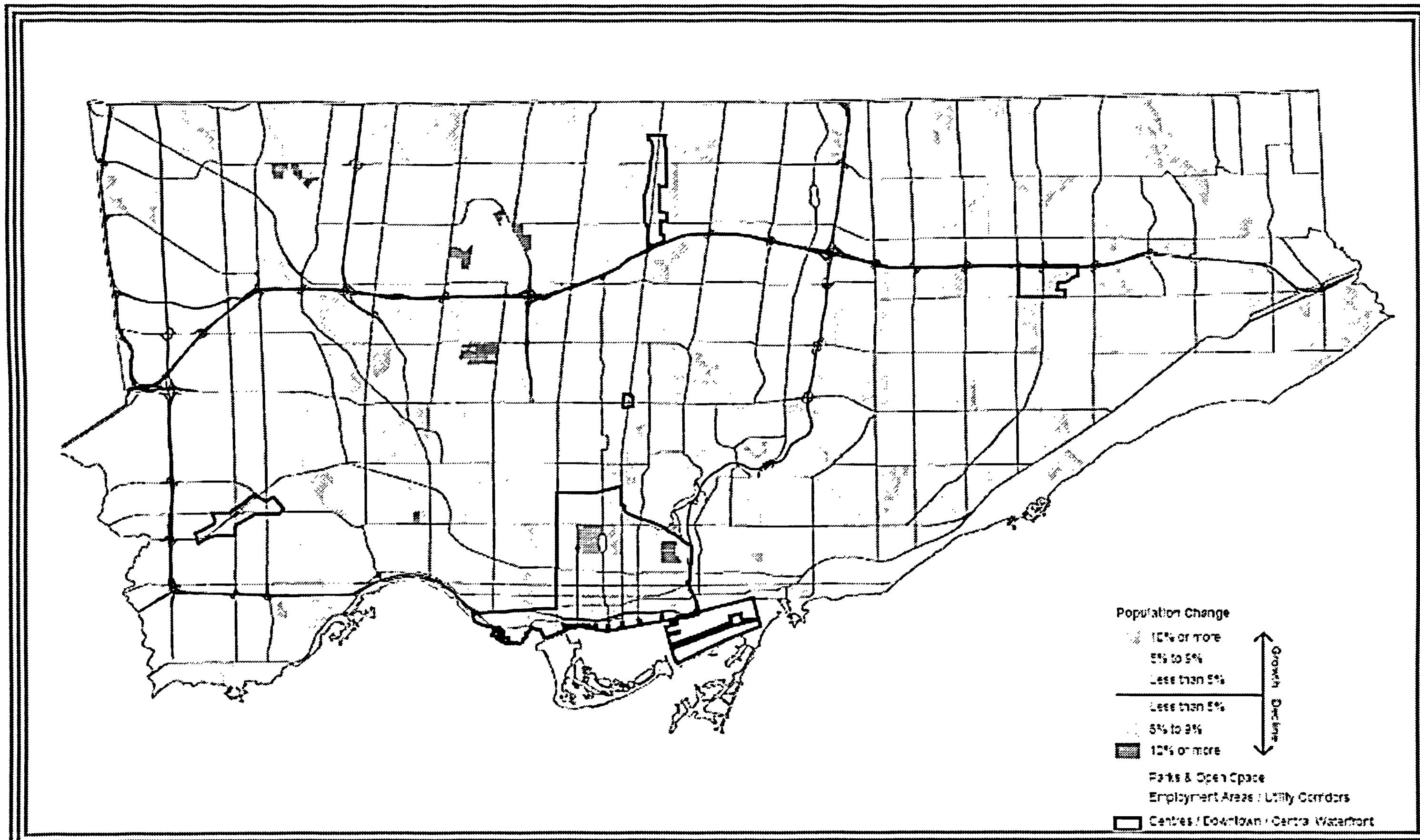
Appendix D

Total Number of Trips and Households

	HH Size	Vehicles/Household						Total	Alpha
		0	1	2	3	4	5+		
Trips	1	194075	198018	113399	71831	29357	16129	622809	
Households	1	123744	63887	27111	13963	5099	1987	235791	
Trip Rate	1	1.57	3.10	4.18	5.14	5.76	8.12	2.64	-2.41
Trips	2	345707	679484	447498	425888	179739	84204	2162520	
Households	2	124692	152068	77359	60618	22778	9097	446612	
Trip Rate	2	2.77	4.47	5.78	7.03	7.89	9.26	4.84	-0.21
Trips	3	20236	385070	352637	472508	221421	106258	1558130	
Households	3	6299	72606	51345	53336	21643	9276	214505	
Trip Rate	3	3.21	5.30	6.87	8.86	10.23	11.46	7.26	2.21
Trips	4	2326	25930	81584	114847	66019	45425	336131	
Households	4	824	4586	11174	12074	5854	3513	38025	
Trip Rate	4	2.82	5.65	7.30	9.51	11.28	12.93	8.84	3.79
Trips	5	371	3075	7901	26525	16485	14907	69264	
Households	5	132	664	1070	2571	1440	1057	6934	
Trip Rate	5	2.81	4.63	7.38	10.32	11.45	14.10	9.99	4.94
Trips	6+	204	1178	2688	2740	5124	3111	15045	
Households	6+	51	197	306	270	380	181	1385	
Trip Rate	6+	4.00	5.98	8.78	10.15	13.48	17.19	10.86	5.81
Total Trips		562919	1292755	1005707	1114339	518145	270034	4763899	
Total Households		255742	294008	168365	142832	57194	25111	943252	
Trip Rate		2.20	4.40	5.97	7.80	9.06	10.75	U = 5.05	
Beta		-2.85	-0.65	0.92	2.75	4.01	5.70		

Tabulation for Category and Multiple Classification Analysis City of Toronto (2001)

Appendix E



Population Change 1996 to 2001 City of Toronto
Source: Statistics Canada, 2001 Census