Equity Implications of Cordon Pricing in Downtown Toronto

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

The City of Toronto has done much to reduce congestion through transportation system management and travel demand measures. Yet, while measures to eliminate the traffic congestion problem have been necessary, they simply have not been sufficient to accommodate over 2.5 million residents and the many more who find their way into the area from points beyond particularly from other regions in the Greater Toronto Area (GTA). In addition, the transportation improvements certainly do not provide capacity adequate to address the needs of the future predicted residents and added economic activity.

Congestion pricing is an untapped transportation strategy that can reduce traffic congestion, improve air quality, and raise the revenue essential to implement needed transportation measures that are effective in improving transportation services and facilities. While experience with congestion pricing is limited, there are sufficient examples and experiences around the world to demonstrate that, when implemented properly, it virtually never fails to be an effective tool to curb congestion. Yet, when initially proposed, it never fails to be controversial. This is due in part to the lack of research on the equity impacts on different socio-economic groups. This is the dichotomy and the dilemma of congestion pricing that every city must face in seeking this new approach to congestion management.

The main goal of the research is to provide empirical research that enhances our understanding of the equity implications of cordon pricing for the urban region of Toronto, Canada. Three research objectives are identified to address the research goal. The first objective is to examine the ways that the GTA is moving toward or away the principles of sustainable transportation, and thus to make a case that Downtown Toronto is a candidate for cordon pricing. The second objective is to investigate if particular socio-economic groups would be disproportionately affected by the implementation of cordon pricing in Downtown Toronto, as one way of approaching the equity dimensions of such a policy. The third objective is to explore some of the policy aspects associated with implementing cordon pricing in Toronto, including public perceptions of such a policy as well as probable responses to the policy.

The major findings of this analysis are that the GTA is not moving in the direction of sustainable transportation, which provides a concrete justification for demand-management interventions and that Downtown Toronto is a candidate for cordon pricing. A Downtown Toronto cordon pricing scheme would be progressive in its effects on the various socio-economic groups, and that the progressivity holds up even when travel is disaggregated by demographic factors such as age, gender, household size and occupational category. Full-time workers account for a larger proportion of the affected trips and the percentage of trips that would be affected is highest for those in the full-time high-income neighborhoods. The analyses show that toll charge is an important factor that would trigger some income groups to change their travel behaviour. People from high-income neighborhoods are more willing to pay the charges and drive as usual than people from other income neighborhoods. Revenue redistribution is critical to assess and achieve equity of congestion pricing.

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I am most indebted to my best friend Dr. Ashad Hamida for his time, dedication, advice, and personal support over more than four years. He gave me a lot of encouragements and unconditional support.

Above all, my deep gratitude goes to my wife Dr. Esmat Zaidan and my children Rawan, Mira, Abdelrahman, Omar, and Adam for their love, understanding, patience, support, and encouragement over the course of all my graduate studies.

Dedication

This dissertation is dedicated to the soul of my father Dr. Othman Ibrahim Abulibdeh. I always dreamed when I grow up to be like you. I can think of no greater honour than to dedicate my own work to you.

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Chapter 1: Problem Statement, Research Questions, and Objectives

1.1 Problem Statement

The second half of the 20th century was a period of rapid population and business growth in Toronto. During this time, the Greater Toronto Area (GTA) in general, and the City of Toronto in particular, succeeded in developing different policies to manage the growing demand for travel. In particular, transit investments were encouraged over adding road capacity resulting from new construction. In spite of these policies, congestion has increased (Miller and Shalaby, 2003). Indeed, the travel trend in the GTA has moved towards increased dependence on the automobile. For example, single occupancy vehicles (SOV) have increased from 75 percent to 85 percent during the period 1981-2006 (Metrloinx, 2008a). The main issues that have contributed to elevated congestion on roads include an increased reliance on private cars for personal mobility, the growth in demand for personal travel and transportation infrastructure at a rate higher than population growth, a reduction in transit modal split and per capita ridership, and an increase in urban sprawl and decentralization of economic activity away from the Central Business District (CBD) of the City of Toronto, with this area losing dominance as the main origin/destination for employment (Miller and Shalaby, 2003; Miller et al., 2004; Buliung and Kanaroglou, 2002).

The possibility of implementing transportation demand management (TDM) in the GTA has received considerable attention during the last five years. Momentum is building in response to deteriorating traffic conditions, the launch of the Smart Commute Program, growing environmental concerns, and the success of high occupancy vehicles (HOV) lanes on Highways 404 and 403. TDM can make more efficient use of the existing transportation system in the GTA and generate additional revenue to help maintain transportation infrastructure (Stewart and Pringle, 1997).

In their report *Climate Change, Clean Air and Sustainable Energy Action Plan: Moving from Framework to Action* to the City of Toronto, Butts and Pennachetti (2007: p10) stated that "the City will work with the Province [and other local authorities] to investigate a road pricing regime for the GTA that will encourage people to use alternative modes of transportation and dedicate any funds raised to transit improvements." Also, the City of Toronto recommended in the study *Blueprint for Fiscal Stability and Economic Prosperity – A Call for Action* (2008) that a tolling system must be implemented on all arterials around the City of Toronto. Several newspaper articles, professional studies, and public opinion polls also have discussed the potential of congestion pricing as a tool to reduce traffic congestion and mitigate environmental damages in the Toronto region. Some emphasize the virtues of congestion pricing, while others consider it to be a form of luxury tax that is not effective in achieving stated goals (Lindsey, 2007; Grush, 2009; Kitchen, 2008; The Star, 2007; Toronto life, 2007).

Although congestion pricing has been suggested in many studies as an effective tool to relieve congestion, protect the environment, and generate revenue, it has not been implemented anywhere in Canada. None of the academic or governmental studies have analyzed the feasibility of implementing congestion pricing in the GTA, particularly its equity implications. Elected officials are reluctant to support the implementation of congestion pricing without a thorough consideration of its implications on equity, traffic, businesses, the environment, and the economy. Therefore, there is a research gap and public need for this type of research.

Based on both theoretical and empirical studies in cities as diverse as London and Singapore, it is believed that congestion pricing differentially impacts various population segments. This is mainly attributed to the differential incidence of benefits received and costs borne among different subgroups. The implementation of congestion pricing can influence the costs of travel by different modes of transportation according to the type and location of journey with subsequent implications for the travel behavior of different income groups. Therefore, concerns about inequitable impacts of congestion pricing can affect the success or failure in moving forward with the implementation of such an approach.

1.2.1 Road Congestion in the GTA

Road congestion in the GTA is receiving continuous and ever-increasing attention in the academic literature and government reports, mainly driven by the gap between investment in transportation facilities and services and population growth (e.g., Kriger et al., 2007; Soberman, 2008; Lindsey, 2007, 2008; Iannuzziello, 2007; Foo and Hall., 2008; Transport Canada, 2006a, Metrloinx, 2008a; Kitchen, 2008; Break, 2007; Grush, 2007). Public transportation and freeways in Toronto are heavily congested. In the GTA, the average commuting time is considered the highest in Canada (Lindsey, 2008), and congestion and its negative consequences on the economy are considered a serious problem. Congestion costs were estimated by different studies to range between $0.9 billion and $4 billion annually (Soberman et al., 2006; Toronto City Summit Alliance, 2007; Transport Canada, 2006b). The economic burden of congestion is estimated at $6 billion, where $2.7 billion represents the lost opportunities from economic expansion and $3.3 billion pertain to the negative impacts on commuters. This cost may double in the next 20 years if the traffic congestion problem is not solved (Metrolinx, 2008b). Table 1.1 provides a summary of the demand and supply of transport in the GTA for the period from 1986 to 2001 and the projected future until the year 2031.

Table 1. 1: GTA transportation demand, supply, performance trends (1986-2031). Source: Toronto City Summit Alliance (2007, pages 4, 6)

Indicator	1986	2001	2031	Change (1986-2031)
Demand				
Total Motorized Trips (AM Peak Period)	1,701,500	2,307,200	3,462,700	103%
Transit Trips (AM Peak Period)	425,300	425,000	620,900	46%
Vehicle-Kilometres Travelled (AM Peak Hour)	6,715,000	11,967,000	16,885,000	150%
Transit Passenger-km Travelled (AM Peak Hour)	1,704,000	2,128,000	3,903,000	129%
Supply				
Road Lane-km	19,600	30,000	33,100	69%
Highway Lane-km	2,600	3,600	4,900	88%
Performance				
Transit Modal Split (AM Peak Period)	24.9%	18.4%	18.2%	-27%
Average Auto Travel Time (AM Peak Period)	18 min	24 min		
Average Transit Travel Time (AM Peak Period)	43 min	54 min		
Average Auto Trip Distance (km) (AM Peak Period)	5.2	6.4	5.9	13%
Average Transit Trip Distance (km) (AM Peak Period)	4.0	5.0	6.3	58%
Average Auto Speed (AM Peak Period)	17.3 km/h	16 km/h		
Socio-Economic				
Population	4,180,000	5,594,000	8,620,000	106%
Employment	2,114,000	2,885,000	4,330,000	105%

As transportation supply is not growing at the same rate as transportation demand, the transportation system in the Toronto area is becoming less capable of achieving the required service level and delivering necessary capacity (Toronto City Summit Alliance, 2007). Metrolinx (2008b) calculated the amount of extra time resulting from traffic congestion in Toronto based on the Travel Time Index (TTI), which it defined by Motrolinx (2008b, p. 8) as “the ratio of peak period travel time to free-flow travel time”. The TTI for Toronto is 1.88, which means 88% extra time is needed to travel during the peak-period compared to free-flow conditions. The high traffic volume has resulted in the reduction of travel speeds ranging between 19 and 39% compared to regular traffic conditions. Total average time spent commuting increased by 36% as a result of these slower speeds and longer average travel distances. In addition, the transit modal split decreased from 25% to 18% during the period 1981- 2001 (Metrolinx, 2008c; Toronto City Summit Alliance, 2007). Table 1.2 provides an overview of the changes in travel demand and patterns and shows that the transportation system in the GTA is not meeting the needs of its populations and businesses.

Table 1. 2: Travel activities in the GTA (Metrolinx, 2008c; IBI, 2007; the City of Toronto, 2009a; Kennedy, 2002; Metrolinx, 2008c, 2008d, 2008e; Toronto City Summit Alliance, 2007).

Increase in person trips	On a typical week-day, morning peak-period increased from 1.9 to 2.6 million person-trips during the period 1986–2001. Automobile trips represent about 83% of the total trips. The dominance of these trips is towards the City of Toronto given its high employment rate.
Low vehicle occupancy	In 2006, almost nine out of 10 vehicles leaving the City of Toronto in the evening peak-period had only one occupant.
Trips flow in the GTA	Drivers make over 100,000 trips each morning during the peak-period driving into Downtown Toronto. Intra-regional travel (trip origin/destination within the same region) comprises 75% of the overall trips in morning peak-period. Trips from Toronto to the other regions in the GTA comprise 18% of the total trips.
Low transit ridership	The transit mode split for trips in Toronto is approximately 30%, compared to 4% within the other regions in the GTA.
Freight movement	Freight movement averages 248,100 trips per day within the City of Toronto alone

1.2 Congestion pricing: An Overview

Congestion pricing is the policy of charging drivers a user fee for using certain lanes of roadways that experience congestion, thereby discouraging many drivers from using those lanes and keeping them free of congestion (Gifford and Stalebrink, 2001, Black 2010). Congestion pricing captures congestion, operating and capital, and environmental costs of vehicle use; therefore, it is considered the best way to deal with congestion and environmental problems (Kitchen, 2008). The main purpose of congestion pricing is to mitigate/manage traffic congestion by encouraging drivers to switch to use other modes of transportation, use other routes, or change time of travel (shifting peak-period travel to other off-peak period) (FHWA, 2006a). One of the objectives of congestion pricing is to reduce the number of congestion points along roads and hence minimize the length of individual queues that do form. This results in relatively smooth traffic flow with improved fuel economy and reductions in emissions (Black 2010).

This research focuses on one type of congestion pricing, which is cordon pricing, as one of various possibly effective measures to manage/mitigate congestion in Downtown Toronto.

The main aim of implementing cordon pricing in Downtown Toronto is to control area-wide congestion as a part of integrated solution to traffic congestion in the GTA. Cordon pricing calls for greater reliance on demand management and on public transportation usage. One aspect of this policy is the restriction of the actual growth of automobile usage through the levy a charge on travelers when they cross the priced zone. Cordon pricing in London and Stockholm have been successful in reducing congestion levels and travel time, and generating revenues to support transport strategies in these two cities. In addition, the traffic and delay reductions have been maintained over time.

Several types of congestion pricing have been implemented in several cities around the world. Recent studies in Europe and Asia envision road pricing in the form of area licensing or cordon tolls (e.g., Hyman and Mayhew, 2002; de Palma et al., 2003; Mun et al., 2003). This system has been implemented recently in Stockholm. Cordon pricing charges motorists whenever they pass any of the charging points that are located at the entrances of an imaginary zone around a congested area. Charges are flexible, meaning that they vary according to vehicle type, time of day, location, and direction traveled (NCHRP, 1994). The charges vary between peak and off-peak hours, and between weekdays and weekends. This system is chosen in this study because it has proven to be effective in mitigating congestion (May et al., 2002).

From the literature we know that congestion pricing impacts the travel activities of different socio-economic groups in different ways, albeit in varying ways depending on the circumstances. What we do not know, however, is the impact of cordon pricing on travelers if implemented in a North American city. Cordon pricing has been implemented in some European and Asian cities and has been proposed, but not implemented for North American cities. It is therefore difficult to anticipate to equity effects of cordon pricing, which is an important consideration. All the studies investigated the changes that may occur on people's travel behaviour and hypothesized different ways of redistributing the generated revenues to achieve equity among different travelers based on their socio-economic characteristics. But none of these studies tried to investigate the traveler's preferences in redistributing the generated revenues to achieve equity between different socio-economic groups.

Concerns about equity are raised when considering this system. Travelers who come from outside the cordon have to pay the tolls while residents inside the cordon receive the benefits; also travelers who must travel into and out of the cordon many times during the day have to pay each time. For example, the proposed cordon pricing in Edinburgh, Scotland, was found to be inequitable since people living at equal distances from the proposed cordon were treated differently. Affluent neighbourhoods were exempted from payment as a result of the city's administrative boundaries. On the other hand, it was suggested that less affluent neighbourhoods be subject to the cordon charges (Raje et al., 2004). This example demonstrates the importance of the link between income distribution and spatial equity when designing cordon pricing systems.

Equity is operationalized in this dissertation by analyzing the progressivity or regressivity of the effects of cordon pricing on groups of travelers based on their socio-economic and demographic factors. Cordon pricing is considered to be regressive or progressive policy if it burdens or favors disadvantaged groups of travelers relative to each other. The interpretation of equity in this dissertation is also based on the broader assessments of transport equity that seek fairness in accessibility and mobility across different socio-economic and demographic groups.

This research stems from an interest in understanding the equity implications of cordon pricing in Downtown Toronto on different travelers based on their socio-economic characteristics. The purpose of the research is to evaluate vertical equity of cordon pricing in Downtown Toronto. The first significant theme of the investigation is the sustainability of the transportation system in the GTA. The significance of this theme is linked to the desirability of applying cordon pricing as a transport policy in Downtown Toronto to manage/mitigate roads congestion in this area. The second theme of the investigation is to determine if particular groups of travelers would be disproportionately affected by the implementation of cordon pricing in Downtown Toronto. People from different socio-economic groups travel to/from Downtown Toronto for different purposes, by different modes of transportation, and through different times during the day and hence may be affected differently. The analysis of the differences in travel activity across these groups gives insight of the potential impacts of cordon pricing on these groups. The third theme of investigation explores perceptions of equity in cordon pricing based on the stated preferences of survey respondents in the GTA.

In transportation planning, equity is a central element because transportation is perceived as a basic right. That is, access to transportation services is a right to members of all social groups within the society. Thus, many scholars have identified equity concerns as one of the main obstacles to public acceptance of congestion pricing proposals.

1.3 Effect of congestion pricing on travelers based on their socio-economic characteristics

Congestion pricing can result in winners and losers among different socio-economic groups. However, different studies differ in their conclusions about who wins and who loses, as shown in Table 1.3, because of different assumptions made. Earlier studies articulated this issue (see May, 1975; Richardson, 1974; Else, 1986; Cohen, 1987; Fridstrom et al., 2000; Langmyhr, 1997; Gomez-Ibanez, 1992; Giuliano, 1994) and concluded that low-income or less-flexible travelers (e.g., based on flexibility of working schedule) are considered the worst-off groups and that the approaches of distributing the generated revenues would not make congestion pricing too regressive as the revenue would be used to benefit those who are left worse off. Recent research focused on addressing the importance of equity issues prior to the implementation of congestion pricing scheme and particularly in the design stage (Mayeres and Proost, 2001; Meng and Yang, 2002; Weinstein and Sciara, 2004; May and Sumalee 2005; Sumalee, 2003; Sumalee et al, 2005; Jones, 2002; Halden, 2003; Eliasson and Mattsson, 2006; Franklin, 2006). Some of these studies proposed a welfare indicator that gives more weight to low-income and disadvantaged groups in terms of cost/benefit ratio. Others proposed a framework for maximizing social welfare (by calculating the optimal road toll) with focusing on spatial equity.

Theoretical studies are different than empirical studies in their conclusions about who wins and who loses. Theoretical studies (e.g., Arnott et al., 1994; Glazer and Niskanen, 2000; Richardson, 1974; Small, 1983; Ecola and Light, 2009; Bhatt et al., 2008; Button and Verhoef, 1998; Giuliano 1992; Johansson and Mattsson 1995; Foster 1975; Richardson and Bae, 1998) focus on whether congestion pricing benefits low income, high income, or both. Different outcomes can be generated based on the assumptions made about different groups in terms of their preferences and travel behaviours. For example, some researchers (e.g., Evans, 1992; Arnott et al., 1994) argue that high income people believe that their time has a higher value than that of low income people and hence they (high income people) benefit the most. In addition, these scholars argue that low income people live in the suburbs and the work destination for many of them is located inside the city. Therefore those scholars consider congestion pricing regressive. Other scholars (e.g., Glazer and Niskanen, 2000) consider congestion pricing as progressive. They argue that the low income group benefits the most from congestion charging since they more often use public transport; hence investing the generated revenue in improving this mode of transportation benefits this group. On the other hand, quantitative (empirical studies) studies have been conducted to study congestion pricing equity for some cities (e.g., Karlstrom and Franklin, 2008; Ramjerdi, 2006; Santos and Rojey, 2004; Yang and Zhang, 2002; Eliasson and Mattsson, 2006; Weinstein and Sciara, 2004; Wilson, 1988; Maruyama and Sumalee, 2006; Eliasson, 2009). Most of these studies conclude that high income people are more negatively affected by a congestion pricing system since they drive more than low income people. Also, high income people tend to live in areas with poor access to public transportation and hence will be more affected by this policy.

Table 1. 3: Winners and losers when road pricing is implemented on an existing road system

Reference	The overall effects	Winners	Losers
Small (1983)	A proper allocation of revenue such as investing in public transportation network and infrastructure or reduce regressive local tax would have better effect on low-income drivers when implementing charging scheme.		Low-income travelers are harmed by the imposition of the charging scheme hence the time saving they would gain would not compensate what they pay.
Hau, 1992; Else, 1986; Giuliano, 1992		High-income travelers	
Gomez-Ibafiez (1992)		Car travelers changing their mode of transportation to public transit if time savings of these facilities are substantial	
Flowerdew (1993)	Road pricing would not be too regressive as the revenue would be used to benefit those who are left worse off.		Those who work in the charged area, drivers with low values of time, solo drivers or travelers in vehicles with lower occupancy, travelers that do not have time flexibility, and those who cannot switch to other modes of transportation to avoid charges.
Richardson, 1974; Evans, 1992; Arnott et al., 1994; Small, 1983; Moses and Williamson, 1963	Congestion pricing will be regressive as the monetary value of time for high-income travelers is greater than those of low-income and hence they are more willing to pay the charges as they feel that their time gain is worth the fees		High-income travelers working in small economic margins suffer more from congestion pricing as they cannot avoid the charges levied during peak hours as they have inferior possibilities to decide their time of work
MVA (1995)	Identified few regressive effects of cordon pricing in London since high-income travelers use their own cars in their commuting more often than low-income travelers.		Even though low-income travelers benefit as a group from this policy, yet low-income individuals who cannot switch to other modes of transportation and still needed to use their cars would be severely affected.
Langmyhr (1997)		Travelers valuing the time savings higher than the fee. Persons now finding it ‘profitable’ to undertake a trip (or change trip timing, route or mode choice), even with a fee, because the travel time will be reduced. Public transport passengers experiencing time savings. Commercial enterprises which	Travelers valuing the time savings below the fee, but having only unattractive travel alternatives. Persons abstaining from travel or changing to less attractive travel times, routes or modes to avoid fee. Persons experiencing congestion on a road or on public transport, caused by persons who have changed travel behaviour to avoid fee.

Reference	The overall effects	Winners	Losers
		undertake substantial transport activities	
Leeds City Council (2000)	Road pricing is progressive rather than regressive as low-income group benefit more as they tend to use public transportation more often. The final effect of this system would be progressive if the generated revenues are distributed on improving public transportation, enhancing cycling and walking, and enhancing traffic calming.	Those who currently use other modes of transportation than cars in their daily commuting. Those who have a high value of time.	who encounter increase in travel cost or take more time as a result of using alternative modes of transportation as well as those who have lower value of time and continue to travel by cars and hence time benefits are not offset by the cost of the charges.
Transport for London (2002)		Public transportation users would all be winners because they reap the benefits of low road congestion and the improvements in public transportation network without paying the charges.	Travelers that pay the standard charges will be the losers because they will most likely experience reduced road congestion and increase in travel speed that are not sufficient to offset the financial loss of the fees. Those who transfer to use public transportation as they are not traveling by their preferred mode of transportation.
Franklin (2005)	Progressivity or regressivity of such a policy is mainly related to the choice of the method of allocating the generated revenue. Neglecting the refund scheme, the welfare effects of the policy are borne largely by high-income travelers as they are predominantly car users, and therefore the scheme itself tends to be progressive.		low-income travelers who use their cars also bear a high burden
Eliasson and Mattsson, 2006			high-income travelers are more likely to live in the suburban areas outside the city core in areas where public transport is poor
Karlstrom and Franklin, 2008; Ramjerdi, 2006; Santos and Rojey, 2004; Yang and Zhang, 2002; Eliasson and Mattsson, 2006; Weinstein and Sciara, 2006; Wilson, 1988; Maruyama and Sumalee, 2006; Eliasson, 2009; Schiller, 1998; Fridstrom et. Al., 2000			High income people are more likely to drive more than low income people and tend to live in areas with poor access to public transportation therefore they will be more likely affected by congestion pricing policy

Differences in conclusions about who may win and who may lose can be attributed to two main reasons which are researcher's background and the methods used in the analysis. Geographers have long held interest in addressing the challenges that urban commuting poses to society (e.g., Berry and Gillard, 1977; Taaffe et al., 1963; Horner, 2004; Wilson, 1974; Clark and Burt, 1980; Wang, 2000, 2003; Black, 2003; Rodrigue et al., 2006). Geographers focus on spatial dimensions when addressing commuting problems. The spatial separation of people's origin (e.g., home) and destination (e.g., work) and the prevailing urban structure influence people's commute. Several geographers, as a result, focused on addressing, theoretically and empirically, the connection between travel patterns and land use (Giuliano and Small, 1993; Levine, 1998; O'Kelly and Mikelbank, 2002). Therefore, in assessing the equity implications of transportation in general and congestion pricing in particular, geographers, as well as transport planners, look at those who may be disadvantaged (e.g., because of age, gender, disability, income) with respect to transportation. In terms of congestion pricing, it is important for geographers to know where people live since some neighbourhoods may burden charges more than others. Traffic engineers, on the other hand, are concerned more with system efficiency more than system equity (Deka, 2004). They seek to enhance transportation infrastructure to increase roadway capacity and to improve traffic flow to maximize tangible benefits for a given cost (Deka, 2004; Horner, 2004). Economists tend to group people based on their income level and are concerned with the distribution of costs and benefits among these groups to assess the equity implications of transportation and congestion pricing.

The second reason is the methods used in the analysis. Different empirical approaches and analytical techniques were used in addressing equity in terms of congestion pricing. These techniques can be grouped into three different categories which are: mathematical models, GIS, and key-interviews and surveys. Mathematical models are built to address different aspects of equity. Numerous data is used such as origin/destination, travel time, gender, income, location, car ownership, and family situation and occupational status. However, the results of some studies that used this approach are contradictory. The second approach is the use of Geographic Information System (GIS). This approach was used by many geographical scholars to address the impact of transportation on the environment and on the society as a whole. GIS is used in commute studies because it has the capability of handling the spatial data that is important in road network modeling process which is vital for computing streets-based measures of both distance between zones and travel time (Horner, 2004; Miller and Shaw, 2001). Studies that used GIS to address transportation and congestion pricing equity used several types of data such as place of residence, place of work, mode of choice, socioeconomic characteristics, and commuting flows. The third approach used is a combination of key interviews, surveys, and focus groups. This approach is an excellent method to collect information about opinions, meanings, and experiences (Dunn, 2005). It is used frequently as a flexible tool to obtain in-depth information from the respondents. However, this approach is restricted by possible bias introduced by the presence of the researcher and researcher's data interpretation and respondents' personal differences in articulation (Babbie, 2001; Creswell, 2003; Walliman, 2006; Dunn, 2005).

1.4 Research Questions and Objectives

This research explores vertical equity implications of a cordon pricing scheme around Downtown Toronto. Vertical equity implies that members of different classes should be treated differently where the distribution of costs and benefits should consider individuals' needs and abilities. It often differentiates among groups based on ability to pay, which is typically measured by an individual's income or wealth.

The main goal of the research is to provide empirical research that would enhance our understanding of the equity implications of cordon pricing for the urban region of Toronto, Canada. Three research objectives and specific research questions relevant to the development of this research are identified to address the research goal as shown in Table 1.4.

Table 1. 4: Research objectives and questions

Objectives	**Research questions**
To examine the ways that the GTA is moving toward or away the principles of sustainable transportation, and thus to make a case that Downtown Toronto is a candidate for cordon pricing.	- What evidence is there for supporting the assertion that the GTA is moving in the direction of sustainable transportation? What evidence is there for refuting this assertion? - How travel activity in the GTA has changed over the period between 1986 and 2006? What is the current distribution of different socio-economic groups in the GTA? - On an average day, how many trips are made from/to the GTA? Who makes them? What are the origins and destinations of these trips? What is the market share of different modes of transportation?
To investigate if particular socio-economic groups would be disproportionately affected by the implementation of cordon pricing in Downtown Toronto, as one way of approaching the equity dimensions of such a policy.	- Which socio-economic groups would be disproportionately affected by the implementation of cordon pricing in Downtown Toronto?
To explore some of the policy aspects associated with implementing cordon pricing in Toronto, including public perceptions of such a policy as well as probable responses to the policy.	- What proportion of GTA drivers are willing to support cordon pricing in Downtown Toronto? What are GTA resident's perceptions of effectiveness of cordon pricing and what they are expecting as personal outcome to be? - What proportion of GTA drivers are willing to pay to save time of their trips to/from Downtown Toronto? How do traveler's household socio-economic characteristics affect their perceptions of their willingness to pay to escape congestion? - How would the implementation of cordon pricing affect GTA drivers' travel behaviour in terms of using their private cars, switch to other modes of transportation, and change their time of travel? - How the distributions of the generated revenue can helps in achieving vertical and spatial equity? - How does household income affect their perceptions of equity in cordon pricing?

1.5 Study Area

The GTA is Canada's largest and fastest growing metropolitan region. Located in Southern Ontario, it has a population of approximately six million. The GTA comprises the City of

Toronto and four regional municipalities (Durham, Halton, Peel, and York) as shown in Figure 1.1. The City of Toronto is the heart of the GTA and is the largest city in Canada. It encompasses six former municipalities which are North York, East York, York, Etobicoke, Scarborough, and Old Toronto. The old City of Toronto covers the area generally known as downtown (City of Toronto website, 2011). The City of Toronto is further subdivided into 16 planning districts (Ghaeli and Hutchinson, 1998). Each regional municipality comprises different towns, townships, cities, and municipalities, and in turn each of these is considered a planning district as classified by the TTS data. The Regional Municipality of Durham includes in its boundaries eight planning districts; the Regional Municipality of York includes in its boundaries nine planning districts; the Regional Municipality of Peel includes three planning districts (Town of Caledon (PD # 34), City of Brampton (PD # 35), and City of Mississauga (PD # 36)); and the Regional Municipality of Halton includes four planning districts.

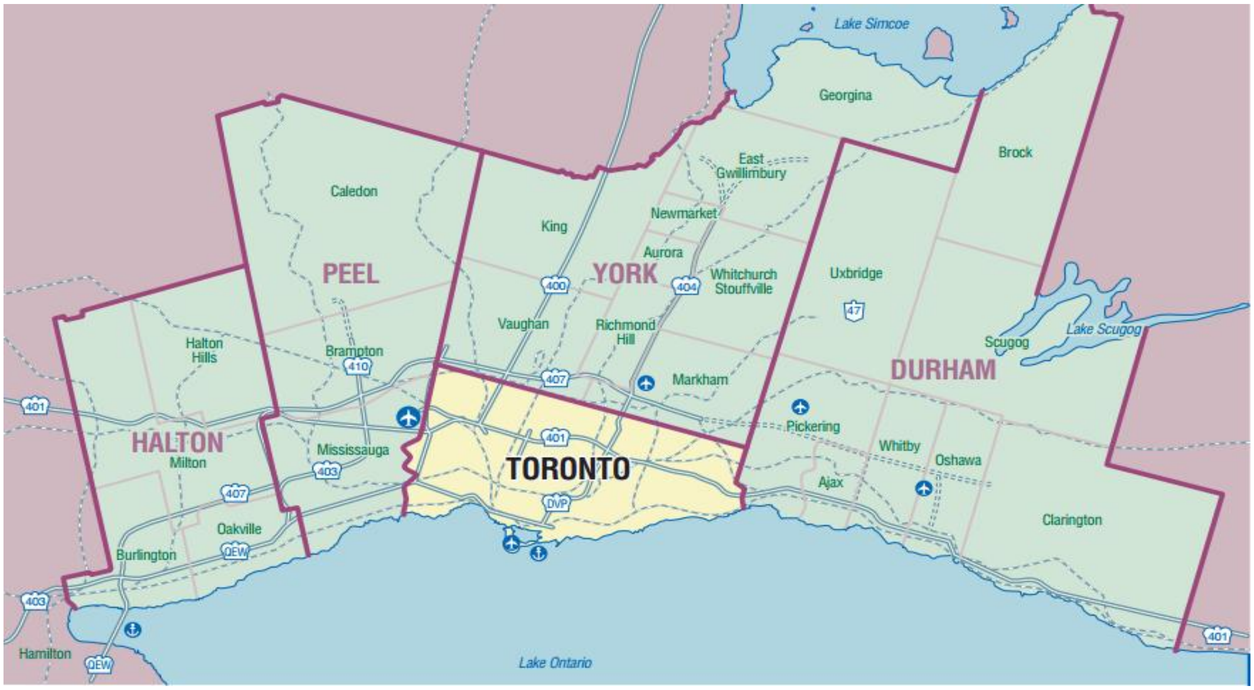

Figure 1. 1: Research site-Greater Toronto Area. (Source: www.toronto.ca[1], 2012)

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[1] http://www.toronto.ca/special_events/pme/pdf/maps/gta_regions.pdf

1.6 Justification for the Study Area

The overall approach that is taken in this study is to define a hypothetical cordon pricing region in the GTA, and then to empirically explore related travel patterns—both as observed in past travel surveys and also as may occur under cordon pricing. Choosing a city for investigation and defining the tolling area are important issues in equity analyses of congestion pricing. As Parkhrst et al. (2006, p. 36) stated "In urban areas, the relationship between gainers, losers and income will depend critically on where different income groups live in relation to the charging areas. This is likely to vary from place to place". Cordon pricing can be progressive, neutral, or regressive (Santos and Rojey, 2004). This is attributed mainly to how different socio-economic groups are spatially distributed in the study area.

The first explanation deals with the choice of the GTA as a focus of investigation. At the international level, Toronto is similar to London, England; Singapore; and to a lesser extent Stockholm, Sweden in terms of population, mobility challenges, and economic activity. Cordon pricing has been implemented in several cities around the world including these cities. On the other hand, the main differences between Toronto and these cities is the public transportation system. There are doubts that Toronto's public transportation system could handle a significant increase in ridership. This is reflected in the current share of commuters using public transit which is 22.5 percent (Transport Canada, 2006c) compared to 85 percent in London before the implementation of area licensing system[2]. This also may affect the modal shifting that could take place.

Also, on the national level, Toronto, Montreal, and Vancouver encounter the highest costs related to traffic congestion in Canada. Not surprisingly, the case for managing/mitigating congestion through congestion pricing appears to be strongest in these cities. However, the cost

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[2] For more information see http://www.streetmanagement.org.uk/

of congestion in the City of Toronto is estimated to be C$1631.7 million dollar per year which is 40 percent and 60 percent higher than the cost of congestion in Montreal and Vancouver respectively (Transport Canada, 2006c).

In terms of the specific cordon area, for the purposes of the this research, the cordon area is in Downtown Toronto, and the boundaries of the proposed zone coincide with Planning District 1 (PD 1), and extend from Jarvis Street on the east, Bathurst Street on the west, Bloor Street on the north, and Lake Ontario on the south with an approximate area of 18 km^2. These boundaries were selected to focus on the employment area which is considered the main destination of many daily trips. The study focuses on commuters that are traveling from the PD1 area to the rest of the City of Toronto and the rest of the GTA and vies versa. The purpose is to focus on travelers who may cross the cordon boundaries in both directions.

The Toronto central area is the largest employment centre in the GTA. The population and employment densities in this area are the largest across the GTA. This area contains the highest and largest cluster of skyscrapers in Canada. In addition this area contains a large concentration of retail stores and the financial district which is the centerpiece of the Canada’s financial industry. These features are not found in any of the core centers of any of the cities or municipalities across the GTA. PD1experienced a renaissance in business improvement and numerous condominiums had been built across the Harbourfront. In comparison to other core cities across the GTA, Downtown Toronto is the largest in area, most populated, and most employed. For example, the total population of Downtown Toronto as of 2006 is 188,668 compared to 30,000 in Downtown Mississuaga which is one of the evolving cities in the GTA (The City of Mississuaga, 2010). In addition, Downtown Toronto is successful market with over 105,000 jobs compared to 20,000 in Mississuaga. The distribution of residential locations of employees working in Toronto city centre shows that about 73% of these employees live within the City of Toronto and the remaining 27% live in other areas throughout the GTA (Soberman, 2008; Bourne, 2003).

The GTA and in particular the Toronto city centre has an extensive multi-modal transportation network. Public transit includes bus routes, rail and long-range bus routes, streetcar lines, three subway corridors. Furthermore, the share of morning commuting trips taken by public transportation in the City of Toronto is the highest among the three cities (Toronto, Montreal, and Vancouver). No area in the Greater Toronto Area surpasses the City of Toronto, particularly the District Centre, in surface transportation capacity – a combination of light, heavy, and commuter rail transit; bus rapid transit; and an extensive freeway network – knitting together a wide array of activity and employment centers. This is an indication about the availability and quality of the public transportation system in the City of Toronto. Improving the current public transportation infrastructure and services by using the generated revenues from cordon pricing enable this mode of transportation to provide viable alternative to driving which is essential for an acceptable and efficient cordon pricing.

Downtown Toronto and traffic congestion have long been synonymous. Most people who live and work in that area are likely to agree that congestion has reached the point of threatening economic activity and quality of life, which have been the essence of the area's appeal.

According to the TTS data, PD1 area is the destination of the highest number of trips originated from the rest of the GTA regions as well as the rest of the City of Toronto. This area is the destination of 12% of the total trips made by all modes of transportation from different regions of the GTA. Semi-regular cordon counts of traffic, which were conducted by the City of Toronto, show that in 2006 more than 180,000 vehicles crossed the boundaries of the PD1 area to/from the rest of the GTA. In addition, the number of person trips to the PD1 area counted for 331,600 persons in 2006 (The City of Toronto, 2007).

Three data sources are used in this study. Transportation Tomorrow Survey (TTS) is the most comprehensive and the largest travel survey conducted in the GTA. This survey is conducted every five years since 1986. In addition, it contains travel information over the entire week (trip origin/destination, travel time and purpose, mode of transportation, etc.) as well as it contains detailed demographic information on all members of a surveyed household (Data Management Group, 2007). The second source of data is Statistics Canada where household income enables comparison across different income groups of travelers. Finally, the third source is a stated preference survey that is conducted by the researcher to examine the potential changes on travel activities of different socio-economic groups of travelers that may occur under cordon pricing if implemented in Downtown Toronto.

1.7 Organization of the dissertation

The dissertation is composed of seven separate but integrated thematic chapters. Chapter One briefly states the problem statement, the research questions, goals and objectives. Chapter Two critically reviews the literature on four main themes: 1) sustainable transportation, 2) congestion pricing, 3) equity, and 4) travel behaviour. Chapter three provides an outline of the conceptual framework and research methodology employed in this research. Chapter four assesses, based on the TTS data, if the GTA is moving toward or away from the principles of sustainable transportation, and if the central Toronto is a candidate for cordon pricing. Chapter five examines, also based on the TTS data, if particular socio-economic groups would be disproportionately affected by the implementation of cordon pricing in PD1. Chapter six discusses the traveler’s perception of the effectiveness of cordon pricing as well as their willingness to support this policy and their expected personal outcomes. This chapter also examines respondents’ willingness to pay to reduce travel time, effect of cordon pricing on their travel behaviour, and their perception of the redistribution of the generated revenues. Finally, chapter seven summarizes the major findings of the study as well as reiterates the research goals and objectives, discusses the academic and practical contributions, and the future research opportunities.

Chapter 2: Research Context

2.1 Introduction

Congestion pricing is a traffic demand management tool that helps move transportation in the direction of economic and environmental sustainability. At the same time, however, it raises equity issues related to social sustainability as it impacts the travel behaviour of commuters. This chapter reviews the literature on four main themes: sustainable transportation, congestion pricing, travel behaviour, and equity.

2.2 Sustainable Transportation

While there has been longstanding concern over the “external effects “of transport (Perrels et al., 2008), a new paradigm – the paradigm of sustainable transportation – has emerged in the past two decades within transportation planning, policy, and research communities. Achieving sustainable transportation is a global aim today. A new era of transportation policy and supporting research has been introduced that seeks to develop and maintain a transport system that goes beyond just enabling people and goods to be mobile. It seeks to achieve this while causing much less social, economic, and environmental damage. One of several aims of this new paradigm is to reduce congestion in cities (Leong et al., 2007).

Sustainable transport is, in some cases, viewed as “anti-automobile” or “anti-highway. Yet, others recognize that the automobile is a means to satisfy the demand of different aspects of people’s everyday lives particularly in North America; as such, much of the research focus is on making this vehicle more efficient, safer, cleaner and less resource intensive. Most proponents of sustainable transport also recognize that highways are a vital component of the system and that they must be improved and reconstructed as required. But expansion or construction of highways will not solve transport problems.

Given that sustainable development has been a global concern since the 1980s, transportation sustainability has become a growing area of interest in practice, research and education (see, for example, OECD, 1996; Gilbert and Tanguay, 2000; Black et al., 2002; Litman, 2003a). In planning for transportation systems, a large number of agencies have adopted sustainability within their mission statements (Jeon, and Amekudzi, 2005). However, defining transportation sustainability and developing indicators to assess sustainability in transportation systems are considered one of the most contentious processes in urban and transport planning. While current visions of sustainable transportation reveal that there is no standard way in which sustainable transportation may be defined or assessed, there seems to be an agreement that advancement should be in three dimensions: economic development, social development, and environmental protection (Jeon, and Amekudzi, 2005). This three dimensional framework for transportation sustainability appears to be the foundation for a number of definitions of sustainable transportation both in practice and in research.

In defining a vision for transportation sustainability and in articulating policies to be adopted in order to achieve this vision, communities and agencies may consider a process based approach in which community representatives and other stakeholders are heavily involved. The next section attempts to explain what is meant by sustainable transport and what is potentially attainable.

2.2.1 Definitions of Sustainable Transport

It is reasonable to start first with definitions of sustainability and sustainable development before reviewing the definitions of sustainable transport that have appeared in the literature over the past fifteen years. This is particularly important because transportation plays an important role in sustainable development as transport activities are resource intensive and have many external costs (Leong et al., 2007), but also potential benefits. The sustainability of a system can be defined as the ability of the system “to continue to be carried on the way it is now without serious difficulties” (OECD, 1996; P 13). Sustainable transportation definition is mainly derived from the definition of sustainable development of the Brundtland Commission (WCED, 1987; p 43) which states that sustainable development is “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. This definition of sustainable development is the dominant approach in transportation planning. Thus, sustainability can be viewed as a guide to humans in their endeavour for a way of creating welfare for current and future generations. Although, there is no standard definition for transportation system sustainability, review of academic and practitioner definitions of sustainable transport system (see Table 2.1) reveals that a consensus is emerging. That is, in order to be effective, a sustainable transport system must comprise impacts on the economy, and environment.

The definitions summarized in Table 2.1 raise the question as to whether a sustainable transport is attainable. Some scholars argue (see, for example, Jeon, and Amekudzi, 2005; Black, 2010) that the major dilemma is not in identifying the ways to solve the problems of a sustainable transport but in identifying how to solve these problems cost effectively. For example, congestion is a serious problem, and it can be solved by applying several ideas (see Garrison and Ward, 2000); however, the major impediment is sufficient funding. Yet, this does not mean that developing a transport system that is more sustainable than the one currently existing is unattainable.

Table 2. 1: Definition of sustainable transport

Source	**Definition of Sustainable Transport**
Daly (1992)	Sustainable transport should ensure that • The rate at which it uses renewable resources does not exceed the rate of regeneration. • The rate at which it uses non-renewable resources does not exceed the rate at which sustainable renewable substitutes can be developed. • Its rate of pollution emission does not exceed the assimilative capacity of the environment.
Gordon (1995, p.2)	Sustainable transport implies three different visions. "The first of these visions centers on changing people and the way they live, the second on changing technology, and the third on changing prices"
ORTEE (1995) Sustainability Indicators: The Transportation Sector, Toronto, Canada.	• Produce outputs, emissions at a level capable of being assimilated by the environment. • Have a low need for inputs of non-renewable resources where non-renewable are used, their use will be for no consumptive investments and they will be recycled when no longer useful or needed. • Minimize disruption of ecological processes, land, and water area.
OECD (1996; P12)	"transportation that does not endanger public health or ecosystems and meets mobility needs consistent with: • use of renewable resources at below their rates of regeneration and • use of non-renewable resources at below the rates of development of renewable substitutes"
TAC (1999) Ottawa. Canada. http://www.tac-atc.ca/english/productsandservices/ui/exec.asp	Sustainable transportation is defined as follows: • In the natural environment: limit emissions and waste that pollute air, soil and water! within the urban area' ability to absorb/recycle/clean provide power to vehicles from renewable or inexhaustible energy sources, such as solar power in the long run; and recycle natural resources used in vehicles and infrastructure , such as steel, plastic, etc. • In society: provide equity of access for people and their goods, in this generation and in all future generations; enhance human health; help support the highest quality of life compatible with available wealth; facilitate urban development at the human scale; limit noise intrusion below levels accepted by communities; and be safe for people and their property. In the economy: be financially affordable in each generation; be designed and operated to maximize economic efficiency. • Minimize economic costs; and help support a strong, vibrant and diverse economy.
TC (2001) Sustainable development strategy 2001–2003, Ottawa, Canada.	Transport Canada has adopted the following principles: • Social principles: safety and health, access and choice, quality of life. • Economic principles: efficiency, cost internalization, affordability. • Environnemental principales: pollution prevention, protection and conservation, environmental stewardship. • Management principles: leadership and integration, precautionary principle, consultation and public participation, accountability.
Litman (2003b)	Sustainable transport, implies finding a proper balance between current and future environmental, social, and economic qualities
Transport Canada (2003a, p. 10)	It is one which provides affordable access to freight and passenger service and does so in an environmentally sound and equitable manner.
The Centre for Sustainable Transportation (2005, p.5)	A sustainable transportation system is one that: • allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations. • is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy. • limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise.
Leong et al. (2007)	Sustainable transportation system is a system that is characterized by its capability of delivering the needed capacity and performance, renewability such as using solar energy, compatibility with the places people want to live in, maintain or improve environmental quality, affordability in terms of costs (e.g., maintenance, operation, capital), and technologically possible.

The various concerns that are identified in the above table include the use of a finite and diminishing petroleum resource, emissions resulting in local and global atmospheric and health problems, excessive crash fatalities and injuries, and traffic congestion. These themes feature prominently in discussions of indicators of sustainable transportation, as discussed next.

2.2.2 Dimensions and Measures of Sustainable Transport

Sustainable transport is mainly measured by a system's effectiveness and efficiency, and its impacts on the economy, environment, and general social well-being. Therefore, sustainability of a transportation system has three pillars or dimensions; the economic, the environmental and the social realm (Figure 2.1). Perrels et al. (2008) argue that expansion in one realm should take into consideration respect for the minimum requirements of the other realms. Moreover, the present use of resources whether natural or man-made should not reduce the welfare per capita of future generations. As sustainability is a holistic concept that encompasses all sectors, the assessment of the degree of progress that transport is making towards achieving sustainability is rooted in an assessment that is two-tiered (Perrels, et al., 2008, p.4):

(1) "The transport system itself has to become appreciably cleaner, substantially reduce its material requirements, be sufficiently productive and should have as few as possible socially adverse effects".

(2) "The way the transport system functions and the alternatives it offers should enable-or at least not disable-other parts of society to remain within its trajectory towards sustainability".

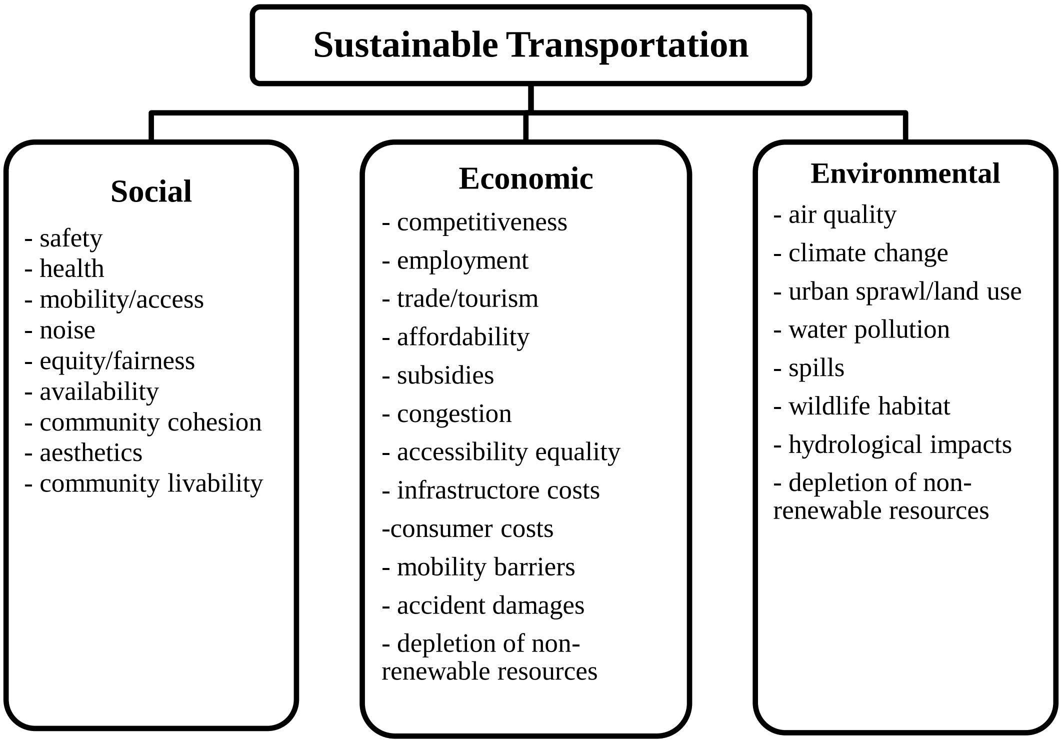


Figure 2. 1: Transportation impact on sustainability.

Consequently, transforming the transportation system into a sustainable one depends on the societal and economic context (point 2) and requires sufficient support of the population and of economic sectors which adds a key challenge to this transformation. Understanding the reservations of the various interest groups requires mapping out the equity effects of a sustainable transport policy. Spatial equity implies avoiding serious restrictions in access for disadvantaged groups and regions. Equity is one of the social dimensions of sustainable transport that may make the transportation system unsustainable. Many researchers (for example, Bae and Mayeres, 2005, Feitelson, 2002; Litman, 1999) conclude that an “equitable system” really maximizes social welfare. In consequence, the present and the future transport system should be planned to be equitable, that is fair, unbiased, and just.

Although there is an ongoing debate worldwide about the indicators that should be used to evaluate progress toward sustainable transportation systems (Johnston, 2007), the indicators would be generally classified in four groups: (1) economic outcome indicators; (2) social outcome and quality of life indicators; (3) environmental outcome indicators (4) system quality indicators. Many researchers have developed indictors to measure possible economic, social, and environmental effects of transport systems (examples, Gilbert and Tanguay, 2000; Litman, 2003a, Himanen, 2008; Steg and Gifford, 2008). Economic indicators listed in these studies include the contribution of the transport system to economic development and welfare, accessibility, macroeconomic changes, GDP, economic efficiency, income distribution, and unemployment rates. Social indicators reflect effects on societal and individual quality of life, such as health and safety. Quality of life (QoL) is a multidimensional concept that refers to the extent to which significant values and needs of individuals are satisfied. According to Steg and Gifford (2008), QoL indicators are crucial for the public acceptability and thus to the feasibility and effectiveness of the transport plans. For example, transport plans aiming at reducing car use may impose restriction on individual freedom of choice and as a sequence such plans may have significant impact on QoL. For equity analysis, indicators can be disaggregated by demographic factors, so impacts of a transport plan on disadvantaged groups (low incomes, people with disabilities, children, etc.) can be compared with overall averages (e.g., Litman, 2005). Environmental indicators measure such variables as energy use, CO_2 emissions, and emissions of toxic and harmful substances, land use, distribution and fragmentation of natural areas, waste, and noise pollution. Lastly, the system quality indicators include commuting speed, congestion delay, availability of quality of transport options for people, accessibility of activities for drivers and non-drivers, and the household expenditures on transport (e.g. Litman, 2003b).

There are currently no standardized sets of indicators for measuring impacts of a transport system on the environment, the economy, and the society. Rather, these indicators need to be defined in terms of goals, objectives, targets, and thresholds.

2.2.3 Unsustainability of Transport System in North America: Trends and Causes

Based on an emerging consensus of the definition of sustainable development, it is clear that the current transportation trends in North America are unsustainable and becoming more unsustainable since they are associated with considerable social, environmental, and economic costs. There are many factors that contribute to unsustainable transportation system in Canada and the USA. The main trend for unsustainable transport in North America is increased automobility. North American society is more strongly adjusted towards the regular use of cars than many European societies. Thus, car dependency (i.e., the level of car use, car-oriented land-use, and quality of travel alternatives; identified in (Steg and Gifford, 2008) is much higher in North America as compared to Europe and indeed most other regions of the world. However, globally, car ownership is increasing, intensifying the trend away from sustainability (Leong et al., 2007). Table 2.2 illustrates the main concerns regarding increased automobility.

Table 2. 2: Main Concerns about Automobility

Automobility	**Main Concerns**
% of Automobility travel of total trips	• 15-30% in the developing countries • 50% in Western Europe • 90% in North America
Distance covered by cars	• Cars are used for distances less that 3 km and more and more people are travelling longer distances • When a car is acquired, most trips are facilitated by automobility
Car fleet increase worldwide	• From 50 million to 580 million vehicles in the last three decades • Five times faster than the population growth in the same period of time
Transport energy (95% of energy comes from oil-based fuels)	• Use about 26% of total world energy in 2004
Automoboility contribution to air polution	• The transport sector as a whole produced 23% of world energy-related CO_2 emissions • 74% of the total transport CO_2 emissions came from road transport
Greenhouse emissions	• the transportation sector is responsible for 27% of U.S. greenhouse gas emissions • 44% of carbon monoxide emissions • 33% of nitrogen oxides • 25% of volatile organic compounds
Impact on city's design	• Cities are organized according the architecture of automobility. • Takes up a huge amount of space (25% of the land in modern cities is a car environment) • Creates congestion and insecurity

Source: The data presented in this table is summarized from *Mobility in Daily Life: Between Freedom and Unfreedom* by Freudendal-Pedersen (2009).

There are many indications that the current transportation system in North American cities is unsustainable. Trip length has been increased as the cities have decentralized, increasing dependency on cars and reducing use of public transit use. The spatial segregation of activities in urban areas also increases trip lengths. In addition, globalisation and the relocation of industry have increased the distribution and fright movement globally, regionally, and locally (Banister, 2005). Automobility is no longer advantageous to economic development (Freudendal-Pedersen, 2009). For example, new road spaces in North America do not create growth, and automobility involves high external costs not related to traditional costs as the maintenance of roads and parking spaces. Thus, addressing the negative impact of transport should take its point of departure from changing transport habits and moving people from private car usage to public transport by improving accessibility rather than mobility. As shown in Figure 2.2, trends in energy use varied significantly amongst countries and regions. In OECD countries, the growth was mostly due to increasing transport energy consumption. In 2005, the transport sector accounted for 35% of total final energy use. It is also shown in Figure 2.2 that the transport sector of the USA and Canada consumes energy equal to half the amount of energy China and India consume whose population exceeds 60% of the world population.

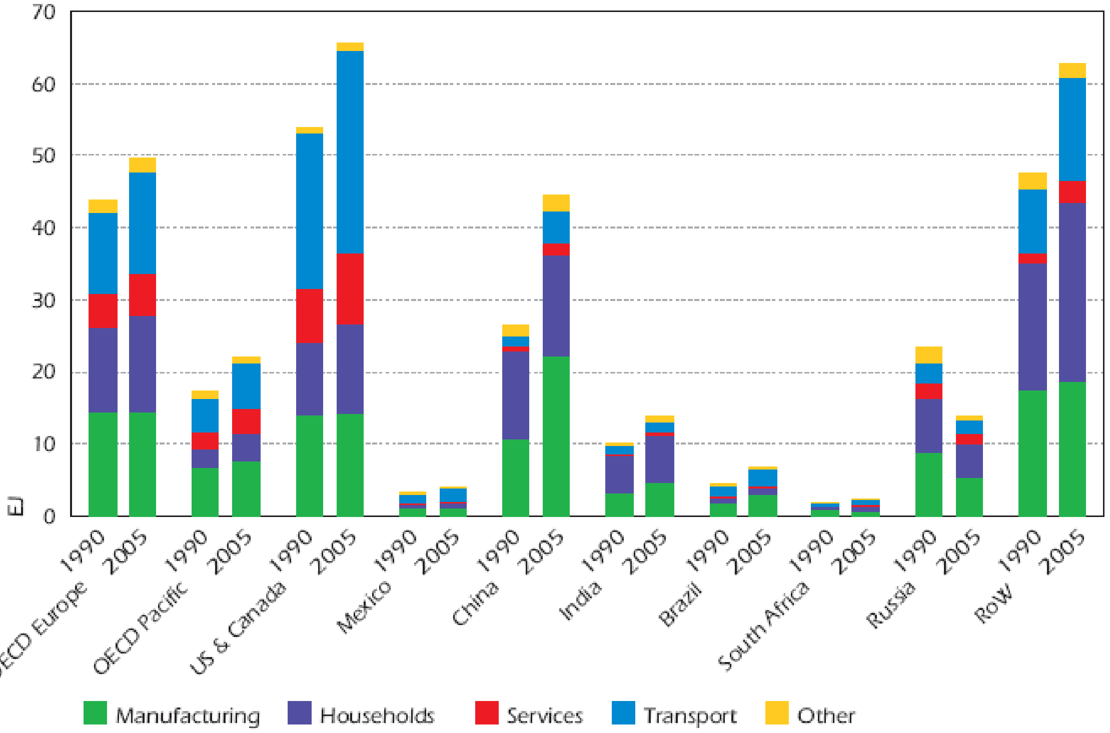


Figure 2. 2: Total Final Energy Consumption by Sector (IEA, 2008)

Furthermore, there are many trends that suggest that North America is moving further away from sustainability. Transport systems in North America are moving towards unsustainability because these systems at present use a fuel that is finite, non-renewable, and fast being depleted. This is true whether this fuel is from conventional or unconventional sources (Black, 2010). Transportation in Canada and the USA has became economically, socially, and environmentally unsustainable. This can be demonstrated from the associated negative health effects from air pollution, an increase in social isolation, reduced economic efficiency, and increased energy costs. The growth of car dependency, truck transport of goods, and air transportation are considered the most serious obstacles to sustainable transportation in Canada. The policies that control urban form and transportation systems do not require consumers to pay the full economic, social, and environmental costs of their transportation or land-use decisions.

2.2.4 Approaches/Solutions for Moving toward Sustainable Transportation

This section provides a brief overview of the various mechanism/approaches that have been adopted as solutions for moving toward sustainable transport in urban areas. These solutions are mainly within the areas of pricing, planning, policy, education, and technology. The possible solutions reviewed in this section are meant to address the problems identified in the previous section, at different levels, with the exception of global warming which requires a global solution, or at least the agreement of key states.

2.2.4.1 Pricing Policies

There are two main approaches for costing/pricing policies. The first implies getting the actual cost of using the different transport modes, particularly the automobile reflected precisely. Some of the indirect costs may be included within the price of the gasoline to make it reveal the actual cost to society of using the automobile. The second approach to pricing solutions includes congestion-free taxing and the use of tolls. Policy solutions may be examined at different levels. For example, speed and speed limit policies may be addressed at different governmental levels: municipalities and localities or states and provinces. Some solutions may be examined at the national level where countries approach sustainability within its borders to improve the situation nationwide and as a consequence contribute in solving the global problems. Examples for these countries are Netherland, United Kingdom, and Canada. Lastly, the role of education is critical in making changes in human behaviour (Black, 2010).

2.2.4.2 Technological Solutions

There are three main sets of technological solutions to move towards sustainable transport. The first set relates to the information and communications technologies and includes telecommuting or teleworking, the several communications alternatives that substitute for travel, and also the role of e-commerce. There is a growing interest in communication technologies (ICT) that reduce the amount of fuel used for travel and transportation. As identified in Black (2010), it is estimated that there are 30 million telecommuters in the United States. Communications over significant distances have always required transportation and at the present there is a potential of substituting telecommunications for travel. Similarly, some studies suggest that e- commerce which is a growing sector of the economy that is greatly changing the ways of in which businesses deal with each other and with consumers may impact the transportation sector. E-commerce or e-services includes e-shopping, e-banking, distance-education, e-entertainment, and e-government services. The United Nations Conference on Trade and Development (2003), claimed that e-commercial trade represented about $43.5 billion in the United States a decade ago, which is 1.34% of the total retail sales. However, there is still a lack of large-scale research that answers questions about how significant e-commerce or telecommuting (teleworking) are contributing to sustainability.

The second set of solutions for moving towards sustainability in transport systems in the long-term relate to the development of alternative fuels that are renewable, less polluting and have less global warming potential. Many studies have examined the use of alternative fuels by using several criteria including cost, availability in the market, fuel attributes, engine modifications, safety, and emissions, (see for example, Gordon, 1991; Nadis and MacKensie, 1993; Mackensie, 1994; Sperling, 1995).

A third set of solutions deals with vehicle engineering and is related to hybrid vehicles, fuels cells and their use in transport, and the prospect role of catalytic converters. There are indications that electric cars, some of which were on sold in limited numbers, are penetrating the market; Ford and Chrysler announced a new model of electric cars in 2011, while Toyota is expected to market a small-battery operated car in the USA in 2012. Unsustainable resources of fossil fuel and the increase focus on limiting CO_2 emissions made looking for other energy resources a priority. Fuel cells are considered as a promising and sustainable option for future transportation. Nevertheless, there are several challenges linked to its production and distribution such as hydrogen purity requirements for use in fuel cells (Ersoz et al., 2006).

Lastly, the fourth set of technological solutions is related to intelligent transport system technologies which are found in almost all urban areas in efforts to better manage the flow of traffic. These technologies do not directly address sustainability issues but they provide a mechanism that improves the flow of traffic, reduces congestion, reduces travel time, decreases the environmental cost of travel (fuel consumption and emissions), and increases safety and mobility, as well as efficiency. Moreover, some intelligent transport system technologies may result in decreasing fatalities from accidents (Black, 2010).

With regard to reducing traffic congestion, ITS can help in different ways, for example by facilitating the implementation of congestion pricing and informing drivers of congestion and route alternatives. There have been major ITS development in different areas such as: the development of automatic restraint systems for passengers and air bags to help minimize injuries. Moreover, the developments of IT systems that adjust the speed of the vehicle to the existing traffic conditions and also keep the vehicle at a safe distance from other vehicles have been developed. Some ITS technologies forewarn the driver if the vehicle is about to collide with other vehicles in order to enable him/her to take over and avoid such crashes. Others provide warning in poor weather conditions, improve vision at night, and prevent excessive speeding. Such ITS systems can make significant contribution to sustainable transportation by reducing crash fatalities and injuries on roads (Black 2010).

2.2.4.3 Behavioural Change Solutions/TDM.

The broad area within transportation planning and engineering related to "travel demand management" (TDM) consists mainly of policies and actions that aim at developing a sustainable transport systems by better managing the demand for travel. It first evolved in the United States as a federal policy initiatives that aimed at improving the efficiency of urban transportation systems by operational improvements. Afterwards, concerns about air quality and energy conservation were integrated into the transportation planning process (Meyer, 1999). As TDM aims at reducing and discouraging individuals' tendency to drive, this in turn decreases fuel consumption, emissions of pollutants, risk of accidents, and traffic congestion, as a consequence providing solutions to multiple problems of sustainable transport system.

Given that the major focus of demand management is to influence the individual travel behaviour of travelers, the first challenge is to find the right mix of incentives and/or disincentives that may promote travelers to change their normal travel practice. Then the second challenge is to implement efficient demand management actions. TDM actions imply an increasing focus on system management activities and the expansion of the process of transportation planning in order to embrace several non-transportation matters including environmental issues. However, due to the increasing high levels of automobile use, the growing number of vehicles available to households, and the reduced average vehicle occupancy in North American urban areas, any serious effort provided to restrict automobile use seems likely to fail (Meyer, 1999). However, Meyer (1999) proposes some strategies to begin the process of attaining public support for the more contentious actions. Such strategies endeavour to link the broad public sense of fairness to public policies that negatively affects individuals' capability or cost to travel by single occupant vehicle. The key means to achieve successful future adoption of TDM actions is linking these actions to the broader goals that the public can support.

In terms of specific actions, Black (2010) and others (e.g., Badland and Schofield 2005; Galante et. Al., 2010) provide inventories that include various initiatives, ranging from traffic calming by using physical devices to slow the movement of traffic particularly in residential areas such as speed pumps to feebates, carpooling, cash-out programs which enables employees to opt for the value of the parking place as additional income in order to promote them to arrange for their own transport to their work places by vans, buses, or carpools, and parking restraint and taxes which are charged for the purpose of increasing the cost of the use of automobiles, thus encouraging people to use other less expensive transportation modes (public transit, biking, or walking).

2.2.4.4 Approaches for Mitigating/Managing Congestion

Over the years, various approaches have been proposed or implemented to curb traffic congestion and improve roadway level of service in many countries around the world. These approaches can be considered under either supply management or traffic demand management. Supply management, which is the conventional response to traffic congestion, consists of different techniques such as increasing roadway capacity by expanding or upgrading existing roads or by building new ones. Conventional approaches focus on managing congestion by maximizing the ability of roads network to accommodate current and future traffic demand. This approach seeks to maximize the physical usage of road capacity to enhance the levels of service.

A second method is by using different traffic demand management techniques such as encouraging people to use public transit, discouraging peak-period travel, imposing bans on commercial vehicles, parking restrictions, and limiting access to congested areas. Another group of traffic demand management techniques focus on improving the efficiency of the road system to accommodate the same demand at a lower cost. Examples of this approach include imposing charges on road users, high occupancy vehicle lanes, and metering access to highway entrance ramps. Table 2.3 describes different approaches to manage/mitigate congestion (Gifford and Stalebrink, 2001; Black, 2003; TCRP, 2005).

Table 2. 3: Different approaches to manage/mitigate congestion

Supply Management	***Building New Infrastructure*** This approach aims to increase the roadway capacity. However, it is constrained by a lack of space in dense urban areas as well as funding and environmental restrictions. This approach is expensive to implement, and it is considered as the last approach to mitigate traffic congestion. In addition, this approach provides only a temporary solution.
	Modifying Existing Infrastructure The aim of this approach is to increase the capacity of the roadway by including new lanes, modifying intersections, creating one-way streets, and modifying the geometric design of roads. These techniques can benefit public transit as well as car users. However, this approach also requires extensive funding.
Traffic Demand Management	***Access Management*** This approach restricts access to specific places or to specific road links. Some of the techniques used in this approach are: physical breaks and barriers to block through traffic, permit-based system or traffic bans, and ramp metering. This approach is used for safety and is considered most appropriate in cases the reduction in capacity for cars is used by public transit. Some limitations of this approach are that it requires robust enforcement and that road traffic is diverted to other roads creating new congestion.
	Parking Management This approach has the potential to modify demand. However, it is under-utilized by many authorities. It can help to reduce demand for automobile travel and, as a result, tackle traffic congestion on the basis of location and time. One limitation of this approach is that the capacity that is freed-up may be filled from through traffic. This approach needs to be supplemented by other approaches to achieve the desired outcomes.
	Improving Traffic Operations This approach is a cost-effect method to achieve improved travel conditions. The techniques used in this approach include road traffic information system, implementation of dynamic speed, pre-trip guidance, and coordinated traffic signal. This approach allows road users to select alternative travel mode or reschedule their trips to off-peak periods.
	Improving Public Transport This approach is considered a fundamental congestion management strategy. It has the potential to transport more travelers than personal automobile for a given amount of road space. It can achieve and maintain high level of access throughout urban areas if the quality of service that provides enhanced and be sufficient (e.g., safety, comfort, reliability, security) for travelers.
	Mobility Management Several mobility strategies can be utilized to mitigate congestion. This approach includes: car pooling, promoting bicycling and walking, and large trip generators.

2.2.5 Pricing and Sustainable Urban Transportation in North America

Although transport pricing has been an actively debated topic, it is a key component when developing strategies for solving transport problems. The main idea of pricing is to increase the price of a transport service to make it less attractive to users. This section provides a brief review of the main pricing approaches that aim at reducing travel and decreasing the attractiveness of the automobile as a main mode of travel.

The main idea of road pricing is to make transport consumers face the incremental costs of their consumption of transport systems. These costs include operating, maintenance and rehabilitation, safety and environmental costs. However, concerns regarding the public or political acceptability of pricing changes are the most considerable barrier to the implementation of road pricing projects. Although transport pricing has had a lot of academic discussion and research, yet, it has had little practical application until this day. The most important applications have taken place in regions other than North America. These applications involve a sophisticated urban road pricing scheme in Singapore, recent cordon pricing schemes in Trondheim and Bergen, truck charging in Switzerland, Austria, and Germany in 2001, 2004, 2005 respectively, and the central area scheme in England in 2003 (Transport Research, 2006).

Reducing congestion by reducing the use of automobiles or encouraging drivers to use other routes, modes, or times for their trip is the goal of pricing. Drivers may also change their destinations or reduce the number of trips. Reducing congestion is one of the main factors for achieving sustainable transport. If reduction is achieved then sustainability would be enhanced by relatively smooth traffic flows in urban areas with improved fuel economy and emission reductions. There are different approaches for road pricing including congestion-free pricing, parking charges, fuel tax increases, vehicle miles traveled (VMT) taxes, and emissions fees. These approaches are described in the following subsections.

It is important to distinguish between the terms taxation and pricing in general and the terms congestion pricing, road pricing, and road taxes in particular. Taxation can be described, in a simple form, as the transfer of resources to the government from individuals, businesses, or organizations. This transfer is compulsory as the government aims to raise money (NCHRP, 1994). Pricing, on the other hand, is the process of charging people for using particular goods and services. The aim of pricing is to encourage people to change their behaviour. The term road taxes represent the general taxes that are imposed on road users such as fuel taxes. Road taxes are not targeted at changing behaviour and some of these money are used for transportation improvement and development. The term, road pricing, is used when motorists at a specified location and/or time are subjected to road charges. When higher charges are imposed under circumstances where congestion occurs, this type of road pricing is known as congestion pricing. The reason for setting higher charges is to let motorists pay for the amount of congestion they cause in using the road network which is considered a high external cost on society (NCHRP, 1994).

2.3 Comparison between Various Approaches for Mitigating/Managing Congestion

The effectiveness of the different approaches in mitigating/managing traffic congestion can be summarized as shown in Figure 2.3. This figure is based on a regional scale and shows the following:

1. Traffic congestion is a consequence of “increased travel demand or inadequate road supply”.

2. “Traffic congestion” mitigation strategies include supply management, demand management, and a third alternative is to do nothing.
3. The “Do nothing” option results in reduced accessibility and mobility, and consequently reduces the level of service (LOS).
4. “Increase infrastructure” which is the main action of “supply management” leads to a temporary improvement in the LOS. Put simply, roads are provided, the cost to travel decreases (e.g., higher speeds) inducing more traffic, soon the new road capacity is used during peak-periods, which tend to expand, resulting in traffic congestion and a vicious cycle continues.
5. For “traffic demand management”, different TDM techniques can be implemented to manage/mitigate traffic congestion, including congestion pricing, which is the focus of this research.
6. As a result of implementing “congestion pricing” the LOS will improve. The improvement of LOS also needs to have a two-way relationship with congestion pricing. Pricing is a tool that can be used to maintain an acceptable LOS, requiring "dynamical" adjustments in the toll rates/fees/charges (in real time) to manage the demand and LOS.

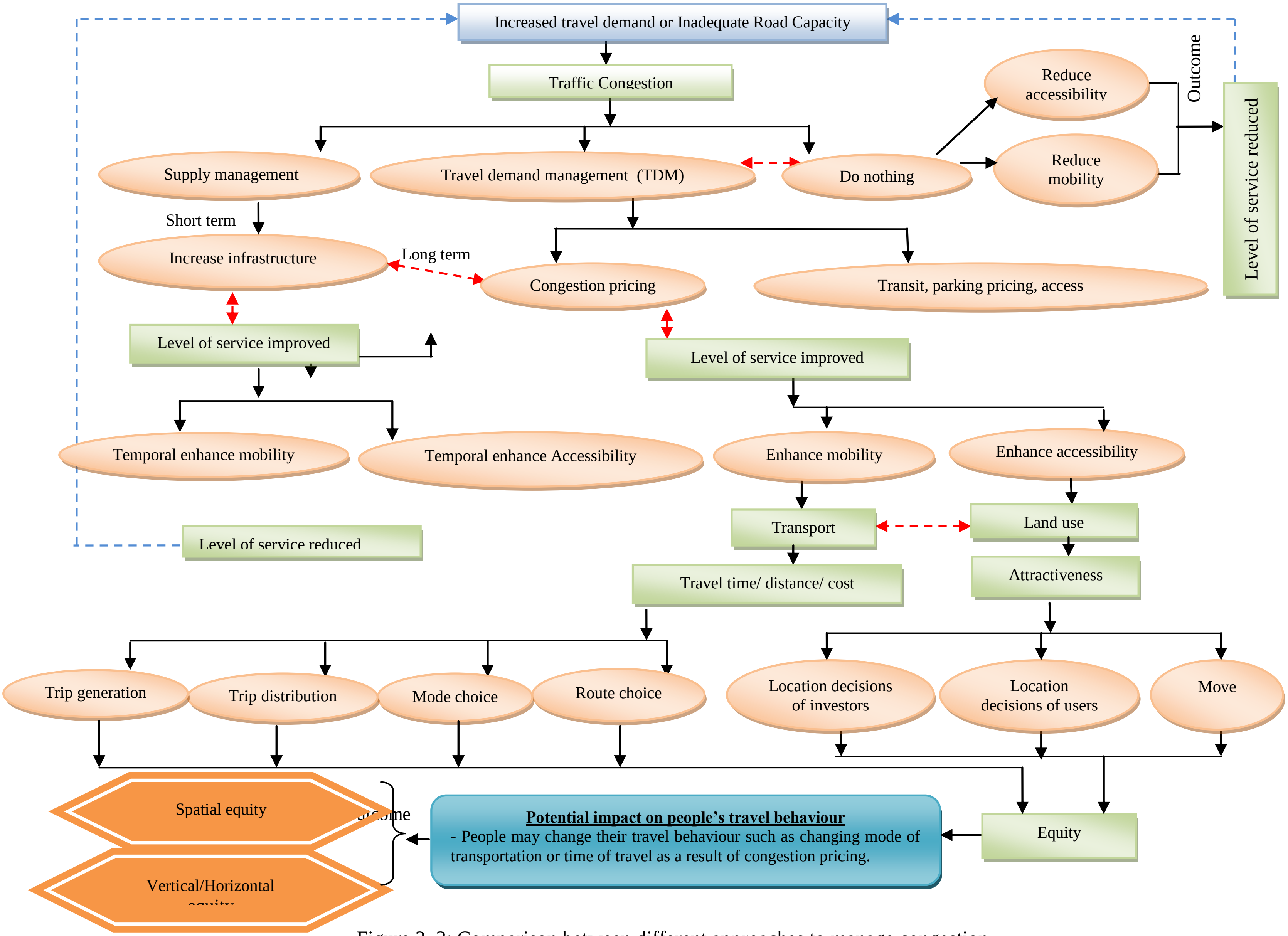


Figure 2. 3: Comparison between different approaches to manage congestion

7. The improvements of LOS enhance mobility and accessibility represented as: “transportation” and “land use”, respectively. The attributes of mobility/accessibility are applicable to both categories. Transportation and land use need to be coordinated since the trip and location decisions co-determine each other. The spatial distribution of activities co-determines the need for travel and goods movement to overcome the space between the locations of activities. On the other hand, the location decisions of households and firms depend on the accessibility of locations which results in changes of the land-use system.

8. Under the “transportation” condition, the diagram includes the role of congestion pricing in the decision making process of making a trip by an individual (trip generation/trip distribution, mode choice, traffic assignment/route choice). Congestion pricing has an impact on every step, and varies according to the type of congestion pricing scheme, the rates, the area covered and the availability of alternative modes of transport.
9. The distribution of land use determines the location of human activities and consequently the location decisions of investors and users.
10. To overcome the distance between human activities in space, spatial interactions or trips in the transport system are required. Changes of land use system are associated with the distribution of accessibility in space which co-determines location decisions.
11. In this regard, it is of outmost importance to emphasize the role of congestion pricing in addressing equity concerns (whether spatial or social).
12. Congestion pricing may impact travel behaviour of different socio-economic groups of travelers. People may change their travel behaviour such as changing mode of

transportation or time of travel. This questions the impacts of congestion pricing on the equity implications of this policy.

2.3.1 Typology of road pricing

Road pricing is a terminology used to include all direct charges imposed on road users including fixed tolls (e.g., toll way) and charges that vary according to the time of the day, location, and vehicle size (e.g., congestion pricing) as shown in Figure 2.4 (Evans et al., 2003; Ungemah, 2007; Weinstein and Sciara, 2004; Davis et al., 2008; Ungemah and Collier, 2007; Ecola and Light, 2009; FHWA, 2006b). Several types of congestion pricing have been implemented in several cities and identified in the literature. The most implemented forms of congestion pricing projects are shown in Figure 2.4 and are presented below:

2.3.1.1 Flat-Rate Toll roads

The aim of imposing fees on travelers in the conventional toll roads is to generate revenues to repay bonds issued to finance the full cost of designing, developing, financing, operating, and maintaining the toll way. This system is not considered as a form of congestion pricing since it aims to generate revenue and not to mitigate/manage traffic congestion. Charges are fixed and do not fluctuate according to time or location and can be collected manually or electronically using transponder technology.

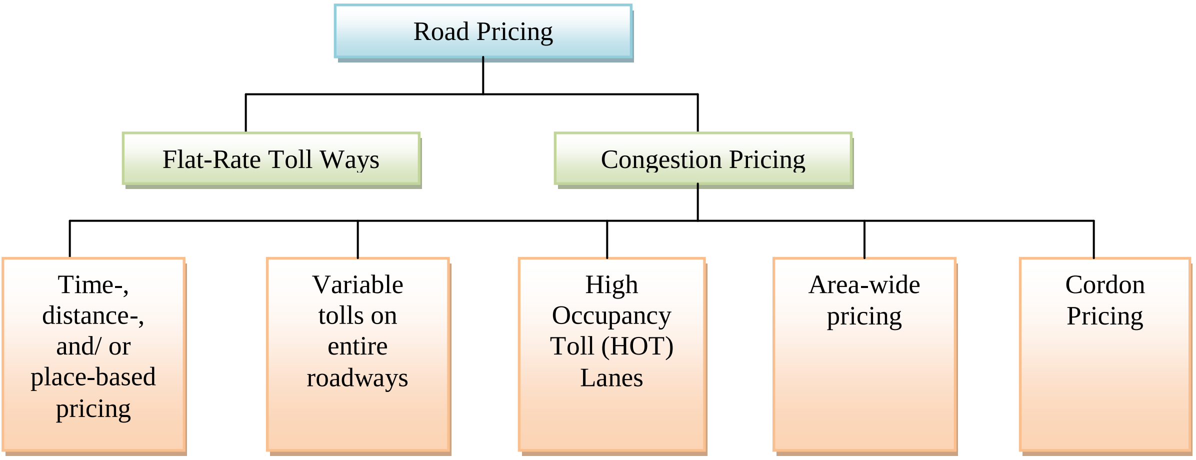


Figure 2. 4: Road Pricing Typology

2.3.1.2 Cordon pricing

Cordon pricing charge motorists whenever they pass any of the charging points that are located at the entrances of an imaginary zone drawn around a congested area. Charges are flexible, meaning that they vary according to vehicle type, time of day, location, and direction traveled (NCHRP, 1994).The charges vary between peak and off-peak hours also between weekdays and weekends. Residents inside the cordon pay discounted fees or are exempted from paying the charges. This system is proven to be effective in mitigating congestion (Mun et al., 2003; Sumalee et al., 2005).

2.3.3.3 Area-Wide Charges

This toll strategy imposes cordon-crossing charges for entering a certain geographic area either by crossing the priced zone or distance traveled (per-km of travel) (FHWA, 2006b). It is different from cordon pricing in that it charges travelers a fixed fee for traveling across the cordon area for an unlimited number of journeys into and within the priced zone. This system provides a discount for the residents inside the cordon. It is less effective than the cordon pricing at reducing congestion since the fees are fixed and do not change with the number of trips to and from the priced zone; however, it may be perceived to be fairer (Maruyama and Sumalee 2006).

Singapore and London implemented this type of congestion pricing in 1975 and 2003 respectively.

2.3.3.4 High Occupancy Toll Lanes (HOT):

This strategy involves variable charges on separated lanes within a highway. It encourages carpooling during peak-periods. HOT lanes are considered a version of High Occupancy Vehicle (HOV) lanes. Ride-sharing travelers can use HOT lanes for free or at a discount, while single-occupant vehicles or those that do not meet the minimum passenger occupancy requirements to access the lanes must pay. Typically, transit and emergency vehicles are charged at a reduced rate or are free of charge. All vehicles still have the choice to travel in free, parallel, general-purpose lanes. This strategy is implemented in many cities of the United States. This type of strategy encourages people to use carpooling and transit system as an alternative to driving alone.

2.3.3.5 Variable Tolls on Entire Roadways

This strategy depends on changing the charging rate during the peak periods to be higher than off-peak periods. This strategy applies to existing toll roads, and bridges to control traffic flow and manage the highway capacity. This aims to encourage drivers to shift to off-peak periods when they use the roads allowing for traffic during the peak periods to flow more freely.

2.3.3.6 Time-, Distance-, and/ or Place-Based Pricing

This strategy charges travelers based on the distance traveled, location, vehicle type, and time of day. The advantage of this system is that it does not require any infrastructure on the ground. It mainly depends on advanced technology where a transponder and a mobile communication device must be installed in each vehicle. This system is implemented in Germany for all heavyduty trucks operating on the national system. Netherland is in process to develop this system for its entire street and road network.

2.3.2 Congestion Pricing

The idea of road pricing was first presented by Pigou in the 1920s when he introduced the concept of externalities, which are defined as the costs or benefits that accumulate to third parties as a function of actions taken by other individuals (Kriger, 2007). More precisely, Pigou argued that road users result in additional social costs that affect other drivers or society in general; therefore they should pay for this extra cost (external cost) so motorists can realise the true social cost of their trips and change their behaviour to make cost-justified trips. Theoretically, road pricing reduces demand as well as congestion and increase traffic flow and speed, thus increasing the total net benefits of travel (Santos and Rojey, 2004).

Congestion pricing can achieve the following objectives and advantages (Evans et al., 2003; Eliasson and Mattsson, 2006; Verhoef, 2008; Lindsey, 2007; Kitchen, 2008; Emmerink, 1997; NCHRP, 1994):

- Congestion pricing can achieve congestion relief, which is important because congestive delay is the largest external cost of road traffic.
- Congestion pricing internalizes external costs (e.g., accident risks, emissions, travel-time losses through congestion, and noise annoyance).
- Congestion pricing provides alternative express lanes for those willing to pay to bypass congestion and hence reduces congestion impacts.
- Congestion pricing generates revenue to improve transportation infrastructure and in particular transit system or can be used to lower taxes.

- Congestion pricing encourages people to change their travel behaviour. The change in behaviour includes changes by mode, time of travel, number of trips per day, travel destination, vehicle occupancy, and route.
- Congestion pricing can result in changing the work decision and location since it is considered as a disincentive tool for urban sprawl.
- Congestion pricing is a financial instrument used to mitigate congestion by offering more road capacity by using money to reduce capacity demand.
- Congestion pricing gives the government the opportunity to privatise part of roadway operations through public-private partnerships, such as the 407 ETR.

However, congestion pricing has disadvantages as well. Implementing and operating congestion pricing can be too expensive, especially for existing roads. It may not achieve equity between different socio-economic groups in the community. Finally, it is not effective if a sound and efficient transit system is not available (Kitchen, 2008; Lindsey, 2007).

2.4 Travel Behaviour

Travel behaviour is the way people move by all modes of travel in order to engage in different activities that are separated by space. The spatial separation of functions or activities as, for example, living (home), work, or leisure makes travel a pre requirement for having relationships with others in our modern society. People`s choices of travel are based on preferences, restraints, habits, and opportunities. The development of methodology and applications in the research of travel behaviour continues to expand in response to the increasing complexity of human travel and activity and associated management strategies. This section reviews the data, methods, and purposes of travel behaviour. However, this section starts with a brief review of behavioural analysis in geography, its history, goals, as well as its links with social science philosophies, all of which are relevant to transportation studies of travel behaviour.

2.4.1 Overview of Behavioural Analysis in Geography

Unlike many scholarly fields, the discipline of geography is not characterized by a distinct subject, method, or philosophy (Gaile and Willmott, 1989). Human geographers often focused on human behaviour, particularly behaviour resulting in a change of physical landscapes and a creation of human or cultural landscapes (Norton, 2001). Other social sciences, such as psychology, also are concerned with the questions of human behaviour but not in the same ways as geography (Ginsburg, 1970). As identified in Norton (2001, p.284), the discipline of human geography is particularly “concerned with the spatial differentiation and organization of human activity and its interrelationships with the physical environment”. In transportation analysis, considerable emphasis is placed on spatial arrangements and related flows.

2.4.2 Travel Behavioural Analyses

Two key dimensions of travel are guiding human mobility analysis: the first interprets travel as a transition in terms of time and space. Both time and space are inseparable components of physical movement. The second dimension implies that travel is chiefly undertaken not for itself but for specific benefits derived at the destination. Thus, trip undertaking should be recognized as a derived demand (Schonfelder and Axhausen, 2010).

Travel behaviour research is actually trans-disciplinary. Its roots are drawn from geography, economics, and engineering. The rapid increase in automobile ownership in the North America and Western Europe created the need for an investment in new road infrastructure on a large scale with a long-life. This in turn required the development of procedures to forecast, evaluate and estimate travel demand twenty to thirty years forward. In the beginning, such procedures were made on an ad hoc basis; however by the mid sixties a standard forecasting methodology had appeared (Jones et al., 1983). This methodology was based on a “four-stage sequential” travel prediction model. Later on, a behavioural validity was imputed to the forecast, particularly; the four step representation of the travel decision process used in the models. The models implied that people decide: Whether to travel or not (generation), the destination of travel (distribution), transport mode (mode choice), and travel route (route choice) (Jones et al., 1983).

Transport mode choice, in particular, has implications for policy and planning. Conventional models characterized transport modes as fairly simple substitutes and this encouraged the idea of promoting people to switch from the private car as a mode of transport to public transport in order to reduce the harm to the environment. By logical extension, either public transport should be improved or the private car should be restrained. Practical experience, however, revealed some significant discrepancies between such assumptions and actual behaviour (Jones et al., 1983). The majority of the literature on mode choice has illustrated that the time required for the different stages of a trip as well as for the different components of each stage are valued in a different ways by travellers due to the differentiation in the levels of comfort and risk they involve (Schonfelder and Axhausen, 2010). Much of the earlier research in travel behaviour had acknowledged that people and vehiclular movement is related to land use profiles, which contributed to the emergence of the macro-level land use and transport modelling systems.

A review of the recent methodological, advances relevant to modelling activity and travel behaviour highlights two main issues. First, discrete-choice models that have been well developed in the past (the multinomial logit and nested logit models) have been generalized in a number of ways to make them more reasonable in their demonstration of travel choice behaviour. Second, the growing recognition of the necessity to model travel as a one part of a large and comprehensive activity-travel pattern resulted in the creation of analysis of activity features (activity participation, duration, home-stay duration, etc.) in separation or together with one another. Some of the most widely models used in travel behaviour analysis are briefly described in Table 2.4.

Table 2. 4: Travel behaviour analysis models

Travel behaviour analysis models	
Discrete Choice Models	“The multinomial logit (MNL) model has been the most widely used structure for modelling discrete choices in travel behaviour analysis. The random components of the utilities of the different alternatives in the MNL model are assumed to be independent and identically distributed (IID) with a type 1 extreme-value (or Gubbel distribution)” (Bhat, 2002, p.382).
Relaxation of Response Homegeneity	“The standard multinomial logit, and other models which relax the IID assumptions across alternatives, typically assume that the parameters determining the sensitivity to attributes of the alternatives are the same across individuals in the population” (Bhat, 2002, p.383).
Discrete Continuous Models	“The methods developed for, and applications of, discrete/continuous choices can be broadly classified under two categories based on the number of alternatives involved in the discrete choice decision. The first category is the dichotomous alternative case and the second is the polychotomous alternative case” (Bhat, 2002, p.389).
Discrete/Ordinal Models	“Can be classified under the dichotomous and polchotomous categories based on the number of alternatives involved in the discrete choice decision” (Bhat, 2002, p.401).

2.4.2.1 Tools for Travel behaviour Analysis

There has been a remarkable improvement in the efficiency and speed of the tools used for travel behaviour data storage and processing in recent years. The advances in computer processing abilities have significantly enhanced the estimation of models that have been considered previously to be unfeasible and also have stimulated the establishment of new and behaviourally good model formation. On the other hand, advances in Geographic Information Systems (GIS) technology have promoted the integration of travel analysis with this technology (Bhat, 2002). GIS softwares, such as TransCAD, can (Bhat, 2002):

- make it possible to spatially represent the transportation network and geographic database management, and
- facilitate a spatially perceptive display of the results from the travel demand models.

2.4.2.2 Data for Travel Behaviour Analysis

The demand for transportation is usually a derived demand resulting from some other desires or purposes. Louviere and Hensher (2001) suggest that a wide range of influential events act as drivers (triggers) that increase the possibility of travel, e.g., changes in the household life cycle, such as marriages, separations, births, and deaths. Other examples are job offers, accumulated or unexpected gains or losses in individual income, suburban gentrification, or changes in pricing of housing and travel. Therefore, developing a sensibly holistic and inclusive set of records and observations of such key triggers is critical in travel behaviour analysis.

The data employed in travel behaviour modelling is generally cross-sectional which does not provide full insights into dynamics of behavioural, household and environmental changes. There is a lack of a comprehensive behavioural framework to guide data collection in order to provide insights that are richer than the present ones.

In collecting SP data, there is a need for realistic representations of the process of behavioural decision. The travel demand models most widely used these days were established in the late 1960s and were not designed for serious changes over the years. In the beginning, these models were established mainly to assess alternative large capital improvements. There is no doubt that this remains to be a significant goal of travel demand models, however, there is a transfer from assessing the long-term investment-based strategies to an acknowledgment of travel behaviour responses to short-term policies regarding congestion management or such as alternate work schedules, telecommuting, and congestion pricing. It is obvious that the existing traditional travel demand models are not appropriate for such purposes because of the many simplifying assumptions employed within these models as well as the narrow “individual-trip” view. As a result, these models are not capable of investigating the potentially complex behavioural responses to demand management initiatives. For example, an early arrival home due to changes in work schedule may result in more trips made in the evening hours because of the availability of extra time that enables individuals to engage in outside home activities; if these trips take place during peak-hour travel, the degree of congestion reduction projected by the conventional models will not recognized. Furthermore, using these traditional models for congestion management policies may lead to unsuitable assessments of travel demand of such policies because these models do not integrate sufficient capability in the substitution pattern among alternatives or the different sensitiveness of people to the alterations in the transportation system. Lastly, it is essential to have precise predictions of travel demand in order to be effectively ready for the changes that the future may bring to us; changes in lifestyles, households structure, urban structure, technology, activity needs of specific groups such as seniors, and changes in the social environment. It is apparent that models with a good behavioural causal connection between the travel patterns and the travel environment are vital to proper design and planning for future transportation infrastructure (Bhat, 2002).

2.5 Overview of the Concept of Equity

The determination of just distribution of rewards, resources, rights, duties, obligations, and liabilities or costs; and the allocations of positive and negative outcomes within social systems are of considerable interest to social scientists (Cook and Messick, 1983). Equity is the value of being equal or fair (Alonso, 1971, p.42). As equity is concerned with the fair distribution of society’s resources among individuals and groups, it is extensively received as positive and as an objective in social policy. Moreover, it has become a significant criterion in assessing public policy and programs dealing with the optimal use and distribution of resources (Kleinburg, 1980; Hodge, 1988). Many social policy definitions include aspects of equity, equality, justice, or fairness (see the definitions by Osterle, 2002; Ecola and Light, 2009). Equity is frequently identified as “distributional fairness”; as its main concern is “who gets what”, and with “who pays” (Truelove, 1993, p.19). “Equity objectives can be identified in four main sets: guaranteeing minimum standards; supporting living standards; reducing inequality; and promoting social integration” (Osterle, 2002, p. 48).

To achieve equity, the distribution of costs and benefits, whether monetary or non-monetary, must be seen by society to be fair and just (Bennett, 1980, Truelove, 1993) depending on an array of criteria. Thus, a policy can be described as equitable if it satisfies a normative standard of fairness (Ecola and Light, 2009). However, reaching an agreement on what constitutes equity is almost always context-specific. Therefore, as Murray and Davis (2001) argue, the definition of equity requires a set of universally accepted norms; while its practice and interpretation is both comparative and specific.

2.5.1 Theories and Principles of Equity

The “egalitarian principle” is the starting point of social justice theory that calls for equality among individuals in a society, and equality is understood as the treatment of people as equals. However, applying the egalitarian principle is difficult. For example, a society may try to achieve an egalitarian distribution of wealth by insuring that equal inputs (food, education…etc.) are offered to each individual. However, this fails to take into consideration the difference among different members of the society in labour as some individuals may convert inputs into greater wealth generation than others. In reality, what comes into view as an egalitarian distribution of wealth may at the end lead to inequality (Hall, 1994). On the other hand, in *Distributive Justice*, Rescher (1966) argues that society should commit unequal inputs to accomplish equal rights for members. He defines rights as the traditional personal freedoms and equal opportunity to education and employment. His solution starts with assuring all members a minimum equal standard of living that he referred to as "utility floor" that points to the minimally acceptable share of necessary goods, such as food and shelter. Beyond this point, he believes that in order to motivate individuals to boost production and consequently, to stimulate the furthermost good for most of the members in a social system, output inequality in terms of inequality of wealth and circumstances should be allowed in society. Without this inequality, which he describes as incentive, scarcity may take place and may hinder the achievement of the "utility floor" for all individuals.

Although the egalitarian principle suggests that resources should be distributed equally among citizens without any segmentation, Osterle (2002) argues that egalitarian principles might be regarded as appropriate in some areas of social policy, while in others they may be regarded as inappropriate. For example, these principles are appropriate in social policy regarding child benefits or education aiming at equal opportunities, while these principles do not seem appropriate when distributing equal shares of care without taking into consideration different levels of disability.

Despite continuing debate, a revolution in our collective understanding of the concept of equity has taken place as many authors have adjusted their earlier definitions taking into consideration the differences in needs and abilities of members of society. Equity theorists (see, for example, Austin and Hatfield, 1980; Cook and Emerson, 1978) are occupied with determining the principles of distributive justice under different social settings and with identifying when such principles are perceived as fair or just by individuals within the social system (Cook and Messick, 1983). Focusing on outcomes or procedures, equity theories imply principles of how equity should be defined and suggest principles to be applied in different contexts. On the other hand, empirical equity studies emphasize equity viewpoints and equity judgments or on testing certain equity interpretations. These are often derived from theories of justice or equity judgments. While, evaluating particular interpretations of equity has received significant attention by scholars, fewer studies consider how concerns about equity are translated into social policy practice. Although, there is increasing information about the distribution of costs and benefits according to particular interpretations of equity, a lack of evaluation research is noticed dealing with "whether and to what extent these interpretations reflect explicit or implicit social policy objectives, or whether there might be competing equity concerns" (Osterle, 20002. p.49). As Osterle (2002, p. 56) further notes, "no attempts have been taking place to study the complete range of such questions and to propose a conceptual and theoretical framework to illumine how institutions distribute costs and benefits. This has lead to a significant gap between "searching for ideal concepts of equity and investigating societal outcomes".

On the other hand, equity concerns in social policy are often determined by three dimensions: what is to be shared (resources and burdens); among whom (the receivers); and how (the principles). Taking into account these three dimensions is a means for the illumination of equity objectives that are in many cases vague or not well-defined (Osterle, 2002). Campbell (1976, p. 3) wrote three decades ago: "The question of how to make operational the equity principle will become an increasing concern. At the heart of these concerns will be defining equity, developing measures of it, collecting and interpreting relevant data, and developing policies responsive to it." Campbell's questions and concerns still occupy many researchers from different disciplines particularly, human geographers, planners, and economists.

With regard to evaluating equity in social policy, it is important to emphasize that a lack of specifically and clearly defined equity objectives is a key difficulty when assessing equity concerns. However, three different sets of approaches can be distinguished in the literature. First, theories of justice are considered as the point of departure to evaluate equity in social policy. However, the issue of equity is at the core of the debate about these theories. Some scholars emphasize issues of social policy as healthcare, for example, by searching for the content of a just distribution of resources (Osterle, 2002). Le Grand (1991 qtd in Osterle, 2002, p. 49) evaluates equity by looking at the range of opportunities and choices that exists for individuals in a society. He states that "*situations where one person is disadvantaged relative to another due to factors beyond either's control are commonly judged inequitable; situations where the disadvantage arises because of differences in individual choices freely made are not.*" Within the same context, Daniels (1985, p. 57) states that "shares of the normal range will be fair when positive steps have been taken to make sure that individuals maintain normal functioning, where possible, and that there are no other discriminatory impediments to their choice of life plans". Although, theories of justice are considered by scholars following such approaches as the point of departure in evaluating equity in social policy, the prospective of these approaches in empirical work remains limited. This is due to constraints in translating ideas of welfare economics, for example, to assessment applications. The second set of approaches emphasizes equity beliefs, expectations, and judgments. Furthermore, causes and effects of such judgments are also emphasized. This approach is useful in the descriptive examination of equity and is considered as the foundation for explanatory studies regarding judgments and beliefs by individuals. However, the main critique within the debate about such an approach is the taking apart from normative, philosophical ideas of justice. The third set of approaches emphasizes the analysis of outcomes. It highlights the extent to which empirical distributions respond to definite interpretations of equity. In healthcare, there are several studies that address such questions. For example, some scholars examine equality in the distribution of health, while others examine the distribution of public expenditure and outcome for a variety of policy areas such as health and social services. In many cases, the analysis is based on five different interpretations of equality: equal public expenditure, equal final income, equal use, equal cost and equal outcome. Equity studies are rather rare in other areas of social policy; a number of studies in long-term care are exceptions (Osterle, 2002).

In summary, the issue of equity is at the core of the debates in the social sciences, particularly with regard to assessing equity in social policy. The following sections illustrate some of the difficulties engaged in evaluating equity in transportation planning with special focus on congestion pricing. Many reasonable and conflicting notions of equity exist and, as identified in Ecola and Light (2009), this is related to the fact that there are several impacts to be considered. At the same time, many of these are difficult to measure, and there are numerous ways to classify "winners and losers". It is therefore not surprising that there is no universally accepted and commonly used manual for evaluating equity in transportation policies, let alone for congestion pricing.

2.5.3 Equity Implications of Congestion Pricing

In transportation planning, equity is a central element because transportation is perceived as a basic right. That is, access to transportation services is a right to members of all social groups within the society. Thus, many scholars have identified equity concerns as one of the main obstacles to public acceptance of congestion pricing proposals. Indeed, a claim that potential equity impacts have not been carefully examined makes the implementation of congestion pricing very slow.

Equity is a major concern that is raised prior to and after congestion pricing implementation. This is due to imposing charges on access to roadways that were previously free, which may be perceived to harm especially lower income groups because they will either have to pay the fees or be priced off the roads. Advocates of congestion pricing argue that implementing this system is more equitable and less regressive than the current systems (e.g., motor fuel taxes, property taxes, license fees, and registration fees) to manage the use of roads as well as to fund transportation improvements. In short, drivers who contribute most to road congestion under a congestion pricing scheme will pay more for using transportation facilities. Critiques of the current financing system in North America suggest that it is regressive and not equitable since low-income drivers pay a higher proportion of their income for transportation fees and taxes than the high-income drivers. In terms of congestion pricing, some critics argue that congestion pricing is unfair, particularly to lower income people who need to drive, because it imposes “double charging,” given that drivers already pay registration and fuel taxes. Moreover, some drivers pay more than others which raises debate about what pricing is equitable and how modifications can be fair and advantageous to the drivers (Viegas, 2001). Another dimension of equity of congestion pricing is its ability to reduce air pollution. This is particularly beneficial to low-income neighbourhoods that are sometimes located in the vicinity of major roads and other transportation facilities (Evans et al., 2003).

Within the economic literature of equity and congestion pricing, the work of Rawls (1971) noticeably renewed the approach of justice within the analysis of transport policy. According to PATS (2000), the theory of Rawls leads to the identification of three dimensions of equity directly relevant to the transport realm and its pricing. These are shown in Table 2.5.

Within these dimension there are four main points that should be highlighted: First, horizontal equity implies that members of the same group or same circumstances should be treated identically. Horizontal equity is concerned with allocating public resources equally among like individuals and like classes; in other words, it is concerned with fairness between persons and groups with equal resources, abilities, and needs (Litman, 2007a; Evans et al., 2003). According to this definition, equal persons or groups should get what they pay for and pay for what they get. They should be treated equally, tolerate equal cost, and receive the same shares of resources (Litman, 2005).

Second, vertical equity is concerned with the distribution of differential effects on individuals or groups that differ by socio-economic factors such as income; in other words, it is concerned with the treatment of persons and groups that are dissimilar (Litman, 2005; 2007b). Based on that, the allocation of costs and benefits should reflect individuals' needs and abilities.

The third and fourth principles deal with motorists as actors. More specifically, the third principle is that those who contribute to a social cost should pay for doing so; this is referred to in the literature as the "cost principle". Fourth, those who receive social benefits pay for them; this is referred to in the literature as the "benefit principle".

Table 2. 5: The three dimensions of equity based on Rawl’s theory (1971).

Dimensions of equity	
Spatial equity	• “Corresponding to the “principle of liberty”, in which the society must guarantee everywhere the access rights to the goods and the services.” (PATS, 2000, p.59). • Benefits of transport strategies and services should be equally distributed particularly on those with special needs; lower income residents, elderly and disabled people, those who don’t own cars, and those living in underprivileged areas. • This dimension of equity is concerned with avoiding worsening accessibility, the environment or safety for any of the social groups. • Social inclusion is a related issue concerned primarily with accessibility (or lack of it) for those without a car or whose mobility is prejudiced.
Horizontal equity	• “Corresponding to the “principle of equal opportunity”, which concerns the equal treatment between users and the user-pays principle.” (PATS, 2000, p.59). • Horizontal equity implies that all people in a given group are equal and should enjoy equal social, political, and economic rights and opportunities. It simply means similar distribution of costs and benefits to individuals within a group. • A transport policy is horizontally equitable if similar individuals are provided with equal opportunities or are made equally well off under the policy. • Horizontal equity assumes that “like should be treated alike.” It is often interpreted to mean that individuals should “get what they pay for, and pay for what they get.” • Road pricing revenues should be dedicated to road improvements or to provide other benefits to people who pay the fee. • Horizontal equity implies transferring benefits from one group (those who pay the fee) to another (those who do not).
Vertical equity	• “Corresponding to the “principle of difference”, which explicitly takes into account the inequalities and its consequences as regards transport.” (PATS, 2000, p.59). • Vertical equity is concerned with the treatment of individuals and classes who are unalike. Therefore, the distribution of costs and benefits should reflect people’s needs and abilities. • It often differentiates between groups based on ability to pay, which is typically measured by an individual’s income or wealth. • A transport policy is progressive or regressive if it favors or burdens, based on some measurable criteria, disadvantaged individuals relative to others. • While these costs and benefits are often expressed in monetary terms, they could be measured in other ways as well. • Vertical equity often requires that disadvantaged people receive more public resources (per capita or unit of service) to accommodate their greater need than those who are advantaged. • It justifies employing revenues to the advantage of underprivileged people, such as low-income drivers as a class and non-drivers. Litman (2007) notes that this can be accomplished by utilizing resources to benefit lower-income drivers or to develop transportation alternatives such as transit, bicycling, and walking; and to furnish public services that benefit low-income earners in the society.

In terms of the use of any potential profits from road pricing schemes, there is a difference of interpretation between horizontal and vertical equity. Horizontal equity implies that profits should be devoted to roadway projects or rebated to vehicle users as a class, but this condition is reduced or removed if the analysis distinguishes the need for users to recompense for the external costs they entail. In contrast, vertical equity justifies employing revenues to the advantage of underprivileged people, such as low-income drivers as a class and non-drivers. Litman (2007) notes that this can be accomplished by utilizing resources to benefit lower income drivers or to develop transportation alternatives such as transit, bicycling, and walking; and to furnish public services that benefit low-income earners in the society.

Equity could be in terms of who pays/who benefits (car users, transit, non-motorized), income equity (need to look for poverty levels and whether charging is more regressive than other taxes), gender equity (male/female), geographic equity (urban/rural/suburban), its relationship to other charges and fees (property taxes, how transportation projects are funded), accessibility to travel alternatives (if I leave my car to avoid charges, are there reliable transit alternatives), business equity (impact on businesses in areas with congestion charges versus those that are not impacted). Equity reflects the changes in the allocation of impacts (costs and benefits) across socio-economic groups, resulting from the introduction of pricing decisions, relative to the existing allocations (Giuliano, 1994).

This leads us to the problem of deciding how to make comparisons among different social groups within the society. The economics literature classifies members of the society based on their income or their place of residence or work (Litman, 2007), while the planning literature consider those who may be disadvantaged with respect to transportation because of disability, age, or gender (Deka, 2004; Stantchev and Menaz, 2006). However, congestion pricing must also consider where people live, as some neighborhoods may experience greater burden than others because of the way in which we implement congestion pricing.

In conclusion to the above discussion, one may argue that there is no easy answer available to the question that is often raised, “Is congestion pricing equitable?” there is not a theory of equity but multiple meanings of the concept proposed by human and social sciences. And the answer to this question largely depends on how we measure equity and how we define groups, the details of the site, and lastly, to what we judge against congestion pricing. However, in an attempt to answer the above question, the literature about congestion pricing and equity has been reviewed and one can suggest the following conclusions regarding this issue:

First, an equity evaluation must carefully consider socio-economics, demographics as well as location. The distribution of residents, job opportunities and other vital destination has, to a great extent, a significant impact on equity implications for all types of congestion pricing. Cordon pricing, for example, may be progressive, regressive, or neutral based on the place of residence of low-income people.

Second, an important factor for the net impact of congestion pricing is how revenues are used. Differences in this respect reduce differences in other factors such as values of time. Having to pay for what was freely available, and the risk of exclusion for low-income social groups for the extra cost of driving causes political hostility (Viegas, 2001). Thus, from an economic perspective, spending revenues in ways that benefit low-income and other transportation-disadvantaged social groups will make congestion pricing more likely progressive rather than regressive. This is largely dependent on how congestion pricing is implemented. However, if revenues and benefits are distributed equally within society, congestion pricing may be taken as a whole as regressive. On the other hand, even with spending revenues in a ways to benefit low-income, it is still possible that some members will still be disproportionately burdened.

In terms of equity impacts, the literature on road pricing has focused mainly on income equity issues and to a lesser extent on spatial equity. In general, the three congestion pricing projects that were implemented in the Asian city (Singapore) and the two European cities (London and Stockholm) gave equity only limited attention and evaluation. When charges are imposed on travelers, these result in perceived road user's "winners" and "losers". This is attributed to the way that travelers value time savings, where some road users value these savings more than the fees they pay. The losers, who are tolled off, may change their travel routes, shift to off-peak times, change the mode of transportation, shift to carpool, or make fewer trips. In Singapore gainers from congestion pricing project were found to outnumber losers 52% to 48% (Bhatt et al., 2008). Also, after implementing congestion pricing in Singapore it was found that residents outside the priced zone considered this project as negative while residents inside the priced zone considered it positive. The enhancement of public transit before implementing congestion pricing can be considered a way to achieve equity between different income groups. In Stockholm, transit service was extended by 7% by adding 16 new bus lines, additional departure for train lines, and new park-ride facilities four months before the start of the tolling (Eliasson et al., 2008).

Two commonly suggested ways to mitigate the risk of negative impacts of congestion pricing on low-income and disadvantage groups are found in literature (Ecola and Light, 2009). The first approach is to distribute the revenue generated from congestion pricing through public works and in particular on public transit system to create better options not to drive and to ensure that project benefits flow to those most disadvantaged individuals by congestion pricing. Other ways identified in the literature on redistributing the generated revenue is through tax credits and credit-based systems to ensure that redistribution is made on an individual basis. However, none of these ways were tested or implemented in reality; therefore, their effectiveness is difficult to judge. The second approach is discounts and exemptions for disadvantaged (e.g., disabled persons) and low-income individuals, vehicles, or types of trips. This approach leads to a less expensive congestion pricing system. However, the incentives to discourage drivers to travel on congested roads will be reduced if a high number of people get discounts or exemptions.

The last point on promoting equitable outcomes is that a region seeking to implement congestion pricing should look at measuring and assessing equity in the early phases of the planning process. Most importantly, a proposal of congestion pricing should be tested through modeling to determine who are more likely to pay the charges and whether the situation of the low-income and transportation-disadvantaged social groups will be worse off with the proposed project. Furthermore, public participation should be facilitated so members of the society affected by this project are aware of it and also are given the chance to offer suggestions. Lastly, even after the implementation of the congestion pricing, equity has to be monitored, and changes should be made every so often to the system if the early tools to endorse equitable outcomes are not achieving their goals. It would be also functional to develop an "equity audit tool" to facilitate this process (Ecola and Light, 2009).

In conclusion to the above discussion, the concept of equity is subject to broad interpretation. This notion deals with principles that identify the fair or just distribution of resources among members of the society. Because the formation of these principles entails ethical and subjective judgment, the study of equity is burdened with definitional mystification and "pluralism". In general, equity definitions stress the significance of a fair distribution of benefits and burdens. Furthermore, accurate definitions of equity are rare in both policy making and policy evaluation. Thus, reaching an agreement on what constitutes equity and the fairness of a specific distribution is almost unattainable which makes the concept of equity a complex one. The difficulty in defining *equity* as descriptive and normative has made the theoretical literature on equity very debatable.

Lastly, it may be useful here to clarify the link between theories and principles of equity (“economic theory”, “social justice theory”, “Rawl’s theory”) that are introduced in this chapter. A theory of social equity was developed and positioned as the "third pillar"; in addition to economy and efficiency for transportation planning including road pricing. In terms of the theoretical progress of equity in the last two decades, the work of Rawls provided a language and a road map for transportation planners to understand the complexity of the subject and to integrate notions of fairness, justice, and equality in their planning.

Rawls derives his two principles of justice: “the liberty principle” and “the difference principle” from his theory that is known as "Justice as Fairness". He claims that adopting two such principles organizes the distribution of economic and social benefits across society. The difference principle justifies unequal distribution of goods only if those inequalities are to the advantage of the worst-off members of society. With the emergent focus on congestion pricing, concern is rising about whether congestion-based charging policies can be designed in an equitable way. Therefore, Rawls theory, particularly the difference principle, can help planners to develop criteria for assessing public policy and programs dealing with the optimal use and most importantly, the distribution of resources. The next chapter has further discussion about theories and principles of equity with regard to congestion pricing.

2.5.4 Chapter Summary

This chapter examines and reviews the literature on four main themes: sustainable transportation, congestion pricing, travel behaviour, and equity. The chapter starts by introducing the concept of sustainable transportation and related definitions and measures. In addition, this chapter introduces some approaches/solutions for moving toward sustainable transportation. In particular, the relationship between pricing and sustainable urban transportation in North America is explored, including the potential role of pricing in mitigating/managing congestion. The chapter highlights the objectives of congestion pricing and its advantages, and the typology of road pricing and different schemes that have been introduced and implemented around the world. The chapter also discusses the concept of travel behaviour and provides an overview of behavioural analysis in geography as well as a discussion of travel behavioural analyses in general. In particular, an overview of the tools, models and data used in analysing travel behaviour in transportation is highlighted. Finally, the chapter ends by introducing and discussing the concept of equity with emphases on the theories and principles of equity as well as equity implications of road pricing.

Chapter 3: Research Methods

3.1 Introduction

The aim of this chapter is to discuss the conceptual framework as well as the methods used in this research to gather and analyze the primary and the secondary data.

3.2 Conceptual framework

The research draws upon equity theories and principles in connection with economic, transportation, and social science literatures. Many previous studies on equity of congestion pricing have drawn on theoretical pluralism, with an emphasis on social science theories. Such a pluralistic approach is seen by many as appropriate to tackle interdisciplinary phenomena. These theories and principles form the base that guides the observations and analysis of this research. The objectives are to better understand both analytically and operationally, and to more appropriately and effectively address, vertical equity of cordon pricing in Downtown Toronto.

Figure 3.1 provides the conceptual framework used in this research. At the bottom there are equity theories that constitute the building-block of this framework. The figure also shows that the role of theories will be: (1) to help explain the impacts of congestion pricing on different socio-economic groups; and (2) to help propose a transportation policy based on equity to mitigate/manage congestion. The figure also illustrates several principles that are important components of these theories.

Vertical equity and spatial (territorial) equity are two dimensions of equity identified in the literature that are directly relevant to transportation system as illustrated in the figure and as discussed above. Congestion pricing is receiving increased attention as a potentially effective means of mitigating/managing congestion. Without examining equity dimensions of congestion pricing, implementing such system cannot be guaranteed. The examination of congestion pricing equity will indicate the impacts on different income group as a result of implementing this policy.

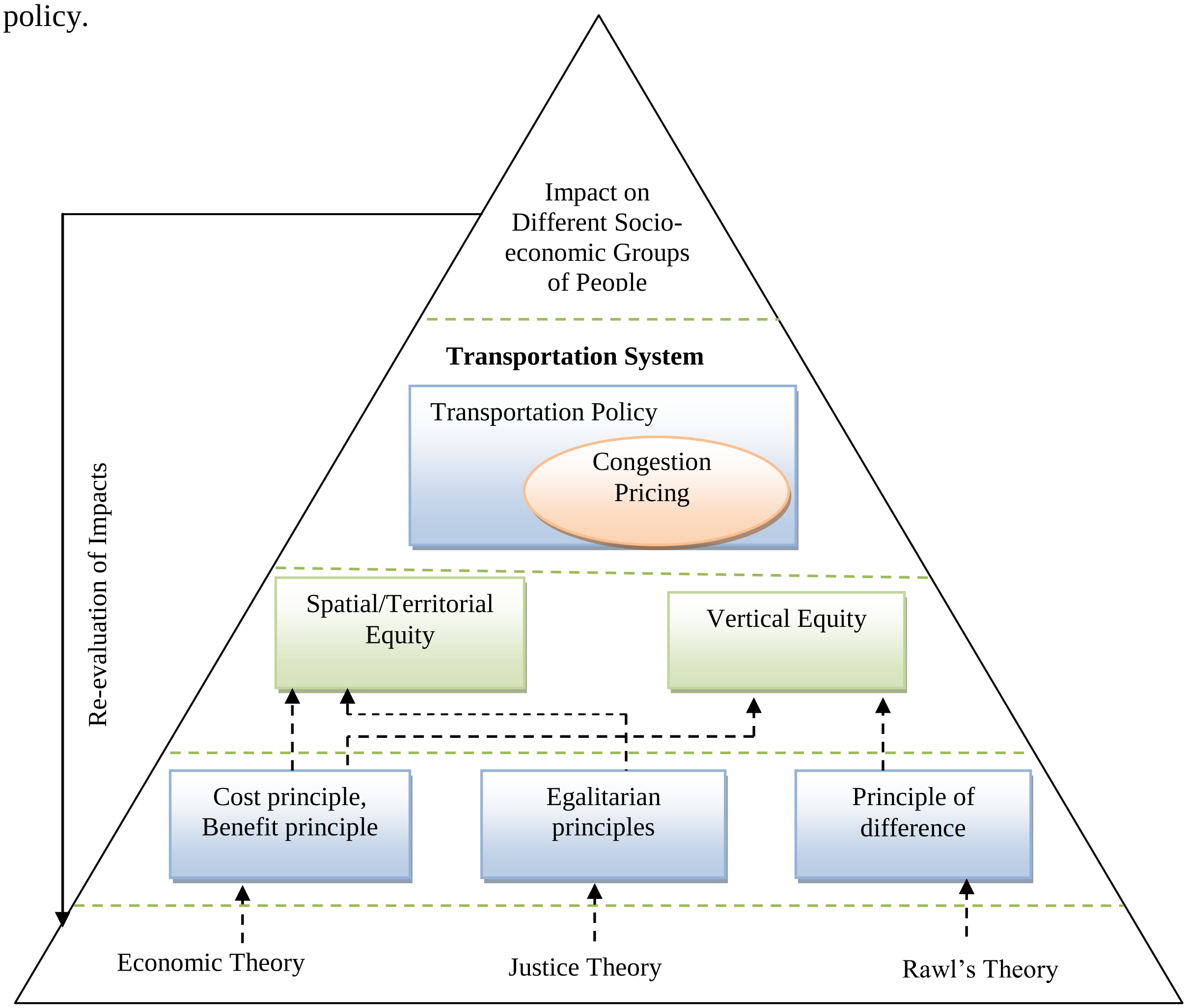


Figure 3. 1: Conceptual framework of the proposed research

3.2.1 Application of the framework

Congestion pricing may impact travelers' behaviour in the short and long term. Figure 3.2 outlines our current understanding of how road pricing in general, and congestion pricing more specifically, influences travel. In the short term, travelers may select new modes of transportation, change the time-of-day during which they travel, select different routes, or alter origin-destination locations (Mastako et al., 2002). In the long term, travelers may change their employment locations, alter their auto ownership, and re-think decisions related to housing and services, thus influencing land use patterns (Deakin et al., 1996; Guo et al., 2011). The research focuses on some of the short- term impacts of cordon pricing.

The research tests the perceptions of equity in cordon pricing based on the Transportation Tomorrow Survey (TTS) data and stated preferences of survey respondents in the GTA based on the outlined theories and principles. The results of the research can inform policy-makers about potential effects of congestion pricing on different socio-economic groups of people.

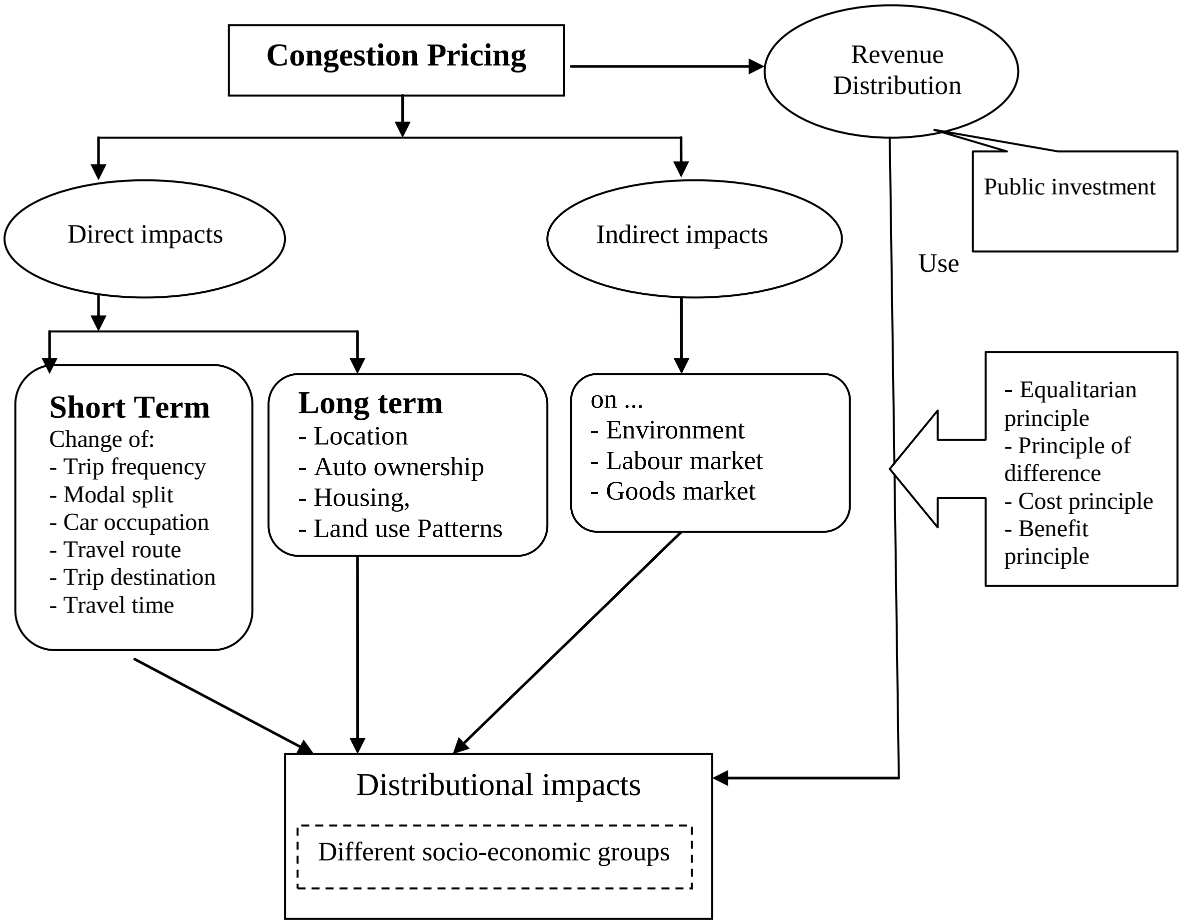


Figure 3. 2: Distributional Impacts of Road User Charges

3.3 Research Design

Three types of approaches are commonly employed in research in the social sciences: quantitative/structured, qualitative/unstructured, and mixed method. Often the main distinction between quantitative and qualitative research is in the basic philosophical assumptions that researchers bring to the study, the types of research strategies (quantitative experiments or qualitative case studies), and the methods for applying these strategies (collecting quantitative or qualitative data) (Creswell, 2009). However, quantitative and qualitative research approaches represent different ends on a continuum rather than being polar opposites (Denzin and Lincoln 2005; Newman, 2003). This study uses quantitative methods to address research questions and objectives. Different socio-economic groups are compared in terms of their perceptions to congestion pricing. Different statistical methods (e.g., chi-square test, ANOVA) were used to test the significant differences between these groups in their perception to cordon pricing in Downtown Toronto.

3.4 Description of the approach used to address equity of cordon pricing

This section addresses the main methods that are used in the research to evaluate equity dimensions of proposed cordon pricing in Downtown Toronto.

3.4.1 Travel behaviour approach

The main approach adopted in this research is to examine the impact of cordon charges on commuting travel behaviour, with a focus on who is affected and where. Examining behaviour change in this research focuses on short- term traveler's responses such as shifts to other modes of transportation. The variables that are considered to influence travel behaviour are traveler characteristics including income, gender, age, location, number of vehicles owned by a household, and household size.

The justification for focusing on traveler demographics emerges from studies of cordon pricing in other cities. Cordon pricing in Singapore, London and Stockholm has reduced congestion significantly by reducing the percentage of vehicles (10% to 30%) entering the priced zone. It is obvious that cordon pricing encouraged travelers to change their behaviour. This is reflected in changed modes of travel as imposing charges encouraged 6% to 40% of car travelers to change their mode of transportation and use public transit and 11% to 25% to use high occupancy vehicles with 4 passengers or more (HOV 4+) in these cities. These results coincide with the outputs of a study conducted by Helali (1994) for the GTA. The study showed that introducing cordon pricing to the GTA may reduce auto driver trips by 11% to 46% depending on the pricing scenario. He concluded that these reductions represent shifts from single-occupancy vehicle trips to transit and shared rides.

3.5 Data collection methods

To explore the proposed research questions, quantitative data and analysis were employed. Quantitative research is a systematic investigation of phenomena through statistical analysis of numerical data (Burns and Grove, 1987). The intent is to provide findings that include generalizations and predictions. The quantitative research process is structured with predetermined methods and instruments by the researcher before gathering data. A large sample size is usually utilized in a quantitative study. Surveys are common sources of such data in transportation studies.

Surveys, which provide a popular mode of observation across the social sciences (Creswell, 2003), provide numeric descriptions of trends, attributes, or opinions of a population by studying a sample group of this population. Researchers collect data by self-administered questionnaires or structured interviews conducted either face-to-face or by telephone with the aim to produce statistics that reflect certain aspects of the sample. They then generalize the results of the study to the wider population (Babbie, 1990, 2005). Surveys have been extensively employed in transportation research because of their convenience for gathering data and conducting statistical analysis. Surveys are also the basis for the current study. More specifically, this dissertation analyzes secondary survey data from the Transportation Tomorrow Survey and primary survey data from a sample of Toronto residents who responded to a mail-out questionnaire related specifically to congestion pricing.

3.5.1 Secondary data collection

Secondary data sets, including statistical information provided by different levels of governments or government's agencies about population or regions can be especially useful in tracking trends, providing that these data are selected carefully and cautiously to ensure their reliability and appropriateness (Creswell, 2003).

Secondary data used in this research were collected from Transportation Tomorrow Survey (TTS). The survey is conducted by telephone in many regions of southern Ontario and interviews approximately five percent of the households participating regions. The data are then expanded to represent the total population of the survey area. This survey is the largest and most comprehensive travel survey performed in Ontario. TTS provide detailed information on the characteristics of the changes in magnitude of travel demand as well as detailed demographic information on household that contribute to the survey and weekday travel information. The TTS is also a transportation time series database which allows analyzing how certain factors (e.g., flexible work hour programs, aging, and relocation of manufacturing employment) influence the purpose of individuals trips and how they travel and how often. In addition, the TTS data provides detailed information on current travel pattern and how existing demographic and socio-economic factors influence travel demand. TTS data includes household, person, and trip information (i.e., origin/destination survey, mode, purpose of the trip). Travel information includes, but is not limited to, trip start time, purpose of the trip, origin/destination points, and travel mode and transit routes.

TTS data was validated as a reliable data source to examine if particular socio-economic groups would be disproportionately affected by the implementation of cordon pricing in Downtown Toronto. The TTS expansion has been validated by performing a comparison between the census dwelling unit and population data with the aggregated expanded totals. Equity implications of cordon pricing in this research is based on analyzing travel activities of people with differing socio-economic or demographic characteristics. TTS provides data on a large sample of representative trips that occurred in the GTA. Insight into what types of persons would be most affected by cordon pricing can be provided by estimating the number of travellers whose auto trip would be charged under such a pricing strategy.

The TTS data were supplemented with demographic data from the Canadian Census. Statistic Canada conduct census every five years. This type of data provides demographic and statistical data used researchers, governments, agencies to plan for different public services such as transportation. The research is based on secondary data for the years 1986- 2006. Key variables for the two data sources are shown in Table 3.1.

Table 3. 1: An example of available data

Census Data (Dissemination area)	**TTS Data (2006)**
Income Data: • Total population 15 years and over by income in 2005, • Median income $, • Average income $, • Standard error of average income $, • Median employment income in 2005 $, • Average employment income in 2005 $, • Standard error of average employment income $.	Household: • Census tract number of household, • Number of vehicles in household, • Number of drivers of household, • Number of full time workers in household. • Number of trips by household.
Total Population	Persons: • Age of person, • Gender of person, • Employment status of a person, • Number of trips by a person.
Gender	
Marital Families and Households	Trips: • GTA 2006 traffic zones of origin, • GTA 2006 traffic zones of destination, • Trip purpose, • Start time of trip

3.5.2 Primary data collection

Primary data were collected through self-administered questionnaire survey which is discussed in the following section.

3.5.2.1 Questionnaire survey

Questionnaires are an information-gathering technique often employed in quantitative research (McGuirk and O'Neill, 2005). Questionnaires are powerful tools for collecting original data about people, their behaviour, attitudes and opinions (McLafferty, 2003). A self-administered questionnaire survey-based approach is selected as the most proper method for this dissertation study because of its suitability for examining and investigating the phenomena in question as well as because of its cost-effectiveness for collecting data. In addition, the research purpose could be satisfied by getting first-hand information from a sample of travelers across the GTA. The self-administered questionnaire surveys enable the researcher to reach a large number of people in a short period of time. In general, the questionnaire employed in this research contains closed-ended questions such as scaled and multiple choice questions. Some of the survey questions are stated preference and others are not.

3.5.2.2 Stated preference (SP) survey

The SP survey is used in transportation planning to forecast impacts on travel demand of transport policies (see for example Bates, 1998; Kroes and Sheldon, 1988; Louviere, 1988; Hensher, 1994; Patil et al., 2011; Tanriverdi et al., 2012). SP survey is also used to examine and analyze the impact of transportation policies on travel demand (see for example Hensher, 1994). SP methods were applied by many scholars in market share modeling (see for example Novaes and de Carvalho, 1994; Beaton et al., 1998). The concept of this method is based on that respondents state their preferences in fictitious situations. SP-surveys are flexible, allowing for the analysis of a range of various prospective indicators. The stated preference data collected from the survey is used to estimate a utility function which is used in turn to forecast behaviour change.

Stated preference survey is used in this research to collect data to analyse changes in travel behaviour for different socio-economic groups commuting into- and out- off the cordon zone. By employing survey-based SP, the study is able to evaluate the perceptions of equity in cordon pricing based on the survey respondents in the GTA in a more comprehensive manner. The main goal of using this technique is to examine the changes in travel behaviour as a result of implementing cordon pricing in Downtown Toronto taking income, gender, age, occupation, household characteristics, and household size factors into consideration. Some of the questions in the survey are SP questions. An SP survey is beneficial in determining changes in motorists' behaviours in terms of shifts to public transit, carpooling, time of travel, and possible suppressing of some trips. In addition, the SP question are designed to evaluate respondents' perceptions about road congestion in the GTA, the effectiveness of cordon pricing as a policy to manage/mitigate congestion, their willingness to support this policy, their expected personal outcomes, their willingness to pay to reduce total travel time, and their perception to redistribute the generated revenues.

Loo (2002, p. 212) defined SP methods as "methods refer to the techniques of collecting and modeling with data collected in the form of preferences (as reflected in rating, ranking, or choices) among hypothetical alternatives characterized by a set of pre-specified attributes that can take different values". Transportation planners used these methods in studying many transportation issues particularly those related to the measurement of perceptions and attitudes, potential demand, estimation of policy responses, and elasticities for transport-related choice sets (e.g., different travel modes, route choice, or vehicle types).

SP survey is an ideal tool to collect data to determine whether cordon pricing can be successful in changing travel behaviour based on people's preferences and choices. For example, if we assume that implementing cordon pricing is expected to encourage modal shift from auto to public transit, a SP survey can be designed to ask commuters whether they would switch to other modes (i.e., public transit, car pooling) as a result of implementing cordon pricing. The answer to this question is then interpreted as a demonstration that automobile or public transit is preferred.

However, this method must be implemented cautiously. In order to maximize the external validity of SP data, attention should be paid to the "hypothetical choice contexts so that they are realistic and relevant to individual respondents; it is also important to be able to present the choice tasks in a way which reflects the context being studied" (Loo, 2002, p. 219). In addition, there can be discrepancies between what respondents may actually do after implementing cordon pricing and what they express in the survey (Loo, 2002; Bradley 1988; Wardman 1988; Bradley and Gunn 1990).

3.5.3 Survey design

This study employs survey-based SP to evaluate the perceptions of equity in cordon pricing based on the survey respondents in the GTA. The survey is design to be completely anonymous, and requires less than 15 minutes to be completed. Core survey questions ask respondents to what extent they are willing to change their travel behaviour if cordon pricing implemented in Downtown Toronto. The purpose of the survey was introduced to respondents prior to questioning through explaining the cordon pricing concept. In the context of the current study, respondents may not be aware of cordon pricing and consequently responses may reflect biases based on a lack of information (Brownstone and Small, 2005). A full copy of the survey is found in Appendix A.

Figure 3.3 shows the relationship between the research questions and the survey questions. A significant portion of the survey was dedicated to acquiring data on the impacts of cordon pricing on travel behaviour and trip decisions. In addition, the survey includes different socio-demographic questions to provide data for a series of statistical tests of difference that assess equity between different groups. In general, the survey consists of three sections:

1- Travel information;
2- Travel behaviour changes; and
3- Respondent demographics.

Section 1, consisting of questions 1-4, acquires data about travel behaviour of individuals in terms of trips made, purpose of the trip, and mode of transportation. Section 2 consists of questions 5-16 and is the core of this questionnaire. This section of the study's stated-preference component addresses four key themes:

- Public desirability for cordon pricing as a congestion mitigation strategy in the GTA;
- Traveller's willingness to pay to reduce their car trip travel time;
- Traveller's willingness to change their travel behaviour and the factors affecting that;
- Public perception of the distribution of the generated revenue from cordon pricing.

These four themes are essential for deciding whether a given driver will benefit or lose from implementing cordon pricing. Where, questions 5-7 address public desirability for and acceptability of cordon pricing as a congestion mitigation strategy in the GTA. Questions 8-11 address drivers' value of travel time savings. These questions reflect the differences in willingness to pay among different groups (i.e., income, age, gender, etc). This issue is an important indicator in determining equity implications of this strategy as the time spent on the road represents a significant component of traveller's total trip cost.

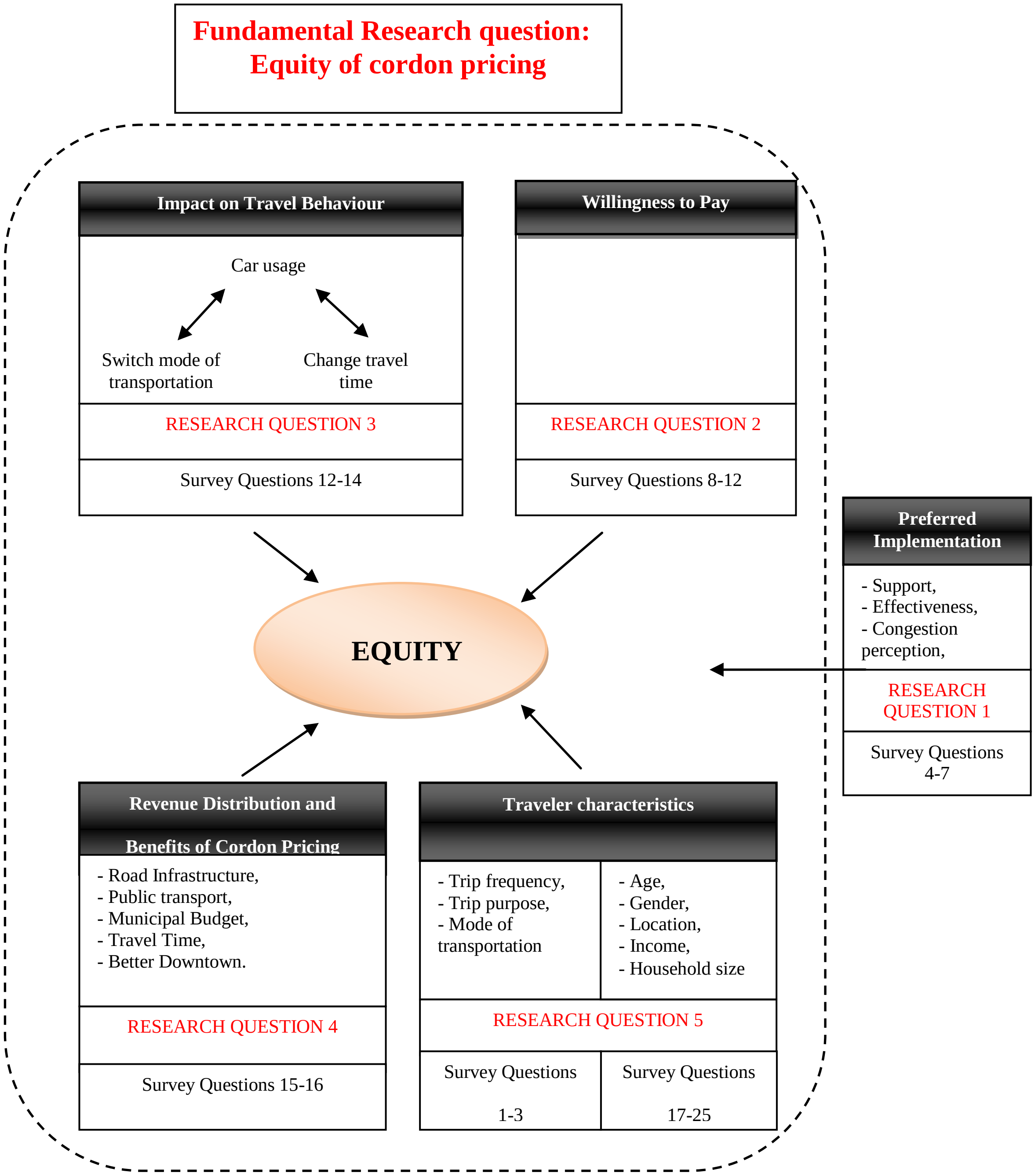


Figure 3. 3: The relationship between research questions and survey questions

Differences in travel behaviour are an essential element in assessing equity of cordon pricing. Questions 12-14 examine travel behavioural changes that could be resulted in response to the implementation of cordon pricing, and comparing those responses across income groups. Question 12 highlights the importance of trip purpose on drivers' willingness to pay the cordon charges. Cordon pricing may have different effects on work, shopping, or recreational trips. This is an important indicator of equity when correlated with income. Question 13 addresses the impact of cordon pricing on individual's travel behaviour, while question 14 examines if cordon pricing have a large effect on car drivers by switching to other modes of transportation. When correlating this information to the household income, we can know exactly who is affected in what ways. The last part of this section addresses the way that the generated revenue should be distributed to achieve equity across different socio-economic and demographic groups. It is essential to investigate distributional effects and to consider the impact of different use of revenues in evaluating the equity of cordon pricing.

Section 3 enquires about respondent demographics. Household income, household size, age, gender, and household location are important elements to assess equity of cordon pricing and are significant indicators of driver's willingness to pay the charges. For example, geographical differences are highlighted in question 20. This can help to evaluate the spatial equity among different groups. This may give an indication that people driving from the rest of the GTA regions to/from the charged zone will be more affected by this system. Equity implications can be examined by correlating this issue with income.

3.5.4 The survey packet

Distributed survey packets contained the following items:

1- 1 questionnaire

2- 1 cover letter

3- 1 return Business Reply Mail envelope

The aim of the cover letter is to inform respondents, in compliance with the University of Waterloo's research ethics requirements, of the purpose of the research as well as to inform them that participation was voluntary and confidential. In addition, the cover letter contains a brief explanation of cordon pricing and the study area. Respondents also were informed that questionnaires should be completed and mailed by March 30th, 2011 to be included in the study.

The sampling and distribution method chosen for this study reflects the survey's purpose, target population, and resource constraints. This study is an evaluation of vertical equity as well as an evaluation of people's perception about equity of cordon pricing if implemented in Downtown Toronto. As such, the target population was Greater Toronto Area's travelers to Downtown Toronto from a variety of socio-economic backgrounds and geographic locations. While a large representative sample for this study would have been ideal, the range of possible sampling methods was limited by resources. In this study, the survey was randomly distributed in different areas of Downtown Toronto, the rest of the City of Toronto, and the rest of the GTA regions as shown in Table 3.2. The sample sites in each area were selected based on the number of trips originated from these sites and destined in the Downtown, location of these sites, and average income. TTS data provides the number of trips made from each traffic zone and destined in the Downtown and hence the sites that were selected generate the highest number of trips that distend in Downtown Toronto. The sample sites were also selected to represent the Downtown, rest of the City of Toronto, and the rest of the GTA which form the study area. In addition, the average income levels from Statistic Canada were used to identify the income categories found in the survey.

Table 3. 2: Survey sample sites

Delivery Area	Zone Number	Postal Code	Delivery Mode	Quantity	Type of residence	Household Income
Downtown Toronto	42	M4Y	LC0106	56	Houses	Low
			LC0107	65	Houses	
			LC0108	49	Houses	
			LC0115	41	Houses	
			LC0116	22	Houses	
			LC0117	27	Houses	
	62	M5V	LC0006	317	APT	Middle
	35	M5E	LC0039	288	APT	High
Toronto	90	M6J	LC0003	218	Houses	Middle
	45	M5R	LC0011	85	APT	High
			LC0018	123	Houses	
	23	M5A	LC0012	168	APT	Low
	189	M5P	LC0052	184	Houses	High
	255	M4L	LC0026	82	APT	Middle
			LC0041	114	APT	
	110	M6K	LC0023	269	Houses	Low
Durham	1075	L1T	LC0031	54	Houses	Middle
			LC0032	112	Houses	
	1069	LIT	SS0014	220	Houses	Low
York	2257	L4S	SS0009	217	Houses	Low
	2107	L6A	SS0031	167	Houses	High
	2367	L3T	LC0015	92	APT	Middle
			LC0016	72	Houses	
Peel	3646	L5H	LC0063	169	Houses	High
	3690	L4Z	LC0072	253	Houses	Low
	3677	L5L	LC0012	217	Houses	Middle
Oakville	4039	L6M	LC0084	126	APT	Middle
	4020	L6J	LC0007	174	Houses	High

In Downtown Toronto, three sample sites (traffic zones) were selected with the aid of TTS data based on the number of trips to the rest of the GTA regions. Each traffic zone represents different population income level (low, middle, or high income). In total, 865 survey packets were randomly distributed in the mail boxes in that area through Canada Post depending on the first three digits of the postal code and the delivery mode as indicated by Canada Post as shown in Appendix (A). In the rest of the City of Toronto, 1243 surveys had been distributed in six different traffic zones, three of them located adjacent to the proposed cordon boundaries and each represents different income level, and the other three is located in different areas in the rest of the City of Toronto were they originate the highest trips to Downtown Toronto and each traffic zone represent different level of income. Finally, 1873 surveys had been distributed in the rest of the GTA regions as shown in the table. The same criteria had been followed to select these sites. In total, 3981 survey packets were distributed in the GTA at the beginning of March, 2011. The response rate was 5.25% from different locations.

3.6 Data analysis

SPSS software was mainly used as a tool to analyze the responses data from returned questionnaires. Different statistical methods were employed to address the research questions in this study. The methods used to analyze and investigate those questions are described in this section and are described in relation to the research questions they are used to answer. In addition, this section states the hypothesized results of statistical analysis based on the literature.

3.6.1 Statistical tests employed to address research themes, research questions, and survey questions.

Two statistical tests were employed to analyze questionnaire results as shown in Table 3.3. Chi-square test is the main statistical test used to address themes one, three, and four in addition to research questions (1, 3, 4, 5) and survey questions (5, 6, 7, 12, 13, 14, 15, 16). Chi-square test is the main statistical test employed to determine the statistical significant between different income groups and effect size of cordon pricing on their potential change in their travel behaviour and traveler's perception about the best way to distribute the generated revenues. In other words, chi-square test is the main test used to examine respondents' perception about cordon pricing vertical equity. One-way ANOVA is used to examine the impact of income on traveler's willingness to pay and determine whether there are any significant differences between these groups. One way ANOVA was used in this study to examine theme two, research question (2), and survey questions (8, 9, 10, 11). The next section describes in details the methods used to analyze each theme, research questions, and survey questions with detailed specific hypotheses for each case.

Table 3. 3: Statistical methods and tests employed to analyze stated preference results

Theme	Research question	Survey question/s	Item	Method	Statistical test
1	1	5, 6, 7	Public desirability for cordon pricing as a congestion mitigation strategy in the GTA	Chi-square test	X^2
2	2	8, 9, 10, 11	Traveler's willingness to pay to reduce their car trip travel time.	One-way ANOVA	F-test
3	3, 5	12, 13, 14, 16	Traveler's willingness to change their travel behaviour and the factors affecting that.	Chi-square test	X^2
4	4, 5	15	Public perception of the distribution of the generated revenue from cordon pricing.	Chi-square test	X^2

3.6.1.1 Methods, statistical tests, and hypotheses employed to address Theme 1 research question (1), and survey questions (5, 6, 7).

Chi-square test:

Chi-square test is the main test used to analyze theme one in this study. Chi-square test for two independent samples is a nonparametric test of the significant of difference between two samples. This test is mainly used to assess the probability of association or independency between two or more classifications of the samples, and can be applied to only discrete data (Maxwell, 1971). Therefore, prior to the analysis, different income categories were classified into different groups so they can be treated as discrete units. The results of the chi-square test allow us to reject the null hypothesis or not. The chi-square test statistic is computed for a two sample comparison using the formula stated in equation 1:

$$x^2 = \sum \frac{(f_o - f_e)^2}{f_e} \quad \text{...... (1)}$$

Where:
f_o: observed frequencies
f_e: expected frequencies,
e: 1, 2, 3, ...n; where n represents the number of cells in the contingency table.

In SPSS, the reliability of the chi-square statistic is diminished when there are fewer than 5 expected cases in a cell. Therefore, for smaller samples this may require collapsing or eliminating categories within variables.

Chi-square test is used first to assess the differences between people from different income neighborhoods in terms of purpose of their trips and their perception about traffic congestion in Downtown Toronto. Chi-square test is also used to assess traveler’s willingness to support cordon pricing in Downtown Toronto based on their different income characteristics, and their perception of its effectiveness as a congestion mitigation strategy in the GTA. In addition, the test is used to assess the effects of income on public perceptions of their personal outcome as a result of this policy.

3.6.1.2 Methods, statistical tests, and hypotheses employed to address theme 2, research question (2), and survey questions (8, 9, 10, 11).

One-way ANOVA

One-way analysis of variance (ANOVA) is a parametric statistical analysis and is useful in assessing the significant of differences between more than two group means. Dependent variable should be measured at the interval or ratio level and is normally distributed in all groups involved in the comparison in one-way ANOVA. Independent variable may include levels that differ quantitatively as well as it may vary naturally (e.g., income, age). One of the advantages of this test is that it is computationally less tedious, meaning that even a few means can generate a substantial number of pairwise comparisons.

Homogeneity of variances is a vital precondition for parametric statistical analysis. This is significant as if the sample variance is differ then the statistical effect of factors cannot be adequately tested. To assess the equality of variances in different samples, Levene's test was used. The Levene's test is a simple test of the equality of the variances for the two groups under the assumption that they are drawn from the same "population" (i.e., no difference). If the test is significant ($p<.05$), this indicates that ANOVA could not be reliably performed on the data as the variances are statistically different. In this case, a robust test for equality of variance such as Welch correction had to be employed in the ANOVA or the data had to be transformed before the analysis.

ANOVA F-test represents the ratio of between-group variance to within group variance and provides a numerical index that reflects the amount of separation between the groups' frequency distributions. Finding a statistically significant F in an ANOVA indicate that there exist a statistically significant difference somewhere in the data.

Eta value is a correlation coefficient that represents the impact of each socio-economic characteristic (x-axis) on willingness to pay (y-axis). The range of this value is between 0 and 1, where a value of 1 indicates that there is a strong relation between the independent and the dependent variables and that a linear equation perfectly describes this relationship. On the other side, eta square represents the share of change in the dependent variable that is explained by each factor. Eta and eta^2 (effect sizes) are calculated by dividing the model sum of squares (SS_{model}) by the total sum of squares (SS_{total}) and as shown by the formula in equation 2:

$$\eta^2 = SSmodel/SStotal \quad ..... (2)$$

$$\eta = \surd\, \eta^2$$

Table 3.5 shows an example of one-way ANOVA used to assess the impact of traveler's income on willingness to pay. Traveler's was grouped into three categories based on their income: low-income, middle income, and high-income travelers. The mean of these income groups is modeled and compared. The effect is significant if a substantial amount of variance can be explained by modelling income group mean values.

Table 3. 4: Examples of one-way ANOVA conducted to examine the significance of different socio-economic characteristics on willingness to pay tolls of different amounts.

INDVIDUAL VARIABLE ANALYSIS – TRAVEL INFORMATION			
Reduced travel time	Person from Low-income neighbourhood	Person from Middle-income neighbourhood	Person from High-income neighbourhood
5 minutes	Effect is significant if a substantial amount of variance can be explained by modelling income group mean values.		
10 minutes	↓		
15 minutes	↓		
20 minutes	**F-test**		

It is expected that household annual income would be found to be significant indicators of traveler's willingness to pay. For example, it is expected that higher-household income are more willing to pay the toll than other income groups particularly as the travel savings increase.

3.6.1.3 Methods, statistical tests, and hypotheses employed to address theme 3, research questions (3, 5), and survey questions (12, 13, 14, 16).

Travel behaviour is a significant indicator of equity of cordon pricing. As a result of the implementation of this policy, drivers may decide to pay the fees and drive as before, switch to other modes of transportation, or change the timing of their car trips to reduce charges. Their rational behind that is also different. For example, drivers from high-income neighborhoods may pay the fees because their time value is greater than the cordon fees and hence will gain from this policy. While, on the other hand, low-income drivers may switch to other modes of transportation because their time value is less than the cordon fees and they will be worst off of this policy.

Table 3.7 shows an example of the different tests used to assess equity between people from different income neighborhoods based on their potential travel behavioural changes. Chi-square test is the main test used to assess vertical equity of cordon pricing based on traveler's willingness to change their travel behaviour. For example, the effect of cordon pricing is significant if a statistically significant difference is identified at the 0.05 level between different income groups in any of the expected changes in travel behaviour suggested in the survey.

Table 3. 5: Examples of chi-square test conducted to examine the impact of cordon pricing on the travel behaviour of travelers based on their different socio-economic characteristics.

HOUSEHOLD VARIABLE ANALYSIS			
	Low- income	Middle-income	High-income
Pay the toll	Effect is significant if a statistically significant difference is identified at the 0.05 level between different income groups.		
Drive less			
Join car pooling			
Use public transportation more often			
Cycle more often			
Walk more often			
Chang travel time			
Use car more often			

Cordon pricing affects the mobility and travel behaviour of many travelers. The survey asked respondents if they are willing to pay the toll and drive as usual; or if they are willing to drive less, join car pooling, change mode of transportation, or change travel time as a result of implementing cordon pricing in Downtown Toronto. It is expected that household income is a significant indicator of changing travel behaviour. For example it is expected that travelers from high-income neighborhoods pay the tolls and drive as before while low-income travelers to drive less and use other transportation modes more often.

3.6.1.4 Methods, statistical tests, and hypotheses employed to address theme 4, research questions (4, 5), and survey questions (16).

Revenue distribution is a vital step in achieving vertical equity among different travelers. This study suggested five different scenarios of allocating the generated revenue among cordon pricing users. These scenarios are: to improve road infrastructure, to improve public transportation facilities and services, to reduce public transportation fares, to support local municipal budget, and to improve cycling and walking conditions.

Chi-square test is used to assess the differences in perception between different travelers based on their income in terms of allocating the generated revenues. It is expected to witness some statistical differences. For example, as travelers from high-income neighborhoods use more their own cars in their commuting and are more willing to pay the toll and drive as usual, then it is expected that they support allocating the generated revenues to improve road infrastructure.

3.7 Chapter summary

This chapter discussed the theoretical and conceptual framework as well as the methods used in this study to gather and analyze stated preference data. In addition, it discussed in details the research methodology and survey design and distribution. Data collected from the on-site survey resulted in 208 usable responses from the residents of the GTA. The study employed quantitative methods to analyze primary and secondary data.

Primary data was gathered through stated preference survey. The aim is to evaluate perceptions of equity in cordon pricing in the Downtown Toronto based on the stated preferences of survey respondents in the GTA. In general, the survey consists of three sections to address four themes. These themes are public desirability for cordon pricing in the GTA; traveller’s willingness to pay to reduce their car trip travel time; traveller’s willingness to change their travel behaviour and the factors affecting that; and public perception of the distribution of the generated revenue from cordon pricing. Finally, the chapter addressed specific hypotheses and the main test employed to measure vertical and spatial equity.

Secondary data used in this research were collected from Transportation Tomorrow Survey (TTS). The aim of using this data is to investigate if Downtown Toronto is moving toward or away the principles of sustainable transportation, and thus to make a case that Downtown Toronto is a candidate for cordon pricing.

Chapter 4: Sustainable Transportation in the GTA

4.1 Introduction

This chapter introduces the study area and explains and justifies the choice of Toronto Downtown as a candidate for cordon pricing. It also provides clarification on how the GTA has been spatially divided for the subsequent analysis. Substantively, the chapter is based on a variety of policies and travel information that provide insights into the ways in which the GTA is moving toward (or away from) sustainable transportation. The main sources of data for the trend analysis are the five large-scale personal travel behaviour surveys conducted in the GTA in 1986, 1991, 1996, 2001, and 2006 as part of the Transportation Tomorrow Surveys (TTS). As will be shown, the data provide a strong basis on which to conclude that, on the whole, the GTA is not moving in the direction of sustainable transportation, which provides a concrete justification for demand-management interventions, such as cordon pricing.

Section 4.2 of this chapter describes the study area and reviews the main initiatives taken by different levels of governments over the past several decades to regulate transportation services and infrastructure in the GTA. Section 4.3 focuses on measuring sustainable transportation in the GTA through exploring changes in employment and population during the last two decades. Section 4.4 examines travel activities in the GTA during the last two decades. Section 4.5 summarizes sustainable transportation in the GTA based on the literature and the results of the analysis of TTS data.

4.2 Study Area and transportation planning in the study area

The GTA, located in Southern Ontario, is Canada’s largest and fastest growing metropolitan region, with a 2006 population of 5.872 million (6.059 million as of 2011). The regional spatial structure of the GTA comprises the City of Toronto and four regional municipalities (Durham, York, Peel, and Halton) as shown in Figure 4.1. Each regional municipality comprises several local municipalities.

The idea of creating Greater Toronto Area was introduced early in the nineteenth century. This idea was motivated by the desire to create a local government that would have the capability to control local infrastructure. In late 1940s, planners started exploring the idea of incorporating the City of Toronto's immediate suburbs which resulted in forming Metropolitan Toronto in 1953 (Solomon, 2007). In 1992, Metropolitan Toronto included the remaining parts of the GTA into its planning (Fletcher, 2003). The total area of the GTA is 7,125 km^2 (Statistic Canada, 2006), and it is bordered by Lake Simcoe on the north, Lake Ontario on the south, Niagara Escarpment on the west, and Kawartha Lakes on the east.

The GTA is also distinguished by its economy and transportation infrastructure. The GTA is the third largest financial centre in North America (City of Toronto, 2011) and generates one fifth of the GDP of Canada. The labour force is employed mainly in the service sector and to a lesser extent in manufacturing, wholesale and retail trade, transportation, construction, and communication and utility services (Greater Toronto Marketing Services, 2011). In terms of transportation infrastructure, the GTA has the largest and busiest freeways in Canada. In fact, highway 401, which is one of the main freeways in the GTA, is one of the busiest freeways in the world. Also, the GTA, and Toronto Downtown in particular, is known for its well established public transportation services and facilities.

The literature used in choosing the cordon design for this dissertation draws on experiences in Stockholm, Singapore, London, Norway, and Hong Kong (Greater London Authority, 2001; Holland and Watson, 1978; Larsen and Ramjerdi, 1991; Harrison et al., 1986; Menon, 2000). None of these studies explored in details the guidelines that have been followed to design cordons in the above cities. However, in most cases cordon pricing is limited to the central area (e.g., May et al., 2002) even though traffic in other areas contributes to congestion. The motivations behind this strategy are to avoid adverse impacts on low income residents and to gain public acceptance to implement this scheme.

In this study, the examination of travel data is based on three zones. The first zone is Downtown Toronto (Planning District 1 (PD1) according to TTS data) as shown in Figure 4.1. The PD1 area is the largest employment centre in the GTA where about 33% of people employed there travel from places located outside its boundaries. Also, a considerable percentage of people travel from the PD1 to work in the rest of the City of Toronto and the rest of the GTA regions. The boundaries of the Downtown constitute the boundaries of the proposed cordon zone.

The second zone is the rest of the City of Toronto which represents Planning Districts 2 to 16 as shown in Figure 4.1. This area represents the most urbanized area in the GTA. Travelers residing in this area are attached to the city core more than travelers living in the other regions of the GTA. In particular, people who are living adjacent to the cordon boundaries and travel more frequently to the city centre may encounter more burdens as a result of implementing cordon pricing.

The third area is the rest of the GTA regions which includes the four regional municipalities in the GTA (Durham, York, Peel, and Halton). People who live in these regions commute longer distances than people traveling from the rest of the City of Toronto. In addition, the only direct transit services from this area are through GO transit. Hence, the impact of cordon pricing should be more noticeable on those travelers.

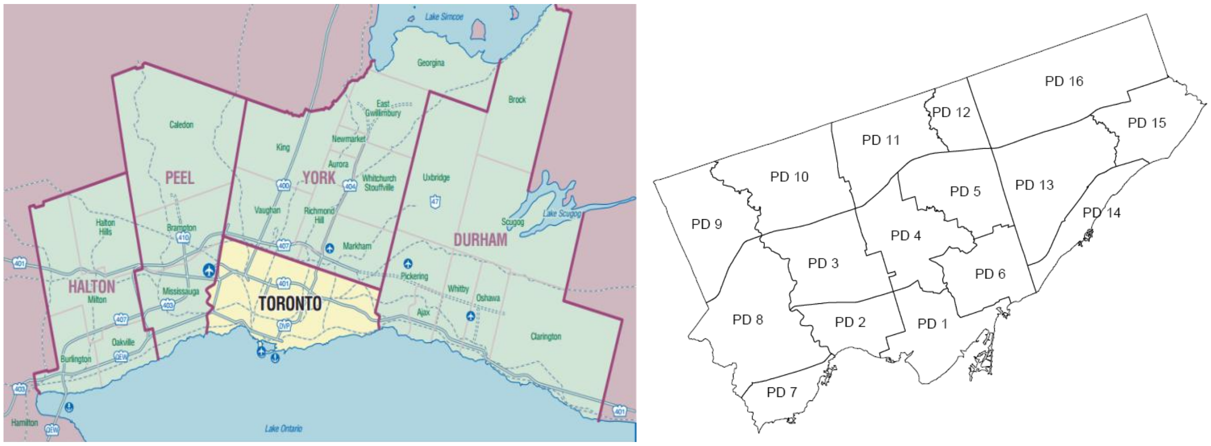


Figure 4. 1: Greater Toronto Area. Source**:** www.toronto.ca, 2012; and 2006 TTS Survey Area Planning Districts (City of Toronto). Source: Data Management Group, 2006

Transportation services and infrastructure in the GTA are regulated by different governing bodies and at different scales and levels. Support for sustainable transportation initiatives has varied across governments and over time. It is important at this point to review the main initiatives taken by different governing bodies over the past several decades to achieve sustainable transportation in the GTA. By analyzing the TTS data through the last two decades, we can determine if these initiatives have been successful in making transportation in the GTA more sustainable or, alternatively, whether more measures should be taken to achieve transportation sustainability.

As a response to population and employment growth in the GTA, provincial policies have encouraged more compact mixed-use land uses. This is considered a vital step to boost transit ridership, cycling, and walking trips in an attempt to decrease the dependence on auto-traffic trips (Urban Strategies Inc., 2005). The Ontario provincial government adopted two complementary regional polices that impact the movement of goods in the Toronto Region. The Greater Golden Horseshoe (GGH) policy provided the greenbelt legislation (Greenbelt Act, 2005). This policy took place in 2005 and aims to create a huge belt of natural lands running through central Ontario. The second policy is Places to Grow (Ministry of Public Infrastructure

Renewal, 2008; Places to Grow Act, 2005). This policy aims to encourage more compact forms of urban growth for lands outside the greenbelt and to improve the transit system to support the intensification of urban growth centres. This development plan is supported by new provincial spending on infrastructure, including transportation (IBI, 2007).

In 2004, Ontario's infrastructure deficit was estimated at $100 billion. As a response to this deficit, the provincial government announced the implementation of a ten-year capital infrastructure plan, including participation from the private sector. The plan considers the transit system as the main mode of transportation for moving people. For the movement of goods, the plan's priority is to connect the GGH to vital markets. In 2005, the Ministry of Public Infrastructure Renewal announced that $6.9 billion of the province's spending plan ($30 billion five-year PPP infrastructure renewal plan) was to be spent on highway improvements and border crossing throughout the province by 2010 (Government of Ontario, 2006).

Local transportation policies in the GTA are differentiated between two major regions: the inner city (the City of Toronto) and all other remaining regions (the split is often referred to as 416/905 based on telephone area codes). The City of Toronto encourages residents to use the transit system as their main mode of transportation. This aims to achieve the goal of its official plan for major intensification to deal with population growth. On the contrary, the official plans for the rest of the regions in the GTA promote rail, airport cargo, and truck modes of transportation and encourage automobile use and the competition for transportation investment funds.

The City of Toronto developed a new Official Plan in 2006 based on the strengths of its 1976 plan. The new plan kept the City's policy of not adding new major roads into the core area. In addition, the new plan recommended that the City should adopt measures to discourage automobile commuting and use throughout its boundaries. The plan contained for the first time a section related to environmental protection, such as reducing air pollution as a consequence of the consumption of carbon-based fuels. The new plan permitted mixed-use zone of development to encouraged housing intensification in the Downtown area. The aim of this plan is to enable more people to live and work within the same area to minimize their need for commuting and consequently, to mitigate/manage the increase in peak-period trips (The City of Toronto, 2009).

The Toronto Official Plan encourages densification of the city's urban structure, as well as public transit intensification to accommodate the future settlement of up to 1 million residents within the city's borders. Toronto's new Official Plan supports the construction of condominiums as an integral part of the overall framework of the provincial Growth Plan. The aim of this policy is to increase the utilization of existing and future rapid transit stations through increasing densities and mixed land use around these stations (Toronto City Summit Alliance, 2007). This policy aims to create an urban structure plan that links public transportation to a series of centres and corridors that would conveniently concentrate people and jobs close to transit and balance population and employment. The City of Toronto tends to increase the zoning areas of Downtown for housing to encourage people working in the Downtown to also live there, thus reducing travel requirement. Also, the City has raised the cost of central area parking to encourage commuters to change their work trip modal choice. Electric light-rail lines are among the solutions that the City of Toronto is planning to implement to mitigate/manage congestion. In 2007, the City of Toronto announced a plan known as Toronto Transit City. The plan aims to construct a 120 km network of electric light-rail lines throughout the entire city (The City of Toronto, 2008b). These policies were successful in accomplishing their anticipated goals (Miller and Shalaby, 2003).

The City of Toronto is continuously and consistently showing support for the transit system by giving higher priority to transit vehicles on congested city road network. For example, over the past 10 years, the City has initiated the notion of reserved lanes for buses, bicycles, and taxis during the peak-periods on some routes in the Downtown. Other attempts to enhance surface transit include the introduction of proof-of-payment fare system and the limited implementation of priority to speed the flows of streetcar to allow faster boarding on selected roads. In addition, the City is not allowing increasing the capacity of the roadways entering the City's core area. The aim is to mitigate the growth of autos entering the core area by encouraging people to switch modes of transport from their own cars to public transit for trips to/from the core area, particularly during peak-periods. Overall, these attempts have achieved encouraging results by improving the travel time for both transit and private vehicles (The City of Toronto, 2009a, Shalaby et al., 2007; Stewart and Pringle, 1997).

Overtime, the City of Toronto has responded to the increased demand for transportation by strengthening public transportation network, services, and facilities. During the 1964 – 1990, the TTC surface system of streetcars, buses, and trolley-buses underwent considerable expansion in terms of the time periods of service, coverage, and service frequencies, and the Toronto subway system expanded. Also in 1970, a significant change in TTC's fare policy took place by using a single system-wide flat fare instead of a zone fare system. This change encouraged people from suburban areas to use this system for journeys to workplaces located in Toronto Downtown (Miller and Shalaby, 2003). However, the TTC services have slightly declined after the year of 1990 as a result of subsidy reductions and ridership losses (Miller and Shalaby, 2003).

The City of Toronto also utilized both supply and demand management as a response to the increasing demand on its highways. Supply management included significant expressway expansions (in particular the provincial 400 series) during the 1964 – 1996 time period. These expansions took place inside and outside the City of Toronto (Miller and Shalaby, 2003). In addition, after linking the Gardiner Expressway and the Don Valley Parkway in 1966, the City of Toronto did not build any new major roads. One of the reasons for that is the establishment of the anti-expressway movement in the late 1960s. This movement focused on concerns about the deterioration in the lifestyle inside the city, neighbourhood destruction, and the high volumes of automobile traffic (Stewart and Pringle, 1997).

In 2010, the City of Toronto developed a new Official Plan. The key components of the plan are the policies that favour the expansion of transit over increases in road capacity in addition to encouraging more mixed used development. The main target is to promote sustainable transportation options that are economically competitive. In this regard the Toronto official plan is designed to address three major areas of concerns. First, the existing transportation system needs to be maintained in a state of good repair. Second, the current transportation capacity should be used in a better way by giving priority to street cars and buses on the roads. Third, the incremental expansion of the rapid transit system should be protected as demand justifies. The City emphasizes using the available road space more efficiently to move people and at the same time reduce the demand for vehicle travel. The City is planning to make transit, walking, and cycling more attractive and travelers can rely on them as alternatives to using automobiles. The City will depend more on travel demand management, including car pooling and increase the average car occupancy rate, to reduce car dependency.

Another key policy in the plan is to integrate transportation at the local and regional levels. At the local level, the plan addresses the differing transportation demand between places that have the capability and potential to grow and those where little physical change is foreseen. The City of Toronto worked with all neighbouring municipalities and the Province of Ontario to develop policies and frameworks to address and deal with growth across the GTA. These policies aim to reduce auto dependency and make better use of existing urban infrastructure to connect the centres of the major cities by an integrated regional transportation system. Toronto’s official plan aims to protect the integrity of the City’s transportation network and identify sections of streets that are suitable for streetcar and bus priority measures. In addition, it aims to create greater opportunities for people to work and live locally by increasing the supply of a full range of housing types in mixed use environments.

The growth in the City is based on the integration of the land use and the transportation system. Future growth within the City of Toronto in general will be mainly concentrated in areas that are well served by transit system and where good transit access can be provided along existing road networks. The growth will be directed to the employment centres, avenues, and the Downtown to use municipal land and infrastructure more efficiently. One of the policies of the City of Toronto is to promote mixed use development to concentrate people and jobs in areas well served by both surface transit and rapid transit stations and to encourage walking and cycling for local trips. This transportation improvement aims also to support the City’s growth. In the rest of the City of Toronto, the Scarborough, North York, Etobicoke, and Yonge-Eglinton Centres are identified as key locations with excellent transit accessibility particularly surface transit.

In Downtown Toronto, the policies are designed to discourage the expansion of automobile commuting and all day parking and give the priority to improve the access to TTC and GO transit. One step towered that is by renovating and improving Union Station to increase its passenger handling capacity to accommodate users of this transportation hub. In addition, surface transit will be given priority on key Downtown streets. Street improvements will be developed to enhance the pedestrian environment by making walking and cycling safer in the Downtown. To encourage walking, underground pedestrian network (the PATH system) is expanded and new developments are motivated to connect and support the system.

In Downtown Toronto, the growth is steered to areas including the central waterfront, the avenues, and the employment districts. Special attention is given to maintain and improve the vitality of the Downtown by renewing the Central Waterfront and connecting it to the employment centre. The aim is to create a vibrant mix of employment and residential growth where the mixed use Avenues and the waterfront condo development will stress residential growth and employment districts will stress the job intensification. This will make the Downtown more attractive and competitive business location and hence new business opportunities and ventures will be created.

In response to the increasing concerns about the performance of the transportation system in the GTA, the Government of Ontario established the Greater Toronto Transportation Authority (GTTA) in 2006. This was done under the Greater Toronto Transportation Authority Act. In 2007, the GTTA became known as Metrolinx. The main goal of Metrolinx is to develop and implement an integrated multi-modal transportation plan, as well as an investment strategy and capital plan for the GTA and the Hamilton area. In addition, Metrolinx was given the mandate to develop and implement programs, such as Bikelinx and the Smart Commute

Initiative (Metrolinx, 2008a). Metrlonix proposed the largest public transportation expansion in the GTA and Hamilton area that amount to two billion dollars annually over the next 25 years. These investments include building over 1,200 kilometres of rapid transit to enable 80% of residents to live within two kilometres of rapid transit. It will also include over 7,000 kilometres of new lanes, trails and pathways to enable pedestrians and cyclists to fulfill their day's activities in a safe and healthy lifestyle. Metrlonix vision over the next 25 years is to reduce the distance that travelers drive every day to one-third compared to 2009. They are looking to accommodate 50% more people in the region with less congestion by increasing the proportion of work trips taken by transit to one-third and walking or cycling will comprise one-fifth of the total work trips. Bike lanes and trials will be six times more.

Metrolinx created a Regional Transportation Plan (RTP) for the GTA and Hamilton area. The main aim of this plan is to create a long term plan for a multi-modal and integrated regional transportation system. This plan also aims to integrate local transit system with each other and with the GO transit system and optimizing transportation infrastructure. The plan also aims to reduce car dependency and ease congestion and commute time. A set of goals and related objectives has been developed to guide progress toward the vision for the regional transportation plan and intended to provide guidance for decision-making and planning at all levels (see Table 4.1). The goals and objectives include:

Table 4. 1: Goals and objectives of the regional transportation plan (Metrolinx 2008b, pp. 15-19)

Goals	Objectives
Transportation Choices	1. Increased transportation options for accessing a range of destinations, 2. Improved accessibility for seniors, children and individuals with special needs and at all income levels, 3. Decreased need for travel, particularly over long distances and at rush hour.
Comfort and Convenience	4. Improved transportation experience and travel time reliability, 5. Faster, more frequent and less crowded transit, 6. Improved information, including real time information, available to people to plan their trips, 7. Region-wide integrated fare structure and collection, and schedule coordination.
Active and Healthy Lifestyles	8. Increased share of trips by walking and cycling.
Safe and Secure Mobility	9. Continued progress towards zero casualties and injuries on all transportation modes, 10. Improved real and perceived traveler safety, especially for women, children and seniors, 11. Improved safety for cyclists and pedestrians.
Fairness and Transparency	12. Increased engagement in the planning and financing of the transportation system from a diverse group of citizens.
A Smaller Carbon Footprint and Lower Greenhouse Gas Emissions	13. Decreased use of non-renewable resources, 14. Significant contribution to the achievement of the transportation related GHG reduction targets of Go Green: Ontario's Action Plan for Climate Change, 15. Improved air quality, and reduced impacts on human health.
Reduced Dependence on Non-Renewable Resources	16. Increased proportion of trips taken by transit, walking and cycling, 17. Improved energy efficiency, including increased use of clean vehicles and green technologies, 18. Reduced use of out-of-province energy sources.
Foundation of an Attractive and Well-Planned Region	19. Reduced consumption of land for urban development, 20. Reduced negative impacts on our agricultural and natural systems, 21. More transit and pedestrian-friendly streetscapes, and improved walking and cycling amenities, 22. Greater prevalence across the region of transit-supportive densities and urban design.
Prosperity and Competitiveness	23. Lower average trip time for people and goods, 24. Greater reliability of the freight and passenger systems, 25. Managed congestion.
Multi-Modal Integration	26. Reduced delays, damage and costs in transferring goods from one mode to another, and more seamless region wide services for travelers and service providers.
Interconnectedness	27. Improved connections and service within the GTHA and to/from regional, provincial, and international terminals and facilities.
Efficiency and Effectiveness	28. Increased prevalence of Transportation Demand Management practices, 29. Improved value of transportation investment and spending for households, businesses and governments, 30. Optimized use of all travel rights-of-way by commercial vehicles through a range of incentives and disincentives, 31. Increased productivity of the transportation system.
Fiscal Sustainability	32. Sufficient, reliable and predictable funding sources for transportation investments, 33. Technical rigour and transparency in the selection and prioritization of major projects, 34. Increased financial self-sufficiency of transportation infrastructure and projects, 35. Competitive shipping cost structure, 36. Fair and effective fiscal treatment of various modes that better reflects the cost of transportation services in the prices paid by users, 37. Minimized direct and indirect economic losses due to accidents.

The RTP contained 10 strategies to achieve these vision, goals, and objectives of the plan as shown in Table 4.2. Each strategy includes priority actions that are broad in scope and include actions relating to legislation, policies, planning, programs, and funding. In addition to priority actions, each strategy includes supporting policies that are needed to guide day-to-day decision making in support of each strategy. Nine of the priority actions will have the largest transformational impacts on the region transportation system and are highlighted as Big Moves as shown in the table.

Table 4. 2: Strategies and big moves to achieve these vision, goals, and objectives of the regional transportation plan (Metrolinx, 2008b)

Strategies	Big Moves
Strategy # 1: Build a comprehensive regional rapid transit network	1. A fast, frequent and expanded regional rapid transit network. 2. High-order transit connectivity to the Pearson Airport district from all directions. 3. An expanded Union Station - the heart of the GTHA's transportation system. 4. Complete walking and cycling networks with bikesharing programs. 5. An information system for travelers, where and when they need it. 6. A region-wide integrated transit fare system. 7. A system of connected mobility hubs. 8. A comprehensive strategy for goods movement. 9. An Investment Strategy to provide immediate, stable and predictable funding.
Strategy # 2: Enhance and expand active transportation	
Strategy # 3: Improve the efficiency of the road and highway network	
Strategy # 4: Create an ambitious transportation demand management program	
Strategy # 5: Create a customer-first transportation system	
Strategy # 6: Implement an integrated transit fare system	
Strategy # 7: Build communities that are pedestrian, cycling and transit-supportive	
Strategy # 8: Plan for universal access	
Strategy # 9: Improve goods movement within the GTHA and with adjacent regions	
Strategy # 10: Commit to continuous improvement	

Metrolinx also developed several "green papers" to support the development of the RTP. The green paper on transportation demand management emphasized the strengths of transportation/congestion pricing as an effective policy to deal with many of the GTA's transportation issues. At present, Highway 407 is the only tolled road in the GTA and there are no plans to construct more toll roads in the future.

More recently, in response to the increase in travel demand, the Province of Ontario has been actively planning high occupancy vehicle (HOV) lanes on the main 400 series across the GTA. To date, two HOV sections have been opened; the first is in Mississauga, on Highway 403, and the second is in Toronto, on Highway 404 between Highway 7 and Highway 401 (IBI, 2007; Metrolinx, 2008b).

4.3 Population and Employment

Population growth and changing land use patterns require changes in transportation service provision. This is the case in the GTA, where the population has increased by 48% over the period 1986-2006 as shown in Table 4.3. The table shows that all regions experienced growth. The largest absolute increase occurred in Peel Region, York Region and City of Toronto, with increases of approximately one-half million in all three cases. The population distribution in 2006 was such that 42% of GTA residents lived in the City of Toronto, with the Regions of Peel, York, Durham and Halton accounting for 21, 16, 10 and 8%, respectively. This indicates that modest decentralization of the GTA population has taken place during the last two decades, resulting in more challenges for the surface transportation sector. One reason for this suburbanization is that population distribution has followed the direction of employment growth as well as transportation infrastructure growth.

Table 4. 3**:** Total number of GTA population by area and year and percentage of GTA population by area and year.

Area	Population 1986	Population 2006	Growth in Population Absolute % Change	Percentage of GTA Population, 1986	Percentage of GTA Population, 2006
PD1	112694	188668	67%	3%	4%
The rest of the City of Toronto	1839084	2257271	23%	51%	42%
Durham	317887	539493	70%	9%	10%
York	344985	857521	149%	9%	16%
Peel	577043	1119122	94%	16%	21%
Halton	264629	422730	60%	7%	8%
Entire GTA	3639570	5384805	48%	100%	100%

Population and employment densities are important indicators of sustainability and sustainable transportation, as they account for a significant share of urban land area. Addressing the density of employment lands is getting more attention because of its link with the use of public transit (The Centre for Sustainable Transportation, 2002). For example, low-density-areas motivate automobiles use, with various environment impacts. On the contrary, high-density areas influences, provides, and supports public transit services. In addition, higher densities support other sustainable modes of transportation such as walking and cycling.

Population density (people per square km) varies across the GTA and has increased over the last two decades as shown in Figure 4.2. The figure shows that population growth occurred fairly steadily, but was particularly rapid in PD1, suggesting a recent re-concentration of population in the city core, albeit on the smaller scale. PD1 area encounters the highest density across the GTA. The density of this area has increased by 54% over the study period. However, the highest increase in density across the GTA had occurred in York region where the density increased by 150% followed by Peel region. Looking at this figure we can conclude that PD1 area is moving toward sustainable transportation. While the density of the rest of the City of Toronto is increasing but slightly and hence this area is moving away from sustainability. In the rest of the GTA regions, the density in the four regions is increasing and it is more pronounced in the regions of York and Peel where we can argue that this increase in density is not related only to population growth but also to economic growth in these areas which attract more people to work there but not yet in the direction of sustainability.

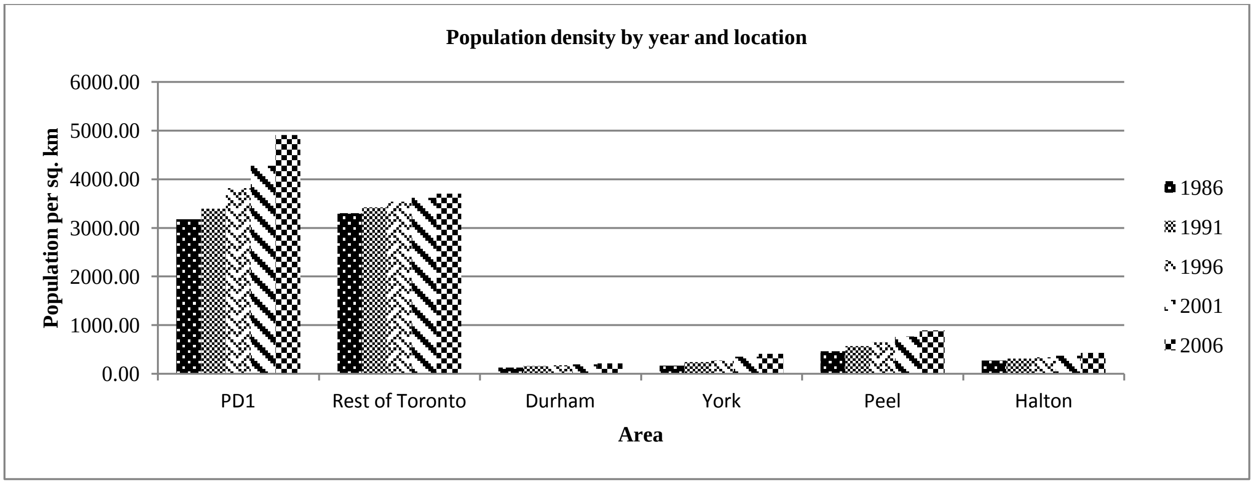


Figure 4. 2: Population density across the GTA.

Table 4.4 shows that jobs remained concentrated in the City of Toronto, with the highest job density in PD1. Over the past two decades, employment density has continued to increase in PDI but not in the City of Toronto overall; job growth in the rest of the GTA has been notable.

Table 4. 4: Total number and percentage of GTA employment by area and year.

Area	Employment 1986	Employment 2006	Growth in employment	Percentage of GTA employment, 1986	Percentage of GTA employment, 2006
PD1	73068	105121	43.87%	3.79%	3.94%
Rest of Toronto	1036856	1057790	2.02%	53.79%	39.64%
Durham	165528	275774	66.60%	8.59%	10.34%
York	185215	440791	137.99%	9.61%	16.52%
Peel	325922	570945	75.18%	16.91%	21.40%
Halton	141138	217772	54.30%	7.32%	8.16%
GTA	1927727	2668193	38.41%	100.00%	100.00%

Employment density (jobs per square km) has also changed over time (Figure 4.2, Table 4.5). Table 4.5 shows that the density is highest in PD1, fairly high throughout the City of Toronto, and comparatively low in the Regions, although Peel Region`s density has increased dramatically over the past two decades; by contrast, employment density in the rest of the City of Toronto has not changed by any significant amount.

Table 4. 5: Population and employment densities within the GTA

Area	**Population density 1986**	**Population density 2006**	**Percentage increase/ decrease**	**Employment density 1986**	**Employment density 2006**	**Percentage increase/ decrease**
PD1	3175.38	4910.24	54%	2071.56	3382.50	63%
Rest of Toronto	3299.89	3700.31	12%	1868.41	1751.66	-6%
Durham	121.22	205.72	70%	63.12	106.81	69%
York	164.84	409.73	149%	88.50	211.41	139%
Peel	459.38	890.92	94%	259.46	455.27	75%
Halton	266.65	425.96	60%	142.22	219.56	54%

Employment self-containment describes the association between the number of employed members of the labour force that live and work within a designated region and the number of jobs available within that area. A perfect balance represents a ratio of 1:1 which means that the employment is self-containment in the defined area. In other words, this means that there is the opportunity for each working resident in the defined area to work in the same area if he/she chooses to do so.

Labour force in the GTA has changed dramatically over the 1986-2006 time period. Employment growth within the GTA has a similar trend to the population. The growth of jobs has increased at a higher rate in the rest of the GTA than the City of Toronto. In general, PD1's employment has increased by 0.3% between 1991 – 2006 time period with a market share of 4.0% in 2006; whereas, the rest of the City of Toronto declined by 10% with a market share of 40%. On the other hand, employment in the rest of the GTA regions increased by 10% with a market share of 56%. This reflects the strong employment growth that has occurred in this area over the past two decades. This also has led to increase the density of employment in this area. This indicates that employment is decentralizing and that the City of Toronto has lost employment market share to the advantage of the rest of the GTA regions between 1986 – 2006 time periods. However, the PD1 still has more jobs than residents, and therefore, people have to commute to the city to get to their jobs. In contrast, the rest of the GTA regions have more residents than jobs, and therefore many people have to leave these areas to work elsewhere.

In the GTA, the majority of workers live and work within the same area. Approximately 50-70 percent of employed people live and work in the same area. For example, in PD1 about 67% of the workers live and work there; this percentage has stayed remarkably constant over the past 20 years as shown in Figure 4.3. The employment self-containment in the rest of the City of Toronto declined slightly over the past 20 years. About 24% of workers who live in the rest of Toronto area work in PD1. The percentage of employment self-containment in the rest of the GTA regions has increased by 7% during the same period to reach 72% in 2006. Peel and York regions are gaining the most which reflects the economic growth and expansion in these two regions. On the other hand, self-containment in Durham are declining and are stabilizing over time in Halton regions, where these two regions have become more interconnected with labour markets in the City of Toronto and other regions in the GTA. This affects the spatial flow of trips with more intra-regional trips within the city or the region.

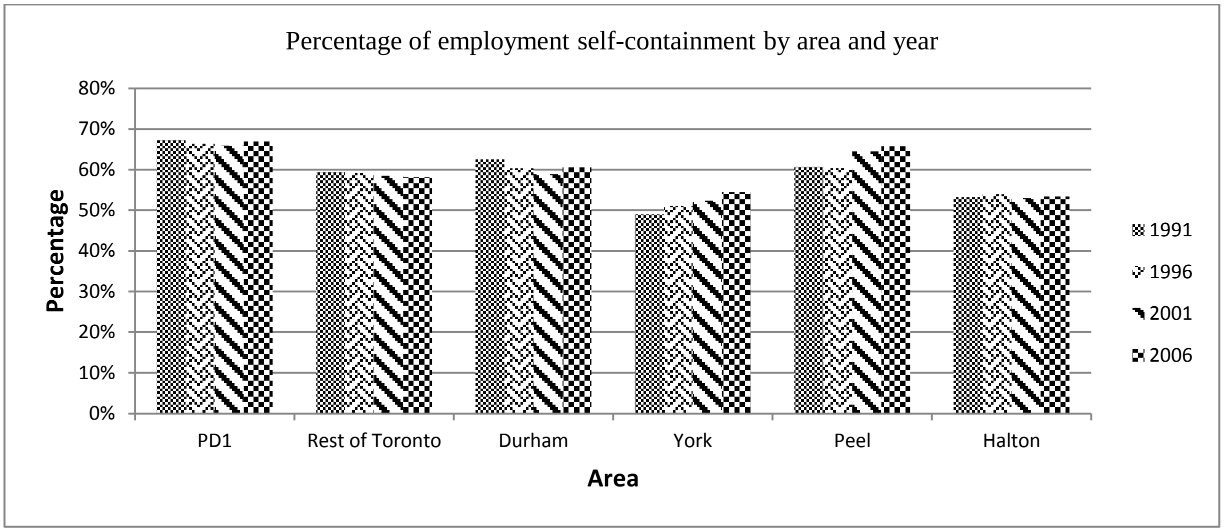


Figure 4. 3: Percentage of employment self-containment in GTA

Figure 4.4 illustrates the distribution of residential locations for workers employed in the GTA. The percentage of workers who live and work in PD1 form about 16% of the total workers in the GTA. This percentage has increased to some extent over the past 20 years. Whereas, the percentage of workers in the GTA that live in the rest of the City of Toronto has declined significantly over the same time period but still compose the highest percentage where more than half of the people working in the GTA live in the rest of Toronto area. The other 29% of the workers in the GTA (as of 2006) commute from the rest of the GTA or from more distant locations around the GTA. This percentage increased by 8% over the same time span.

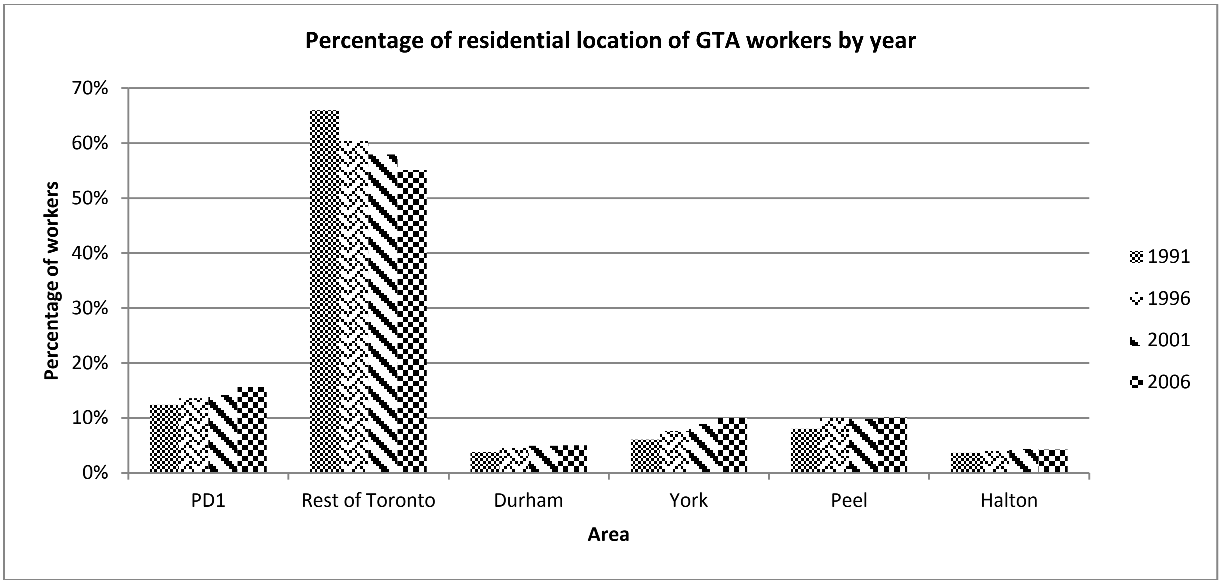


Figure 4. 4: Percentage of residential location of GTA workers by year

This increase in the percentage of workers who commute from the rest of the GTA regions demonstrates that the Toronto region is losing self-containment with respect to its core area workers especially in the areas around the city core, while the increase in the percentage of workers in PD1 who live there indicates that policies designed to promote population growth within the city core is an effective one. In addition, the increase in workers who commute from the rest of the GTA regions to PD1 is not of any benefit to the Toronto Transit Commission (TTC), because most of these workers would use their personal cars or GO-Transit in their commute. This percentage also illustrates the continuing growth of the functional interdependence between the rest of the GTA regions and the City of Toronto (Miller and Shalaby, 2003).

The substantial decentralization of employment densities and areas from denser (PD1), urban locations to low-density (the rest of the GTA regions) is a major obstacle to improving transit ridership in the GTA during this time period. Decentralized areas are difficult to serve efficiently and cost-effectively by urban transit. The key finding from these observations is that population and employment growth is increasing more in absolute terms and on a per-capita basis particularly in the rest of the GTA regions. In general, this trend is in contrast with the direction of progress toward sustainable transportation and sustainability.

4.4 Travel analysis in the GTA

Travel pattern is a fundamental factor in measuring sustainability. It has a direct effect on the quality of life, land consumption (e.g., roads, transit facilities, parking, etc.), environmental and public health (e.g., emission to air), and economic efficiency. This section explores the key trends of personal travel activity (for people aged 11 years and older) in the GTA over 1986-2006 time period. The analysis includes the trends of trip rates at personal and household levels.

4.4.1 Trips distributed over different times of a day

Figure 4.5 shows the distribution of trips by purpose and throughout different times of the day in the GTA as of 2006. The number of trips was measured over four different time periods where two of them represent the morning and evening peak periods while the other two represent the times that extend between the two peak periods. Although the percentage of home-based work trips is higher during the morning peak period, the highest number of trips is generated during the evening peak period as shown in the figure. The percentage of home-based discretionary trips and the non home-based trips is higher in the evening peak period trips than in the morning.

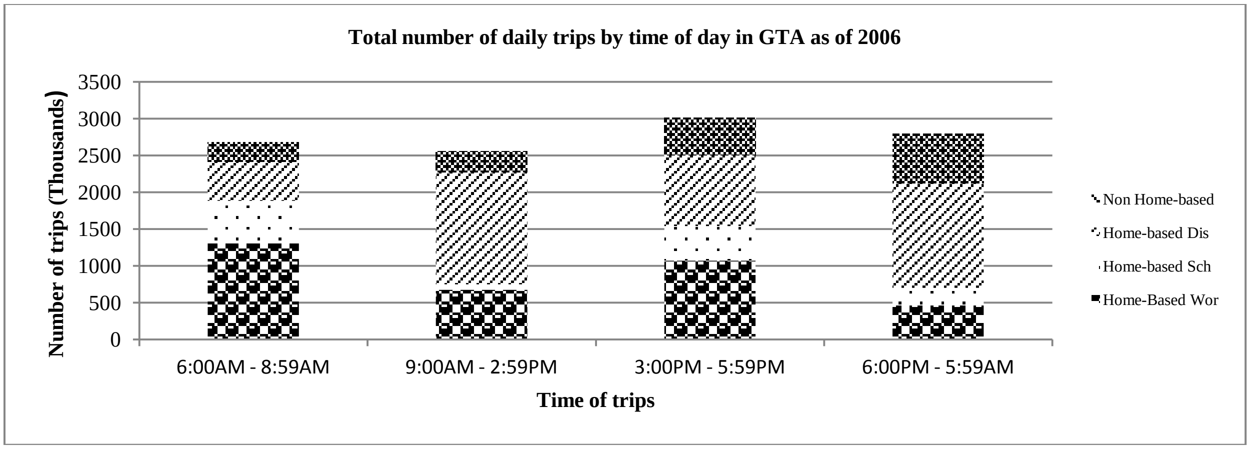


Figure 4. 5: trips distributed over different times of a day

The total number of trips in the evening peak period time is almost evenly distributed between home-based work trips on one side and home-based discretionary trips and non home-based trips on the other side. This makes the traffic flow in a complex way during that period as a result of the diverse mix of travel activities in which travelers are engaging. In this chapter the analysis still focuses on the morning peak period because as indicated earlier more home-based work trips are made during this time. On the other hand, the figure shows that the total number of trips is almost evenly distributed between the four time periods. The peak periods are dominated by home-based work trips while the non-peak periods are dominated by home-based discretionary trips.

The above analysis applies on the different areas across the GTA as shown in Figure B.1 (Appendix B). Home-based work trips are the dominant during the morning peak period and home-based discretionary trips are the dominant during the off-peak periods in all regions. Figure B.2 (Appendix B) shows that the percentage of home-based work trips has been declining in all regions.

4.4.2 Trips distribution by residents of GTA

Table 4.6 shows the percentage of trips made by residents of the GTA based on their area of residence. The table reflects the significance of PD1 as an employment centre to the GTA residents as well as the high level of accessibility to that area provided by the transportation system. The table also clearly shows that the rest of the GTA regions are witnessing an increase in the inter-regional and intra-regional trips originating from the rest of the GTA regions. In addition, the table demonstrates that the rest of the City of Toronto is losing trip generation to the expense of the rest of the GTA regions. Trip rates in these regions, particularly York and Peel regions, increased over the study period as the concentration and densification of population and employment have increased. In addition, higher trip rates may relate to the improvements in road and transit infrastructure which is the case in the rest of the GTA regions.

Table 4. 6: The number and percentage of trips originated and destined in different parts of the GTA and the changes on these numbers and percentages that took place between 1986 and 2006

	PD1	Rest of Toronto	Durham	York	Peel	Halton	Total
Number of trips generated by the residents of the GTA originating in their area of residence (2006)	86,883	913,156	298,252	502,493	633,276	236,043	2,670,103
Percentage increase/decrease compared to 1986	40%	15%	86%	167%	97%	72%	33%
Percentage of trips originating in travelers' area of residence within the GTA from the total trips	3%	35%	11%	19%	23%	9%	100%
Changes in the percentage of trips originating in travelers' area of residence within the GTA between 1986 and 2006	0%	-14%	2%	7%	4%	1%	
Percentage of trips originating in and destined for the same area (2006)	62%	75%	73%	63%	74%	66%	
Increase/decrease in the percentage of trips originating in and destined for the same area since 1986	45%	19%	78%	218%	128%	81%	
Number and percentage of trips destined for the designated areas originating in the GTA (2006)	332,100 (38%)	238,468 (31%)	15,861 (2%)	122,788 (14%)	121,633 (12%)	28,331 (3%)	859,181
Increase in the number of trips destined for the designated areas originating in the GTA since 1986	9%	49%	30%	83%	43%	128%	
Percentage of trips destined for the designated areas compared to total trips made in the GTA (2006)	12%	10%	1%	5%	4%	1%	

4.4.3 Mode of transportation

Travel by automobile either as a driver or passenger is the main mode of transportation used in the GTA over the past two decades. In 2006, about 71% of the GTA residents used this mode of transportation as drivers (58%) and passengers (13%) each day during the morning peak period in their commuting within the GTA with an increase of 6% since 1986. The second largest mode of transportation is the public transportation. Public transit model share counts for 17% in 2006 with a decrease of 5% since 1986. Walking and cycling trips form 8% of the total trips generated in the GTA. However, this percentage fluctuates higher at the traffic zones within the PD1 and the rest of the City of Toronto. It can be concluded from these observations that auto drivers dominate all trip times and purposes except school trips, where most of the students use school buses, walk/cycle, or use transit system.

In PD1, the usage of public transportation exceeds the usage of automobiles and is considered to be the main mode of transportation in that area as shown in Table 4.7. Most importantly is the fast increase in the transit ridership. This can be considered an encouraging point for regional urban growth strategies and sustainable transportation. However, these trips are limited to the trips to/from/within PD1 area. Over the past 20 years the percentage of automobile users has declined by 4% with cycling and walking gaining.

In summary, the analysis shows that mode share of trips made within PD1 area have always been balanced and have had almost similar shares for both cars and transit and to less extent walk and cycle. Over the past two decades the percentage of trips by both cars and transit has decreased. Interestingly, the percentage of trips, both walking and cycling has increased. This may be attributable to the policies that have been followed to encourage sustainable transportation and the creation of home-work balance.

Table 4. 7: Percentage of trips by mode of transportation in the GTA

Area of origin		**Mode of transportation**									
		Auto passenger	Transit	School bus	Cycle	Taxi passenger	Auto driver	Walk	GO rail only	Joint GO rail	Total
PD1	Percent (2006)	5%	37%	1%	3%	1%	26%	27%	0%	0%	100%
	Increase/decrease since 1986	49%	34%	78%	118%	24%	25%	59%	18%	0%	
Rest of Toronto	Percent (2006)	12%	26%	1%	1%	0%	50%	8%	1%	0%	100%
	Increase/decrease since 1986	39%	-8%	10%	112%	-7%	9%	3%	44%	55%	
Durham	Percent (2006)	13%	4%	4%	0%	0%	66%	8%	3%	2%	100%
	Increase/decrease since 1986	88%	40%	39%	-20%	94%	96%	46%	244%	99%	
York	Percent (2006)	14%	7%	5%	0%	0%	66%	6%	2%	1%	100%
	Increase/decrease since 1986	216%	118%	57%	24%	36%	175%	114%	588%	99%	
Peel	Percent (2006)	15%	6%	4%	0%	0%	64%	7%	2%	1%	100%
	Increase/decrease since 1986	149%	59%	72%	5%	46%	100%	46%	132%	101%	
Halton	Percent (2006)	12%	1%	4%	0%	0%	70%	6%	3%	2%	100%
	Increase/decrease since 1986	88%	-14%	66%	7%	9%	77%	32%	127%	80%	

The main mode of transportation in the rest of the City of Toronto and the rest of the GTA regions is automobiles. Automobile usage increases as the distance from the city centre increases. As shown in Table 4.7, more travelers in the rest of the GTA regions depend on the automobiles than in the rest of the City of Toronto, while, on the other hand, more travelers in the rest of the City of Toronto depend on public transportation than travelers from the rest of the GTA regions. Also, the numbers of travelers who use GO rail increase as the distance from the core city increases. On the other hand, walking and cycling encounter significant decline in these areas.

The mode share in the GTA reveals that automobile use in nearly every aspect has increased at the expense of more sustainable modes such as public transit, walk, and cycle. However, the car trip rate in PD1 area is consistently lower than the GTA average over the study period. One reason for this is the high transit share that this area has maintained compared with the GTA average. Therefore the trips originated from and destined to PD1 area have always retained a good balance between different mode shares particularly automobile and transit with a continuous increase in walk/cycle mode share. Another reason for increasing rates of auto trips in the GTA is the lack of local accessibility to transit system. This influences travel activities because despite the increase in housing-employment balance still the general travel activities in the GTA did not show any significant changes.

Public transit share within the PD1 area declined slightly over the past two decades; however, it remained dominant in that area. In addition, automobile share declined over the same time period. However, it can be seen from the table that automobiles share is increasing as the distance from the PD1 increases. Public transit shares constitute a small portion of mode share in the rest of the City of Toronto and rest of the GTA regions over the same time period. These trends suggest that PD1 area achieved some progress toward reducing the automobiles mode share to the expense of walking and cycling. These trends are consistent with progress toward sustainable transportation. On the other hand, these trends suggest that over the past two decades the rest of the City of Toronto and the rest of the GTA regions did not achieve enough progress toward reducing the usage of automobiles and hence these areas are not moving in the direction of sustainable transportation.

Figure 4.6 shows the trends in transit and automobile ridership and population growth over the last 20 years within the GTA. Transit ridership increased significantly in York and Peel regions, while it encounterd considerable reduction in both the rest of the City of Toronto and Halton region. This suggests that transit ridership is increasing over time in PD1, York, Peel and Durham regions which would suggest progress toward sustainability. Despite this increase in transit ridership, the increase in automobiles ridership outweighs this increase as shown in the figure. Except for PD1 area, the growth in automobiles and transit ridership suggests that these areas are not moving in a direction that is consistent with sustainability.

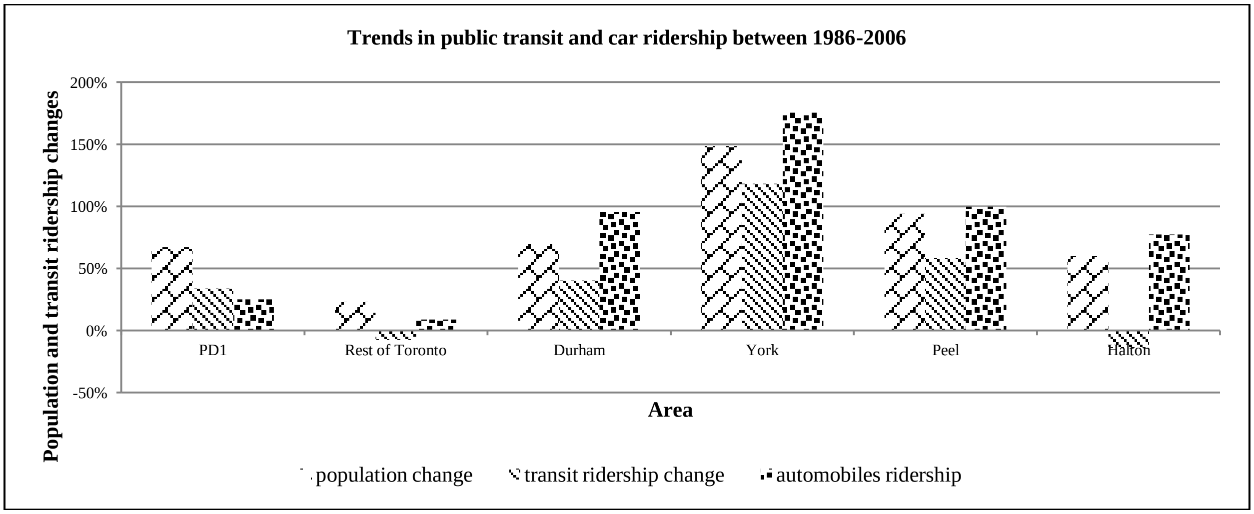


Figure 4. 6: population, automobile, and transit ridership changes between 1986 and 2006

The origin or destination of a trip plays an important role in selecting the mode of transportation and hence affects the sustainability of the transportation system. Origin/destination flow within the GTA during the last two decades has not changed significantly as shown in Figure 4.7. Table 4.8 shows changes in GTA morning peak-period origin/destination trips over 1986 – 2006 time period. The table shows that car and transit trips during the morning peak-period increased by more than 800,000 car trips and over 48,000 transit trips over the past two decades. Residents who live in populated areas where there are many businesses, schools, shops, or services, tend to use public transportation as these areas have a propensity to be well served by transit system. This explains the high dependency on the transit system and less reliance on automobile in PD1 and to a less extent in the rest of the City of Toronto. On the other hand, residents who live in the rest of the GTA regions, which are considered as low density areas and the services expand across the area, are more likely to depend more on automobile in their travels.

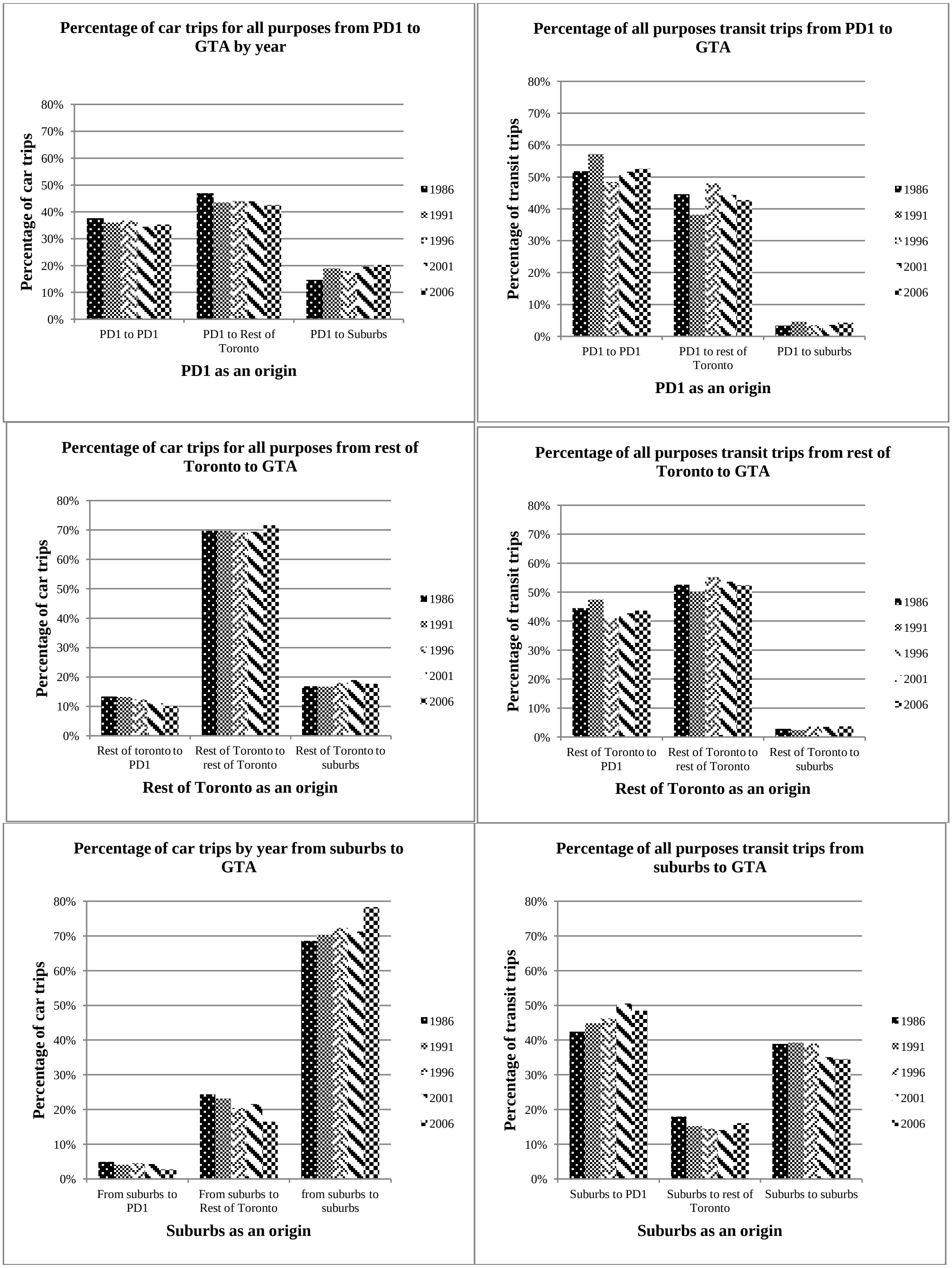


Figure 4. 7: Percentage of car and transit trips for all purposes by year in GTA

Figure 4.7 shows the percentage of inter-regional and intra-regional car and transit trips. The figure illustrates a high dependency on transit in commuting to PD1 area from different areas in the GTA, particularly from the rest of the GTA regions. This is attributed to GO rail services that provide a reliable mode of transportation that costs travelers less than traveling by private cars. Travelers from the rest of the City of Toronto mainly use public transit rather than GO rail in their commuting to the PD1 area. The figure also shows that the destination of the majority of car trips originated from the PD1 is the rest of the City of Toronto, whereas, the final destination of more than half of the transit trips originated in PD1 is PD1 area itself.

A significant growth in trip origins and destinations has taken place in the rest of the GTA regions. The table shows that the decline of the number of trips from the rest of the City of Toronto to PD1 area is compensated for by a combination of increased trips from the rest of the GTA as well as increased self-containment within the area itself. The table also shows that a significant decrease on new transit trips originated in the rest of the City of Toronto, while a slightly increase on the new car trips originated from that area. The trip’s pattern and growth shown in the table demonstrates that the rest of the GTA are attracting the highest share of car and transit trips in the GTA. Also, this pattern coincides with the population and economic growth in the GTA. Another concluding point is that PD1 area is the most important transit trip attractor in the GTA.

Table 4. 8: Changes in GTA Morning Peak-Period Trips by area between 1986 and 2006

Origin	Destination									
	Cars					Transit				
	PD1	Rest of Toronto	Rest of GTA	Total	Percentage of Total	PD1	Rest of Toronto	Rest of GTA	Total	Percentage of Total
PD1	2704	5555	3558	11817	1.48%	5235	3619	663	9517	19.75%
Rest of Toronto	-13254	67471	19362	73579	9.20%	-12731	-12482	2082	-23131	-48.00%
Rest of GTA	7186	74017	633569	714772	89.33%	34331	8803	18672	61806	128.25%
Total	-3364	147043	656489	800168	100.00%	26835	-60	21417	48192	100%
Percentage of Total	-0.42	18.38	82.04	100.00		55.68	-0.12	44.44	100	

In general, the number of trips generated by individuals has remained stable at 2.4 trips per person per day for the GTA as shown in Figure 4.8. In addition, the average number of work trips has also stabilized at 0.77 trips per worker per day compared to 1986; however, a considerable decline on average work trips has occurred since the 1990’s. This is a result of the stabilization of the average persons and workers in household over the same time period.

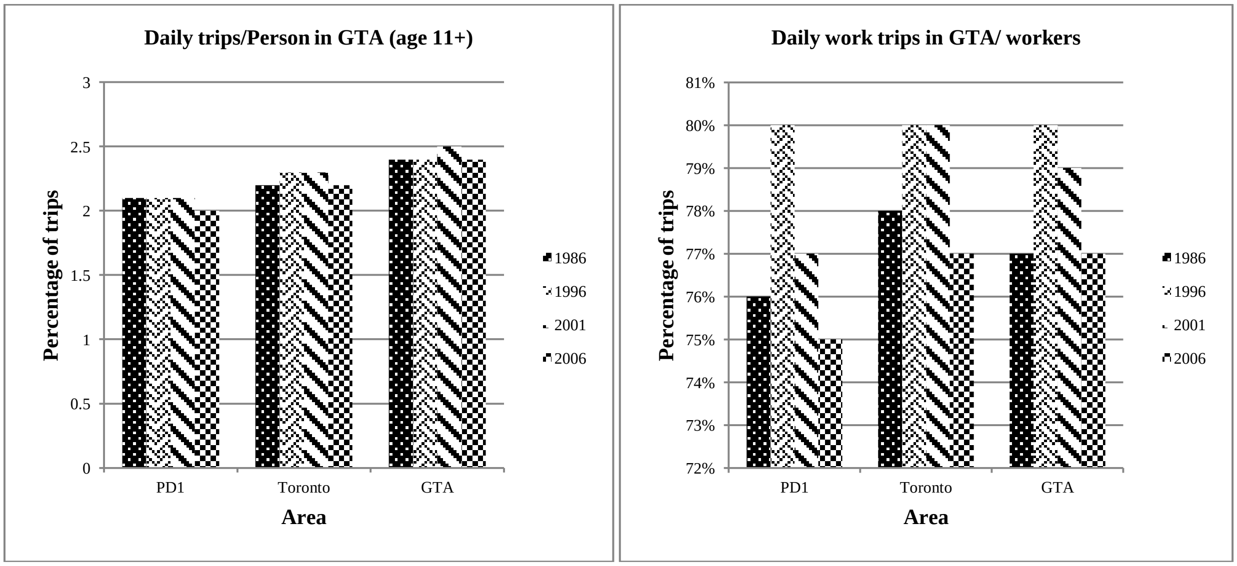


Figure 4. 8: Daily trips per person and daily work trips per worker in GTA

These trends are important for policy makers as they show that regional policies that encourage transit-supportive urban development have had limited results. The policies and strategies to reduce trip making in general and automobile trips in particular do not appear to have earned satisfactory results to date.

The spatial flow in the GTA has undergone some slight but interesting changes. The analysis reveals the dominance of PD1 area as travel destination of the majority of travel flows among the intra-regional flows in GTA as a result of high employment levels and increase of population growth. The reverse travel flow by the residents of PD1 area is also significant and growing over time. This is mainly attributed to the increase of suburbanization of population and employment growth. However, intra-regional trips, where both trip origin and destination are within the same area, constitute the vast majority of trips. As such, inter-regional trips particularly between the rest of the GTA regions and the rest of the City of Toronto constitute a significant proportion of overall GTA trip-making. In general, the spatial distribution of trip rates reveals low trips in PD1 and the rest of the City of Toronto and higher comparatively trip rates in the rest of the GTA regions. Overall travel behaviour patterns shows increased automobile use and less transit ridership.

The number and percentage of trips made for different purposes have altered to some extent. Work-based trips have declined. This may be attributed to the changes in urban form such as the changes in demographic and economic/employment structure or possibly to the adopting of other work arrangements such as telecommuting. However, most of the trips generated are auto-oriented trips. Still, home-based trips made for non-work purposes slightly outnumber all other types of trips; this may provide new insight for transportation planning. On the other hand, work-based trips outweigh other trip purposes on an individual bases to form fewer than half of the total trips in the GTA. However, a considerable decline (13%) of work-based trips has occurred during the last two decades to the expense of home-based discretionary trips. This decline of work-based trips can be attributed, among other reasons, to the changes in job structure in the GTA as well as to the reduction of full-time jobs and the declining trends of labour force participation. Another reason is the increase of elderly people as well as children under 15 years which requires generating more non-work trips. The significant increase on non home-based trips in the GTA demonstrates the significance of densification and spatial distribution of residential locations in shaping the general spatial trend of trip-making within the GTA.

In PD1, as of 2006, about two-thirds of the originated trips were home-based work with a considerable decline from 1986 as shown in Figure 4.9. Home-based school and home-based discretionary trips forms the second largest trips in PD1. A significant declined on the percentage of home-based work trips in the rest of the City of Toronto had occurred over the study period. On the other hand, a significant increase on the home-based discretionary trips has occurred over the same time period. The rest of the GTA regions have the same trend as the rest of the City of Toronto in terms of trip purposes. A significant decrease in home-based work trips has occurred over the past two decades.

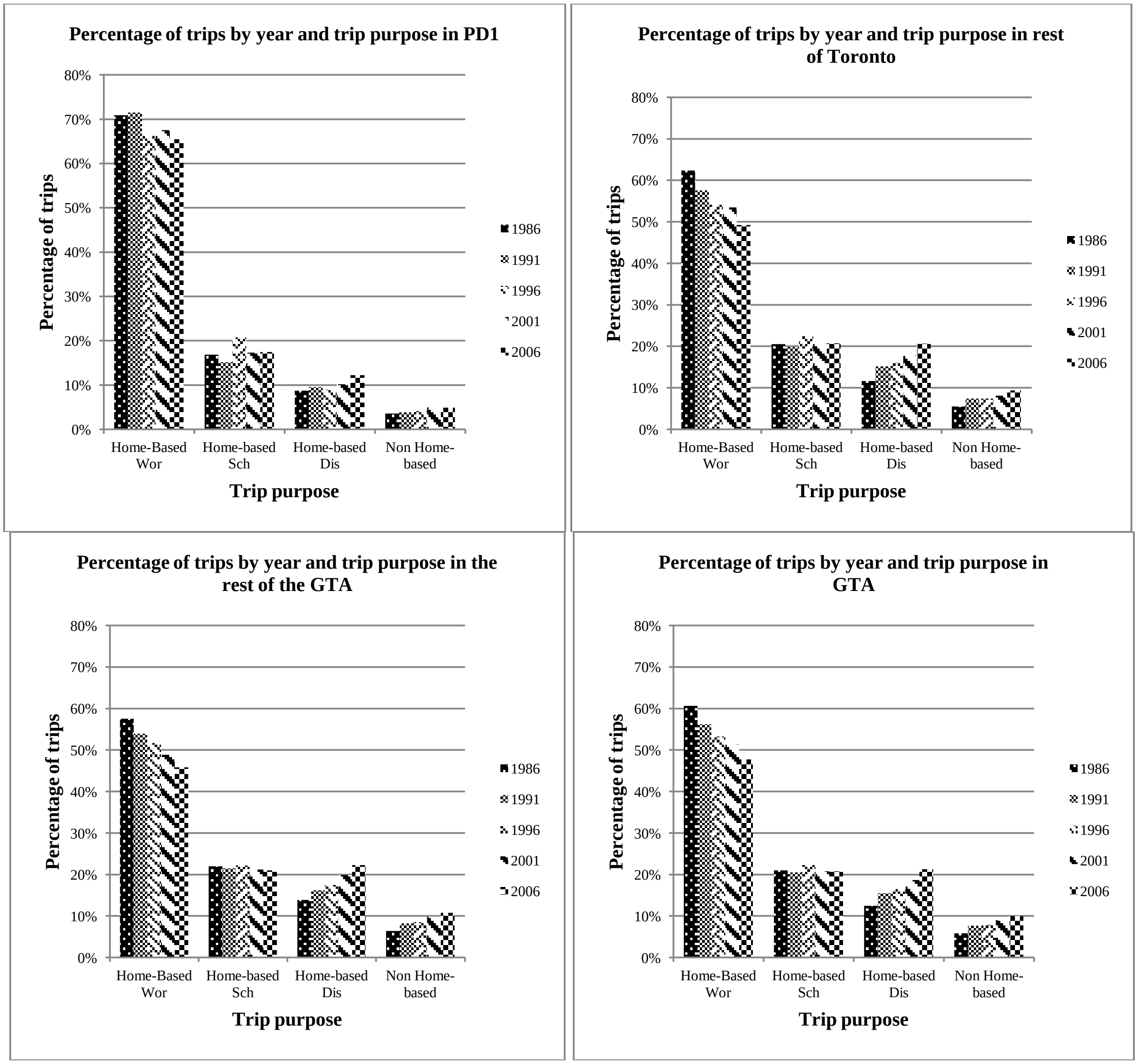


Figure 4. 9: Percentage of trips by trip purpose in the GTA

Journey-to-work mode shares provide insights as to how transport activity is changing. Journey-to-work made by personal automobile and public transit in the GTA witnessed some changes over the past two decades. Figure 4.10 shows that car and transit work-based trips that originated in the PD1 area and destined in the same area or in the rest of the City of Toronto had declined over the past 20 years to the expense of the trips distend in the rest of the GTA regions. The same trend is shown for both the rest of the City of Toronto and the rest of the GTA regions. This trend clearly demonstrates that the rest of the GTA regions attracted more jobs over the past two decades. On the other hand, the incidence of walking to work is high in the PD1 area compared to the rest of the City of Toronto and the rest of the GTA regions where houses and jobs tend to be far apart.

Overall, the number of trips generated within the GTA has increased significantly over the study period, keeping pace with high level of urban growth. The distribution of the spatial flow of trips in general and work trips in particular has become more complex as the majority of these trips are from the rest of the GTA regions to the rest of the GTA regions by nature. These findings are beneficial for transportation planners as increased trips on roads represent increased travel demand pressure on transportation infrastructure.

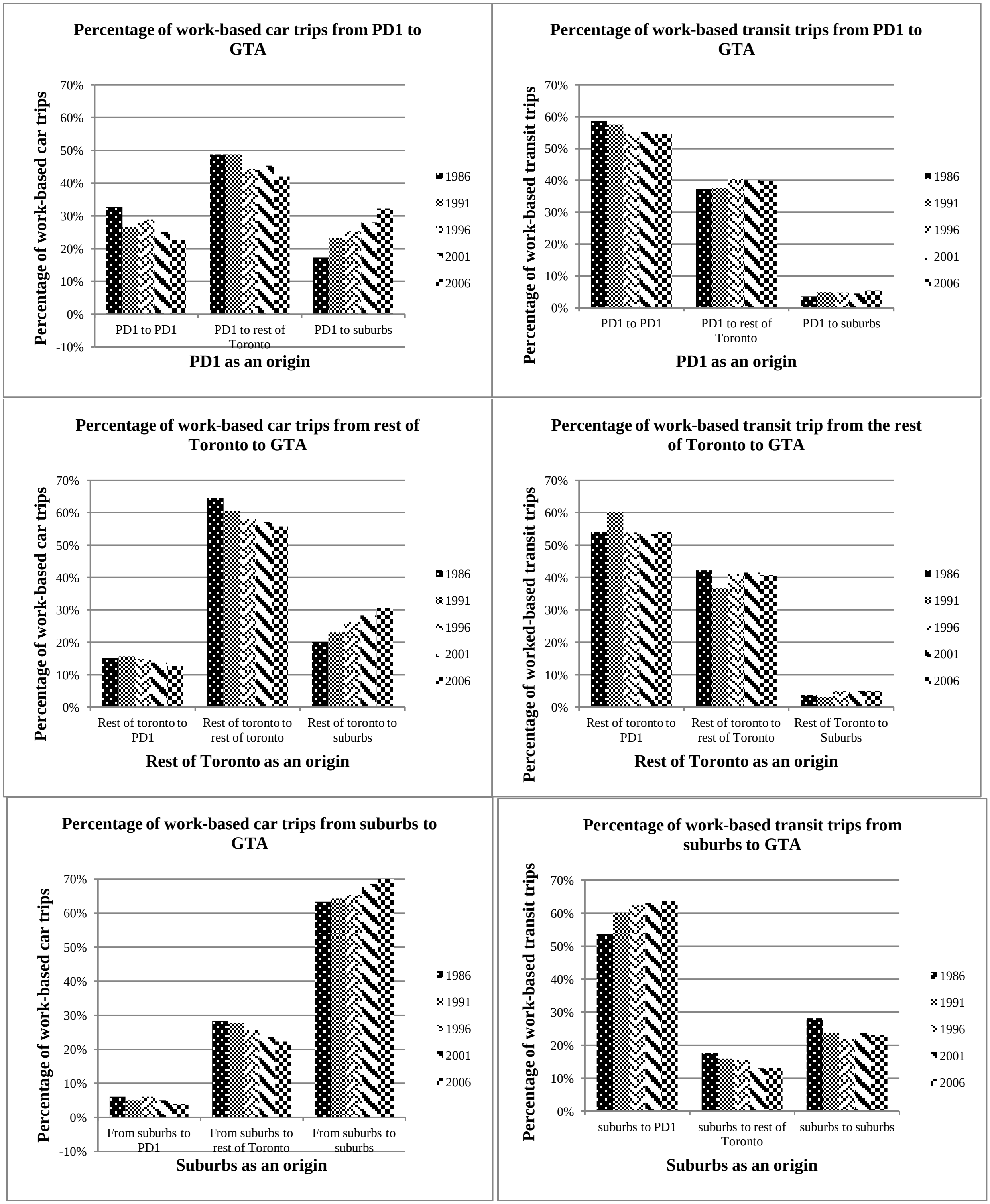


Figure 4. 10: Percentage of work-based car and transit trips by year in GTA

4.4.4 Number of vehicles owned by household

The number of cars owned by a household varies spatially within the GTA. In general, the percentage of households that own two cars is the dominant in the GTA and its increasing over time as shown in Figure 4.11. While the number of households that own one- and three or more cars have decreased slightly over the study period. The number of households that own zero cars has increased also slightly since 1986 in the GTA.

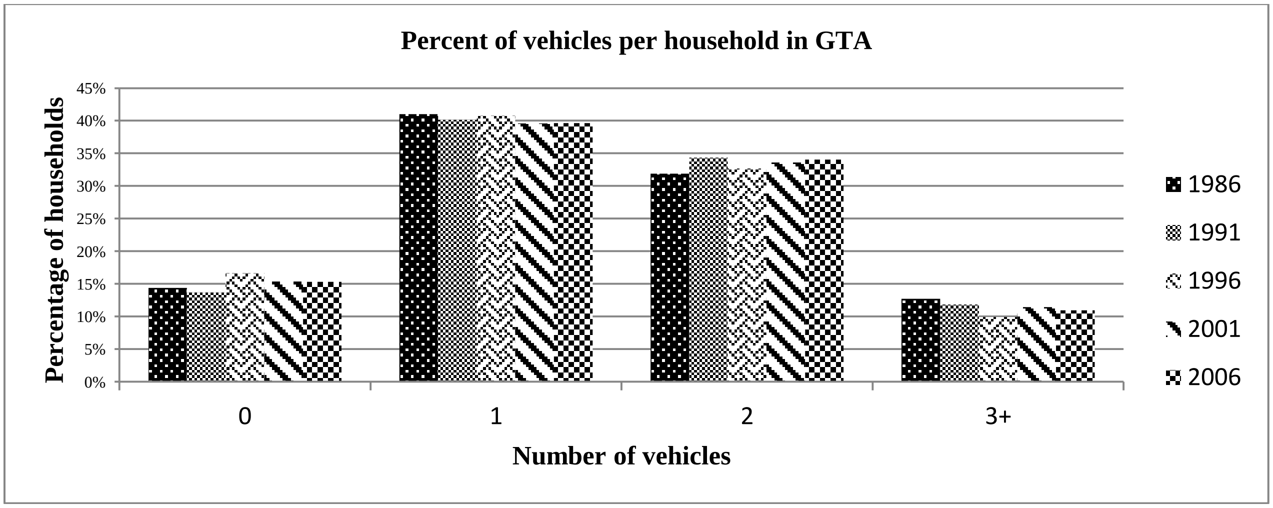


Figure 4. 11**:** Percentage of number of vehicles per household in GTA

People in PD1 area have the lowest average automobile ownership level. People who own zero cars had increased in this area during the last two decades as shown in Table 4.9. This indicates that people who live in PD1 depend more on other modes of transportation particularly transit, walk, or cycle to reach their destinations. On the other hand, people in the rest of the City of Toronto and the rest of the GTA regions are highly depending on automobile usage for their commuting. The percentage of owing one car is the highest in the rest of the City of Toronto and owing two cars or more is the highest in the rest of the GTA regions as shown in Tables 4.9 and B.2 (Appendix B). Despite this discrepancy in car ownership, the average vehicles per household is 1.4 in the GTA between 1986 and 2006. This shows that the residents of these areas rely more on automobiles in their mobility. The number of automobiles owned by households correlated to the number of persons in the household. Automobile ownership increases with higher number of persons in the household and also to the number of persons in the households that are participating in the work force. On the other hand, it decreases with the residential and commercial density in which the household lives (Miller and Shalaby, 2003).

Table 4. 9: Percentage of number of vehicles per household in GTA

Number of vehicles owned by a household	**PD1**			**Rest of Toronto**			**Rest of the GTA regions**		
	Percent increased*	Current percent	Total increase or decrease**	Percent increased	Current percent	Total increase or decrease	Percent increased	Current percent	Total increase or decrease
Zero	70%	47%	+4%	42%	19%	+5%	140%	6%	+1%
One	53%	43%	-1%	18%	47%	+3%	95%	33%	-1%
Two or more	17%	10%	-2%	6%	34%	-1%	100%	47%	+0.7%

* Percentage increased or decreased over the period between 1986 and 2006.

** Total increase or decrease in the percentage of households who own specific number of vehicles as of 2006 compared to the total number of households in specific area.

Household automobile ownership maintained the same trend over the study period. The average automobile ownership has remained static at 1.4 vehicles per household in the GTA as mentioned earlier, which implies that this trend become steady over the past two decades despite the growth in auto-ownership. This growth in auto-ownership within the GTA was consistent to some degree with the growth of population and employment in the same period but with no affects on overall ownership pattern. Also, household auto-ownership in PD1 has remained static over the same time period by 0.8 vehicles per household despite the strong public transportation infrastructure and government policies that encourage transit usage in that area. This can be attributed to demographic and changes of urban form among other factors. PD1 area has small household size, dense in population and employment, and very strong public transportation infrastructure. These factors play an important role in minimizing car usage and ownership to the expense of public transportation as we saw earlier. On the other side, the rest of the GTA regions show higher rates of auto-ownership. The same argument can be made to explain this trend (low population and employment density areas, larger household size, and less transit ridership).

4.4.5 Daily person trips rates by employment status

Figure 4.12 shows the daily trip rates by employment statues of the person generating the trip in the GTA area. As shown in the figure, part-time and home part time workers slightly make more trips than full-time workers as of 2006. Some of these trips are to work and the others to different destinations. In general, full-time workers make 2.82 trips per day per person while the part time and home part-time workers make 2.83 and 2.86 trips per day per person respectively. This demonstrates that home workers or telecommuters do not reduce their usage of roads. However, this type of employment may reduce peak period trips at the morning or evening but may produce more trips at other times to different destinations.

The PD1 area is different than the norm in the GTA. The daily person trips of full time workers are higher than part time and home part-time workers. Full time workers make 2.42 trips per day with an increase of 0.02 trips per day compared to 1986 and with a considerable decline since 1991. Part time and home part-time workers generate slightly lower trips per day where they generate 2.25 and 2.11trips per day. Home full-time workers generate 1.79 trips per day in 2006 compared to 2.08 in 1986. Not-employed people make the lowest trip rates where they generate only 1.15 trips per day per person in 2006 compared to 1.23 in 1986.

In the rest of the City of Toronto, full-time workers generate more trips than the part-time workers and less than home part-time workers. As of 2006, full time workers generate 2.74 trips per person per day compared to 2.82 for home part-time workers. Full-time and home part-time trip rates have declined since 1986 while for part time workers have increased since that time. Still the not-employed persons generate the lowest trip rates with 1.31 in 2006 compared to 1.42 in 1986.

In rest of the GTA regions, part-time and home part-time workers generate highest trip rates than full-time workers. Home full-time workers also generate high trip rates per person while not-employed people generate the lowest trip rates. In general, workers in rest of the GTA regions generate higher trip rates than that in PD1 or the rest of the City of Toronto.

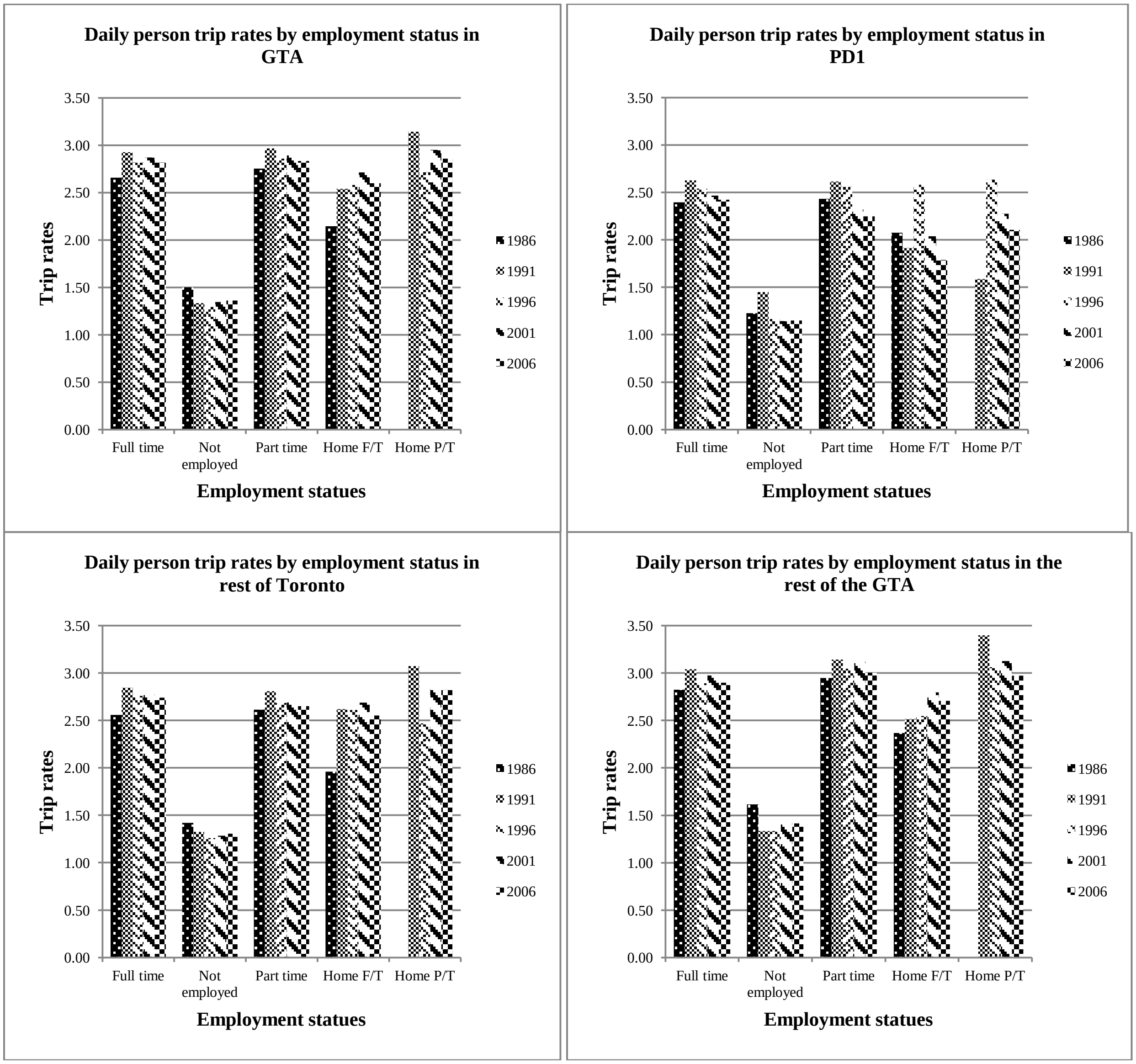


Figure 4.12: daily person trip rates by employment statues in GTA.

4.5 Are current trends moving toward sustainability?

Urban form and personal travel activities in the GTA has witnessed some interesting changes over the 1986-2006 time period. These changes have different implications and impacts on the transportation system and its sustainability. It appears from the analysis that urban form and personal travel activities have some similarities and contrasts in the way they have been distributed and evolved over the study period. The rest of the GTA regions have higher and increasing rates of individual and household trips which correspond with the increasing growth in population and employment in these areas. As a result, the percentage of car trips has increased incrementally in these areas as well in the rest of the City of Toronto. These trends of urban form and personal travel activities in PD1 and the rest of the City of Toronto are to some extent implementations of the policies undertaken by the City. PD1 area can be considered an obvious manifestation of a successful and liveable urban development in the GTA that can be retained and spread out without increasing the roadway capacity. However, the analysis shows that the urban form and personal travel activities is not following the policies that encourages transit supportive urban development, despite that some insight in these trends exists in terms of intensification development with local transit system as in PD1 area.

Spatial flow within the GTA has witnessed some interesting changes over the study period. Not surprisingly, PD1 is still considered as an important employment centre, despite the fact that the rest of the GTA regions experienced the highest growth as trips origin/destination areas. Most of the new trips generated in these areas are automobile trips reflecting the automobile mode split generating more pressure on the roads. At the same time, reverse commuting from PD1 area to other areas within the GTA has increased. This affects the self-containment of that area, although PD1 and the rest of the City of Toronto are the major concentration of employment opportunities. The number of PD1 residents who travel to other areas for work increased over the study period. This trend explains the previous findings of the distribution of daily household trips. Trip making by labour force living in the rest of the GTA may have influenced by the increase choice of employment options. Most of the trends explored illustrate increase dependence on cars which resulted in increase in trip rates.

The increase of inter-regional and intra-regional of the rest of the GTA regions' trips suggests new planning ideas. In general, the official plans of all the regions within the GTA encourage and emphasise transit oriented development. This is also the case of the provincial Places to Grow Plan where it proposes a wide transportation network to encourage growth corridors to connect major urban centers. Nevertheless, the population and employment growth over the past two decades reformed the urban structure of the rest of the GTA regions to entirely auto-centric areas. The biggest challenge lies in converting these areas towards transit-supportive.

The analysis above shows that transportation choices of residents of the GTA vary depending on the origins and destinations of their trips. The density of residential or employment areas that are well served by public transportation system reinforce and encourage people to use transit in their mobility or journey to work as in PD1 area. Consequently, it can be concluded that where automobile usage is high such as in the rest of the GTA regions, the tendency to travel by transit is low, and vice versa. The home-based work constitutes a large portion of transit trips within the GTA. The high transit market share can be attributed to quality of the Toronto Transit Commission (TTC) – the agency responsible for consolidating, coordinating, and planning for almost all forms of local passenger transportation within the urban area of Toronto – or GO rail services in the City of Toronto and the rest of the GTA regions as well to the planning policies that promote transit-supportive land use by fostering high residential and commercial densities along or close to transit routes in addition to road and transit networks that result in an effective and efficient transit routes and connections. Also, densification encourages walking and cycling as an alternative mode of transportation. The general personal travel behaviour trend suggests that the individual and household trips have increased with suburbanization across the GTA over the study period. It is obvious from the above analysis that the increased trip rates can completely be related to the increased automobile use; where transit ridership has declined consistently over the study period.

The distribution of residential locations of employees working in PD1 area shows that the number (and percentage) of workers who live outside that area, but work inside it, has increased over the past two decade. This indicates that the City of Toronto, particularly the Downtown area, is losing its self containment in terms of its core area workers. This trend is in spite of efforts designed to motivate and encourage population growth within the city's core as stated above. Consequently, TTC is losing transit ridership. This trend emphasizes the systematic growth of the functional inter-dependence between the City of Toronto, the other parts of the GTA, and the transportation system (Miller and Shalaby, 2003).

Despite of the policies discussed above, the analysis of all these trends illustrates that the transportation system of the GTA faces several problems that are likely to increase if actions is not taken. The increasing dependency on private automobile for personal mobility leads to increased deterioration in levels of road traffic congestion, increases in urban sprawl, increased emissions of carbon dioxide, increased consumption of land for automobile-related facilities, increase fatalities and injuries from road accidents, reduction in transit modal split and ridership, decrease travel options particularly for those who do not own a car, and decentralization of economic activity, with the City of Toronto losing its dominance as the main origins/destinations for employment to the benefit of the rest of the GTA regions as revealed from the analysis. Despite the many negative impacts of automobile ownership and use, it is clear that automobiles will remain to be the main mode of transportation and the one most preferred by commutters. This fact presents a challenge to sustainable urban development because it is resource intensive and causes environmental degradation (Dudson, 1998; Wheeler, 2003; Geurs and Wee, 2004; Metrolinx, 2008f, 2008g). Therefore, the transportation trends in the GTA are not in the path of sustainability. Most of the region's travel and transportation trends encourage the movement toward travel that is difficult to be served by transit, which leads to economic, social, and environmental challenges.

The findings of the above analysis are also significant from the policy perspective and in particular to transportation planning. The provincial policies encourage compact and mixed urban form to support sustainable urban growth. However, the current trends of urban form do not show an optimistic picture in this respect. The data above shows that the current trends are not moving in the direction of sustainability. Beside increasing automobile usages and ownership levels, other trends include increasing decentralization of population and employment, increasing daily trips per person mainly as auto-drive trips, increasing non-working and non-home based trips which make travel patterns more complex, and increasing number of trips during the non-peak periods. These trends constitute to and encourage for trips by automobiles and travel that is difficult to serve by transit.

The levels of car use and ownership have risen significantly over the past two decades. On the other hand, road capacity is increasing, but not at the same rate. GTA new roads increased by 51% lane kilometres while automobile and truck travel kilometres increased by

78% as shown in Figure 4.14. Public transit seat kilometres increased by 1% and transit passenger-kilometres by 25% (Toronto City Summit Alliance, 2007). This shows that the transportation demand in the GTA exceeded transportation supply during this period. This demand-supply imbalance may cause problems, such as traffic congestion on the roads.

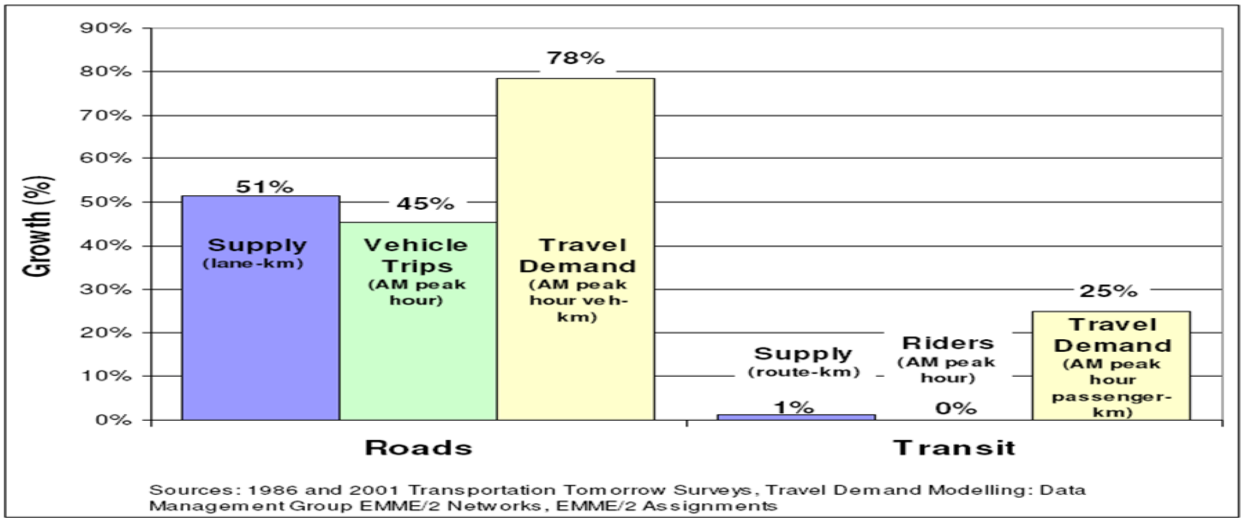
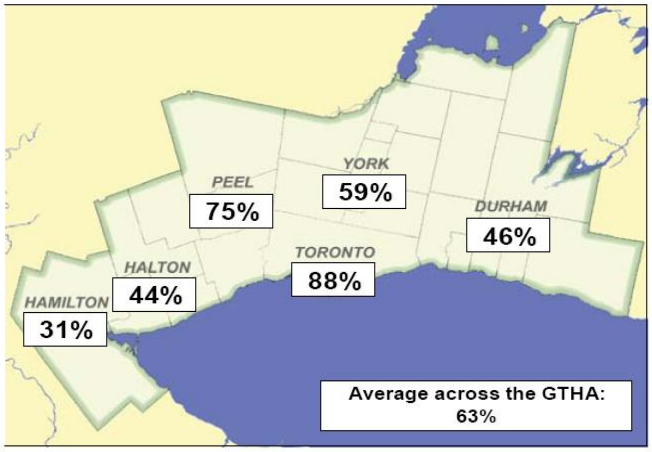
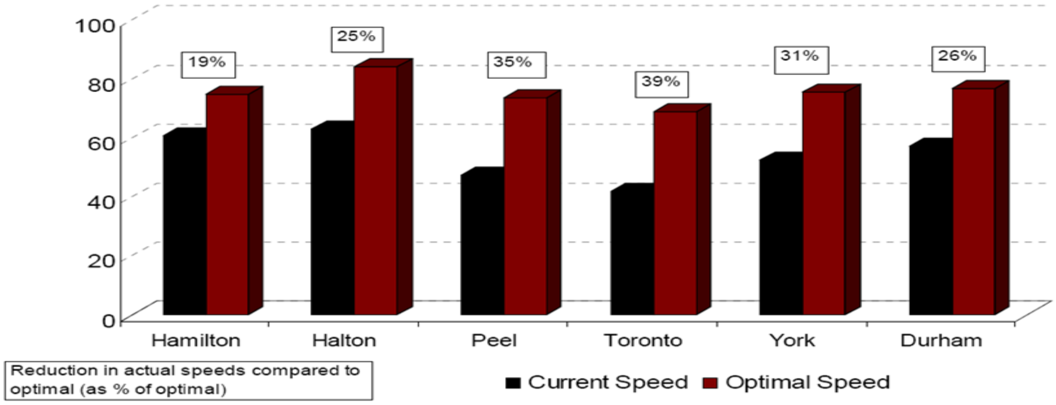


Figure 4. 13: 1986-2001 GTA and Hamilton transportation demand and supply trends. Source: Toronto City Summit Alliance, 2007

Public transportation and freeways in Toronto are heavily congested. Drivers make over two million and nine hundred trips each morning during the peak-period driving into the GTA, while in the PD1 the number of trips exceed three hundred thousand trips from and to that area. In the GTA, the average commuting time is considered the highest in Canada (Lindsey, 2008) where about 88% extra time is needed in Toronto city to travel during the peak-period compared to free-flow conditions as shown in Figure 4.14. The high traffic volume has resulted in the reduction of travel speeds ranging between 19-39% compared to regular traffic conditions as shown in the figure. Total average time spent commuting increased by 36% as a result of these slower speeds and longer average travel distances. In 2006, almost nine out of 10 vehicles leaving the city of Toronto in the evening peak-period had only one occupant (Metrolinx, 2008e, 2008f).



REGION NAME[5]	TRAVEL TIME INDEX (TTI)
City of Hamilton	1.31
Halton Region	1.44
Peel Region	1.75
City of Toronto	1.88
Region of York	1.59
Durham Region	1.46
GTHA AVERAGE	**1.63**



Note: Optimal speed refers to the implied speed at the economically efficient level of congestion. See footnote for more on its interpretation.

Figure 4. 14: Increase in travel time and travel speed (km/hr in AM peak period) due to congestion in 2006 in the GTA and Hamilton area in 2006. Source Moterlinx (2008c)

Again, all these travel activities combined result in inconvenient transit service, highly congested roads and highways, health problems, economic disruption, unsafe conditions for bikeways and pedestrian pathways, and environmental degradation. The competition for limited road space and time across the city is increased by growing urban automobile traffic. These combined problems lead to passengers being left behind at transit stops and transit vehicles being overcrowded.

Depending on cars for personal mobility has increased traffic volumes, distances traveled, and urban sprawl. This dependence has reduced public transit service and accessibility and has resulted in negative impacts, mainly to people who have difficulties to access cars. This has resulted in reduced sustainable transport options, such as walking, cycling, and transit service. Moreover, it is difficult to expand transit services due to lower suburban densities, dispersed employment locations, auto-oriented road network, widespread free parking, and large single-use urban developments.

From the environmental perspective, public transit is a more sustainable than private automobiles. Emissions from automobile use are one of the main contributors to air pollution and environmental degradation and causes serious health problems. The growing dependence on private modes of transportation is having a significant negative impact on the environment in terms of resources energy use, noise, land use, air pollution, and climate change (Kennedy, 2002). However, in determining GTA residents' preferential mode choice, the social costs of automobile use are more likely to be less significant than the social benefits. From an economic perspective, important economic benefits can be achieved from the relatively higher travel speeds and access of auto use. Different innovative approaches are required to improve the sustainability of the GTA. An important innovation is to improve the performance level of public transportation and to better manage travel demand of single occupancy vehicles (Kennedy, 2002).

On the other hand, there are some unique characteristics of the GTA transportation system that could be the starting point for developing a more sustainable transportation system. For example, Toronto is considered an urban area known for its public-transit orientation and metropolitan-wide planning capacity (Filion et al., 2006). This is attributed to transportation polices that balanced roads and public-transit investments. Densification of PD1 is one reason for the high rate of transit use, other reasons can be attributed to the planning policies that promote transit-supportive land use as well as the quality of the transit service in that area. In addition and as stated above, the federal and provincial governments are increasingly participating in providing transit funding needs, which has resulted in higher per-capita ridership and sustained ridership growth in recent years (Lindsey, 2008; Toronto City Summit Alliance, 2007). An effective and efficient transportation system, including public transit encourages, improves, and enhances the economic growth, competitiveness, and productivity of the GTA.

The notion of implementing TDM in the GTA is getting considerable attention during the last five years. Momentum is building in response to deteriorating traffic conditions, the launch of the Smart Commute Program, growing environmental concerns, and the success of high occupancy vehicles (HOV) lanes on Highways 404 and 403. TDM has the capability to make more efficient use of existing transportation system in the GTA and generate additional revenue to help maintain transportation infrastructure in a good situation (Stewart and Pringle, 1997).

Residential density impacts journey to work travel patterns. These patterns are somehow restricted by the imperfect interaction of urban density and public transportation services, particularly during peak-periods of travel demand. This is also attributed to inadequate planning that has facilitated the development of neighbourhoods without encouraging high-density residential developments (Taylor and Nostrand, 2008). The coordination of high density residential development and high-quality public transportation services are hampered by many obstacles in the GTA (Filion et al., 2006). Although transit system improvements are aimed mainly to reduce the dependency on private automobile and to increase transit ridership, relying on these improvements alone is not sufficient to encourage people to reduce their dependence and use of their own automobile for their travel needs.

Congestion is emerging as an important transportation problem. Some may argue that supply management, by building new roads or widening existing ones, is a solution to congestion. Others may argue that this solution is short-term one, and the long-term solution should make transit system more convenient and affordable than automobiles to help to achieve a sustainable future for the transportation system of the GTA. In general, some actions that could be considered to solve these transportation problems and to move the GTA towards a more sustainable transportation system include:

- Implementing congestion pricing so that drivers pay the real cost of their trips and using automobiles,
- Encouraging more transit-supportive development and more investment in transit infrastructure and services,
- Discouraging people from using their own vehicles by increasing parking prices or limiting available parking spots,
- Increasing gas prices and taxes to increase the cost of trips, and
- Encouraging other modes of transportation such as walking and cycling.

4.6 Chapter summary

The aim of this chapter was to explore if the GTA is moving toward the principle of sustainable transportation. Several indicators had been used to examine if the central Toronto is candidate for tolls. Sustainable transportation in the GTA is evaluated primarily in terms of mobility. Some of these indicators include: population and employment density, vehicle ownership per capita and per household, origin/destination trips, trips length, and mode split. In addition, this chapter investigated the policies that have been adopted by the provincial and local levels of government to manage the growing demand for travel and transportation infrastructure

Several policies have been considered and implemented in the GTA by provincial and local levels of government to manage the growing demand for travel and transportation infrastructure as well as to achieve sustainable transportation in the GTA. These policies encourage residents to use the transit system as their main mode of transportation through encouraging more compact mixed-use land uses. The City of Toronto encourages residents to use the transit system as their main mode of transportation to achieve major intensification to deal with population growth. On the contrary, the rest of the regions in the GTA encountered increase dependence on automobile use which is oppose to achieving sustainability.

The demographic characteristics of the GTA population have witnessed significant changes over the study period. The distribution of population and employment growth across the GTA shows increased suburbanization. The trend of the rest of the GTA population growth led to decentralization of labour force in the GTA over the study period. This trend impacts the transportation system by generating more inter-regional trips on average and mainly auto-oriented trips in nature.

Labour force in the GTA has changed dramatically over the 1986-2006 time period. However, employment growth has occurred in a dispersed way following the direction of population growth and transportation infrastructure. Although the majority of workers live and work within the same area, the employment growth concentrated in the suburban areas and to a little extent in PD1 area. The City of Toronto lost its job dominance to the benefit of the rest of the GTA regions. This indicates that employment is decentralizing. However, still the PD1 has more jobs than residents and therefore people have to commute to the city to get to their jobs. However, when taking population and employment growth together it is apparent that the urban form has grown at a lower density than what was intended in the policies.

Among the impacts is a decrease in the number of full-time jobs in favour of part-time and telecommuting jobs. While the employment rate of full-time workers has declined considerably, the employment rate for both part-time and telecommuting workers only increased slightly. However, this slight increase does not compensate the loss of full-time jobs. One reason for this decline in employment is due to the decentralization of some employment into areas other than the employment core of the City of Toronto. However, PD1 area is still the main source of employment in the GTA.

PD1 area is different in its urban development and travel behaviour patterns than the rest of the City of Toronto and the rest of the GTA regions. PD1 experienced dense urbanization and successfully maintained its character as a liveable and compact employment centre. PD1 area represents the dominant concentration of employment and transit destinations particularly employment from the rest of the GTA regions.

Some indicators used in the analysis showed that PD1 area is moving toward the principle of sustainable transportation. Some indications that PD1 area is moving toward sustainability and sustainable transportation are that this area encounters the highest population and employment density across the GTA and that the percentage of workers in PD1 who live there had increased during the last two decades. In addition, the usage of public transportation exceeds the usage of automobile and that PD1 area achieved some progress toward reducing the automobiles mode share to the expense of walking and cycling. Another indication is that people in PD1 area have the lowest average automobile ownership level. On the other hand, some indications that PD1 area is not moving toward sustainability and sustainable transportation are that this area lost employment market share to the advantage of the rest of the GTA regions between 1986 – 2006 time periods. The increases of the percentage of workers who commute from the rest of the GTA regions to PD1 area create congestion on the roads. The reverse travel flow by the residents of PD1 area to the rest of Toronto city and the rest of the GTA regions is also significant and growing over time.

The indicators above show that the rest of Toronto city is moving away from sustainability and sustainable transportation. Although the population density in these areas is slightly increasing, the employment density is decreasing with a higher rate. Travel by automobile either as a driver or passenger is the main mode of transportation used in these areas; however, still the percentage of travelers who use public transportation is high. In addition, the percentage of owing one car is the highest in the rest of Toronto city.

In the rest of the GTA regions, the population density in the four regions is increasing and it is more pronounced in the regions of York and Peel. Transit ridership increased significantly in York and Peel regions. While it encounterd considerable reduction in both the Halton region. Looking at this indicator in isolation, it suggests that transit ridership is increasing over time in these areas which would suggest progress toward sustainability. Despite this increase in transit ridership, the increase on automobiles ridership outweighs this increase.

Chapter 5: Analysis of Travel Patterns in the GTA

5.1 Introduction

Travel patterns can provide insights into the equity implications of transportation policies. Equity studies in transportation generally, and road pricing specifically, often derive these insights by considering the travel activities (as observed or predicted) of people with differing socio-economic or demographic characteristics. Resulting variations in travel patterns can be crucial in designing equitable transport policies and can have important consequences for the 'success' or 'failure' of these polices.

Based on the TTS survey in 2006, this chapter analyzes travel activity by residents of different parts of the GTA who vary in terms of their socio-economics (related to income and employment) and/or demographics (age, gender, household size). The focus is on auto travel in and out of the proposed cordon pricing zone, PD1, as described earlier. By estimating the number of travellers whose auto trip would be charged under a cordon pricing scheme, it is possible to provide insight into what types of persons would be most affected by such a pricing strategy.

This section provides an introduction to the TTS trip data and a summary of equity-relevant socio-economic and demographic variables that are available from the TTS data. It also explains how household income data were approximated by blending TTS and Census data. Section 5.2 is devoted to the travel analysis, using the same three spatial zones as in Chapter 4—PD1, the rest of the City of Toronto, and the rest of the GTA. This section explores the issue of vertical equity associated with a cordon pricing zone imagined to coincide with the boundaries of PD1. This section analyzes the total number of trips made by the GTA residents who travel only within the GTA. Because the dissertation pertains to cordon pricing, the focus is on four origin-destination flows, all of which would be charged under a cordon scheme: PD1 to (and from) the rest of the City of Toronto, and PD1 to (and from) the rest of the GTA. Section 5.3 provides more details about the vertical equity of cordon pricing through the analysis of the impact of cordon pricing on the trips made by different demographic groups such as gender, age, household size, and occupation.

5.1.2 Equity-Relevant Socio-Demographic Variables

As explained in Chapter 3, the TTS provides data on a large sample of representative trips that occurred in the GTA. These data are available at five year-intervals, e.g., 1986, 1991, 1996, 2001 and 2006; and provide information on literally tens of thousands of trips. These data, which constitute daily trips by a five percent sample of households, have then been expanded in order to represent the travel of the entire population of GTA residents, as summarized in Table 5.1. These counts represent all trips made in a typical weekday. Control totals from the Canada Census have been used to expand the survey data. For a given area, the expansion factor is "the number of dwelling units obtained from the census divided by the number of household interviews contained in the final TTS database for the same area" (DMG, 2007; p1). This is applied to all the trip, household, and person data associated with the households in that geographic area (DMG, 2007).

Table 5. 1: Estimated Daily Weekday Trips (based on TTS Data by all residents of the GTA)

	Trips made by all travelers 11 years and older	**Individuals**	**Households**
1986	7,695,296	3,639,552	1,309,811
1991	8,824,940	4,124,841	1,487,282
1996	9,028,248	4,464,381	1,625,939
2001	10,274,243	4,900,189	1,786,273
2006	11,062,024	5,383,395	1,965,579

Each trip is characterized in various ways including origin, destination, mode, purpose, and start time. Each trip is assigned to the person who took the trip, who can in turn be assigned to his/her household and also to the traffic zone in which the person resides. Person-level information that is of relevance to the current study includes those variables that provide insight into employment status (e.g., full-time or part-time), age, gender, and occupation. At the household-level, data on household income and household size are of interest as they allow exploration of relative equity implications of cordon pricing. Household income is the most fundamental indicator of equity implications, as it relates to issues of affordability and willingness to pay.

5.1.3 Socio-economic status

Socio-economic status is of primary concern in equity studies. Studies that deal with the equity aspects of congestion pricing consider socio-economic status to evaluate the distributional effects of this pricing scheme for various groups of individuals considering their individual characteristics, including employment status and income (Ecola and Light, 2009). The TTS database provides person-level information on employment status, which is reported as full-time (including a small percentage of home-based full-time workers), part-time (including a small percentage of home-based part-time workers) and not employed. Employment status provides some insight into affordability/ability to pay, but is not sufficient on its own for an assessment of the potential equity implications of congestion pricing.

Unfortunately, the TTS data do not provide information on individual or household income. In order to have at least general insight into differences in travel patterns by income level, Census data were used in conjunction with the TTS data. More specifically, each trip in the TTS was assigned to the traffic zone of the trip maker’s residence. Each traffic zone is a spatial unit typically covering a geographic area between 0.02 square kilometers and 120.27 square kilometers and having a population of between 12 and 21200. Most traffic zones correspond well with Census boundaries, with each traffic zone typically comprising two or more Census dissemination areas, for which average household income data are available. An estimate of the average income of each traffic zone was then calculated as a weighted mean based on the average income of each dissemination area included in the traffic zone multiplied by the population of that area. The resulting sum was then divided by the total population of all the dissemination areas in the traffic zone. Frequency distributions of the average household income for the 6898 dissemination areas, and 2428 traffic zones, in the GTA are provided in Figure 5.1. As shown here, for both distributions, approximately half of the neighbourhoods have average annual household incomes between $60,000 and $89,999.

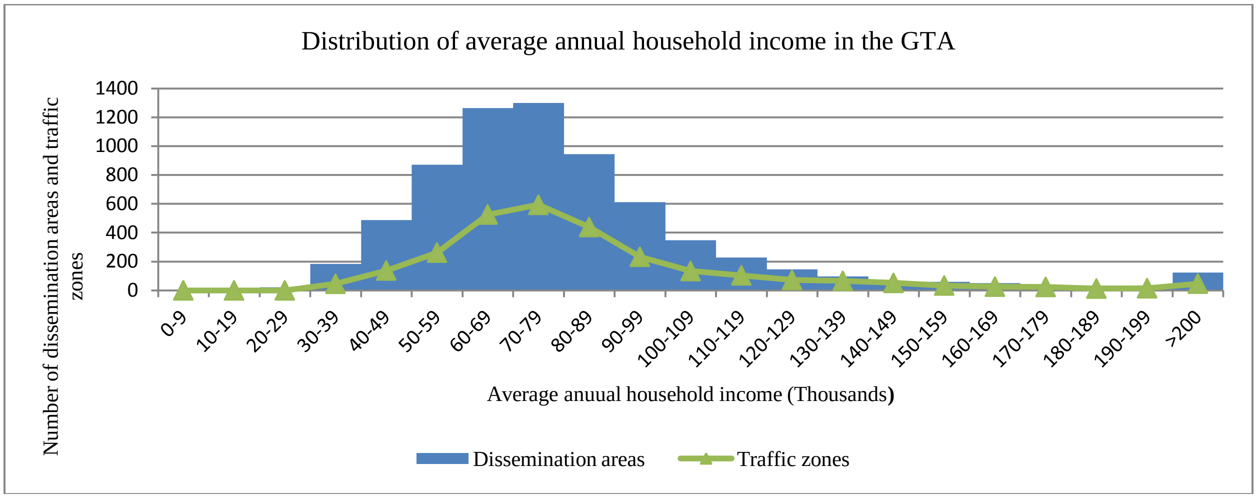


Figure 5. 1: Distribution of the average household income for all 6898 dissemination areas in the GTA

In subsequent analysis, the income data were summarized as four categories: low-income neighbourhood (average household income less than $60,000), lower middle-income neighbourhood (average household income of $60,000 to $89,999), upper middle-income neighbourhood (average household income of $90,000 to 119,999) and high-income neighbourhood (average household income of $120,000 or higher). Income categories were grounded by Canada Census results as in 2008 low income cut off was 58,673[3] before tax and average household income for two parents with children was 86,500[4] (88,900 as for 2010). The traffic zones were combined in order to represent PD1, the rest of the City of Toronto and the rest of the GTA.

In order to provide a fuller description of socio-economic status in the subsequent travel analysis in sections 5.2 and 5.3, income categories were cross-tabulated with employment status to create eight socio-economic groups as illustrated in Table 5.2. As shown here, the average number of daily trips made by people who are members of the various categories varies considerably.

Table 5. 2: Socio-economic groups

Socio-economic Groups	**Socio-economic status of Trip Makers**	**# Persons in 2006 TTS Database**	**# Trips in 2006 TTS Database**
Group 1	Employed Full-time , Low-income Neighbourhood	135,192	323,755
Group 2	Not Employed/Part-time, Low-income Neighbourhood	265,034	296,270
Group 3	Employed Full-time, Lower Middle-income Neighbourhood	979,081	2,608,598
Group 4	Not Employed/Part-time, Lower Middle-income Neighbourhood	1,463,817	2,040,267
Group 5	Employed Full-time, Upper Middle-income Neighbourhood	695,625	2,066,243
Group 6	Not Employed/Part-time, Upper Middle-income Neighbourhood	917,583	1,571,413
Group 7	Employed Full-time, High-income Neighbourhood	390,617	1,131,143
Group 8	Not Employed/Part-time, High-income Neighbourhood	533,170	1,024,335

5.1.4 Other demographics

Gender, age, household size, and occupation are other demographic variables that provide additional insights into the equity implications of cordon pricing. This more detailed analysis gives more insight into whether members within each socio-economic group are affected similarly or differently by cordon pricing. This analysis thus provides more detailed insights into what types of persons would be most affected by cordon pricing. The TTS database provides person-level information on gender, age, household size, and occupation, the latter of which is

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[3] http://www.statcan.gc.ca/pub/75f0002m/2009002/tbl/tbl-3-eng.htm

[4] http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/famil21a-eng.htm

reported as general office/clerical, professional/management/technical, retail sales and service, manufacturing/construction/trades, and not employed. Table 5.3 show these demographic characteristics of trip-makers.

Table 5. 3: Characteristics of trip-makers for each socio-economic group

Socio-economic Groups	Socio-economic status of Trip Makers
Gender	Female, male
Age	0-19, 20-34, 35-49, 50-64, 65 years and older
Household size	One-person household, two-person household, three-person household, four-person household, households with five and more persons.
Occupation	Office/clerical, professional/management/technical, retail sales and service, manufacturing/construction/trades, and not employed.

5.2 First Insights into the Vertical Equity of Cordon Pricing in Downtown Toronto

Vertical equity is concerned with the treatment of individuals and classes who are not alike. It often differentiates between groups based on ability to pay, which is typically measured by an individual's income or wealth. To get insights into this phenomenon, people are categorized by socio-economic and geographic factors to estimate the proportion of different sub-populations that would be potentially affected by cordon pricing.

In examining travel patterns from an equity perspective, it is necessary to link trip makers' characteristics with their travel patterns. Since income is central to equity considerations, and the available income data is at the traffic zone level, it is important to extract trip data in such a way that each traveller's residential neighbourhood can be identified. It is also important to consider how cordon pricing charges vary by time of day. In most cordon and other road pricing schemes, charges are highest during peak-period travel.

Figure 5.2 shows the distribution of all trips, by trip purpose, throughout different times of the day made only by the residents of the GTA as of 2006. The number of trips was counted for four different time periods where two of them represent the morning and evening peak periods and the other two represent the times that extend between the two peak periods. At all times of day, most trips are home-based, i.e., either the origin or the destination is the trip maker's residence. The peak periods are dominated by home-based work trips while the non-peak periods are dominated by home-based discretionary trips. The percentage of home-based work trips is particularly high during the morning peak period.

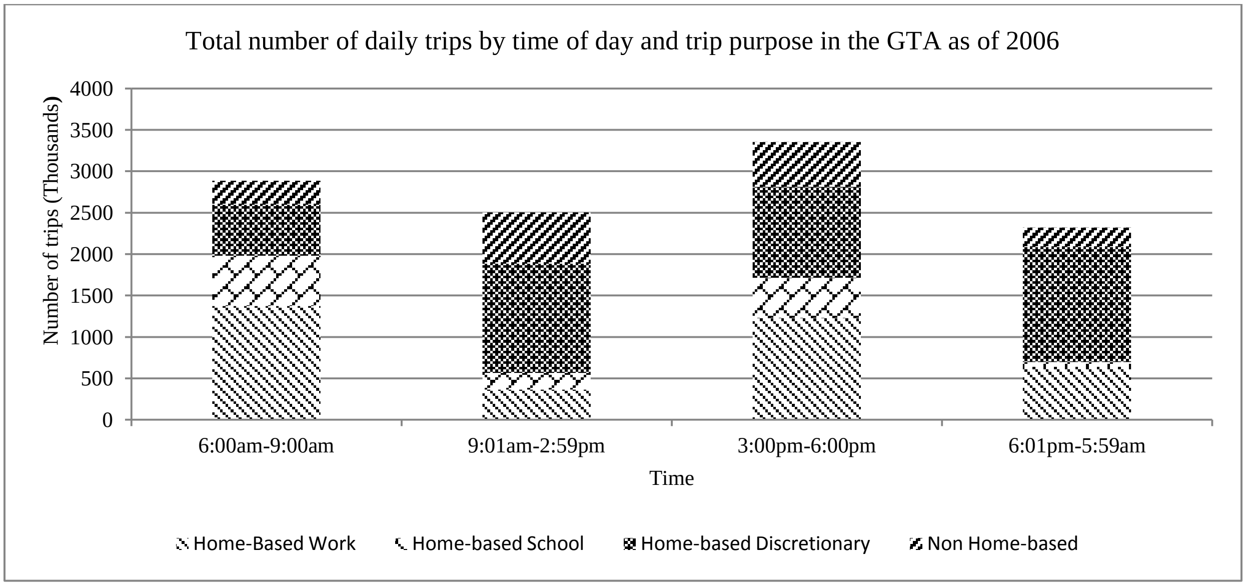


Figure 5. 2: Trips distributed over different times of a day, times represent the start time of the trip.

Table 5.4 summarizes the same data as in Figure 5.2, and provides the percentage of trips during the four times of the day. The table clearly shows the home-based work trips generated in the morning peak period, both overall and by auto, are higher than in the evening peak period.

Table 5. 4: The number and percentage of home-based car and transit trips compared to the total home-based trips made by different modes of transportation in different times of the day in the GTA as of 2006.

	Total # trips	Total # home-based trips	% of home-based trips by time of day	Total # home-based work trips	% of home-based work trips by time of day	Total # home-based work trips made by autos	% of home-based work trips made by autos by time of day
6:00 am-9:00am	2883953	2595951	27.7%	1375062	38.1%	1010216	37.6%
9:01am-2:59pm	2504040	1882106	20.1%	363604	10.1%	278049	10.4%
3:00pm-6:00pm	3351994	2811083	30.0%	1229657	34.1%	901044	33.6%
6:01pm-5:59am	2322037	2085808	22.2%	638760	17.7%	494095	18.4%
Total	**11062024**	**9374948**	**100%**	**3607083**	**100%**	**2683404**	**100%**

The analysis of the traffic flows in the remainder of this chapter is based on home-based, morning peak-period trips only. The aim is to ignore all trips that do not originate from trip-makers' home traffic zones, and to focus on a time of day when cordon prices would be relatively high. Table 5.5 illustrates the distribution of home-based and non home-based trips across the GTA during the morning peak period. The table is organized by origin-destination flow, using the three geographic zones introduced earlier. In terms of spatial patterns, these data show that approximately 1.28 million morning peak-period trips both start and end outside the City of Toronto in the region referred to as the rest of the GTA, and another 253 thousand trips originate in the rest of the GTA and enter into the City of Toronto, but do not enter the Downtown region defined by PD1. Thus, nearly two-thirds of the traffic in the GTA is suburban in origin, and is not affected by (does not contribute to) Downtown congestion.

In terms of trip origin, trips originate from home comprise about 93% of the total home-based morning peak-period trips, while home is the destination of the other 7%. About 55% of trips originating from home are work trips and the other trips are made from home to school, shopping, daycare, and other purposes. Trips that are destined for home originated from work, daycare, and other places.

Table 5. 5: Number and percentage of home-based and non home-based trips during morning peak period based on traffic flow from each geographic area in the GTA as of 2006.

Traffic flow	Number of home-based trips (%)	Number of non home-based (%)	Total (%)
PD1→PD1	51,936 (96.3%)	1,972 (3.7%)	53,908 (100%)
PD1→Rest of the City of Toronto	23,774 (95.4%)	1,632 (6.4%)	25,406 (100%)
PD1→ Rest of the GTA	6,812 (92.4%)	559 (7.58%)	7,371 (100%)
Rest of the City of Toronto → PD1	197,560 (91.5%)	18,133 (8.4%)	215,693 (100%)
Rest of the City of Toronto → Rest of the City of Toronto	706,281 (91.0%)	69,883 (9.0%)	776,088 (100%)
Rest of the City of Toronto → Rest of the GTA	130,603 (87.9%)	17,992 (12.1%)	148,595 (100%)
Rest of the GTA → PD1	105,249 (90.4%)	11,161 (9.6%)	116,410 (100%)
Rest of the GTA → Rest of the City of Toronto	217,365 (85.6%)	36,049 (14.2%)	253,414 (100%)
Rest of the GTA → Rest of the GTA	1,156,368 (89.9%)	130,628 (10.2%)	1,286,996 (100%)
Nine flows combined	2,595,948 (90.1%)	288,009 (10.0%)	2,883,881 (100%)

5.2.1 Traffic flow in the GTA

Analyzing traffic flow amongst the three areas allows estimates of the number and percentage of trips that would be affected by cordon pricing, assuming that travel patterns in the future are similar to what occurred in 2006—at least in terms of the socio-economic and demographic characteristics of travellers from one part of the GTA to another. In addition, it demonstrates the importance of area of residence for equity analysis.

Table 5.6 shows the home-based morning peak-period trips taken from trip makers' home traffic zones by all modes of transportation. The table clearly demonstrates the importance of PD1 area as a destination for many trips originating from the rest of the City of Toronto as well as from the rest of the GTA regions. The trips destined for the PD1 area are four times higher than the number of outbound trips originated from it. The four shaded cells identify those flows where auto trips would be affected by cordon pricing. About 13% of the home-based, morning peak-period trips made within the GTA would be affected by cordon pricing in Downtown Toronto.

Table 5. 6: Home-based morning peak-period trips (2006)

	Destinations				
		PD1	Rest of City of Toronto	Rest of GTA	All Origins
Origins	PD1	51936	23774	6812	82522
	Rest of City of Toronto	197560	706281	130603	1034444
	Rest of GTA	105249	217365	1156368	1478982
	All Destinations	354745	947420	1293783	2595948

A cordon pricing system would charge only auto users; therefore, it is important to know the number of trips that each traveller group makes and what percentage of these trips would be subject to charges. This gives insight to the analysis of vertical equity. Table 5.7 shows the number and percentage of home-based morning peak-period trips made by different modes of transportation taken from trip makers' home traffic zones. The table shows that trips made by auto are dominant for all groups where travellers are employed full-time. The not-employed or part time groups depend more on public transportation or non-motorized modes in their commuting and the percentage of trips using these modes increases as the income decreases.

Table 5. 7: Number and percentage of home-based morning peak-period trips by all modes of transportation taken from trip makers' home traffic zones.

Socio-economic Group	Modal split									
	# auto trips as driver (%)		# auto trips as passenger (%)		# transit trips (%)		# trips by non-motorized modes (%)		Total # trips (%)	
Employed full-time, Low-income	47985	57.0%	8356	9.9%	25414	30.2%	2484	2.9%	84239	100.0%
Not Employed/part-time, low-income	13242	20.0%	10839	16.4%	27818	42.0%	14287	21.6%	66186	100.0%
Employed full-time, Lower-middle income	411319	65.1%	56144	8.9%	139042	22.0%	25042	4.0%	631547	100.0%
Not Employed/part-time, Lower-middle income	109644	27.4%	82178	20.6%	123360	30.9%	84340	21.1%	399522	100.0%
Employed full-time, Upper-middle income	356441	77.0%	31597	6.8%	64361	13.9%	10802	2.3%	463201	100.0%
Not Employed/part-time, Upper-middle income	97933	33.6%	70927	24.3%	69343	23.8%	53211	18.3%	291414	100.0%
Employed full-time, High-income	187212	72.4%	12792	4.9%	48216	18.7%	10229	4.0%	258449	100.0%
Not Employed/part-time, High-income	65843	38.6%	41038	24.1%	36632	21.5%	26944	15.8%	170457	100.0%
All Groups	1289619	54.5%	313871	13.3%	534186	22.6%	227339	9.6%	2365015	100.0%

Cordon pricing in Downtown Toronto would affect a considerable percentage of trips generated by different groups. The highest number of trips affected by this system is generated by the people from lower-middle and upper-middle income neighbourhoods, as shown in Table 5.8; however, the percentage of trips that would be affected is highest for people in the full-time high-income neighbourhoods. This is because a comparatively a high percentage of high-income full-time workers reside in the rest of the City of Toronto and the rest of the GTA area and use their automobiles in traveling to jobs in PD1.

Table 5. 8: Total number of auto trips and number and percentage of affected trips generated by each socio-economic group.

Socio-economic group	**Number of auto trips as driver or passenger**	**Number of trips in/out of PD1 (% of the group)**
Employed full-time, Low-income	56341	2590 (4.6%)
Not Employed/part-time, low-income	24081	1009 (4.2%)
Employed full-time, Lower-middle income	467463	33959 (7.3%)
Not Employed/part-time, Lower-middle income	191822	7199 (3.8%)
Employed full-time, Upper-middle income	388038	23836 (6.1%)
Not Employed/part-time, Upper-middle income	168860	3847 (2.2%)
Employed full-time, High-income	200004	24819 (12.4%)
Not Employed/part-time, High-income	106881	4221 (3.9%)
All Groups	1603490	101504 (6.3%)

It is interesting to know what percentage of the trips potentially affected by cordon pricing was made by each socio-economic group because it shows who would be affected and to what degree. Table 5.9 is organized by origin-destination flow, using the three geographic zones. The table shows the count and percentage of the affected trips made by each socio-economic group. The percentages are calculated based on the total number of affected trips made by all socio-economic groups.

In general, the impact of cordon pricing varies across different socio-economic groups. Full-time workers account for a larger proportion of the affected trips. In addition, the majority of the affected trips by all groups originated outside the PD1 area. In particular, most of the affected trips are originated from the rest of the City of Toronto except for upper-middle income groups (full-time and not-employed/part-time) where most of the affected trips made by this group are originated from the rest of the GTA region. This demonstrates the contribution of each group in Downtown traffic congestion. In more details, the following observations are particularly noteworthy:

- People from low-income neighbourhoods (full-time and not-employed/part-time) generate the lowest number and percentage of affected trips.

- For the people from low-income neighbourhoods, the lowest number of trips is coming from the rest of the GTA. This indicates that low-income groups that reside outside PD1 tend not to travel into the Downtown for work.
- People from lower-middle income neighbourhoods (full-time and not-employed/part-time) are affected more by cordon pricing than other full-time and not-employed/part-time groups as they generate the highest number of trips that cross the cordon borders.
- The majority of affected trips made by those in the lower-middle income neighbourhoods (full-time and not-employed/part-time) originated in either the PD1 area or the rest of the City of Toronto. In addition, this group is commuting mainly between these two areas.
- As indicated earlier, the affected trips made by people from upper-middle income neighbourhoods (full-time and not-employed/part-time) originated from the rest of the GTA area.
- The trips made by people from high-income neighbourhoods (full-time and not-employed/part-time) originated almost equally from the three areas, with the highest number of trips made from the rest of the GTA. This shows the distribution of the high-income travelers in the GTA and highlights the importance of the PD1 area as a working destination for this group.

Table 5. 9: Number and percentage of the auto trips potentially affected by cordon pricing made by each socio-economic group.

Auto trips (as driver or passenger)		Socio-economic Group								
		Employed full-time, Low-income	Not Employed/ part-time, low-income	Employed full-time, Lower-middle income	Not Employed/ part-time, Lower-middle income	Employed full-time, Upper-middle income	Not Employed/ part-time, Upper-middle income	Employed full-time, High-income	Not Employed/ part-time, High-income	All Groups
Auto trips that would be affected by cordon pricing	PD1→Rest of the City of Toronto	406 (4%)	180 (2%)	3373 (37%)	969 (11%)	1770 (19%)	529 (6%)	1499 (16%)	474 (5%)	9200 (100%)
	PD1→ Rest of the GTA	290 (5%)	17 (0%)	2230 (40%)	257 (5%)	1283 (23%)	100 (2%)	1317 (24%)	20 (0%)	5514 (100%)
	Rest of the City of Toronto → PD1	1705 (3%)	812 (1%)	20872 (37%)	4579 (8%)	8595 (15%)	1314 (2%)	15262 (27%)	2744 (5%)	55883 (100%)
	Rest of the GTA → PD1	189 (1%)	0 (0%)	7484 (24%)	1394 (5%)	12215 (40%)	1904 (6%)	6741 (22%)	983 (3%)	30910 (100%)
	Four flows combined	2590 (3%)	1009 (1%)	33959 (33%)	7199 (7%)	23863 (24%)	3847 (4%)	24819 (24%)	4221 (4%)	101507 (100%)

While a profile of affected travellers is illuminating, examining vertical equity requires a closer look at representation within socio-economic groups. This is done by considering the percentage of trips within a particular group that fall into the various flows. For example, the right-most column of Table 5.10 indicates that overall, 0.4% of all trips are auto trips between PD1 and the rest of the City of Toronto, 0.2% of all trips are auto trips between PD1 and the rest of the GTA, 2.4% of all trips are auto trips made between the rest of the City of Toronto and PD1. Thus, overall, 4.3% of all home-based, peak-period morning trips that originate in the GTA would be affected by cordon pricing, as proposed. However, the percentage of affected trips varies across socio-economic groups.

Table 5.10 shows that people from full-time high-income neighbourhoods would be most affected by this pricing strategy since a disproportionate number of them reside in the rest of the City of Toronto and commute to PD1 area. People from full-time lower- and upper-middle income neighbourhoods are affected by approximately the same magnitude. Interestingly, the data shows that most of full-time lower-middle income commuters who would be affected by this policy reside in the rest of the City of Toronto while full time upper-middle income commuters reside in the rest of the GTA.

The differential effect of cordon pricing across the socio-economic groups is explained in large part by differences in area of residence and mode of travel. Auto trips that would not be affected by cordon pricing are mainly concentrated outside the PD1 area. For people from low-income and lower-middle income neighbourhoods, these trips are originated in the rest of the City of Toronto and destined in the same area. Trips generated by other groups are originated and destined in the rest of the GTA regions. This demonstrates the importance of intra-regional trips made by all groups within the GTA areas. The same pattern is found in transit trips. The majority of trips made by people from low-income neighbourhoods are made within the rest of the City of Toronto and for the other groups are made within the rest of the GTA. This also emphasizes the importance of area of residence as the main origin and destination of most of the trips.

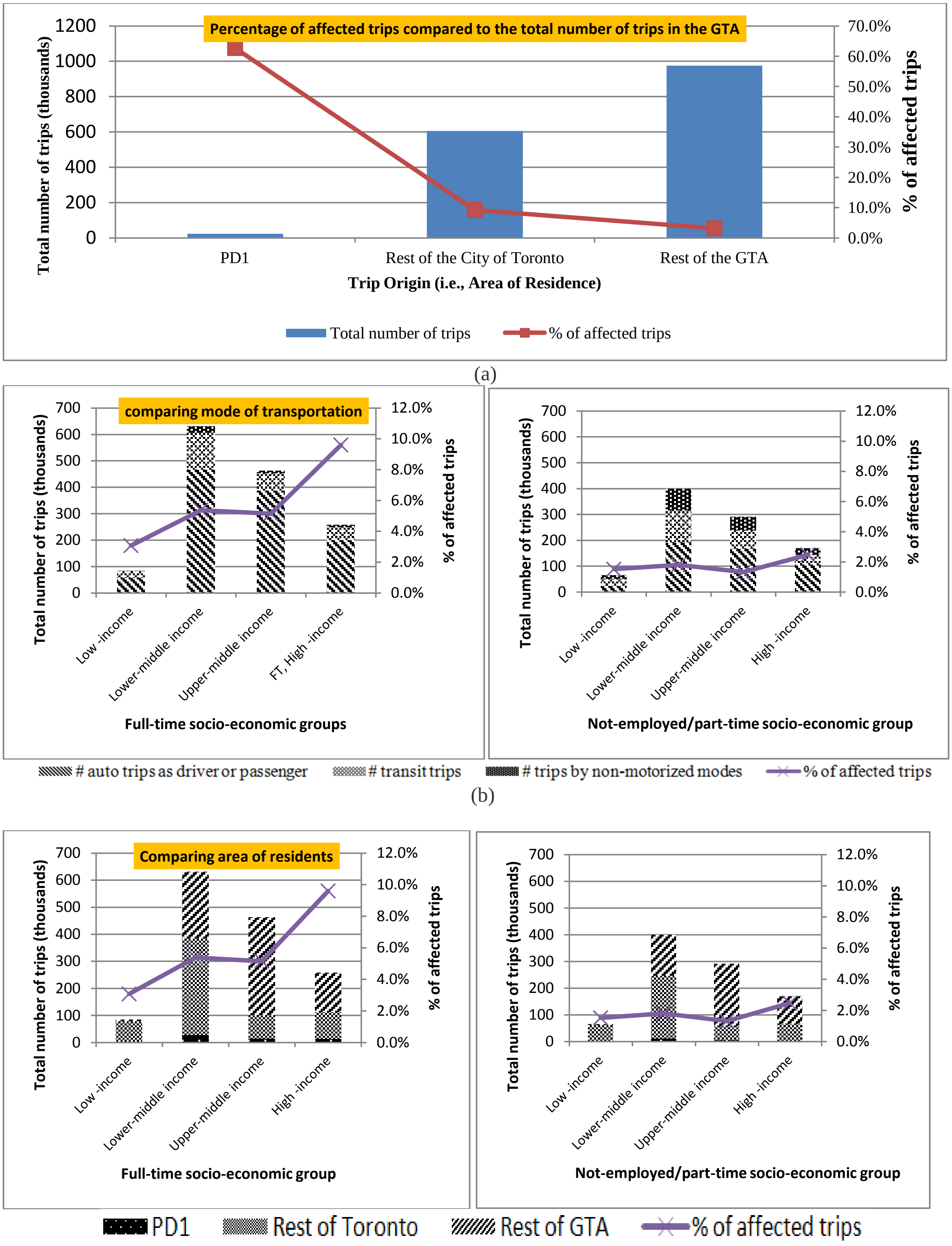
Table 5. 10: Distribution of trips made by different socio-economic groups.

Auto trips (as driver or passenger)		Socio-economic Group								
		Employed full-time, Low-income	Not Employed/ part-time, low-income	Employed full-time, Lower-middle income	Not Employed/ part-time, Lower-middle income	Employed full-time, Upper-middle income	Not Employed/ part-time, Upper-middle income	Employed full-time, High-income	Not Employed/ part-time, High-income	All Groups
Auto trips that would be affected by cordon pricing	PD1→Rest of the City of Toronto	406 (0.5%)	180 (0.3%)	3373 (36.7%)	969 (10.5%)	1770 (19.2%)	529 (5.8%)	1499 (0.6%)	474 (0.3%)	9200 (0.4%)
	PD1→ Rest of the GTA	290 (0.3%)	17 (0.0%)	2230 (40.4%)	257 (4.7%)	1283 (23.3%)	100 (1.8%)	1317 (0.5%)	20 (0.0%)	5514 (0.2%)
	Rest of the City of Toronto → PD1	1705 (2.0%)	812 (1.2%)	20872 (37.3%)	4579 (8.2%)	8595 (15.4%)	1314 (2.4%)	15262 (5.9%)	2744 (1.6%)	55883 (2.4%)
	Rest of the GTA → PD1	189 (0.2%)	0 (0.0%)	7484 (24.2%)	1394 (4.5%)	12215 (39.5%)	1904 (6.2%)	6741 (2.6%)	983 (0.6%)	30910 (1.3%)
	Four flows combined	2590 (3.1%)	1009 (1.5%)	33959 (5.4%)	7199 (1.8%)	23863 (5.2%)	3847 (1.3%)	24819 (9.6%)	4221 (2.5%)	101507 (4.3%)
Auto trips that would not be affected by cordon pricing	PD1→PD1	393 (0.5%	528 (0.8%)	2655 (0.4%)	1064 (0.3%)	1577 (0.3%)	366 (0.1%)	1542 (0.6%)	622 (0.4%)	8747 (0.4%)
	Rest of the City of Toronto → Rest of the City of Toronto	34535 (41.0%)	19644 (29.7%)	157889 (25.0%)	91191 (22.8%)	35892 (7.7%)	23244 (8.0%)	38233 (14.8%)	31797 (18.7%)	432425 (18.3%)
	Rest of the City of Toronto → Rest of the GTA	13848 (16.4%)	1089 (1.6%)	63240 (10.0%)	8504 (2.1%)	13421 (2.9%)	2087 (0.7%)	12463 (4.8%)	2062 (1.2%)	116714 (4.9%)
	Rest of the GTA → Rest of the City of Toronto	1120 (1.3%)	161 (0.2%)	42292 (6.7%)	8748 (2.2%)	72909 (15.7%)	15101 (5.2%)	27744 (10.7%)	7911 (4.6%)	175986 (7.4%)
	Rest of the GTA → Rest of the GTA	3855 (4.6%)	1650 (2.5%)	167428 (26.5%)	75116 (18.8%)	240376 (51.9%)	124215 (42.6%)	95203 (36.8%)	59921 (35.2%)	767764 (32.5%)
	Five flows combined	53751 (63.8%)	23072 (34.9%)	433504 (68.6%)	184623 (46.2%)	364175 (78.6%)	165013 (56.6%)	175185 (67.8%)	102313 (60.0%)	1501636 (63.5%)
Transit trips	PD1→PD1	454 (0.5%)	1058 (1.6%)	5972 (0.9%)	2441 (0.6%)	3423 (0.7%)	1079 (0.4%)	3177 (1.2%)	911 (0.5%)	18515 (0.8%)
	PD1→Rest of the City of Toronto	431 (0.5%)	1037 (1.6%)	4403 (0.7%)	2674 (0.7%)	1564 (0.3%)	1013 (0.3%)	1467 (0.6%)	613 (0.4%)	13202 (0.6%)
	PD1→ Rest of the GTA	52 (0.1%)	17 (0.0%)	493 (0.1%)	77 (0.0%)	280 (0.1%)	85 (0.0%)	272 (0.1%)	56 (0.0%)	1332 (0.1%)
	Rest of the City of Toronto → PD1	10563 (12.5%)	4090 (6.2%)	51427 (8.1%)	19212 (4.8%)	15302 (3.3%)	4788 (1.6%)	19790 (7.7%)	4668 (2.7%)	129840 (5.5%)
	Rest of the City of Toronto → Rest of the City of Toronto	11535 (13.7%)	20544 (31.0%)	42877 (6.8%)	62548 (15.7%)	7993 (1.7%)	10218 (3.5%)	7772 (3.0%)	9294 (5.5%)	172781 (7.3%)
	Rest of the City of Toronto → Rest of the GTA	1458 (1.7%)	430 (0.6%)	5936 (0.9%)	2184 (0.5%)	621 (0.1%)	332 (0.1%)	749 (0.3%)	220 (0.1%)	11930 (0.5%)
	Rest of the GTA → PD1	309 (0.4%)	38 (0.1%)	15205 (2.4%)	3485 (0.9%)	25341 (5.5%)	5654 (1.9%)	12222 (4.7%)	2426 (1.4%)	64680 (2.7%)
	Rest of the GTA → Rest of the City of Toronto	169 (0.2%)	201 (0.3%)	4473 (0.7%)	4624 (1.2%)	4876 (1.1%)	5895 (2.0%)	1608 (0.6%)	2205 (1.3%)	24051 (1.0%)
	Rest of the GTA → Rest of the GTA	443 (0.5%)	403 (0.6%)	8256 (1.3%)	26115 (6.5%)	4961 (1.1%)	40279 (13.8%)	1159 (0.4%)	17073 (10.0%)	98689 (4.2%)
	Nine flows combined	25414 (30.2%)	27818 (42.0%)	139042 (22.0%)	123360 (30.9%)	64361 (13.9%)	69343 (23.8%)	48216 (18.7%)	37466 (22.0%)	535020 (22.6%)
Trips by non-motorized modes	PD1àPD1	386 (0.5%)	729 (1.1%)	9045 (1.4%)	4216 (1.1%)	4292 (0.9%)	1697 (0.6%)	3900 (1.5%)	535 (0.3%)	24800 (1.0%)
	PD1→Rest of the City of Toronto	36 (0.0%	124 (0.2%	283 (0.0%	268 (0.1%	110 (0.0%	355 (0.1%	104 (0.0%	123 (0.1%	1403 (0.1%
	PD1à Rest of the GTA	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	Rest of the City of Toronto → PD1	178 (0.2%)	62 (0.1%)	2444 (0.4%)	904 (0.2%)	1298 (0.3%)	512 (0.2%)	1485 (0.6%)	438 (0.3%)	7321 (0.3%)
	Rest of the City of Toronto → Rest of the City of Toronto	1723 (2.0%)	12154 (18.4%)	9896 (1.6%)	45277 (11.3%)	2400 (0.5%)	9904 (3.4%)	3460 (1.3%)	10386 (6.1%)	95200 (4.0%)
	Rest of the City of Toronto → Rest of the GTA	36 (0.0%)	0 (0.0%)	271 (0.0%)	118 (0.0%)	34 (0.0%)	0 (0.0%)	19 (0.0%)	0 (0.0%)	478 (0.0%)
	Rest of the GTA → PD1	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	Rest of the GTA → Rest of the City of Toronto	19 (0.0%)	0 (0.0%)	147 (0.0%)	100 (0.0%)	20 (0.0%)	84 (0.0%)	43 (0.0%)	55 (0.0%)	468 (0.0%)
	Rest of the GTA →Rest of the GTA	106 (0.1%)	1218 (1.8%)	2956 (0.5%)	33457 (8.4%)	2648 (0.6%)	40659 (14.0%)	1218 (0.5%)	14920 (8.8%)	97182 (4.1%)
	Nine flows combined	**2484 (2.9%**	**14287 (21.6%)**	**25042 (4.0%)**	**84340 (21.1%)**	**10802 (2.3%)**	**53211 (18.3%)**	**10229 (4.0%)**	**26457 (15.5%)**	**226852 (9.6%)**
All trips		**84239 (100%)**	**66186 (100%)**	**631547 (100%)**	**399522 (100%)**	**463201 (100%)**	**291414 (100%)**	**258449 (100%)**	**170457 (100%)**	**2365015 (100%)**

The table above clearly indicates that cordon pricing in Downtown Toronto (without any assumptions about the spending of cordon revenues) is progressive. The percentage of trips that are affected by this policy increases as the income increases. People from full-time, high-income neighbourhoods are affected the most by the charges. This conclusion can be explained by looking at the origin-destination trips, modal split, and spatial distribution of socio-economic groups as shown in Figure 5.3.

The origin-destination of most of the auto trips is within the same area except for the PD1 area as shown in Figure 5.3(a). More than 60% of auto trips originated in the PD1 are destined for the rest of the City of Toronto and the rest of GTA regions. One reason for that is that PD1 area is a small area compared to the other two areas. Also, PD1 contains a robust public transportation network and services. As such, residents of this area use other modes of transportation than autos to commute within this area, although many use autos to commute outside its boundaries.

Auto usage and the spatial distribution of the different groups are other factors that explain the progressivity of cordon pricing in Downtown Toronto. Figure 5.3 (b) shows that full-time (FT) groups depend more on automobile to generate their trips. At the same time the percentage of these auto trips that would be affected by cordon pricing is higher than for not-employed/part time (NE/PT) groups. Another side of progressivity can be explained by the spatial distribution of the different groups. People from low-income and lower-middle income neighbourhoods travel the most from the rest of the City of Toronto as shown in Figure 5.3(c).



(a)

(b)

(C)

Figure 5. 3: The percentage of affected trips based on (a) total number of trip (b) mode of transportation, (c) spatial distribution of the groups.

5.3 Detailed Analysis of Vertical Equity Based on Demographic Factors of Socio-economic Groups

The aim of this section is to give more insights into vertical equity of cordon pricing in Downtown Toronto. Different demographic variables are considered, as indicated earlier. By considering the demographic factors (age, gender, household size, and occupation), more detailed comparisons can be made between the different socio-economic groups. In addition, the analysis examines to a greater extent if cordon pricing would impact different travelers within the same socio-economic group based on their demographic characteristics in a similar or different ways. This aims to examine if the previous conclusion is upheld when we consider the demographic factors. For example, taking gender in consideration, the analysis aims to show if trips made by males are more affected by cordon pricing than females. Also, the analysis aims to demonstrate if cordon pricing would affect males or females from high-income neighbourhoods more than males or females from other neighbourhoods. To explain that, the analysis is based on the origin-destination factor, mode of transportation used, and the spatial distribution of socio-economic groups based on their demographic characteristics. Two types of comparison are conducted, the first compares between different socio economic groups based on each of the demographic factors; for example males from low-income neighbourhoods versus males of other neighbourhoods. This aims to show which group are more affected based on this demographic factor and if this policy is considered progressive or regressive based on that. Second, a comparison is conducted between the components of the demographic factors in each group; for example, males from low-income neighbourhoods versus females from low-income neighbourhoods. This aims to show who would be more affected by this policy or if they are affected at the same extent and hence lead us to a conclusion about the progressivity or regressivity of a Downtown Toronto cordon pricing scheme.

5.3.1 Gender

The analysis of vertical equity based on gender comprises two sections. The first one compares males and females in different socio-economic groups. The second part compares between males and females to determine who is more affected by cordon pricing. The comparison is based on the number of trips that would be affected, mode of transportation, and area of residents.

Analysis of the trips made by males residing in the GTA to/from the PD1 area indicates that cordon pricing is progressive. Table 5.11 illustrates the number and percentage of trips made by males by mode of transportation and the number of auto trips that would be affected by cordon pricing. As shown, the percentage of the affected trips increases as income increases. This clearly shows that cordon pricing would affect people from high-income neighbourhoods more than people from low-income neighbourhoods. Also evident in this table is the modal usage and its effect on total number of affected trips. For example, males in full-time groups use automobiles as their main mode of transportation in their traveling; on the other hand, not-employed/part-time males use transit or non-motorized modes in most of their traveling.

Table 5. 11: Distribution of trips made by males by mode of transportation as of 2006.

Socio-economic groups	# auto trips as driver (%)	# auto trips as passenger (%)	# transit trips (%)	# trips by non-motorized modes (%)	Total # trips (%)	# of affected trips (%)
Male trips – Full-time groups						
Low-income	32607 (68.5%)	2754 (5.8%)	10188 (21.4%)	1040 (2.2%)	47589 (100.0%)	1831 (3.9%)
Lower-middle income	255045 (75.0%)	17469 (5.1%)	55595 (16.4%)	11759 (3.5%)	339868 (100.0%)	20083 (5.9%)
Upper-middle income	205054 (82.7%)	10534 (4.3%)	27081 (10.9%)	5147 (2.1%)	247816 (100.0%)	13957 (5.6%)
High-income	109050 (77.2%)	4200 (3.0%)	22599 (16.0%)	5384 (3.8%)	141233 (100.0%)	15121 (10.7%)
Male trips – Not-employed/part-time groups						
Low-income	7100 (22.3%)	4449 (14.0%)	12670 (39.9%)	7558 (23.8%)	31777 (100.0%)	466 (1.5%)
Lower-middle income	48948 (26.7%)	33797 (18.4%)	54531 (29.7%)	46029 (25.1%)	183305 (100.0%)	3426 (5.9%)
Upper-middle income	34195 (27.3%)	30472 (24.4%)	31904 (25.5%)	28524 (22.8%)	125095 (100.0%)	1771 (1.4%)
High-income	19292 (27.5%)	18268 (26.1%)	17947 (25.6%)	14559 (20.8%)	70066 (100.0%)	1820 (2.6%)
All Groups	**711291 (59.9%)**	**121943 (10.3%)**	**232515 (19.6%)**	**120000 (10.1%)**	**1186749 (100.0%)**	**58475 (4.9%)**

Cordon pricing can be considered as a progressive policy when looking at female trips within the GTA. This is illustrated in Table 5.12, show that the percentage of trips that would be affected by cordon pricing increases as the income increases. This policy is progressive as it favors people low-income neighbourhoods relative to people from high-income neighbourhoods. In addition, full-time female groups are more affected than not-employed/part-time female groups. Interestingly, the table shows that the full-time employed, low-income female group depends on transit in their commuting more than automobiles as drivers. On the contrary, other full-time female groups depend more on automobiles in their commuting. This illustrates that cordon pricing less harmed female from low-income neighbourhoods.

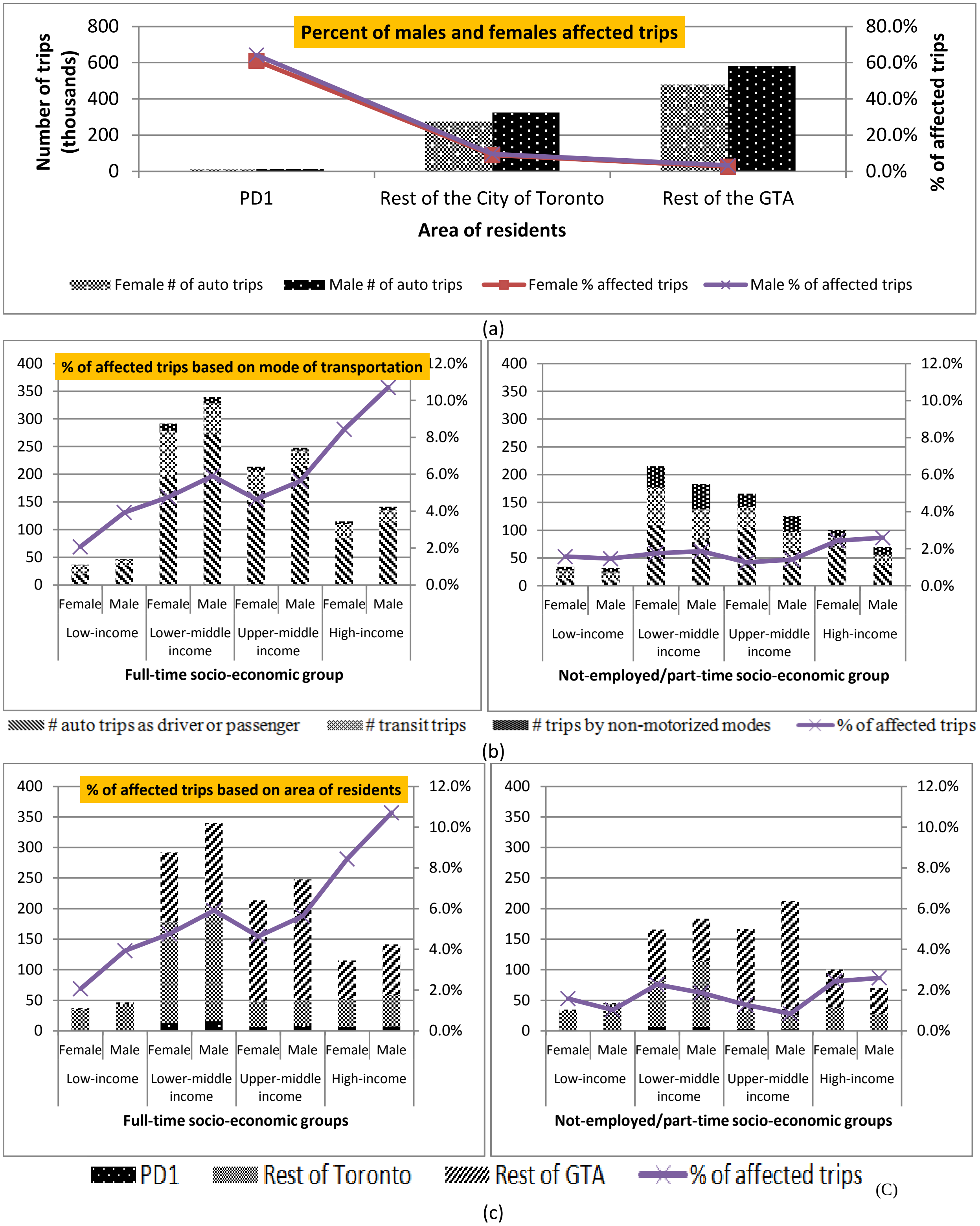
Table 5. 12: Distribution of trips made by females by mode of transportation as of 2006.

Socio-economic group	Modal split - Female					
	# auto trips as driver (%)	# auto trips as passenger (%)	# transit trips (%)	# trips by non-motorized modes (%)	Total # trips (%)	# of affected trips (%)
Female trips – Full-time groups						
Low-income	14610 (38.7%)	5567 (14.7%)	15183 (40.2%)	1429 (3.8%)	37789 (100.0%)	759 (2.0%)
Lower-middle income	156240 (53.6%)	38646 (13.2%)	83585 (28.7%)	13263 (4.5%)	291734 (100.0%)	13879 (4.8%)
Upper-middle income	149515 (70.0%)	21027 (9.8%)	37323 (17.5%)	5634 (2.6%)	213499 (100.0%)	9910 (4.6%)
High-income	75950 (66.1%)	8548 (7.4%)	25599 (22.3%)	4775 (4.2%)	114872 (100.0%)	9689 (8.4%)
Female trips – Not-employed/part-time groups						
low-income	6143 (17.9%)	6392 (18.6%)	15114 (44.0%)	6735 (19.6%)	34384 (100.0%)	542 (1.6%)
Lower-middle income	60712 (28.2%)	48375 (22.5%)	67928 (31.6%)	38263 (17.8%)	215278 (100.0%)	3768 (1.8%)
Upper-middle income	63787 (38.4%)	40442 (24.4%)	37112 (22.4%)	24687 (14.9%)	166028 (100.0%)	2112 (1.3%)
High-income	46570 (46.5%)	22380 (22.4%)	19238 (19.2%)	11885 (11.9%)	100073 (100.0%)	2441 (2.4%)
All Groups	**573527** **(48.9%)**	**191377** **(16.3%)**	**301082** **(25.7%)**	**106671** **(9.1%)**	**1173657** **(100.0%)**	**43100** **(3.7%)**

Males and females in the GTA make just about the same total number of trips, but males travel more by car as drivers and females travel more by transit as shown in Tables 5.11 and 5.12. As a result, the total number of trips made by males, from different socio-economic groups, that would be affected from cordon pricing outweigh the total number of trips made by females. Looking at each group, males and females follow the same pattern in terms of the affected trips based on income. Employed full-time male and female from low-income neighbourhoods are affected the least and the percentage of affected trips starts increasing as the income increases. The same applies to the not-employed/part-time male and female groups.

The comparison of the effects of cordon pricing on males and females trips is based on the percentage of affected trips by each gender, the mode of transportation, and the area of residents. Figure 5.4 illustrates the comparison between different socio-economic groups based on gender. Figure 5.4 (a) shows that males make more trips originating from the three areas than females. Most of these affected trips made by males and females are originated in the rest of the City of Toronto. The number of male trips that would be affected by cordon pricing is slightly higher than females. About 64% and 61% of car trips made by males and females respectively from the PD1 area would be affected by cordon pricing. This percentage decreases as the distance from PD1 area increases. About 10% and 3% of male affected trips originated in the rest of the City of Toronto and the rest of the GTA regions respectively compared to 9% and 2.6% of females. However, the highest number of the affected trips made by males and females that would be affected originates from the rest of the City of Toronto. This indicates that cordon pricing impact trips made by both genders in the same pattern.

Employed full-time males and females depend mainly on automobiles in their daily commuting as illustrated in Figure 5.4 (b). Employed full-time males depend more on automobile than females, and employed full-time females depend more on transit or non-motorized modes in their commuting than males. One reason behind that is the participation in the work-force. Males participate more than females in full-time jobs and therefore drive more. The figure shows that employed full-time people from lower-middle income neighbourhoods from both genders generate the highest number of car trips. This reflects on the number of car trips that would be affected by cordon pricing which is the highest compared to the other socio-economic groups. An important observation from Figure 5.4 is that the affected trips of full-time males in different socio-economic group are higher than trips made by full-time females in these groups. However, still the percentage of affected car trips is made by people from high-income neighbourhoods from both genders. On the other hand, not-employed/part-time male and female groups relies more on transit and non-motorized modes than full-time male and female socio-economic groups but still cars are the primary mode of transportation. Not-employed/part-time males and females from lower-middle income neighbourhoods generate the highest number of trips within the GTA and the number of the affected trips is the highest. However, still the percentage of affected trips that made by the not-employed/part-time males and females from high-income neighbourhoods is the highest. An interesting observation is that trips made by not-employed/part-time females are more affected than those by males which is the opposite of the full-time observation. Another observation from this figure is that more of not-employed/part time socio-economic groups commute by transit or non-motorized modes relative to what occurs for full-time groups. However, full-time males from lower-middle income neighbourhoods and surprisingly full-time males and females from high income neighbourhoods use public transportation more than not-employed/part-time males and females from lower-middle and high income neighbourhoods. This can be explained by looking at the spatial distribution of different groups in the GTA as shown in Figure 5.4 (c). Most of the transit trips made by full-time males and females from high-income neighbourhoods and full-time males from lower middle income neighbourhoods are commuting from the rest of the City of Toronto which is connected with the Downtown through a good public transportation network. In addition, these groups made the highest number of car trips to the Downtown. This indicates that Downtown Toronto is a main destination for these groups.



Primary Y- axis indicates total number of trips (thousands),
Secondary Y- axis indicates the percentage of affected trips

Figure 5. 4: comparison between males and females in different socio-economic groups based on (a) affected trips (b) mode of transportation (c) area of residents.

5.3.2 Age

Age is another demographic factor that is important when considering the equity of cordon pricing. Cordon pricing may impact different age groups in different ways. It is not expected that cordon pricing would impact travelers that are 19 years or younger as this group is less likely to use cars as drivers because they are mainly students and under the age of driving. On the other hand, it is interesting to know how cordon pricing may impact younger people who recently joined the work force versus those who are well established in the work force based on their age. Most importantly, is to know the impact of cordon pricing on the elderly people and those who are not-employed/part-time travelers from different ages. Therefore, to examine vertical equity of cordon pricing, travelers were distributed into different groups based on age. Figure 5.5 illustrates the age groups and the number of persons in each group.

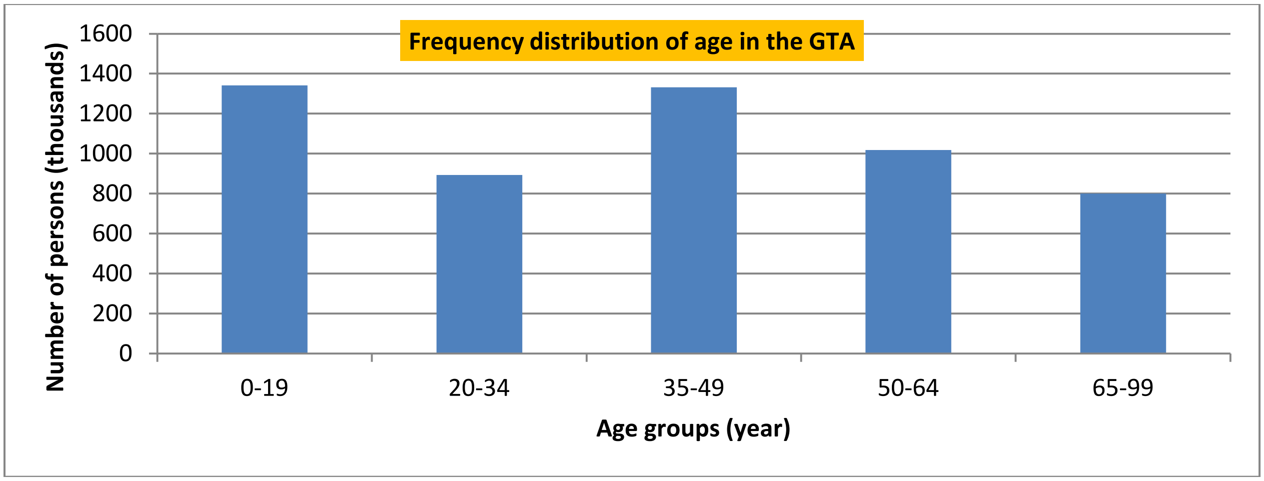


Figure 5. 5: Frequency distribution of residents of the GTA based on their age.

The analysis based on age is conducted in different ways. First, each age group is compared to the same age group in other socio-economic groups. For example, the employed-full time 20-34 years age group from low-income neighborhoods is compared to the same age group in other socio-income groups. Second, each age group is compared to the other age groups within the same socio-economic group. For example, the employed-full time 20-34 years age group from low-income neighborhoods is compared to the employed-full time 35-49 years age group from low-income nighborhoods. Finally, different full-time age groups are compared with not-employed/part-time age groups. The aim of these steps is to give more insight into vertical equity and to reach to an accurate conclusion about the progressivity or regressivity of this policy.

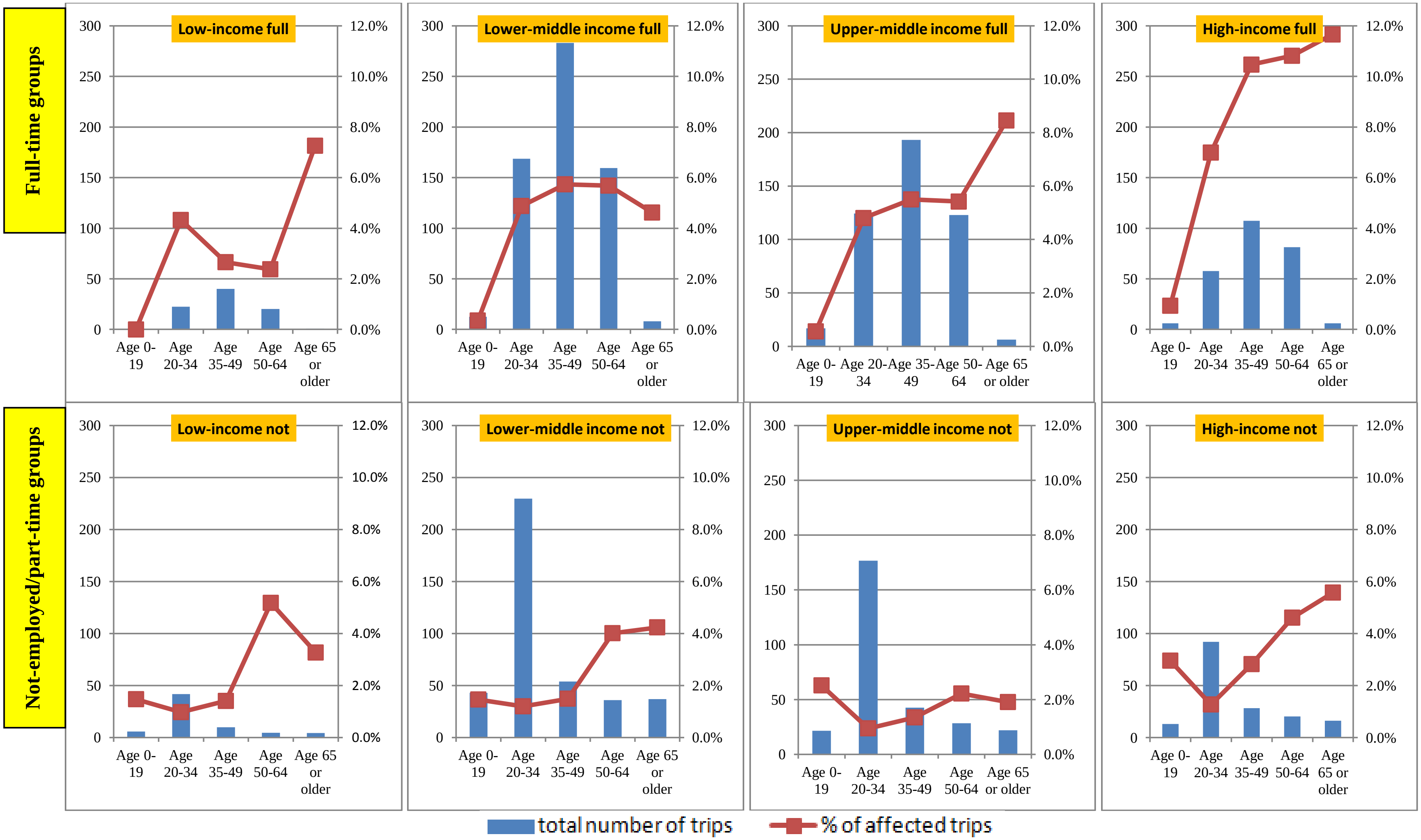
Looking across the rows in Figure 5.6, it is apparent that the relative frequency of trips by people of different ages is similar. Figure 5.6 illustrates the number of trips and the percentages of the affected trips relative to the total number of trips made by each age cohort in different socio-economic groups. The 35-49 year old group accounts for the largest proportion of trips, and the very young (11-19) and older (65+) groups make the fewest trips. The employed full-time 35-49 age cohort generates the highest number of trips across all socio-economic groups and consequently the number of affected trips by this age cohort is the highest. The percentage of the affected trips by this age cohort increases as their income increases. The same applies to the 20-24 and 50-64 age cohorts, as the figure also shows that the percentage of affected trips increases as the income increases. However, employed full-time 65 or older age cohort is the most affected age cohort as the percentage of trips that is affected is the highest among most of the socio-economic groups. This is because this age cohort generates a small number of trips, and many of them are made to/from the PD1 area and hence the percentage of the affected trips is high.

The not-employed/part-time age cohort groups are different than full-time age cohort groups in terms of the number of trips they made, the number and percent of affected trips, and who is affected more by cordon pricing. Not-employed/part-time 20-34 age cohort makes the highest number of trips within the GTA compared to other not-employed/part-time age cohorts in all socio-economic groups and the number of the affected trips is the highest as shown in Figure 5.6. This is expected as many individuals in this age group are in transitional status from students to searching for new jobs. However, the percentage of their affected trips is the lowest among all age groups in all socio-economic groups. One reason for this observation is that this age cohort use cars as passengers more than using it as drivers. The same applies to the not-employed/part-time 0-19 age cohort where the figure shows a high percentage of their trips would be affected by cordon pricing. This is because this age cohort travels as car passengers as most of them are students and their parents drive them to school. An interesting observation is the number and percentage of trips made by not-employed/part-time elderly people. Travelers in this age cohort are retired people and hence live outside the PD1 and travel mainly for shopping, recreation, or other purposes.

Cars are the main mode of transportation used by all age categories in full-time socio-economic groups as shown in Figure 5.7. Travelers' 19 years and younger mainly use cars as passengers as many of them cannot drive which explains the small number of trips made by this age cohort in all socio-economic groups. The other groups mainly use cars as drivers but people from the lower-income neighborhoods depends more on transit and non-motorized modes than do people from higher income neighborhoods. Full-time travelers, aged 34-49, generate the highest number of trips; however, the percentage of the affected trips is not the highest compared to other age cohorts. This may be because this age cohort travels less from/to the PD1 area and mainly travels in the rest of the City of Toronto and the rest of the GTA regions. Another interesting observation is that full-time travelers in 20-34 and 50-64 age groups (except for those in the high income neighborhoods) generate almost same number of trips but the percentage of affected trips varies. Still, this percentage for both age cohorts increases as the income increases.

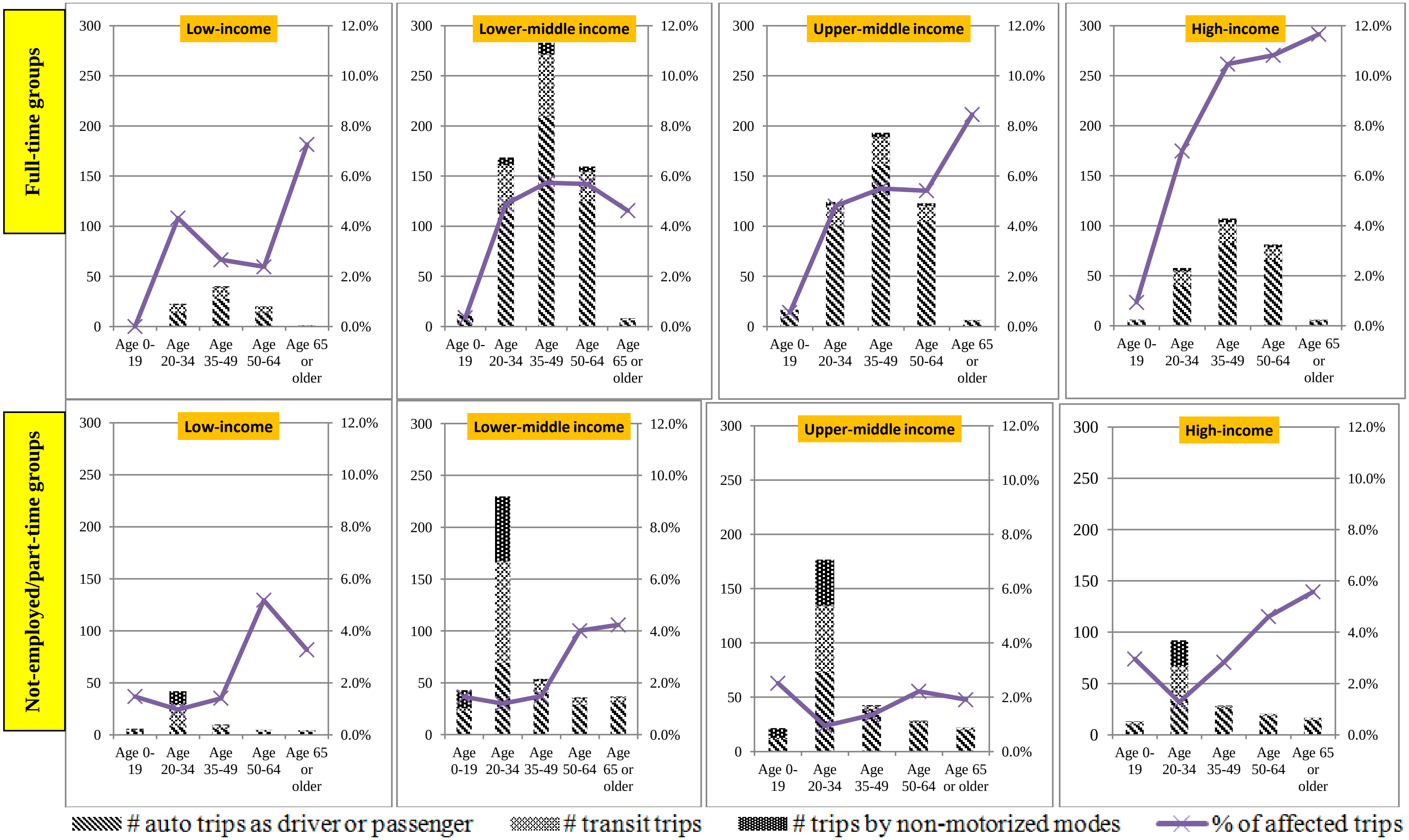
Not-employed/part-time travelers in different age cohorts have the same pattern of generating trips using different modes of transportation across different socio-economic groups. Travelers in the 20-34 age cohort generate the highest number of trips by different modes of transportation. They rely more on transit and non-motorized modes in generating their trips. In general, the percentage of affected trips made by not-employed/part-time age cohort groups increases as the income increases.

Vertical equity can also be examined by looking at the area of residents of travelers. An interesting observation from Figure 5.8 is that lower income groups reside mainly in the rest of the City of Toronto and the higher income groups reside mainly in the rest of the GTA regions. The same applies for the not-employed/part-time groups. This indicates that low-income groups reside close to the business central districts to avoid long commuting and to look to more job opportunities.



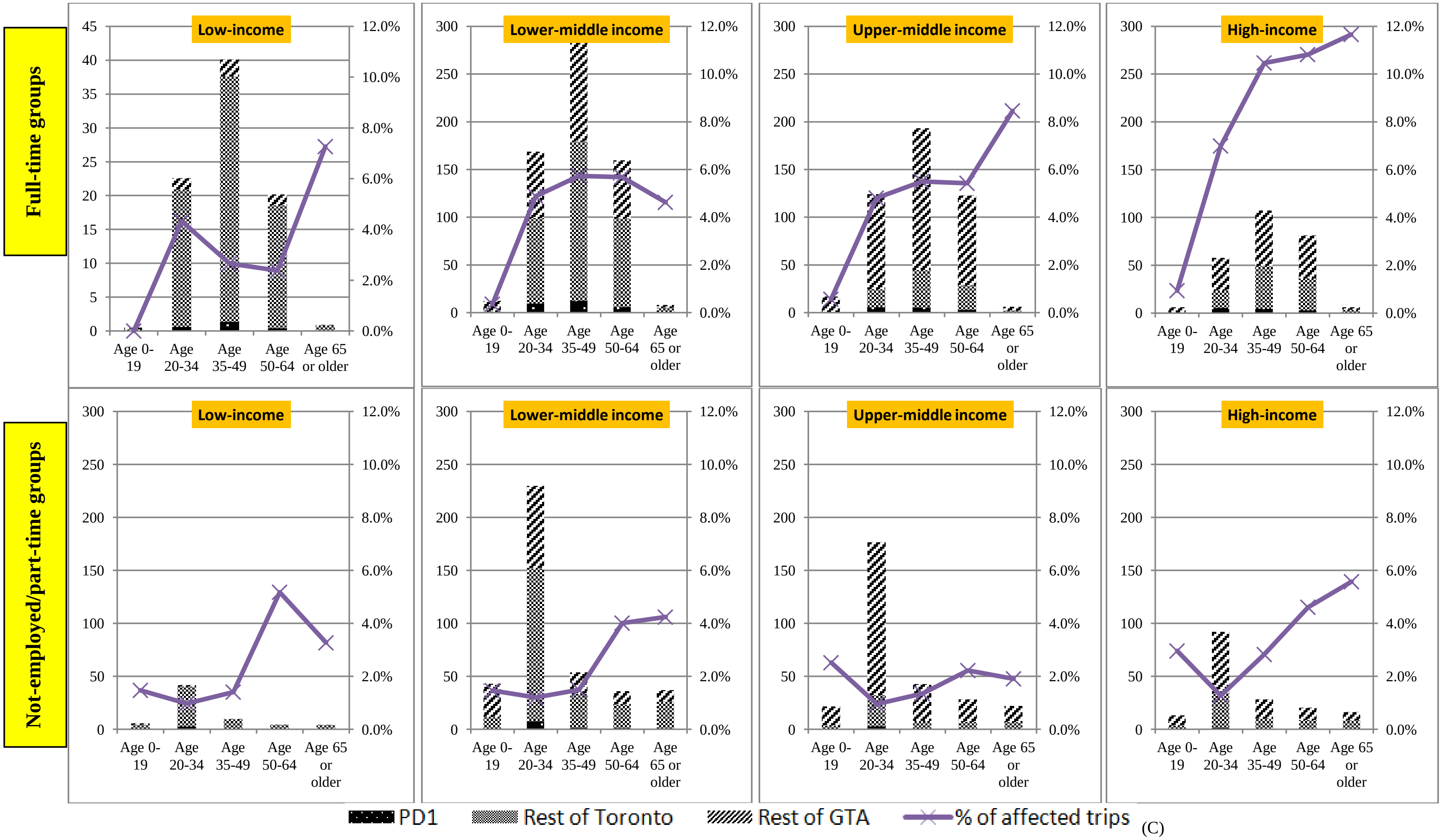
x-axis represent age groups,
Primary Y-axis represents number of trips made by indicated group (thousands),
Secondary Y-axis indicates percentage of affected trips by indicated group

Figure 5. 6: Comparison of the number of trips and affected trips by age demographic factor



x-axis represent age groups,
Primary Y-axis represents number of trips made by indicated group (thousands),
Secondary Y-axis indicates percentage of affected trips by indicated group

Figure 5. 7: Comparison of the percentage of affected trips by age demographic factor based on mode of transportation



x-axis represent age groups,
Primary Y-axis represents number of trips made by indicated group (thousands),
Secondary Y-axis indicates percent of affected trips by indicated group

Figure 5. 8: Comparison of the number of affected trips by age demographic factor based on area of residents

5.3.3 Household size

Household size is an important demographic factor to consider in examining the equity implications of cordon pricing. Cordon pricing imposes extra charges on travelers and this extra burden varies based on household size. Households with more people may require more trip making or be more likely to use private cars. Selecting household size categories for this study is based mainly on the frequency distribution of households of different sizes in the GTA, as shown in Figure 5.9. Five categories of household size were used in the analysis. As in the examination of gender and age, first, the number of trips and percentage of affected trips for each household size is examined and compared across different socio-economic groups. Then mode of transportation and area of residents are used to explain who would be more affected by this policy.

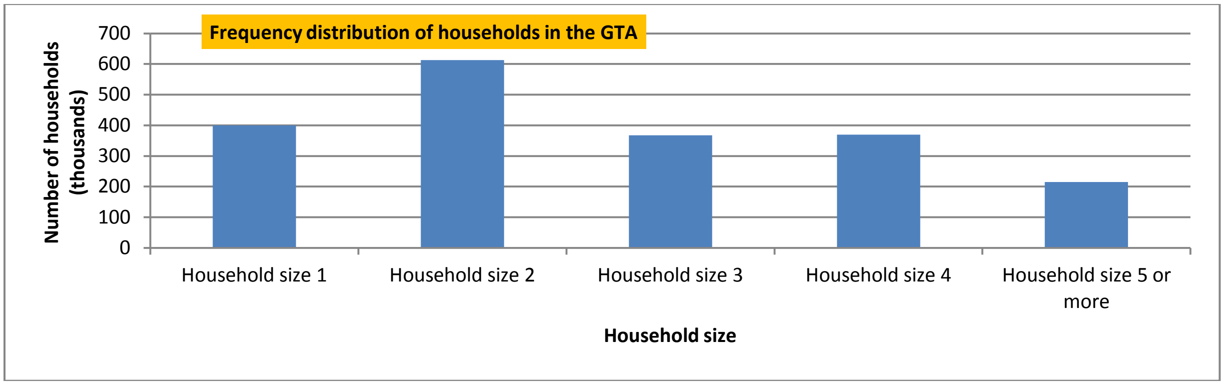
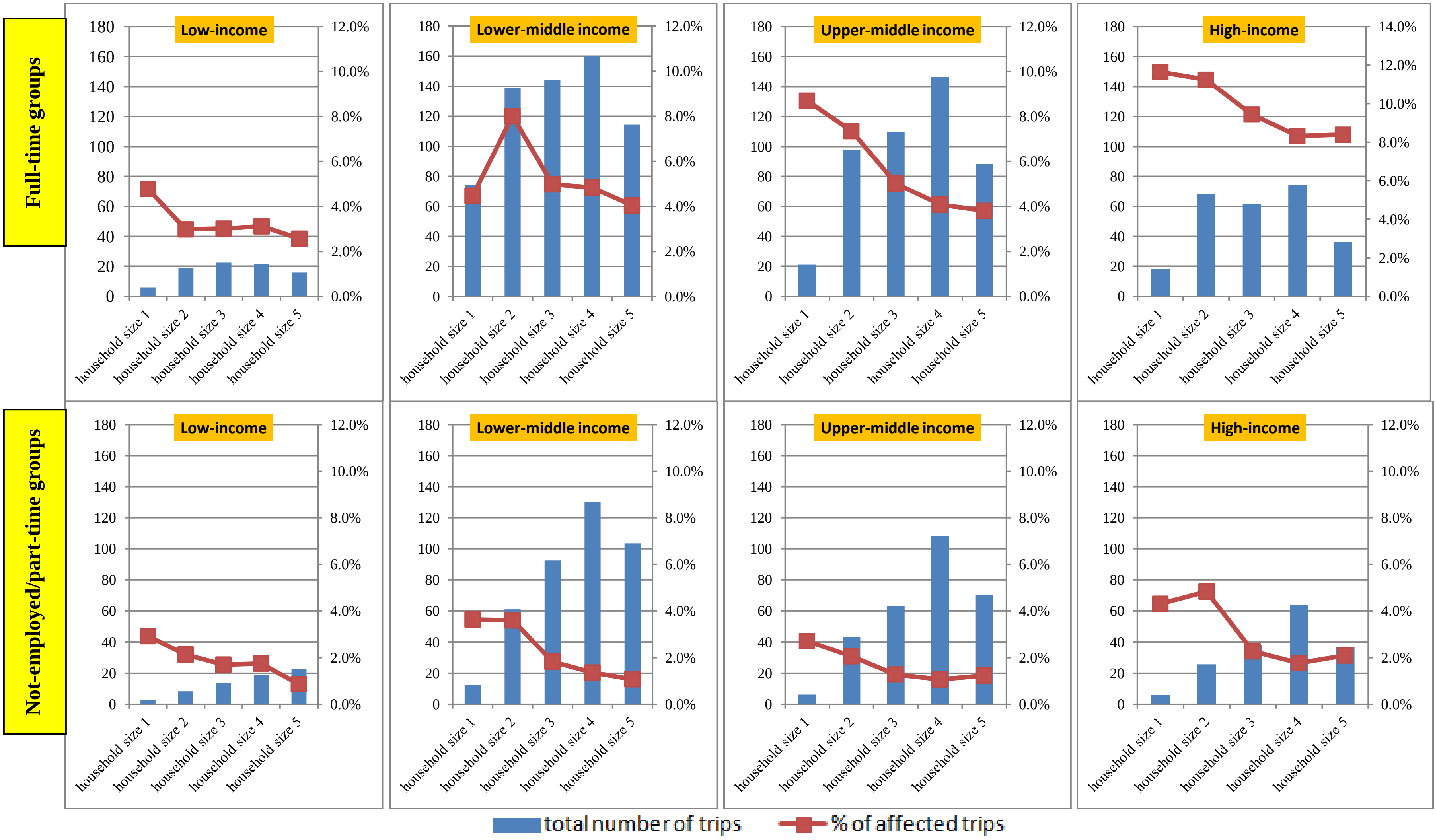


Figure 5. 9: Frequency distribution of the number of households based on household size in the GTA.

Cordon pricing would affect travelers based on their household size in different ways across different socio-economic groups. Employed full-time one-person households generate the fewest trips within the GTA; however, the percentage of their trips that would be affected is the highest across all the groups except for people from lower-middle income neighborhoods as shown in Figure 5.10. This is attributed to that this group is concentrated in central Toronto and commute to/from the PD1 more than other household sizes who generate more trips that originated and destined away from the PD1 area or inside it and hence are not subject to the charges. Most of the trips originated in and destined for the GTA are made by two-, three-, and four person households. This is expected as the more persons in a household the more trips may be generated for different purposes such as work, school, shopping, etc. Of importance for the equity analysis is the finding that, for all household sizes, the percentage of trips that would be affected by cordon pricing increases as income increases.

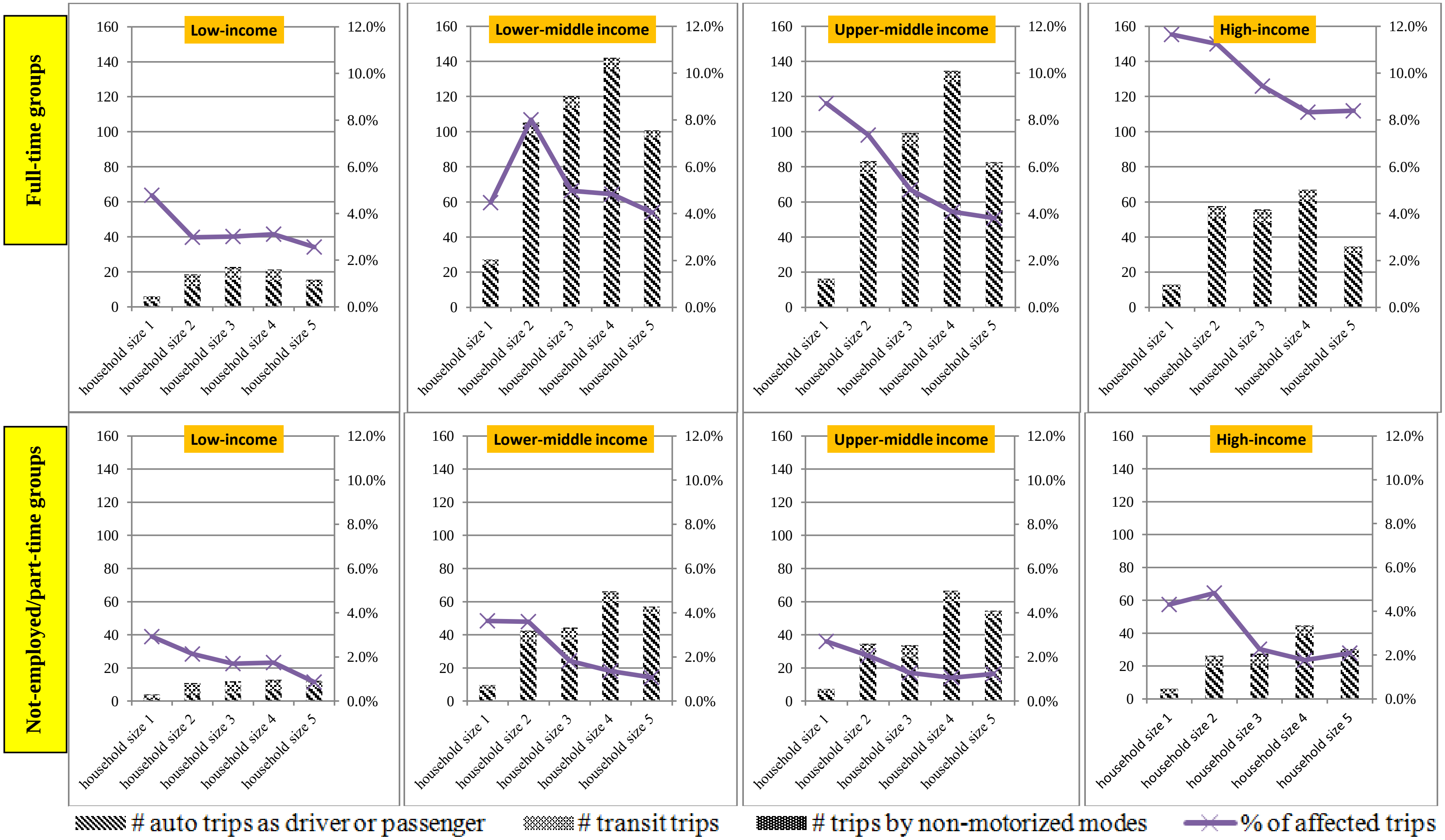
Not-employed/part-time groups are different in their travel pattern than full-time travelers based on household size. In general, all household sizes depend mainly on automobiles in their traveling regardless of whether they belong to the full-time or not-employed/part-time socio-economic groups as shown in Figure 5.11. This can probably be attributed to the convenience that cars provide. The exception is travelers from low-income neighborhoods. Not-employed/part-time people from low-income neighborhoods rely on transit and non-motorized modes more than automobiles.

Households' area of residence explains the usage of automobile by different household sizes. Figure 5.12 shows that many of people from low-income (full-time and not-employed/part-time) groups reside in the rest of the City of Toronto. These groups depend more on transit system which probably reflects the strong transit network that connect the rest of the City of Toronto with the Downtown.



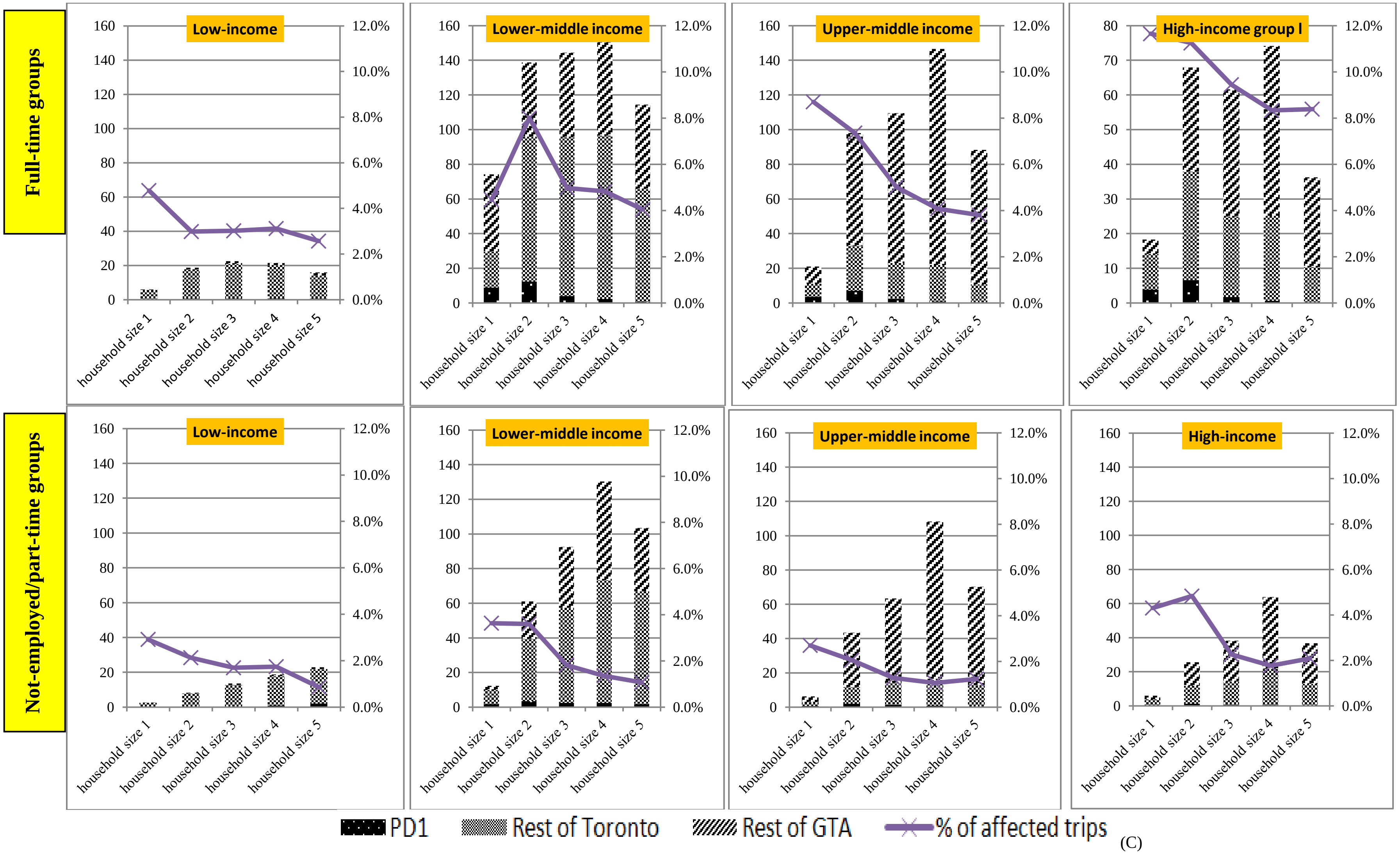
x-axis represent age groups,
Primary Y-axis represents number of affected trips made by indicated group (thousands),
Secondary Y-axis indicates percentage of affected trips by indicated group

Figure 5. 10: Comparison of the number of affected trips by household size demographic factor



x-axis represent age groups,
Primary Y-axis represents number of trips made by indicated group (thousands),
Secondary Y-axis indicates percent of affected trips by indicated group

Figure 5. 11: Comparison of the number of affected trips by household size demographic factor based on mode of transportation



x-axis represent age groups,
Primary Y-axis represents number of trips made by indicated group (thousands),
Secondary Y-axis indicates percent of affected trips by indicated group

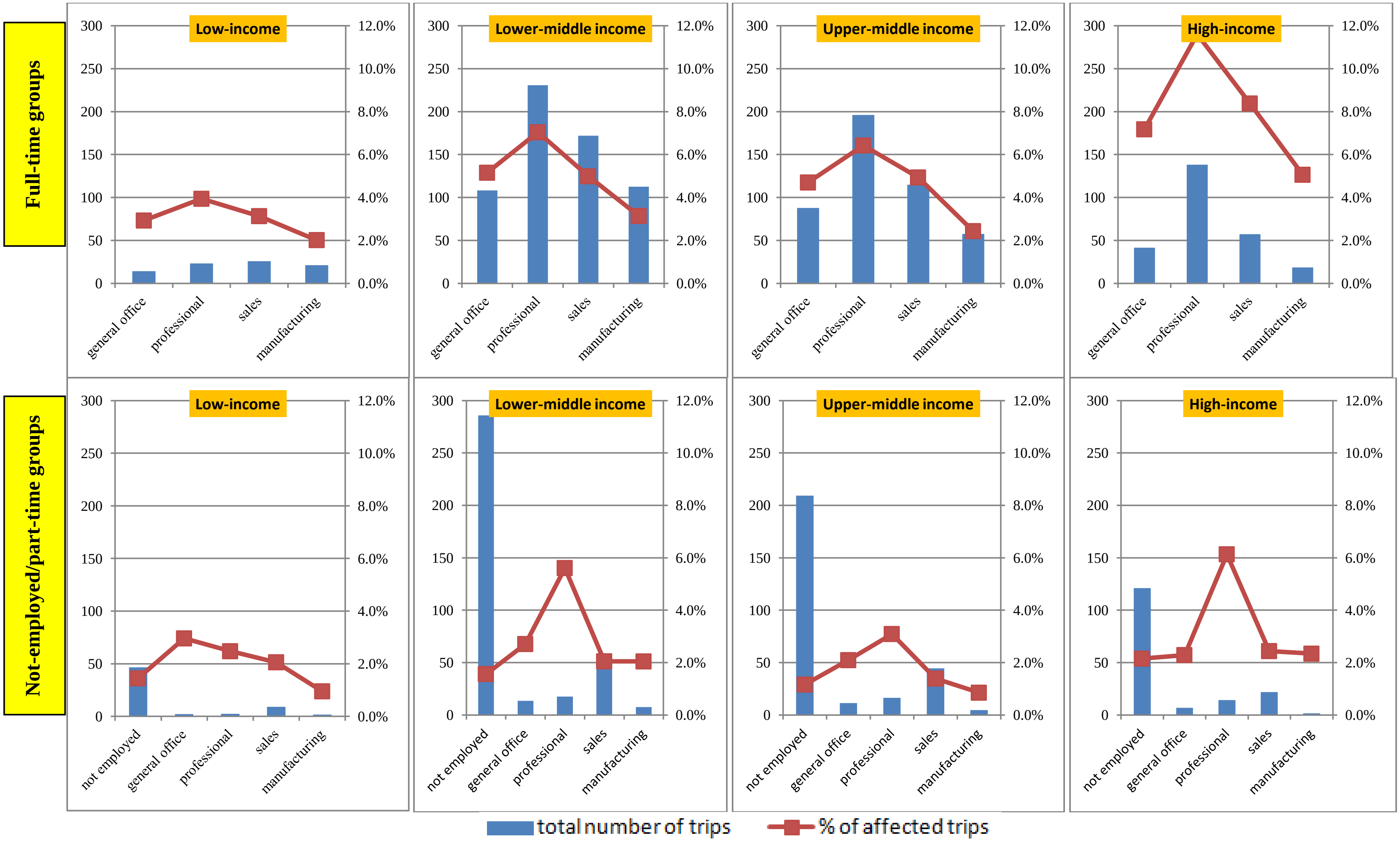
Figure 5. 12: Comparison of the number of affected trips by household size demographic factor based on area of residents

5.3.4 Occupation

This section aims to investigate which occupational group would be disproportionately affected by cordon pricing in Downtown Toronto. Five occupational groups are compared which were classified by the TTS data. These groups are general office / clerical, manufacturing /construction / trades, professional / management / technical, retail sales and service, and not employed. The examination and comparison is based on the total number of trips made by each occupational category in different socio-economic groups and the percentage of the affected trips. Then to elaborate more, mode of transportation and area of residents of these categories are highlighted.

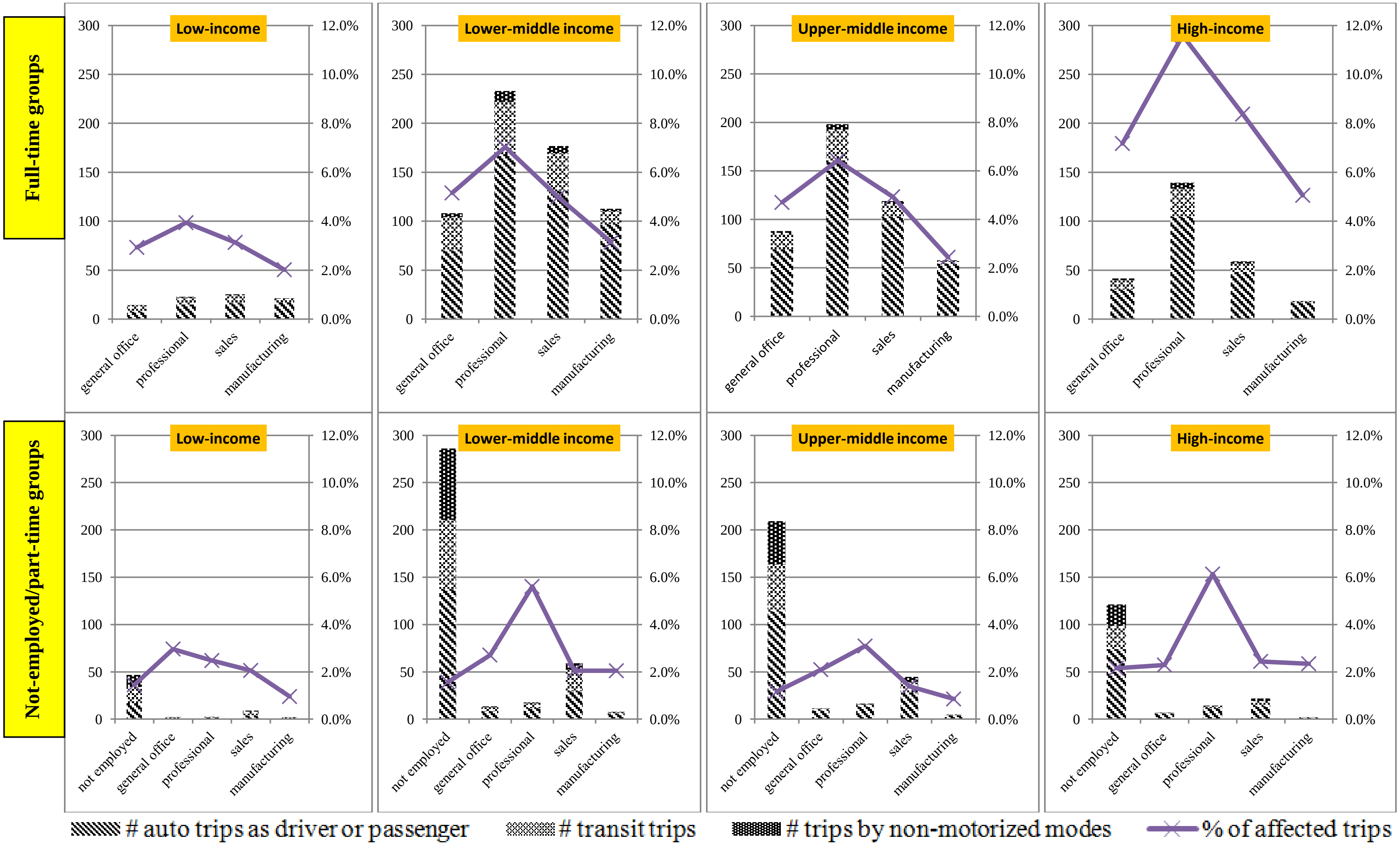
In terms of total number of trips, full-time professionals in all socio-economic groups are by far most affected (see Figure 5.13). Regarding total traveling, the full-time manufacturing group would be the least affected. This is logical due to the characteristics of Downtown Toronto as the main activities associated with the central business district are management, services, and sales among others, while on the other side manufactures are rarely found in this area. Compared to the professional category, trips made by all other occupational categories decreases as the income increases. On the other hand, the not employed category generates the highest number of trips compared to the other categories. However, the most affected category is the professionals and their trips are more affected as their income increases. Another interesting observation from the figure is that not-employed/part-time people from low-income neighborhoods differ in the percentage of trips that would be affected compared to the other socio-economic groups. Not employed/part-time general office people from low-income neighborhoods are the most affected in this group and professionals are the most affected in other socio-economic groups. This is due to income, as usually professionals are higher income than other categories.

Mode of transportation and area of residence can also explain the impact of cordon pricing on different occupational categories in different socio-economic groups. Automobile is the main mode of transportation used by all occupational categories either in full-time or not-employed/part-time socio-economic groups as shown in Figure 5.14. However, people from low-income neighborhoods rely more on transit and non-motorized modes in their commuting. Again, what explains this is where they live. Figure 5.15 shows that people from low-income neighborhoods are concentrated mainly in the rest of the City of Toronto. On the other hand, the other occupational categories are distributed mainly between the rest of the City of Toronto and the rest of the GTA regions.



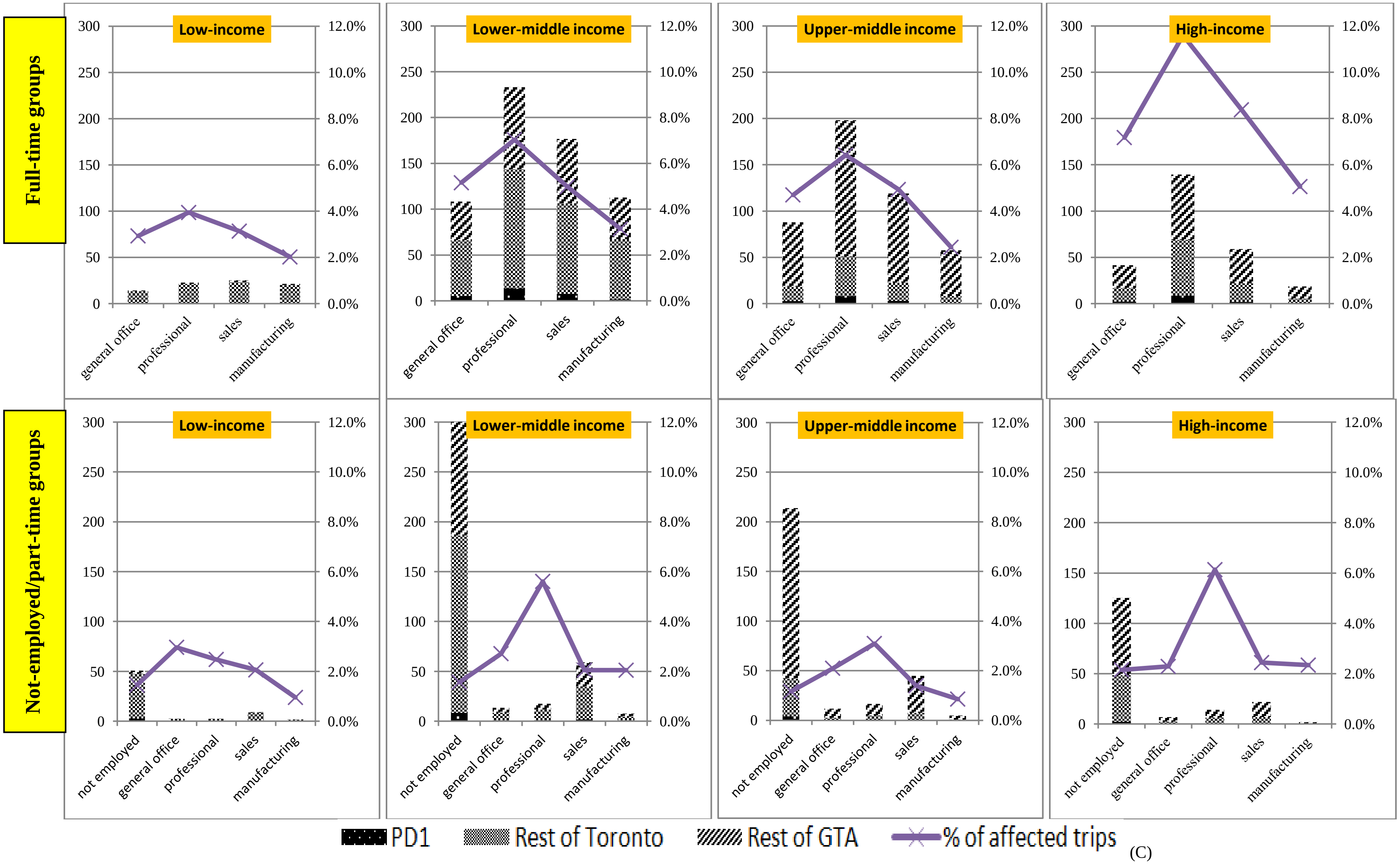
x-axis represent age groups,
Primary Y-axis represents number of trips made by indicated group (thousands),
Secondary Y-axis indicates percent of affected trips by indicated group

Figure 5. 13: Comparison of the number of affected trips by occupation demographic factor



x-axis represent age groups,
Primary Y-axis represents number of trips made by indicated group (thousands),
Secondary Y-axis indicates percent of affected trips by indicated group

Figure 5. 14: Comparison of the number of affected trips by occupation demographic factor based on mode of transportation



(C)

x-axis represent age groups,
Primary Y-axis represents number of trips made by indicated group (thousands),
Secondary Y-axis indicates percent of affected trips by indicated group

Figure 5. 15: Comparison of the number of affected trips by occupation demographic factor based on area of residents

5.4 Summary

This chapter analyzed travel activity by residents of different parts of the GTA who vary in terms of their socio-economics and/or demographics based on the TTS survey in 2006. The focus was on auto travel in and out of the proposed cordon pricing zone. This chapter provided insight into what types of persons would be most affected by such a pricing strategy by estimating the number of travellers whose auto trip would be charged under a cordon pricing scheme. The chapter also provided an introduction to the TTS trip data and a summary of equity-relevant socio-economic and demographic variables that are available from the TTS data. It also explained how household income data were approximated by blending TTS and Census data. It explored the issue of vertical equity associated with a cordon pricing zone imagined to coincide with the boundaries of PD1 through the analysis of the impact of cordon pricing on the trips made by different demographic and socio-economic groups. Eight socio-economic groups were created by cross-tabulating income categories with employment status. The analysis of the demographic variables provided additional insights into the equity implications of cordon pricing by estimating the proportion of different sub-populations that would be potentially affected by cordon pricing. The analysis of the traffic flows was based on home-based, morning, peak-period trips made only by the residents of the GTA. The number and percentage of trips that would be affected by cordon pricing was estimated by analysing traffic flow amongst the three areas.

Two types of comparison are conducted in this chapter. The first compares between different socio economic groups based on each of the demographic factors. The major finding of this comparison is that Downtown Toronto cordon pricing scheme would be progressive in its effects on the various socio-economic groups, and that the progressivity holds up even when travel is disaggregated by demographic factors such as age, gender, household size and occupational category. Full-time workers account for a larger proportion of the affected trips and the percentage of trips that would be affected is highest for full-time people from high-income neighborhoods. Full-time people from lower- and upper-middle income neighborhoods are affected by approximately the same magnitude. The differential effect of cordon pricing across the socio-economic groups was explained in large part by differences in area of residence and mode of travel. Most of the affected trips originated from the rest of the City of Toronto except for upper-middle income group where most of the affected trips made by this group are originated from the rest of the GTA region. In general, the analysis showed that the percentage of trips that would be affected increases as the traveler's income increases. Second, a comparison was conducted between the demographic groups. This aimed to show who would be more affected by this policy within the same group based on the demographic factors. The major finding is that males, those in the 35-49 age cohort, those in one-person households, and professionals would be more affected than other groups. In both findings, not-employed/part-time groups are different than full-time groups in terms of the number of trips they made, the number and percent of affected trips, but almost similar in terms of whom is affected more by cordon pricing.

Chapter 6: Perceptions of Equity in Cordon Pricing Based on the Stated Preferences of Survey Respondents in the GTA

6.1 Introduction

Chapter 5 provided quantitative estimates of the extent to which different socio-economic and demographic groups would be affected by cordon pricing in Downtown Toronto. A more comprehensive assessment of the equity implications of such a policy should also consider the ways in which travellers may change their travel patterns under a pricing scheme, and how the related revenue should be expended. The distribution of the generated revenue among individuals in different socio-economic groups is one of the pillars of vertical equity drawing from Rawls's "principle of difference". These are the themes to be addressed in Chapter 6.

While the TTS survey provides information about the travel activity by residents of the GTA, it does not provide any information on the potential changes in this travel activity or the distribution of the generated revenue in case cordon pricing is implemented in Downtown Toronto. Therefore, a survey needed to be conducted to explore these issues. The survey also provided an opportunity to explore the motivations that encourage travelers to maintain or change their travel behaviour and the overall level of support for such a policy. Section 6.2 summarizes respondent characteristics, and explains the ways in which the sample is (and is not) representative of the GTA population and the relevant implications for the analysis. Section 6.3 provides insights into Toronto residents' perceptions of congestion and their potential support for cordon pricing. Section 6.4 investigates the potential impact of cordon pricing on travelers' travel behaviours and the distribution of generated revenue.

6.2 First Insight into Respondents' Travel Characteristics and Demographic Data

The frequencies of the socio-economic and demographic characteristics of the travelers included in the sample are shown in Table 6.1, which is followed by a discussion of each characteristic.

6.2.1 Age

The age distribution of the respondents in the sample shows that travelers are mainly in the middle age groups. The 25-34 and 35-44 years age groups account for the largest proportions of respondents; fewer respondents fall into the very young (18-24 years) and older (65 and older) groups. The age profile of respondents does not completely coincide with the age distribution of the GTA population, based on the TTS data, as shown in Table 6.1. The TTS data show that the population of the GTA is predominantly in the 35-64 age cohort groups. However, both the survey sample and the TTS data show that the majority of travelers are of working age which connects with the labour force activity. In the survey analysis, respondents were categorized into three age groups: 18 - 34 years, 35 -54 years, and 65+ years.

6.2.2 Gender

Table 6.1 shows sex ratios with nearly equal numbers of males and females. The table shows that 99 respondents (51.8%) are males, and 92 (48.2%) are females, representing a total of 191 individual responses. The male : female ratio is close to being balanced and coincides with TTS data.

6.2.3 Occupation

Information was gathered on six occupational groups: not-employed, general office, professional/manager, sales/services, manufacturing, and others. These categories are consistent with the classifications of occupation used by the TTS data. The table shows that the majority of respondents (43.4%) work as professionals/managers. This partially reflects the characteristics of Downtown Toronto, as the main activities associated with the central business district are management, services, and sales, while on the other hand manufactures are rarely found in this area. The TTS data show a different distribution of occupations. Not-employed people comprise about 50% of occupational groups. This is because this category includes children, students, etc. As the number of respondents with careers in manufacturing is small, this occupational category is joined with the "others" category for analysis purposes.

6.2.4 Household income

Respondents were grouped into three income categories intended to reflect different socio-economic groups. These three categories are: people from low income neighborhoods with an annual income ranging between $0 and $59,999, people from middle income neighborhoods with annual income ranging between $60,000 and $119,999, and people from high income neighborhoods with an annual income of more than $120,000. As shown in chapter 5, people from lower- and upper-middle income neighborhoods are affected by cordon pricing by approximately the same magnitude. Due to the small sample size, people from lower- and upper middle-income neighborhoods are combined in this chapter. The table shows that there is almost an equal representation of the three income groups in the sample. The table shows that 56 respondents, 32.0% of the sample, are people from low income neighborhoods, while 51 respondents, 29.2% of the total sample, are people from middle income neighborhoods. Also, the table shows that 63 respondents, 35.0% of the total respondents, are from high-income neighborhoods. However, this distribution does not match the distribution of income across the GTA.

Table 6. 1: Demographic characteristics of the travelers in the sample.

Socioeconomic characteristic	**Number of responses**	**Percentage**	**TTS and Census[5] percentage**
Age (years)			
18-24	12	6.3	9.3
25-34	47	24.5	15.0
35-44	46	24.0	21.2
45-54	38	19.8	20.8
55-64	32	16.7	14.5
65 and over	17	8.9	19.3
Gender:			
Male	99	51.8	51.8
Female	92	48.2	48.2
Occupation:			
Not working	17	9.0	50.5
General office	30	15.9	7.3
Professional/manager	82	43.4	17.6
Sales/services	22	11.6	17.2
Manufacturing	2	1.1	7.5
Other	36	19.0	NA
Household income:			
$20,000-$39,999	25	14.3	1.3
$40,000-$59,000	31	17.7	12.5
$60,000-$79,999	18	10.3	31.7
$80,000-$99,999	15	8.6	24.3
$100,000-$119,999	18	10.3	11.0
$120,000-$139,999	18	10.3	5.5
$140,000 or more	45	25.7	13.7
Number of vehicles			
0	28	14.7	9.9
1	79	41.4	35.7
2	70	36.6	41.3
3 or more	14	7.3	13.1
Household size:			
1	35	18.3	7.4
2	69	36.1	22.8
3	37	19.4	20.5
4	31	16.2	27.5
5 or more	19	9.9	21.9
Household characteristics:			
Single adult with no children	37	19.4	NA
Single adult with a child or children	8	4.2	NA
Two or more adult with no children	75	39.3	NA
Two or more adult with a child or children	71	37.2	NA
Number of male workers in household:			
0	1	0.7	15.8
1	126	84.6	35.0
2	20	13.4	38.0
3 or more	2	1.3	11.2
Number of female workers in household:			
0	0	0	20.2
1	121	88.3	34.8
2	15	10.9	35.3
3 or more	1	0.7	9.7
Location:			
Downtown Toronto	38	20.5	3.5
Rest of the City of Toronto	65	35.1	41.9
Rest of the GTA	82	44.3	54.6

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[5] Census data is used to demonstrate income distribution only

6.2.5 Number of vehicles

Automobile ownership varies in the sample. Table 6.1 shows that a high percentage of households in the sample own one or two cars. The number of vehicles owned by a household is associated with different factors such as area of resident, income, and number of persons and workers in household. These relations are further examined in this chapter. People who do not own automobiles tend to either walk, cycle, or take transit to their destinations.

6.2.6 Household size and characteristics

The sample shows that respondents' household size varies, but that two-person households dominate. In general, the sample shows that a large proportion of respondents are from smaller household sizes (i.e., 3 or less). The distribution of household characteristics based on the survey sample shows the same results. A high proportion of respondents reported that they are either a single adult with no children or in a household with two or more adults with no children. On the other hand, the TTS data show that there are almost equal proportions of small and large household sizes in the GTA as shown in Table 6.1.

6.2.7 Area of residence

Table 6.1 shows the distribution of the respondents' residential areas. The returned sample included responses from the three areas. Comparing this distribution with the one indicated by the TTS data demonstrates that Downtown Toronto has been over-sampled. The table shows that 38 respondents reside in Downtown Toronto which forms 20.5% of the sample compared to only 3.5% based on the TTS data.

6.3 Traveler's perceptions of congestion and congestion pricing

This section is devoted to provide a sense as to Toronto residents' perceptions of congestion and cordon pricing. From the 209 respondents, only 17 respondents (8.1% of the total respondents) indicated that they did not travel to/from Downtown two weeks prior to the distribution of the survey. Those respondents were removed from the analysis as the focus is on those who traveled to/from Downtown.

6.3.1 Descriptive analysis

The first theme to be explored in the survey pertains to respondents' perceptions of cordon pricing and its effectiveness as a tool to curb congestion and their ability to support it and if they consider this policy it would be to their advantage or disadvantage. The overall opinion concerning reduction of Downtown traffic is clear. The awareness level of this strategy is very high, which is surprising because cordon pricing is a relatively recent consideration in North America. The majority of respondents (72%) agreed with the statement "There is a need to reduce traffic congestion in Downtown Toronto" Only 10% disagreed as shown in Table 6.2. Such unanimity in response is an indicative of the severity of traffic congestion in the Downtown. In general, travelers residing in the three areas strongly support this statement. However, the main differences are between travelers from the Downtown and the rest of the City of Toronto versus travelers residing in the rest of the GTA. More than 80% of travelers from each of Downtown and the rest of the City of Toronto support this statement compared to about 58% of travelers from the rest of the GTA regions.

Table 6. 2: Travelers' responses about the need to reduce congestion in Downtown Toronto.

How do you feel about the statement: there is a need to reduce traffic congestion in Downtown Toronto?						
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total
Frequency (%)	10 (5.2)	9 (4.7)	34 (27.6)	82 (42.7)	57 (29.7)	192 (100.0)

The perception of the effectiveness of cordon pricing to reduce road congestion is moderate among the respondents. A considerable percentage (44%) of respondents believe that cordon pricing is an effective tool to reduce traffic congestion in comparison to 33.5% of respondents who are less sure, indicating that it "may be effective" in reducing traffic congestion as shown in Table 6.3. However, since only 17.8% of the total number of respondents stated that cordon pricing is not an effective strategy to eliminate or manage congestion, this may indicate that cordon pricing is not a completely unknown traffic-demand strategy. An interesting observation is the percentage of respondents who stated that they are not sure or they don't know if this policy is an effective one. This may be attributed to the reality that cordon pricing is a new policy option and has never been implemented in North American cities. In general, these responses clearly show that respondents are aware of this policy and some are confident that it could be effective, but a considerable percentage of them perhaps want to see more research on this point.

Table 6. 3: Travelers' responses about the effectiveness of congestion in Downtown Toronto.

Do you think that cordon pricing would be effective in reducing traffic congestion in Downtown Toronto?					
	No	Maybe	Yes	I do not know	Total
Frequency (%)	34 (17.8)	64 (33.5)	84 (44.0)	9 (4.7)	191 (100.0)

Public acceptability is perceived as an essential element of successful implementation and formation of future policies and planning of cordon pricing strategies. Government agencies should consider increasing public acceptance and support prior to the planning and implementation of any project. Table 6.4 shows the current acceptability level by respondents. These responses reveal a moderate support of this policy where only 39.3% of the respondents support it against 34.4%. Others reported less firm positions.

Table 6. 4: Travelers' responses about their support of congestion in Downtown Toronto.

Would you support cordon pricing if implemented in Downtown Toronto?					
	No	Maybe	Yes	I do not know	Total
Frequency (%)	66 (34.4)	40 (20.8)	75 (39.3)	10 (5.2)	191 (100.0)

Participants' personal outcome expectations associated with cordon pricing vary. As shown in Table 6.4, the responses show that about one-third of the respondents expect that cordon pricing would be to their advantage. However, there is a considerable percentage of respondents (31.7%) who consider cordon pricing to their disadvantage. Another one-third of the respondents expected no change to their personal outcomes.

Table 6. 5: Travelers' responses of their perception of the benefits of congestion in Downtown Toronto.

Do you think the implementation of cordon pricing in Downtown Toronto would be:				
	To your advantage	Of little relevance to you	To your disadvantage	Total
Frequency (%)	70 (37.0)	59 (31.2)	60 (31.7)	189 (100.0)

Respondents generally expect positive personal outcomes from cordon pricing in the Downtown. They expect shorter travel time to/from Downtown, less air pollution and fewer environmental problems. They also expect that Downtown would become a better place to work and live. However, they also expect moderate negative personal outcomes, such as additional travel cost, unfairly restricted travel options, and more difficulties in planning trips. In this regard, it is noteworthy to mention that shorter travel time is a dominant expectation. Overall, it can be concluded that the image of cordon pricing seems to be positive.

In general, the perception of respondents toward each of these outcomes varies. Table 6.6 shows that about 80% of the respondents expect to see shorter travel time to the Downtown, and about 63% of them expect less air pollution and fewer environmental problems. In addition, more than half of the respondents see Downtown Toronto as becoming a better place to live and work. On the other hand, respondents are almost equally divided in their perception that cordon pricing may result in unfairly restricted travel options or it will lead to more difficulties in planning trips.

Table 6. 6: Frequency distribution of travelers’ perception of benefits of cordon pricing as indicated in the survey.

	Strongly disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly agree (%)	Total (%)
Shorter travel time to Downtown Toronto	6 (3.1)	16 (8.5)	16 (8.5)	93 (49.5)	57 (30.3)	188 (100.0)
Additional cost to your trips	20 (10.8)	22 (11.8)	14 (7.5)	86 (46.2)	44 (23.7)	186 (100.0)
Less air pollution and fewer environmental problems	8 (4.3)	24 (12.8)	38 (20.2)	71 (37.8)	47 (25.0)	188 (100.0)
Unfairly restricted travel options	23 (12.7)	46 (25.4)	43 (23.8)	40 (20.8)	29 (15.1)	181 (100.0)
More difficulties in planning trips	27 (15.0)	51 (28.3)	36 (18.8)	43 (22.4)	23 (12.0)	180 (100.0)
Downtown Toronto as a better place to work	17 (9.2)	18 (9.7)	47 (25.4)	62 (33.5)	41 (21.4)	185 (100.0)
Downtown Toronto as a better place to live	15 (8.1)	14 (7.6)	40 (21.6)	68 (36.8)	48 (25.9)	185 (100.0)

Awareness of the high congestion problem will lead to increased willingness to accept solutions for this problem. Indeed, as shown in Table 6.7, respondents who feel affected by the traffic congestion are more likely to support this policy. If respondents clearly identify the congestion problem and its consequences and recognise the aims of solving this problem (reduce traffic congestion), they may recognise if cordon pricing is an appropriate and effective solution to congestion in Downtown Toronto. Lastly, respondents who know about cordon pricing are more aware of the advantages and disadvantages of this system.

Table 6. 7: The relationship between problem perception and support of cordon pricing and respondents’ perception about its effectiveness and their personal benefits

		How do you feel about the statement: there is a need to reduce traffic congestion in Downtown Toronto?					
		Strongly disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly agree (%)	Total (%)
Effectiveness of cordon pricing	No	6 (17.6)	5 (14.7)	6 (17.6)	10 (29.4)	7 (20.6)	34 (100.0)
	Maybe	1 (1.5)	3 (4.7)	16 (19.0)	32 (50.0)	12 (18.8)	64 (100.0)
	Yes	3 (3.6)	1 (1.2)	8 (9.5)	36 (42.9)	36 (42.9)	84 (100.0)
	I do not know	0 (0.0)	0 (0.0)	4 (44.4)	3 (33.3)	2 (22.2)	9 (100.0)
	Total	10 (5.2)	9 (4.7)	34 (17.8)	81 (42.4)	57 (29.8)	191 (100.0)
Support of cordon pricing	No	8 (12.1)	7 (10.6)	19 (28.8)	20 (30.3)	12 (18.2)	66 (100.0)
	Maybe	2 (5.0)	1 (2.5)	7 (17.5)	25 (62.5)	5 (12.5)	40 (100.0)
	Yes	0 (0.0)	1 (1.3)	5 (6.7)	33 (44.0)	36 (48.0)	75 (100.0)
	I do not know	0 (0.0)	0 (0.0)	3 (30.0)	3 (30.0)	4 (40.0)	10 (100.0)
	Total	10 (5.2)	9 (4.7)	34 (17.8)	81 (42.4)	57 (29.8)	191 (100.0)
Implementation of cordon pricing	to your advantage	2 (2.9)	2 (2.9)	3 (4.3)	34 (48.6)	29 (41.4)	70 (100.0)
	of little relevance to you	1 (1.7)	0 (0.0)	17 (28.8)	27 (45.8)	14 (23.7)	59 (100.0)
	to your disadvantage	7 (11.7)	7 (11.7)	13 (21.7)	20 (33.3)	13 (21.7)	60 (100.0)
	Total	10 (5.3)	9 (4.8)	33 (17.5)	81 (42.9)	56 (29.6)	189 (100.0)

The awareness level of the problem and its solution have an impact on respondents' perceptions about the effectiveness of cordon pricing and their willingness to support it and their expectations of this policy as shown in Table 6.7. A high proportion of respondents, who believe that there is a congestion problem in the Downtown, evaluate cordon pricing as an effective measure to manage/mitigate congestion in Downtown Toronto. This seems to indicate that the respondents believe that cordon pricing is capable of successfully addressing the congestion problem, and thus, they are willing to trust this strategy even if it is new. Public acceptability is an important precondition factor for a successful implementation of cordon pricing to manage/mitigate traffic congestion problems. In addition, evaluating cordon pricing as an effective policy is assumed to be an important factor influencing the high level of acceptability of the implementation of cordon pricing. High public perception and awareness of the congestion problem has an important role in encouraging them to accept solutions for the perceived problem. Congestion is considered a serious problem and obviously in the Downtown, and cordon pricing is recognized as an effective method to solve this problem. Table 6.7 shows that cordon pricing is capable of winning major support among respondents who agreed or strongly agreed that congestion is a problem in the Downtown. Table 6.7 shows that those who agreed that congestion should be reduced in the Downtown are willing to support cordon pricing because they consider it as an effective policy to curb congestion and, to some extent, they are expecting personal advantages of this system. The table shows no indications that respondents justify denial of cordon pricing by claiming that they perceive it as ineffective. Still many respondents are not sure or they do not know if they are willing to support this policy. Perceived justice or equity is another basic factor that contributes to and effects public acceptability. This factor influences personal perception and differs among people in different situations and people in a similar situation with comparable objective benefits and costs. Some individuals consider imposing fees to be unfair.

6.4 Equity-focused bi-variate analysis

This section explores the links between respondent characteristics and their current and potential travel patterns. It must be noted, however, that various socio-economic and demographic factors are inter-related and are not independent of one another. Therefore, it can be misleading to consider the relation between the answer to any of the research questions and any one of the socio-economic and demographic factors in isolation. Each one of these factors may be acting as a proxy for one or more other factors with which it is correlated. For example, responses to the survey show that respondents from Downtown tend to be younger, less likely to have children, more likely to live in smaller households, more likely to have few vehicles and more likely to have lower incomes as compared to respondents from the other two areas. Therefore, these factors are confounded, such that it is difficult to disentangle their effects on response patterns to questions on travel. In addition, the sampling design was intended to provide a similar number of respondents from each of the three study areas for each of the three income levels. This was to enable comparisons of response patterns across areas or income levels. Unfortunately, the response rate was low overall (limiting multi-variate analysis). Also, the number of respondents from Downtown with middle or high income was disproportionately low, so this means that area is confounded with income (and other associated variables), which limits the usefulness of some of the bivariate analyses.

Given the confounded nature of the socio-economic/demographic variables, groups have to be defined carefully. Therefore, it is necessary to come up with analytical frameworks whereby subsets of variables are combined and analyzed in targeted ways in order to address the research goal.

Respondents were categorized into two different groups where trip frequencies were cross-tabulated with mode of transportation as illustrated in Table 6.8. The first group includes of those who cross the cordon zone with auto as the main mode of transport. This group is directly affected by cordon pricing as they have to pay the charges or change their travel behaviour. The second group is the ones who cross the cordon zone despite trip frequency with public transit or walking/cycling as the main transport modes. This group would not be negatively affected by cordon pricing since using transit or walking/cycling are free of charge.

Table 6. 8: Travel groups

Groups	Description of groups	Frequency (%)
Group 1	Respondents who rely primarily on autos for travelling to/from Downtown	107 (57.8)
Group 3	Respondents who rely primarily on transit for travelling to/from Downtown	81 (42.2)

In examining the impact of cordon pricing on travel behaviour from an equity perspective, it is necessary to link the characteristics of trip makers with those of their trip. Since income is central to equity considerations, each of the above groups is divided into three subgroups to represent different income levels as shown in Table 6.9.

Table 6. 9: travel groups based on income

Groups	Low income	Middle income	High income	Total
Respondents who rely primarily on autos for travelling to/from Downtown	33	31	39	103
Respondents who rely primarily on transit for travelling to/from Downtown	26	20	24	70
Total	59	51	63	173

Trips generated by different income groups to/from the Downtown vary in their purposes. The survey asked respondents to state their travel purpose to/from the Downtown. It suggested six different trip purposes which are: 1) to work, 2) to school, 3) to shopping, 4) to visit friends or family, 5) to recreation, and 6) others. Work trips are the main trips generated by all these groups. Table 6.10 shows that work trips constitute about two-thirds of people from low-income neighborhoods total trips using autos or transit, and lower than that for other income neighborhoods. On the other hand, shopping, recreation, and visiting friends/family trips are the lowest among low-income travelers and higher for travelers from middle- and high-income neighborhoods.

Table 6. 10: Frequencies of trips made by the two groups based on the purpose of the trip

	Income groups	Trip frequency						
		Work trips	School trips	Shopping	Visiting friends/ family	Recreation activities	others	Total
Respondents who rely primarily on autos for travelling to/from Downtown (percentage)	Low-income	23 (69.7%)	0 (0.0%)	0 (0.0%)	4 (12.1%)	2 (6.1%)	4 (12.1%)	33 (100.0%)
	Middle-income	14 (45.2%)	0 (0.0%)	3 (9.7%)	9 (29.0%)	4 (12.9%)	1 (3.2%)	31 (100.0%)
	High-income	18 (46.2%)	1 (2.6%)	6 (15.4%)	2 (5.1%)	5 (12.8%)	7 (17.9%)	39 (100.0%)
	Total	55 (53.4%)	1 (1.0%)	9 (8.7%)	15 (14.6%)	11 (10.7%)	12 (11.7%)	103 (100.0%)
Respondents who rely primarily on transit for travelling to/from Downtown (percentage)	Low-income	16 (61.5%)	4 (15.4%)	1 (3.8%)	2 (7.7%)	0 (0.0%)	3 (11.5%)	26 (100.0%)
	Middle-income	9 (45.0%)	1 (5.0%)	1 (5.0%)	4 (20.0%)	3 (15.0%)	2 (10.0%)	20 (100.0%)
	High-income	13 (54.2%)	2 (8.3%)	0 (0.0%)	2 (8.3%)	3 (12.5%)	4 (16.7%)	24 (100.0%)
	Total	38 (54.3%)	7 (10.0%)	2 (2.9%)	8 (11.4%)	6 (8.6%)	9 (12.9%)	70 (100.0%)

Perceptions about the potential impacts of cordon pricing on travelers' trips by trip purposes is almost the same among different respondents who rely primarily on autos for travelling to/from Downtown. A chi-square test reveals no statistically significant differences between those respondents based on their income in terms of the impact of cordon pricing on their trips based on trip purpose. More than two-thirds of the respondents from different income groups that use autos in their commuting stated that they do not expect any impact of cordon pricing on their journey to work. Only 14.9% of the respondents stated that cordon pricing will have large impact on their journey to work as shown in Table 6.11. The table also shows that the majority of respondents stated that cordon pricing will have no impact on their journey to school. This is expected as students usually use public transportation, cycle, or walk to their school. However, the table shows that cordon pricing has little to some impacts on shopping, visiting friends/family, business purpose, and recreation trips. It can be noted that, in particular, respondents who use their auto to commute to/from work state an auto dependency. On the contrary, shopping and recreation trips are mainly the auto trips that respondents are willing to reduce if cordon pricing is implemented which in turn, could be problematic for small businesses inside the cordon zone. This may be considered as an indicator that some trips such as shopping, recreation activities may be directed to other places outside the cordon zone.

Table 6. 11: The extent of impact of cordon pricing on respondents' trips by trip purpose

		Respondents who rely primarily on autos for travelling to/from Downtown				
		Low-income	Middle-income	High-income	Total	Statistical significance
Commute to/from work	No impact	15 (51.7%)	19 (67.9%)	29 (78.4%)	63 (67.0%)	0.074
	Little impact	10 (34.5%)	4 (14.3%)	3 (8.1%)	17 (18.1%)	
	Some to large impact	4 (13.8%)	5 (17.9%)	5 (13.5%)	14 (14.9%)	
	Total	29 (100.0%)	28 (100.0%)	37 (100.0%)	94 (100.0%)	
Commute to/from school	No impact	24 (82.8%)	23 (92.0%)	30 (90.9%)	77 (88.5%)	0.489
	Little impact	3 (10.3%)	0 (0.0%)	2 (6.1%)	5 (5.7%)	
	Some to large impact	2 (6.9%)	2 (8.0%)	1 (3.0%)	5 (5.7%)	
	Total	29 (100.0%)	25 (100.0%)	33 (100.0%)	87 (100.0%)	
Shopping	No impact	11 (35.5%)	8 (29.6%)	12 (33.3%)	31 (33.0%)	0.987
	Little impact	8 (25.8%)	7 (25.9%)	10 (27.8%)	25 (26.6%)	
	Some to large impact	12 (38.7%)	12 (44.4%)	14 (38.9%)	38 (40.4%)	
	Total	31 (100.0%)	27 (100.0%)	36 (100.0%)	94 (100.0%)	
Visiting friends/family	No impact	10 (31.3%)	10 (37.0%)	15 (45.5%)	35 (38.0%)	0.734
	Little impact	13 (40.6%)	8 (29.6%)	10 (30.3%)	31 (33.7%)	
	Some to large impact	9 (28.1%)	9 (33.3%)	8 (24.2%)	26 (28.3%)	
	Total	32 (100.0%)	27 (100.0%)	33 (100.0%)	92 (100.0%)	
Business purposes	No impact	12 (38.7%)	12 (48.0%)	19 (54.3%)	43 (47.3%)	0.295
	Little impact	14 (45.2%)	6 (24.0%)	8 (22.9%)	28 (30.8%)	
	Some to large impact	5 (16.1%)	7 (28.0%)	8 (22.9%)	20 (22.0%)	
	Total	31 (100.0%)	25 (100.0%)	35 (100.0%)	91 (100.0%)	
Recreation	No impact	9 (29.0%)	8 (29.6%)	20 (52.6%)	37 (38.5%)	0.117
	Little impact	6 (19.4%)	9 (33.3%)	6 (15.8%)	21 (21.9%)	
	Some to large impact	16 (51.6%)	10 (37.0%)	12 (31.6%)	38 (39.6%)	
	Total	31 (100.0%)	27 (100.0%)	38 (100.0%)	96 (100.0%)	
Others	No impact	13 (46.4%)	15 (71.4%)	17 (58.6%)	45 (47.7%)	0.238
	Little impact	11 (39.3%)	2 (9.5%)	8 (27.6%)	21 (26.9%)	
	Some to large impact	4 (14.3%)	4 (19.0%)	4 (13.8%)	12 (15.4%)	
	Total	28 (100.0%)	21 (100.0%)	29 (100.0%)	78 (100.0%)	

No statistically significant differences at 0.05 level examined

6.4.1 Willingness to pay

This section examines how different trip characteristics (i.e., trip frequency) and traveler's income factor affect willingness to pay the toll to reduce travel time and escape congestion. One-way ANOVA is used to assess the significance of these trip characteristics and driver's income factor.

Respondents were asked to indicate how much they would be willing to pay to reduce their auto trips by 5, 10, 15, and 20 minutes respectively – facilitated by crossing a value along a liner scale ranges from $0 to $25, increasing by $0.25 intervals between $0 and $2, $0.5 intervals between $2.0 and $5.0, and $5 intervals between $10 and $25. The percentage of total respondents willing to pay more than $0 was displayed for each travel time reduction. It is considered that the aim of the respondents who are willing to pay more than $0 to reduce travel time is to minimize travel disutility by paying the charges rather than enduring road congestion. In addition, respondents who are willing to pay to escape congestion can be considered as an indicator of public acceptance of cordon pricing as a policy to reduce congestion.

It is important to know if and how household income affects willingness to pay for the analysis of the equity implications of cordon pricing. It is expected that a large share of respondents, particularly travelers from high-income neighborhoods, would be willing to pay to reduce 15 and 20 minutes of their travel time, while a comparatively smaller share of respondents would be willing to pay to reduce 5 or 10 minutes. Table 6.12 shows that almost half of the respondents are not willing to pay any amount of money to minimize their car trip by 5 minutes. However, this percentage starts to decrease as the saved travel time increases. Only 25% of the total respondents are not willing to pay to save 20 minutes from their travel time. From this reading, it can be concluded that even such a policy is not supported at an attitudinal response level; respondents have the ability to change their travel behaviour in response to this strategy.

Travel time spent on the roads represents a significant component of travel disutility. This travel time constitutes part of traveler’s total trip cost and an important part of the overall generalized cost of travel; therefore, shorter trip option that results in reduction in travel time is traveler’s best or preferred choice. Value of travel time saving and willingness to pay to reduce travel time and escape congestion are related measures. If the value of time saving of a traveler exceeds the charging rate, then traveler disutility is minimized by paying the toll and driving as usual. On the contrary, if the value of time saving of a traveler does not exceed the charges, traveler's disutility is minimized by avoiding the charges through switching to other modes of transportation that are free of charge.

In this study, willingness to pay to escape congestion was influenced by reduction in travel time and driver's income status. The range of driver's value of travel time saving influence the capability of cordon pricing to function as if all drivers have the same value of time then cordon pricing would not be an effective policy, as drivers would either pay the fees and drive as usual or nobody pays the fees. In general, driver's willingness to pay is influenced by the degree of travel time saved and their income.

Respondents' willingness to pay values ranged from \$0 to \$25; however, the vast majority of them reported a value within the \$0 and \$5 range. Therefore, the values exceeding \$5 were reduced to \$5 to eliminate the impact of outliers on mean values. The number of responses reduced to \$5 is 10 as shown in Table 6.12.

Table 6. 12: Respondents’ willingness to pay to reduce travel time.

Amount of money ($)	**Reduce car trip by 5 min.**			**Reduce car trip by 10 min.**			**Reduce car trip by 15 min.**			**Reduce car trip by 20 min**		
	Frequency	Percent	Average ($)	Frequency	Percent	Average ($)	Frequency	Percent	Average ($)	Frequency	Percent	Average ($)
0.00	49	48.5	0.73	38	38.8	1.06	29	28.4	1.16	25	25.3	1.91
0.25	9	8.9		7	7.1		3	2.9		4	4.0	
0.50	16	15.8		7	7.1		5	4.9		4	4.0	
0.75	4	4.0		9	9.2		2	2.0		1	1.0	
1.00	11	10.9		17	17.3		21	20.6		7	7.1	
1.25	0	0.0		1	1.0		1	1.0		3	3.0	
1.5	5	5.0		7	7.1		10	9.8		8	8.1	
1.75	0	0		0	0		3	2.9		3	3.0	
2.00	3	3.0		6	6.1		16	15.7		20	20.2	
2.5	1	1.0		2	1.3		4	3.9		4	4.0	
3.00	1	1.0		2	2.0		4	3.9		9	9.1	
3.50	0	0		0	0		0	0.0		2	2.0	
4.00	0	0		0	0		0	0.0		4	4.0	
5.00	1	1.0		3	3.1		0	0.0		1	1.0	
7.00	0	0		0	0		2	2.0		1	1.0	
10.00	0	0		0	0		1	1.0		2	2.0	
25.00	1	1.0		1	1.0		1	1.0		1	1.0	
Total	101	100.0		98	100.0		102	100.0		99	100.0	

Some of the results calculated, to examine the differences in willingness to pay between different income groups, using one-way ANOVA from untransformed willingness to pay findings were inaccurate as they violated Levene's test of equity of error variances. For example, Table 6.13 shows that heterogeneity of error variances in the tested means is revealed in Levene's test, F (2, 89) = 2.265, at significant $p < 0.05$. Therefore, willingness to pay to reduce travel time had to be transformed to ensure reliable result.

Table 6. 13: Levene's test of equality of error variances. Dependent Variable: Willingness to Pay to reduce 10 minutes

Levene Statistic	df1	df2	Sig.
2. 265	2	89	0.110

To reduce the right tail of the distribution, a logarithmic base 10 transformation was employed in the SPSS. Since mathematically it is impossible to drive a logarithm of "0" value, and as the first value of willingness to pay in the survey is "0"; therefore, it is necessary to add "1" to each original data point in the survey. The equation for transforming the data point in one-way ANOVA was log (original willingness to pay value + 1). The equation results were acceptable because they did not violate Levene's test of equality of error variances. For example, Table 6.14 reveals that Levene's test did not show heterogeneity of error variances in the test means.

Table 6. 14: Levene's test of equality of error variances after transforming data point.

Levene Statistics	df1	df2	Sig.
2.367	2	89	0.100

One-way ANOVA test reveals that statistically significant differences are identified at the 0.05 level in terms of reducing the total travel time by 15 and 20 minutes. Table 6.15 shows that household income has a significant and predictable effect on mean willingness to pay only to reduce 15 and 20 minutes from the total travel time.

Table 6. 15**:** Effect of household income on willingness to pay to reduce travel time

Trip and Household characteristics	**Reduced time**	**One-way ANOVA**					
		df1	**df2**	**F**	**Sig.**	**Eta**	**Eta^2**
Household income	5 minutes	2	92	0.545	0.582	0.160	0.026
	10 minutes	2	89	2.475	0.090	0.230	0.053
	15 minutes	2	93	4.823	**0.010***	0.307	0.094
	20 minutes	2	90	4.223	**0.018***	0.293	0.086

* Statistically significant differences at 0.05 level examined

In a more detailed comparison, One-way ANOVA test shows significant differences between people from low income and middle- and high-income neighborhoods in terms of their willingness to pay to save 15 minutes of the total travel time to/from the Downtown as shown in Table 6.16. The test also shows significant differences between people from middle- income and high-income neighborhoods in terms of their willingness to pay to save 20 minutes of the total travel time.

Table 6. 16: Differences between different income groups in their willingness to pay

(I) Household income	**(J) Household income**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**
Reduce 5 min.				
Low income	Middle income	.00530	.05616	.995
	High income	-.06733	.05251	.409
Middle income	Low income	-.00530	.05616	.995
	High income	-.07263	.05353	.368
High income	Low income	.06733	.05251	.409
	Middle income	.07263	.05353	.368
Reduce 10 min.				
Low income	Middle income	.00124	.06302	1.000
	High income	-.11140	.05880	.146
Middle income	Low income	-.00124	.06302	1.000
	High income	-.11264	.05999	.151
High income	Low income	.11140	.05880	.146
	Middle income	.11264	.05999	.151
Reduce 15 min.				
Low income	Middle income	.02631	.06491	.914
	High income	-.14829*	.06062	**.043**
Middle income	Low income	-.02631	.06491	.914
	High income	-.17460*	.06236	**.017**
High income	Low income	.14829*	.06062	**.043**
	Middle income	.17460*	.06236	**.017**
Reduce 20 min.				
Low income	Middle income	.03315	.07293	.893
	High income	-.15194	.06868	.075
Middle income	Low income	-.03315	.07293	.893
	High income	-.18508*	.06936	**.024**
High income	Low income	.15194	.06868	.075
	Middle income	.18508*	.06936	**.024**

* The mean difference is significant at the 0.05 level.

Household income has a substantial and predictable effect on willingness to pay to save 15 and 20 minutes of total trip travel time. Travelers from high income neighborhoods were willing to pay more to reduce travel time by 15 and 20 minutes and escape congestion more than the other income groups. Travelers from low-income neighborhoods are willing to pay less to save travel time and escape congestion than other income travelers in every suggested travel time reduction. Figure 6.1 shows the mean value that each group is willing to pay to reduce travel time. The figure shows that people from middle-income neighborhoods are willing to pay to reduce 5 and 10 minutes of travel time more than other income groups. Also the figure shows that travelers from high-income neighborhoods are willing to pay more to reduce 15 and 20 minutes of their travel time. This is an interesting observation which reflects the value of time for each income group.

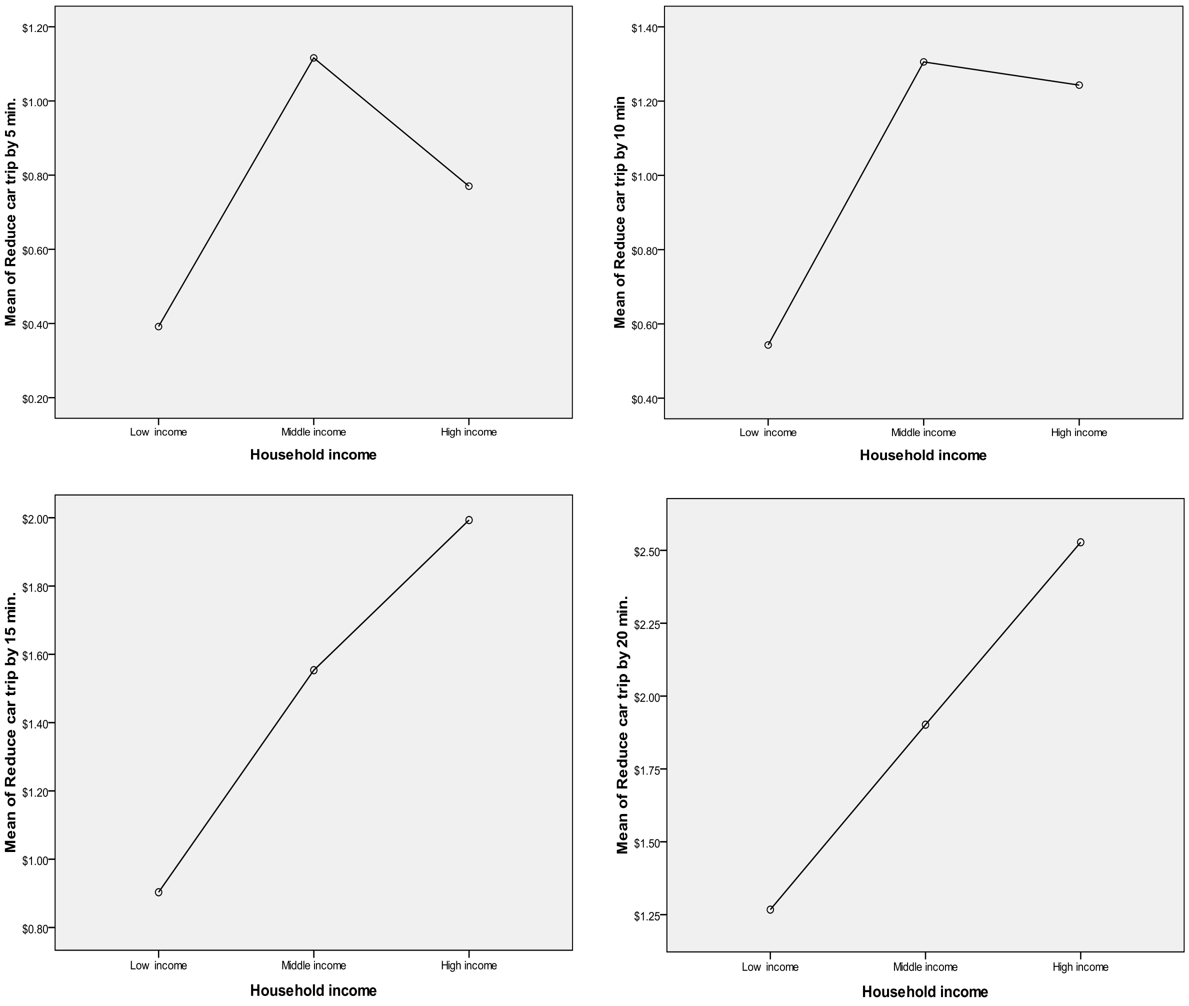

Figure 6. 1: Comparison of the effect of different income groups on willingness to pay to reduce travel time

6.4.2 Impact of cordon pricing on respondents' travel behaviour

This section investigates the third theme related to travellers' willingness to change their travel behaviour and the factors affecting these decisions. The analysis addresses research question number three which asks "How would the implementation of cordon pricing affect GTA drivers' travel behaviour in terms of using their private autos, switching to other modes of transportation, and/or changing their time of travel." Therefore, only those respondents who reported in the survey that they use autos in their commuting to/from Downtown Toronto are considered in this analysis. Respondents who use transit, walk, or cycle are only used to analyze if they are willing to change their mode of transportation to cars.

The impact of implementing cordon pricing on respondents' travel behaviour varies. Regarding the perceived dependency on auto use, fewer than half of the respondents stated that it would be difficult to reduce auto trips substantially and an almost equal percentage (43.1%) of the respondents report that they would use public transportation more often. Table 6.17 shows the expectations about how personal auto trips would be affected in the case of cordon pricing. Most respondents report a very low capability concerning a reduction of personal auto trips.

In general, Table 6.17 shows that there seems to be a willingness to make a moderate change in travel behaviour in order to adapt to the new policy. Respondents have the intention to reduce auto use moderately through driving less or changing to other modes of transportation. In particular, it seems that using public transportation more often can be seen as an alternative to paying the charges for more than half of the respondents. On the other hand, the respondents indicate a lack of interest in using car pooling, cycling, and walking; they also indicate that they would not change their travel time. While there were some indications that people would be willing to use public transportation more often, this was not the case for walking or cycling. This may indicate that these alternatives are not feasible or functional particularly if respondents are traveling longer trips to reach their destinations. On the other hand, there is a considerable percentage of respondents expecting no difference at all on their current travel behaviour if cordon pricing is implemented. In summary, a considerable percentage of respondents would intend to pay the charges and drive as before, while others are likely to respond by using public transportation more often.

Table 6. 17: Frequency distribution of potential travel behaviour response to cordon pricing

		Frequency (%)					
		strongly disagree	disagree	neutral	agree	strongly agree	Total
Pay the fees and drive as before	Respondents who rely primarily on autos for travelling to/from Downtown	22 (20.0)	19 (17.3)	5 (4.5)	46 (41.8)	18 (16.4)	110 (100.0)
Drive less		29 (27.6)	29 (27.6)	12 (11.4)	25 (23.8)	10 (9.5)	105 (100.0)
Join car pooling		48 (46.6)	26 (25.2)	11 (10.7)	13 (12.6)	5 (4.9)	103 (100.0)
Use public transportation more often		28 (27.5)	14 (13.7)	16 (15.7)	36 (35.3)	8 (7.8)	102 (100.0)
Use bicycle more often		56 (57.1)	14 (14.3)	8 (8.2)	10 (10.2)	10 (10.2)	98 (100.0)
Walk to destination more often		58 (58.6)	8 (8.1)	8 (8.1)	16 (16.2)	9 (9.1)	99 (100.0)
Change the timing of my car trips to reduce charges		41 (39.4)	18 (17.3)	12 (11.5)	22 (21.2)	11 (10.6)	104 (100.0)
Switch from public transportation to car	Respondents who rely primarily on transit for travelling to/from Downtown	29 (43.3)	13 (19.4)	18 (26.9)	3 (4.50	4 (6.0)	67 (100.0)

Vertical equity is analyzed by examining behavioural adjustments that could be employed as stated in the survey in response to cordon pricing, and comparing those responses across different income groups. The behavioural adjustments include: driving less; joining car pooling; using public transportation, cycling, walking more often to destination; changing travel time, switching to car from other modes of transportation; or paying the fees and drive like before. Cross-tabulation and chi-square test of potential impact of cordon pricing on daily travel behaviour showed significant differences between people from different income neighborhoods in their potential response to cordon pricing and at the same time there is consistency in many of the potential reaction among these groups.

Inspection of the entries in Table 6.18 shows that there is a strong association (sig = 0.034) between income and paying the toll and driving like before as well, using public transportation more often in their commuting (sig=0.047). These analyses show that toll charge is an important factor that would trigger some income groups to change their travel behaviour because of the additional burden and cost to their daily trips. This result is expected as people from high-income neighborhoods are more willing to pay the charges and drive as before than people from low- and middle-income neighborhoods. The data reveals that about half of respondents from high-income neighborhoods stated that they would be willing to pay the toll and drive as before compared to 30% and 20% of low- and middle income respectively. About 47% of the respondents from low-income neighborhoods are willing to use public transportation more often compared to 28% and 26% of respondents from middle- and high-income neighborhoods. The data show that travelers from middle- or low-income neighborhoods are more willing to drive less and reduce their travel the most to/from the cordon zone.

Table 6. 18: Impact of cordon pricing on travel behaviour based on traveler's household income

		Respondents who rely primarily on autos for travelling to/from Downtown (%)				
		Low income	Middle income	High income	Total	Statistical significance
Pay the charges	strongly disagree/disagree	12 (37.5)	16 (51.6)	10 (25.6)	38 (37.3	**0.034***
	Neutral	2 (6.3)	3 (9.7)	0 (0.0)	5 (4.9)	
	strongly agree/agree	18 (56.3)	12 (38.7)	29 (74.4)	59 (57.8)	
	Total	32 (100.0)	31 (100.0)	39 (100.00	102 (100.0)	
Drive less	strongly disagree/disagree	18 (56.3)	15 (50.0)	21 (60.0)	54 (55.7)	0.685
	Neutral	2 (6.3)	4 (13.3)	5 (14.3)	11 (11.3)	
	strongly agree/agree	12 (37.5)	11 (36.7)	9 (25.7)	32 (33.0)	
	Total	32 (100.0)	30 (100.0)	35 (100.0)	97 (100.0)	
Join car pooling	strongly disagree/disagree	20 (64.5)	22 (73.3)	27 (79.4)	69 (72.6)	0.343
	Neutral	2 (6.5)	4 (13.3)	3 (8.8)	9 (9.5)	
	strongly agree/agree	9 (29.0)	4 (13.3)	4 (11.8)	17 (17.9)	
	Total	31 (100.0)	30 (100.0)	34 (100.0)	95 (100.0)	
Use public transportation more often	strongly disagree/disagree	6 (19.4)	12 (41.4)	19 (54.3)	37 (38.9)	**0.047***
	Neutral	5 (16.1)	5 (17.2)	5 (14.3)	15 (15.8)	
	strongly agree/agree	20 (64.5)	12 (41.4)	11 (31.4)	43 (45.3)	
	Total	31 (100.0)	29 (100.0)	35 (100.0)	95 (100.0)	
Cycle more to destination	strongly disagree/disagree	24 (80.0)	17 (63.0)	24 (70.6)	65 (71.4)	0.646
	Neutral	2 (6.7)	2 (7.4)	3 (8.8)	7 (7.7)	
	strongly agree/agree	4 (13.3)	8 (29.6)	7 (20.6)	19 (20.9)	
	Total	30 (100.0)	27 (100.0)	34 (100.0)	91 (100.0)	
Walk more to destination	strongly disagree/disagree	22 (73.3)	16 (59.3)	23 (65.7)	61 (66.3)	0.729
	Neutral	2 (6.7)	2 (7.4)	4 (11.4)	8 (8.7)	
	strongly agree/agree	6 (20.0)	9 (33.3)	8 (22.9)	23 (25.0)	
	Total	30 (100.0)	27 (100.0)	35 (100.0)	92 (100.0)	
Change travel time	strongly disagree/disagree	22 (71.0)	18 (60.0)	17 (47.2)	57 (58.8)	0.413
	Neutral	2 (6.5)	3 (10.0)	5 (13.9)	10 (10.3)	
	strongly agree/agree	7 (22.6)	9 (30.0)	14 (38.9)	30 (30.9)	
	Total	31 (100.0)	30 (100.0)	36 (100.0)	97 (100.0)	
Switch from public transportation to car	strongly disagree/disagree	11 (55.0)	12 (66.7)	14 (63.6)	37 (61.7)	0.963
	Neutral	6 (30.0)	5 (27.8)	6 (27.3)	17 (28.3)	
	strongly agree/agree	3 (15.0)	1 (5.6)	2 (9.1)	6 (10.0)	
	Total	20 (100.0)	18 (100.0)	22 (100.0)	60 (100.0)	

* Statistically significant differences at 0.05 level examined

In comparison to previous empirical and theoretical studies, such as (Karlstrom and Franklin, 2008; Eliasson and Mattsson, 2006), this research tested some potential changes on commuter’s travel behaviour found in the literature and at the same time tested additional ways to those used in previous research. Some of the common potential travel behaviour changes are changing mode of transportation and changing time of traveling. For example, Karlstrom and Franklin (2008) assessed vertical equity effects of the Stockholm trial in terms of travel behaviour adjustment, and they considered mode choice and departure time choice, as two specific potential behavioural adjustments and examined them based on traveler’s household income. These scholars found that middle- or high-income travelers are more willing to reduce their travel the most. Their conclusion is based on that these groups make more car trips and consequently will pay most charges even though the value of their time is higher than low-income groups.

One of the adjustments of travel behaviour suggested in the survey to the commuters is the change of their travel departure time. Cordon pricing is a time differential policy; therefore, it is interesting to examine if there could be any changes in the departure time among the respondents. Examining this behavioural adjustment is important in the context of equity analysis. It is identified by some scholars (Richardson, 1974; Giuliano, 1994) as a potential source of regressivity. They considered flexibility of working-hours to be strongly correlated with household income; therefore, commuters in high-income group would have the opportunity to avoid the charges to a greater extent than people in other income groups and through changing their departure time. Similarly, Arnott et al. (1994) argued that low-income people have inferior possibilities to choose their time for work, and hence cannot avoid paying the charges during the peak period.

The findings of this study vary in some aspects, compared to the findings in the previous studies. For example, Karlstrom and Franklin (2008) detect peak period spreading by 15 minutes, whereas the findings of this research show no evidence of peak hours spreading. Table 6.18 shows no differences in respondents' perception toward changing their travel time based on their income as a result of implementing cordon pricing. This finding is expected for different reasons. First, cordon pricing policy charges car drivers during the peak hours (i.e., 6:00 am – 9:00 am, 4:00 pm – 7:00 pm) and off-peak hours (9:00am – 4:00 pm with lower charges during the off-peak periods); therefore avoiding the charges would be difficult for auto-based work trips. Second, as indicated earlier work schedule flexibility is restricted for different socio-economic groups (e.g., Giuliano, 1994; Arnott et al., 1993, 1994, 1998; Cohen, 1987; Evans, 1992; Layard, 1977; Teubel, 2000; Raux and Souche, 2004; Small, 1983) and that high-income travelers have more flexible work time than other income groups, still this flexibility is restricted by the working hours, and hence drivers will be charged when crossing the cordon zone. As a result, we can argue that there are no signs of peak spreading due to the charges either in early or later departure time.

The implementation of cordon pricing may encourage some public transportation travelers to use their own autos instead. Respondents who are willing to do so may attribute that as they see possible reduction in their travel time which is more valuable than the new charges. Even though the table shows that there are some travelers who are willing to do so, the chi-square test reveals no significant differences between any income groups. All income groups are willing to change their mode of transportation in this sense with some discrepancies between them. About half of the people from low-income neighborhoods who use public transportation are willing to do that compared to 16% of people from middle-income neighborhoods and about one third of the people from high-income neighborhoods.

The survey suggested six possible reasons that force travelers to change their travel behaviour. These are: 1) the traveler's value of time, 2) the increase in their travel cost, 3) the travel time saving, 4) the increase in travel speed, 5) the current situation of transit service, and 6) the value of comfort and convenience of auto travel. Traveler's value of time is an important factor that influences their response and their potential travel behavioural changes as a result of the implementation of cordon pricing. About two thirds of the respondents stated that their value of time is higher than the charges they think they would be imposed by the scheme. This percentage indicates that there are discrepancies between different income groups in evaluating the value of their travel time. Travel monitory cost increases in case of cordon pricing as drivers have to pay the toll charges. This may lead some travelers to change their mode of transportation to avoid additional travel costs. This indicates that those respondents expect increase in car-related costs and car driving would become more expensive in the future. Cordon pricing may also encourage travelers to use their own autos and not to switch to different modes because it gives advantages to auto use in different perspectives. The implementation of cordon pricing aims to reduce traffic on the roads, and consequently travelers who keep using their autos would witness reduction in travel time and increase in travel speed. Furthermore, autos always provide comfort and convenience to travelers who are not found in other modes of transportation, particularly public transportation. These auto motivations are included in the survey to determine if they impact travelers' decision in terms of paying the toll and keep driving, or it is not important at all.

Table 6.19 clearly shows that there is a significant difference (sig = 0.002) between different income groups in terms of their value of time compared to the cordon charges. The data reveals that more than three quarters of respondents from high-income neighborhoods stated that the potential intention to pay the toll and drive as before is that their value of time is higher than the charges compared to half of the respondents from middle-income neighborhoods and about 62% of respondents from lower-income neighborhoods.

In comparison with the literature, several scholars (Richardson, 1974; Evans, 1992; Arnott et al., 1994; Small, 1983) argued that high-income travelers have a higher value of time. Eliasson and Mattsson (2006) argued that travelers with high time value would prefer to choose an expensive but fast route, whereas a traveler with low time value would prefer a cheap but slow route. Value of time is a function of income, and hence they hypothesized, in the case of cordon pricing, that travelers with high time value would change their departure time to avoid the charges or pay it and drive as before; on the other hand, travelers with low travel time value would choose to switch to other modes of transportation that are not subject to charges such as public transportation or even change their destination.

Table 6. 19: The impact of cordon pricing on traveler's travel behaviour based on their income

		Respondents who rely primarily on autos for travelling to/from Downtown (%)				
		Low income	Middle income	High income	Total	Statistical significance
Your value of time is greater than the cordon pricing fees	strongly disagree/disagree	11 (34.4)	7 (23.3)	5 (13.9)	23 (23.5)	**0.002***
	Neutral	1 (3.1)	8 (26.7)	1 (2.8)	10 (10.2)	
	strongly agree/agree	20 (62.5)	15 (50.0)	30 (83.3)	65 (66.3)	
	Total	32 (100.0)	30 (100.0)	36 (100.00	100 (100.0)	
Increase in travel cost as a result of fees	strongly disagree/disagree	16 (51.6)	14 (48.3)	11 (31.4)	41 (43.2)	0.209
	Neutral	2 (6.5)	4 (13.8)	9 (25.7)	15 (15.8)	
	strongly agree/agree	13 (41.9)	11 (37.9)	15 (42.9)	39 (41.1)	
	Total	31 (100.0)	29 (100.0)	35 (100.00	95 (100.0)	
You would save travel time by car	strongly disagree/disagree	6 (19.4)	8 (26.7)	3 (7.9)	41 (43.2)	0.250
	Neutral	4 (12.9)	6 (20.0)	6 (15.8)	16 (16.2)	
	strongly agree/agree	21 (67.7)	16 (53.3)	29 (76.3)	66 (66.7)	
	Total	31 (100.0)	30 (100.0)	38 (100.00	99 (100.0)	
Travel speeds by car would be increased	strongly disagree/disagree	9 (29.0)	11 (39.3)	4 (11.1)	24 (25.3)	0.124
	Neutral	7 (22.6)	11 (39.3)	6 (15.8)	16 (16.2)	
	strongly agree/agree	21 (67.7)	16 (53.3)	23 (63.9)	49 (51.6)	
	Total	31 (100.0)	28 (100.0)	36 (100.00	95 (100.0)	
The current level of service of mass transit	strongly disagree/disagree	14 (45.2)	11 (39.3)	4 (11.1)	36 (39.6)	0.155
	Neutral	6 (19.4)	4 (14.3)	13 (40.6)	23 (25.3)	
	strongly agree/agree	11 (35.5)	11 (39.3)	10 (31.3)	32 (35.2)	
	Total	31 (100.0)	28 (100.0)	32 (100.00	91 (100.0)	
I value the comfort and convenience of car travel	strongly disagree/disagree	4 (12.5)	4 (13.3)	2 (5.6)	10 (10.2)	0.240
	Neutral	6 (18.8)	2 (6.7)	2 (5.6)	10 (10.2)	
	strongly agree/agree	22 (68.8)	24 (80.0)	32 (88.9)	78 (79.6)	
	Total	32 (100.0)	30 (100.0)	36 (100.00	98 (100.0)	

* Statistically significant differences at 0.05 level examined

6.4.3 Revenue distribution

Revenue redistribution is critical to assess equity of cordon pricing. As indicated earlier, the distribution of the generated revenue among individuals in different groups, who are unequal in other aspects, is one of the pillars of vertical equity drawing from Rawls's "principle of difference." Cordon pricing, in general, can achieve more desirable distributional outcomes when the generated revenues are distributed to those who pay the charges. The use of the revenue plays an important role in considering fairness among drivers that pay the toll and make them feel that they are treated fairly among themselves. Accordingly, utilizing the generated revenue effectively is a significant step toward achieving equity between different socio-economic travelers. Revenue allocation among travelers in equal or unequal shares could play an important role in solving the aforementioned inequity issues (Yang and Zhang, 2002). It can help diminish the negative impacts on different socio-economic groups (Ecola and Light, 2009). In addition, people must see benefits for themselves corresponding to the additional cost of trip as a result of the charges. Therefore it is vital to examine revenue redistribution among travelers and how equitable is that distribution. This section examines the distributional effects of different use of the revenues of cordon pricing in Downtown Toronto.

The survey investigates five different refund scenarios of the generated revenue of the proposed cordon pricing in Downtown Toronto. These scenarios are: 1) to improve road infrastructure, 2) to improve public transportation, 3) to reduce public transportation fares, 4) to support the municipal budget in general, and 5) to improve cycling and walking conditions. The aim of this section is to examine the effects of the redistribution of the generated revenue among travelers from different income groups and determine on the kind of revenue redistribution they prefer and how equitable that distribution is.

Respondents' perception about revenue redistribution varies within these scenarios. The percentage of respondents who support the distribution of the generated revenue to improve public transportation is the highest. Also, most of the other purposes are considerably more favoured by the majority of the respondents. Table 6.20 shows that revenue distribution can be divided into three parts in terms of respondents' perception of the way they think it is beneficial to them: First, the revenue can be used for direct traffic related purposes such as improve infrastructure, improve public transportation, or reduce public transportation fares. This distribution of revenue is accepted by the vast majority of respondents. In addition, the majority of the respondents believe that the authorities will spend the revenue for these purposes. Second, the generated revenue could be used to support the municipal budget in general. However, using the money to support the municipal budget is widely rejected by respondents; in addition, about two thirds of them believe that the authorities will use the money for this cause. Third, revenue could be used to improve cycling and walking conditions. Utilizing the revenue to improve cycling and walking conditions is supported by the majority of the respondents; however, two thirds of them believe that the authorities would not spend the money on this cause.

The redistribution of the generated revenue based on the suggested schemes shown in the table may affect different income groups in different ways. Table 6.20 illustrates that there are significant differences between different income groups in their perception to redistribute the revenues in order to improve the road infrastructure. It is expected that travelers from higher-income neighborhoods would be more likely to support this scenario the most, as they need better road infrastructure, and they would pay the charges and continue driving as before. However, the majority of individuals in these groups support the first scenario and surprisingly travelers from low-income neighborhoods support it the most. About 94% of respondents from low-income neighborhoods support this scenario compared to 70% and 92% of respondents from middle- and high-income neighborhoods respectively. The table also shows that travelers from low-income neighborhoods support investing the generated revenue to improve cycling and walking more than other income groups.

Table 6. 20: Perception of respondents about revenue distribution based on their income status

		Respondents who rely primarily on autos for travelling to/from Downtown (%)				
		Low-income	Middle-income	High-income	Total	Statistical significance
Improve road infrastructure	Strongly disagree/ disagree	1 (3.0)	5 (18.5)	3 (7.9)	9 (9.2)	**0.039***
	Neutral	1 (3.0)	3 (11.1)	0 (0.0)	4 (4.1)	
	Strongly agree/ agree	31 (93.9)	19 (70.4)	35 (92.1)	85 (86.7)	
	Total	33 (100.0)	27 (100.0)	38 (100.0)	98 (100.0)	
Improve public transport	Strongly disagree/ disagree	0 (0.0)	3 (10.0)	0 (0.0)	3 (3.0)	0.053
	Neutral	2 (6.3)	1 (3.3)	5 (13.5)	8 (8.1)	
	Strongly agree/ agree	30 (93.8)	26 (86.7)	32 (86.5)	88 (88.9)	
	Total	32 (100.0)	30 (100.0)	37 (100.0)	99 (100.0)	
Reduce public transport fares	Strongly disagree/ disagree	0 (0.0)	5 (16.7)	9 (24.3)	14 (14.4)	0.062
	Neutral	5 (16.7)	4 (13.3)	7 (18.9)	16 (16.5)	
	Strongly agree/ agree	25 (83.3)	21 (70.0)	21 (56.8)	67 (69.1)	
	Total	30 (100.0)	30 (100.0)	37 (100.0)	97 (100.0)	
Support the municipal budget in general	Strongly disagree/ disagree	16 (53.3)	19 (61.3)	22 (59.5)	57 (58.2)	0.977
	Neutral	5 (16.7)	4 (12.9)	5 (13.5)	14 (14.3)	
	Strongly agree/ agree	9 (30.0)	8 (25.8)	10 (27.0)	27 (27.6)	
	Total	30 (100.0)	31 (100.0)	37 (100.0)	98 (100.0)	
Improve cycling and walking conditions	Strongly disagree/ disagree	3 (9.7)	8 (26.7)	7 (18.9)	18 (18.4)	**0.028***
	Neutral	2 (6.5)	6 (20.0)	9 (24.3)	17 (17.3)	
	Strongly agree/ agree	26 (83.9)	16 (53.3)	21 (56.8)	63 (64.3)	
	Total	31 (100.0)	30 (100.0)	37 (100.0)	98 (100.0)	

* Statistically significant differences at 0.05 level examined

The alternative allocation of the generated revenue by the authorities is of the paramount for both equity and the public acceptability of cordon pricing scheme. Authorities are responsible for blocking the implementation of different types of congestion pricing. Congestion pricing may appear to be regressive, but the authorities may distribute the generated revenue so that different socio-economic groups can benefit from this policy and hence can be seen as progressive (Morrison, 1986; Small, 1983; Eliasson and Mattsson, 2006; Mayeres and Proost, 1997; Levine and Garb, 2002).

Respondents’ expectations about how the local authorities may use the generated revenue also vary. However, the majority of the respondents want the generated revenue to be distributed in a more conventional manner as shown in Table 6.21. About 85% of the respondents would like to see the money put in to improve road infrastructure and about 61% believe that the authorities will do so. As expected, around 88% of the respondents support using the money to improve public transportation; however, only 55% of them believe that the authorities would use the money to do so. Interestingly, there is an opposition from about 58% of the respondents to use the money to support the municipal budget. Nevertheless, more than half of them believe that the authorities will use the money to support the municipal budget. The most positive expectations are expressed in the case of improving public transportation and road infrastructure. In general, the expectations of how the authorities would use the revenues are negative in terms of using it to support municipal budget or to improve cycling and walking conditions. Respondents would like to see reduction in the rate of using public transport; however, they believe that the authorities will not use the generated revenue as intended. Table 6.21 shows some evidence that respondents are convinced with the objectives of revenue distribution and also believe in the sincere use of revenue by the responsible authorities in most revenue distribution objectives as stated in the questionnaire. Table 6.21 shows some association between income and the perception of how the local authorities may distribute the generated revenue. Travelers from low-income neighborhoods believe that local authorities would use the generated revenue to improve road infrastructure and public transportation as well as to improve cycling and walking conditions more than other income groups.

The most common way to redistribute the generated revenue addressed by most of the scholars and within existing congestion pricing implementation is through public spending and mainly through public transportation improvements. For example, the City of London and I-15 in San Diego enhance bus services using most of the generated revenue (Transport for London, 2008). In addition, the Norwegian toll rings use the generated revenue for roadway and transit improvements (Ieromonachou et al., 2006). On the other hand, Singapore earmark the generated revenue into a general fund and invests mainly in transit and affordable housing close to transit (Menon et al., 2004). In New York, several proposals of implementing congestion pricing recommended using the generated revenue to improve public transportation or reduce transit fares (Komanoff, 2008; New York City Traffic Congestion Mitigation Commission et al., 2008). Investments in improving public transportation are commonly cited as the most beneficial scenario of utilizing the generated revenue because it improves options not to drive.

The third scenario to use the generated revenue suggested in this study is to reduce the public transportation fare. None of the empirical studies found in the literature suggested or examined this scenario. It is expected that travelers from low-income neighborhoods support this scenario the most as they will benefit from it more than other income groups. However, the table shows no significant differences between any of the different income groups in their response to this scenario. The data reveal that people from low-income neighborhoods favour this scenario the most, and so do the individuals in other income groups who support this scenario.

Support municipal budget scenario is widely rejected from most of the respondents. The table shows no difference between individuals in any income groups in their perception of how the local authorities may use the revenues. This may be attributed to the notion that respondents don’t trust the way the municipality would use the money in transportation related issues and that the municipality should have other resources to support its budget. The data reveal that people from middle-income neighborhoods oppose this scenario the most.

Surprisingly, the chi-square test reveals that there are significant differences between different income groups in terms of their perception of the last scenario, improving the cycling and walking conditions. As expected, people from low-income neighborhoods support conveying the generated revenue to improve cycling and walking conditions, hence they are more often to cycle or walk to their destinations than other income groups. At the same time, more than 60% of the respondents from low-income neighborhoods believe that local authorities may use the revenues for this cause compared to only about 27% and 23% of respondents from middle- and high-income neighborhoods respectively.

Table 6. 21: Perception of respondents about how the local authorities would distribute the generated revenue

		Respondents who rely primarily on autos for travelling to/from Downtown (%)				
		Low-income	Middle-income	High-income	Total	Statistical significance
Improve road infrastructure	Yes	25 (83.3)	11 (50.0)	13 (46.4)	49 (61.3)	**0.007***
	No	5 (16.7)	11 (50.0)	15 (53.6)	31 (38.8)	
	Total	30 (100.0)	22 (100.0)	28 (100.0)	80 (100.0)	
Improve public transport	Yes	21 (72.4)	8 (36.4)	15 (53.6)	44 (55.7)	**0.036***
	No	8 (27.6)	14 (63.6)	13 (46.4)	35 (44.3)	
	Total	29 (100.0)	22 (100.0)	28 (100.0)	79 (100.0)	
Reduce public transport fares	Yes	12 (42.9)	4 (19.0)	5 (18.5)	21 (27.6)	0.076
	No	16 (57.1)	17 (81.0)	22 (81.5)	55 (72.4)	
	Total	28 (100.0)	21 (100.0)	27 (100.0)	76 (100.0)	
Support the municipal budget in general	Yes	11 (39.3)	13 (59.1)	17 (60.7)	41 (52.6)	0.212
	No	17 (60.7)	9 (40.9)	11 (39.3)	37 (47.4)	
	Total	28 (100.0)	22 (100.0)	28 (100.0)	78 (100.0)	
Improve cycling and walking conditions	Yes	16 (57.1)	6 (27.3)	6 (23.1)	28 (36.8)	**0.019***
	No	12 (42.9)	16 (72.7)	20 (76.9)	48 (63.2)	
	Total	28 (100.0)	22 (100.0)	26 (100.0)	76 (100.0)	

* Statistically significant differences at 0.05 level examined

6.5 Chapter summary

This chapter examined the four themes of the survey. These themes are: 1) public desirability for cordon pricing as a congestion mitigation strategy in the GTA; 2) travellers willingness to pay to reduce their car trip travel time; 3) travellers willingness to change their travel behaviour and the factors affecting that; and 4) public perception of the distribution of the generated revenue from cordon pricing. Two main statistical test were used to do so, which are one-way ANOVA and chi-square test. In addition, frequency distribution of respondents was highlighted and respondents’ perception about personal affectedness by cordon pricing was examined.

Respondents were asked to indicate how much they would be willing to pay to reduce their car trips by 5, 10, 15, and 20 minutes respectively. The association between different income groups and travelers' willingness to pay was examined. The results showed that there were statistically significant differences identified between different income groups in terms of reducing the total travel time by 15 and 20 minutes. The results showed that travelers from high-income neighborhoods are willing to pay more than other income groups to reduce total travel time from/to the Downtown by 15 and 20 minutes.

The impact of implementing cordon pricing on respondents' travel behaviour varied. Many of the respondents stated that it would be difficult to reduce their car trips substantially although more than half of the respondents reported that they would use public transportation more often. In general, there is willingness to a moderate change of travel behaviour among the respondents to adapt to the new policy. Respondents have the intention to reduce car use moderately through driving less or changing to other modes of transportation. The analysis revealed that there are statistically significant differences between different income groups in terms of paying the toll and drive as before as well using public transportation, walking, and cycling more often in their commuting.

Travelers' value of time is an important factor which influenced their response. In addition, many respondents stated that the reason for their potential travel behaviour changes is attributed to the increase in travel cost as a result of the charges. Respondents generally expect positive personal outcome as compensation to implementing cordon pricing. They expect shorter travel time to Downtown, less air pollution and fewer environmental problems, and Downtown as a better place to work and live. However, they also expect, to a less extent, moderate negative personal outcomes such as additional travel cost, unfairly restricted travel options, and more difficulties in planning trips.

Revenue redistribution is critical to assess equity of cordon pricing. Cordon pricing in general can achieve more desirable distributional outcomes when the generated revenues are distributed to those who pay the charges. The revenue distribution suggested in this study is divided into three parts in terms of respondents' perception of the way they think it is beneficial to them: First, the revenue can be used for direct traffic related purposes such as improve infrastructure, improve public transportation, or reduce public transportation fares. This distribution of revenue is accepted by the vast majority of respondents. Second, the study suggested to distribute the generated revenue to support the local municipal budget, and finally to invest it in improving walking and cycling conditions. These last two options are opposed by the majority of the respondents.

The analysis showed that respondents from different socio-economic groups have the intention to change their mode of transportation and reduce auto use, yet in different percentages. The data reveal that about half of respondents from high-income neighborhoods stated that they are willing to pay the toll and drive as before compared to 30% and 20% of respondents from low- and middle-income neighborhoods respectively. This indicates that cordon pricing in Downtown Toronto can reduce auto use substantially. It is not expected that cordon pricing can solve traffic congestion entirely, however. The objective of introducing cordon pricing in Stockholm, for example, is to reduce the number of automobiles that cross the boundaries, in and out, of the cordon zone by 10-15% during the morning and evening peak periods. Cordon pricing in Downtown Toronto, based on the survey results, can reduce the number of automobiles by a larger percentage than in Stockholm.

Chapter 7: Evaluation, Observation, and Conclusion

7.1 Introduction and overview

Road traffic congestion is recognized as a growing and important urban ill. It occurs in different contexts, takes on many faces, and is caused by a variety of processes. It affects both work trips and non-work trips, both passengers and goods flow. It affects the quality of life and the competitiveness of a region. It is an attendant cost that arises in the forms of delay, environmental degradation, diminished productivity, standard of living, and wasted energy.

Congestion continues to increase and the traditional approaches of expanding transportation infrastructure or building more roads to operate at minimum congestion at all times will not be a solution due to financial and environmental reasons. Congestion pricing has become an increasingly practical option implemented in various forms for managing congestion, protecting the environment, and raising revenue for investments in transportation. However, the equity of pricing schemes is a major concern among the public and elected officials prior to and after congestion pricing implementation. This is due to charges being imposed on access to roadways that were previously free, a change which may harm different socio-economic groups such as low-income travelers, because they will either have to pay the fees or be priced off the roads.

The main goal of the research was to provide empirical research that would enhance our understanding of the equity implications of cordon pricing for the urban region of Toronto, Canada. Three research objectives were identified to address the research goal. The first objective was to examine the ways that the GTA is moving toward or away from sustainable transportation, and thus to make a case that Downtown Toronto is a candidate for cordon pricing. The second objective was to investigate if particular socio-economic groups would be disproportionately affected by the implementation of cordon pricing in Downtown Toronto as one way of approaching the equity dimensions of such a policy. The third objective was to explore some of the policy aspects associated with implementing cordon pricing in Toronto, including public perceptions of such a policy as well as probable responses to the policy. An analysis of primary (questionnaire) and secondary (TTS) data was undertaken to address these perceptions. This chapter summarizes the findings related to each objective and provides a summary of research contribution and suggestions for future research.

7.2 Evaluation of research objectives

7.2.1 Indications that the GTA is moving toward or away from sustainable transportation.

The first objective was to examine the ways that the GTA is moving toward or away from sustainable transportation, and thus ascertain whether Downtown Toronto is a candidate for cordon pricing. This objective was met through the analysis of secondary data obtained from the TTS data. The data provide a strong basis to conclude that, on the whole, the GTA is not moving in the direction of sustainable transportation, which provides a concrete justification for demand-management interventions, such as cordon pricing. Population and employment in the GTA has grown significantly between 1986 and 2006, with corresponding increases in trip-making. The majority of this growth occurred in the rest of the GTA regions (Durham, Halton, Peel, and York), where transit services are low compared to the Downtown region (PD1) or the rest of the City of Toronto.

Urban planning and urban growth policies in the GTA over the past two decades have been directed mainly toward anti-automobile strategies. The municipalities have become more worried about the negative effects (environmental, social, and economical perspectives) of automobile travel. These concerns have been reflected in official plans and urban growth strategies. These polices have been rather ineffective in curbing automobile travel; however, planners' strategies to reduce the percentage of trips made by automobiles do not seem to have had reasonable outcomes overall, notwithstanding the fact that the PD1 area has maintained a high transit mode share.

The analysis of TTS data showed an increase in the suburbanization and the dispersion of both population and different categories of the labour force in the GTA over the study period. This dispersion has contributed to increased auto-dependency for personal trips in general and for work trips in particular since the rest of the GTA is characterized by comparatively lower population and employment densities, which are not conducive to transit usage. In 2006, about 71% of the GTA residents used automobiles, as drivers and as passengers, each day during the morning peak period in their commuting within the GTA, an increase of 6% since 1986. The suburbanization of employment led to changes in the spatial flows within the GTA over the study period. The distribution of work trips has become more suburbanized in nature. Total inter- and intra-regional trips increased in most GTA areas. Not surprisingly, trips destined to PD1 and the rest of the City of Toronto also increased. An interpretation of this trend is that most of the new trips originated from the rest of the GTA. The substantial decentralization of employment densities has been a major obstacle to improving transit ridership in the GTA during the past two decades. Decentralized areas are difficult to serve efficiently and cost-effectively by urban transit. The key finding from these observations is that population and employment growth is increasing in absolute terms and on a per-capita basis, particularly in the rest of the GTA regions. In general, this trend is in contrast with the direction of progress toward sustainable transportation and sustainability.

The observations in chapter 4 showed some positive indications of the trends of change in personal travel activity across the PD1. PD1 area encounters the highest density across the GTA. This area has witnessed a density increase by 54% over the study period. It also has the largest population and number of jobs and has a robust transportation system that focuses on bringing people into the city core. In addition, this area maintained its character as a balanced community regarding population, jobs, and houses; with high employment self-containment. In summary, the analysis showed that mode share of trips made within PD1 area have always been balanced and have had almost similar shares for both cars and transit, and to a less extent walk and cycle. Over the past two decades the percentage of trips by both cars and transit has decreased. Interestingly, the percentage of trips, both walking and cycling has increased. This may be attributed to the policies that have been followed to encourage sustainable transportation and the creation of home-work balance.

Some trends that characterize this study period are increased GO transit ridership, increased trip self-containment in some areas, and stabilization of automobile ownership. The analysis shows that the PD1 area will likely continue to maintain a balanced mode split in the future. The rest of the GTA is characterized by auto-oriented areas and this mode of transportation will continue to be the primary mode if present growth trends continue. Therefore, the GTA is moving toward un-sustainable transportation where automobile ownership is increasing and particularly in the rest of the GTA regions.

The analysis of TTS data in chapters 4 and 5 demonstrate that Downtown Toronto is a candidate for cordon pricing. The analysis in these chapters clearly demonstrates the importance of PD1 area as a destination for many trips originating from the rest of the City of Toronto as well as from the rest of the GTA regions. The trips destined for the PD1 area are four times higher than the number of outbound trips originated from it. On the other hand, reverse commuting from the PD1 area to other areas within the GTA has increased. The number of PD1 residents who travel to other areas for work increased over the study period. More than 60% of auto trips that originated in the PD1 are destined for the rest of the City of Toronto and the rest of GTA regions. In general, about 13% of the home-based, morning peak-period trips made within the GTA are destined for Downtown Toronto.

7.2.2 The extent that socio-economic groups would be disproportionately affected by the implementation of cordon pricing in Downtown Toronto

Vertical equity is concerned with the distribution of differential effects on individuals or groups that vary by socio-economic factors such as income; in other words, it is concerned with the treatment of persons and groups that are dissimilar. In order to approach the equity dimensions of cordon pricing in Downtown Toronto, this research investigated if particular socio-economic groups would be disproportionately affected by the implementation of cordon pricing in Downtown Toronto. One way to do that was by analyzing travel activity by residents in different parts of the GTA who vary in terms of their socio-economics (income and employment) and/or demographics (age, gender, household size). The focus was on auto travel in and out of the proposed cordon pricing zone. By estimating the number of travellers whose auto trip would be charged under a cordon pricing scheme, it was possible to provide insight into what types of persons would be most affected by such a pricing strategy.

To get more insight into vertical equity of cordon pricing in Downtown Toronto, the total number of trips made by the GTA residents who travel only within the GTA were analyzed. Socio-economic status (e.g., income, age, gender, household size, occupation) of these travelers was considered in the analysis to evaluate the distributional effects of this pricing scheme for various groups of individuals considering their individual characteristics, including employment status and income. This more detailed analysis gave more insight into whether members within each socio-economic group were affected similarly or differently by cordon pricing. Two types of comparison were conducted, the first compared between different socio economic groups based on each of the demographic factors. Second, a comparison was conducted between the components of the demographic factors in each group (e.g., males from low-income neighborhoods versus females from low-income neighborhoods). This aims to show who would be more affected by this policy and if different groups are affected to the same extent. This analysis then provides the basis for concluding if cordon pricing in Downtown Toronto would be progressive or regressive.

The major finding of this comparison is that Downtown Toronto cordon pricing scheme would be progressive in its effects on the various socio-economic groups, and that the progressivity holds up even when travel is disaggregated by demographic factors such as age, gender, household size and occupational category. The percentage of trips that are affected by this policy increases as the income increases. The full-time people from high-income neighborhoods would be most affected by this pricing strategy since a disproportionate number of them reside in the rest of the City of Toronto and commute to PD1 area. In general, the impact of cordon pricing varied across different socio-economic groups. Full-time workers account for a larger proportion of the affected trips. Turning to more specific results, males, those in the 35-49 age cohort, those in one-person households, and professionals would be more affected than other groups. In addition, the majority of the affected trips by all groups originated outside the PD1 area. In particular, most of the affected trips originated from the rest of the City of Toronto except for people from upper-middle income neighborhoods (full-time and not-employed/part-time) where most of the affected trips made by this group are from the rest of the GTA region.

7.2.3 Evaluating vertical equity of cordon pricing in Downtown Toronto based on SP survey.

The ways in which travellers may change their travel patterns under a pricing scheme and how the related revenue should be expended should be considered to explore a more comprehensive assessment of the equity of cordon pricing in Downtown Toronto. A stated preference survey was conducted to explore these issues since TTS does not provide any information on the potential changes in this travel activity or the distribution of the generated revenue if cordon pricing is implemented in Downtown Toronto. This approach focuses on the immediate effects of cordon charges and aims to examine how travelers adjust their travel behaviour and the appropriate ways to compensate them for this change as shown in Figure 7.1. This step is critical to evaluate equity in the context of who is harmed by and who benefits from a proposed cordon pricing. Therefore, utilizing the generated revenue from such a scheme in an effective way is considered a critical step toward addressing equity concerns.

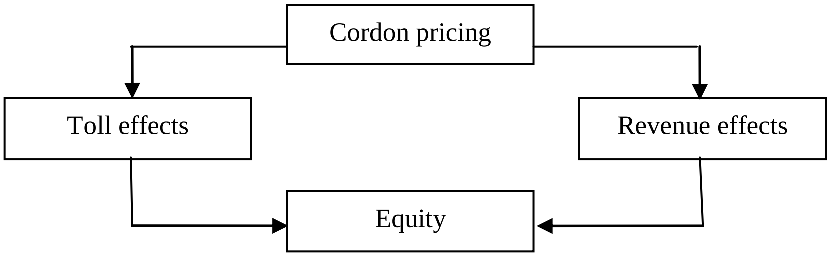

Figure 7. 1: general framework to analyse equity effects of cordon pricing

These analyses show that toll charge is an important factor that would trigger some income groups to change their travel behaviour because of the additional burden and cost to their daily trips. This result is expected, as people from high-income neighborhoods are more willing to pay the charges and drive as before than other income groups. This is mainly due to their value of time. This factor encourages travelers from high income neighborhoods to pay the toll and drive as before and travelers from low-income neighborhoods to use public transit more often.

Corresponding to paying the charges or changing travel behaviour, all income groups would like to see the generated revenue redistributed according to their benefits. For example, we have seen that there are significant differences between different income groups in supporting the notion of redistributing the generated revenue to improve road infrastructure and improve cycling and walking conditions. People from low-income neighborhoods generally supports using the revenues to improve cycling and walking conditions; not surprisingly, they indicated that they are more willing to cycle or walk to their destinations than other income groups. On the other hand, all income groups supported the notion of allocating the generated revenue to improve the public transportation network and services or reduce public transportation fares.

To analyse vertical equity of cordon pricing based on household income level, the toll effects on travel behaviour and the revenue distribution effects are examined as shown in Figure 7.2. From these results we can conclude the following about the vertical equity effects of the cordon pricing system:

1. As we have seen, there is a significant difference between income groups in terms of paying the tolls and using public transportation more often. People from low-income neighborhoods is less willing to pay the charges and they are more willing to use public transportation more often. Also, we have seen that there is no significant difference between different income groups in terms of redistributing the generated revenue in improving public transportation. Therefore, allocating the generated revenue to enhance the transit system makes cordon pricing more equitable and progressive.

2. Travelers from low-income neighborhoods are also willing to cycle or walk more often to their destinations than other income groups. Also, they support investing the generated revenue to improving cycling and walking conditions. Therefore, this scenario can also be considered as progressive.
3. Travelers from low-income and high-income neighborhoods are more willing to pay the toll and drive as usual than the travelers from middle-income neighborhoods; in addition, these groups are more willing to support investing the generated revenue to improve road infrastructure. Therefore, we can conclude that this scenario can also be considered progressive.
4. We can also argue that cordon pricing is progressive in the case of redistributing the generated revenues to reducing public transportation fares. On the other hand, allocating the revenues to support the municipal budget makes cordon pricing regressive.

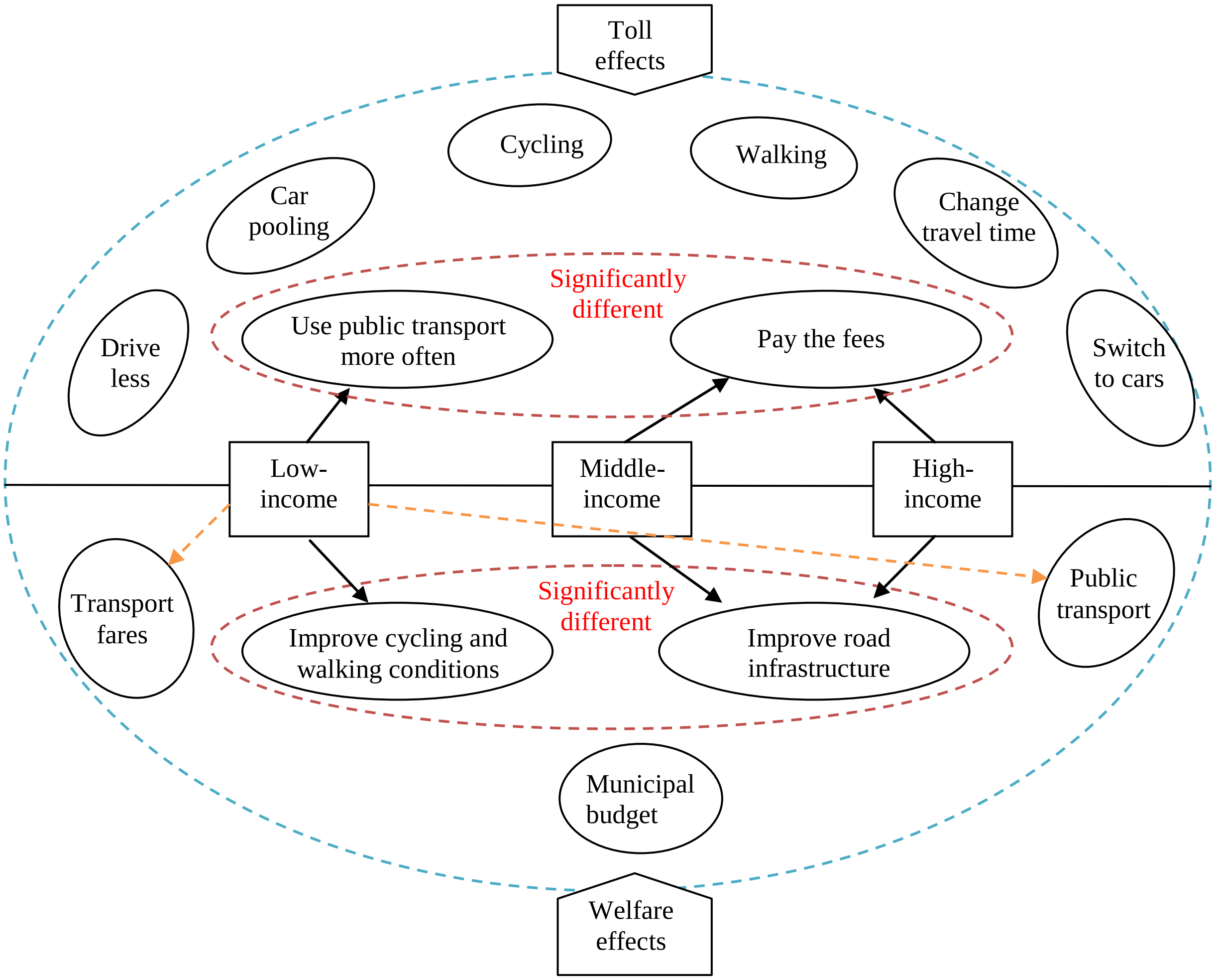

Figure 7. 2: Toll effects and revenue effects of cordon pricing to analyse equity effects based on household income

7.3 Cordon pricing and sustainable transportation in the GTA

This study showed that the GTA, in general, is moving away from the principles of transportation sustainability. Increased automobility and the decrease in public transportation ridership are the main trends for un-sustainable transport in the GTA. Consequently, people are increasingly suffering from congestion, emission, in addition to the negative impact of traffic noise on their health.

The core of the regional transportation plan is to integrate the regional rapid transit in a seamlessly operating network across the regions. Robust local transit networks, transit-supportive land use, pedestrian and cycling networks, and supporting policies are needed to support the regional network. For example, bus bypass shoulders can provide transit service that is fast and reliable on busy highways. The aim is to use the available capacity more efficiently to implement an inter-connected regional network of multi-purpose reserved lanes. This network enhances the existing and future plans for high occupancy vehicles (HOV) lanes to improve the efficiency of the highways for transit and car pooling. The plan aims to achieve an integrated transportation system in the GTA that enhances the quality of life. The plan also tends to improve connections to local and regional transit services. However, the TTS data showed that the trend in the GTA, excluding Downtown Toronto, is toward more automobile use, growing number of vehicles owned by households, and reducing average vehicle occupancy. In addition, communities in the GTA have been built to depend on automobiles. The GTA is characterized by its lower density and dispersed development which resulted in a travel pattern that is more difficult to serve by transit. The region continued to respond to automobile demand by increasing the supply through expanding the road network. The GTA is experiencing excessive traffic congestion where more than two million automobile trips are made during the morning peak period, and this number is expected to increase to three million by the year 2031 (Metrolinx 2008b). The current transportation system in the GTA does not offer travelers a high level of customer service and comfort. In addition, it does not offer travelers an assurance that they can get where they need to go on time. In the GTA and Hamilton area, the transit system comprises of nine separately-governed transit agencies and one regional transport provider. However, this transit system is poorly integrated, and therefore, traveling across different cities within the GTA and Hamilton area by public transportation is an inconvenient and costly option for many travelers.

Traffic demand management is considered an effective tool to curb the demand for travel. This tool has the ability to change when, how, whether, and where to travel and hence to make more efficient use of the transportation system. The major focus of demand management is to influence people travel behaviour and encourage them to change their normal travel routine. This creates a challenge for transportation officials who have to find the right mix of incentives and/or disincentives that will encourage people to change their travel behaviour. There is a need to develop transportation demand management policies that include priced and non-priced strategies for the GTA. The non-priced strategies aim to reduce congestion by encouraging travelers to use public transportation more often, walk, cycle, change their time of travel, or share vehicles (car pooling).

The survey results show that cordon pricing in Downtown Toronto was capable to make changes of individual’s behaviour in order to attain a sustainable transport system. It was capable to move some travelers from private car usage to public transport one. It provides some incentives that promote travelers to change their normal travel practice. For example, investing the generated revenue to improve public transportation network and services encourages more people to use it.

Implementing cordon pricing restrains the use of private cars in the GTA and at the same time gives the opportunity to improve public transportation by investing the generated revenues in this cause. Promoting public transportation reduces the adverse impacts of transportation and is definitely associated with overall sustainability. Cordon pricing allows public transportation to increase travel speed and to access areas of low density. Improving public transportation helps the disabled and the elderly, who are no longer able to drive, commute and access different places more easily.

Cordon pricing strategy in Downtown Toronto should be designed as one element of an integrated package of demand management policy measures in the GTA. Such a package should include High Occupancy Vehicles (HOV) on the 400 series as well as parking pricing in other congested areas within the GTA. This package should also include other complementary measures such as improvements to the public transportation system, walking, and cycling to provide alternatives for those travelers who are negatively impacted by cordon pricing or other traffic demand management schemes. This can result in maximizing the effectiveness and efficiency of the overall package. Other measures may also be included to overcome any adverse side-effects of the charging scheme such as local traffic management parking restrictions, and road capacity enhancements. One of the advantages of cordon pricing is that charges can be adjusted to the optimum economic level during the morning and evening peak periods and thus eliminating induced traffic. Another merit of cordon pricing is that it can have a vital role in complementing other non-price policies such as car pooling, walking, and cycling, and thus it insures the congestion reduction benefits from the priced policies. Parking policy in Downtown and other congested areas in the GTA can be designed and used as a pricing demand management tool by restraining the level of parking and consequently the road traffic movements. This policy should be designed to meet other policy system objectives such as accessibility for business and shoppers and traffic management goals rather than balancing supply and demand for parking. These policies should be considered as guidelines for planning applications for any major employment, commercial, or institutional development. Without considering these complementary congestion management measures, cordon pricing may not be a desirable policy option to curb congestion in the Downtown. It may result in some level of traffic diversion adjacent to the Downtown which would result in increased traffic volumes and negative environmental impacts in these areas, which could be inappropriate for carrying high traffic volume.

From an environmental perspective, public transportation is more sustainable than automobiles. By reducing car usage, accumulating greenhouse gases and carbon dioxide in the atmosphere would be reduced while air pollution control can be improved. In addition, reducing car usage results in reducing fuel and energy consumption that causes significant negative environmental impacts. Car emission contributes significantly to air pollution as indicated earlier. On the other side, public transportation modes use less fuel and energy and produce lower emission. As a result, cordon pricing helps to reduce the environmental degradation that results from the transportation system in the GTA. In addition, reducing and discouraging individual’s tendency to drive decreases fuel consumption and the risk of accidents. All these consequences provide solutions to multiple problems of sustainable transport system in the GTA.

Cordon pricing in the Downtown is one path that leads to sustainable transportation. It reduces congestion, which means reducing travel time and consequently travel delay. By reducing congestion, sustainability would be enhanced by relatively smooth traffic flow with improved fuel economy. This also may result in reducing the negative health impact resulting from car usage. It can also reduce different social effects of using cars by increasing safety and reducing the rate of injuries and fatalities as a result of car accidents. In addition, it reduces the cost of maintaining the road network as well as parking facilities. The generated revenues from cordon pricing would provide the municipal government with additional financial resources for expanding and improving public transportation infrastructure. In summary, cordon pricing reduces travel time, improves the environment, and increases revenues. These trends are closely associated with the principles of sustainable transportation in terms of social equity, environmental responsibility, and economic efficiency.

An understanding of how individuals perceive congestion and cordon pricing in the GTA and the impact of this scheme on their travel behaviour is crucial for the development of an equitable, effective and relevant policy. Cordon pricing in Downtown Toronto is progressive in its effects. Travelers from high-income neighborhoods are the most affected and they are willing to pay the tolls and drive as usual more than other income groups, while travelers from low-income neighborhoods are more willing to change their mode of transportation. Therefore, investing the generated revenue in improving the public transportation network across the GTA and improving walking and cycling conditions are regarded as compensation to those who stopped driving and changed their mode of transportation.

7.4 Research contribution

The overall research goal is to contribute to the academic and practical knowledge of congestion pricing in Toronto, particularly, to gain a better understanding of the potential impacts of cordon pricing schemes in the GTA. For this purpose, the examination of the vertical equity of cordon pricing was addressed. Although, theories of justice are considered by scholars following such approaches as the point of departure in evaluating equity in social policy, the prospective of these approaches in empirical work remains limited. In general, the three congestion pricing projects that were implemented in the Asian city (Singapore) and the two European cities (London and Stockholm) gave equity limited attention and evaluation.

7.4.1 Conceptual and methodological contributions

This research is based on theories and concepts already present in the debate around the issues of equity and congestion pricing. The literature provides an academic foundation for this research, giving support to the conceptual framework and to the approach being adopted.

Very few studies empirically tested equity impacts of cordon pricing, even those who did, did not refer to equity theories and principles. The approach used in this research is linked with specific interpretation of equity through a variety of principles that are based on which resources are distributed to or accessed by groups of individuals. These principles characterize the target groups and determine the methods of distributing the generated revenues to achieve equity.

The main methodological contributions of this dissertation are classified into three groups:

1. Identifying socio-economic groups: this dissertation identified socio-economic groups by cross-tabulating income categories with employment status and created eight socio-economic groups. The analysis extended to include other demographic factors (i.e., gender, age, occupation) to give more insight to vertical equity of cordon pricing. Previous studies that explored equity of congestion pricing compared between travelers based on separate factors such as income, age, and gender.
2. Spatial patterns: this dissertation analyzes travel activity by residents of different parts of the GTA. The examination of travel data is based on three zones PD1, the rest of the City of Toronto, and the rest of the GTA. This demonstrates the importance of the area of residence for equity analysis. The analysis of the traffic flow based on these three areas allows estimates of the number and percentage of trips that would be affected by cordon pricing on the part of travelers from each area. The method used in the study estimates the number of travellers whose auto trip would be charged under a cordon pricing

scheme. Consequently, it is possible to provide insight into what types of persons would be most affected by cordon pricing. Differences in area of residence and mode of travel explained, in large part, the differential effect of cordon pricing across the socio-economic groups.

3. New factors and variables: this study added new factors and variables that have not been previously analysed in the literature such as traveler's perceptions of congestion and congestion pricing, motivations that encourage travelers to maintain or change their travel behaviour and the perception of travelers of how the local authority would use the generated revenue. The method used in this study linked several factors in the analysis to build a comprehensive analysis of equity of cordon pricing. The study linked respondents' perceptions of cordon pricing and its effectiveness as a tool to curb congestion. In addition, their ability to support it if implemented in Downtown Toronto and if they consider this policy would be to their advantage or disadvantage. In addition, the study linked how different trip characteristics (i.e., trip frequency) and traveler's income factor affect willingness to pay the toll to reduce travel time and escape congestion.

7.4.3 Academic contribution

Equity objectives are concerned with fair distribution of the benefits of transport strategies with special focus on specific socio-economic groups in the society. Furthermore, equity objectives are concerned in the avoidance of decreasing accessibility, safety, or the environment for any of these social groups (Stantchev and Menaz, 2006). Implementing cordon pricing can be a powerful instrument to fight congestion in urban traffic, but it has faced an unreceptive public and political environment. This is due to the lack of assurance of its promised (traffic) results and concerns about equity (Viegas, 2001). This research provides insight into the equity of cordon pricing in a large urban centre in Canada. The purpose of this research is to address both theoretical and practical issues related to equity associated with the implementation of cordon pricing taking Downtown Toronto as a case study. Academics and practitioners have not yet done much to address and understand equity implications of such a scheme on different socio-economic groups of people.

This research addresses research needs in, at least, three academic fields: geography, economics, and transportation planning. This is because geographers are heavily interested in addressing and investigating the links between the well-being of different members of the society, public investment, and spatial organization of urban systems (Hall, 1994). Transportation planners have been giving more consideration to equity regarding the distribution of transportation infrastructure and services (Deka, 2004). The significance of equity as an objective in transportation planning has been increasingly growing in recent years (Stantchev and Menaz, 2006), and that is because research about equity in urban transportation is largely related to people from low-income and minority groups (Deka, 2004). This is because households, particularly those from low-income neighborhoods, spend a significant portion of their income on transportation-related activities.

The notion of equity, which can be seen as a concept and part of the broader field of social science, seeks to understand the differences and interactions of various socio-economic groups of humans resulting, for example, from the implementation of different projects at different locations. A variety of purposes and methods can be used in the study of this interaction. It can include, for example, the development of indicators (e.g., Gini coefficient) and frameworks to be applied in national policies and regional development programs. Numerous studies have been undertaken in this field, but the vast majority have concentrated on variation in the direct benefits and costs among the different socio-economic groups. The propose research can bring some innovation to this field, while seeking to understand how equity between different groups can be affected by implementing a cordon pricing scheme in Downtown Toronto.

This research also addressed the specific academic needs of decision-makers, public, and private transportation agencies in the area of cordon pricing. This research also contributes in improving planning and decision-making processes. Congestion has challenged traffic engineers and urban policy decision makers to explore solutions outside the conventional approach of supply management (e.g., increasing road capacity).

Equity is one of the main reasons why cordon pricing/tolling or any other charging schemes are not popular with the general public and politicians. This research contributes to the debate on the equitability of this system. The research extended the debate on the equitability of cordon pricing; it also has different implication for current academic knowledge on equity in terms of cordon pricing in general.

Evidence based on proposed hypothetical and real-world implementations of different congestion pricing schemes has been growing. However, reviewing a number of published papers does not lead to a general conclusion about the equitability of cordon pricing. All of this provides an academic foundation for this study, giving support to the conceptual framework and to the approach being adopted.

7.4.4 Applied and practical contribution

In addition to the inputs to the academic literature, this work provided some practical contributions. The potential practical contribution of the research is very significant, as it explores equity implications of cordon pricing scheme. Congestion pricing in general has become an increasingly practical option implemented in various forms to manage/mitigate congestion, protect the environment, and raise revenue for transportation investments. It has been easily implemented in recent years because of the advances in technologies that make it achievable to charge motorists as they drive. Although, transportation planners and policy makers are considering congestion pricing as a promising alternative to mitigate/manage congestion, it has thoroughly faced an unreceptive public and political environment. While few cities succeeded in implementing different schemes of congestion pricing, yet many proposals were discarded based on equitability concerns. In general, equity has been given limited attention and evaluation when cordon pricing implemented in different cities around the world. By filling these gaps, this research provided a more realistic and practical sense on how a more effective cordon pricing scheme can be implemented and at the same time achieve equity between different socio-economic groups.

In addition, policy-makers and transportation planners would be more aware of which factors should be considered, in the planning stage, to achieve equity between different socio-economic groups when implementing such a system. Thus policy- and decision-makers would be able to adopt new practices and draw more appropriate policies.

7.4.5 Benefits for specific audiences

The findings of this study can be useful to all sorts of public and private institutions and stakeholders concerned about the impacts of cordon pricing on different socio-economic groups. These include, among others, researchers, policymakers, Ontario Ministry of Transportation, Metrolinx, international organizations, local communities, and industry organizations. Given the study’s focus on equity implications of cordon pricing, the stakeholders of this sector are likely to benefit more than others. The research can be especially significant in that policy-makers and the population in general can benefit from the information provided and may be stimulated to promote cordon pricing as a way to mitigate/manage congestion on the roads.

7.4.6 The Downtown Toronto case and its contribution to the literature

Although congestion pricing has been suggested in many studies as an effective tool to relieve congestion, protect the environment, and generate revenue, it has not been implemented anywhere in any of its forms in the GTA or Canada. However, it is receiving considerable attention from different academic and government levels, including transportation agencies. Yet, none of the academic or governmental studies have analyzed the feasibility of implementing cordon pricing in the GTA, particularly its equity implications. Elected officials are reluctant to support the implementation of cordon pricing without a thorough consideration of its implications on equity, traffic, businesses, the environment, and the economy.

North American and European cities have implemented two different forms of congestion pricing. High-occupancy toll (HOT) lanes are the most widespread type of congestion pricing in many cities in the United States of America. They are the least rejected congestion pricing scheme because of fewer equity concerns among drivers. HOT lanes provide users with an extra choice of using priced lanes while they can continue, using parallel, free lanes when desired. Still this type of congestion pricing encourages travelers to use their own cars or car pooling. On the other hand, many European cities implemented cordon pricing to encourage travelers to change their travel behaviour through using other modes of transportation, particularly public transit.

As indicated in this study and in the literature, the main trend for un-sustainable transport in North- America is increased automobility. North American society is more strongly tuned towards the regular use of cars than many European societies. Thus, car dependency (i.e., the level of car use, car-oriented, land-use, and quality of travel alternatives) is much higher in North America compared to Europe. The GTA is similar to many European cities (e.g., London and Stockholm) in terms of population, mobility challenges, and economic activity. The main difference between the GTA and these cities is the public transportation system. This is reflected in the current share of commuters using public transit, which is 22.5 percent compared to 85 percent in London before the implementation of congestion pricing scheme. Therefore, investigating the feasibility of implementing cordon pricing in North American cities can add more insight into this type of policy into the literature.

7.5 General lessons emerged from the dissertation

The main lessons generalized from the dissertation can be summarized in the following:

1- There are differences between the Downtown area and the rest of the City of Toronto and the rest of the GTA regions in terms of urban development, travel behaviour patterns, and local transportation policies. The analysis showed that employment density is highest in PD1, fairly high throughout the City of Toronto, and comparatively low in the rest of the GTA. Despite the policies that encourage residents to use the transit system as their main mode of transportation the substantial decentralization of employment densities and areas from denser (PD1), urban locations to low-density the rest of the GTA regions is a major obstacle to improving transit ridership in the GTA. Decentralized areas are difficult to serve efficiently and cost-effectively by urban transit. Automobiles share is increasing as the distance from the PD1 increases. Public transit shares constitute a small portion of mode share in the rest of the City of Toronto and rest of the GTA regions.

2- The major contribution of road congestion in the Downtown is the automobiles originating from the rest of the City of Toronto as well as from the rest of the GTA regions. The analysis showed that the trips destined to the PD1 area are four times higher than the number of outbound trips originated from it. Public transit share within the PD1 area is dominant. The usage of public transportation exceeds the usage of automobile. In addition, PD1 area achieved some progress toward reducing the automobiles mode share on the expense of walking and cycling.

3- Cordon pricing in Downtown is progressive. The percentage of trips that are affected by this policy increases as the income increases. The full-time people from high-income neighborhoods are affected the most by the charges. Considering the distribution of the generated revenue, cordon pricing in Downtown Toronto can result in perceived road users in a win-win situation. Those who are willing to pay the charges and drive as usual can benefit from reducing their travel time while those who decide to switch to public transportation can benefit from the enhancements of this service. The findings of the dissertation add to the findings presented in Table 1.3 as shown in Table 7.1. Despite the progressive nature of cordon pricing in Toronto, it is important to mention that approximately 40% of affected trips would originate from neighbourhoods characterized as having low or lower-middle incomes. This is because these neighbourhoods account much of Toronto, i.e., for 68% percent of all the neighbourhoods of the GTA.

Table 7. 1: Winners and losers as a result of implementing cordon pricing in Downtown Toronto

The overall effects	Winners	Losers	Win-win
The overall effect of cordon pricing would be progressive. High income travelers are affected the most and they are willing to pay the charges. Investing the generated revenue in improving public transportation and walking and cycling conditions compensate travelers who decide to switch to use these modes instead of their cars.	High-income travelers benefit the most as they would encounter reduction in travel time and their value of time is higher than the imposed charges.	Low-income travelers would have to change their mode of transportation	Most travelers benefit from cordon pricing if the generated revenue is used to enhance public transportation. High-income travelers would benefit from time saving and low-income travelers who would use public transportation would benefit from the improvements in public transportation services and facilities.

4- A proper allocation of the generated revenue is of paramount and most crucial element to achieve equity. To achieve equity as a result of implementing cordon pricing in Downtown Toronto, the generated revenue should be dedicated to public transportation system across the GTA and not only within PD1 area. This can accelerate the integration of transportation system at the local and regional levels.

5- The major conceptual challenge is identifying socio-economic groups. Differences in the ways we consider the groups make us reach different conclusions. For example, classifying members of the society based on their income, their place of residence or work, or as disadvantaged with respect to transportation because of disability, age, or gender may affect the analysis. Another conceptual challenge is defining equity; equity means different things to different people, partly for the reason that the concept of equity can be multifaceted.

7.6 Future research

This section provides suggestions for future research related to sustainable transportation and travel behaviour in the GTA as well as for cordon pricing and equity implication of such a policy. Some future research suggested includes:

1. The socio-demographic structure of GTA population has undergone some interesting changes over the study period. The main feature that characterizes this time period is the suburbanization of population and employment. In reviewing the findings of the above analysis, we see first that the population of the GTA increased rapidly between 1986 and 2006. The distribution of the GTA population growth has become more dispersed, however. The main growth is concentrated in the rest of the GTA regions and to less extent in PD1 area. This population growth can impact the transportation system and personal travel activities in the GTA in different ways. For example, more demand for

travel would be generated, which will put more pressure on the transportation system and cause more congestion on the roads. In addition, the continuous dispersion of population and labour force growth in suburban areas implies increased automobile-oriented development particularly in low density areas, which results in changes of personal travel activity. However, this dispersion may be beneficial to think about more sustainable transportation solution based on region-wide mass transit such as GO rail transportation system. This point needs more discussion and worth more research.

2. This study has examined vertical equity of cordon pricing. However, horizontal equity needs to be addressed in this context. Horizontal equity is concerned with allocating public resources equally among like individuals and like groups. In other words, it is concerned with fairness between persons in the same group. Horizontal equity in the context of congestion pricing directs to assessing cost and benefits by users and non-users or by geographical area (Evans et al., 2003). In terms of user versus non-users, the aim is to assess the benefits received and charges made by users of a pricing project versus the non-users with similar travel needs who look for alternatives to avoid paying the charges. In this case, it is more equitable from the horizontal perspective that the users who pay the charges benefit the most from congestion reduction or capacity expansion.

   Horizontal equity is concerned with the distribution of impacts between individuals from the same group fare relative to one another. Based on this definition, equal individuals should receive equal shares of resources, treated the same, and bear equal costs. If similar individuals are made equally well off or are provided with equal opportunities under a policy, then this policy is considered horizontally equitable. Investigating horizontal equity of cordon pricing in this regard requires collecting data of individual travelers such as individual income, area of residence, gender, age, household size, etc. This data is then used to identify groups of individuals that have the same characteristics. The income data provided by Statistic Canada is based on dissemination area level not on individual level. To investigate horizontal equity of cordon pricing in Downtown Toronto, travel activity by residents of different parts of the GTA who are similar in terms of their socio-economics and/or demographics should be analyzed using the same approaches used in this research to investigate vertical equity. However, to provide insight into what types of persons would be most affected, travelers should be categorized in a fine scale based on socio-economic and geographic factors to estimate the proportion of different sub-populations that would be potentially affected by cordon pricing. The income data for each of the eight socio-economic groups identified in chapter 5 can be sub-divided into groups that combine individuals with household income differences that do not exceed $5000. For example, the people from low-income neighborhoods sub-category starts from $0-$4,999 then from $5,000 to $9,999 etc. In terms of geographic factors, analyzing horizontal equity should be based on comparing individuals in the same sub-groups based on their area of residence. This is because those people share almost the same transportation facilities and services and share almost equal access to public transportation. For example, the analysis should compare the impact of cordon pricing on the $0-$4,999 socio-economic sub-group in the PD1 area separately from the same group in the rest of the City of Toronto or the rest of the GTA. Analyzing traffic flow amongst these socio-economic sup-groups in the three areas allows estimates of the numbers and percentages of trips that would be affected by cordon pricing. This gives insight to the analysis of horizontal equity. This requires more detailed research.

3. Spatial equity can be viewed as a geographic application of both the vertical and horizontal equity. The incidence of cordon pricing largely depends on location. People in the same socio-economic groups may experience cordon pricing very differently, depending on their area of residence or work. The distribution of the benefits and costs of cordon pricing across individuals or group of individuals from different areas within the GTA describes spatial equity impacts of such a policy. The design of cordon pricing around the Downtown must ensure that the spatial equity impact is carefully addressed by examining the impact of cordon pricing on individuals or different socio-economic groups within the three tested areas. If cordon pricing benefits travelers from certain areas and harm travelers from other areas then this policy is spatially inequitable. Spatial patterns in the socio-economic and demographic distribution in the three areas play an important role in investigating the spatial equity of cordon pricing. Because spatial patterns differ with geography, the spatial equity should reflect these differences and appropriate provisions should be made to ensure that cordon pricing would not restrain traveler's mobility or spatial accessibility to the Downtown area, particularly for those who do not have other options but to take their own automobiles to travel from\to that area. This issue needs further research.

    Travel patterns of residents of different parts in the GTA who vary in terms of their socio-economic and/or demographics provided insights into the investigation of congestion and equity implications of cordon pricing. Investigating travel patterns can indicate how congestion in the GTA is developing and can help in identifying solutions to manage/mitigate this congestion. In addition, resulting variations in travel patterns can be crucial in designing equitable cordon pricing policy and can have important consequences for the success or failure of this policy. Another important point in this research is the focus on auto travel. This provided insight into who would be most affected by cordon pricing by estimating the number of travellers whose auto trip would be charged. Dividing the GTA into three areas is important to investigate congestion and vertical and spatial equity of cordon pricing. Downtown Toronto is the core of the GTA. People travel there for work, shopping, recreation, and many other reasons. People from the rest of the City of Toronto make more trips and are more attached to their Downtown than the people from the rest of the GTA, and hence they would be far more affected by cordon pricing. Therefore, it was necessary to divide the study area into three parts.

4. A special analysis should be conducted on the areas adjacent to the cordon zone. The aim is to examine the impacts of cordon pricing on people living or working in that area in terms of their mobility as well as to the capability of public transportation to accommodate more people there. This is due to the fact that these people may travel more frequently inside or outside the cordon zone.
5. This study has examined one category of congestion pricing, cordon pricing. Other categories of congestion pricing should be investigated to develop a comprehensive plan to mitigate/manage congestion in the GTA. These categories include, for example, High Occupancy Tolls (HOT) lanes of the major freeways and parking pricing in the Downtown Toronto or the main planning district in each region within the GTA.
6. The relationship between implementing cordon pricing and equity consequences of economic impacts and business development needs more extensive research.
7. More research is needed on some important topics such as the impacts of cordon pricing on the environmental justice in the GTA, the use of revenue for building new roads, the

long-term land-use impacts, the equity implication in case of adding congestion pricing revenue to existing transportation-finance mechanisms such as fuel tax.

7.7 Conclusion

The issue of equity is at the core of the debate in social science, particularly with regard to assessing equity in social policy. Several reasonable and conflicting notions of equity exist and, as identified in Ecola and Light (2009), this is related to the fact that there are several impacts to be considered. But, at the same time, many of these are difficult to measure, and there are numerous ways to classify “winners and losers”. There is not an accepted and commonly used manual for evaluating equity in transportation policies.

In conclusion to the above discussion, one may argue that there is no easy answer available to the question that is raised by this research, “Is implementing cordon pricing in Downtown Toronto equitable?” There is not a theory of equity but multiple meanings of the concept proposed by human and social sciences. However, the answer to this question largely depends on how we measure equity and how we define groups. Taking into consideration all aspects of equity is impossible. However, in an attempt to answer the above question, one can suggest the following conclusions regarding this issue:

1. It is concluded that the most important factor for the net impact of cordon pricing is how revenues are used. Differences in this respect reduce differences in other factors such as values of time. Having to pay for what was freely available, and the risk of exclusion for impacted socio-economic groups for the extra cost of driving causes political hostility. Thus, spending revenues in ways that benefit people from low-income neighborhoods and other transportation-disadvantaged social groups will make cordon pricing more likely progressive rather than regressive. On the other hand, even with spending revenues

in ways to benefit these groups, it is likely that some members will still experience a burden

2. Although utilizing revenues to improve transit services is considered to be an effective strategy for increasing equitable outcomes, still not all transit is created equal and it is not considered by many as a viable strategy for addressing equity concerns. Investments in various modes of transportation and different neighbourhoods may have different impacts.
3. Different approaches can generally evaluate the measurement of equity in transportation in many ways. The difficulties of these evaluations are greater when applied to cordon pricing than other forms of transportation demand management or financing schemes such as taxation. This is due to the fact that the range of cordon pricing impacts is quite larger. The evaluation of equity for cordon pricing policy can be complicated due to the many variables involved. For example, the incidence of cordon pricing relies on location. Therefore, the places where individuals in the same income groups live, worship, work, and shop are a critical element of how these individuals experience congestion pricing.
4. Other essential factors are cost, convenience, presence, and cost of alternatives to driving. Equity implications are different if individuals can switch from using their own autos during congested time to other modes of transportation such as public transit, walking, or cycling. In addition, comparing equity implications of cordon pricing in different cities around the world is fundamentally impossible because of the many other factors that may play a significant role in the outcomes.

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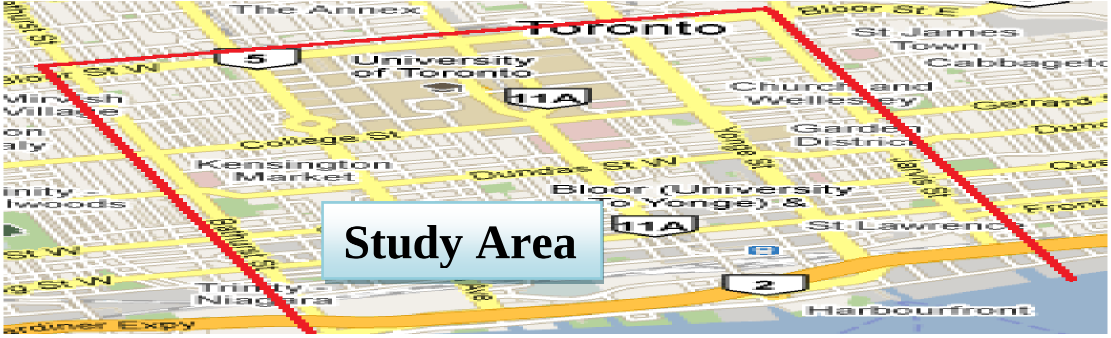
Appendix A

Dear Greater Toronto Area Resident:

You are invited to participate in a brief, anonymous survey related to transportation issues in Toronto. This study is being conducted by Ammar Abulibdeh as part of the requirements for a PhD Degree, and is being conducted for a doctoral thesis and not for a business or government. The study is being carried out under the supervision of Dr. Jean Andrey, jandrey@uwaterloo.ca, 519-888-4567 ext. 33629, "Department of Geography and Environmental Management, University of Waterloo".

The survey is about the possibility of implementing cordon pricing in Toronto. Cordon pricing charges motorists whenever they pass charging points that are located at the entrances of an imaginary zone around a congested area. Charges are flexible, meaning that they vary according to vehicle type, time of day, location, and direction traveled. The charges vary between peak and off-peak hours, and between weekdays and weekends. Cordon pricing has been implemented in different cities around the world, and has been found to reduce traffic congestion, improve air quality, and raise the revenue essential to implement needed transportation improvements. However, concerns about "social and spatial equity" are raised when discussing these systems.

For the purposes of the doctoral research, the boundaries of the proposed zone extend from Jarvis Street on the east, Bathurst Street on the west, Bloor Street on the north, and Lake Ontario on the south with an approximate area of 18 km^2 as shown on the map.



As a participant in this study, you will complete the 15-minute survey centres on how you may change your travel behaviour to the Downtown Toronto if cordon pricing is implemented. Your participation in the survey is voluntary and anonymous. You may omit any question you prefer not to answer and withdraw your participation at any time. The completed surveys will be kept in a secure location for 3 years, and then confidentially destroyed. Electronic data will be kept on a secure server.

Please return the completed survey in the attached addressed, stamped envelope by March 30, 2011

This study has been reviewed by, and received ethics clearance through the office of Research Ethics. If you have any questions, comments, or concerns resulting from your participation in this study, please contact Dr. Susan Sykes in the Office of Research Ethics by e-mail at ssykes@uwaterloo.ca, or by phone at 519-888-4567 Ext. 36005.

Thank you for your participation
Kindest regards

The aim of this **10-15 minutes questionnaire** is to find out what the public thinks about the possible implementation of cordon pricing in Downtown Toronto. A map of the cordon zone boundaries in Downtown is provided with the cover letter.

This questionnaire is being conducted for academic purposes only, and its completion is your consent to participate in this study. **Your name and identity will not be known by the survey team. The results will be presented in aggregate only.**

PART A: TRAVEL INFORMATION

1) In the past two weeks (14 days), how often have you travelled to/from Downtown Toronto? (e.g., if you commute in and out of Downtown Toronto from the 905 region each weekday, but make no other trips to/from Downtown Toronto, you will make 10 trips in and 10 trips out, and you will respond d).

a. Not at all **b.** 1-5 times **c.** 6-10 times **d.** 11-20 times **e.** more than 20 times

If 'a' selected, please end survey here and mail back in the envelope provided?

2) What is the main purpose of your most frequent trip to/from Downtown Toronto?

a. Commuting to/from work **b.** Commuting to/from school **c.** Shopping
d. Visiting friends/family **e.** Recreation activities **f.** Other

3) What is the mode of transportation that you usually use for your most frequent trip to/from Downtown Toronto?

a. Car as a driver **b.** Car as a passenger **c.** Public transit **d.** Motorcycle **e**. Bicycle/ Walk

4) How do you feel about the statement: There is a need to reduce traffic congestion in Downtown Toronto?

a. Strongly disagree **b.** Disagree **c.** Neutral **d.** Agree **e.** Strongly Agree

PART B: WOULD YOU CHANGE YOUR BEHAVIOUR AS A RESULT OF CORDON PRICING?

Several cities around the world have recently introduced road pricing in order to manage traffic congestion. I am interested in your perceptions about one possible type of road pricing, whereby vehicles would have to pay to enter or leave Downtown Toronto from or to outlying areas while public transportation and carpooling are free of charge; this type of road pricing is called cordon pricing. For example, if you are traveling from Mississauga to Downtown Toronto and then going back to Mississauga you will be charged twice. People living and traveling inside the cordon zone only will not pay the charges. The fee would be collected during weekdays only, 6:00 am to 7:00 pm, and be higher during rush hour periods. All charges would be collected using a system similar to Highway 407.

5) Do you think that cordon pricing would be effective in reducing traffic congestion in Downtown Toronto?

a. No **b.** Maybe **c.** Yes **d.** I do not know

6) Would you support cordon pricing if implemented in Downtown Toronto?

a. No **b.** Maybe **c.** Yes **d.** I do not know

7) Do you think the implementation of cordon pricing in Downtown Toronto would be:

a. To your advantage **b.** Of little relevance to you **c.** To your disadvantage

If you do not own a vehicle please skip questions 8 to 12, and go directly to question 13.

8) How much would you be willing to pay to reduce **your car** trip travel time to/from Downtown Toronto by **5 minutes**?

$0.0	$0.25	$0.50	$0.75	$1.0	$1.25	$1.50	$1.75	$2.0	$2.50	$3.0	$3.50	$4.0	$4.50	$5.0	$7.0	$10	$15	$20	$25

9) How much would you be willing to pay to reduce **your car** trip travel time to/from Downtown Toronto by **10 minutes**?

$0.0	$0.25	$0.50	$0.75	$1.0	$1.25	$1.50	$1.75	$2.0	$2.50	$3.0	$3.50	$4.0	$4.50	$5.0	$7.0	$10	$15	$20	$25

10) How much would you be willing to pay to reduce **your car** trip travel time to/from Downtown Toronto by **15 minutes**?

$0.0	$0.25	$0.50	$0.75	$1.0	$1.25	$1.50	$1.75	$2.0	$2.50	$3.0	$3.50	$4.0	$4.50	$5.0	$7.0	$10	$15	$20	$25

11) How much would you be willing to pay to reduce your car trip travel time to/from Downtown Toronto by **20 minutes**?

$0.0	$0.25	$0.50	$0.75	$1.0	$1.25	$1.50	$1.75	$2.0	$2.50	$3.0	$3.50	$4.0	$4.50	$5.0	$7.0	$10	$15	$20	$25

12) If cordon pricing were implemented in Downtown Toronto, how would this impact your use of a **car** for the following trips?

	No impact	Little impact	Some impact	Large impact
a. Commuting to/from work	☐	☐	☐	☐
b. Commuting to/from school	☐	☐	☐	☐
c. Shopping	☐	☐	☐	☐
d. Visiting friends/family	☐	☐	☐	☐
e. Business purposes	☐	☐	☐	☐
f. Recreation activities	☐	☐	☐	☐
g. Other	☐	☐	☐	☐

13) If cordon pricing were implemented in Downtown Toronto, how would it impact **<u>your</u>** travel behaviour? I would …

	Strongly disagree	disagree	Neutral	Agree	Strongly agree
a. Pay the fees and drive as before	☐	☐	☐	☐	☐
b. Drive less	☐	☐	☐	☐	☐
c. Join in car-pooling	☐	☐	☐	☐	☐
d. Use public transportation more often	☐	☐	☐	☐	☐
e. Use my bicycle more often	☐	☐	☐	☐	☐
f. Walk to my destination more often	☐	☐	☐	☐	☐
g. Change the timing of my car trips to reduce charges	☐	☐	☐	☐	☐
h. Switch from public transportation to car	☐	☐	☐	☐	☐

14) The thinking behind your answers to question 13…

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. Your value of time is greater than the cordon pricing fees	☐	☐	☐	☐	☐
b. Increase in travel cost as a result of fees	☐	☐	☐	☐	☐
c. You would save travel time by car	☐	☐	☐	☐	☐
d. Travel speeds by car would be increased	☐	☐	☐	☐	☐
e. The current level of service of mass transit	☐	☐	☐	☐	☐
f. I value the comfort and convenience of car travel	☐	☐	☐	☐	☐

15) Cordon pricing would generate revenue that could be spent in different ways. In your opinion, how should revenue generated from cordon pricing be spent. Also, using the last two columns (shaded), indicate how you think the **authorities** would use the revenue generated.

	Revenue should be used to:					**Expected use by authorities**	
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Yes	No
a. Improve road infrastructure (e.g., new roads)	☐	☐	☐	☐	☐	☐	☐
b. Improve public transport	☐	☐	☐	☐	☐	☐	☐
c. Reduce public transport fares	☐	☐	☐	☐	☐	☐	☐
d. Support the municipal budget in general	☐	☐	☐	☐	☐	☐	☐
e. Improve cycling and walking conditions	☐	☐	☐	☐	☐	☐	☐

16) If you were to pay the cordon pricing fees, what would you expect to see compared to the present situation?

	Strongly Disagree	Disagree	Neutral	Agree	Strongly agree
a. Shorter travel time to Downtown Toronto	☐	☐	☐	☐	☐
b. Additional cost to your trips	☐	☐	☐	☐	☐
c. Less air pollution and fewer environmental problems	☐	☐	☐	☐	☐
d. Unfairly restricted travel options	☐	☐	☐	☐	☐
e. More difficulties in planning trips	☐	☐	☐	☐	☐
f. Downtown Toronto as a better place to work	☐	☐	☐	☐	☐
g. Downtown Toronto as a better place to live	☐	☐	☐	☐	☐

PART C: ABOUT YOU

17) How old are you?
a. 18 – 24
b. 25 – 34
c. 35 – 44
d. 45 – 54
e. 55 – 64
f. 65 +

18) Your gender:
a. Male
b. Female

19) Your occupation:
a. Not working
b. General office
c. Professional/Manager
d. Sales/ Services
e. Manufacturing
f. Other

20) What is your postal code (please write)? ______-______

21) What is your annual household income?
**** Household income involves all income of family members in the house***
a. Less than $20,000
b. $20,000 - $39,999
c. $40,000 - $59,999
d. $60,000 - $79,999
e. $80,000 - $99,999
f. $100,000 - $119,999
g. $120,000 - $139,999
h. $140,000 or more

22) How many vehicles do members of your household own or lease:
a. None
b. 1
c. 2
d. 3 or more

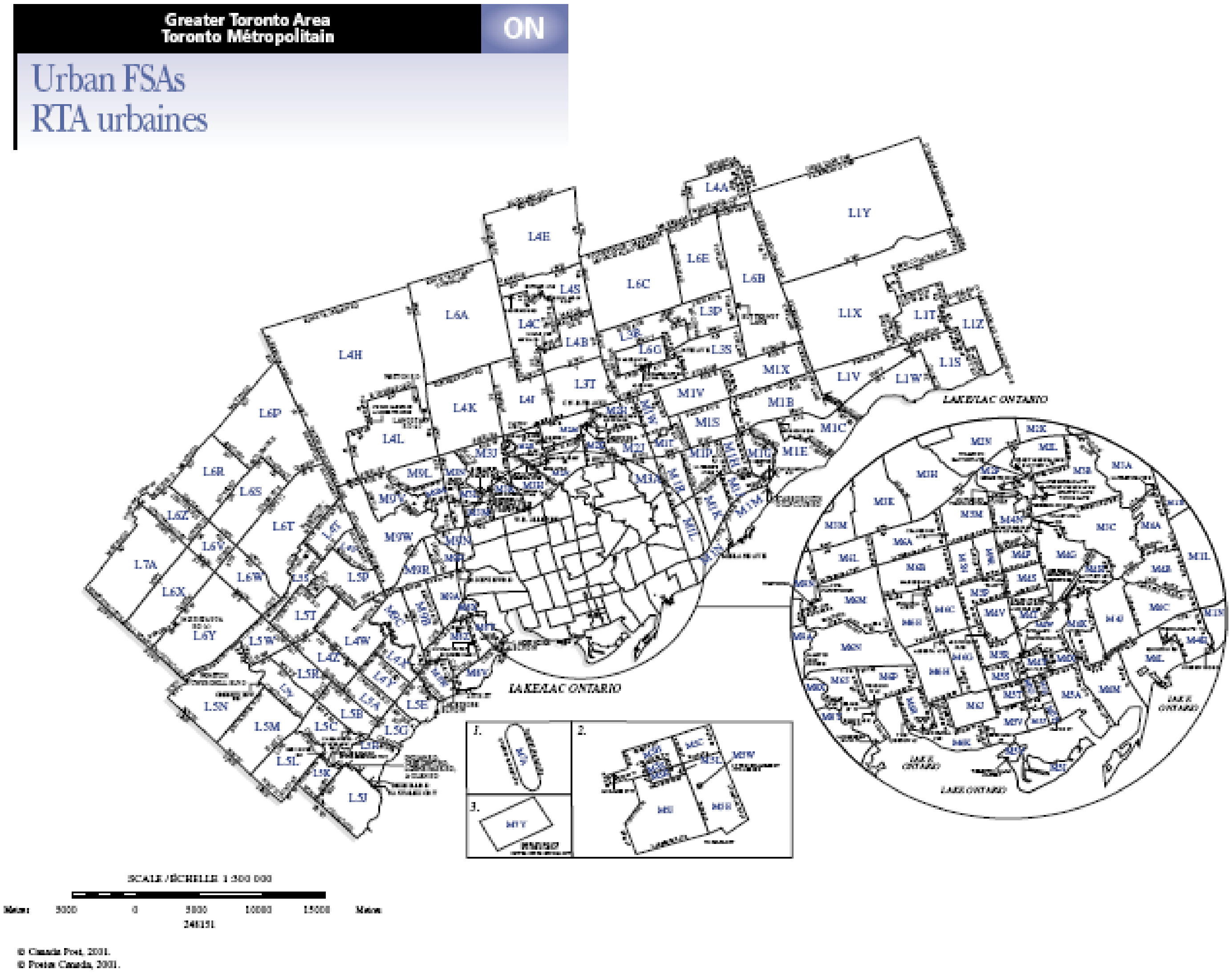
23) Number of persons in household:
a. 1
b. 2
c. 3
d. 4
e. 5 or more

24) Household characteristics
a. Single adult with no children
b. Single adult with child or children
c. Two or more adults with no children
d. Two or more adults with child or children

25) Number of male and female workers in household
a. Number of male workers______
b. Number of female workers______

Thank you for your participation.

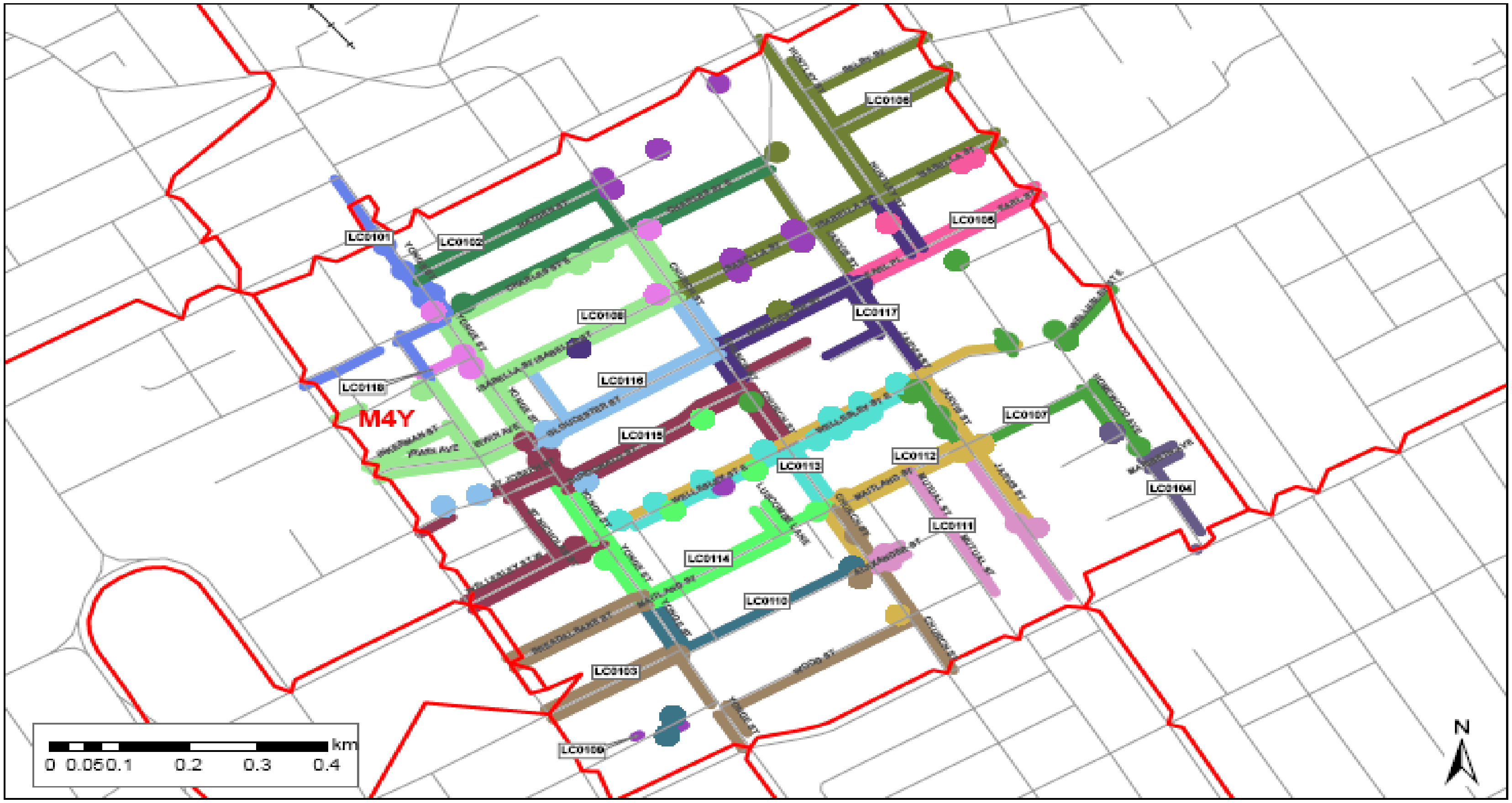
Selected sites for distributing the stated preference survey



M4Y Downtown Toronto

CANADA POST POSTES CANADA

FSA/RTA: M4Y



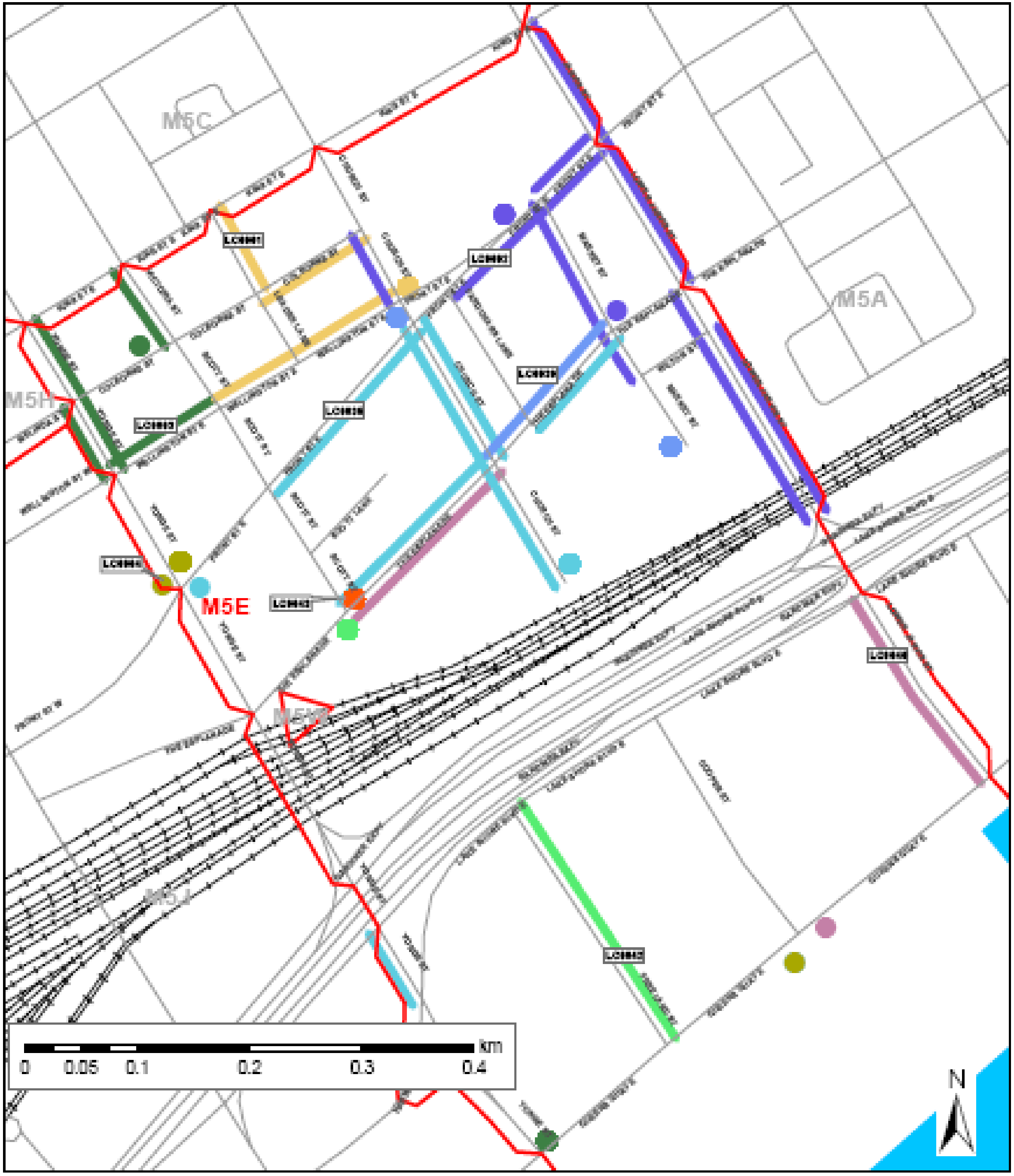
FSAs adjacent to / RTA's Adjacente a M4Y: M4W, M4X, M5A, M5B, M5G, M7A, M5S

11/2009

M5E Downtown Toronto

CANADA POST POSTES CANADA

FSA/RTA: M5E



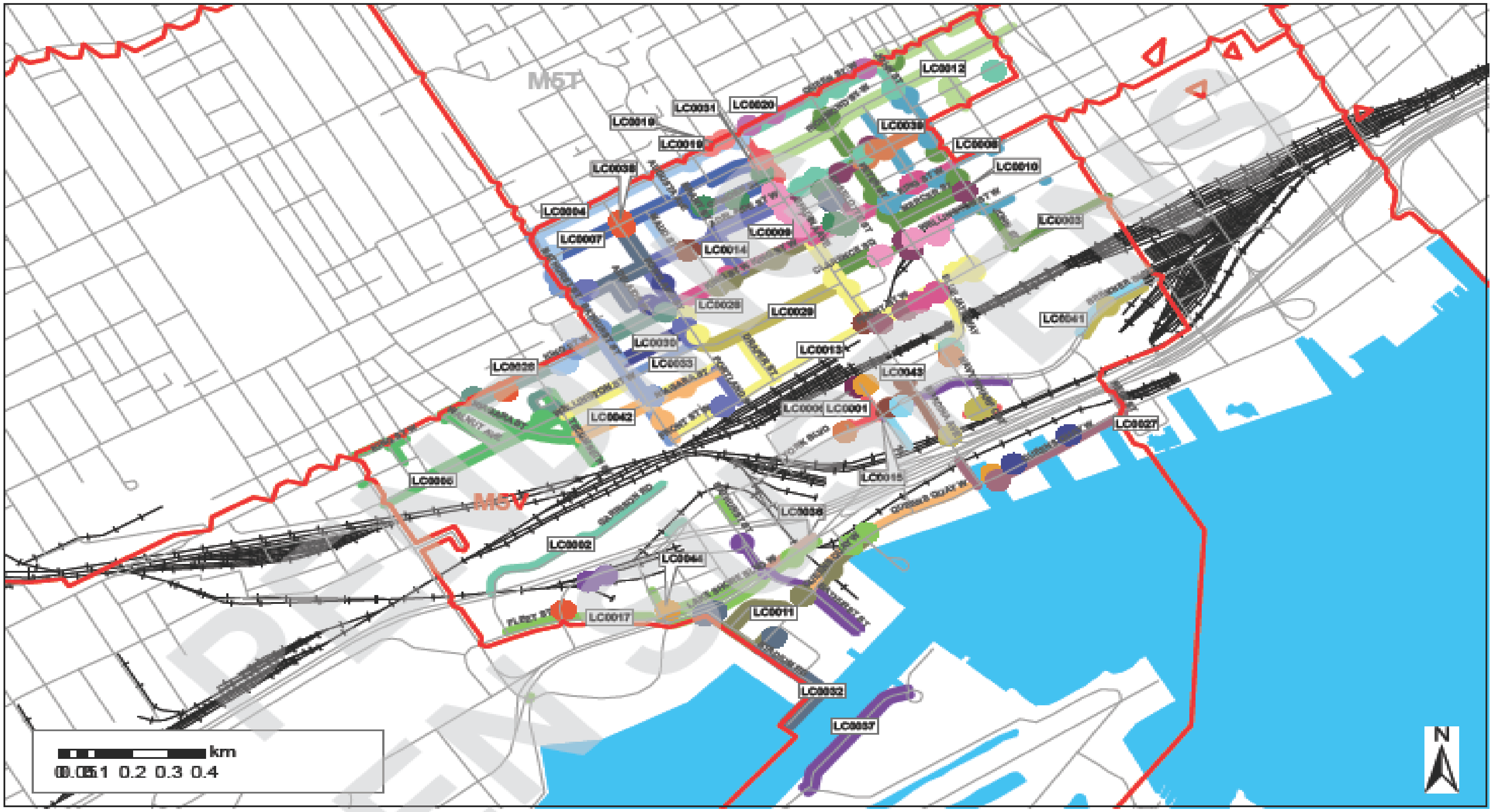
FSAs adjacent to / RTA's Adjacente à M5E: M5A, M5E, M5H, M5J

10/2009

M5V Downtown Toronto

CANADA POST POSTES CANADA

FSA/RTA: M5V



FSAs adjacent to / RTA's Adjacente à M5V: M6K, M6J, M5T, M5H, M5J

02/2011

M4L Rest of the City of Toronto

FSA/RTA: M4L

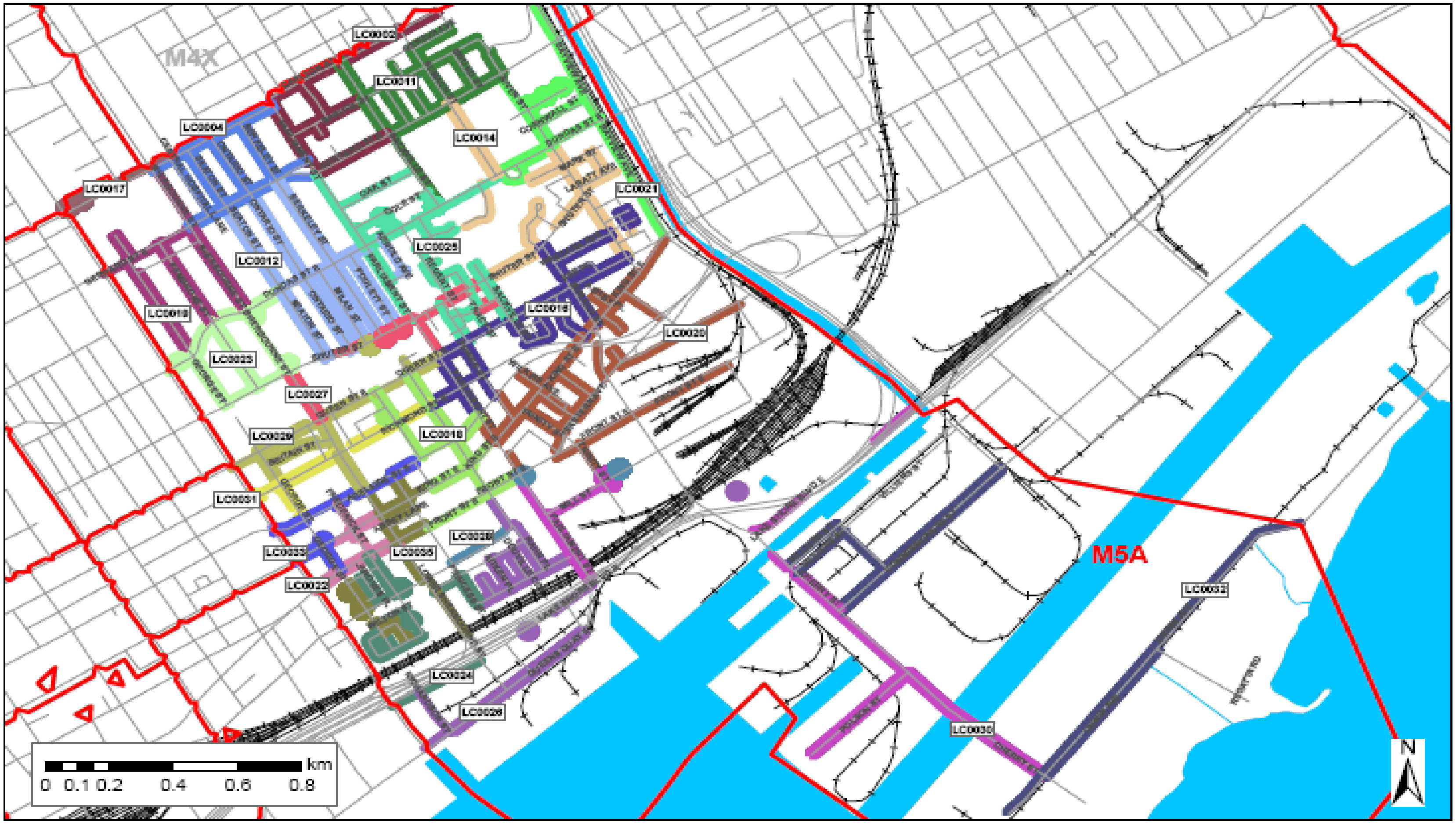
FSAs adjacent to / RTA's Adjacente à M4L: M4M, M4J, M4C, M4E

06/2009

M5A Rest of the City of Toronto

CANADA POST
POSTES CANADA

FSA/RTA: M5A



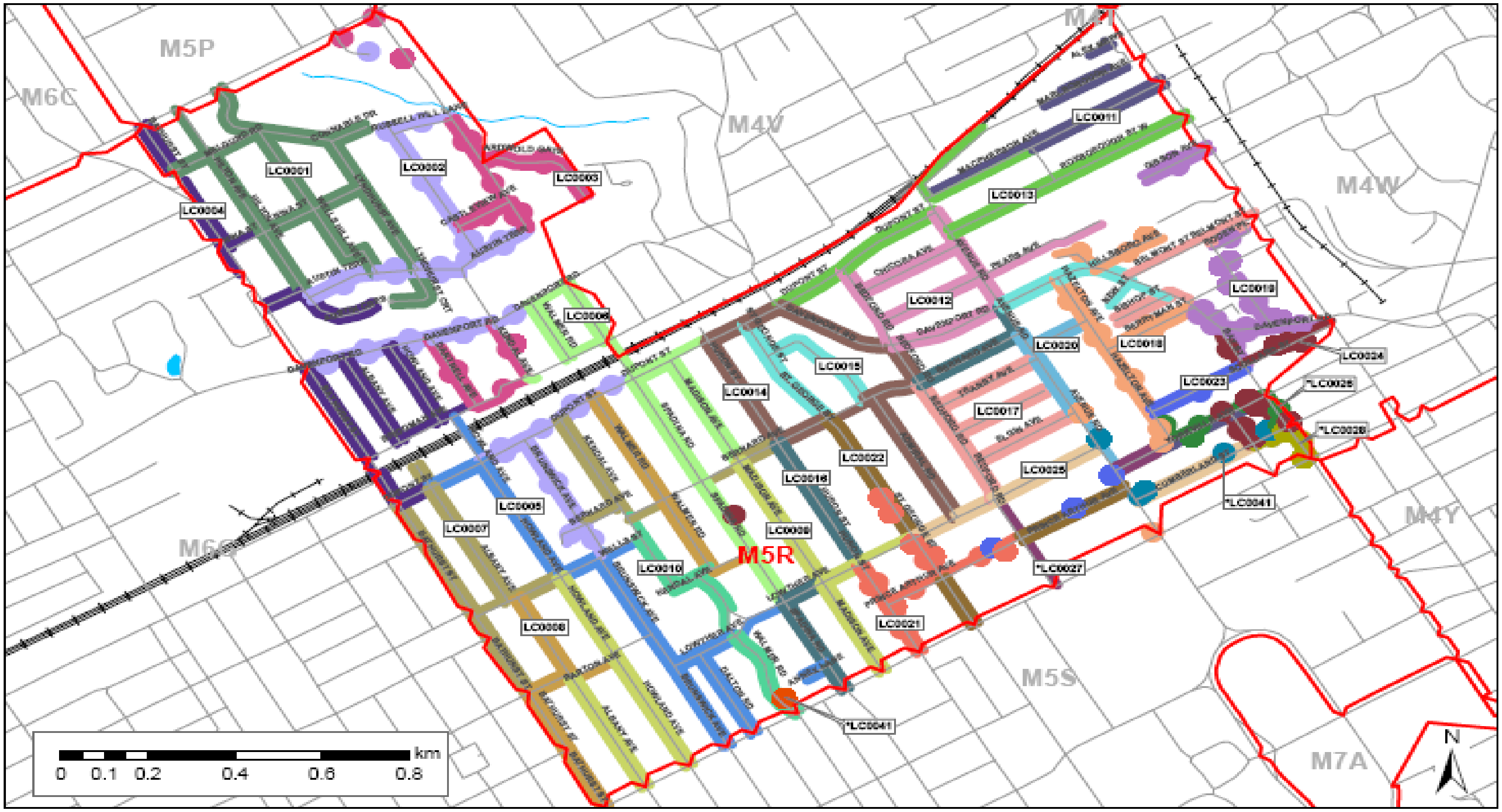
FSAs adjacent to / RTA's Adjacente à M5A: M5E, M5C, M5B, M4Y, M4X, M4K, M4M

01/2011

M5R Rest of the City of Toronto

CANADA POST POSTES CANADA

FSA/RTA: M5R



FSAs adjacent to / RTA's Adjacente à M5R: M4V, M4W, M5S, M6G, M5P

05/2009

M6J Rest of the City of Toronto

CANADA POST POSTES CANADA

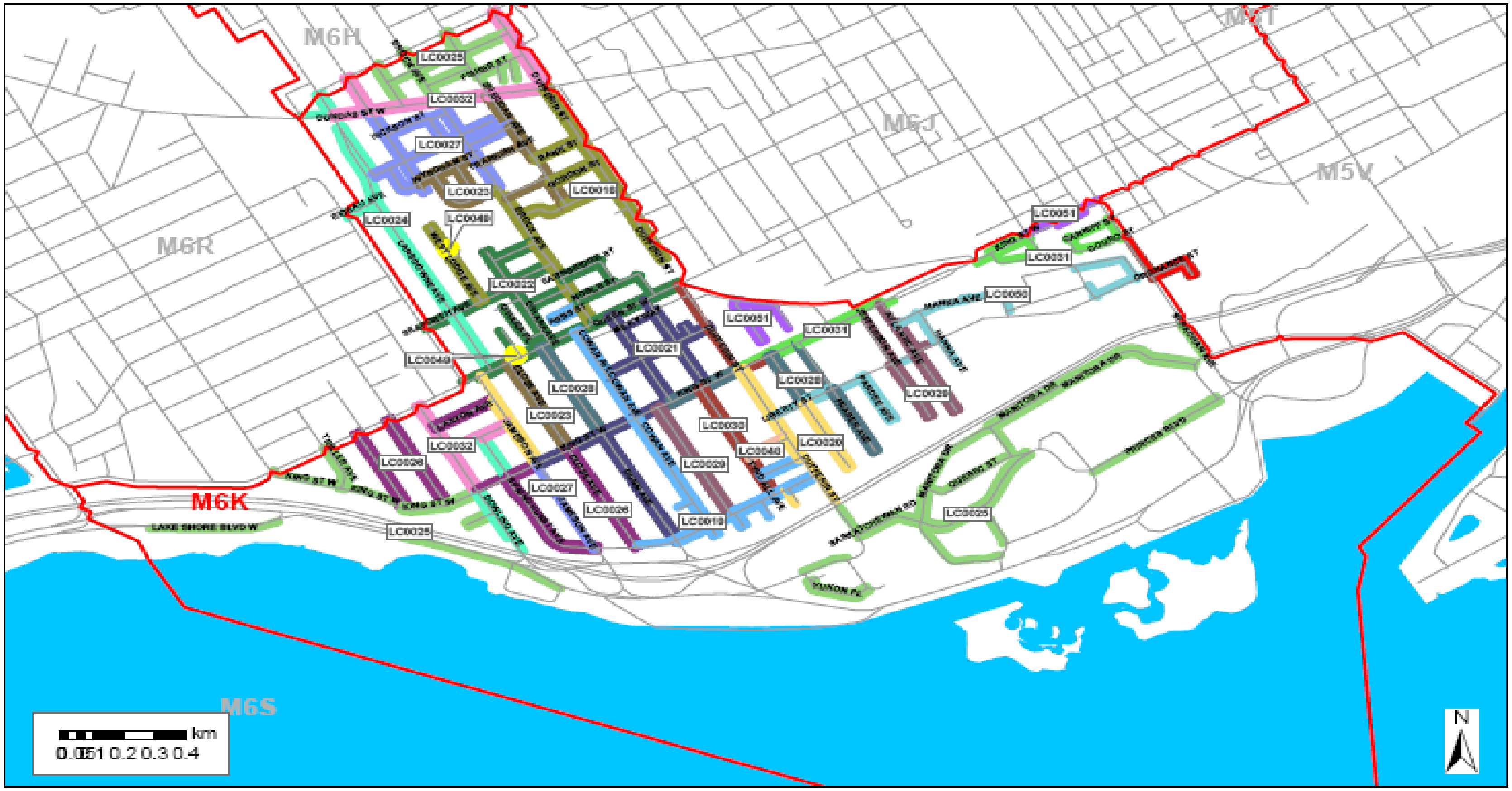
FSA/RTA: M6J

FSAs adjacent to / RTA's Adjacente à M6J: M6H, M6G, M5T, M5V, M6K

M6K Rest of the City of Toronto

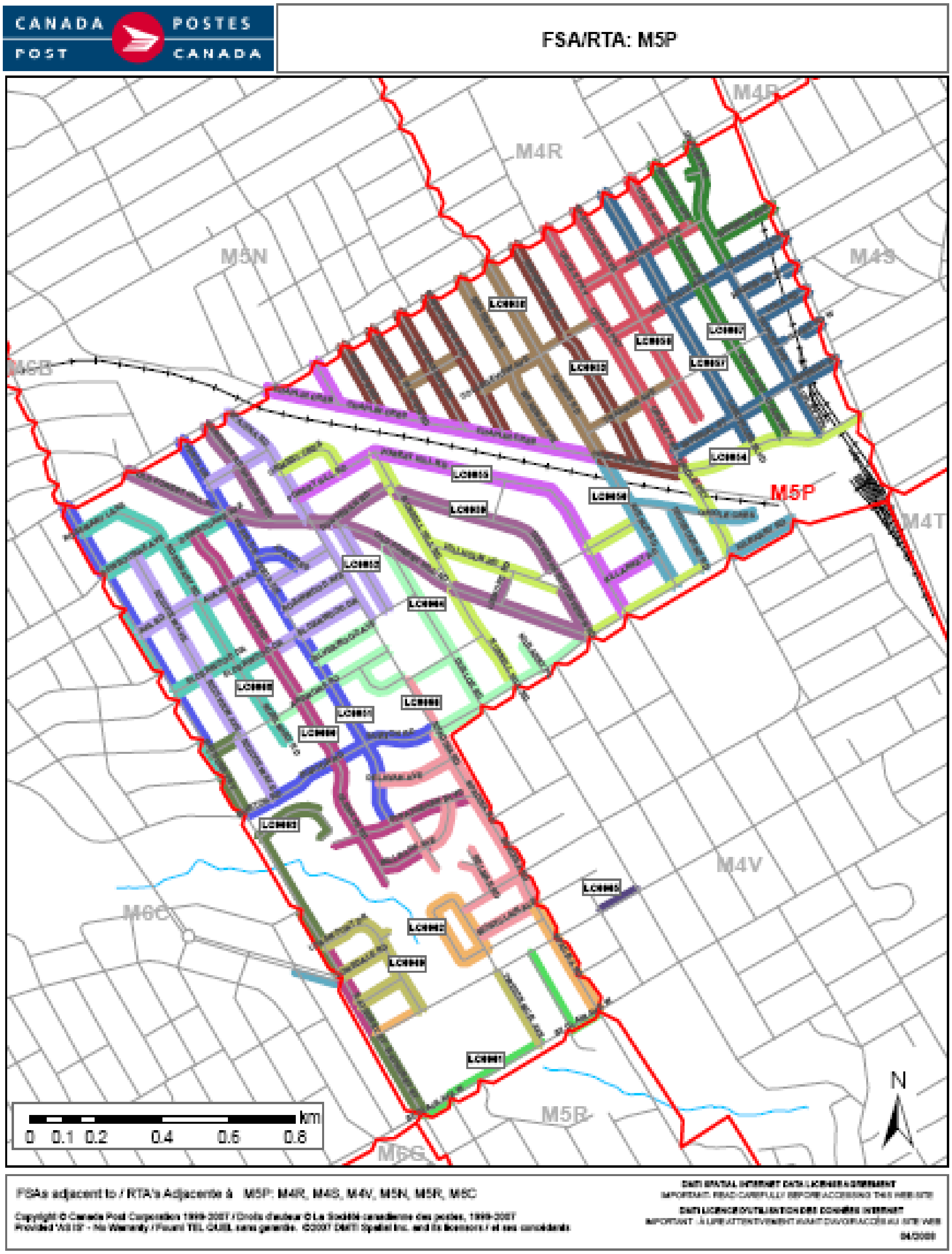
CANADA POST POSTES CANADA

FSA/RTA: M6K



FSAs adjacent to / RTA's Adjacente à M6K: M6H, M6J, M5V, M6S, M6R

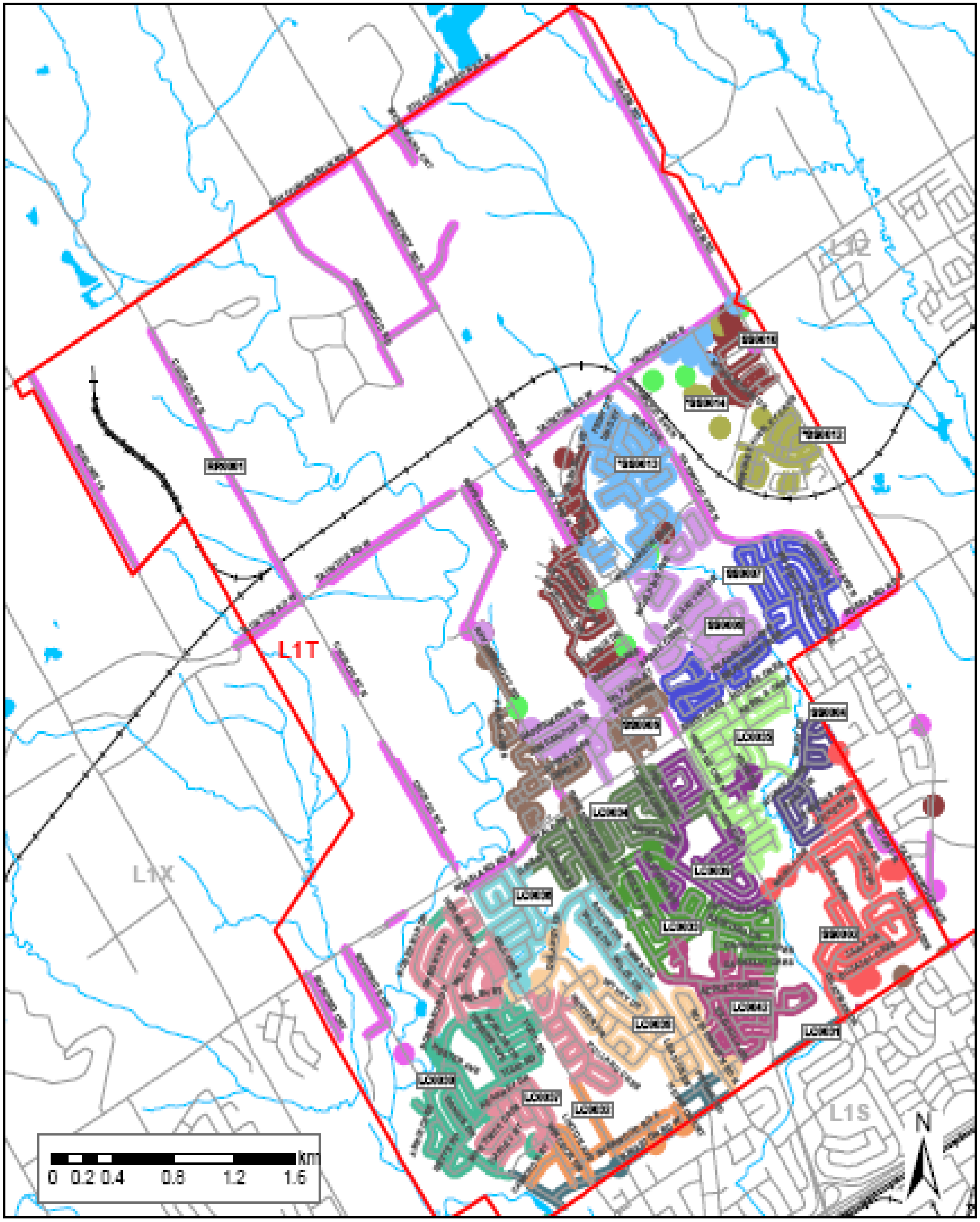
M5P Rest of the City of Toronto



L1T Durham

CANADA POST POSTES CANADA

FSA/RTA: L1T



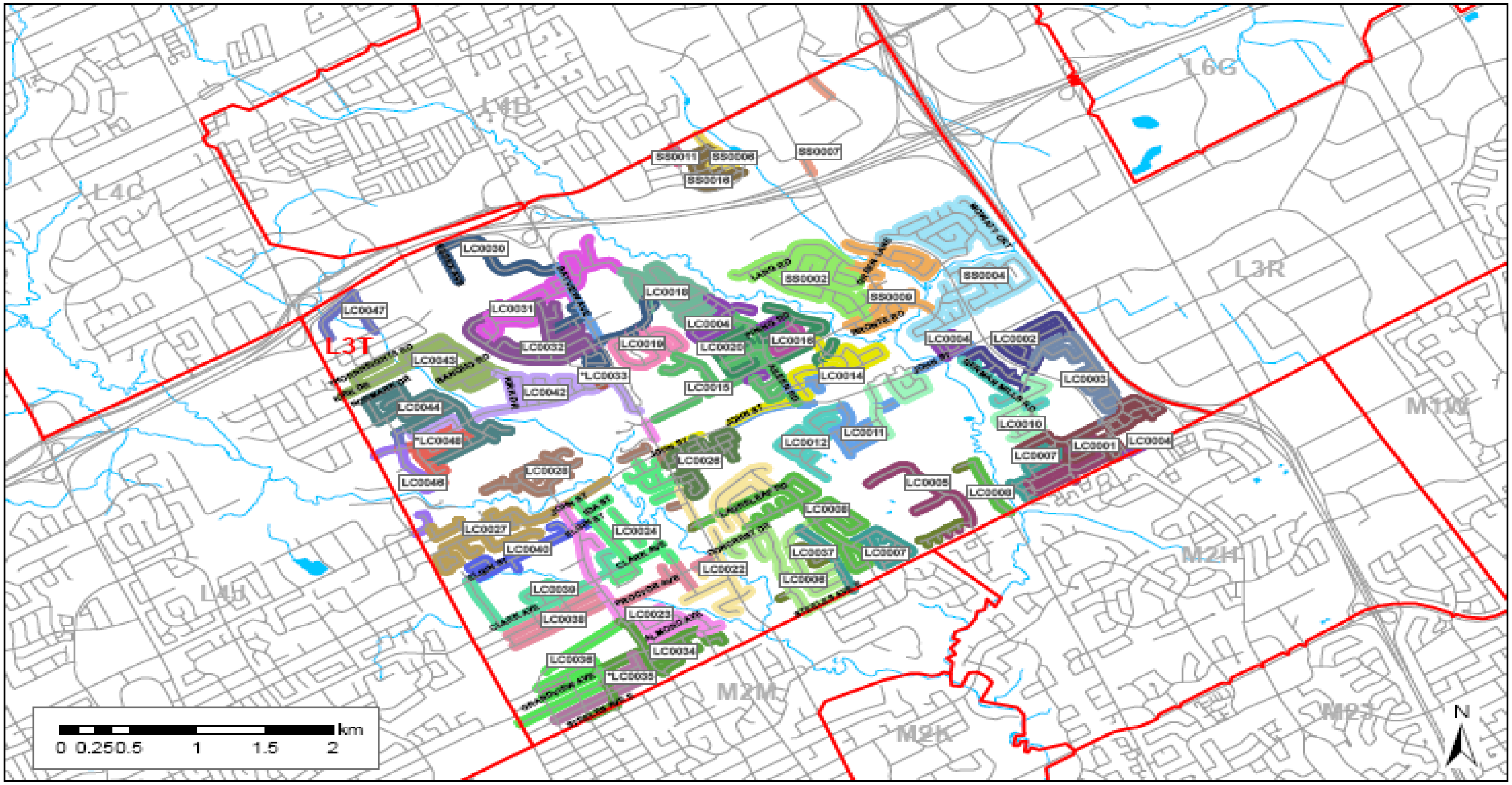
FSAs adjacent to / RTA's Adjacente à L1T: L1X, L1Z, L1S

05/2009

L3T York

CANADA POST POSTES CANADA

FSA/RTA: L3T

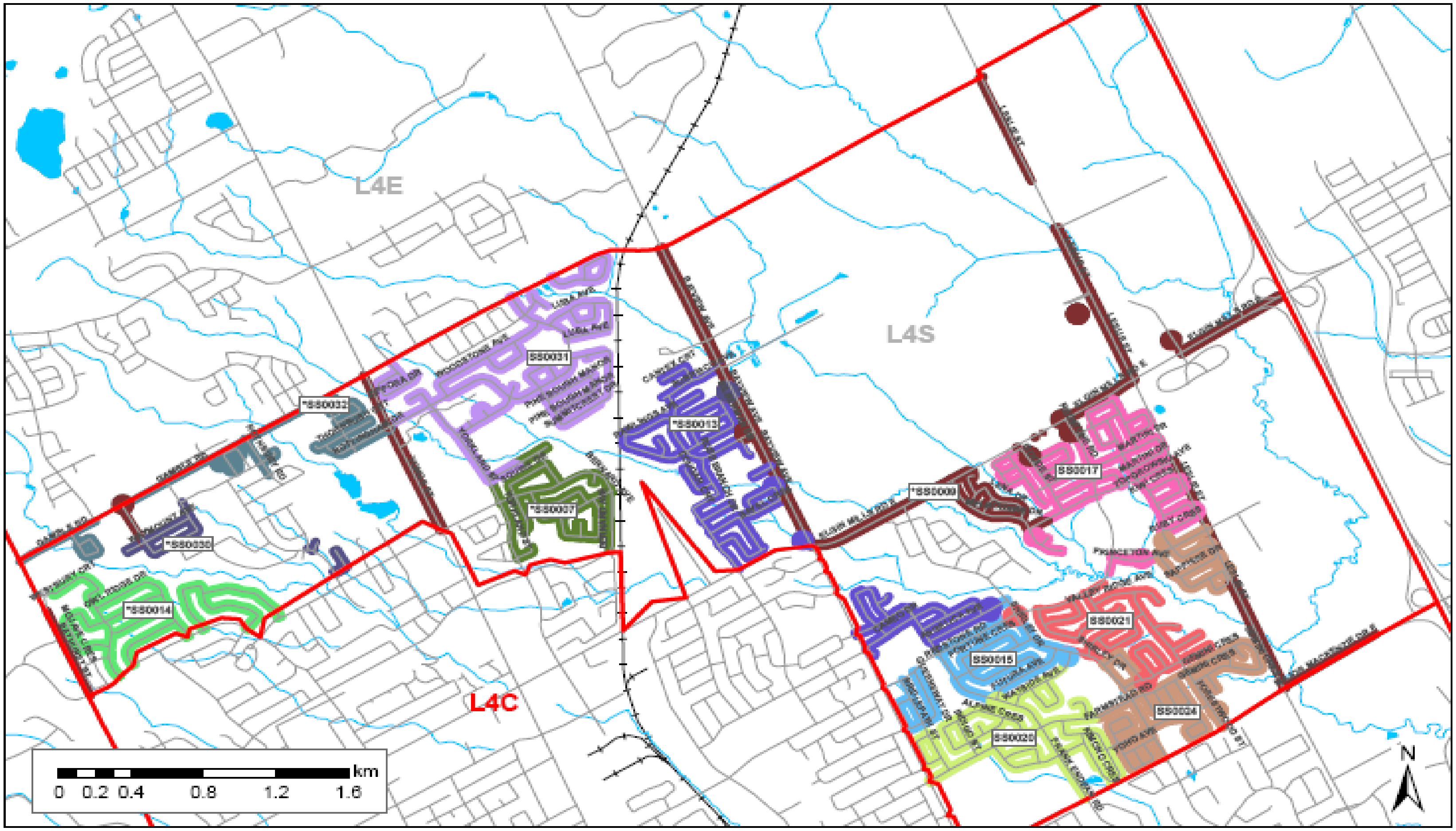


FSAs adjacent to / RTA's Adjacente à L3T: L4J, L4C, L4B, L3R, M2H, M2M

01/2008

L4S York

FSA/RTA: L4S



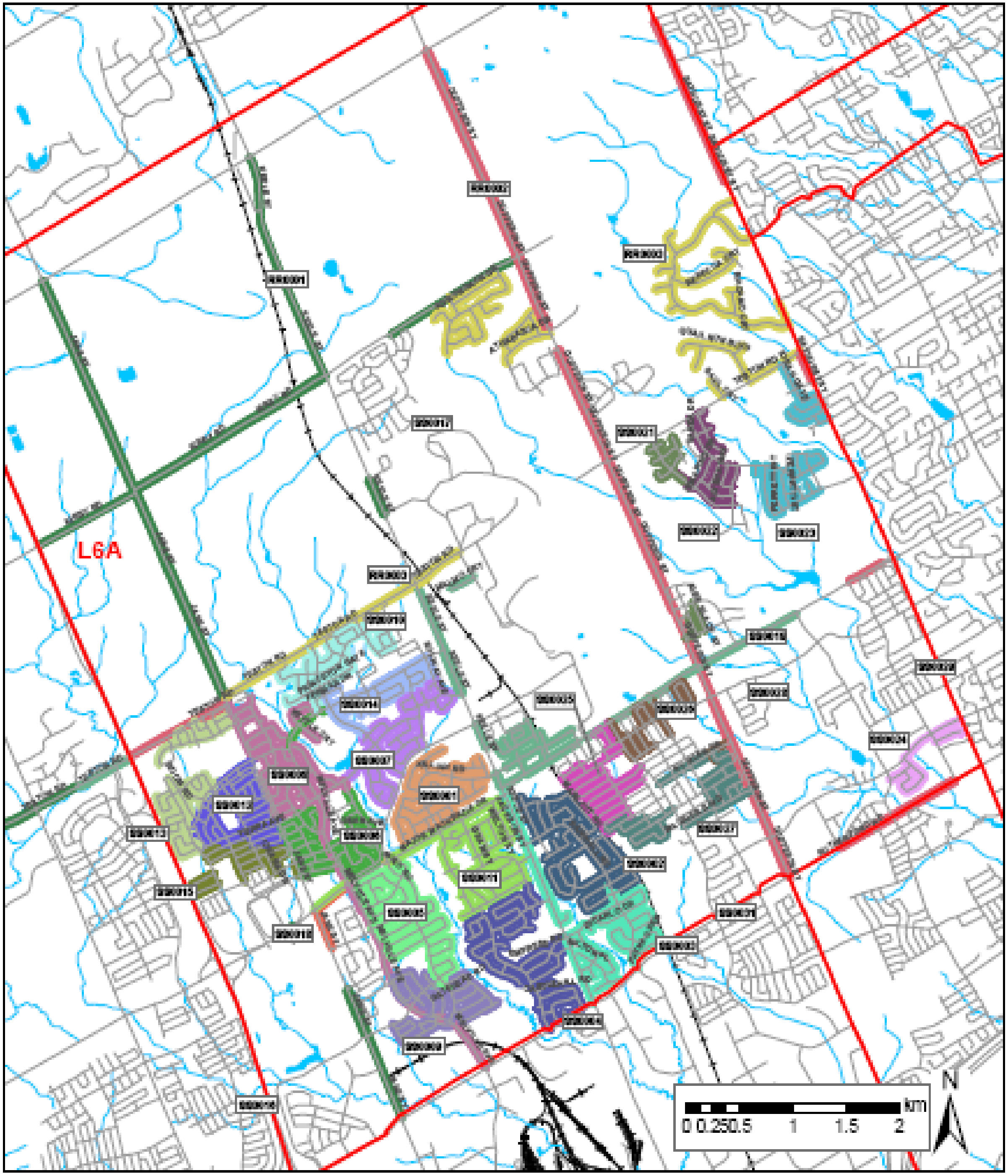
FSAs adjacent to / RTA's Adjacente à L4S: L4C,L6A,L4E,L6C,L4B

02/2010

L6A York

CANADA POST POSTES CANADA

FSA/RTA: L6A



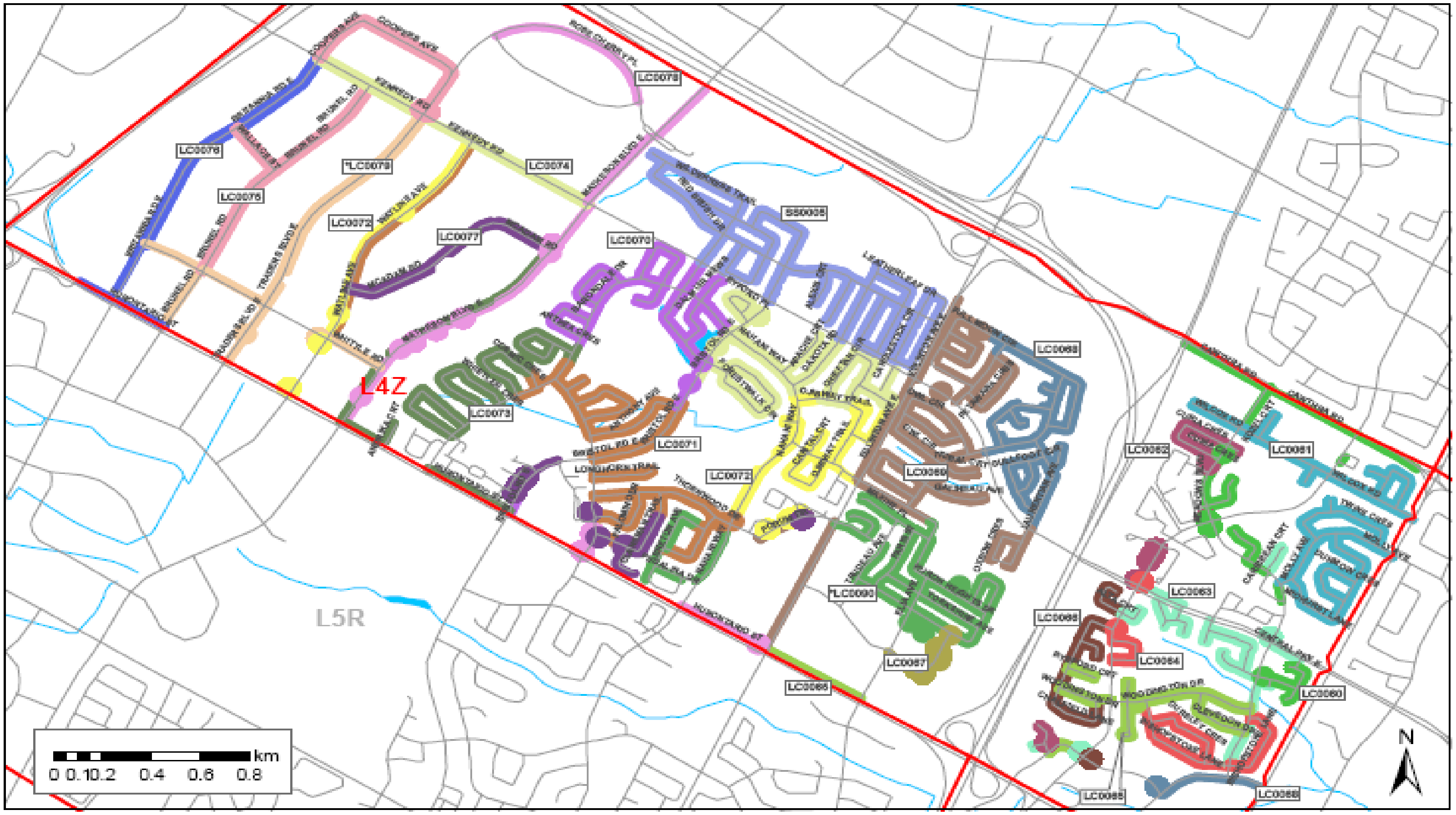
FSAs adjacent to / RTA's Adjacente à L6A: L4C, L4E, L4H, L4J, L4K, L4S, L7B

08/2010

L4Z Peel

CANADA POST POSTES CANADA

FSA/RTA: L4Z



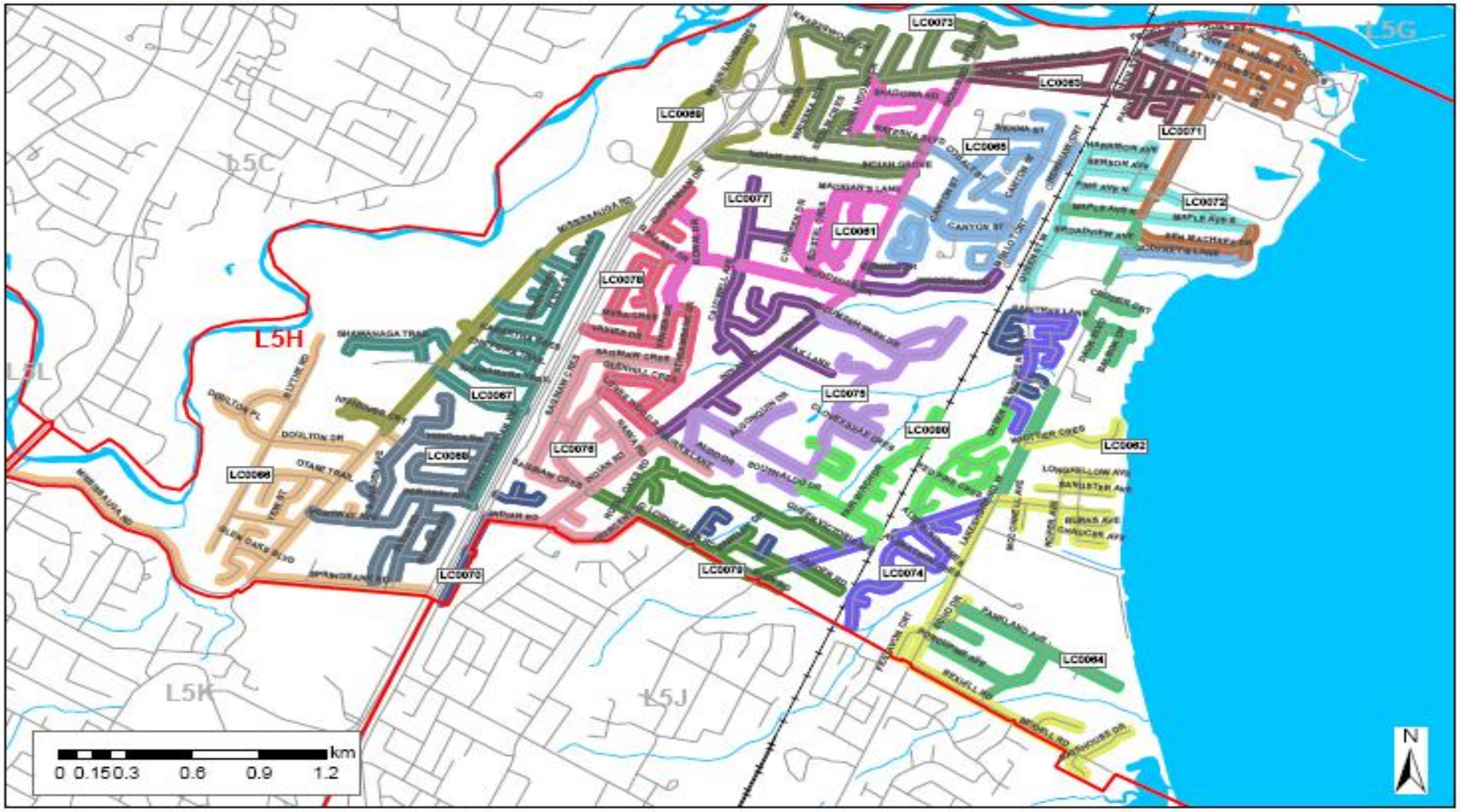
FSAs adjacent to / RTA's Adjacente à L4Z: L5T, L4W, L5A, L5B, L5R

06/2010

L5H Peel

CANADA POST POSTES CANADA

FSA/RTA: L5H



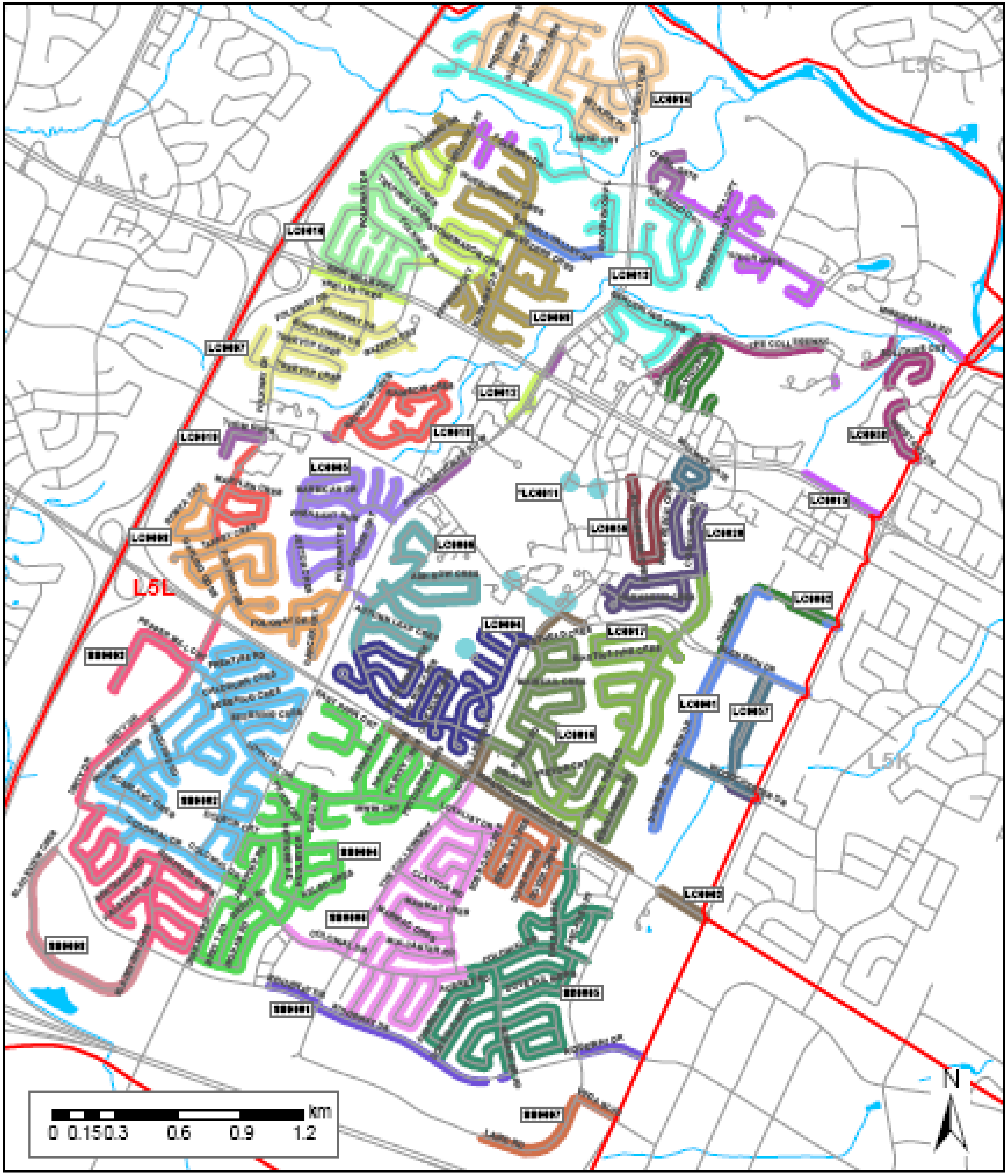
FSAs adjacent to / RTA's Adjacente à L5H: L5J, L5K, L5C, L5G

07/2009

L5L Peel

CANADA POST / POSTES CANADA

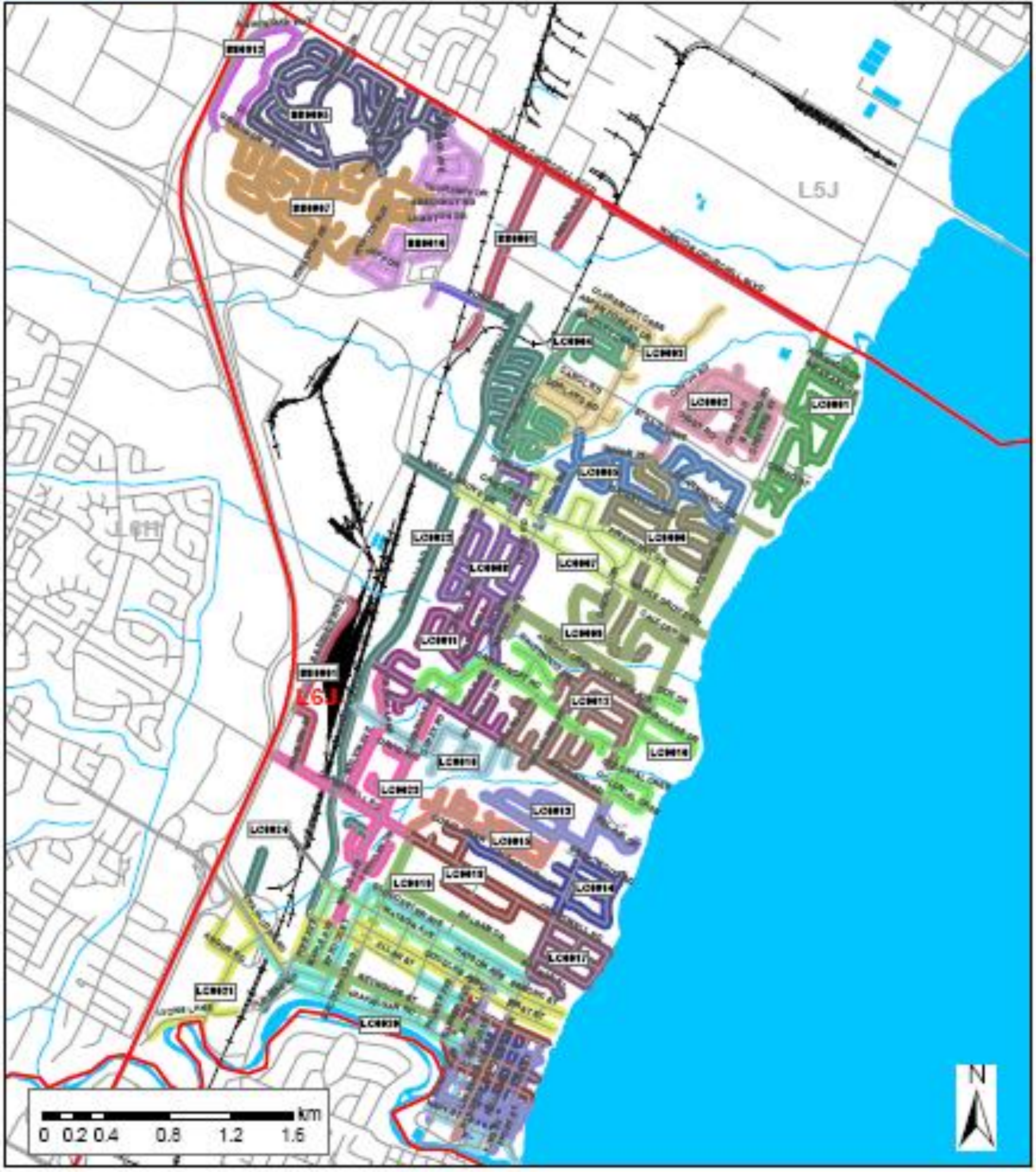
FSA/RTA: L5L



FSAs adjacent to / RTA's Adjacente à L5L: L5M, L5C, L5K, L6H, L5T

L6J Oakville

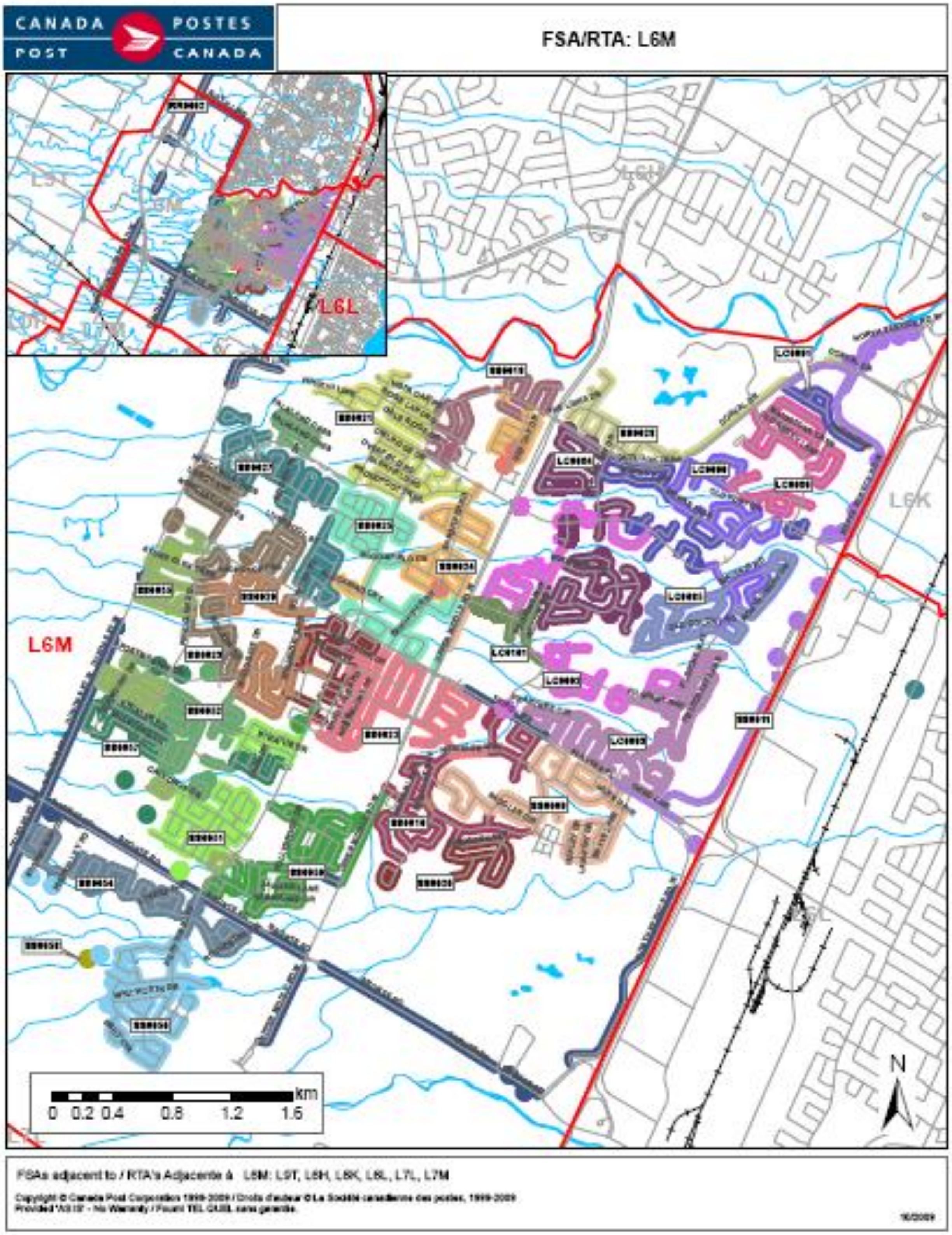
FSA/RTA: L6J



FSAs adjacent to / RTA's Adjacente à L6J: L6K, L6H, L5J

10/2009

L6M Oakville



Appendix B

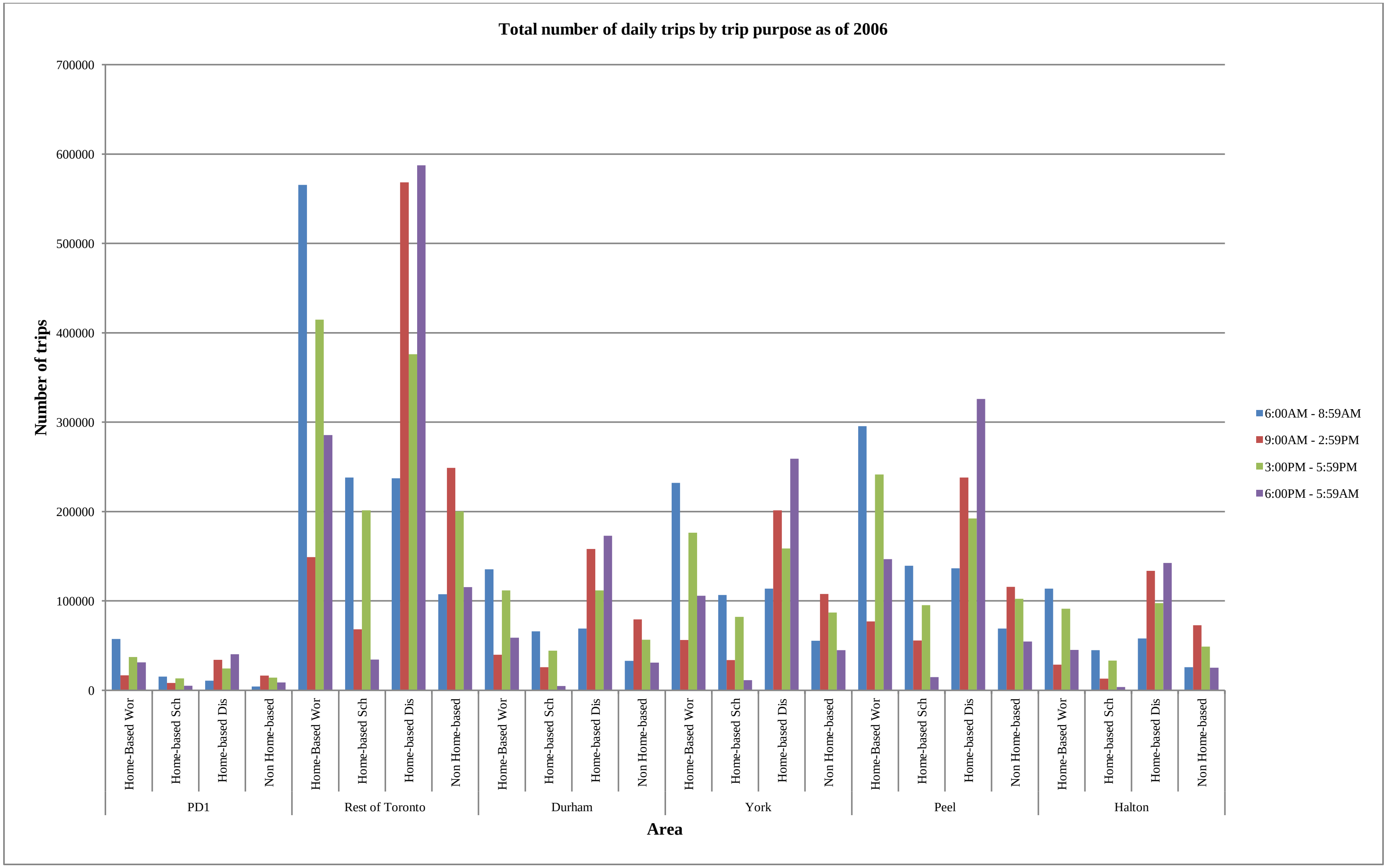


Figure B. 1**:** Distribution of trips by trip purpose across the GTA regions as of 2006

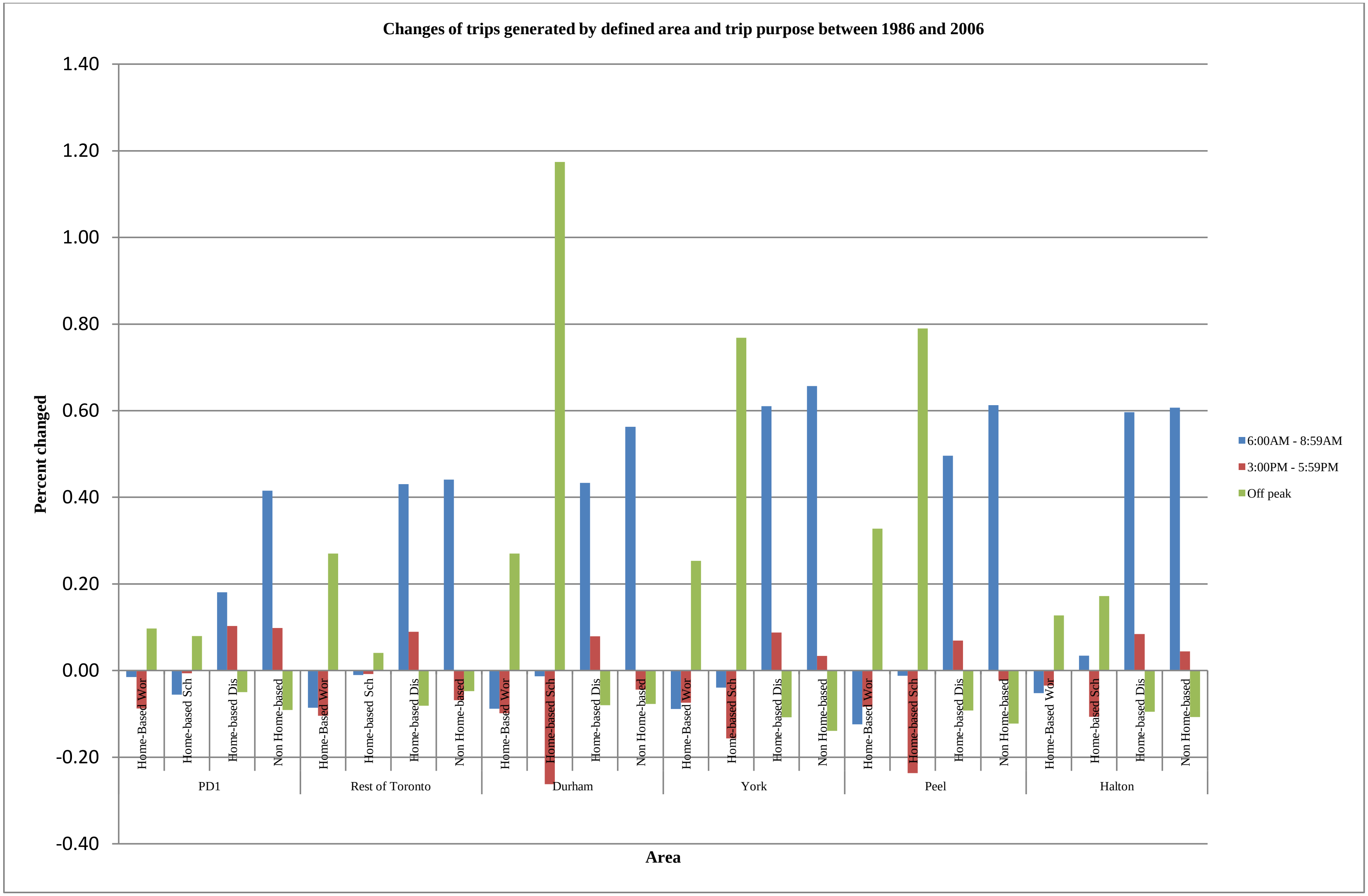


Figure B. 2: Changes occurred on the percentage of trips by trip purpose between 1986 and 2006

Table B. 1: Vehicle per capita and vehicle per household in the GTA by year.

Number of vehicles	Area	Vehicle per capita					Percentage of households				
		1986	1991	1996	2001	2006	1986	1991	1996	2001	2006
No vehicles	PD1	0.27	0.27	0.28	0.27	0.27	0.47	0.51	0.52	0.51	0.51
	Rest of Toronto	0.08	0.07	0.09	0.09	0.09	0.19	0.19	0.23	0.22	0.23
	Durham	0.02	0.02	0.02	0.02	0.02	0.05	0.04	0.06	0.06	0.06
	York	0.01	0.01	0.01	0.01	0.01	0.04	0.03	0.04	0.04	0.04
	Peel	0.02	0.02	0.02	0.02	0.02	0.05	0.05	0.07	0.06	0.06
	Halton	0.02	0.02	0.02	0.02	0.02	0.05	0.04	0.06	0.05	0.05
One vehicles	PD1	0.24	0.22	0.21	0.22	0.22	0.43	0.40	0.40	0.41	0.42
	Rest of Toronto	0.19	0.18	0.19	0.19	0.19	0.47	0.48	0.48	0.48	0.48
	Durham	0.12	0.11	0.12	0.12	0.12	0.37	0.33	0.35	0.34	0.33
	York	0.09	0.09	0.09	0.09	0.09	0.28	0.29	0.28	0.27	0.29
	Peel	0.12	0.11	0.12	0.12	0.12	0.37	0.35	0.37	0.36	0.37
	Halton	0.12	0.11	0.12	0.12	0.12	0.35	0.33	0.34	0.33	0.31
Two or more vehicles	PD1	0.06	0.05	0.04	0.04	0.04	0.11	0.09	0.08	0.08	0.08
	Rest of Toronto	0.14	0.13	0.11	0.12	0.11	0.34	0.33	0.29	0.30	0.29
	Durham	0.19	0.21	0.20	0.21	0.22	0.58	0.62	0.59	0.60	0.61
	York	0.21	0.21	0.21	0.22	0.21	0.68	0.68	0.67	0.69	0.66
	Peel	0.19	0.19	0.18	0.19	0.18	0.58	0.60	0.56	0.58	0.56
	Halton	0.21	0.22	0.22	0.23	0.24	0.60	0.63	0.60	0.62	0.64