The HOT Solution:

An Examination of the Desirability for High-Occupancy/Toll (HOT) Lanes in the Greater Toronto Area

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.

Jeremy Finkleman

ABSTRACT

This study assessed the desirability for High-Occupancy/Toll (HOT) lanes in the Greater Toronto Area (GTA) through stated preference and revealed traffic volume data gathering and analysis techniques.

4,000 surveys, distributed in five sample areas, asked respondents how much they would be willing to pay to escape congestion in eight unique trip conditions. Stated preference results found considerable public support for HOT-lanes in the GTA. In six out of eight trip conditions, a majority of respondents preferred to pay to travel in express lanes rather than endure congestion. Respondent willingness to pay (WTP) mean values varied considerably by trip condition.

Willingness to pay to escape congestion was influenced by trip characteristics and driver factors. Trip urgency, traffic speed, and freeway trip distance were found to be statistically significant trip characteristic indicators of WTP. Previous exposure to electronic tolling and annual household income were found to be significant driver factor indicators of WTP in most trip conditions. Respondent gender and freeway travel frequency were found to be statistically significant driver factor indicators of WTP in some trip conditions.

The presence of Hwy 407-ETR, an electronically tolled by-pass to Hwy 401, allowed for an examination of the effects of Hwy 401 volume and trip urgency on driver choice to use the tolled alternative. Results indicated that trip urgency and Hwy 401 volume were correlated with Hwy 407 throughput share. During periods of high trip urgency and high Hwy 401 volume, a substantial proportion of Hwy 401/407 corridor drivers chose to pay approximately $0.20/km to escape congestion.

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LIST OF ACRONYMS AND TERMS USED

400-series highways – Ontario Provincial limited access expressways

AADT – Annual Average Daily Traffic

BRT – Bus Rapid Transit

CTC – Census Tract Centroid

DVP – Don Valley Expressway

EPOI – Enhanced Points of Interest (GIS shapefile)

GDP – Gross Domestic Product

GHG – Greenhouse gas

GP Lane – General Purpose Lane

GTA – Greater Toronto Area

GTHA – Greater Toronto and Hamilton Area

HOT – High Occupancy/Toll

HOV – High Occupancy Vehicle

Hwy 407-ETR – Highway 407-Electronic Toll Route

ITS – Intelligent Transportation Systems

LOS – Level of Service

MnPASS – HOT-lanes along I-394 and I-35W in Minneapolis, MN

MTO – Ontario Ministry of Transportation

NJTP – New Jersey Turnpike

RTV – Revealed Traffic Volume (data gathering and analysis technique)

SOV – Single Occupant Vehicle

SP – Stated preference (data gathering and analysis technique)

VTTS – Value of Travel Time Savings

WTP – Willingness to Pay

1 INTRODUCTION

The Greater Toronto and Hamilton Area (GTHA) in Ontario, Canada suffers extensively from traffic congestion. In 2006, congestion cost commuters $3.3 billion and the economy a further $2.7 billion in lost GDP (The Big Move, 2008). Despite this, 2006 average GTHA peak-period auto occupancy was 1.2 persons per vehicle. With the metropolitan region expected to grow by 2.6 million residents by 2031, the situation will only worsen if commuting volumes grow commensurately. Provincial and Regional growth and transportation plans recognize that holistic paradigm shifts are required to curb worsening trends. Regional transportation goals have been re-conceptualized away from prioritizing auto-mobility and location-connectivity towards prioritizing person-mobility and activity-based connectivity (Places to Grow, 2006). A key objective in fulfilling this vision is improving the efficiency of the highway network by increasing overall person-throughput along the network.

Managing traffic flow allows transportation agencies to mitigate roadway demand in pursuit of pre-determined objectives. High-Occupancy/Toll (HOT) lanes are a lane management technique that combines elements of High Occupancy Vehicle (HOV) lanes and road pricing. HOT-lanes are market-managed highway facilities that parallel conventional unmanaged general purpose (GP)-lanes in a corridor. Typically, HOVs access HOT-lanes free of charge while single-occupant vehicles (SOVs) are required to pay congestion-dependent tolls for access. Satisfactory levels of service (LOS) are maintained through real-time tolling, providing HOT-lane drivers with a reliable driving experience. Although there are a number of HOT-lane facilities in the United States, HOT-lanes have not been planned or implemented in any Canadian city.

This study evaluates the desirability for HOT-lanes in the Greater Toronto Area (GTA). For the purpose of this thesis, desirability is defined broadly as general driver willingness to pay to use HOT-facilities to escape highway congestion. If results reveal high levels of driver willingness to pay to escape congestion, HOT-lanes could be considered as part of an overall solution to improve highway network efficiency in the GTA.

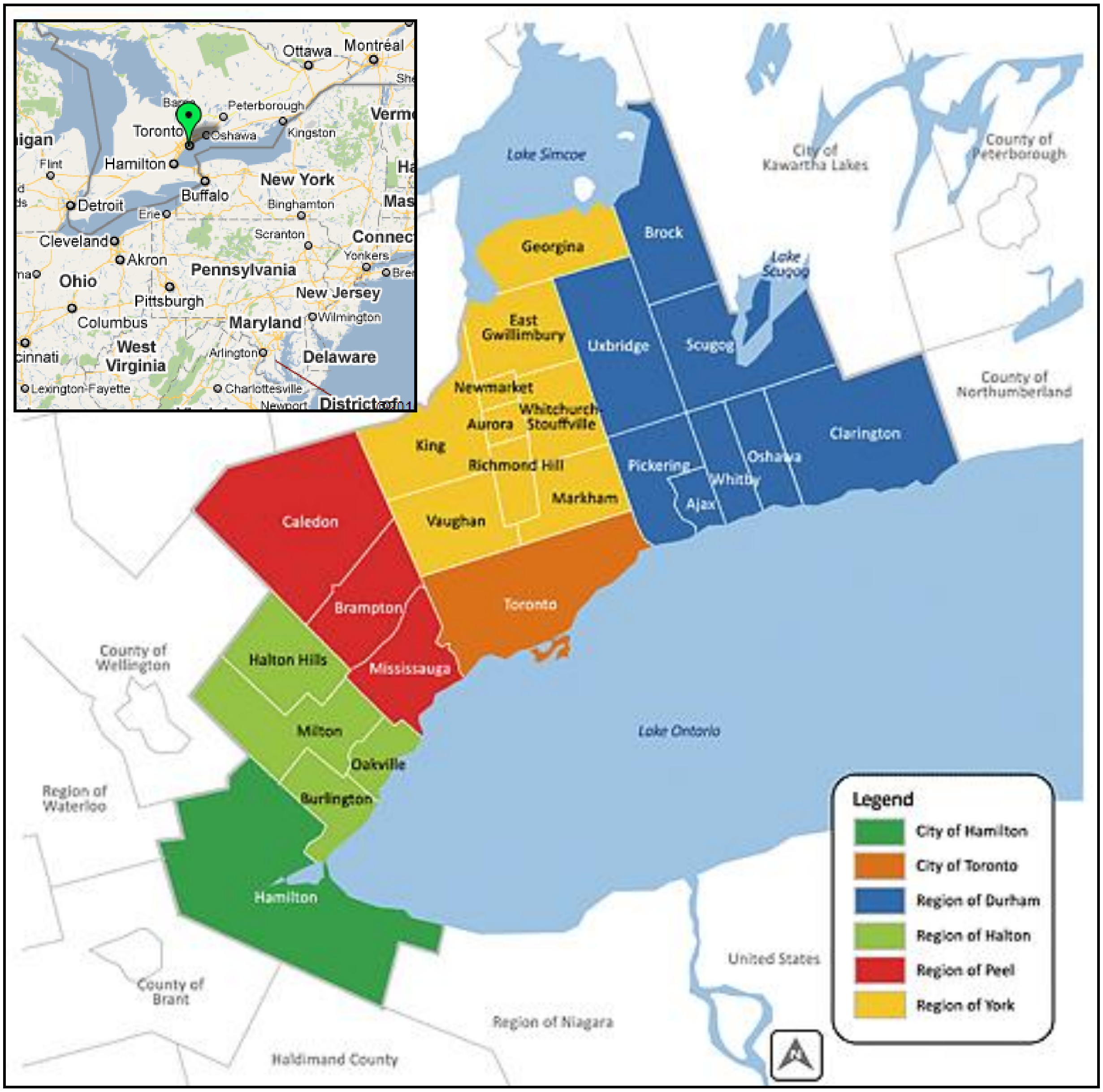


Figure 1.1: Location and composition of the Greater Toronto and Hamilton Area in Southern Ontario, Canada

Sources: The Big Move (2008), Google Map

1.1 *Research advancements*

This study advances the literature on HOT-lanes in 3 distinct ways:

1. Methodologically, by gathering conclusions from both stated preference surveys and revealed traffic volumes;
2. Through survey design, by orienting stated-preference questionnaires around traffic speed;
3. Geographically, by expanding the field of HOT-lanes research to Canada.

While post-implementation HOT-lane research has employed both stated preference and revealed preference methods of analysis, past willingness to pay (WTP) research in regions without HOT-lanes has been conducted exclusively with stated preference surveying. Although stated-preference surveys are a powerful research tool, there can be discrepancies between what a respondent indicates he will do under certain traffic conditions and what he actually chooses to do (see Brownstone and Small, 2005). General respondent unfamiliarity with HOT-lanes, road pricing and electronic tolling can also lead to varied responses. This study uses both stated preference surveys and revealed traffic volumes to investigate desirability for HOT-lanes. The GTA is a unique case study because of the presence of Hwy 407-ETR, a privately-owned and operated, electronically tolled expressway that functions in part as a bypass to the region's busiest roadway – Hwy 401. By comparing average hourly vehicle counts, this study assesses the effects of urgency and Hwy 401 volume on driver choice to use Hwy 407-ETR. The presence of Hwy 407-ETR also allows for an analysis of the effect of previous exposure to electronic tolling on willingness to pay to use HOT-facilities.

Most stated-preference research to date has been based on questionnaires that present the benefits of HOT-lane travel in terms of travel time savings (see Davis *et al*., 2009; Burris and Appiah, 2004; Burris and Xu, 2006; Brownstone and Small, 2005). As a result, the effect of traffic speed on willingness to pay to escape congestion is largely ignored in questionnaire design. It could be argued, however, that traffic speed is more apparent to drivers in real-time than potential travel time savings. Some drivers may have poor conceptions of time and may struggle to accurately estimate time savings. Moreover, varying speeds in GP-lanes make reasoned immediate calculations of travel time savings difficult. Speed, on the contrary, is a direct and tangible representation of highway congestion. The questionnaire used for this study employs situational questions to elicit responses. Respondents are presented with 8 different trip conditions with varying highway speed, trip urgency, and freeway-trip distance values. Relative speed is directly examined as a potential real-time indicator of willingness to pay to escape congestion.

While research has been conducted in a number of US jurisdictions, the applicability of HOT-lanes has not been extensively investigated outside the United States. Although the GTA is similar in a variety of ways to many American cities, it is unclear whether the Canadian public will support the concept of pay-per-use road pricing schemes. By examining the desirability for HOT-lanes in Greater Toronto, this study extends the reach of HOT-lane research beyond the United States and investigates the applicability of the concept in Canada.

1.2 *Study goal and key research questions*

The main goal of this study is to determine the desirability for HOT-lanes in the Greater Toronto Area through an analysis of stated preference survey results and revealed traffic volumes. In support of this goal, the following research questions will be examined:

From stated-preference survey data:

1. What proportion of Toronto-area drivers are willing to pay to escape congestion?
2. How do trip characteristics, including trip urgency, traffic speed, and freeway trip distance affect willingness to pay to escape congestion?
3. How do driver factors, including annual household income, respondent age, respondent gender, frequency of freeway travel, and previous exposure to electronic tolling/Hwy 407 exposure affect willingness to pay to escape congestion?
4. Do HOT-lanes accompanied by bus rapid transit (BRT) encourage transit use?
5. Do HOT-lanes encourage carpooling?
6. Do GTA residents want to see HOT-lanes implemented along major highways in the metropolitan area?

From revealed traffic volume data:

1. Under what trip conditions are GTA residents presently paying to escape congestion along Hwy 401 by using Hwy 407-ETR, an electronically-tolled by-pass corridor?

1.3 *Thesis organization*

This thesis is organized into six chapters, each with a number of sections and subsections.

Chapter 2 is a literature review of relevant past research. Chapter 3 introduces the GTA case context. Chapter 4 discusses the methodological choice to use both stated preference surveys and revealed traffic volume data to investigate HOT-lane desirability; the chapter then details the research and analysis methods used for both techniques. Chapter 5 presents the results of all stated preference and revealed traffic volume observations and statistical analyses. Finally, Chapter 6 discusses the key research findings and conclusions of the study. Appendices include a copy of the survey instrument, a thorough discussion of the site selection process and full statistical results.

2 LITERATURE REVIEW

This chapter is divided into three sections. Section 2.1 provides the conceptual grounding for HOT-lanes and describes the micro-economics of willingness to pay to escape congestion. This section explains how tolling can be used to maintain free flow conditions and maximize managed lane utilization. Section 2.2 examines trip characteristics and driver factors that affect HOT-lane use and includes a discussion of the equity implications of HOT-lane facilities. Section 2.3 discusses public perceptions of HOT-lanes and road pricing.

2.1 *High-Occupancy/Toll lane concept*

High-Occupancy/Toll (HOT) lanes are managed lanes that are designed to mitigate congestion and maximize utilization of road-space by charging single occupant vehicle (SOV) drivers congestion-dependent tolls. Road pricing in tolled facilities ensures predictable travel times and travel speeds for those willing to pay (WTP). HOT-lanes operate parallel to general purpose (GP) facilities along limited access freeways and generally provide reduced or free access to vehicles with higher occupancies.

HOT-lanes are a relatively new concept in transportation planning, having first been articulated by Fielding and Klein in 1993. Since then, the concept has been implemented on a number of roadways in the United States. As of August 2009, there were a total of nine HOT-lane corridors in six US states (see Table 2.1). A number of other corridors have been planned or proposed in other US jurisdictions. There are no Canadian examples of HOT-lanes nor are there serious proposals to construct HOT-facilities in Canada.

Table 2.1: HOT-lane facilities in the United States

State	Metropolitan region	Highway	Length of facility	Price per SOV (US$)	Incentive to carpool
California	San Diego	I-15	16 mi	\$0.50 - \$8.00	HOV +2 free
California	Los Angeles (Orange Co.)	SR-91	10 mi	\$1.30 - \$9.50	HOV +3 free. 50% discount M-F 4 – 6 PM for EB travel
Colorado	Denver	I-25	7 mi	\$0.50 - \$3.50	HOV +2 free
Florida	Miami	I-95	8 mi	\$0.25 - \$6.20	HOV +3, registered hybrid vehicles free
Minnesota	Minneapolis	I- 394; I-35 W	8 mi; 16 mi	\$0.25 - \$8.00	HOV +2 free
Texas	Houston	I-10/Katy Fwy; US290/NW Fwy	Unknown	SOV prohibited HOV-2 toll: \$2.00	Toll HOV-2 during peak, off-peak free. HOV+3 free.
Washington	Seattle	SR-167	12.5 mi	\$0.50 - \$9.00	HOV +2 free

Sources: Bhatt *et al*. (2009); SANDAG (2010); 91-Express Lanes (2010); Colorado DOT (2010); 95-Express (2010); MnPass (2010); Metropolitan Transit Authority of Harris County/Houston, TX (2010), Washington State DOT (2010)

2.1.1 HOT-lanes as a hybrid of HOV-lanes and road pricing

High-Occupancy/Toll lanes are a form of lane management that combines two traffic control techniques: (1) High-Occupancy Vehicle lanes and (2) road pricing.

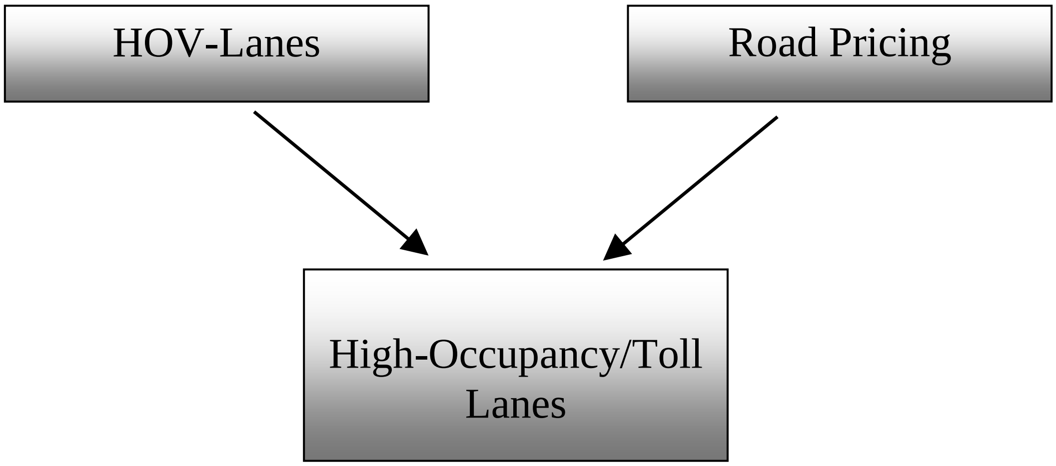


Figure 2.1: Lane management techniques

High Occupancy Vehicle lanes are designated and reserved for the particular use of buses, vanpools, and carpools. According to Henderson (2003), HOV-lanes have 6 primary goals and purposes. These include:

1. Encouraging higher occupancy modes;
2. Increasing highway-person carrying capacity;
3. Reducing total travel time;
4. Reducing the need to increase highway vehicle-carrying capacity;
5. Improving the efficiency and economy of public transit options;
6. Reducing vehicle fuel consumption.

Despite their merits, HOV-lanes have drawbacks. Facilities often operate below free-flow capacity resulting in under utilized lane-space. Moreover, carpooling as a mode share is decreasing in 36 of 40 major American cities resulting in situations where under-used HOV-lanes run parallel to slow moving and often heavily congested GP-lanes (Poole, 2002).

In conventional general purpose lanes, drivers are not charged for the delay and inconvenience they impose on other road users. By contrast, road pricing charges drivers congestion-dependent tolls for roadway access (Fielding and Klein, 1993). As with other commodities and scarce resources, congestion pricing allows highway travel to be bought and sold at market prices that relate directly to demand.

The economics underpinning road pricing can be represented graphically (see Figure 2.2). Supply should be viewed as a fixed quantity as it represents the static number of lane-kilometres available on a highway in a particular corridor. Demand to use the highway at a given time can be seen as a function of price. In Figure 2.2, D_1 represents average demand while D_2 and D_3 conceptually represent weekday demand at 4 AM and 4 PM respectively. As demand rises or falls from its average, the equilibrium price paid by the user to travel the highway increases or decreases in order to maintain free flow conditions and satisfactory levels of service (LOS).

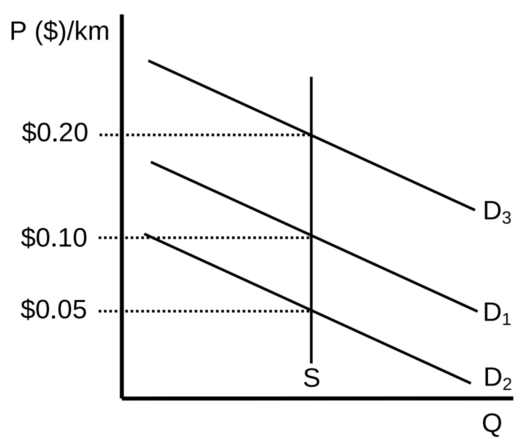


Figure 2.2: Economics of congestion pricing

Road pricing can improve highway flow by shifting demand for road access (Arnott *et al.*, 1990). Under conventional, untolled driving conditions, during peak periods, a large number of commuters leave their origins and travel to their destinations at the same time – putting vast strains on the highway network. Congestion-dependent tolls flatten demand, by influencing commuters' departure time decisions. Flow is spread out over longer periods, improving the efficiency of the roadway network. In Lee County, Florida the toll rates on two existing bridges were modified to provide discounts to drivers who travel in off-peak periods (see Figure 2.3). The implementation of variable pricing led to significant shifts in traffic (Casello *et al.*, 2005).

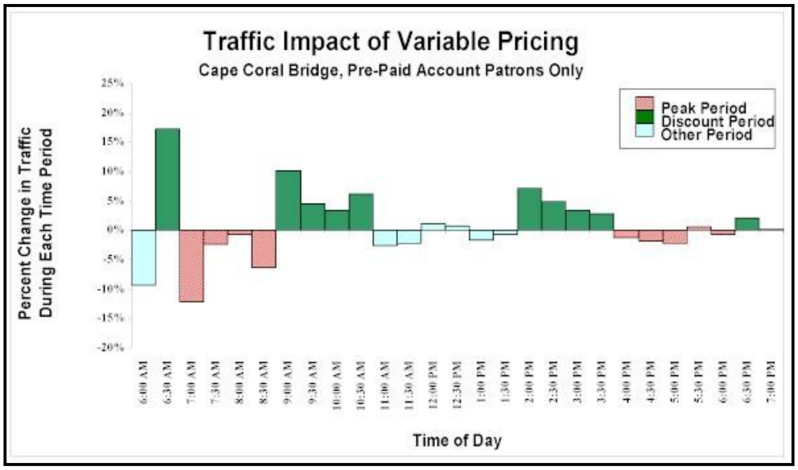


Figure 2.3: Impact of variable toll rates on traffic change, Cape Coral Bridge, FL
Source: Casello *et al.,* 2005

High levels of service in HOT lanes are maintained by combining aspects of HOV-lanes and road pricing. By ensuring high levels of speed and trip reliability, HOT-lanes offer an incentive to carpool while providing single occupant vehicle (SOV) drivers a choice to access premium express lane service should their value of travel time savings (VTTS) exceed the price of the toll. The following section discusses the micro-economics of HOT-lanes and the importance of driver VTTS to the concept.

2.1.2 **Driver Value of Travel Time Savings (VTTS) and the micro-economics of road pricing**

According to classical economic theory, consumers seek to maximize their utility by choosing the good or service from a number of discrete choice options that leads to the highest level of overall satisfaction. However, goods and services in and of themselves do not have utility; rather, goods have characteristics which give rise to utility (Lancaster, 1966). Individual consumers choose options or items that maximize characteristics they feel possess the greatest utility to them.

Travellers rarely derive utility from the trip itself; the trip is normally the result of a traveller's need to temporarily relocate to another area in order to engage in other activities such as work, shopping, and entertainment (Casello and Hellinga, 2008). As such, travel consumers should not be considered as typical utility maximizers, but rather as disutility minimizers. Theoretically, trip routings are chosen based on lowest generalized cost (time and out-of pocket expense) to consumers. Chorus, Arentze, and Timmermans (2008) expanded the discussion by introducing the concept of random-regret minimization to mode choice decisions. The authors asserted that travellers choose one mode or corridor over another in a bid to avoid or lessen negative emotions associated with travel. Individuals do not make their choices solely on the anticipated performance of a particular option but also on the anticipated performance of alternatives.

A significant component of travel disutility is represented by time spent on the road. As most travel is a result of derived demand, time spent in travel constitutes part of a traveller's total trip cost. As such, holding out-of pocket costs and all other variables constant, the shortest trip option is generally a traveller's best or preferred choice. As trip time is an important part of the overall generalized cost of travel, it can be attributed a dollar value.

Burris and Xu (2006) examined potential SOV demand for HOT lane-space during off-peak hours along I-10/Katy Freeway in Houston, TX. Stated preference surveys revealed that SOV drivers value travel time savings at approximately 45% of their hourly wage. Studies by Brownstone *et al*. (2003) and Brownstone and Small (2005) measured commuters' values of time and reliability in the SR-91 and I-15 HOT-lane corridors in Orange County and Metro San Diego, CA respectively. Revealed travel behaviour indicated high morning VTTS (US$20 - US$40 per hour) while stated preference findings indicated VTTS of less than half that amount.

VTTS and willingness to pay to use HOT-lanes are related measures. If an individual driver's VTTS exceeds the toll rate, the driver's disutility is minimized by using HOT-facilities (see Figure 2.4). On the contrary, if an individual driver's VTTS does not exceed the toll rate, the driver's disutility is minimized by avoiding HOT-facilities and instead driving in GP-lanes.

Whether or not to use tolled facilities:

If driver VTTS > Toll Rate → Use HOT-lanes
If driver VTTS < Toll Rate → Use GP-lanes

Figure 2.4: The relationship between driver VTTS and the toll rate

HOT-lanes are capable of functioning as a result of a range of driver VTTS that exists in any given corridor at any time. If all road users had equal VTTS, HOT-lanes could not effectively function as they would either be preferred (and chosen) by everybody or by nobody. A corridor's range of driver VTTS is influenced by trip characteristics and driver factors, which will be discussed in detail in Section 2.2.

2.1.3 Tolling: A market-based approach to traffic management

Traffic flow in HOT-lanes is managed by congestion-dependent tolls. Tolling is conducted by in-vehicle transponders and phantom toll booths which remove the need for staffed toll plazas and their associated queues. HOV-drivers avoid being tolled by either registering their vehicle beforehand or, as in the case of I-394 HOT-lanes in Minneapolis, MN by turning their transponder off (Halvorson *et al*., 2006). Toll rates are generally determined dynamically with the twin objectives of maintaining free flow conditions and maximizing vehicle throughput in the managed lanes.

Efficiency-maximizing dynamic tolls regulate flow in HOT-lanes. Driver choice to enter or exit HOT-facilities is informed by signage displaying the applicable toll rate. Dynamically derived toll rates correspond to HOT-facility traffic volumes. Halvorson *et al*. (2006) described the dynamic tolling process on I-394 MnPASS HOT-lanes in Minneapolis, MN. To maintain speeds of at least 50 – 55 mph, tolls are adjusted as frequently as every 3 minutes. Rates can range from a maximum of US$8.00/segment during high-peak periods to a minimum of US$0.25/segment during off-peak hours. Average tolls paid per trip range from US$0.51 – US$0.73/segment depending on the day of the week.

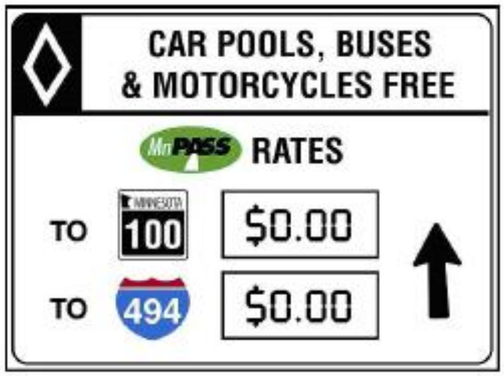


Figure 2.5: Example of an I-394 MnPASS sign displaying the posted toll rate
Source: Halvorson *et al*. (2006)

Besides maintaining free flow conditions and maximizing vehicle throughput in HOT-facilities, tolls can be specifically targeted to address strategic goals. In most HOT-facilities the strategic goal of increasing corridor person-throughput is encouraged by allowing HOVs and transit vehicles to travel free-of-charge in the managed lanes. More advanced forms of tolling can be implemented in pursuit of environmental, equity, or accessibility goals. Chu (2006) discussed how 10 US states have considered allowing single-occupant hybrid vehicles to use HOV- or HOT-facilities free of charge in order to encourage more environmentally sustainable vehicle purchases. Ochieng *et al.* (2008) demonstrated how policy objectives can be translated into charging indicators that can be calculated in real time on a per vehicle basis. In support of policy objectives, user charges can vary depending on geographic area, road class, distance of trip, time of day, pollutant emissions, driving behaviour, and traffic density.

Despite the technological ability to implement differential tolling rates in support of policy objectives, complex tolling arrangements are limited in a practical sense by the public's ability to internalize and respond to them. Bonsall *et al.* (2006) investigated the capability of British drivers to respond to congestion-, time of day- and road class-sensitive distance-based tolling. Findings indicated that individuals respond best to simple tolls but that complex pricing can be understood if logical.

2.1.4 **Why build HOT-lanes?**

HOT-lanes have been implemented, planned or proposed in a number of US jurisdictions because they are viewed as a solution to the under-utilization of HOV-lane space, as a way to improve overall corridor mobility, and as a source of revenue that can be used for roadway, transit, or other improvements (Chu *et al.*, 2007).

HOV-lanes often operate below free-flow capacity while neighbouring GP-lanes are congested and slow (Dahlgren, 1999). This situation can be difficult to remedy. While lane space may be underutilized in situations where an HOV is defined as a vehicle with three or more persons, lanes may become congested if HOV status is reduced to include two-person vehicle occupancies. This presents a basic problem for HOV-lanes: lane utilization cannot be maximized. By contrast, HOT-lanes are capable of maximizing lane throughput without reducing the LOS in managed facilities (Naik *et al.*, 2008). As a result of increased lane use, HOT-lanes are capable of drawing more traffic from GP-lanes, leading to improvements in traffic flow in all lanes.

HOT-facilities have been shown to improve the LOS in all lanes along a corridor. Vladisavljevic *et al.* (2008) found that converting HOV-lanes to low-tech HOT-lanes along I-15 in Salt Lake City, UT led to reductions in journey time for those using HOT-facilities and overall improved LOS for all I-15 drivers.

Moreover, person-throughput can be improved by providing bus rapid transit (BRT) along HOT-lane corridors. HOT-lanes provide reliable lane-space for high-capacity transit operations without requiring significant additional infrastructure costs for separate bus rights-of-way (Barker and Polzin, 2004).

Many industry leaders believe that existing sources of revenue are inadequate to tackle urgent transportation issues such as heavy highway congestion, crowding on transit vehicles, and declining reliability for both passengers and freight shippers (DeCorla-Souza, 2006). As a result, transportation agencies are increasingly considering innovative approaches such as road pricing and HOT-lanes as solutions to fund needed transportation improvements. HOT-lane-enabling legislation in Minnesota stipulates that fees collected from HOT-operations be used to repay in-full all capital and maintenance costs of HOT-facilities and that excess revenues be divided between capital road and bus transit improvements in the corridor (Halvorson *et al*., 2006).

It is necessary to note, however, that HOT-lanes do not generate substantial amounts of revenue. HOT-lane revenue depends on the overall level of congestion in the corridor, the number of lanes that are tolled, and the amount of vehicle class categories that are able to use the facilities free of charge. The expectation that tolls generated from HOT-lanes will entirely pay for their construction and annual operation costs depends on these factors as well as the capital construction costs of the facilities. Tolls generated from most HOV to HOT lane conversion projects cover HOT-lane operating costs, not capital costs (Goodin and Fuhs, 2009).

Of course the imperative for additional sources of revenue can at times be at odds with the objective of maximizing person-throughput. Although BRT and HOV-free travel in tolled express lanes can improve corridor-person-throughput, providing free access to these modes can decrease corridor SOV-mode share, in effect lowering aggregate revenue (DeCorla-Souza, 2005).

2.2 *Trip characteristics and driver factors that influence WTP to use HOT-Lanes*

Road travellers have a range of values of travel time savings (VTTS). As discussed in Section 2.1.2, individual non-HOV driver VTTS is correlated with willingness to pay (WTP) to use HOT-lanes. Driver VTTS is influenced by trip characteristics and driver factors. This section explores which trip characteristics and driver factors significantly affect VTTS and WTP.

2.2.1 **Trip characteristics that influence WTP**

Past research has indicated that trip characteristics can significantly affect driver willingness to pay to use managed facilities. Through stated preference surveys Senbil and Kitamura (2006) discovered that time pressure significantly affected commuter willingness to pay to travel on an Osaka, Japan, tolled expressway. Davis *et al*.'s (2009) stated preference survey of Indianapolis, IN drivers found trip purpose to be a key determinant of WTP; for work trips, travellers were willing to pay US$0.60 to save 10 minutes and US$0.26 to save 3 minutes, while for non-work trips travellers were willing to pay US$0.36 to save 10 minutes and US$0.14 to save 3 minutes (see Figure 2.6). These findings are backed by Li's (2001) analysis of SR-91 indicators which showed that home to leisure trips were 88% less likely to use HOT-lanes than home to work trips.

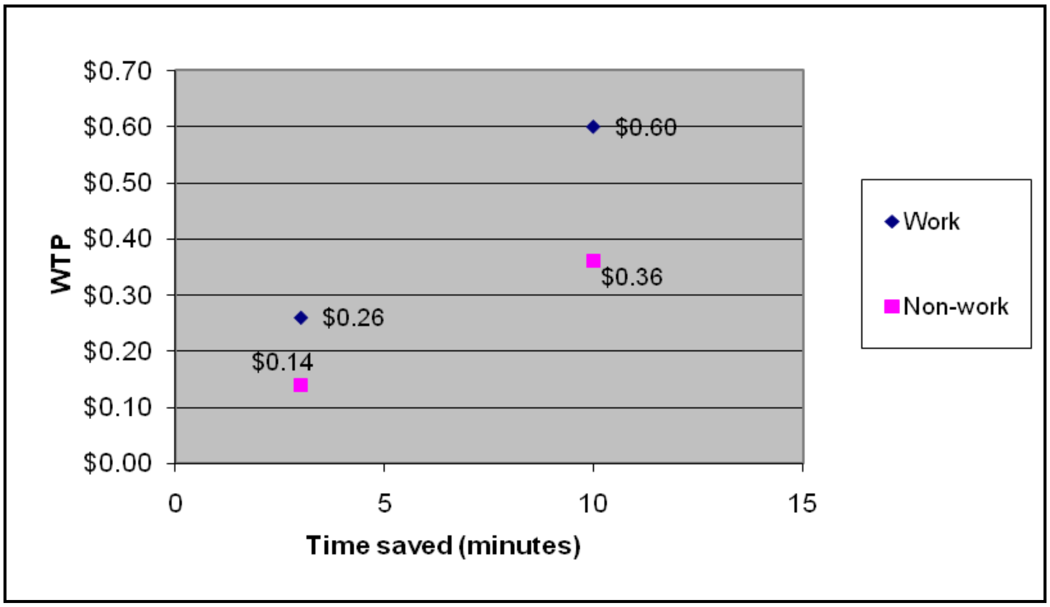


Figure 2.6: WTP/travel time saved among Indianapolis, IN drivers (US$)

Source: Davis *et al.* (2009)

Burris and Appiah (2004) analyzed HOT-lane program participation and usage rates for the I-10/Katy and US-290/Northwest freeway QuickRide facilities in Houston, TX. Houston's QuickRide HOT-operations are unique in that they entirely prohibit single occupant vehicles from using them. Instead, the program restricts peak-period free entry to HOV+3 while permitting HOV-2 to use the managed facilities for a US$2 toll. Findings indicated that total trip length, perceived time savings, trip purpose, and frequency of trips in the corridor affected QuickRide program participation rates.

Kaan *et al*. (2006) explored the impact of trip characteristics on VTTS and elasticity (responsiveness to toll changes) along the New Jersey Turnpike (NJTP). The NJTP presents an interesting case study due to its characteristics: it is a highly-urbanized travel corridor with high user-income levels and limited user-flexibility, where the possibility of shifting to a different mode of transportation or highway corridor is limited. Main findings from driver surveys indicated high VTTS (US$15 to US$20 per hour) and low driver elasticities to toll fluctuations (-0.06 to -0.18). Driver VTTS and elasticity were shown to be influenced by trip purpose, desired arrival time, travel time, toll rate, and driver income.

2.2.2 **Driver factors that influence WTP**

Ranges in WTP are not uniform for everyone in a metropolitan region. In addition to trip characteristics, research has shown that WTP is informed by socio-demographic and other driver factors.

Li (2001) conducted an extensive survey of SR-91 HOT-lane drivers to determine what factors influenced HOT-lane usage. Results indicated that household income and age were important determinants of HOT-lane use while gender, trip length, trip frequency, household size, and household type did not significantly affect use. Mastako *et al*.'s (1998) survey of SR-91 users found that household income significantly influenced HOT-lane use among two-occupant vehicle commuters, while household type significantly influenced HOT-lane use among SOV commuters.

Reinforcing these findings, Davis *et al*.'s (2009) stated preference analysis in Indianapolis also found income and age to be significant indicators of driver willingness to pay. Beyond that, Davis *et al*. identified transit usage and driver perceptions of congestion as significant WTP indicators. Burris and Appiah's (2004) analysis of QuickRide participation and usage in Houston found that traveller age, household type, and education had significant effects on QuickRide project participation rates while household size, occupation, and hourly wage did not exhibit significant effects.

To summarize, willingness to use HOT-lanes is influenced by trip characteristics and driver factors. Past research has indicated that time pressure, trip purpose, trip length, and perceived time savings are trip characteristics that significantly affect driver willingness to use HOT-facilities. Income, age, transit usage, household type, education level, and frequency of travel in the corridor are driver factors that significantly affect willingness to use HOT-facilities.

2.2.3 **Equity issues and HOT-lanes**

The innate fairness of HOT-lanes is a subject of considerable discussion in the literature. As revealed in the previous section, driver income has repeatedly been found to be a key indicator of HOT-lane use. Despite this, the literature recognizes that HOT-operations are not necessarily inequitable due to their ability to provide incentives to carpoolers, function as efficient corridors for BRT, improve flow in all lanes, and act as a funding source for public transit (see Baker *et al.*, 2008, Levine and Garb, 2002). Mowday (2006) argued that from the perspective of horizontal equity, HOT-lanes are more equitable than other forms of road funding as those who choose to use the facilities pay directly for their construction and upkeep.

To remedy equity concerns, innovative approaches to pricing can be employed to reduce purchasing power disparities. Complex derived tolls could incorporate driver income, vehicle type, or fuel efficiency. Transportation agencies in Atlanta, GA have suggested a unique approach involving commuter credits for proposed HOT-lanes along I-85/Northwest Expressway. The program would reward positive driving practices by allowing participants to accrue credits for driving during off-peak hours or in GP-lanes. Credits could then be redeemed for free HOT-lane trips when desired (Rountree *et al.*, 2008).

Equity issues, however, are not unique to HOT-lanes or other tolled facilities. Conventional revenue generating schemes can also have wide-scale negative consequences for equity.

Schweitzer and Taylor (2007) contrasted the equity aspects of sales-tax-based road funding with HOT-operations. The cost-burden of SR-91 HOT-lanes was compared to Orange County's local transportation sales tax. SR-91 HOT-lane user profile data and Consumer Expenditure Survey information were used to model expenditures by income group. Findings indicated that the sales tax scheme redistributed as much as US$26 million from less affluent to more affluent residents in order to fund road construction. Zhang and McMullen's (2008) exploratory analysis of universal distance-based pricing in Oregon compared the equity impacts of the proposed funding system with Oregon's current gas tax road funding structure. Findings revealed universal distance-based road funding to be slightly more regressive than the gas tax. Despite this, the paper noted that these disparities could be addressed with differential pricing based on fuel efficiency, vehicle type, level of congestion, location, and/or income. Clearly, equity concerns inherent to HOT-lanes need to be assessed holistically with an adequate perspective of the equity drawbacks of other funding models.

2.3 *Public perceptions of HOT-lanes and road pricing*

One of the greatest barriers to HOT-lane implementation is initial public apprehension. Opposition typically focuses around several core themes: equity for low-income drivers, spatial distribution of toll burdens and benefits, privacy concerns related to electronic toll collection, and claims of "double taxation" for highway infrastructure (Ungemah and Collier, 2007).

Public perceptions of HOT-lanes can change dramatically with driver exposure to tolled facilities and/or effective public advocacy. Ungemah and Collier (2007) discussed the results of several San Diego-area HOT-lane public approval studies. Following the implementation of a sticker-based, fixed-monthly priced program for SOV access to HOV facilities along I-15, corridor drivers were asked whether they would support converting the facilities to full HOT-lanes with electronic, pay-per-use tolling. At that point, corridor drivers expressed some reservations about the planned switch to per-use tolling. In 2001, a subsequent survey was taken after the full implementation of HOT-facilities in the corridor which revealed dramatically different results.

Polling employed a variety of methods including focus groups, intercept and telephone surveying, and stakeholder interviews. Findings revealed that:

- 66% of respondents approved of the I-15 HOT-lanes program;
- At least 60% of respondents from all income groups approved of the concept;
- The majority of respondents had no philosophical or practical objection to the concept (Ungemah and Collier, 2007).

Despite studies that show general satisfaction with managed lanes post-implementation, a certain level of public support is required at earlier stages to ensure that projects are politically feasible. Ungemah and Collier (2007) noted that public support for managed lanes can be bolstered by marketing individual driver reliability benefits, improvements to the HOV and transit network, and overall system improvements. Moreover, the support of high-profile politicians and grass-roots coalitions can help in convincing key decision makers to move-ahead on HOT-lane projects.

2.4 *Summary*

This chapter described the HOT-lanes concept, outlined the micro-economics of VTTS and dynamic tolling, examined how VTTS and WTP for HOT-lanes are affected by trip characteristics and driver factors, and briefly discussed equity and public perceptions of HOT-facilities.

3 CASE CONTEXT

The Greater Toronto Area (GTA) is the largest metropolitan region in Canada. It consists of the City of Toronto and the surrounding regional municipalities of Durham, York, Peel, and Halton. Currently the GTA and nearby Hamilton have a population of over 6 million residents; this number is expected to reach 8.6 million by 2031 (The Big Move, 2008).

The region has an extensive multi-modal transportation network. Public transit is operated by eight separate agencies and includes commuter rail and long-range bus routes, three subway corridors, and a multitude of local streetcar lines and bus routes. The GTA also has the busiest and most extensive freeway network in Canada comprised of both provincially funded and operated 400-series highways and municipal expressways. Highway 401, the GTA's principle expressway, is North America's busiest freeway. In 2006 it had an annual average daily traffic (AADT) count of 367,100 vehicles between Bathurst St. and W. R. Allen Rd (MTO, 2006).

The GTA is unique in that it is served by the only private, electronically-tolled highway in the country. Hwy 407-ETR serves the GTA's auto-oriented northern suburbs and functions as a by-pass to Hwy 401 (see Figure 3.1). Tolling is conducted at access points by electronic transponders or video imaging. Toll rates vary based on distance travelled, time-of-day, and vehicle class. Toll rates are not prominently displayed along the highway or at access points from other roadways but are available online. February 2010 light vehicle toll rates are presented in Table 3.1.

Table 3.1: Hwy 407-ETR toll rates, February 2010

	Transponder recorded	**Video recorded**
Regular Zone Peak Rate *Weekdays 6 AM – 10 AM, 3 PM – 7 PM*	$0.2135 / km	$0.2135 / km
Light Zone Peak Rate *Weekdays 6 AM – 10 AM, 3 PM – 7 PM*	$0.2010 / km	$0.2010 / km
Off-Peak Rate *Weekdays 10 AM – 3 PM, 7 PM – 6 AM,* *Weekends & Holidays*	$0.1835 / km	$0.1835 / km
Monthly Transponder Lease	$2.50	$0.00
Annual Transponder Lease	$21.50	$0.00
Monthly Account Fee	$0.00	$2.50
Video Toll Charge	$0.00	$3.60 per trip
Trip toll charge	$0.40 per trip	$0.40 per trip
A $50.00 FLAT TOLL CHARGE PER TRIP is billed to any light vehicles without a transponder whose rear licence plate is not visible to, or recognizable by the toll system.		

Source: 407-ETR

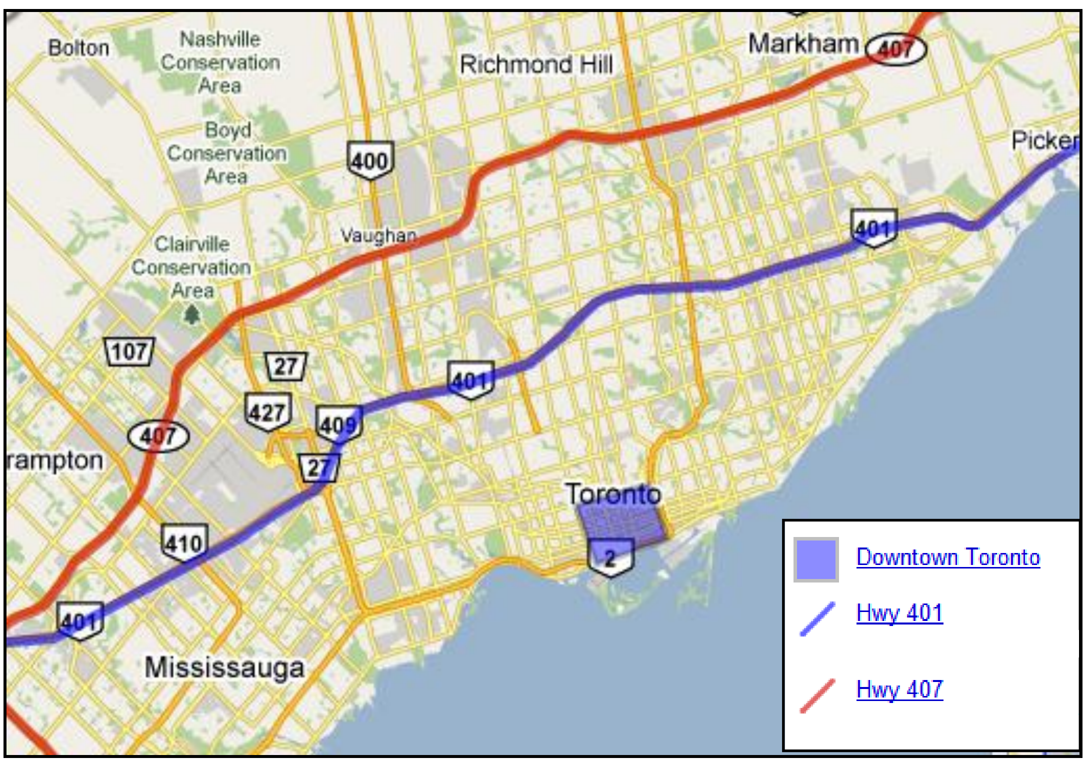


Figure 3.1: Location of Hwy 401, Hwy 407, and Downtown Toronto

Source: Google Maps

3.1 *Traffic congestion and auto-dependence in the GTA*

The GTA is the fourth most congested urban region in North America (The Big Move, 2008). Traffic congestion costs GTA and Hamilton commuters $3.3 billion annually; it costs the economy a further $2.7 billion in lost GDP per year. If current trends continue, by 2031 the projected cost of congestion is forecasted to be $7.8 billion and $7.2 billion to commuters and the economy, respectively (The Big Move, 2008). Congestion undermines Greater Toronto's regional competitiveness and results in late arrivals to work, delayed delivery of goods, and increased driver stress. Congestion increases commuting time by an average of 32% compared to free-flow conditions.

Conventional road-funding techniques are not structured to transfer the cost of travel choices to the commuter. Roadway commuters have little financial incentive to carpool or travel in off-peak periods. This results in the inefficient use of existing highway facilities. Average GTA and Hamilton peak-period occupancy is a mere 1.2 persons per vehicle – a significant waste of energy and road-space. In essence, much of the GTA's scarce roadway space is being misallocated to transporting empty seats (The Big Move, 2008).

Although the City of Toronto has a varied transportation mode share, the GTA as a whole is predominantly auto-centric (see Table 3.2). While the GTA's SOV mode share is comparatively low by North American standards, SOV trips still account for nearly two-thirds of all work-bound travel. Furthermore, past trends indicate that automobile reliance in the region is increasing. Over the past 20 years, total GTA and Hamilton car trips grew by 56% while the population increased by 45% (The Big Move, 2008). Auto-dependence is strongly connected to land-use and development patterns. Separation of land-uses, low-density housing, and superblock-based neighbourhood units – elements that discourage non-auto forms of transportation – are common to much of the metropolitan region.

Table 3.2: 2006 mode of transportation to work in the City of Toronto and the GTA

	City of Toronto	GTA (Toronto CMA)
Car, truck, van, as driver	49%	64%
Car, truck, van, as passenger	6%	7%
Public transit	34%	22%
Walked or bicycled	9%	6%
All other modes	1%	1%

Source: Canada Census 2006

3.2 *Policy and planning framework*

Places to Grow (2006), the *HOV-Lanes Plan* (2007), and *The Big Move* (2008) are wide-ranging provincial and regional plans that aim to curtail prevailing trends in transportation and improve overall accessibility. With regard to transportation, these policy initiatives involve a paradigm shift away from prioritizing the movement of vehicles and towards prioritizing person-connectivity. Two of the three plans commit the region to highway network lane management as a means to improve person-throughput and reduce congestion along GTA highways. Each plan is discussed here.

Places to Grow (2006), the GTA and surrounding area's legislated land-use policy document, seeks to decrease trip length and promote public transit by encouraging nodal, mixed-use, and dense development in designated urban growth areas and along public transit corridors. Transportation will be planned and managed to, amongst other goals:

- Offer transportation choice;
- Provide multi-modal access to jobs, housing and schools;
- Provide connectivity; and
- Prioritize other forms of transportation over SOV mobility

The Ontario Ministry of Transportation's (MTO) *HOV-Lanes Plan* (2007) calls for the development of 450 new HOV-lane-kilometres along GTA 400-series highways over the next 25 years. The Plan stipulates that HOV-lanes be constructed as new facilities, that they be considered for any new highway corridor, and that they be defined as HOV+2. As shown in

Figure 3.2, when fully built-out, HOV-lanes will be present on all major 400-series approaches to the City of Toronto. HOV-lanes, however, are not proposed for some of the busiest 400-series sections including the City of Toronto portions of Highways 401, 400, and 427.

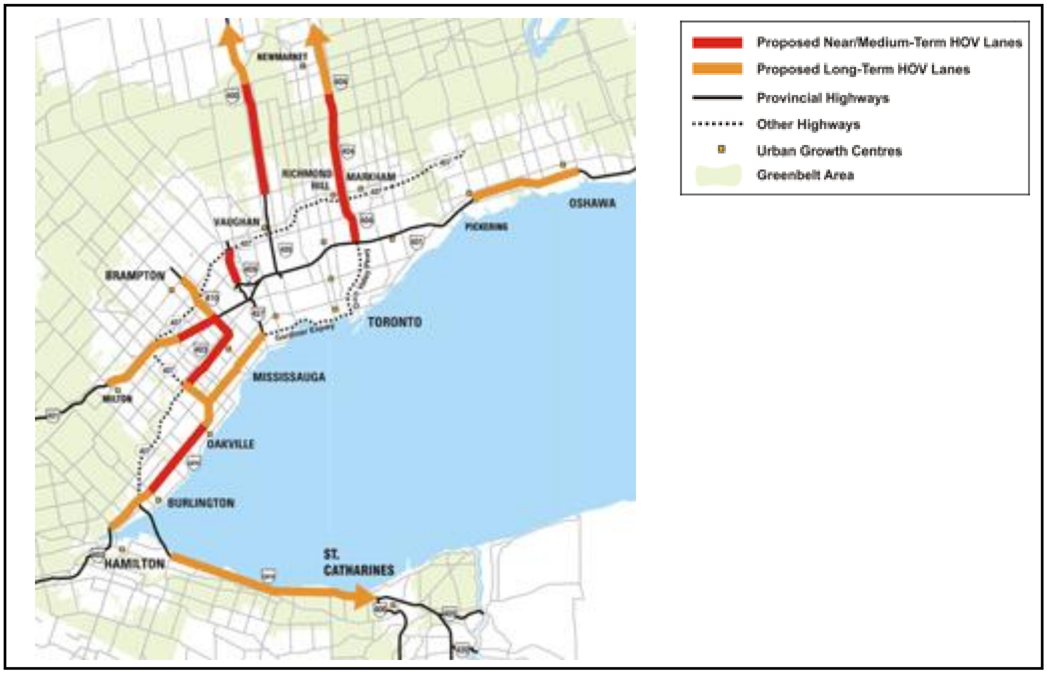


Figure 3.2: GTA HOV 400-series-network to be developed within 25 years
Source: HOV-Plan, 2007

The Big Move (2008), the Greater Toronto Transportation Authority's (Metrolinx) high-level transportation master plan re-focuses the imperative of regional transportation around the movement of people and goods, not single-occupant vehicles. In order to do this, Metrolinx will:

- Construct a comprehensive regional rapid transit network consisting of additional subway, LRT, and commuter rail lines;
- Enhance active transportation; and
- Work towards the efficient use of roads and highways.

The Big Move provides explicit policy grounding for the development of HOV-lanes, road pricing, and HOT-lanes in the GTA. The document requires all new road infrastructure projects to be considered within a transportation hierarchy that prioritizes walking, cycling, public transit, and HOV-mobility over SOV-mobility. Strategy #3 outlines the role of carpool/vanpool facilities, intelligent transportation systems (ITS), and lane management in improving the efficiency of highway networks. Strategy 3.3 directs Metrolinx to:

> "Assess and implement an inter-connected regional network of multi-purpose reserved lanes… with the potential for high occupancy toll (HOT) lanes. The use of both existing and new lane capacity as well as shoulders will be explored."

The Big Move also identifies fiscal sustainability as a goal of the regional transportation plan. Objective 34 calls for "increased financial self-sufficiency of transportation infrastructure and projects" while objective 36 directs the GTA towards "fair and effective fiscal treatment of various modes that better reflects the cost of transportation services in the prices paid by users."

3.3 *HOT-lanes and the GTA*

Past exploratory research has recognized the conceptual suitability of HOT-lanes to the GTA. Lindsey provided a preliminary assessment of the case for road pricing in Canada (2007). The assessment recommended bridge-based cordon tolling for Montreal and Vancouver and HOT-lanes for the GTA. The Toronto area, unlike Greater Montreal or Metro Vancouver, does not have a geography that lends itself to "gateways" (i.e. bridges) – as a result, corridor-based tolling was found to be better suited to this area.

This study takes as a starting point that:

- The current transportation reality in the GTA is unacceptable and will worsen;
- Road charging can mitigate traffic congestion;
- Key policy documents have recognized the imperative for more efficient management of the GTA's highway network;
- Past exploratory research has identified HOT-lanes as a conceptually suitable approach to road charging in the GTA.

This study provides statistical grounding by examining public desirability for HOT-lanes in the GTA through stated preference surveys and revealed traffic volumes (for exact research questions see Section 1.2). The following chapters detail the research methods used and display the results of all analyses.

4 RESEARCH METHODS

This chapter discusses the methods used in this study to gather and analyze stated preference and revealed traffic volume data.

4.1 *Use of stated preference and revealed traffic volume data*

This study employs survey-based stated-preference (SP) and vehicle count-based revealed traffic volume (RTV) techniques to assess the desirability for HOT-lanes in the GTA. Both techniques have inherent advantages and disadvantages. By employing both methods, this study is able to evaluate GTA-driver willingness to pay to escape congestion in a more comprehensive manner.

4.1.1 **Stated preference survey method: Advantages and disadvantages**

Value of Travel Time Savings (VTTS)-oriented stated-preference surveys are a well established data gathering tool in HOT-lanes research (see Davis *et al*., 2009; Burris and Appiah, 2004; Brownstone and Small, 2005; Burris and Xu, 2006). SP-surveys have been used to gauge willingness to pay (WTP) and to identify the statistical significance and effect size of a variety of trip characteristics and driver factors on willingness to pay. While vehicle-count revealed traffic volume (RTV)-techniques are inherently limited in their breadth, stated preference (SP)-surveys are versatile, allowing for the analysis of a range of different potential indicators.

Despite these advantages, SP-surveys have been found to underestimate the magnitude of driver WTP (Brownstone and Small, 2005). Questionnaires have several drawbacks: respondents may be unaware of HOT-lanes or electronic tolling and consequently responses may reflect biases based on a lack of information. Also questionnaires, regardless of question wording, are incapable of directly re-creating driver feelings of urgency, frustration, and uncertainty experienced during periods of road congestion. Whereas VTTS SP-surveys can elicit rational, thought-out responses to clearly described situations, in reality, driver choices occur in atmospheres of limited information. During periods of congestion, speeds in GP-lanes are subject to fluctuations, making accurate calculations of time savings very difficult. As such, driver choice is informed by momentary highway-speed conditions, not comprehensive understandings of potential travel time savings. As a result, real-time driver choice involves an additional consideration: uncertainty – a choice between a relatively reliable option and an unreliable one. Although methods can be employed to improve the accuracy of SP-surveys – respondents could be asked to drive the roadway being studied prior to answering the survey – responses to hypothetical situational questions remain statements of driver intent, not actual driver choice.

4.1.2 Revealed traffic volume method: Advantages and disadvantages

SP-findings are supplemented by vehicle count-based RTV-findings to provide a more comprehensive understanding of the factors affecting WTP. The revealed impact of traffic congestion and trip urgency on real-time driver choice to pay is investigated by comparing assumed trip urgencies and hourly traffic volumes along Highways 401 and 407-ETR. The RTV analysis is powerful in that it represents actual real-time driver choices, not statements of intent.

That expressed, the vehicle-count RTV-analysis employed in this case study suffers from a number of constraints. Hwy 407-ETR transponder-assessed toll rates are lower than video-assessed rates. As a result, it is likely that willingness to use Hwy 407 is influenced by whether or not a driver possesses a valid transponder. In addition, typically RTV-techniques have been used to assess the impact of trip conditions and driver factors on *parallel* HOT-lane use post-implementation (see Supernak *et al*., 2003; Halvorson *et al*., 2006; or Brownstone and Small, 2005). The use of Hwy 407-ETR traffic volume as a proxy for parallel Hwy 401-HOT lane volume limits the power of RTV-findings. The characteristics of Hwy 407-ETR are quite different from those of parallel HOT-lane facilities. Hwy 407-ETR is an express tolled facility operating in its own right-of-way. Although Hwy 407 is a by-pass for Hwy 401, the highway corridors are approximately 8 to 11 km apart. As a result, unlike HOT-lanes, where non-HOV use is composed solely of drivers willing to pay to escape congestion, Hwy 407 traffic also includes drivers who have no realistic alternative to that highway. Drivers with no realistic alternative to Hwy 407 are not necessarily using the highway to escape Hwy 401 congestion;

instead they are using the highway because it is the most direct route from/to their origin and/or destination in Brampton, Vaughan, Richmond Hill, or Markham. Despite these limitations, the presence of Hwy 407 accords a unique opportunity to investigate the relationship between road congestion along a trunk freeway and driver choice to pay to by-pass this congestion.

4.2 *Stated preference technique: Objectives of the SP analysis, questionnaire design, and sampling method*

The study's stated-preference component addressed three key themes:

- Driver WTP to escape highway congestion along GTA limited access highways;
- Public desirability for HOT-lanes as a congestion mitigation strategy in the GTA;
- Traveller willingness to use non-SOV transportation provided in HOT-lanes.

From these themes the following six research questions were developed:

1. What proportion of Toronto-area drivers are willing to pay to escape congestion?
2. How do trip characteristics, including trip urgency, traffic speed, and 400-series trip distance affect willingness to pay to escape congestion?
3. How do driver factors, including annual household income, respondent age, respondent gender, 400-series travel frequency[1], and previous exposure to electronic tolling/Hwy 407 exposure affect willingness to pay to escape congestion?
4. Do HOT-lanes accompanied by bus rapid transit (BRT) encourage transit use?
5. Do HOT-lanes encourage carpooling?
6. Do GTA residents want to see HOT-lanes implemented along major highways in the metropolitan area?

Paper-based stated-preference questionnaires were designed to address these research questions.

[1] For this study, Toronto municipal expressways (Don Valley Parkway, Gardiner Expressway, W.R. Allen Rd.), although technically not 400-series highways, were considered and categorized as 400-series highways.

A significant portion of the questionnaire was devoted to acquiring data on the effects of trip characteristics and driver factors on WTP to escape congestion. A majority of the items chosen for analysis were identified elsewhere as significant predictors of HOT-lane use (see Table 4.1). This study was the first of its kind to directly analyze the effects of speed and previous exposure to electronic tolling on WTP to escape congestion.

Table 4.1: Trip characteristics and driver factors analyzed

Item type	Item	Study
Trip characteristics	Trip distance	Burris and Appiah (2004); Kaan *et al*. (2006) (travel time)
	Highway speed	-
	Trip urgency / trip purpose	Senbil and Kitamura (2006); Li (2001), Davis *et al*. (2009); Burris and Appiah (2004); Kaan *et al*. (2006)
Driver factors	Annual household income	Mastako *et al*. (1998); Kaan *et al*. (2006); Li (2001); Davis *et al*. (2009)
	Respondent age	Li (2001); Davis *et al*. (2009); Burris and Appiah (2004)
	Respondent gender	Tested in Li (2001). Not significant.
	Limited access freeway travel frequency	Burris and Appiah (2004)
	Previous exposure to electronic tolling	-

Alongside the objectives of the analysis, a consideration of data analysis methods was integral to the design of the questionnaire. Trip condition/situational questions were used to gather data to assess the influence of trip urgency, traffic speed, and trip distance on WTP through factorial ANOVA. A range of socio-demographic and highway usage questions were included to provide data for a series of statistical tests that assessed the effect of driver factors on WTP to escape congestion, willingness to carpool, and willingness to take transit.

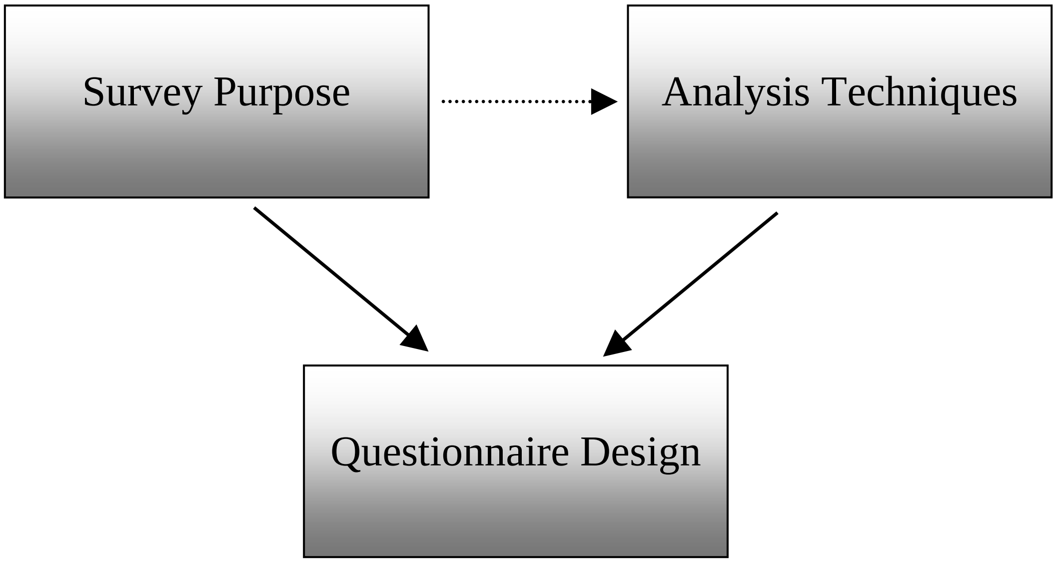


Figure 4.1: The questionnaire was designed to fulfill the survey purpose and render appropriate data for the chosen analysis techniques

4.2.1 Questionnaire design

Appendix 1 contains a copy of the survey instrument and cover letter that were distributed.

The questionnaire used in this study consisted of four sections:

1. Highway usage and familiarity;
2. Willingness-to-pay to escape traffic congestion;
3. Implementation preference and impact on carpooling & transit use; and
4. Respondent demographics.

The questionnaire was designed to be entirely anonymous – respondents were not asked to provide identifiers such as their name, telephone number, or address. Most participants would not have required more than five minutes to complete the questionnaire.

Figure 4.2 shows the relationship between research questions and survey questions.

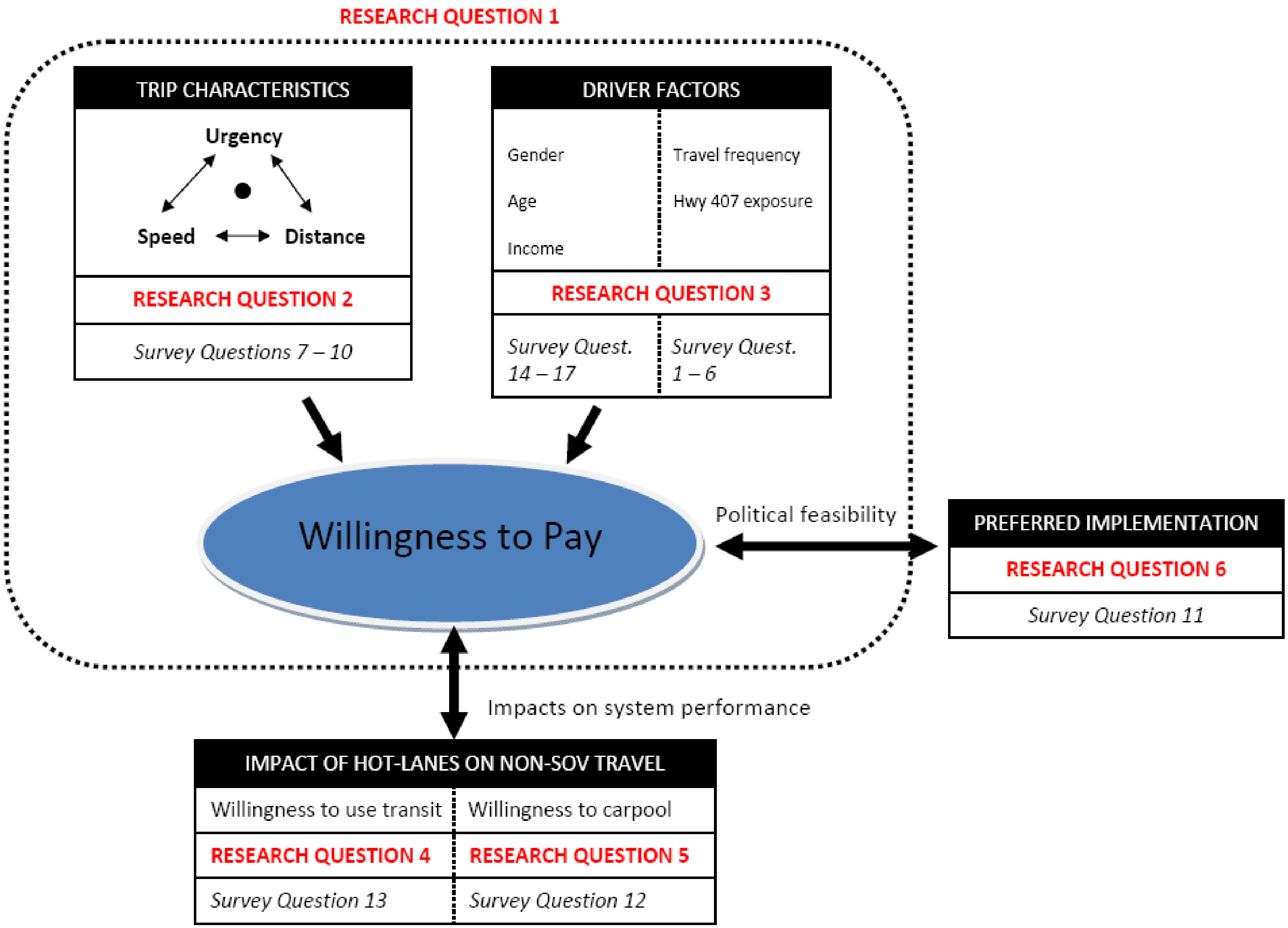


Figure 4.2: The relationship between research questions and survey questions

Core survey questions asked respondents how much they would be willing to pay to escape congestion in eight unique trip conditions (survey questions 7 – 10). The HOT-lanes concept was introduced prior to questioning in order to inform respondents of the purpose of the survey. HOT-lanes were described as “congestion-free toll lanes that run adjacent to existing regular lanes on freeways and provide fast and reliable lane-space at a cost to the driver.”

Trip conditions were defined by one of two trip urgency values, one of two traffic speed values, and one of two 400-series trip distance values, resulting in a total of 2^3 or 8 unique trips (see Figure 4.3). For a description of all trip conditions see Table 4.2.

TRIP URGENCY	TRAFFIC SPEED	TRIP DISTANCE
High or **Low**	**30 km/h** or **70 km/h**	**15 km** or **40 km**

Figure 4.3: Given trip urgency, traffic speed and trip distance values

Table 4.2: Trip Conditions (urgency, speed, trip distance)

Trip 1	High urgency, 30 km/h, 15 km
Trip 2	Low urgency, 30 km/h, 15 km
Trip 3	High urgency, 70 km/h, 15 km
Trip 4	Low urgency, 70 km/h, 15 km
Trip 5	High urgency, 30 km/h, 40 km
Trip 6	Low urgency, 30 km/h, 40 km
Trip 7	High urgency, 70 km/h, 40 km
Trip 8	Low urgency, 70 km/h, 40 km

Trips occurred in either urgent or non-urgent circumstances. To provide a more standardized respondent understanding of urgency, urgent circumstances were described as follows: “You are in a rush to get somewhere important (i.e. due at work, late for scheduled activity).” Non-urgent circumstances were described as: “You are not in a rush or it is not important that you arrive at your intended destination at a particular time (i.e. driving to a recreational activity, driving to a scheduled activity when you have ample time to spare).”

Traffic speeds were either 30 km/h or 70 km/h, reflecting heavy and mild congestion levels along the freeway network. To standardize responses, uncertainty was removed by informing respondents that they were to assume constant speeds for each trip.

Finally, 400-series trip distances were either 15 km or 40 km. For perspective, Figure 4.4 displays two circles with diameters of 15 km and 40 km and centre-points at the interchange of Highways 401 and 404/Don Valley Parkway. 15 km 400-series trips are short-distance highway trips in the GTA – the entire Don Valley Parkway (DVP), from Hwy 401 to the Gardiner Expressway, is 14.6 km, while Hwy 401 between Hwy 400 and Hwy 404/DVP is 16 km. By contrast, 40 km 400-series trips represent medium-long distance highway trips in the GTA – Hwy 401 between Milton (Halton-25 interchange) and Hwy 400 is 38.9 km, while Hwy 404/DVP from Aurora (Wellington St. interchange) to Downtown Toronto (Queen St. E. interchange) is 42.5 km.

Figure 4.4: 15 and 40 km distance diameters with centre-points at the interchange of Highways 401 and 404/DVP

Source: Google Maps

Given the urgency, speed, and distance characteristics of each trip condition, respondents were then asked to indicate how much they would be willing to pay to escape congestion and drive at

100 km/h in parallel HOT-facilities by circling a value along a linear scale. Scale values ranged from $0 to $10, increasing by $0.25 intervals between $0 and $2, $0.50 intervals between $2 and $6, and $1 intervals between $6 and $10. Respondents willing to pay more than $10 were asked to write in a value below the scale.

Supplemental questions

WTP situational questions were supplemented by highway usage and socio-demographic questions which investigated respondent 400-series familiarity, frequency of network use, dominant mode choice, most frequently used 400-series highway and dominant 400-series trip purpose. Due to the GTA's unique case context, this section included a question on driver exposure to Hwy 407-ETR. This question aimed to shed light on whether previous exposure to an electronic tolled facility affected WTP. Respondents were also asked if they have ever been frustrated by congestion along a GTA 400-series highway. In addition, respondents were asked their age and gender as well as their residential postal code and average annual household income.

The political feasibility of HOT-lanes was assessed by asking respondents if they would prefer the conversion of some existing GP-lanes to HOT-lane facilities at an average use cost of $0.10/km or the expansion of some freeways to include new HOT-lane facilities at an average use cost of $0.20/km. Alternatively, respondents could indicate a preference that no HOT-lanes of any kind be built in the GTA. Current Hwy 407-ETR rates were considered in the determination of the hypothetical toll rates used in this question.

In addition, the survey investigated whether the incentive of free HOV travel and the presence of high-order, fast, frequent, reliable and inter-connected bus service in the facilities would affect respondent willingness to carpool and take transit, respectively.

4.2.2 The survey packet

Distributed survey packets contained the following items:

- 1 questionnaire
- 1 cover letter
- 1 return Business Reply Mail envelope
- 1 candy

The cover letter informed respondents of the purpose of the research and, in compliance with the University of Waterloo's research ethics requirements, advised respondents that participation was voluntary and confidential. Respondents were informed that completed questionnaires had to be mailed by May 31st, 2009 to be included in the study. The letter also contained a URL for a weblog where survey findings were presented and discussed.

4.2.3 Sampling and distribution method

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 HOT-lane desirability in the GTA. As such, the target population was Greater Toronto Area 400-series drivers from a variety of socio-economic backgrounds and geographic locations. To test the impact of previous exposure to electronic tolling, a significant number of respondents needed to be familiar with Hwy 407-ETR.

While a truly representative sample of GTA 400-series drivers would have been ideal, the range of possible sampling methods was limited by resources. In this study five sample sites were selected based on pre-determined criteria with the aid of GIS. 800 survey packets per sample site were randomly distributed on vehicle windows. In total 4,000 survey packets were distributed over a period of ten sample days in May, 2009.

The five sample sites were chosen based on a number of criteria. Criteria were formulated to direct surveying to the target population. They were based on four key assumptions:

1. Drivers frequenting sites near 400-series highways are more likely to regularly use 400-series highways than drivers frequenting sites far from 400-series highways.
2. Drivers frequenting sites near Hwy 407-ETR are more likely to regularly use Hwy 407-ETR than drivers frequenting sites far from Hwy 407-ETR.
3. Driver demographic and trip-purpose heterogeneity is greater at sites that have a variety of commercial, educational, social, and residential uses than at sites with few or uniform uses.
4. 400-series driving patterns are affected by location, built-form and land-use.

Chosen sample sites were as follows (see Figure 4.5):

1. Downtown Toronto (corner Adelaide and Yonge Streets)
2. Midtown Toronto West (corner Holland Park and Oakwood Avenues)
3. Willowdale-Fairview (corner Don Mills Rd. and Sheppard Ave.)
4. Richmond Hill-Hillcrest (corner Oak Ave. and Yonge St.)
5. Mississauga Centre (corner City Centre Dr. and Kariya Gate)

Questionnaires were distributed within a 1 km radius of sample sites 1, 3 and 5 and within a 2 km radius of sample sites 2 and 4. Differences in distribution radii were related to urban form.

For a detailed discussion of the sample site selection process, as well as sample area maps and descriptions see Appendix 2.

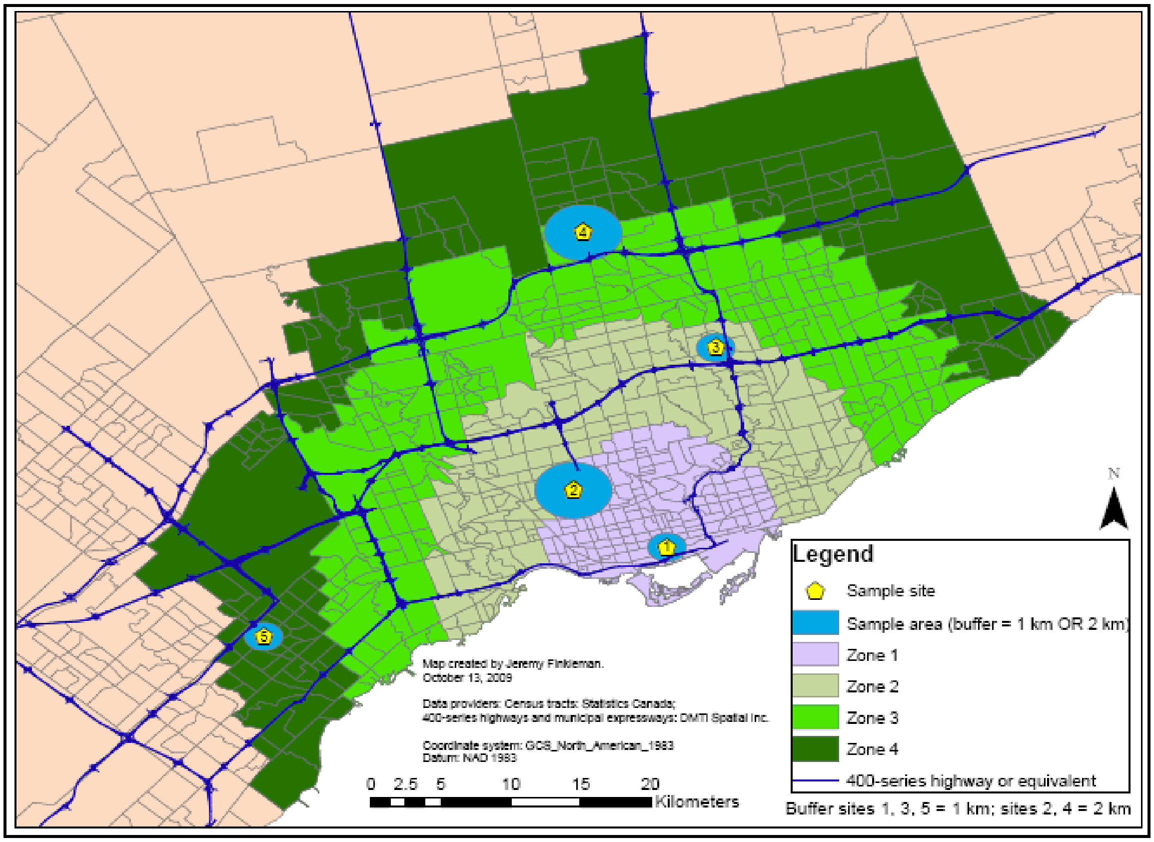


Figure 4.5: Location of sample sites

Survey packets were distributed to every second parked vehicle at select sites within the five sample areas. Surveys were placed under the driver-side windshield wiper of vehicles parked along city streets and in parking lots. To increase respondent heterogeneity, half of all survey packets were distributed on weekdays and half were distributed on weekend-days (see Table 4.3). Distribution occurred exclusively during daylight hours.

Table 4.3: Sample area distribution dates and total survey packets distributed

Sample Area	Distribution dates				
	Weekend	*Total dist.*	*Weekday*	*Total dist.*	*Sample Area Total*
1 – Downtown Toronto	Sat May 23; Sun May 24	400	Tue May 19	400	800
2 – Midtown Toronto West	Sun May 10; Sat May 23	400	Wed May 13	400	800
3 – Willowdale-Fairview	Sun May 10	400	Fri May 8	400	800
4 – Richmond Hill-Hillcrest	Sat May 16	400	Fri May 22	400	800
5 – Mississauga Centre	Sun May 17	400	Mon May 11	400	800
TOTAL	-	**2,000**	-	**2,000**	**4,000**

4.3 *Stated preference technique: Data analysis*

Responses from returned questionnaires were input and analyzed in SPSS. A variety of statistical methods were employed to address the six research questions (for a list of the six research questions see the introduction to Section 4.2). This section describes the methods used to investigate those questions and states the hypothesized results of statistical analyses. Analysis methods are presented in relation to the research question they are employed to answer. The statistical results of analyses described in this chapter are presented in Chapter 5.

Due to large sample sizes, parametric tests were used for all statistical procedures. The Central Limit Theorem holds that parametric tests are robust in large samples regardless of sample distribution (Bernstein and Bernstein, 1999). All tested samples exceeded 55 cases.

4.3.1 Methods employed to address Research Question 1: What proportion of Toronto-area drivers are willing to pay to escape congestion?

Respondents who were willing to pay more than $0 to escape congestion in the worst trip condition were defined to be "willing to pay to escape congestion." If trip conditions were dire enough, the travel disutility of these respondents was minimized by paying a toll rather than enduring highway congestion. The proportion of respondents who were willing to pay to escape congestion is an indicator of public acceptance for market-based alternatives, such as HOT-lanes, to the status-quo. Respondents who are strictly opposed to the concept of paying to access public road-space should be unwilling to pay to escape congestion under any circumstance.

The percentage of total respondents willing to pay more than $0 was displayed for each trip condition. It was expected that a large share of respondents would be willing to pay to escape congestion under poor conditions while a comparatively smaller share of respondents would be willing to pay under moderate and good conditions. It was also expected that a substantial percentage of respondents would be willing to pay to escape congestion in the worst trip condition (trip 5 – High urgency, 30 km/h traffic speed, 40 km 400-series trip) because of the severity of road congestion in the GTA and respondent conceptual familiarity with electronic tolling due to the presence of Hwy 407-ETR.

4.3.2 Methods employed to address Research Question 2: How do trip urgency, traffic speed, and 400-series trip distance affect WTP to escape congestion?

The mean price respondents were willing to pay to escape congestion in eight trip conditions was derived from questionnaire findings. To reduce the impact of outliers on the mean, individual WTP values in excess of $12 were reduced to $12. In the data set, a small number of respondents indicated that they would be willing to pay more than $12 to escape congestion (see Table 5.2 for a precise quantification of outliers). These results were decreased to $12 so as not to unduly influence trip condition mean values. Two sets of mean WTP values were calculated: the mean value of all trip condition responses and the mean value of potential HOT-lane users – defined as respondents who were willing to pay to escape congestion in at least the worst trip condition.

It was expected that mean WTP values for potential HOT-lane users would be higher than mean WTP values of all respondents in every trip condition. Logically, respondents who were unwilling to pay to escape congestion in the worst trip condition would also be unwilling to pay to escape congestion in better conditions. Removing these respondents should result in increased mean values across all conditions. It was also expected that the difference between potential-HOT-lane user mean values and aggregate mean values would be more pronounced in poor conditions than in moderate or good conditions.

It was hypothesized that trip urgency would have the greatest impact on WTP, followed by traffic speed and then by 400-series trip distance (in that order). As a result of these assumptions, the *a priori* expectation for WTP by trip type was:

Table 4.4: WTP is expected to be highest for Trip 5 and to decrease in the following order

	Trip Condition	**Trip Urgency**	**Traffic Speed**	**400-series distance**	**Qualitative description of trip condition**
Decreasing WTP ↓	Trip 5	High	30 km/h	40 km	Poor
	Trip 1	High	30 km/h	15 km	Poor
	Trip 7	High	70 km/h	40 km	Moderate/discretionary
	Trip 6	Low	30 km/h	40 km	Moderate/discretionary
	Trip 3	High	70 km/h	15 km	Moderate/discretionary
	Trip 2	Low	30 km/h	15 km	Moderate/discretionary
	Trip 8	Low	70 km/h	40 km	Good
	Trip 4	Low	70 km/h	15 km	Good

Between-subjects factorial ANOVA was used to assess the statistical significance and effect size of trip urgency, traffic speed, and 400-series trip distance on willingness to pay to escape congestion, as well as the significance and effect size of all interactions. The statistical significance and effect size of all factors was assessed in the sample as a whole (see Section 4.4 for a thorough discussion of all statistical tests used in the study).

To eliminate dependency between results, each questionnaire was randomly assigned a trip condition from 1 to 8 and the response associated with each questionnaire's assigned trip condition was used in the ANOVA. Although most respondents indicated how much they would be willing to pay to escape congestion in all eight trip conditions, only one of eight trip conditions was used from each questionnaire.

As described previously, each trip condition had one of two urgency levels, one of two traffic speeds, and one of two 400-series trip distances. Four trip conditions had high urgencies (trips 1, 3, 5, 7) while four trip conditions had low urgencies (trips 2, 4, 6, 8); four trip conditions had traffic speeds of 30 km/h (trips 1, 2, 5, 6) while four trip conditions had traffic speeds of 70 km/h (trips 3, 4, 7, 8); four trip conditions had 400-series trip distances of 15 km (trips 1, 2, 3, 4) while four trip conditions had 400-series trip distances of 40 km (trips 5, 6, 7, 8).

The impact of urgency, speed, and distance on WTP was assessed by modeling the bi-categorical mean values for each main effect as shown in Figure 4.6. Each main effect was isolated by holding other main effects constant.

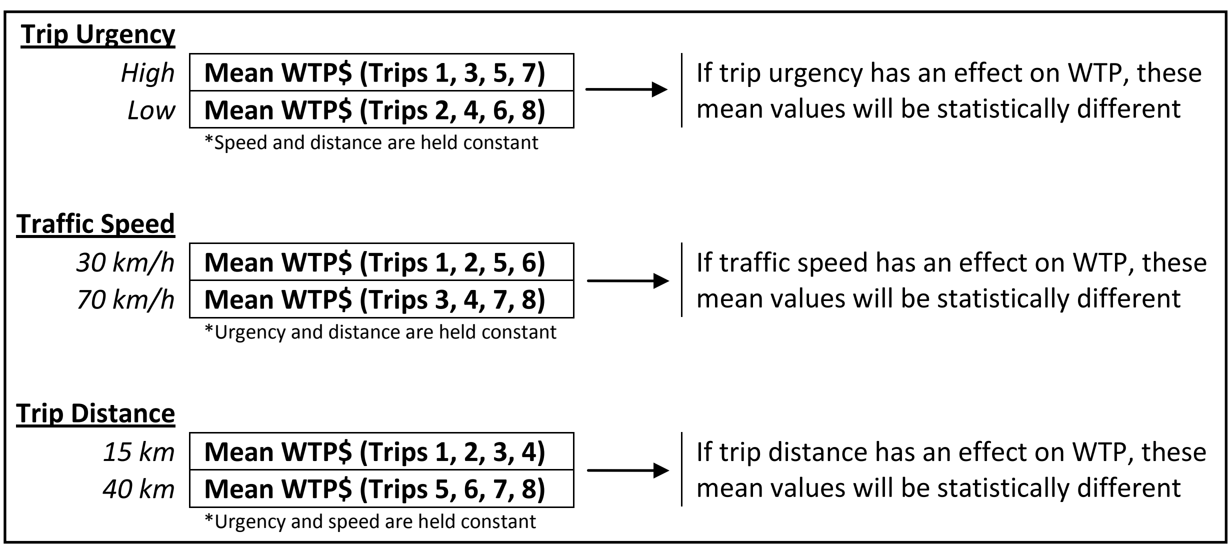


Figure 4.6: Main effect mean values tested in ANOVA

Interactions assessed whether the effects of urgency, speed, and distance on WTP differed depending on their relationship to one another. The impact of effect interactions on WTP was determined by modeling four mean values (see Figure 4.7). The interaction of two main effects was isolated by holding the third effect constant.

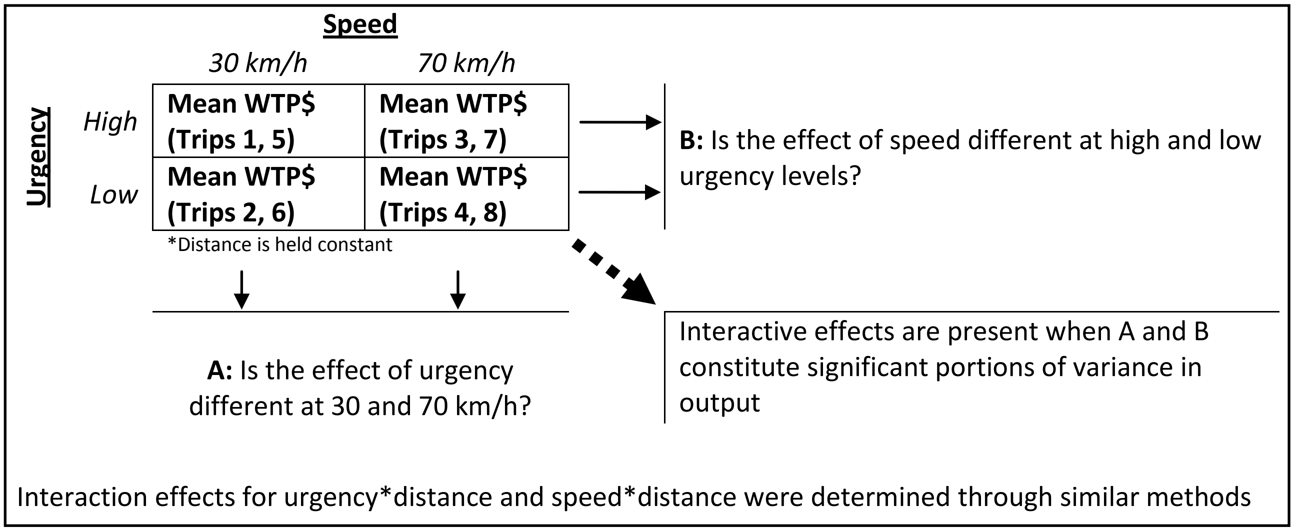


Figure 4.7: Interactions tested in ANOVA

It was expected that trip urgency, traffic speed, and 400-series trip distance would all be found to be significant indicators of WTP. It was also expected that trip urgency would have the greatest effect on WTP, followed by traffic speed and trip distance.

The effect interactions of trip urgency and traffic speed, as well as trip urgency and 400-series trip distance were expected to be statistically significant while the interaction of traffic speed and 400-series trip distance was not expected to reveal significant results. The interaction of trip urgency and traffic speed was expected to be more pronounced than the interaction of trip urgency and 400-series trip distance.

Table 4.5 details all specific hypotheses:

Table 4.5: Hypothesized results of tested main effects and interactions

Item	Statistical method used	Hypothesis
Effect of **trip urgency** on WTP	Between-groups factorial ANOVA. 2 levels: high urgency, low urgency	Respondents with high trip urgency will be willing to pay more to escape congestion than respondents with low trip urgency.
Effect of **traffic speed** on WTP	Between-groups factorial ANOVA. 2 levels: 30 km/h, 70 km/h	Respondents travelling at slow traffic speeds (30 km/h) will be willing to pay more to escape congestion than respondents travelling at moderate traffic speeds (70 km/h).
Effect of **400-series trip distance** on WTP	Between-groups factorial ANOVA. 2 levels: 15 km, 40 km	Respondents with medium-long (40 km) 400-series trip distances will be willing to pay more to escape congestion than respondents with short (15 km) 400-series trip distances.
Comparative effect sizes of main factors	-	Trip urgency will have the greatest effect on WTP, followed by traffic speed and 400-series trip distance.

Table 4.5 continued		
Interaction effect of **trip urgency and traffic speed**	Between-groups factorial ANOVA. 4 levels: High urgency-30 km/h, high urgency-70 km/h, low urgency-30 km/h, low urgency-70 km/h	The effect of trip urgency on WTP will be more pronounced in slow traffic speeds (30 km/h) than in moderate traffic speeds (70 km/h). The effect of traffic speed on WTP will be more pronounced under high trip urgency than under low trip urgency.
Interaction effect of **trip urgency and 400-series trip distance**	Between groups factorial ANOVA. 4 levels: High urgency-15 km, high urgency-40 km, low urgency-15 km, low urgency-40 km	The effect of trip urgency on WTP will be more pronounced for medium/long-distance 400-series trips (40 km) than for short-distance 400-series trips (15 km). The effect of 400-series trip distance will be more pronounced under high trip urgency than under low trip urgency.
Interaction effect of **traffic speed and 400-series trip distance**	Between groups factorial ANOVA. 4 levels: 30 km/h-15 km, 30 km/h-40 km, 70 km/h-15 km, 70 km/h-40 km	A significant interaction effect is not expected.
Comparative effect sizes of interactions	-	The interaction of trip urgency and traffic speed is expected to be more pronounced than the interaction of trip urgency and 400-series trip distance.

4.3.3 Methods employed to address Research Question 3: How do annual household income, respondent age, respondent gender, 400-series travel frequency, and previous exposure to electronic tolling/Hwy 407 exposure affect WTP to escape congestion?

The impact of each driver factor on WTP was assessed in all eight trip conditions (see Table 4.6). Unlike the method employed to address Research Question 2, all questionnaire responses were used in the analysis of driver factors. Independence existed between analyzed responses as each case was drawn from a separate questionnaire.

To assess the effect of income, respondents were grouped into three income categories: low income ($0 - $59,999), middle income ($60,000 - $119,999), and high income ($120,000 +). Categories were chosen to reflect three distinct socio-economic groupings: lower class/lower-middle class, middle class/upper-middle class, and upper class/affluent. Income categories were grounded by Canada Census results. In 2005 the Toronto CMA's median household income was $69,321 (Canada Census, 2006).

The impact of age on WTP was assessed by grouping respondents into three categories: young (18 – 34), middle-aged (35 – 54), and older (55 +). To assess the impact of respondent gender, the WTP mean of male and female respondents were modeled and compared. To assess the impact of 400-series travel frequency, the WTP mean of daily 400-series users was contrasted to the WTP mean of less-than-daily 400-series users. Finally, to assess the impact of Hwy 407 exposure on WTP, the WTP mean of respondents with previous exposure to Hwy 407 was contrasted to the WTP mean of respondents with no previous exposure to Hwy 407. One-way ANOVAs or independent t-tests were conducted to reveal the significance and effect size of all driver factors in each trip condition. For a thorough discussion of the statistical tests employed see Section 4.4.

Table 4.6: Tests conducted to assess the significance of driver factors across trip conditions

Trip condition *(Urg-Spd-Dist)*	**Income** *(low, mid, high)*	**Age** *(young, mid-age, older)*	**Gender** *(male, female)*	**400-series travel frequency** *(Daily, less-than-daily)*	**Previous Hwy 407 exposure** *(yes, no)*
Trip 1 (H, 30, 15)	Effect is significant if a substantial amount of variance can be explained by modelling income group mean values.	Effect is significant if a substantial amount of variance can be explained by modelling age group mean values.	Effect is significant if: $\overline{WTP_M} \neq \overline{WTP_F}$	Effect is significant if: $\overline{WTP_D} \neq \overline{WTP_{LTD}}$	Effect is significant if: $\overline{WTP_Y} \neq \overline{WTP_N}$
Trip 2 (L, 30, 15)	↓	↓	↓	↓	↓
Trip 3 (H, 70, 15)	↓	↓	↓	↓	↓
Trip 4 (L, 70, 15)	↓	↓	↓	↓	↓
Trip 5 (H, 30, 40)	↓	↓	↓	↓	↓
Trip 6 (L, 30, 40)	↓	↓	↓	↓	↓
Trip 7 (H, 70, 40)	↓	↓	↓	↓	↓
Trip 8 (L, 70, 40)	↓	↓	↓	↓	↓
Driver factor effects	How is the effect of income influenced by trip condition?	→	→	→	→

It was expected that annual household income and previous Hwy 407-ETR exposure would be found to be significant indicators of WTP in all 8 trip conditions and that respondent age, gender, and 400-series travel frequency would be found to be significant indicators of WTP in some conditions. Previous Hwy 407 exposure was expected to have the largest effect on WTP in most trip conditions, followed by annual household income, respondent age, 400-series travel frequency and gender.

Table 4.7 details all specific hypotheses:

Table 4.7: Hypothesized results of the effects of driver factors on WTP

Item	Statistical method used	Hypothesis
Effect of **annual household income** on WTP	One-way ANOVA in 8 trip conditions. 3 levels: low income ($0 - $59,999), middle income ($60,000 - $119,999), high income ($120,000+). Planned contrasts for trip conditions where ANOVA results were significant. Contrast 1: low income vs. combined middle income and high income. Contrast 2: middle income vs. high income.	Income will be a statistically significant indicator of WTP in all 8 trip conditions. For all conditions, respondents with higher annual household incomes will be willing to pay more to escape congestion than respondents with lower incomes. The effect of income is expected to be more pronounced in moderate/discretionary conditions and less pronounced in good or poor conditions. While good conditions should yield low WTP values across all income levels and poor conditions should yield high WTP values across all income levels, under moderate conditions respondents with higher incomes will consider it worthwhile to pay substantial amounts to escape congestion while respondents with lower incomes will not consider it worthwhile. For good trip conditions respondents with low incomes will not be willing to pay very much to escape congestion while respondents with middle and high incomes will be willing to pay significantly more. Middle and high income group means are not expected to be significantly different. In poor trip conditions, respondents of all income levels will be willing to pay substantially to escape congestion; the wealthiest respondents, however, will be willing to pay significantly more than middle-income (and low income) respondents.

Table 4.7: continued		
Effect of **age** on WTP	One-way ANOVA in 8 trip conditions. 3 levels: young (18-34), middle-aged (35 – 54), older (55+).	Age will be a statistically significant indicator of WTP in some trip conditions. When significant, younger and middle-aged respondents will be willing to pay more to escape congestion than older respondents. The effect will be more pronounced in moderate and good conditions and less pronounced in poor conditions.
Effect of **gender** on WTP	Independent t-tests in 8 trip conditions. 2 levels: male, female.	Gender will be a statistically significant indicator of WTP in some trip conditions. When significant, male respondents will be willing to pay more to escape congestion than female respondents. The effects of gender will be more pronounced in moderate and good conditions and less pronounced in poor conditions.
Effect of **400-series travel frequency** on WTP	Independent t-tests in 8 trip conditions. 2 levels: daily users, less-than-daily users.	400-series travel frequency will be a statistically significant indicator of WTP in some trip conditions. When significant, daily 400-series users will be willing to pay more to escape congestion than less-than daily users. Effects will be more pronounced in poor trip conditions and less pronounced in moderate and good trip conditions.
Effect of **Hwy 407-ETR exposure** on WTP	Independent t-tests in 8 trip conditions. 2 levels: Respondents with previous exposure to Hwy 407, respondents without previous exposure to Hwy 407	Previous Hwy 407 exposure will be a statistically significant indicator of WTP in all trip conditions. For all conditions, respondents with previous Hwy 407 exposure will be willing to pay more to escape congestion than respondents without previous Hwy 407 exposure. The effect will be more pronounced under moderate and good trip conditions and less pronounced under poor conditions.
Comparative effect sizes of driver factors	-	In most trip conditions, previous Hwy 407 exposure will have the greatest impact on WTP, followed by annual household income, age, 400-series travel frequency and gender.

4.3.4 **Methods employed to address Research Questions 4 through 6**

Research Questions 4 through 6 were addressed with similar methods. To answer Research Question 4, the percentage of total respondents that indicated that the presence of fast, frequent, and reliable BRT service in HOT-lanes would influence their decision to take public transit was computed. For Research Question 5, the percentage of total respondents that indicated that the incentive of free HOV travel in HOT-lanes would influence their decision to carpool was calculated.

To address Research Question 6, the HOT-lane implementation preferences of respondents were computed. The percentage share for each of three choices was displayed:

1. Percentage of total respondents who prefer that HOT-lanes be constructed as new facilities that charge on average $0.20/km per use;
2. Percentage of total respondents who prefer that existing GP lanes be converted to HOT-lanes that charge on average $0.10/km per use;
3. Percentage of total respondents who prefer that HOT-lanes not be implemented along the GTA's 400-series network.

The percentage of respondents who support the presence of HOT-lanes along GTA 400-series highways (%-share$_{choice1}$ + %-share$_{choice2}$) was also calculated.

The effect of select driver factors on willingness to use transit, willingness to carpool, and stated desire for HOT-lanes was statistically analyzed with one-way ANOVAs and independent t-tests (see Table 4.8).

Table 4.8: Select driver factors assessed

Item	**Income** *(low, mid, high)*	**Age** *(young, mid-aged, older)*	**400-series travel frequency** *(daily, less-than daily)*	**Hwy 407 exposure** *(yes, no)*
Willingness to use transit	Effect is significant if a substantial amount of variance can be explained by modelling income group means.	Effect is significant if a substantial amount of variance can be explained by modelling age group means.	Not analyzed	Not analyzed
Willingness to carpool	↓	↓	Effect significant if: $\overline{\text{Value}_{\text{D}}} \neq \overline{\text{Value}_{\text{LTD}}}$	Not analyzed
Stated desire for HOT-lanes	↓	↓	↓	Effect significant if: $\overline{\text{Value}_{\text{Y}}} \neq \overline{\text{Value}_{\text{N}}}$

Table 4.9 details all hypotheses:

Table 4.9: Hypothesized results for Research Questions 4 through 6

Item	Main finding	Impact of select driver factors on main finding
RQ 4: Do HOT-lanes accompanied by Bus Rapid Transit (BRT) encourage transit use?	It is expected that a large share of respondents will indicate that the presence of BRT in HOT-lanes would influence their decision to use transit.	**ANOVA:** Regarding **income**, it is expected that respondents with higher annual household incomes will be less willing to take transit than respondents with lower annual household incomes. It is also expected that low-income respondents will be more willing to take transit than others and that middle-income respondents will be more willing to take transit than high-income respondents. Regarding **respondent age**, it is expected that younger respondents will be more willing to take transit than older respondents. It is also expected that younger respondents will be more willing to take transit than others but that the means of middle-aged and older respondents will not be significantly different.
RQ 5: Does the incentive of free HOV travel in HOT-lanes encourage carpooling?	It is expected that a moderate share of respondents will indicate that the incentive of free-HOV travel in HOT-lanes would influence their decision to carpool.	**ANOVA:** Regarding **income**, it is expected that respondents with higher annual household incomes will be less willing to carpool than respondents with lower annual household incomes. It is also expected that low-income respondents will be more willing to carpool than others but that the means of middle income and high income respondents will not be significantly different. Regarding **respondent age**, it is expected that younger respondents will be more willing to carpool than older respondents. It is also expected that younger respondents will be more willing to carpool than others but that the means of middle-aged and older respondents will not be significantly different. **Independent t-tests:** Regarding **400-series travel frequency**, it is expected that daily 400-series users will be more willing to carpool than less-than-daily 400-series users.

Table 4.9: continued		
RQ 6: Do GTA residents want to see HOT-lanes implemented along major highways in the metropolitan area? HOT-lane political feasibility and respondent implementation preference.	It is expected that a majority of respondents will support the presence of HOT-lanes along 400-series highways.	**ANOVA:** Regarding **income**, it is expected that support for HOT-lanes along 400-series highways will be higher among more affluent respondents than among poorer respondents. It is expected that the mean of low income respondents will not be significantly different from the mean of other respondents but that support for HOT-lanes will be significantly highest among high income respondents. Regarding **respondent age**, it is expected that support for HOT-lanes will be higher among younger respondents than among older respondents. It is expected that the mean of younger respondents and the mean of other respondents will not be statistically different but that support for HOT-lanes will be higher among middle-aged respondents than among older respondents. **Independent t-tests:** Regarding **400-series travel frequency**, it is expected that support for HOT-lanes will be higher among daily 400-series users than among less-than-daily 400-series users. Regarding **Hwy 407 exposure**, it is expected that support for HOT-lanes will be higher among respondents with previous Hwy 407 exposure than among respondents without previous Hwy 407 exposure.

4.4 *Statistical tests*

Results were analyzed using one of three statistical tests (see Table 4.10). Between-subjects factorial ANOVA was used to determine the statistical significance and effect size of trip urgency, travel speed, and 400-series trip distance on WTP, as well as all trip characteristic interactions. One-way ANOVAs were used to assess the impact of annual household income and respondent age on willingness to pay, willingness to take transit, willingness to carpool, and support for HOT-lanes. When desirable, planned contrasts were employed to provide a more precise understanding of the impacts of these driver factors on the dependent variable. Independent t-tests were used to determine the significance and effect size of gender, 400-series travel frequency, and Hwy 407 exposure on willingness to pay and, when applicable, willingness to take transit, willingness to carpool, and support for HOT-lanes. One-way ANOVAs were used in place of independent t-tests in the analysis of income and age because unlike other driver factors, income and age each had three indicator categories. Income was categorized as either low, middle, or high while age was categorized as either young, middle-aged, or older.

Table 4.10: Statistical tests used to analyze SP results

Research Question	Item	Method	Levene's test p > .05	Main stat. test	Planned contrasts
RQ 2	Effect of **urgency, speed and distan**ce on WTP	Between-subjects Factorial ANOVA	Required	F-test	N/A
RQ 3	Effect of **income** on WTP	One-way ANOVA	Required	F-test	Contrast 1 = probability that $\overline{WTP_{\$0-\$59,999}} \neq \overline{WTP_{\$60,000+}}$ Contrast 2 = probability that $\overline{WTP_{\$60,000-\$119,999}} \neq \overline{WTP_{\$120,000+}}$
	Effect of **age** on WTP	One-way ANOVA	Required	F-test	Not conducted
	Effect of **gender** on WTP	Independent t-test	N/A	t-test	N/A
	Effect of **400-series travel frequency** on WTP	Independent t-test	N/A	t-test	N/A
	Effect of **Hwy 407 exposure** on WTP	Independent t-test	N/A	t-test	N/A
RQ 4 - 6	Effect of **income** on willingness to take transit, willingness to carpool, and support for HOT-lanes	One-way ANOVAs	Required	F-test	Contrast 1 = probability that $\overline{\text{Value}_{\$0-\$59,999}} \neq \overline{\text{Value}_{\$60,000+}}$ Contrast 2 = probability that $\overline{\text{Value}_{\$60,000-\$119,999}} \neq \overline{\text{Value}_{\$120,000+}}$
	Effect of **age** on willingness to take transit, willingness to carpool, and support for HOT-lanes	One-way ANOVAs	Required	F-test	Contrast 1 = probability that $\overline{\text{Value}_{\text{Age } 18-34}} \neq \overline{\text{Value}_{\text{Age } 35+}}$ Contrast 2 = probability that $\overline{\text{Value}_{\text{Age } 35-54}} \neq \overline{\text{Value}_{\text{Age } 55+}}$
	Effect of **400-series frequency** on willingness to carpool and support for HOT-lanes	Independent t-tests	N/A	t-test	N/A
	Effect of **Hwy 407 exposure** on support for HOT-lanes	Independent t-tests	N/A	t-test	N/A

An important precondition for parametric statistical analysis is homogeneity of variances. The statistical effect of factors cannot be adequately tested when sample variances differ. Levene's test was used to assess the equality of variances in different samples. Levene's test p-values greater than .05 indicated that variances were not statistically different and that data could be analyzed using traditional methods. Levene's test p-values less than or equal to .05 indicated that variances were statistically different and that the ANOVA could not be reliably performed on the data. Under these conditions, data had to either be transformed prior to analysis or a robust test for equality of variances, such as Welch's correction, had to be employed in the ANOVA.

ANOVA F-test results represent the mean variance explained by the model divided by the mean variance left unexplained by the model. If the model is capable of explaining a great deal of a variation, it is likely that the item being tested influences the outcome.

The statistical significance of all ANOVA effects was based on a two-tailed significance $p < .05$. A p-value of .05 means that there is a 5% chance of obtaining the test statistic if the null hypothesis is correct. In other words, if the item in reality has no effect on the phenomenon, an F-statistic as high as the one calculated would occur by chance at most only 5 out of every 100 times – as such there is only a 5% probability that the means are equal and a 95% probability that the means are different.

Effect sizes (eta and eta^2) were calculated from the model sum of squares (SS_{model}) and total sum of squares (SS_{total}).

For the factorial ANOVA used to assess the impacts of urgency, speed, and distance on WTP:

$$SS_{total} = SS_{urgency}+SS_{speed}+SS_{distance}+SS_{urg*spd}+SS_{urg*dist}+SS_{spd*dist}+SS_{urg*spd*dist}+SS_{error}$$

For the one-way ANOVAs used to assess the impact of income or age on dependent variables:

$$SS_{total} = SS_{between\ groups\ (model)}+SS_{within\ groups\ (unexplained\ variance)}$$

$$\eta^2 = SS_{model} / SS_{total}$$

$$\eta = \sqrt{\eta^2}$$

Equation 4.1: Formula to calculate effect size from ANOVA results

As a correlation coefficient, eta-values represent the impact of each effect (x-axis) on WTP (y-axis). Eta -values range from 0 to 1; an eta-value of 1 indicates that a linear equation perfectly describes the relationship between the independent variable (item) and the dependent variable (effect). η^2 represents the share of change in the dependent variable (expressed as a percentage) that is explained by the item; for example, an η^2 value of .06 means that the item explains 6% of the change in the dependent variable.

In addition to F-test results, planned contrasts were employed in select cases to enhance the understanding of how income and age affected willingness to pay, willingness to use transit, willingness to carpool, and stated support for HOT-lanes. While a significant F-test result reveals that the tested item has an effect on the dependent variable, it does not specify where the item is affecting mean values. To illustrate the need for further statistical analysis, Figure 4.8 provides a hypothetical example of two scenarios where the effects of income on WTP are very different. While F-test results would reveal that income significantly affects WTP in both scenarios, in scenario 1 low income individuals are willing to pay substantially less than other categories to escape congestion while in scenario 2 the effect of income is more incremental. Planned contrast results would identify these differences. Planned contrast 1 isolated the low income group by contrasting the WTP mean of low income respondents with the mean of other respondents:

$$\text{Planned contrast 1 = probability that } \overline{WTP_{\$0-\$59,999}} \neq \overline{WTP_{\$60,000+}}$$

Planned contrast 2 assessed the significance of income on WTP between the middle income and high income groups:

$$\text{Planned contrast 2 = probability that } \overline{WTP_{\$60,000-\$119,999}} \neq \overline{WTP_{\$120,000+}}$$

In scenario 1, contrast 1 would reveal significant results while contrast 2 would not (see Figure 4.8). In scenario 2, both contrasts would reveal significant results. Knowing not just if but how income affects WTP is important in an analysis of the equity implications of HOT-facilities.

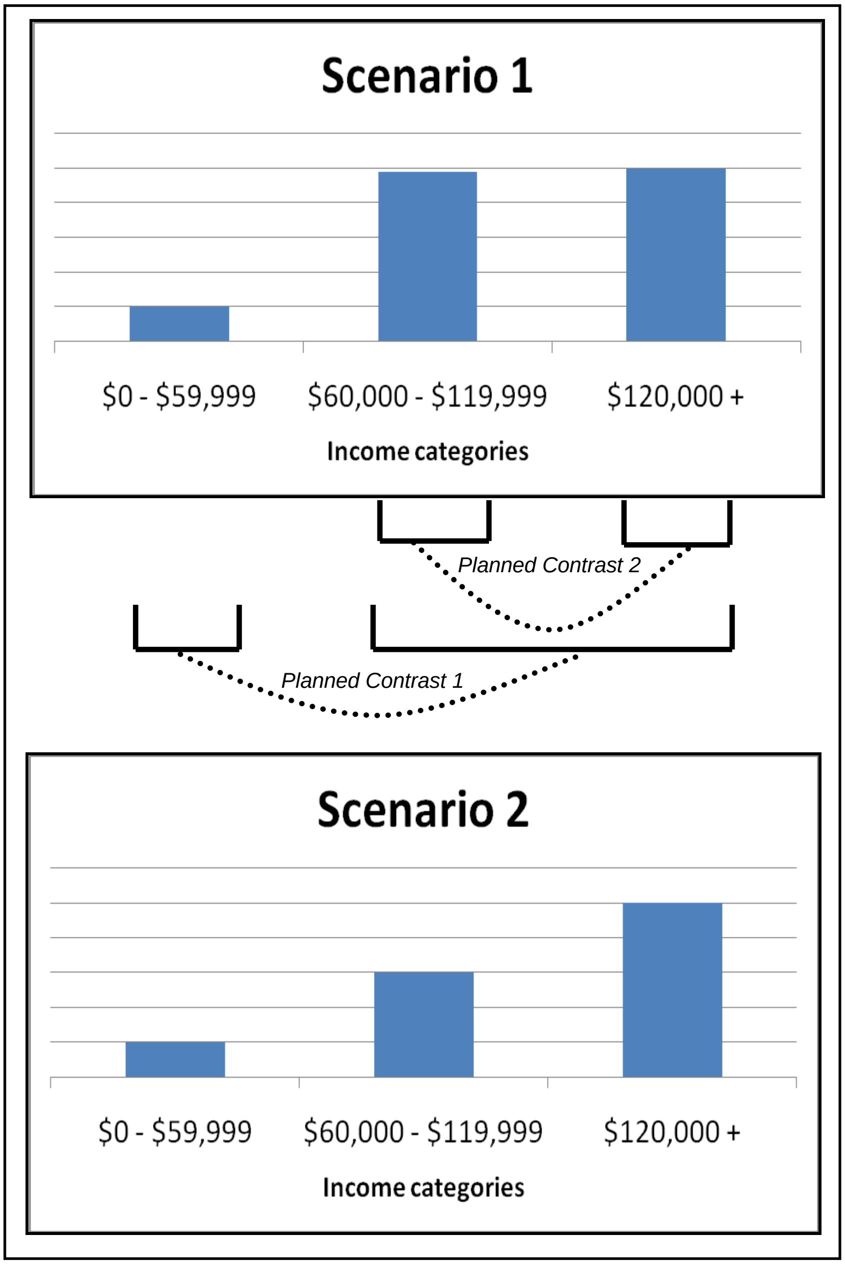


Figure 4.8: While income has an effect on WTP in both scenarios, in scenario 1 the effect of income is isolated to the low income category while in scenario 2 the effect of income increases incrementally. Planned contrast 1 compared the mean of the low income group with the combined mean of the mid and high income groups while planned contrast 2 compared the mean of the middle income group with the mean of the high income group.

Independent t-tests were used to assess the significance of driver factors in planned contrasts. A t-statistic is a ratio of the variance explained by the bi-mean model to the variance not explained by the model. T-statistics are calculated by dividing the change in mean values by the standard error of the mean. The associated p-value indicates the probability of the derived t-statistic occurring by chance if the means are, in fact, equal. A contrast was deemed statistically significant if a t-test's associated p-value was less than or equal to .05. The effect size (Pearson-r and R^2) was calculated from the t-statistic (t) and the degrees of freedom (df):

$$r = \sqrt{\frac{t^2}{(t^2 + df)}}$$

$$R^2 = r * r$$

Equation 4.2: Formula to calculate effect size from t-test results

Independent t-tests were used to assess the significance and effect size of respondent gender, 400-series travel frequency, and previous exposure to electronic tolling / Hwy 407 exposure on WTP for each trip condition. To determine the statistical significance of each driver factor on WTP, a t-statistic and p-value were calculated for each trip condition. The effect size (Pearson-r and R^2) was calculated from the t-statistic and the degrees of freedom. For a thorough discussion of the theory and practical application of ANOVA and independent t-tests see Field, 2005.

4.5 *Revealed traffic volume technique*

GTA Hwy 401 corridor drivers presently have an option to pay to escape congestion. Toll Highway 407-ETR parallels Hwy 401 approximately 8 to 11 km to the north (for map see Figure 4.10). Corridor drivers can choose to travel without toll along Hwy 401 or pay approximately $0.20/km to use Hwy 407. At this rate, a short 15 km trip costs Hwy 407 users $3.00 and a medium-long 40 km trip costs $8.00. With lower traffic volumes per lane in all travel periods, Hwy 407 is a more reliable travel option than Hwy 401.

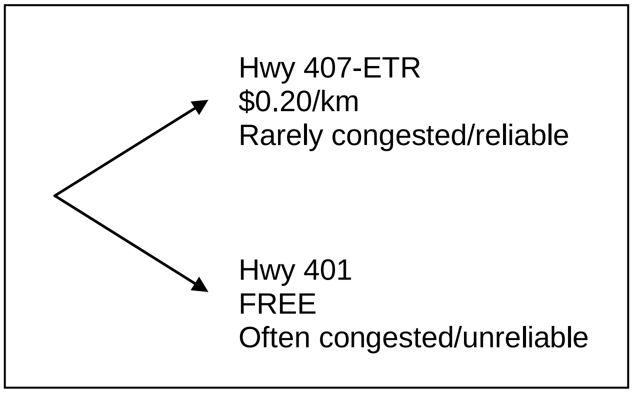


Figure 4.9: Hwy 401 corridor drivers have a choice to pay to escape congestion by using toll Hwy 407-ETR

The relationship of Hwy 407 to Hwy 401 allowed for an investigation of how corridor drivers behave when presented with a choice of a more reliable, tolled alternative. The revealed traffic volume analysis reinforces stated preference findings by demonstrating the relationships between trip urgency, Hwy 401 volume, and driver choice to use Hwy 407.

To conduct the analysis, hourly traffic volume counts along Highways 401 and 407 were acquired from the Ministry of Transportation of Ontario (MTO) and 407-ETR. Data spanned a 5 week period beginning Monday March 9 and ending Sunday April 12, 2009. The data period included the Good Friday statutory holiday, which fell on Friday April 10, 2009.

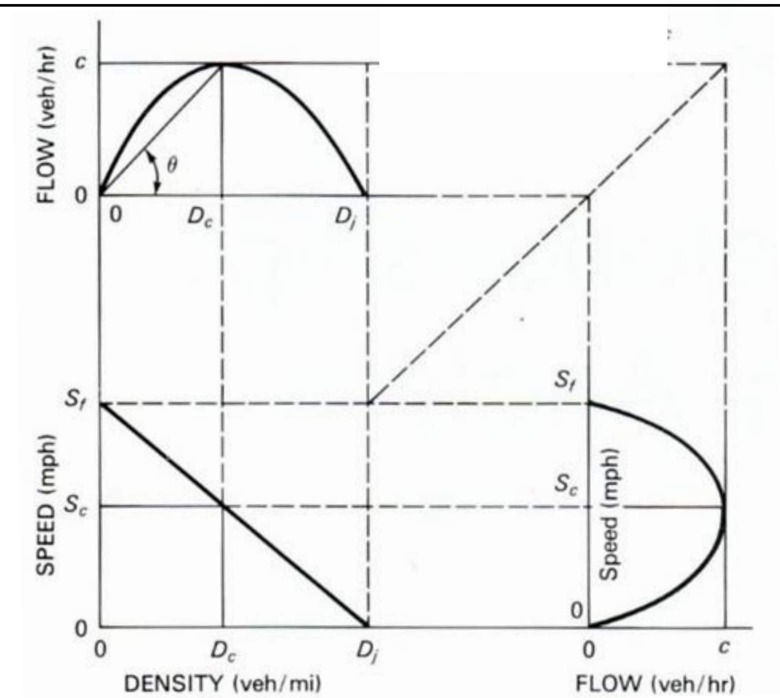
Average Eastbound and Westbound, weekday and Saturday/Sunday/holiday directional hourly vehicle counts were analyzed along both highways East of Dufferin St. (Hwy 407)/W. R. Allen Rd. (Hwy 401) (see Figure 4.10).

Figure 4.10: The screenline was located East of Dufferin St. (Hwy 407) / W.R. Allen Rd. (Hwy 401)
Source: Google Maps

4.5.1 **Traffic profiles**

Average weekday and Saturday/Sunday/holiday traffic profiles were prepared for eastbound and westbound directions. Traffic profiles charted the average number of vehicles per hour over a 24 hour period. Highways 401 and 407 average hourly traffic volume was plotted on the same graph to enable comparisons.

General and detailed observations about corridor throughput and willingness to use Hwy 407 were noted for each traffic profile. Observations noted the shape of traffic volumes along both highways, highlighted periods of congestion-induced reductions in Hwy 401 throughput, and discussed the relationship of Hwy 401 volume, time of day, and Hwy 407 usage. The identification of periods of congestion-induced reductions in throughput was based on an understanding of the relationship of speed, density and flow (see Figure 4.11). When density is zero, the speed of traffic moves at free-flow conditions (S_f). As density increases, speed decreases until jam density is reached (D_j) – the density at which all movement stops ($S = 0$ mph). When density is zero, flow is zero as there is no traffic on the road. Flow increases with density until critical density (D_c) is reached and capacity is achieved. Additional increases in density reduce total flow as traffic slows to D_j (McShane and Roess, 1990). Thus, there exists periods where increases in vehicle density result in decreased throughput. In the analysis of highways 401 and 407 throughput data, it is assumed that lower-than-expected throughput in peak periods are a result of this phenomenon.



Where c = capacity, the maximum rate of flow (veh/hr)

S_c = critical speed, the speed at which capacity occurs (mph)

D_c = critical density, the density at which capacity occurs (veh/mi)

D_j = jam density, the density at which all movement stops, S = 0 mph

S_f = free-flow speed, the theoretical speed of traffic when density is zero (mph)

Figure 4.11: The relationship of speed, flow and density on a limited access freeway

Source: McShane and Roess, 1990, p. 286.

4.5.2 **Highway 407-ETR throughput share**

Total corridor throughput is the combined Hwy 401 and Hwy 407 directional throughput passing the screenline each hour.

$$\text{TOTAL throughput}_{dir} = \text{Hwy 401 throughput}_{dir} + \text{Hwy 407 throughput}_{dir};$$

Where *dir* represents the direction, eastbound or westbound.

Equation 4.3: Formula to calculate total corridor throughput share

Hwy 407 throughput share is the percentage of total corridor throughput using Hwy 407.

$$\text{Hwy 407 throughput share}_{dir} = \text{Hwy 407 throughput}_{dir} / \text{TOTAL throughput}_{dir} * 100$$

Equation 4.4: Formula to calculate Hwy 407 throughput share

Average weekday and Saturday/Sunday/holiday Hwy 407 throughput share values were calculated for each hour of the day for both directions of travel. Results were compared with assigned trip urgency levels and revealed hourly Hwy 401 volumes to highlight the effect of those factors on route choice.

For this analysis, trip urgencies were assumed for each hour of the day. Urgency was categorized as low, medium, or high. Weekday morning (5 to 9 AM) and afternoon periods (3 – 7 PM) – including both peaks – were categorized as high urgency; the weekday midday period was categorized as moderate urgency; and all other periods (including all Saturday/Sunday/holiday periods) were categorized as low urgency. The values are summarized in Table 4.11

Table 4.11: Trip urgency categories

Travel period	Hours	Assumed trip urgency
Weekday early morning	12 AM – 5 AM	Low
Weekday morning (incl. peak)	5 AM – 9 AM	High
Weekday midday	9 AM – 3 PM	Moderate
Weekday afternoon (incl. peak)	3 PM – 7 PM	High
Weekday evening	7 PM – 12 AM	Low
Sat/Sun/holiday	12 AM – 12 AM (24 hrs)	Low

For this analysis, Hwy 401 hourly traffic volumes were categorized as follows: low (0 – 799 vehicles/hour/lane), moderate (800 – 1,199 vehicles/hour/lane), and high (1,200 + vehicles/hour/lane) (see Table 4.12). Traffic volume per traffic lane was obtained by dividing hourly Hwy 401 one-way throughput by the number of one-way Hwy 401 through travel lanes at the screenline. The number of lanes at the screenline was obtained from Google Map streetview images.

$$\text{Hwy 401 vehicles/hr/lane}_{dir} = \text{Hwy 401 throughput}_{dir} \,/\, \text{Hwy 401 travel lanes}_{dir}$$

Equation 4.5: Formula to calculate Hwy 401 vehicles/hour/lane

Table 4.12: Hwy 401 volume classification

Hwy 401 volume designation	One-way traffic volume per lane
Low	0 – 799 veh/hr/lane
Moderate	800 – 1,199 veh/hr/lane
High	1,200 + veh/hr/lane

It was expected that Hwy 407 throughput share would be influenced by trip urgency and Hwy 401 volume in the following manner:

Table 4.13: Expected Highway 407 throughput share (LOW, MODERATE, HIGH)

		Hwy 401 traffic volume		
		High	Moderate	Low
Trip urgency	High	HIGH	MOD-HIGH	MOD-LOW
	Moderate	MOD-HIGH	MODERATE	LOW
	Low	MODERATE	MOD-LOW	LOW

1. When Hwy 401 traffic volume is low and trip urgency is low, Hwy 407 throughput share will be low. Few drivers will be willing to pay to use the tolled alternative.
2. When Hwy 401 traffic volume is high and trip urgency is high, Hwy 407 throughput share will be high. Many drivers will be willing to pay to use the tolled alternative.
3. When Hwy 401 traffic volume is low and trip urgency is moderate, Hwy 407 throughput share will be low.
4. When Hwy 401 traffic volume is low and trip urgency is high, Hwy 407 throughput share will be moderate-low. Despite high urgency, most drivers will take the non-tolled highway if flow is unimpeded.
5. When Hwy 401 traffic volume is high and trip urgency is low, Hwy 407 throughput share will be moderate. Some drivers will pay to escape congestion but most will not consider it worthwhile.

5 RESULTS

This chapter presents the results of observations and statistical analyses performed on stated preference survey and revealed traffic volume data. Findings are organized and presented by research question.

5.1 *Respondents' travel characteristics and demographic data*

Of the 4,000 survey packets distributed, a total of 255 eligible questionnaires were returned for a return rate of 6.4%. All questionnaires mailed by the due date were included in the sample. The returned sample included responses from all 5 sample areas (see Table 5.1).

Table 5.1: Sample area distribution

Sample Area	Frequency	Percent
1	67	26.3
2	51	20.0
3	55	21.6
4	43	16.9
5	39	15.3
Total	255	100.0

To reduce the impact of outliers on mean values, WTP values exceeding $12 were reduced to $12. Individual WTP values ranged from $0 to $30 but the vast majority of responses were within the $0 to $10 range. Table 5.2 quantifies the number of responses reduced to $12 per trip condition.

Table 5.2: Outlying WTP responses >$12 that were reduced to $12

Trip condition (Urg, Spd, Dist)	Number of cases affected	Original WTP values
Trip 1 (H, 30 km/h, 15 km)	5	$15 (2), $20 (2), $22
Trip 2 (L, 30 km/h, 15 km)	0	-
Trip 3 (H, 70 km/h, 15 km)	0	-
Trip 4 (L, 70 km/h, 15 km)	0	-
Trip 5 (H, 30 km/h, 40 km)	9	$20 (7), $22, $30
Trip 6 (L, 30 km/h, 40 km)	2	$20 (2)
Trip 7 (H, 70 km/h, 40 km)	3	$15, $20 (2)
Trip 8 (L, 70 km/h, 40 km)	1	$20

The vast majority of respondents primarily drove alone (80%). The remaining 20% carpooled, took public transit, or used active transportation most of the time (see Figure 5.1).

Mode	Frequency	Percent	Valid Percent	Cumulative Percent
Drive alone	204	80.0	80.3	80.3
Drive with others	14	5.5	5.5	85.8
Passenger	8	3.1	3.1	89.0
Public transit	22	8.6	8.7	97.6
Bicycle	1	.4	.4	98.0
Walk	5	2.0	2.0	100.0
Total	254	99.6	100.0	
MISSING	1	.4		
TOTAL	255	100.0		

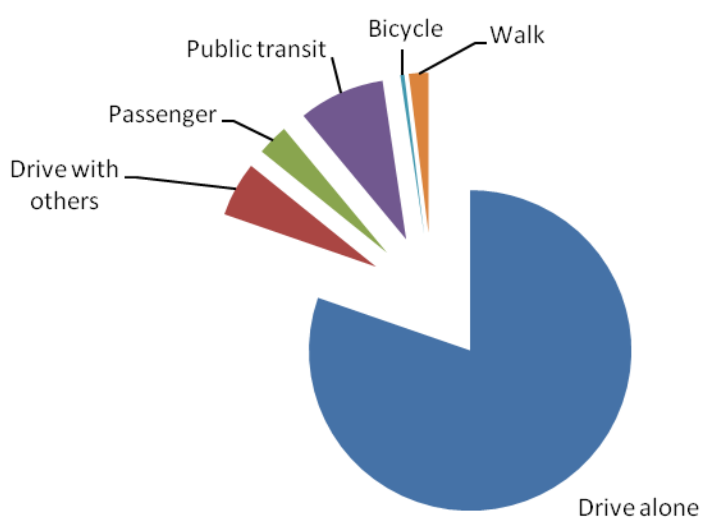


Figure 5.1: Respondent dominant trip mode

Nearly half of all respondents primarily used the 400-series network to commute between home and work/school (49.4%). While 5.8% of respondents mainly used the highways for business purposes, 44.8% of respondents primarily used the freeways to travel to/from leisure activities such as shopping, recreational activities, or visits with friends or family (see Figure 5.2).

Trip Purpose	Frequency	Percent	Valid Percent	Cumulative Percent
Commuting to/from work/school	120	47.1	49.4	49.4
Going shopping	19	7.5	7.8	57.2
Travelling to recreation activities	43	16.9	17.7	74.9
Visiting friends/family	47	18.4	19.3	94.2
Business purposes	14	5.5	5.8	100.0
Total	243	95.3	100.0	
MISSING	12	4.7		
TOTAL	255	100.0		

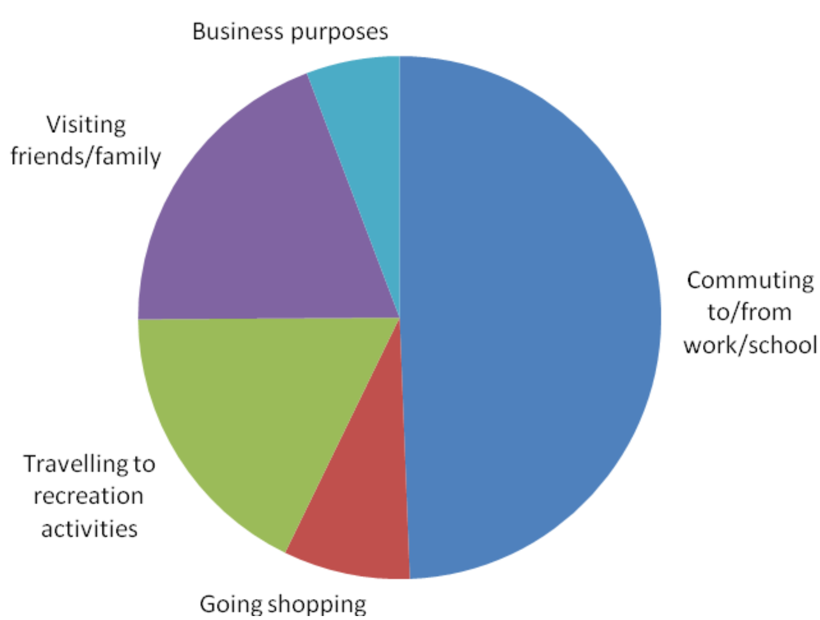


Figure 5.2: Most common 400-series trip purpose

Most respondents were regular 400-series users. 42.5% of respondents indicated that they travel the 400-series network at least once a day; 33.9% and 16.9% travelled the highways at least once a week and once a month, respectively. Only a small minority of respondents used the network less than once a month or not at all (6.7%) (see Figure 5.3).

Travel frequency	Frequency	Percent	Valid Percent	Cumulative Percent
Daily	108	42.4	42.5	42.5
At least once a week	86	33.7	33.9	76.4
At least once a month	43	16.9	16.9	93.3
At least once every 6 months	11	4.3	4.3	97.6
Less than once every 6 months	4	1.6	1.6	99.2
Never travel on a 400-series hwy	2	.8	.8	100.0
Total	254	99.6	100.0	
MISSING	1	.4		
TOTAL	255	100.0		

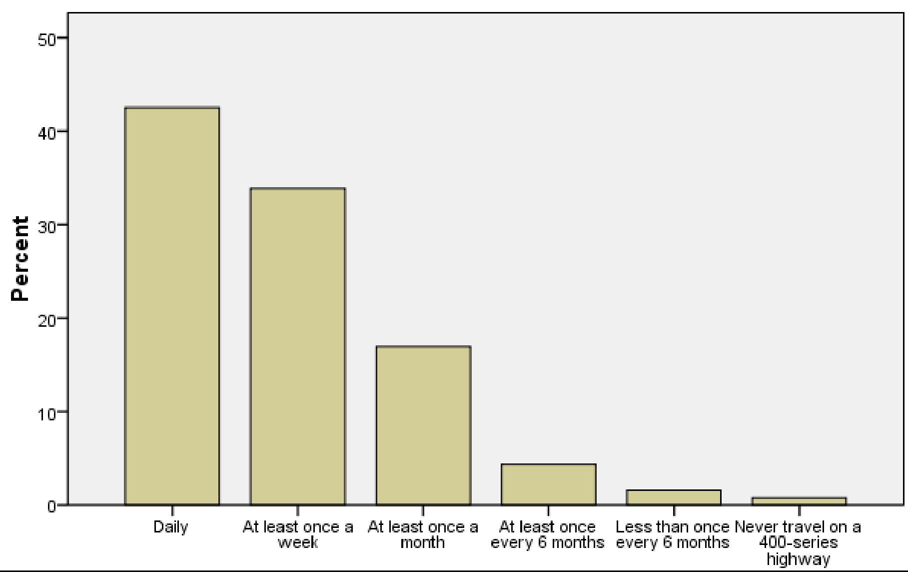


Figure 5.3: Frequency of travel on the 400-series network

Previous exposure to Hwy 407-ETR can be interpreted as an indicator of whether or not respondents have had experience with electronic tolling. In all, 61.1% of respondents have travelled the highway while 38.9% have never travelled the highway. 6.3% of respondents travelled the road at least once a day, while an additional 9.1% travelled the road at least once a week. Cumulatively, 45.6% of respondents travelled Hwy 407-ETR at least once every 6 months (see Figure 5.4)

Travel frequency	Frequency	Percent	Valid Percent	Cumulative Percent
Daily	16	6.3	6.3	6.3
At least once a week	23	9.0	9.1	15.5
At least once a month	36	14.1	14.3	29.8
At least once every 6 months	40	15.7	15.9	45.6
Less than once every 6 months	39	15.3	15.5	61.1
Never travel on Hwy 407	98	38.4	38.9	100.0
Total	252	98.8	100.0	
MISSING	3	1.2		
TOTAL	255	100.0		

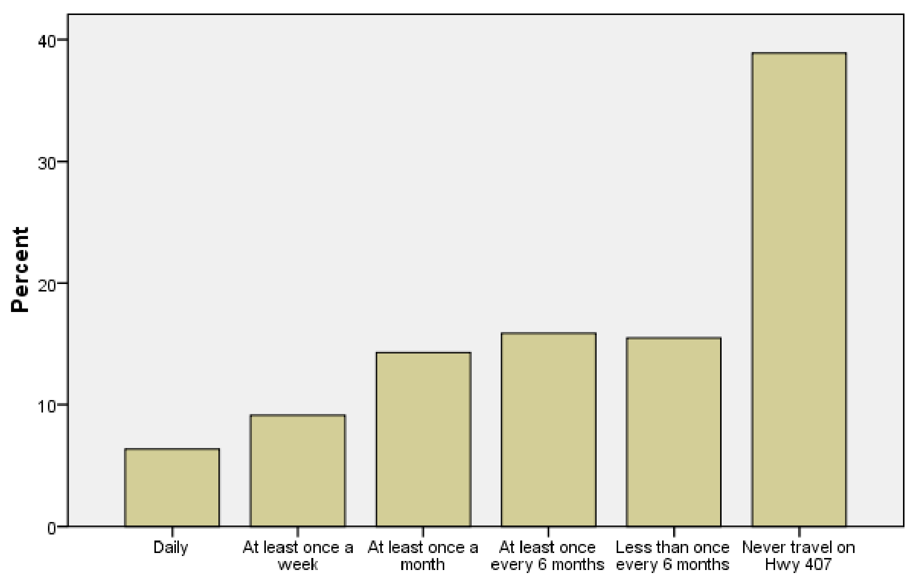


Figure 5.4: Frequency of travel on Hwy 407-ETR

Despite the varied locations of sample areas, 47% of respondents identified Hwy 401 as the GTA highway they travel the most. The Don Valley Parkway/Hwy 404 placed a distant second at 22.2%. The remaining GTA highways, including the Gardiner Expy/QEW, Hwy 400, and Hwy 427 were each selected by fewer than 10% of respondents (see Figure 5.5) [2].

400-series highway	Frequency	Percent	Valid Percent	Cumulative Percent
Hwy 400	15	5.9	6.5	6.5
Hwy 401	108	42.4	47.0	53.5
Hwy 403	16	6.3	7.0	60.4
Hwy 410	3	1.2	1.3	61.7
Hwy 427	8	3.1	3.5	65.2
DVP/Hwy 404	51	20.0	22.2	87.4
Gardiner/QEW	22	8.6	9.6	97.0
W.R. Allen Road	7	2.7	3.0	100.0
Total	230	90.2	100.0	
MISSING	25	9.8		
TOTAL	255	100.0		

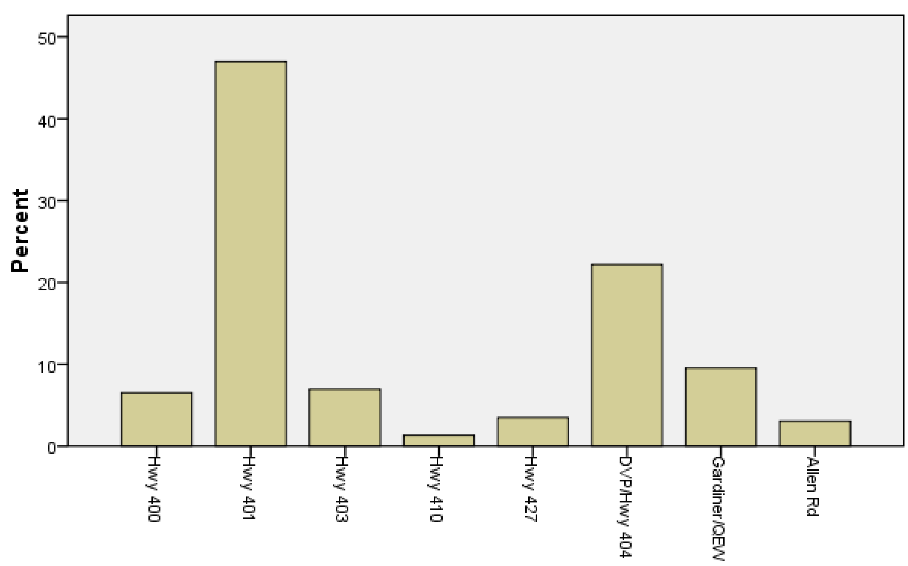


Figure 5.5: Most frequently travelled GTA 400-series highway

[2] Response options did not include Hwy 407-ETR.

Nearly all respondents indicated that they have been frustrated by congestion along a GTA 400-series highway (95.3%). Such unanimity in response is indicative of the extent and severity of highway congestion in the GTA (see Table 5.3).

Table 5.3: Respondents frustrated by congestion along GTA 400-series highways

	Frequency	Percent	Valid Percent	Cumulative Percent
Not frustrated	12	4.7	4.7	4.7
Frustrated	241	94.5	95.3	100.0
Total	253	99.2	100.0	
MISSING	2	.8		
TOTAL	255	100.0		

The gender distribution of the sample was fairly even. 53% of respondents were male and 47% of respondents were female (see Table 5.4).

Table 5.4: Gender of respondents

	Frequency	Percent	Valid Percent	Cumulative Percent
Male	134	52.5	53.0	53.0
Female	119	46.7	47.0	100.0
Total	253	99.2	100.0	
Missing	2	.8		
TOTAL	255	100.0		

Respondents were of every eligible age group. While a plurality (44.2%) of respondents were middle-aged (35 – 54), 28.1% were young (18 – 34) and 27.7% were older (55+). Respondents had to be at least 18 years of age to participate in the study (see Figure 5.6).

Age range	Frequency	Percent	Valid Percent	Cumulative Percent
18 – 24	20	7.8	7.9	7.9
25 – 34	51	20.0	20.2	28.1
35 – 44	57	22.4	22.5	50.6
45 – 54	55	21.6	21.7	72.3
55 – 64	41	16.1	16.2	88.5
65+	29	11.4	11.5	100.0
Total	253	99.2	100.0	
Missing	2	.8		
TOTAL	255	100.0		

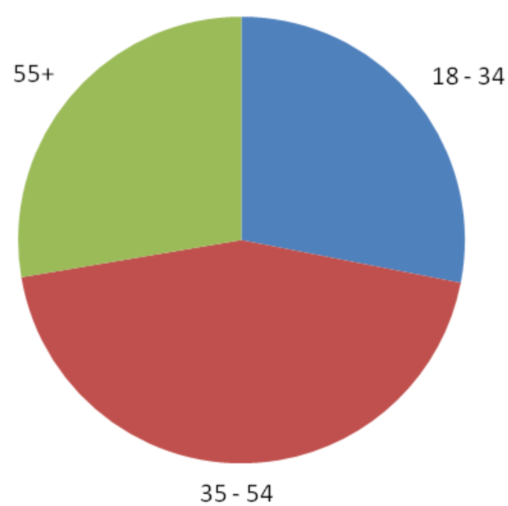


Figure 5.6: Respondent age

Participants came from a range of socio-economic backgrounds. Although a plurality of respondents (45%) were from middle-income household ($60,000 - $119,999/year), 25.2% of respondents were from lower-income households ($0 - $59,999) and 29.8% of respondents were from high-income households ($120,000 or more). A substantially large percentage (22.3%) of respondents had annual household incomes of $140,000 or more (see Figure 5.7).

Income group	Frequency	Percent	Valid Percent	Cumulative Percent
Less than $20,000	4	1.6	1.7	1.7
$20,000 - $39,999	19	7.5	8.0	9.7
$40,000 - $59,999	37	14.5	15.5	25.2
$60,000 - $79,999	37	14.5	15.5	40.8
$80,000 - $99,999	36	14.1	15.1	55.9
$100,000 - $119,999	34	13.3	14.3	70.2
$120,000 - $139,999	18	7.1	7.6	77.7
$140,000 or more	53	20.8	22.3	100.0
Total	238	93.3	100.0	
Missing	17	6.7		
TOTAL	255	100.0		

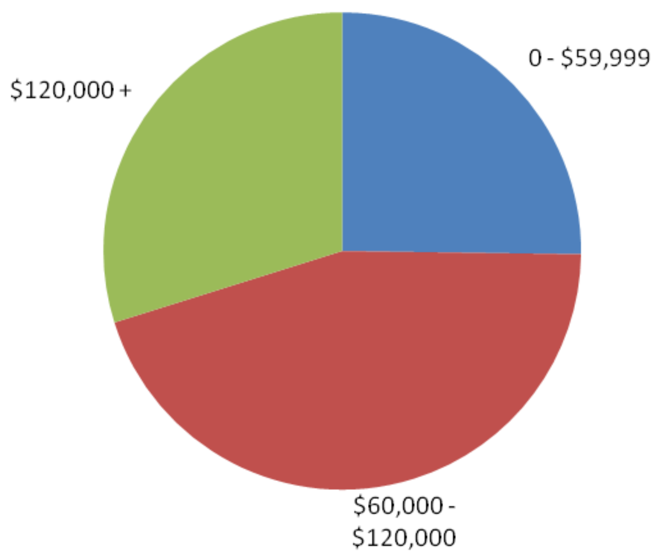


Figure 5.7: Respondent annual household income

5.2 *Results to Research Question 1: What proportion of Toronto-area drivers are willing to pay to escape congestion?*

The vast majority of respondents were conditionally willing to pay to escape congestion along GTA 400-series highways (see Figure 5.8). In trip 5, where trip urgency was high, traffic speed was 30 km/h and 400-series trip distance was 40 km, 86.2% of respondents were willing to pay to escape congestion. Only a small minority of respondents (13.8%) refused to pay entirely.

A similar percentage of respondents were willing to pay to escape congestion (84.5%) in trip 1 where trip urgency was high, traffic speed was 30 km/h and 400-series trip distance was 15 km. In fact, a majority of respondents was willing to pay to escape congestion in 6 out of 8 trip conditions. Even in low urgency trip conditions 6 and 2, 65.3% and 58.3% of respondents were willing to pay to escape congestion, respectively.

A significant percentage of respondents were willing to pay to escape congestion in “good” travel conditions. In trip 4, where trip urgency was low, traffic speed was 70 km/h, and 400-series trip distance was 15 km, 37.7% of respondents were willing to pay to escape congestion.

Trip Condition (Urg-Spd-Dist) hypothesized worst to best condition	**%-WTP (Response > $0)**	**%-Not WTP (Response = $0)**
Trip 5 (H-30-40)	86.2%	13.8%
Trip 1 (H-30-15)	84.5%	15.5%
Trip 7 (H-70-40)	75.1%	24.9%
Trip 6 (L-30-40)	65.3%	34.7%
Trip 3 (H-70-15)	69.2%	30.8%
Trip 2 (L-30-15)	58.3%	41.7%
Trip 8 (L-70-40)	44.3%	55.7%
Trip 4 (L-70-15)	37.7%	62.3%

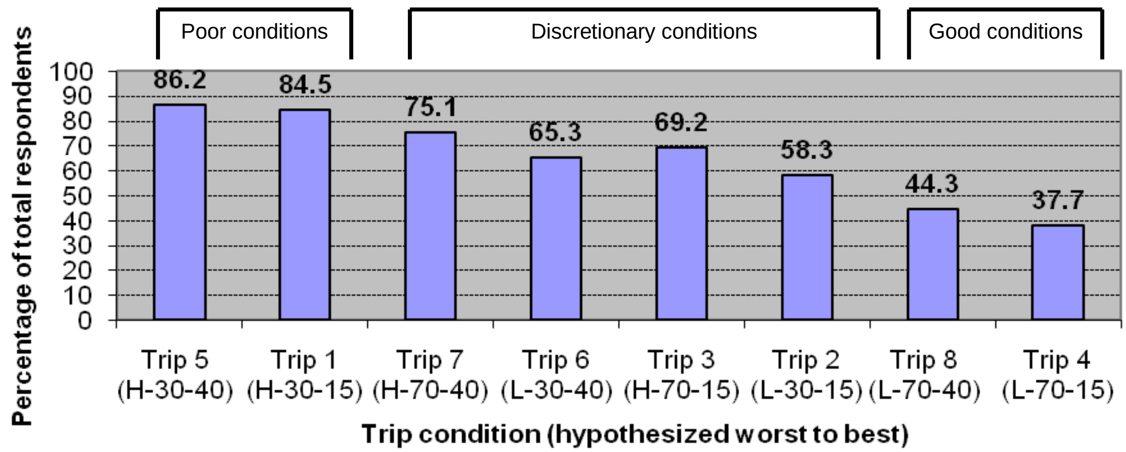


Figure 5.8: Percentage of respondents who are willing to pay to escape congestion by trip condition

5.3 *Results to Research Question 2: How do trip urgency, traffic speed, and 400-series trip distance affect WTP to escape congestion?*

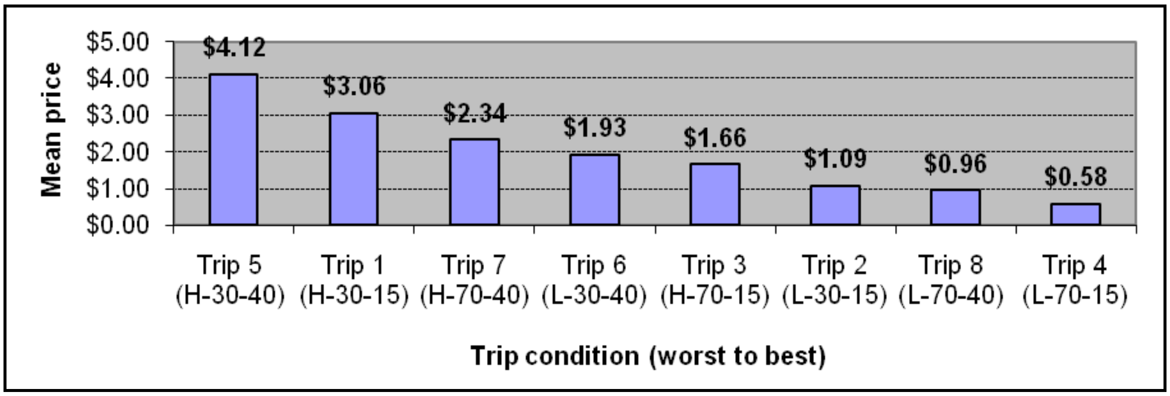
Two sets of WTP mean values are presented in this section. The first set is the mean price all respondents (N = 251) were willing to pay to escape congestion; the second set is the mean price potential HOT-lane users (Trip 5 WTP > $0, N = 217) were willing to pay to escape congestion.

The mean values of all respondents are graphed twice in Figure 5.9 – from worst to best trip condition (A) and sequentially (B) – to allow for easier identification of key trends. Trip condition mean WTP values varied considerably. As expected, respondents were willing to pay the most to escape congestion in trip 5 and the least to escape congestion in trip 4, $4.12 and

$0.58, respectively. WTP was highest to escape congestion in high urgency trips taken in 30 km/h traffic speeds (trips 5 and 1). Conversely, WTP was lowest in low urgency trips taken in 70 km/h traffic speeds (trips 4 and 8). The means of trips 1 through 4 and trips 5 through 8 exhibited similar downward sloping peak-trough-peak-trough patterns (see Figure 5.9 B), illustrating that WTP was more affected by trip urgency than by traffic speed (see Section 5.3.1 for quantified statistical findings). Increasing trip distance from 15 km to 40 km amplified WTP mean values but did not alter the overall pattern. Of the four trips with highest WTP means, three had high urgency values (trips 5, 1, 7), three had low/30 km/h traffic speeds (trips 5, 1, 6), and three had high/40 km 400-series trip distances (trips 5, 6, 7).

To standardize trip costs, average WTP/km was calculated for each trip condition. Respondents were willing to pay more on a per kilometre basis to escape short trips (15 km) than they were to escape medium-long (40 km) trips. Interestingly, respondents were willing to pay $0.20/km to escape congestion in trip 1 (high urgency, 30 km/h, 15 km) but only half that amount to escape congestion in trip 5 (high urgency, 30 km/h, 40 km) – the worst trip condition. If HOT-lanes were priced at the current Hwy 407-ETR rate of approximately $0.20/km, the average traveller would choose to use HOT-facilities to escape trip condition 1 but would use free GP-lanes for the other seven trip conditions.

Trip condition (Urg-Spd-Dist)	N	Mean	Std. Error	$/km	Std. Deviation
Trip 5 (H-30-40)	253	$4.12	$0.22	$0.10	$3.43
Trip 1 (H-30-15)	252	$3.06	$0.18	$0.20	$2.85
Trip 7 (H-70-40)	253	$2.34	$0.16	$0.06	$2.51
Trip 6 (L-30-40)	251	$1.93	$0.16	$0.05	$2.48
Trip 3 (H-70-15)	253	$1.66	$0.13	$0.11	$2.12
Trip 2 (L-30-15)	252	$1.09	$0.10	$0.07	$1.63
Trip 8 (L-70-40)	253	$0.96	$0.11	$0.02	$1.79
Trip 4 (L-70-15)	252	$0.58	$0.09	$0.04	$1.40



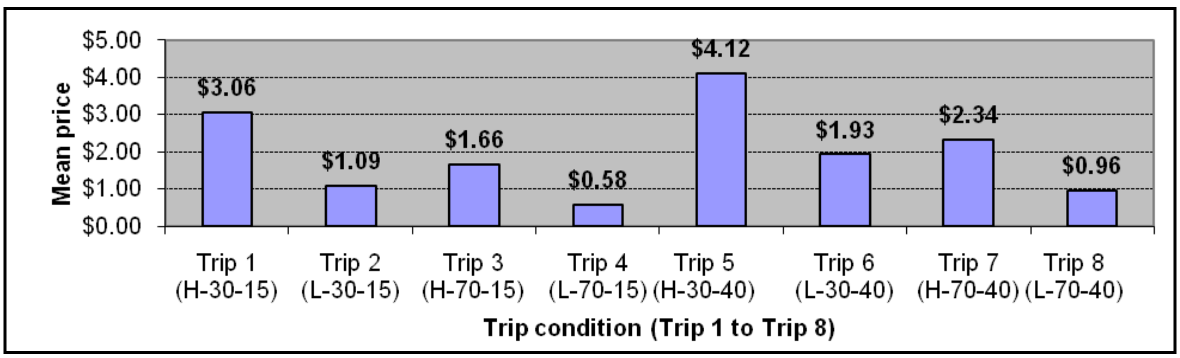


Figure 5.9: (A) WTP means presented from worst to best condition and **(B)** sequentially

The trip condition mean values of potential HOT-lane users were similar in pattern to those of the sample as a whole (see Figure 5.10). As expected, potential HOT-lane user mean values were higher than all respondent means in each trip condition. The difference between potential HOT-lane user and all respondent mean values was more pronounced under poor traffic conditions.

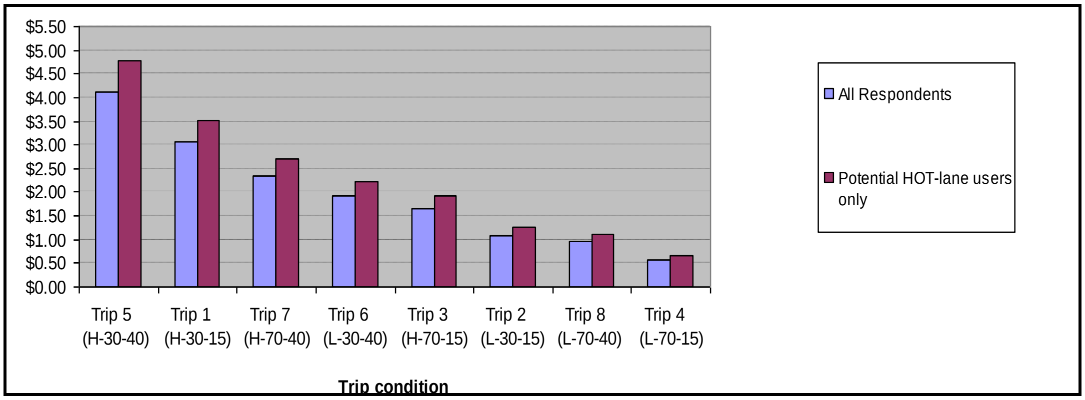


Figure 5.10: Trip condition mean WTP values of all respondents and potential HOT-lane users

Trip condition case frequency distributions for the sample as a whole are presented in Figure 5.11. In general, poor trip conditions exhibited wide case frequency distributions while good trip conditions exhibited far narrower distributions. Cases were normally distributed in poor trip conditions; good cases exhibited substantial kurtosis and were noticeable positively skewed due to the high frequency of WTP = $0 responses.

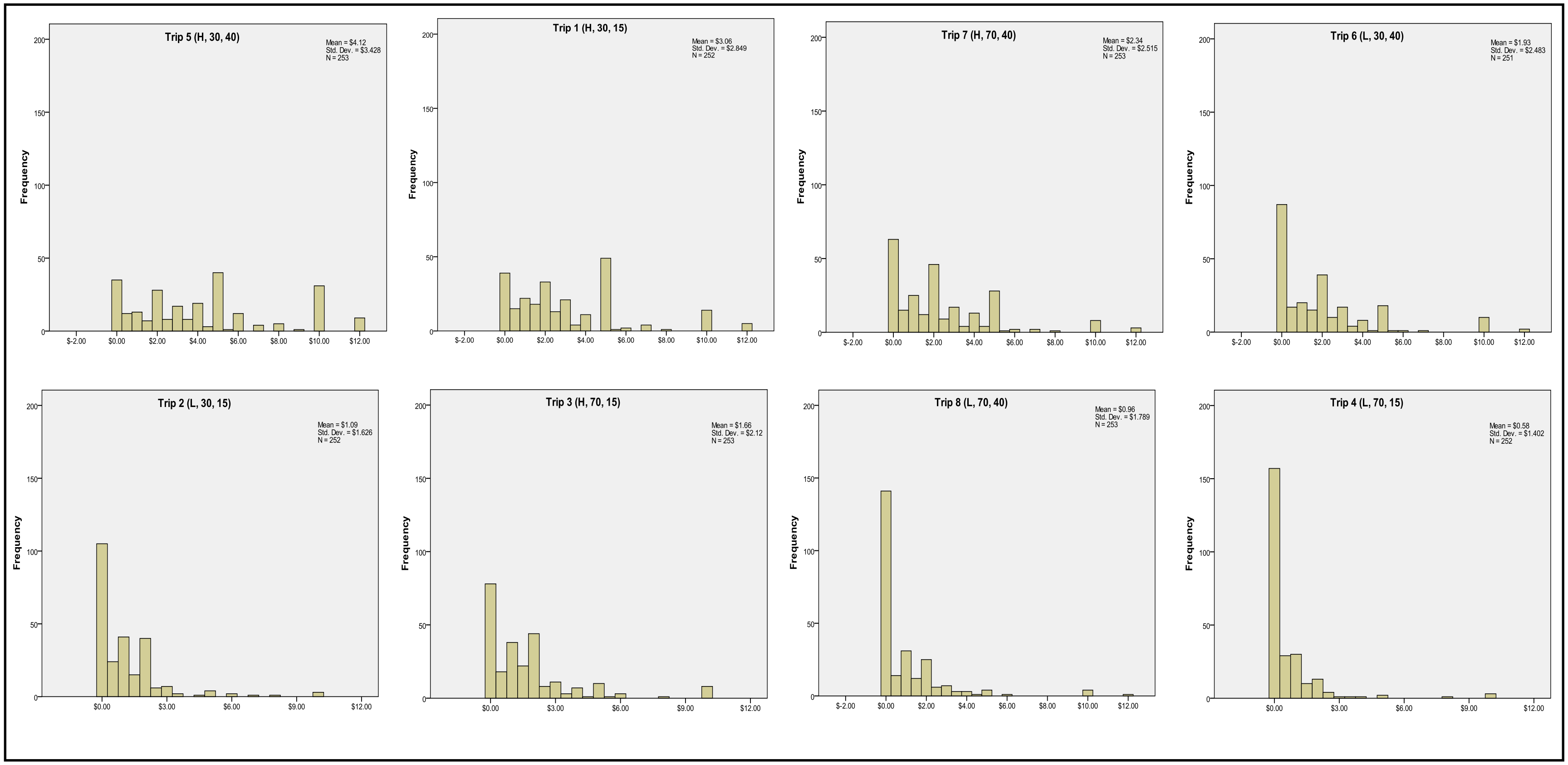


Figure 5.11: Trip condition case frequency distributions (presented from best to worst trip condition)

5.3.1 **Statistical tests**

The impacts of three main effects (urgency, traffic speed, and trip distance) and four interaction effects (urgency*speed, urgency*distance, speed*distance, urgency*speed*distance) on WTP were assessed among the sample as a whole (N = 252).

Factorial ANOVA results calculated from untransformed WTP findings were inaccurate because they violated Levene's test of equality of error variances (see Table 5.5). Levene's test revealed heterogeneity of error variances in the tested means, $F(7, 244) = 2.646$, at significance $p < .05$. As a result, WTP data had to be transformed to ensure reliable results.

Table 5.5: Levene's test of equality of error variances

Dependent Variable: Willingness to Pay to Escape Congestion			
F	df1	df2	Sig.
2.646	7	244	.012

A logarithmic base 10 transformation was employed to reduce the right tail of the distribution. Being that a number of inputted WTP values were $0 and that it is mathematically impossible to derive a logarithm of '0', it was necessary to add '1' to each original data point. Transformed data points inputted into factorial ANOVA were thus the log(original WTP value+1).

Factorial ANOVA results calculated from log(original WTP value+1) transformed findings were admissible because they did not violate Levene's test of equality of error variances. Levene's test did not reveal heterogeneity of error variances in the tested means, $F(7, 244) = 1.007$, at significance $p > .05$.

As explained in Section 4.3.2, to ensure independence every questionnaire was randomly assigned a trip condition from 1 to 8. Each questionnaire's assigned trip condition and associated WTP value were used in the ANOVA – all other trip condition responses were discarded. Table 5.6 displays the number of cases that make up each trip condition used in the ANOVA, along with each trip condition's untransformed mean value.

Table 5.6: Mean values of trip conditions used in the ANOVA

Trip Condition (Urg, Spd, Dist)	Mean	Standard Deviation	N
Trip 1 (H, 30 km/h, 15 km)	$2.5000	$1.80836	32
Trip 2 (L, 30 km/h, 15 km)	$1.0887	$1.96272	31
Trip 3 (H, 70 km/h, 15 km)	$1.1875	$1.46601	32
Trip 4 (L, 70 km/h, 15 km)	$.7581	$1.97324	31
Trip 5 (H, 30 km/h, 40 km)	$3.6641	$3.04708	32
Trip 6 (L, 30 km/h, 40 km)	$1.9766	$2.72263	32
Trip 7 (H, 70 km/h, 40 km)	$2.3281	$2.15099	32
Trip 8 (L, 70 km/h, 40 km)	$1.0250	$1.96121	30

To assess the impact of urgency on WTP, the ANOVA compared the transformed mean value of all low urgency cases with the transformed mean value of all high urgency cases. The ANOVA employed the same method to assess the main effects of speed and distance. The untransformed mean values of all high urgency and low urgency cases, all 30 km/h and 70 km/h cases, and all 15 km and 40 km cases are displayed in Table 5.7.

Table 5.7: Between-subjects factors

	Label	Mean	Standard Error	N
Trip urgency	High urgency	$2.420	$0.194	128
	Low urgency	$1.212	$0.197	124
Traffic speed	30 km/h	$2.307	$0.195	127
	70 km/h	$1.325	$0.196	125
Trip distance	15 km trip	$1.384	$0.195	126
	40 km trip	$2.248	$0.195	126

Full transformed factorial ANOVA results are presented in Table 5.8:

Table 5.8: Tests of between-subjects effects (N = 252)

Dependent Variable: LOG of WTP to Escape Congestion

Source	Type IV Sum of Squares	df	Mean Square	F	Sig.	η	η^2
Corrected Model	4.972[a]	7	.710	9.169	.000		
Intercept	27.845	1	27.845	359.422	.000		
URGENCY	2.612	1	2.612	33.714	.000	0.331	0.109
SPEED	1.332	1	1.332	17.195	.000	0.236	0.056
DISTANCE	.854	1	.854	11.029	.001	0.189	0.036
URGENCY * SPEED	.057	1	.057	.738	.391	0.049	0.002
URGENCY * DISTANCE	.022	1	.022	.280	.597	0.030	0.001
SPEED * DISTANCE	.001	1	.001	.016	.898	0.007	0.000
URGENCY * SPEED * DISTANCE	.095	1	.095	1.222	.270	0.063	0.004
Error	18.903	244	.077			0.890	0.792
Total	52.106	252					
SS(total)	23.876					1.000	1.000

*Significant values shaded (two-tailed significance p < .05)

The mean WTP for high urgency trips was derived from 128 cases while the mean WTP for low urgency trips was derived from 124 cases.

There was a significant main effect of urgency on willingness to pay, $F(1) = 33.714$ at significance $p < .001$, $\eta = .331$ ($\eta^2 = .109$ or 10.9%). Respondents with high trip urgencies were willing to pay significantly more to escape congestion than respondents with low trip urgencies. This finding validated the hypothesis and was congruent with results from past research.

Similar tests were conducted for speed and distance and each was found to be statistically significant. The interaction of urgency and speed, urgency and distance, speed and distance, and urgency, speed, and distance did not reveal significant effects. Table 5.8 summarizes the results. For a full write-up of all statistical findings see Appendix 3.

Of the three factors that significantly affected WTP to escape congestion, trip urgency was found to have the greatest effect ($\eta = .331$, $\eta^2 = .109$ or 10.9%), followed by traffic speed ($\eta = .236$, $\eta^2 = .056$ or 5.6%), and 400-series trip distance ($\eta = .189$, $\eta^2 = .036$ or 3.6%) (see Figure 5.12). This finding validated the hypothesis. The effect size of interactions was not displayed as none was found to be significant.

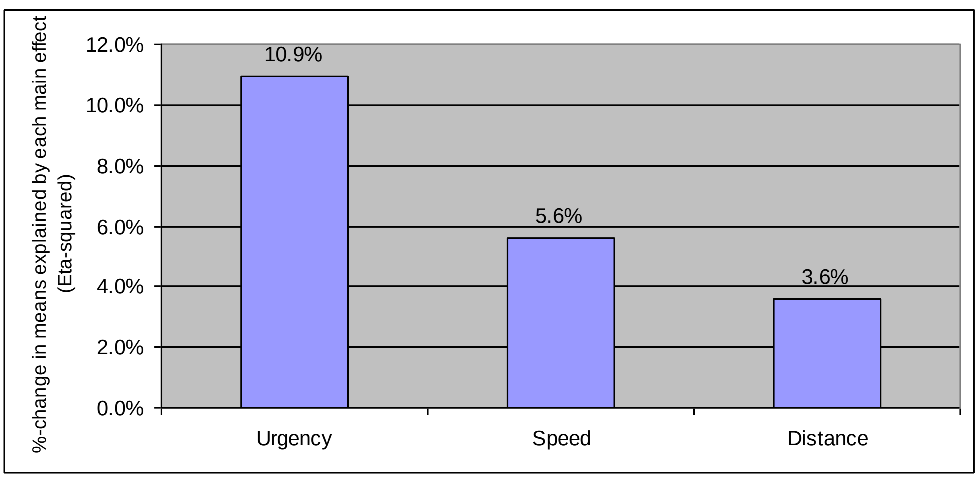


Figure 5.12: The effect size of urgency, speed, and distance on WTP

5.3.2 WTP as a function of travel time saved

Value of travel time savings were calculated from survey results by combining speed and distance indicators and subtracting travel time at 100 km/h for each trip condition.

$$\text{Travel Time Saved}_{x\ (hrs)} = (\text{Distance}_{x\ km} / \text{Speed}_{x\ km}) - (\text{Distance}_{x\ km} / 100\ \text{km/h})$$

$$\text{Travel Time Saved}_{x(mins)} = \text{Travel Time Saved}_{x(hrs)} * 60\ \text{minutes}$$

Equation 5.1: Formula to calculate travel time savings

$$\text{VTTS}_x = \text{WTP}_x / \text{Travel Time Saved}_{x(hrs)}$$

Equation 5.2: Formula to calculate hourly VTTS

Figure 5.13 charts WTP means against travel time saved for high urgency and low urgency trips. Results reveal that the marginal cost respondents were willing to pay to save an additional minute of travel time decreased with travel time saved. Respondents were willing to pay a substantial minimal mean value to save even a few minutes of travel time; as travel time savings increased, the rate of WTP/travel time saved flattened.

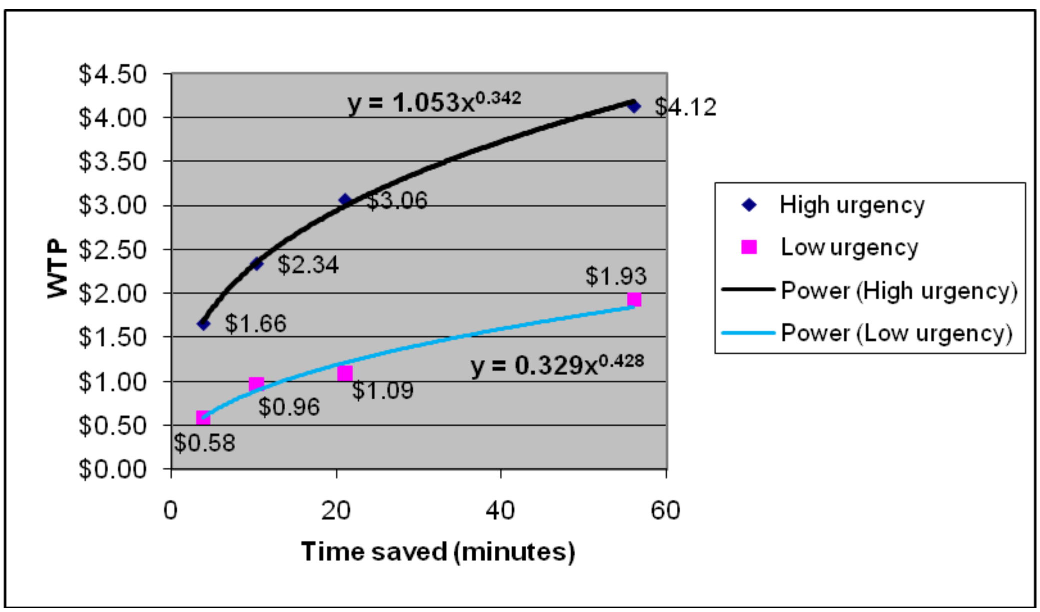


Figure 5.13: Amount respondents were willing to pay for travel time saved

Derived equations are as follows:

$$WTP = f(tts)$$

For urgent trips $WTP = 1.0532(tts^{0.3462})$

Equation 5.3: Willingness to pay to escape urgent trips

For non-urgent trips $WTP = 0.3295(tts^{0.4281})$

Equation 5.4: Willingness to pay to escape non-urgent trips

Where tts = travel time saved (minutes)

WTP = willingness to pay ($)

The shape of WTP/travel time saved was not linear. For both urgent and non-urgent trips, WTP/travel time saved increased rapidly at first; as travel time saved increased, the marginal WTP rate decreased. High urgency trips had consistently higher WTP/travel time saved values than low urgency trips. Further, the slope of WTP/travel time saved in high urgency trips was far steeper between 0 and 40 minutes saved than the slope in low urgency trips over the same period.

The shape of this relationship indicates that *hourly* VTTS values are a misleading measurement of WTP. In trip 3 (high urgency, 70 km/h traffic speed, 15 km 400-series trip distance), respondents were willing to pay, on average, $1.66 to save approximately 4 minutes of travel time. This amount rendered an hourly VTTS of $25.81. By contrast, in trip 5 (high urgency, 30 km/h traffic speed, 40 km 400-series trip distance), drivers were willing to pay, on average, $4.12 to save 56 minutes of travel time. This amount rendered an hourly VTTS of $4.42.

5.4 *Results to Research Question 3: How do annual household income, respondent age, respondent gender, 400-series travel frequency, and previous exposure to electronic tolling/Hwy 407 exposure affect WTP to escape congestion?*

One-way ANOVA was used to assess the significance and effect size of annual household income and respondent age on WTP while independent t-tests were used to assess the significance and effect size of respondent gender, 400-series travel frequency, and exposure to Hwy 407-ETR on WTP. Full statistical results are presented in Appendix 3.

5.4.1 **Annual household income**

Based on reported annual household income, each respondent was grouped into one of three income levels: low income ($0 - $59,999), middle income ($60,000 - $119,999) or high income ($120,000 +). In each trip condition there were 60 low income cases, approximately 106 middle income cases, and approximately 70 high income cases, representing a total of approximately 236 independent responses per trip condition (for the precise number of cases in each income group per trip condition see Appendix 3).

As shown in Figure 5.14, household income appears to have a substantial and predictable effect on mean WTP to escape congestion in most, if not all, trip conditions. An overview of mean values suggests that the high income group was willing to pay more to escape congestion than the middle income or low income groups in every trip condition. Also, the low income group was willing to pay less to escape congestion than the middle income or high income groups in every trip condition except trip 5, where the middle income group mean was slightly lower than that of the low income group. Generally, there was a greater difference between the means of the middle income and high income groups than between the means of the low income and middle income groups.

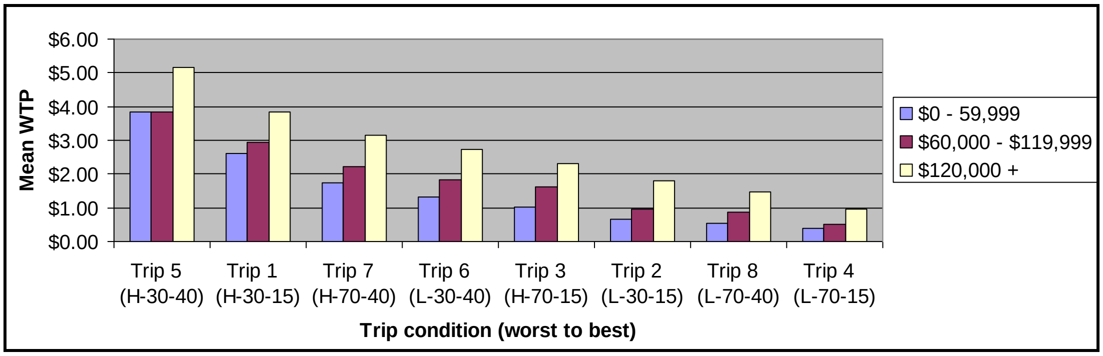


Figure 5.14: WTP mean values of low-, mid-, and high-income respondents per trip condition

Annual household income significantly affected mean WTP to escape congestion in trips 1 through 3, and 5 through 8 (see Table 5.9). Annual household income did not significantly affect WTP to escape congestion in trip 4. When significant, respondents with higher incomes were willing to pay more to escape congestion than respondents with lower incomes. With the exception of trip 4, F-test results validated all hypotheses. The results of planned contrasts revealed that in poor trip conditions (trips 1 and 5), there was no statistical difference between the mean of low income respondents and the mean of others; however, high income respondents were willing to pay more to escape congestion than middle income respondents (see Figure 5.15, A). In the best trip condition (trip 8), the low income group was willing to pay significantly less than other respondents while there was no statistical difference between middle income and high income respondents (see Figure 5.15, B). In most moderate/discretionary trip conditions (trips 2, 6 and 7), income affected WTP in both contrasts (see Figure 5.15, C). Planned contrasts validated most hypotheses.

Table 5.9: Effect of income on WTP to escape congestion

	Main ANOVA					Planned contrasts					
Trip Condition	Df	F	Sig. (2-tailed)	Eta	Eta2	Contrast	T	Df	Sig. (2-tailed)	Pearson-R	R2
Trip 1	2	3.553	0.030	0.030	0.030	1	1.859	233	0.064	0.121	0.015
	233					2	-2.095	233	0.037	0.136	0.018
Trip 2	2	7.398	0.001	0.274	0.075	1	3.644	158.184	0.000	0.278	0.077
	135.599					2	-2.858	100.581	0.005	0.274	0.075
Trip 3	2	8.055	0.000	0.228	0.052	1	4.021	170.441	0.000	0.294	0.087
	139.568					2	-1.827	111.473	0.070	0.171	0.029
Trip 4	2	2.265	0.108	0.164	0.027	1	1.974	154.724	0.050	0.157	0.025
	135.420					2	-1.736	96.674	0.086	0.174	0.030
Trip 5	2	3.713	0.026	0.176	0.031	1	1.277	234	0.203	0.083	0.007
	234					2	-2.530	234	0.012	0.163	0.027
Trip 6	2	5.633	0.004	0.212	0.045	1	3.148	161.918	0.002	0.240	0.058
	140.445					2	-2.067	122.485	0.041	0.184	0.034
Trip 7	2	4.949	0.008	0.217	0.047	1	2.918	142.942	0.004	0.237	0.056
	134.544					2	-2.156	110.864	0.033	0.201	0.040
Trip 8	2	5.088	0.007	0.205	0.042	1	3.152	165.730	0.002	0.238	0.057
	138.870					2	-1.877	107.384	0.063	0.178	0.032

*Significant results shaded (two-tailed significance p < .05)

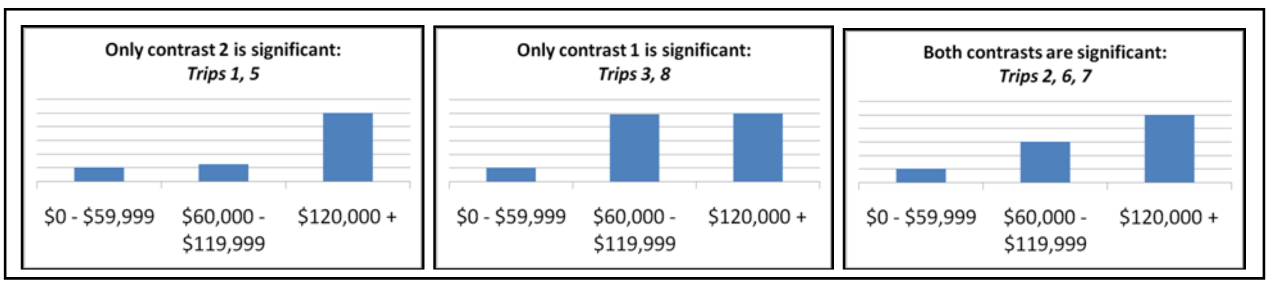


Figure 5.15: Conceptual bar graphs illustrate the three ways in which income impacted WTP.

Figure 5.16 displays the effect size (η^2-value) of income in each trip condition. Trips are arranged from worst (trip 5) to best trip condition (trip 4) to facilitate an evaluation of trends across conditions. Although income had an effect in most trip conditions, it was most pronounced in moderate/discretionary trip conditions (trips 7 through 2), peaking at trip 2. This finding validated the hypothesis. This phenomenon can be explained as follows: For trips 5 and 1, conditions were poor enough that respondent WTP means for all income groups were high and, consequently relatively similar to one-another. For trips 8 and 4, conditions were good enough that respondent WTP means for all income groups were low and, consequently, relatively similar to one-another. Trips 7 through 2 however, presented a different dynamic.

These trip conditions had widely disparate mean scores which indicated that respondents with higher incomes valued escaping these trip conditions considerably more than respondents with lower incomes.

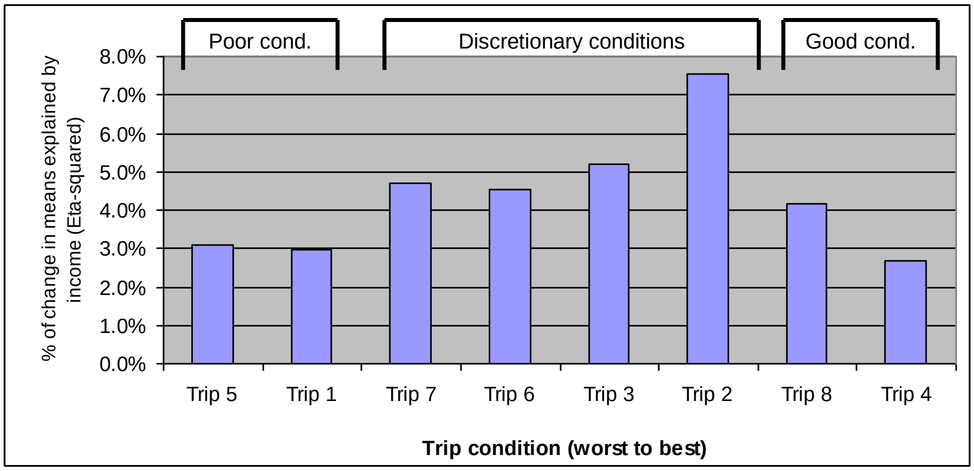


Figure 5.16: Effect of income on WTP to escape congestion per trip condition

5.4.2 **Respondent age**

Respondents were categorized into one of three age groups: young (18 - 34), middle-aged (35 – 54) and older (55 +). 71 cases were classified as young, approximately 110 cases were classified as middle-aged and approximately 70 cases were classified as older, representing a total of approximately 251 independent responses per condition.

As shown in Figure 5.17, age appears to have a moderate, predictable effect on mean WTP. An overview of mean values suggests that older respondents were willing to pay less to escape congestion than young and middle-aged respondents in all trip conditions, although differences in WTP means are not sizeable. There was no consistent trend across trip conditions that explain for differences in the mean values of young and middle-aged respondents. Although young respondents exhibited higher means in trips 1, 2, 4, 5, and 6, middle-aged respondents exhibited higher means in trips 7 and 8 and the two-age groups were virtually tied in trip 3.

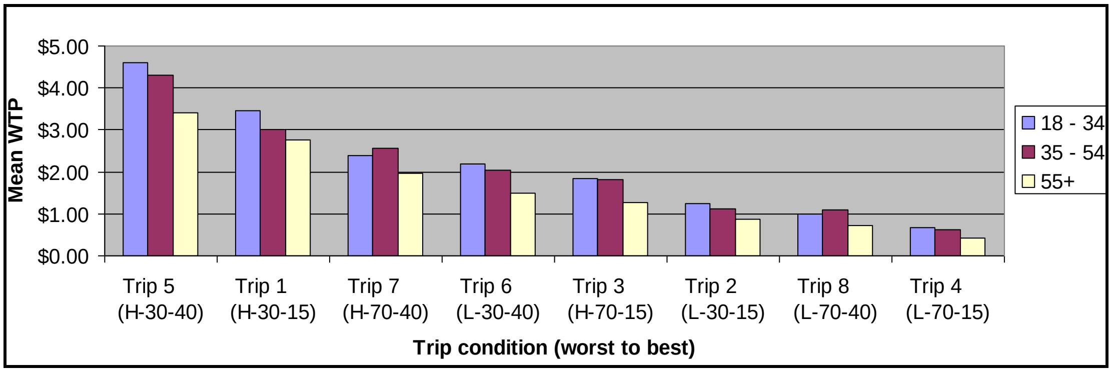


Figure 5.17: WTP mean values of young, middle-aged, and older respondents per trip condition

No significant impacts of age were revealed for any trip condition (see Table 5.10). The hypothesis that predicted that in most trip conditions younger respondents would be willing to pay more to escape congestion than older respondents was proven incorrect.

Table 5.10: Effect of age on WTP to escape congestion

	Main ANOVA				
Trip Condition	Df	F	Sig.	Eta	Eta2
Trip 1	2 248	1.062	.347	0.089	0.008
Trip 2	2 248	1.043	.354	0.089	0.008
Trip 3	2 249	1.686	.187	0.114	0.013
Trip 4	2 248	.578	.562	0.071	0.005
Trip 5	2 249	2.413	.092	0.138	0.019
Trip 6	2 247	1.579	.208	0.114	0.013
Trip 7	2 249	1.294	.276	0.100	0.010
Trip 8	2 249	.927	.397	0.084	0.007

*Significant results shaded (two-tailed significance p < .05)

As respondent age did not have a statistical effect on WTP to escape congestion in any trip condition, an analysis of trends in effect size would be inappropriate.

5.4.3 **Respondent gender**

Approximately 132 respondents were male and approximately 119 respondents were female, representing a total of approximately 251 individual responses per trip condition.

As shown in Figure 5.18, respondent gender appears to have had a consistent effect on WTP to escape congestion. An overview of mean values suggests that males were willing to pay more to escape congestion than females, regardless of trip condition. Also, it appears that the impacts of gender on WTP were more pronounced in good trip conditions (trips 8 and 4) than in poor trip conditions (trips 5 and 1).

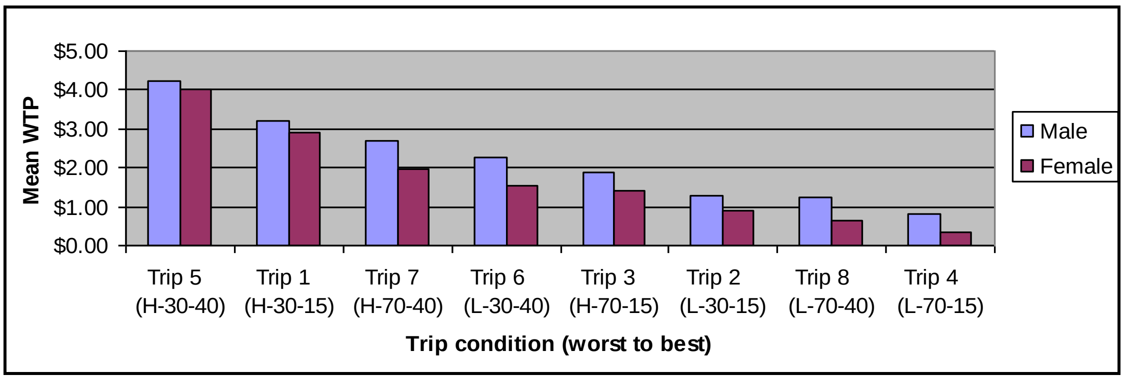


Figure 5.18: WTP mean values of male and female respondents per trip condition

Respondent gender significantly affected mean WTP to escape congestion in trips 4, 6, 7, and 8 but did not significantly affect WTP in trips 1, 2, 3, and 5 (see Table 5.11). When significant, males were willing to pay more than females to escape congestion. Findings validated all hypotheses.

Table 5.11: Effect of gender on WTP to escape congestion

	Independent t-test				
Trip condition	T	Df	Sig. (2-tailed)	Pearson R	R2
Trip 1	.911	249	.363	0.058	0.003
Trip 2	1.865	249	.063	0.117	0.014
Trip 3	1.811	234.433	.071	0.117	0.014
Trip 4	2.529	209.620	.012	0.172	0.030
Trip 5	.532	250	.595	0.034	0.001
Trip 6	2.283	234.725	.023	0.147	0.022
Trip 7	2.428	236.396	.016	0.156	0.024
Trip 8	2.869	218.706	.005	0.190	0.036

*Significant results shaded (two-tailed significance $p < .05$)

The effect of gender was pronounced in good trip conditions (trips 8 and 4) and almost non-existent in poor conditions (trips 5 and 1) (see Figure 5.19). While males and females alike were willing to pay similarly high amounts of money to escape congestion in poor conditions, males were willing to pay significantly more than females to escape congestion in good conditions. Interestingly, of the moderate/discretionary trips, there was a significant effect of gender on WTP in poor-moderate conditions (trips 7 and 6) but not in moderate-good conditions (trips 3 and 2) – the opposite of the overall trend.

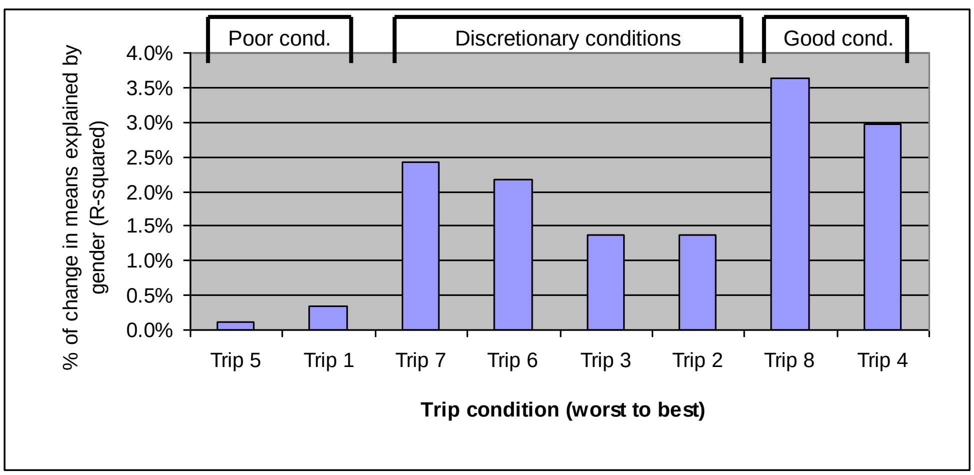


Figure 5.19: Effect of gender on WTP to escape congestion per trip condition

5.4.4 **400-series travel frequency**

Based on reported frequency of travel along the GTA's 400-series network, each respondent was grouped into one of two trip frequency categories: daily 400-series user or less-than-daily 400-series user. In each trip condition approximately 106 respondents were daily users and approximately 145 respondents were less-than-daily users, representing a total of approximately 251 individual responses per trip condition.

As shown in Figure 5.20, 400-series frequency appears to have conditionally had an effect on WTP to escape congestion. An overview of mean values suggests that in poor trip conditions (trips 1 and 5), respondents who use the 400-series network less than once a day were willing to pay more to escape congestion than respondents who use the network daily. By contrast, in moderate/discretionary and good trip conditions, 400-series frequency appears to have had little to no effect on WTP means.

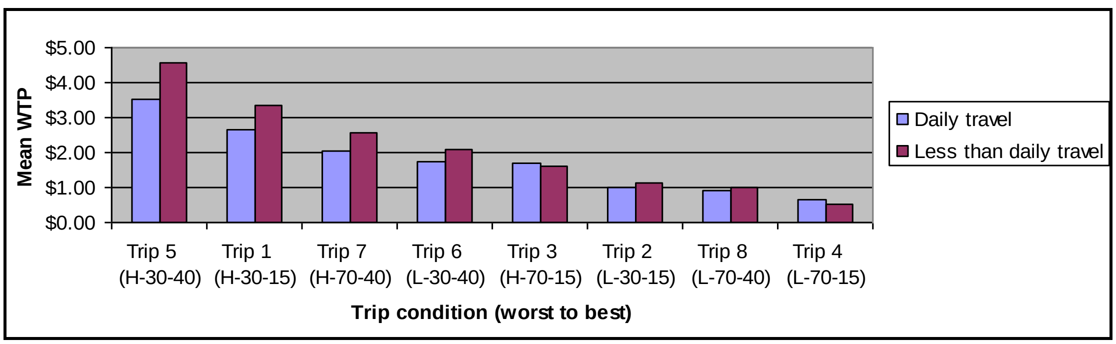


Figure 5.20: WTP mean values of daily and less-than daily 400-series users per trip condition

400-series travel frequency significantly affected mean WTP to escape congestion in trip 5 only (see Table 5.12). The hypothesis that predicted that in some conditions daily 400-series users would be willing to pay more to escape congestion than less-than-daily 400-series users was proven incorrect. In trip 5, the opposite was in fact true: less-than-daily 400-series users were willing to pay more to escape congestion than daily 400-series users.

Table 5.12: Effect of 400-series travel frequency on WTP to escape congestion

	Independent t-test				
Trip condition	T	Df	Sig. (2-tailed)	Pearson R	R2
Trip 1	-1.859	249	.064	0.117	0.014
Trip 2	-.610	249	.542	0.039	0.001
Trip 3	.362	250	.717	0.023	0.001
Trip 4	.786	249	.433	0.050	0.002
Trip 5	-2.460	250	.015	0.154	0.024
Trip 6	-1.107	248	.269	0.070	0.005
Trip 7	-1.706	245.008	.089	0.108	0.012
Trip 8	-.401	250	.689	0.025	0.001

*Significant results shaded (two-tailed significance $p < .05$)

As trip conditions worsened, less-than-daily 400-series users were increasingly willing to pay more to escape congestion than daily 400-series users (see Figure 5.21). While spending a large sum of money could be deemed unreasonable if one had to travel the corridor on a frequent basis, less-than daily 400-series users may be able to rationalize a larger expenditure due to their limited frequency of freeway travel.

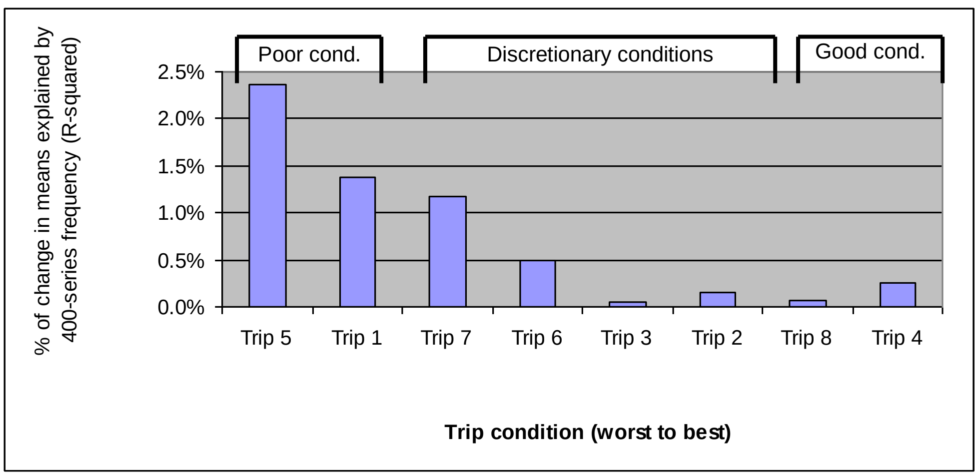


Figure 5.21: Effect of 400-series travel frequency on WTP to escape congestion per trip condition

5.4.5 **Exposure to Hwy 407-ETR**

Respondents were grouped by previous exposure to Hwy 407-ETR. Approximately 152 respondents had previously travelled the highway while approximately 98 respondents had never travelled the highway, representing a total of approximately 250 individual responses per trip condition.

As shown in Figure 5.22, previous exposure to Hwy 407-ETR appears to have had a large effect on WTP to escape congestion in all trip conditions. An overview of mean values suggests that in every trip condition, respondents who have previously travelled Hwy 407-ETR were willing to pay substantially more to escape congestion than respondents who have never used the roadway. The effect of Hwy 407 exposure on WTP does not seem to vary substantially by trip condition.

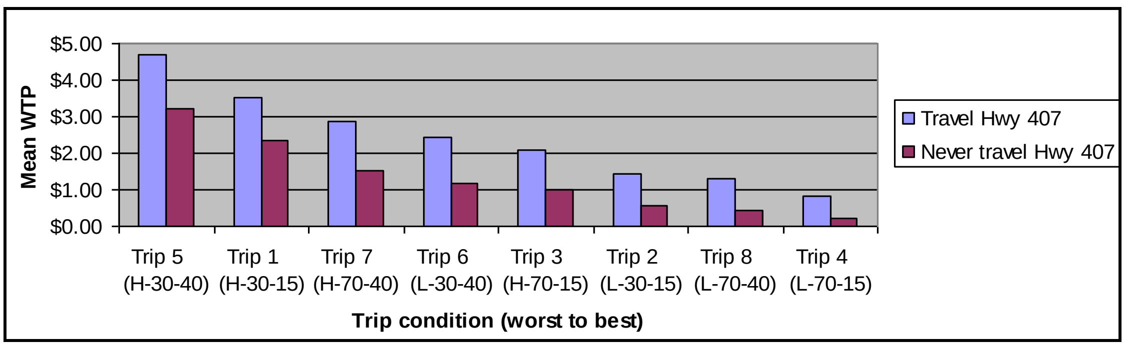


Figure 5.22: WTP mean values of respondents with and without previous Hwy 407-ETR exposure per trip condition

Previous exposure to Hwy 407-ETR significantly affected WTP to escape congestion in all 8 trip conditions (see Table 5.13). In all cases, respondents with previous exposure to Hwy 407 were willing to pay significantly more to escape congestion than respondents who have never travelled the highway. Findings validated all hypotheses.

Table 5.13: Effect of Hwy 407-ETR exposure on WTP to escape congestion

	Independent t-test				
Trip condition	T	Df	Sig. (2-tailed)	Pearson R	R2
Trip 1	3.414	228.230	.001	0.220	0.049
Trip 2	4.985	228.773	.000	0.313	0.098
Trip 3	4.275	244.018	.000	0.264	0.070
Trip 4	3.851	196.151	.000	0.265	0.070
Trip 5	3.336	249	.001	0.207	0.043
Trip 6	4.213	241.391	.000	0.262	0.069
Trip 7	4.468	239.724	.000	0.277	0.077
Trip 8	4.198	247.674	.000	0.258	0.066

*Significant results shaded (two-tailed significance $p < .05$)

Hwy 407 exposure had a substantial effect on WTP in every trip condition – each trip condition's effect size exceeded an R^2 value of .042 or 4.2% (see Figure 5.23). Trends in effect size indicate that Hwy 407-ETR exposure had less of an impact in poor conditions (trips 5 and 1 had R^2 values of .043 and .049, respectively) than in moderate/discretionary or good conditions (trips 7, 6, 3, 2, 8, and 4 all had R^2 values in excess of .065). Both respondents with and without previous Hwy 407 exposure were willing to pay a great deal to escape congestion in the worst trip conditions. By contrast, respondents without Hwy 407 exposure were willing to pay a great deal less than respondents with Hwy 407 exposure in good and moderate/discretionary conditions. Many respondents with Hwy 407 exposure may already be using the toll highway to escape anticipated moderate congestion along Hwy 401. Trends in effect size validated the hypothesis.

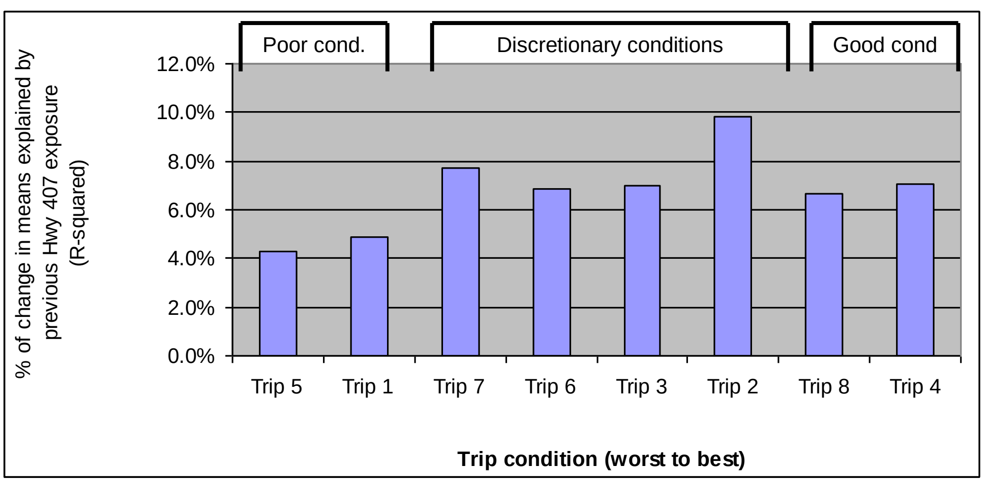


Figure 5.23: Effect of previous Hwy 407-ETR exposure on WTP to escape congestion per trip condition

It is important to note that there was a strong statistical correlation between annual household income and previous Hwy 407 exposure. While 76% of high income respondents had previous Hwy 407 exposure, only 35% of low income respondents had previously travelled the highway.

5.4.6 **Effect size of driver factors**

The effect sizes of driver factors were averaged from all 8 trip conditions (see Figure 5.24). On a whole, previous Hwy 407 exposure had the greatest impact on WTP, followed by annual household income, respondent gender, age, and 400-series travel frequency. Findings validated the hypothesis.

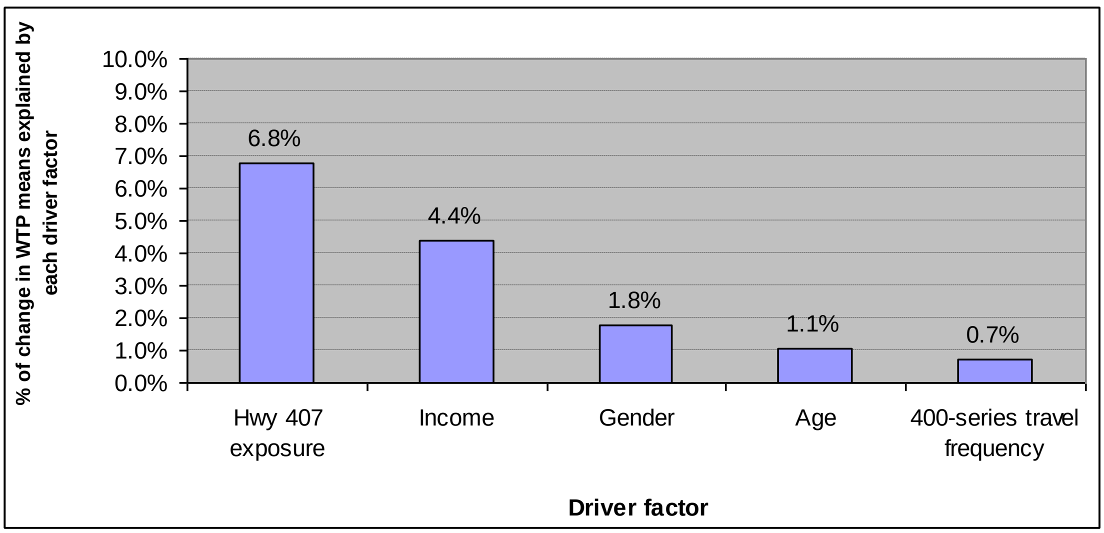


Figure 5.24: Effect size of driver factors

5.5 *Results to Research Question 4: Do HOT-lanes accompanied by Bus Rapid Transit (BRT) encourage transit use?*

Of the general sample (N = 255), 57.6% of respondents indicated that the presence of fast, frequent, and reliable bus service operating in HOT-lanes, with connections to major activity centres and park and ride lots would influence their decision to take public transit. This finding validated the hypothesis (see Table 5.14).

Table 5.14: Willingness to take transit

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	106	41.6	42.4	42.4
	Yes	144	56.5	57.6	100.0
	Total	250	98.0	100.0	
Missing	No response	4	1.6		
	System	1	.4		
	Total	5	2.0		
Total		255	100.0		

There was a significant effect of income on willingness to take transit. Planned contrasts revealed that low income respondents were more willing to take transit than others and that middle income respondents were more willing to take transit than high income respondents (for income group means see Figure 5.25). Findings validated all hypotheses.

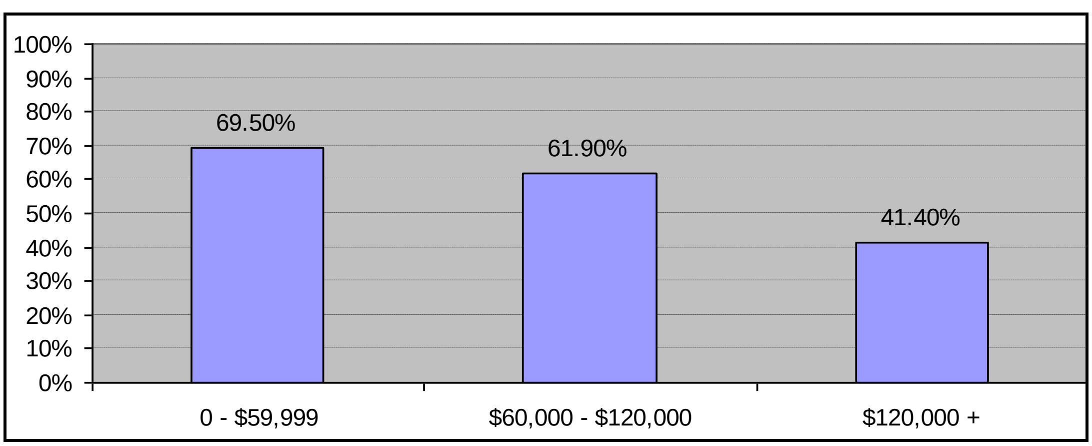


Figure 5.25: Percentage of respondents willing to take transit by income group

There was also a significant effect of age on willingness to take transit. Younger respondents were more willing than others to take transit. Middle-aged and older respondent means were not significantly different (for age group means see Figure 5.26). Findings validated all hypotheses.

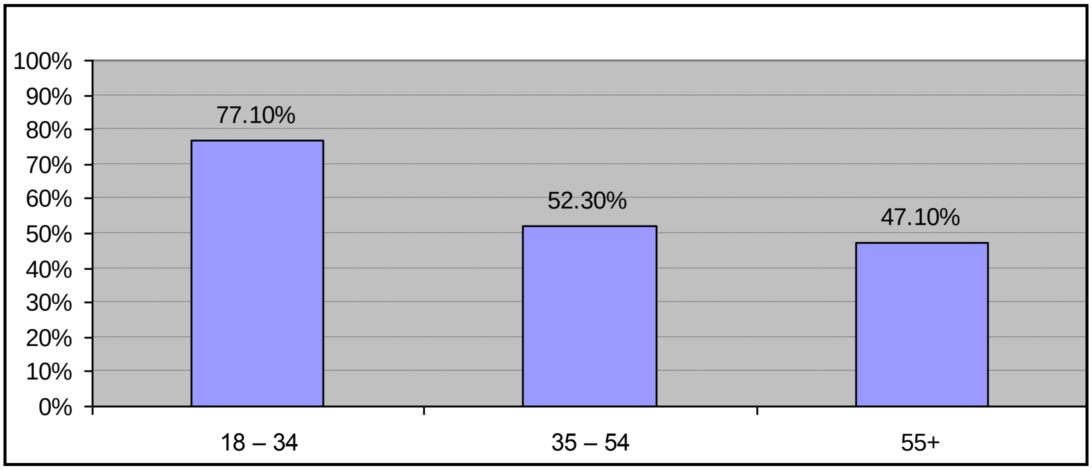


Figure 5.26: Percentage of respondents willing to take transit by age group

Full statistical results are presented in Appendix 3.

5.6 *Results to Research Question 5: Does the incentive of free HOV travel in HOT-lanes encourage carpooling?*

Of the general sample (N = 255), 51.2% of respondents indicated that the incentive of free HOV travel in HOT-lanes would influence their decision to carpool. This finding validated the hypothesis (see Table 5.15).

Table 5.15: Willingness to carpool

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	122	47.8	48.8	48.8
	Yes	128	50.2	51.2	100.0
	Total	250	98.0	100.0	
Missing	No response	5	2.0		
Total		255	100.0		

There was a significant effect of income on willingness to carpool. Low income respondents were significantly more willing to carpool than others. The means of the middle and high income categories were not significantly different (for income group means see Figure 5.27). Findings validated all hypotheses.

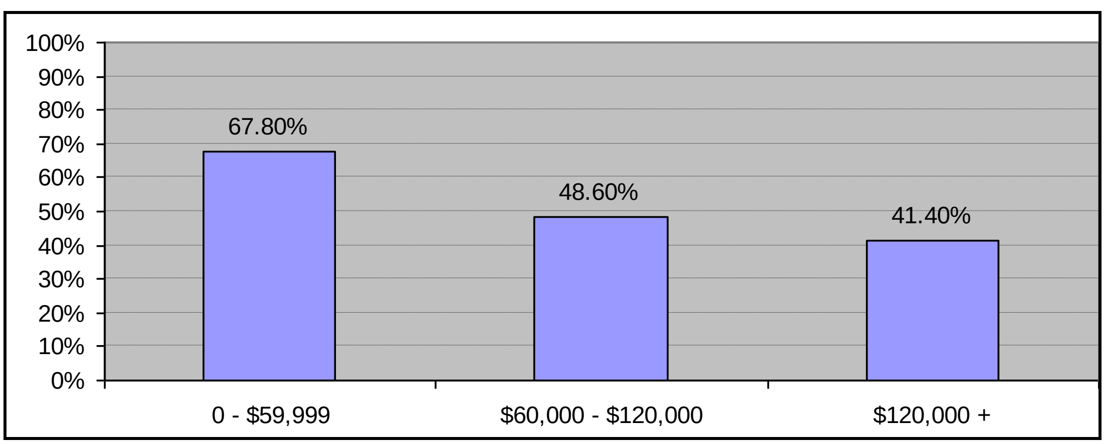


Figure 5.27: Percentage of respondents willing to carpool by income group

There was a significant effect of age on willingness to carpool. Younger respondents were more willing than others to carpool but the means of middle aged and older respondents did not significantly differ (for age group means see Figure 5.28). Findings validated all hypotheses.

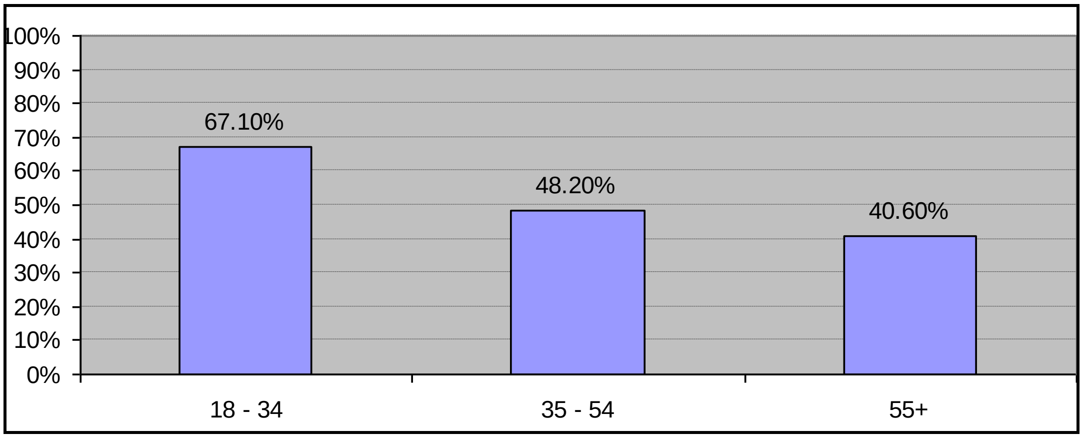


Figure 5.28: Percentage of respondents willing to carpool by age group

The hypothesis that daily 400-series users would be more willing to carpool than less-than-daily 400-series users was proven incorrect.

Full statistical results are presented in Appendix 3.

5.7 *Results to Research Question 6: Do GTA residents want to see HOT-lanes implemented along major highways in the metropolitan area? HOT-lane political feasibility and respondent implementation preference*

Of the general sample (N = 246), 63% of respondents indicated that they would support the presence of HOT-lanes along GTA 400-series highways (see Figure 5.29). 39.4% preferred that HOT-lanes be constructed as new facilities that charge on average $0.20/km per use while 23.6% preferred that existing GP lanes be converted to HOT-lanes that charge on average $0.10/km per use. Only 37% preferred that HOT-facilities not be implemented. Findings validated the hypothesis.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Convert existing lanes	58	22.7	23.6	23.6
	Build new lanes	97	38.0	39.4	63.0
	No HOT lanes	91	35.7	37.0	100.0
	Total	246	96.5	100.0	
Missing	No response	9	3.5		
Total		255	100.0		

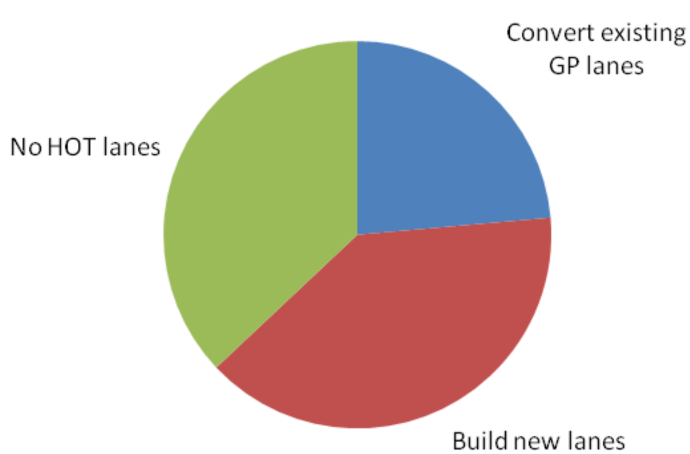


Figure 5.29: Implementation preference

There was a significant effect of income on stated desirability for HOT-lanes. While the mean of the low income category was not significantly different from the mean of other respondents, respondents in the high income category were more likely to desire HOT-lanes along the 400-series network than respondents in the middle-income category. HOT-lane desirability was considerably higher among respondents with incomes of $120,000 or more (for income group means see Figure 5.30). Despite the significance of income, a majority of respondents in each income group supported the presence of HOT-lanes. Findings validated all hypotheses.

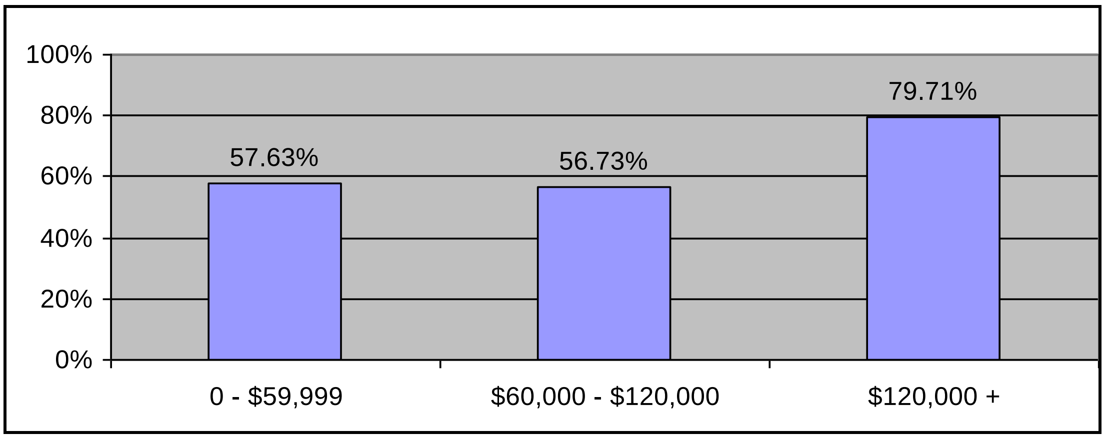


Figure 5.30: Percentage of respondents desiring HOT-lanes along the 400-series network by income group

There was a significant effect of age on stated desirability for HOT-lanes. Although the mean of younger respondents was not significantly different from the mean of other respondents, older respondents were considerably less likely to support HOT-lanes than middle-aged respondents (for age group means see Figure 5.31). Findings validated all hypotheses.

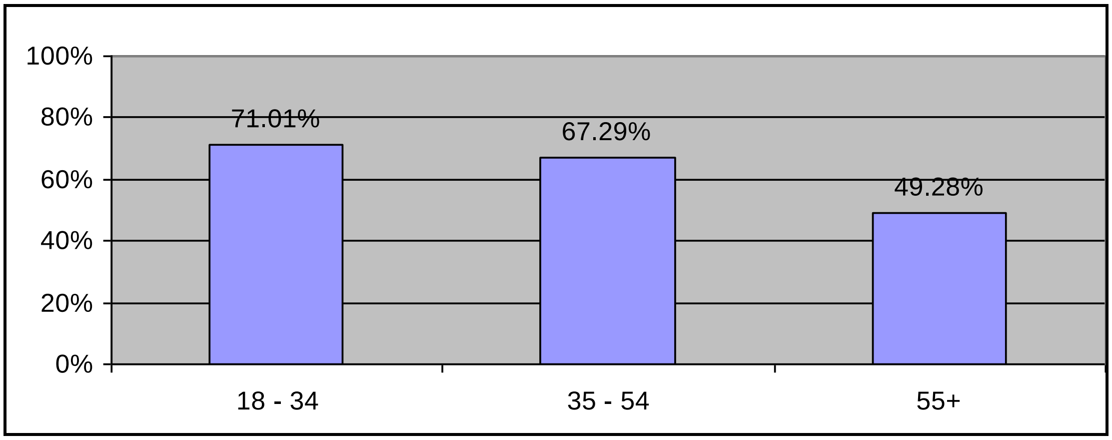


Figure 5.31: Percentage of respondents desiring HOT-lanes along the 400-series network by age group

Respondents with previous Hwy 407 exposure were more likely to desire HOT-lanes along the 400-series network than respondents without previous Hwy 407 exposure (for previous Hwy 407 exposure group means see Figure 5.32). Findings validated all hypotheses.

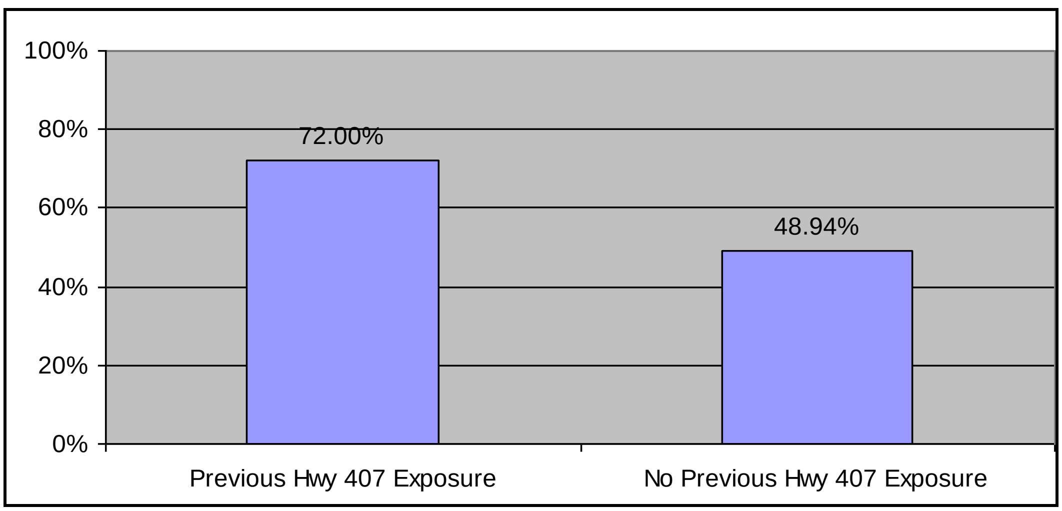


Figure 5.32: Percentage of respondents desiring HOT-lanes along the 400-series network by Hwy 407 exposure

The hypothesis that support for HOT-lanes would be higher among daily 400-series users than among less-than-daily 400-series users was proven incorrect.

Full statistical results are presented in Appendix 3.

5.8 *Revealed traffic volume analysis results*

The intention of the revealed traffic volume (RTV) analysis was to validate the stated preference (SP) analysis with regards to WTP to escape congestion. In this section, RTV results are presented showing Hwy 407 throughput share as a function of Hwy 401 traffic and trip urgency defined by time of day.

5.8.1 **Eastbound traffic (E of Dufferin St. / W. R. Allen Rd.)**

Average eastbound hourly throughput along Highways 401 and 407 East of Dufferin St./W.R. Allen Rd. was analyzed from data collected over a five week period beginning March 9 and ending April 12, 2009. The analysis focused on comparing traffic profiles along the two highways and identifying key indicators of Hwy 407 throughput share.

Weekday traffic profiles

Traffic profiles clearly indicate the presence of peak periods on both highways (see Figure 5.33). Throughput increased sharply in the morning, levelled-off in the midday period, increased once again for the afternoon peak period, then fell gently along Hwy 401 and abruptly along Hwy 407. Total traffic volume was highest during the afternoon peak period. In all probability congestion, causing reduced speeds, led to decreases in Hwy 401 throughput between 4 and 6 PM – a two-hour period which, if not for reduced speeds, would have presumably exhibited the highest throughput values. By contrast, Hwy 407 throughput was highest during this period.

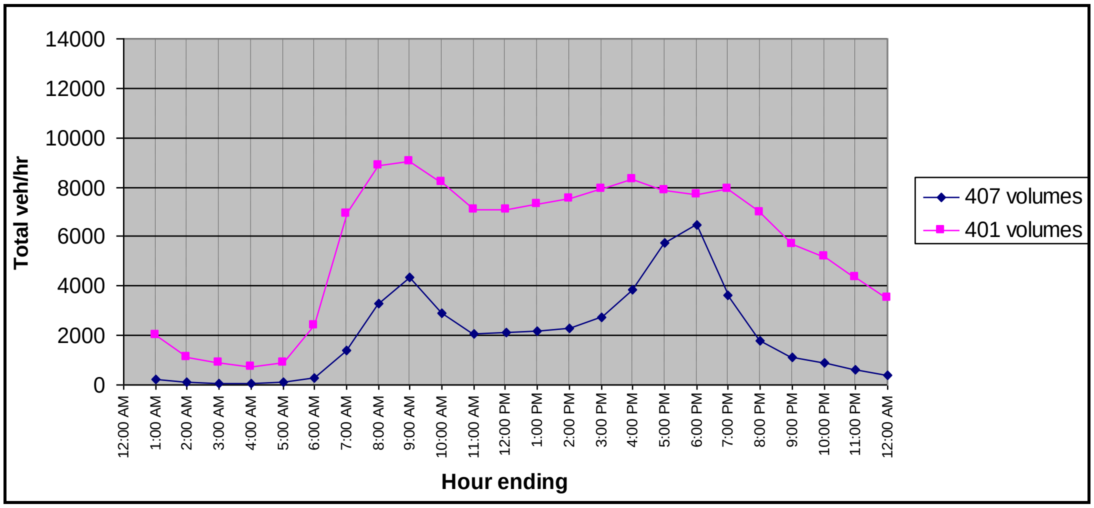


Figure 5.33: Average eastbound weekday vehicles/hour east of Dufferin St./Allen Rd.

Hwy 407 usage was very low during the early morning and late evening-night periods. From 5 to 7 AM, Hwy 401 traffic volume increased dramatically while Hwy 407 volume increased at a much slower rate (see Table 5.16). As traffic volume increased along Hwy 401 towards the morning peak hour, additional volume predominantly shifted to Hwy 407. Despite the high urgency of the 5 to 7 AM period, corridor drivers predominantly avoided Hwy 407 in favour of the free alternative. Only when Hwy 401 volume was already high, rendering actual or anticipated congestion a concern, did volume along Hwy 407 increase substantially.

Table 5.16: Hourly throughput change (weekday EB traffic)

Hour	Change in Hwy 401 throughput	Hwy 401 throughput	Change in Hwy 407 throughput	Hwy 407 throughput	% new volume to Hwy 407
5 – 6 AM	1,496	2,392	217	306	12.7%
6 – 7 AM	4,526	6,918	1,110	1,417	19.7%
7 – 8 AM	1,940	8,858	1,896	3,313	44.4%
8 – 9 AM	186	9,045	1,031	4,344	84.7%

Saturday/Sunday/holiday traffic profiles

Both highways exhibited uni-modal traffic profiles; total throughput slowly built over the course of the morning, plateaued in the afternoon (1 to 7 PM), then gently descended (see Figure 5.34).

This gentle sloping and plateau pattern represents a situation of dispersed trip start times and non-conformed trip schedules. There is little to no indication of congestion along Hwy 401.

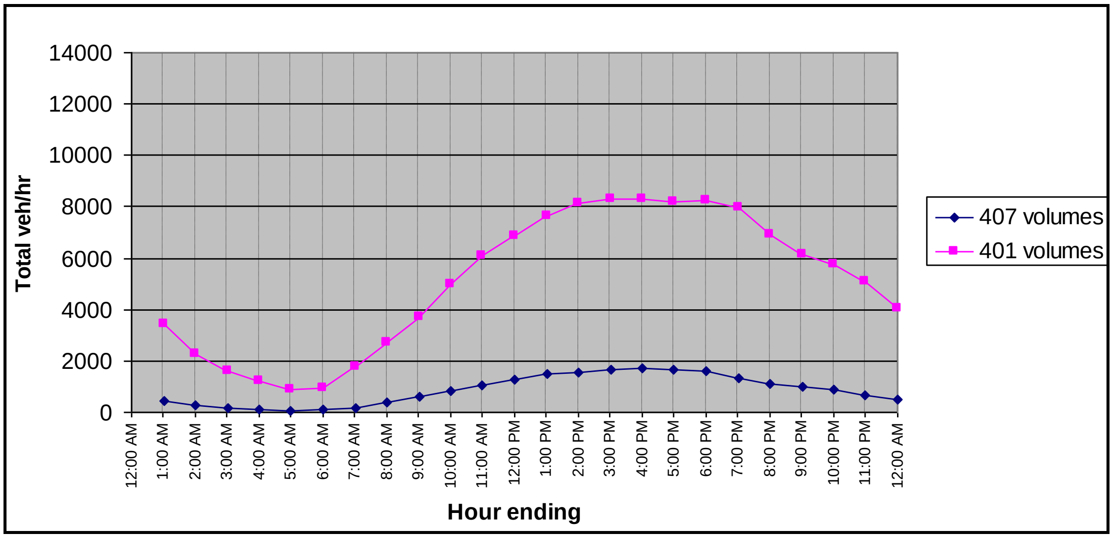


Figure 5.34: Average eastbound Saturday/Sunday/holiday vehicles/hour east of Dufferin St./Allen Rd.

Despite high Hwy 401 volume in the afternoon, Hwy 407 volume remained low. This pattern can be compared to the one observed during the weekday midday when Hwy 401 throughput was comparatively lower and Hwy 407 throughput was comparative higher (see Table 5.17). Low Saturday/Sunday/holiday Hwy 407 throughput may be due to the lower trip urgencies of this period. Low Saturday/Sunday/holiday Hwy 407 throughput may also be due to the fact that the highway connects a number of employment zones, boosting weekday roadway usage.

Table 5.17: Hwy 401 and 407 throughput/lane in the weekday and Sat/Sun/holiday midday period

	Travel period	**Hwy 401 throughput/lane (veh/hr/lane)**	**Hwy 407 throughput/lane (veh/hr/lane)**	**Hwy 407 throughput share**
Weekday	Midday (9 AM – 3 PM)	1,251	477	27.6%
Sat/Sun/holiday	Midday (12 AM – 7 PM)	1,350	315	18.9%
*The weekday midday is defined as the period between the morning and afternoon peak periods while the Sat/Sun/holiday midday is defined as the period of highest sustained total traffic volume.				

Hwy 407-ETR throughput share

Weekday and Saturday/Sunday/holiday average Hwy 407 throughput share/hour profiles are presented graphically in Figure 5.35. For full results tables see Appendix 3.

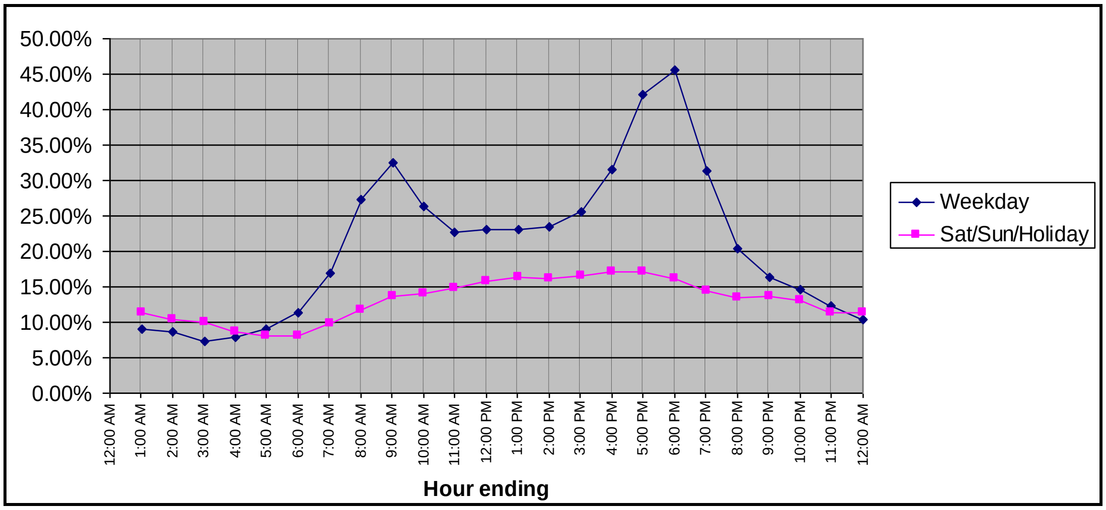


Figure 5.35: Percentage of total eastbound throughput using Hwy 407 east of Dufferin St./Allen Rd.

Hwy 407 throughput share was highest during the weekday peak periods and was particularly high during the weekday afternoon peak (exceeding 45% of total EB corridor throughput between 5 and 6 PM). Simplified Hwy 407 throughput share results for all possible trip urgency and Hwy 401 volume combinations are presented in Table 5.18.

Table 5.18: Observed impact of trip urgency and Hwy 401 volume on EB Hwy 407 throughput share

Trip urgency	Hwy 401 volume	Period of travel	Hypothesized Hwy 407 thput. share	Revealed Hwy 407 thput. Share
High	High	Weekdays 7 – 9 AM; Weekdays 3 – 7 PM	High	High
High	Moderate	Weekdays 6 – 7 AM	Moderate-high	Low-moderate
High	Low	Weekdays 5 – 6 AM	Low-moderate	Low
Moderate	High	Weekdays 9 – 10 AM; Weekdays 12 – 3 PM	Moderate-high	Moderate
Moderate	Moderate	Weekdays 10 AM – 12 PM	Moderate	Moderate
Low	High	Sat/Sun/hol 12 – 7 PM	Moderate	Low-moderate
Low	Moderate	Weekdays 7 – 10 PM; Sat/Sun/hol 9 AM – 12 PM; Sat/Sun/hol 7 – 11 PM	Low-moderate	Low
Low	Low	Weekdays 10 PM – 5 AM (overnight); Sat/Sun/hol 11 PM – 9 AM (overnight – morning)	Low	Low

In periods of high urgency and high Hwy 401 volume (weekdays 7 to 9 AM, weekdays 3 to 7 PM), the percentage of total EB throughput using Hwy 407 was high. By contrast, in periods of low urgency and low Hwy 401 volume (weekday overnight periods 10 PM to 5 AM, Saturday/Sunday/holiday overnight-morning periods 11 PM to 9 AM), the percentage of total EB throughput using Hwy 407 was low.

Although Hwy 401 volume had an impact on Hwy 407 throughput share at each urgency level, the influence of Hwy 401 volume increased with urgency (see Figure 5.36). Additionally, when Hwy 401 volume was low, trip urgency had little impact on Hwy 407 throughput share. The influence of urgency on Hwy 407 throughput share increased with Hwy 401 volume.

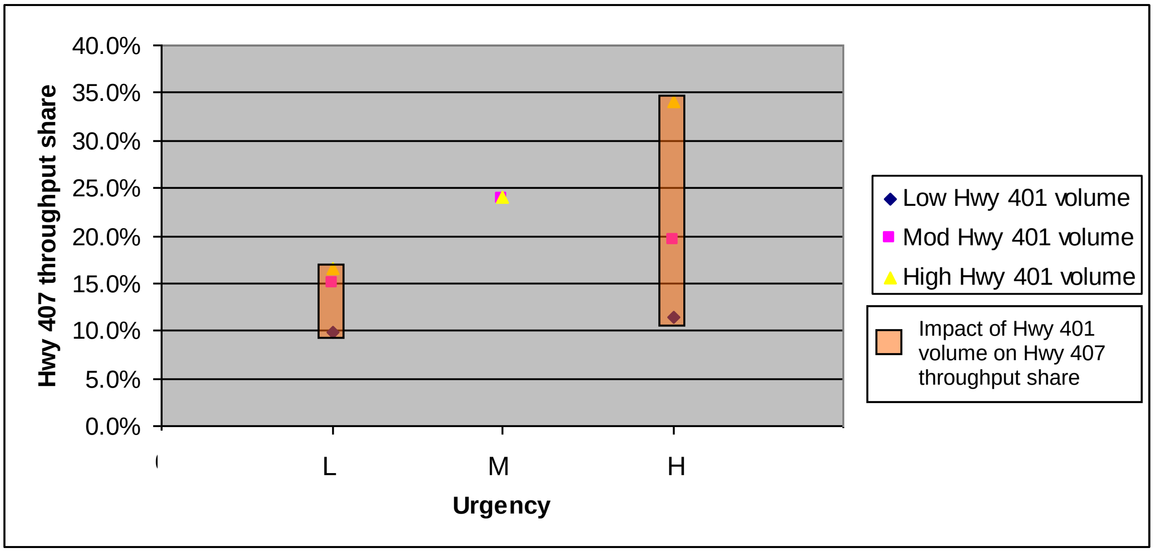


Figure 5.36: Effect of Hwy 401 volume on Hwy 407 throughput share at different urgency levels (eastbound traffic)

5.8.2 Westbound traffic (E of Dufferin St. / W. R. Allen Rd.)

Westbound results were similar to eastbound findings. Unlike eastbound throughput, westbound weekday traffic volume was highest during the morning peak (see Figure 5.37).

Weekday traffic profiles

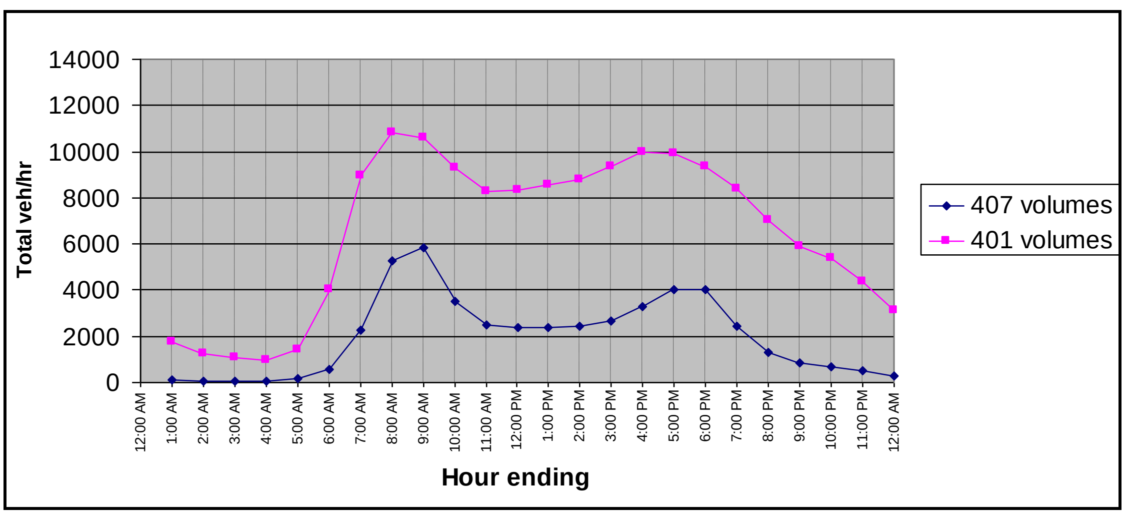


Figure 5.37: Average westbound weekday vehicles/hour east of Dufferin St./Allen Rd.

Table 5.19 presents the change in hourly throughput along Highways 401 and 407 from 5 to 9 AM. Although westbound morning hourly traffic volume was higher than eastbound levels, overall westbound findings were similar to those revealed from eastbound data. Despite high assumed trip urgency levels, driver choice to use Hwy 407 only markedly increased when Hwy 401 volume was high. The percentage of new westbound volume using Hwy 407 dramatically increased an hour earlier than in eastbound traffic due to substantially higher westbound Hwy 401 throughput between 7 and 8 AM.

Table 5.19: Hourly throughput change (weekday WB traffic)

Hour	Change in Hwy 401 throughput	Hwy 401 throughput	Change in Hwy 407 throughput	Hwy 407 throughput	% new volume to Hwy 407
5 – 6 AM	2,587	4,026	438	589	14.5%
6 – 7 AM	4,937	8,963	1,699	2,288	25.6%
7 – 8 AM	1,858	10,821	2,966	5,254	61.5%
8 – 9 AM	-221	10,600	580	5,834	161.6%

Saturday/Sunday/holiday traffic profiles

Westbound results were, on a whole, similar to eastbound findings. Unlike eastbound results, westbound traffic did not plateau over the midday period but rather peaked between 1 and 3 PM then gently descended (see Figure 5.38).

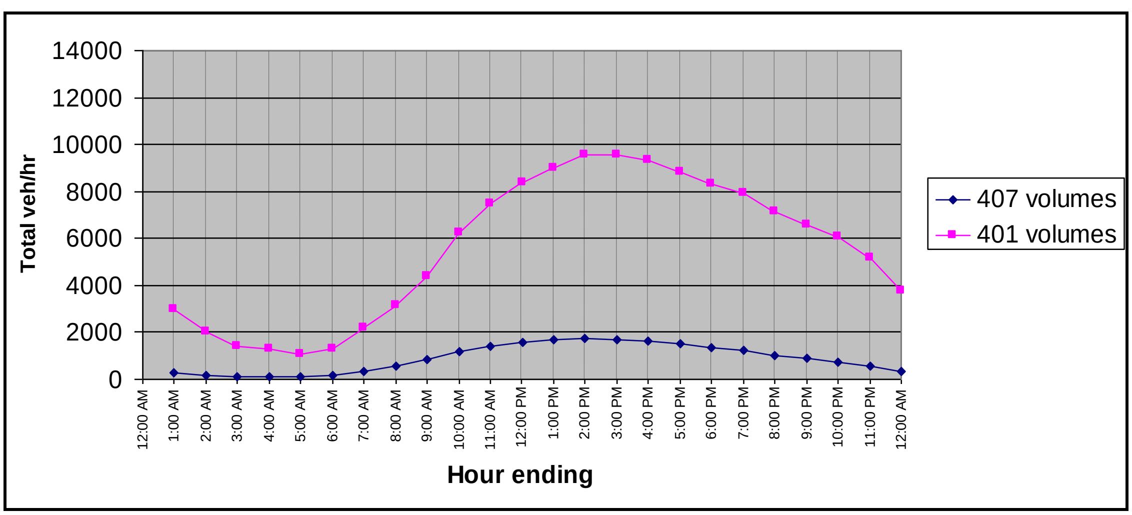


Figure 5.38: Average westbound Saturday/Sunday/holiday vehicles/hour east of Dufferin St./Allen Rd.

Hwy 407-ETR throughput share

Weekday and Saturday/Sunday/holiday average Hwy 407 throughput share/hour profiles are presented in Figure 5.39. For full results tables see Appendix 3.

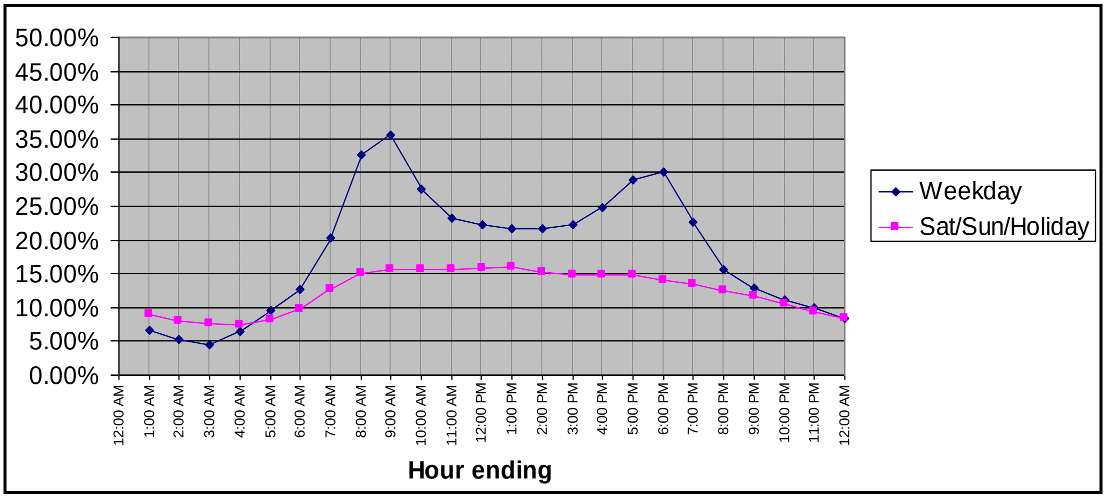


Figure 5.39: Percentage of total westbound throughput using Hwy 407 east of Dufferin St./Allen Rd.

Hwy 407 throughput share was highest during the weekday peak periods and was particularly high during the weekday morning peak (exceeding 35% of total WB corridor throughput between 8 and 9 AM). The interaction of trip urgency, Hwy 401 volume, and Hwy 407 throughput share exhibited the same findings as eastbound results.

6 CONCLUSIONS

Results from stated preference and revealed traffic volume analyses indicated that there is considerable public support for high-occupancy/toll lanes in the GTA. The core results of the study are as follows:

1. Respondents are nearly unanimously frustrated by congestion along GTA 400-series highways.
2. A vast majority of respondents are conceptually willing to pay (WTP) to escape congestion. A majority of respondents are conceptually WTP to escape congestion in all but two trip conditions.
3. Mean WTP values are affected by urgency, traffic speed and trip distance. Urgency has the greatest impact on WTP (η^2 = 10.9%) followed by traffic speed (η^2 = 5.6%), then trip distance (η^2 = 3.6%).
4. The relationship of WTP and travel time saved is not linear (see Figure 6.1). Respondents are willing to pay a substantial amount of money to save a few minutes of travel time. As travel time saved increases, the marginal rate of WTP/minute decreases.

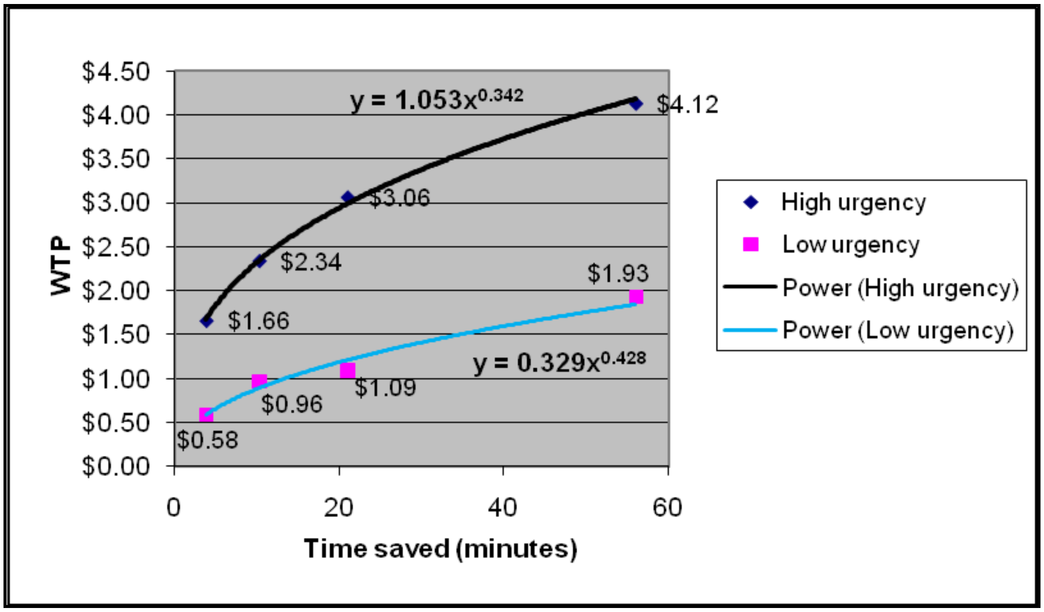


Figure 6.1: Amount respondents were willing to pay for travel time saved

5. Mean WTP values are affected by previous exposure to road tolling (average R^2 across trip conditions = 6.8%) and annual household income (average η^2 = 4.4%). These factors have their greatest effects on WTP in discretionary trip conditions.
6. GTA residents regularly pay to escape congestion by taking Hwy 407. In fact, Hwy 407 traffic represents 35 to 45% of corridor throughput during weekday peak periods.
7. Hwy 401 traffic volume and trip urgency affect willingness to use Hwy 407. Hwy 407 throughput share is only high when Hwy 401 volume and trip urgency are high (see Table 6.1).

Table 6.1: Observed effect of assumed trip urgency and Hwy 401 volume on Hwy 407 throughput share

	Period of Travel	**Hwy 407 throughput share**	**Rationale**
High urgency, high Hwy 401 volume	Weekday peak periods	High	Strong motivation to pay as many drivers are in a rush to get to their destination and congestion is impeding flow on Hwy 401.
High urgency, low Hwy 401 volume	Weekday mornings 5 – 7 AM	Low	No reason to pay when flow on Hwy 401 is unimpeded.
Low urgency, high Hwy 401 volume	Sat/Sun/holiday midday	Low-moderate	Little reason to pay as most drivers are not in a particular rush to get to their destination.
Low urgency, low Hwy 401 volume	Nights, Sat/Sun/holiday mornings	Low	No reason to pay as most drivers are not in a rush to get to their destination and flow on Hwy 401 is unimpeded.

8. A majority of respondents in each income category would like to see HOT-lanes implemented along GTA 400-series highways. Respondents who have higher incomes, are younger, or who have previous exposure to road tolling support the concept more strongly.
9. HOT-lanes have the potential to attract choice riders to public transit. Most respondents would be more willing to take transit if high order transit service existed in HOT-lanes. The presence of transit service in HOT lanes is more likely to influence younger and poorer respondents to use transit than others.

10. HOT-lanes have the potential to encourage carpooling. Most respondents would be more willing to carpool if HOT-lanes were built. The presence of HOT lanes is more likely to influence younger and poorer respondents to carpool than others.

6.1 *Discussion*

This study revealed very high levels of public support for high-occupancy tolling – when asked directly, 63% of respondents supported the presence of HOT-lanes along GTA 400-series highways. By contrast San Diego-area public support for HOT-lanes prior to implementation was decidedly mixed (see Section 2.3) (Ungemah and Collier, 2007). Though 63% is a firm majority, it is interesting to note that there is a discrepancy between the share of respondents who indicated that they would be willing to pay under the worst traffic conditions (trip 5 %WTP = 86.2%) and the share of respondents who would like to have the opportunity to choose a paid option, should conditions warrant. Discrepancies between these two figures may in part be due to the average price values associated with response options in survey question 11 (see Section 5.7).

In addition to high levels of support for HOT-lanes, Toronto-area mean WTP/travel time saved values were comparatively very high (see Figure 6.2). While Indianapolis, IN drivers were willing to pay US$0.26 to save 3 minutes and US$0.60 to save 10 minutes for work-based trips, GTA drivers were willing to pay CAN$1.66 to save 4 minutes and CAN$2.34 to save 10 minutes in high urgency trips. GTA low urgency trips also exhibited comparatively higher WTP/travel time saved means than Indianapolis-area non-work trips (see Section 2.2.1 for a discussion of Indianapolis WTP/travel time saved results) (Davis *et al.*, 2009).

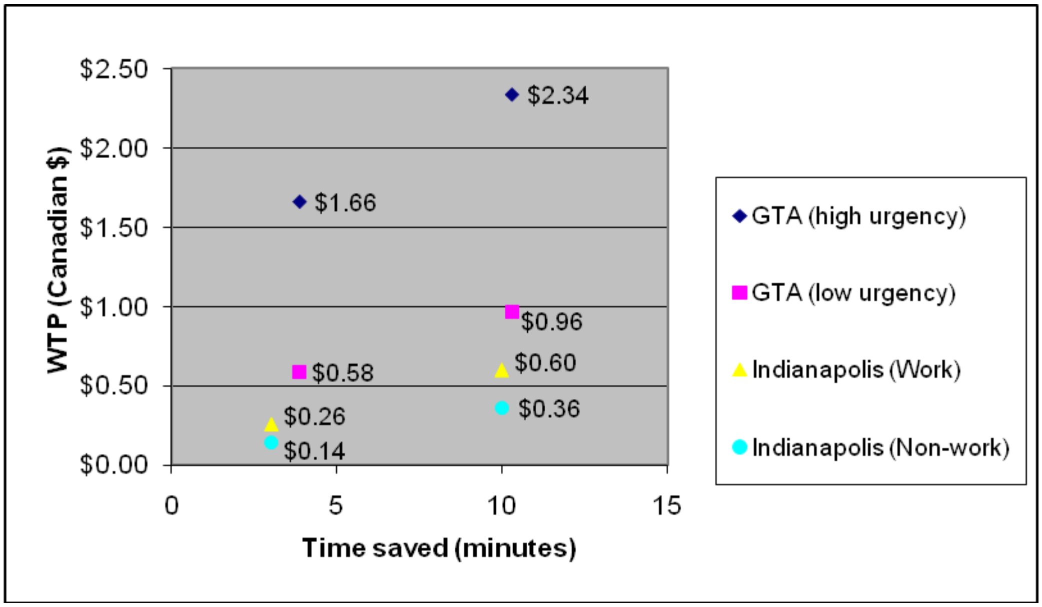


Figure 6.2: WTP/travel time saved in the GTA and Indianapolis, IN

US$ converted to CAN$ according to the April 7, 2010 exchange rate, US$1 = CAN$1.00570

Source (Indianapolis data): Davis *et al. (2009)*

High GTA WTP/travel time saved mean values and high overall levels of public support for HOT-lanes are likely due to:

- The extent of driver frustration with congestion along GTA roadways;
- The presence of Hwy 407-ETR. Respondents with previous Hwy 407 exposure understand electronic tolling and are familiar with the concept of paying to escape congestion. Respondents without previous Hwy 407 exposure presumably are aware of the existence and nature of the highway.

Previous exposure to electronic tolling plays a very significant role in support for HOT-lanes. While 72% of respondents with previous Hwy 407 exposure supported the presence of HOT-lanes on GTA highways, that figure dropped to only 48.9% for respondents without previous Hwy 407 exposure. It is also imperative to re-highlight that Hwy 407 exposure was identified as the single most important driver factor indicator of WTP across all trip conditions. If HOT-lanes were to be implemented in the GTA, it is possible that both support for HOT-lanes and WTP values across all trip conditions would increase as more road users are exposed to electronic tolling. Support for HOT-lanes in the San Diego-area increased substantially post-implementation; polling conducted after HOT-lanes were fully operational indicated that 66% of respondents surveyed approved of the HOT-lanes project (Ungemah and Collier, 2007).

The design of the questionnaire may have also had some influence on the magnitude of support for HOT-lanes. The survey instrument introduced respondents to the concept of HOT-lanes prior to posing WTP situational questions. As such, respondents were somewhat familiar with the purpose of the questions being asked.

Transportation planners and policy makers considering implementing HOT-lanes need to be aware of the effect of familiarity on support for HOT-lanes. In regions without existing HOT-lanes, public support for the concept rests largely on how well advocates are able to communicate the benefits of tolling to the population at large. As such, any attempt to implement high-occupancy tolling in the GTA should be accompanied by a thorough education campaign that outlines the various benefits of the facilities while dispelling prominent myths and half-truths.

6.1.1 Equity implications of HOT-lanes in the GTA

This study identified annual household income as a significant indicator of WTP in 7 of 8 trip conditions. If HOT-lanes were built in the GTA, road users with lower annual household incomes would, on a whole, be less willing to pay to use the facilities than road users with higher incomes. Because HOT-lanes promote carpooling and transit usage, however, the facilities are not necessarily inequitable. 57.6% of respondents indicated that the presence of BRT in HOT-lanes would influence their decision to take transit while 51.2% of respondents indicated that the incentive of free HOV travel in HOT-lanes would influence their decision to carpool. Among respondents in the low income group, those figures were 69.5% and 67.8%, respectively. Low income travellers are far more likely than high income travellers to take advantage of the free travel options provided in HOT-lanes. Also, the presence of BRT in HOT-lanes would improve accessibility for current captive transit riders.

Although overall support for HOT-lanes is certainly higher among high and middle income earners, it should be noted that 57.6% of respondents in the low income group support the presence of HOT-lanes along GTA highways. If equity remains a concern, the feasibility of a credit-based program similar to the one proposed for Atlanta, GA could be investigated for the GTA (see Section 2.2.3 for a discussion of the Atlanta program) (Rountree *et al*., 2008).

Figure 6.3 shows how HOT-lanes can potentially improve travel for three types of transportation consumers: SOV drivers, carpoolers, and transit users.

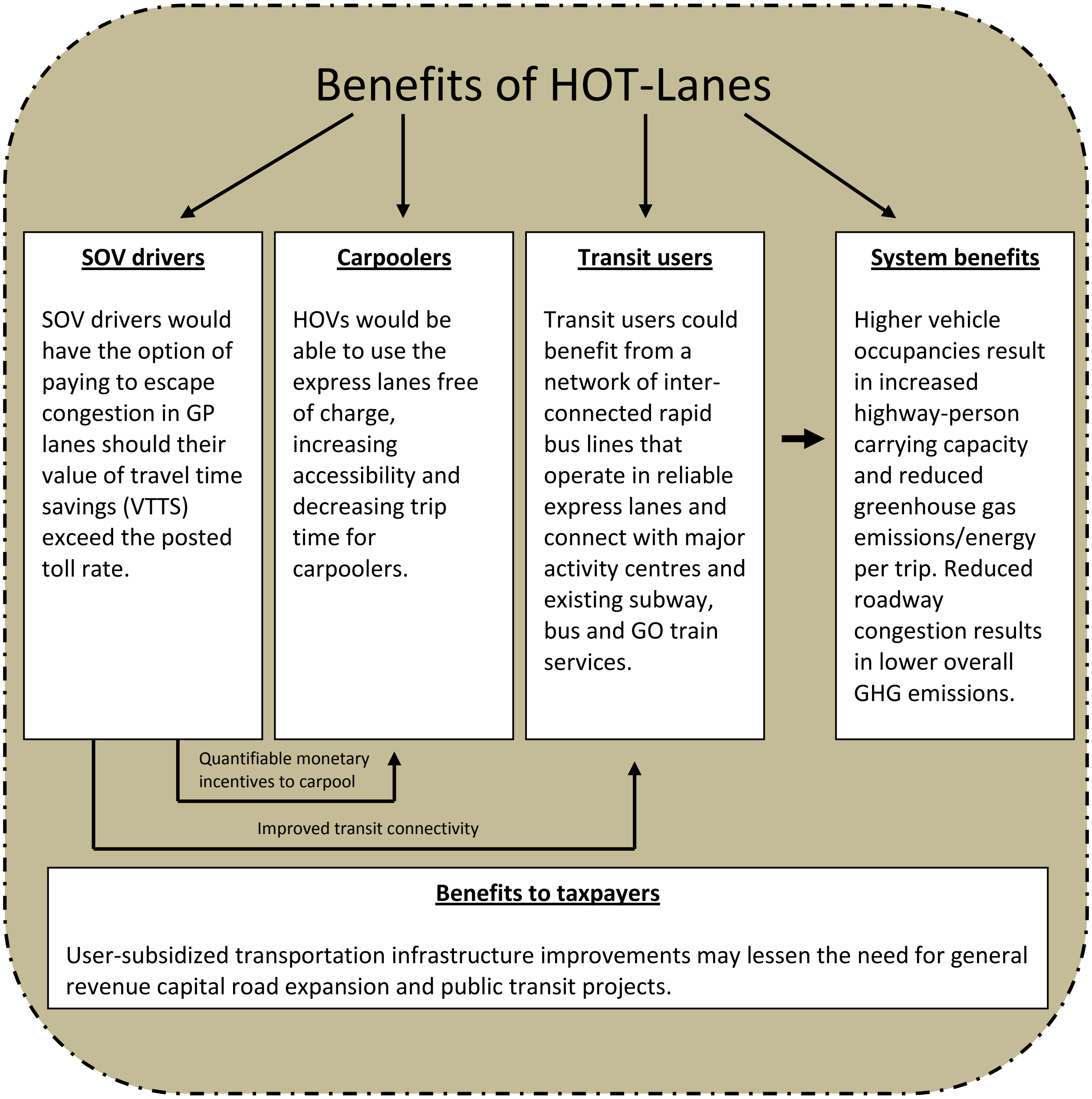


Figure 6.3: HOT-lanes can potentially benefit SOV drivers, carpoolers and transit users, resulting in overall system benefits. They also have the potential to decrease the need for general revenue transportation infrastructure improvements.

6.1.2 Criteria for selecting candidate corridors for HOT-lanes

Although a shortlist of GTA 400-series corridors suitable for HOT-lanes is beyond the scope of this study, survey results identified several key criteria that should be considered when assessing a corridor's relative advantages and disadvantages. These criteria include the following:

1. Significant traffic congestion. As identified in stated preference and revealed traffic volume results, WTP is closely linked to traffic speed. Regardless of trip urgency, if traffic flow is unimpeded few drivers will choose a paid alternative over free GP-lane travel.
2. Heavy traffic volume during typical weekday peak periods. As trip urgency is assumed to be highest during these periods, locating HOT-lanes in corridors that suffer from peak congestion would be of the highest value to drivers and, consequently, would result in high toll revenues during peak periods.
3. Good service to origins and destinations that attract road users with high annual household incomes.
4. Excellent connections to existing mass transit services including, if possible, subway lines, GO train stations, GO bus termini, and major activity hubs.
5. Relatively high carpool corridor mode share.

In addition to the criteria derived from the results of this study, candidate corridors should possess significant and sustained traffic throughput. Total corridor volumes must be high enough to generate sufficient revenue and justify the capital and operating costs of HOT-lane facilities.

Candidate corridors need not extend over tens of kilometres. Survey results indicated that respondents were willing to pay substantially to save a small amount of travel time and that the amount respondents were willing to pay per additional minute saved decreased as travel time saved increased (see Figure 6.1). Similarly the amount respondents were willing to pay per kilometre decreased with trip distance (see Figure 5.9). These findings indicate that it is likely more valuable to potential HOT-lane users to construct several short 10 to 15 km HOT-lane corridors with excellent connectivity to the existing public transit network than to build one 40 km long HOT-lane corridor across the GTA.

6.2 *Limitations*

In addition to the issues mentioned in Section 4.1, including the inherent limitations of stated preference surveys and the methodological limitation of substituting Hwy 407 throughput for parallel Hwy 401 HOT-lane volume, there were three other key limitations worth noting.

1. While the stated preference data gathering technique employed a variety of criteria to broaden the representativeness of the sample (see Section 4.2.3 and Appendix 2), a random sampling method was not used due to resource and time constraints.
2. In the revealed traffic volume analysis, the weekday morning (5 to 9 AM) and afternoon (3 to 7 PM) peaks were assumed to be periods of high trip urgency, the weekday midday (9 AM to 3 PM) was assumed to be a period of moderate trip urgency, and all other travel times were assumed to be periods of low trip urgency. While aggregate trip urgencies were based on a logical understanding of trip patterns, some hours of the day may have been incorrectly assigned. Indeed a case could be made that the weekday 5 to 6 AM and 6 to 7 PM hours should be considered periods of moderate urgency.
3. Based on an understanding of the relationship between traffic density, speed, and flow (described in Section 4.5.1), it was assumed that revealed Hwy 401 throughput decreased during the weekday peak period as result of slowed speed caused by excessive traffic density. This assumption helped underpin a central finding about the relationship of assumed trip urgency, Hwy 401 volume, and Hwy 407 throughput share. It is possible that observed decreases in Hwy 401 throughput during this period were caused by decreases in overall traffic density.

6.3 *Recommendations for future research*

Research on HOT-lanes in the GTA could be furthered by devising a mathematical model capable of predicting WTP from inputted trip characteristics and driver factors. A model could be derived for WTP per travel time saved with trip urgency, traffic speed, and 400-series trip distance as trip characteristic inputs and Hwy 407 exposure and respondent income as driver factor inputs.

Also, a HOT-lane corridor feasibility study could be conducted to identify suitable 400-series corridors. By using stated preference surveys, road volume data, and Canada Census data, the study could assess corridor driver urgency, average speed/period of travel, average driver trip distance on the highway, annual household income of cities and neighbourhoods directly served by the corridor, and corridor suitability for public transit. By assessing the criteria for selecting candidate HOT-lane corridors against 400-series corridor data, a shortlist of suitable corridors can be prepared. Corridor HOT-lane capital construction and operating costs could then be assessed against projected revenues to determine (a) suitable corridor candidate(s) for HOT-lanes in the Greater Toronto Area.

REFERENCES

407-ETR website. 407-ETR Tolls & Fees. Available online at: http://www.407etr.com/About/custserv_fees.asp. Accessed February 2, 2010.

91-Express Lanes FasTrak website (Orange Co, CA). Available online at: http://www.91expresslanes.com/. Accessed January 26, 2010.

95-Express website (Metro Miami, FL). Available online at: http://www.95express.com/. Accessed January 26, 2010.

Appiah, J (2004). An examination of factors affecting High Occupancy Toll Lane demand. Masters Thesis: Texas A&M University.

Arnott *et al*. (1990). Economics of a bottleneck. *Journal of Urban Economics: Vol. 27, Issue 1,* pp. 111 – 130.

Baker *et al*. (2008). Moving beyond Lexus lanes: Equity considerations for managed lanes. *DVD: Transportation Research Board 87th Annual Meeting*, 20 pages.

Barker, William G, Polzin, S E (2004). Synergies of Bus Rapid Transit and High-Occupancy Toll Lanes: Simulation of Bus Rapid Transit in a congested corridor with roadway value pricing. *Transportation Research Board: Issue 1884*, pp. 3 – 9.

Bernstein, Stephen and Bernstein, Ruth (1999). *Elements of Statistics II: Inferential Statistics.* Toronto: McGraw-Hill, pp. 108 – 110.

Bhatt, Kiran *et al*. (2009). US and worldwide experience with congestion pricing: An overview. *TR News, Number 263*, pp. 8 – 15.

Bonsall, Peter *et al*. (2006). Can people respond to complex pricing signals? *CD-ROM: Transportation Research Board 85th Annual Meeting*, 19 pages.

Brownstone *et al*. (2003). Drivers' willingness-to-pay to reduce travel time: evidence from the San Diego I-15 congestion pricing project**.** *Transportation Research Part A: Vol. 37, Issue 4,* pp. 373-387.

Brownstone, D. and Small, K. (2005). Valuing time and reliability: assessing the evidence from road pricing demonstrations. *Transportation Research Part A: Vol. 39, Issue 4*, pp. 279-293.

Burris, M W and Appiah, J (2004). Examination of Houston's QuickRide participants by frequency of QuickRide usage. *Transportation Research Record: Journal of the Transportation Research Board: Issue 1864,* pp. 22 – 30.

Burris, M. and Pendyala, R. (2002). Discrete choice models of traveler participation in differential time of day pricing programs. *Transport Policy***:** *Vol. 9, Issue 3*, pp. 241-251.

Burris, Mark and Xu, Lei (2006). Potential single-occupancy vehicle demand for high-occupancy vehicle lanes: Results from stated-preference survey of travelers in High-Occupancy Toll corridors. *Transportation Research Board: Issue 1960,* pp. 108 – 118.

Burris, Mark W (2009). Investigating the impact of tolls on high-occupancy-vehicle lanes using managed lanes. *Transportation Research Board: Issue 2099,* pp. 113 – 122.

Canada Census 2006. City of Toronto and Toronto CMA Journey to Work Figures. Available online at: http://www.statcan.gc.ca/. Accessed October 23, 2009.

Canada Census 2006. Toronto CMA Median Household Income (before tax) Figures. Available online at http://www.statcan.gc.ca/ . Accessed January 26, 2010.

Casello, J., C. Puchalsky and M. Semmler (2005). Implementing Road Pricing: A comparison of North America and Europe, 12th International HOV Systems Conference, Houston, TX.

Casello, J. and Hellinga, B. (2008). Impacts of express bus service on passenger demand. *Journal of Public Transportation: Vol. 11, No. 4*.

Chorus, C., Arentze, T. and Timmermans, H. (2008). A random regret-minimization model of travel choice. *Transportation Research Part B: Vol. 42, Issue 1*, pp. 1 – 18.

Chu, Lianyu *et al*. (2007). Priority-based high-occupancy-vehicle lane operation. *CD-ROM: Transportation Research Board 86th Annual Meeting*, 26 pages.

Colorado DOT I-25 HOV Express Lanes website (Denver, CO). Available online at: http://www.coloradodot.info/programs/tolling/i-25-hov-express-lanes. Accessed January 26, 2010.

Dahlgren, J. (1999). High Occupancy Vehicle / Toll Lanes: How do they operate and where do they make sense? *Institute of Transportation Studies.* University of California, Berkeley. Available online at: http://www.path.berkeley.edu/PATH/Publications/PDF/PWP/99/PWP-99-08.pdf. Accessed January 26, 2010.

Davis, Ronald William III *et al.* (2009). Factors affecting Willingness to Pay for High-Occupancy-Toll Lanes. *DVD: Transportation Research Board 88th Annual Meeting*, 22 pages.

DeCorla-Souza, Patrick (2006). A new financing approach for transportation infrastructure expansion. *CD-ROM: Transportation Research Board 85th Annual Meeting*, 25 pages.

DeCorla-Souza, Patrick (2005). Trade-off for road pricing between transportation performance and financial feasibility. *Transportation Research Board: Vol. 1932*, pp. 23 – 32

Field, Andy (2005). *Discovering Statistics Using SPSS (2nd Edition).* London: Sage Publications.

Fielding, G. and Klein, D. (1993). High occupancy/toll lanes: phasing in congestion pricing a lane at a time. *Reason Foundation: Policy Study No. 170.* Available online from *SSRN* at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=473602. Accessed February 2, 2010.

Goodin, Ginger and Fuhs, Chuck (2009). Tolled Managed Lanes: Lessons learned and challenges to meet. *TR News: Number 263*, pp. 20 – 22.

Google Maps (2010). Available online at http://maps.google.ca.

Halvorson *et al*. (2006). High-Occupancy Toll Lane innovations: I-394 MnPASS. *Minnesota Department of Transportation.* Available online at http://www.trb-pricing.org/docs/06-1265.pdf. Accessed January 26, 2010.

Henderson, D. (2003). The state of the practice in HOV system performance monitoring. *Transportation Research Record: Number 1856 (Freeways, High-Occupancy Vehicle Systems, and Traffic Signal Systems),* pp. 152 – 160.

Highway Capacity Manual (2000). Transportation Research Board. Washington, DC.

HOV-Lanes Plan. Ministry of Transportation Ontario (MTO) (2007). Available online at: http://www.mto.gov.on.ca/english/traveller/hov/plan2007.shtml. Accessed October 6, 2009.

Kaan *et al*. (2006). Theoretical derivation of value of travel time and demand elasticity: Evidence from New Jersey Turnpike Toll Road. *Transportation Research Record: Issue 1985*, pp. 248 – 256.

Lancaster, K. (1966). A new approach to consumer theory. *Journal of Political Economy: Vol. 74, Number 2*, pp.132 – 157.

Levine, J. and Garb, Y. (2002). Congestion pricing's conditional promise: Promotion of accessibility or mobility? *Transport Policy: Vol. 9, Issue 3*, pp. 179 – 188.

Li, J. (2001). Explaining high-occupancy-toll lane use. *Transportation Research Part D: Vol. 6, Issue 1*, pp. 61 – 74.

Lindsey, Robin (2007). Congestion Relief: Assessing the case for road tolls in Canada. *C.D. Howe Institute Commentary, Number 248.* Available online at: www.cdhowe.org/pdf/commentary_248.pdf. Accessed January 27, 2010.

Mastako, K A *et al*. (1998). Commuter behavior on California State Route 91 after introducing variable-toll express lanes. *Transportation Research Record: Issue 1649*, pp. 47 -54.

McShane, William R. and Roess, Roger P (1990). *Traffic Engineering.* Englewood Cliffs, NJ: Prentice-Hall.

Metrolinx / Greater Toronto Transportation Authority (2008). The Big Move – Transportation Master Plan for GTHA. Available online at: http://www.metrolinx.com/Docs/big_move/TheBigMove_020109.pdf. Accessed October 4, 2009.

Metropolitan Transit Authority of Harris County (Metro Houston, TX). Available online at: http://www.ridemetro.org/SchedulesMaps/HOV.aspx. Accessed January 26, 2010.

Ministry of Transportation – Ontario / MTO (2006). Ontario Provincial Highway Traffic Volumes on Demand. Available online at: http://www.raqsa.mto.gov.on.ca/techpubs/TrafficVolumes.nsf/tvweb. Accessed January 26, 2010.

MnPass website (Minneapolis, MN). Available online at: http://www.mnpass.org/. Accessed January 26, 2010.

Mowday, Megan (2006). Equity and High-Occupancy Toll Lanes: Literature review and Minnesotans' perceptions about I-394 High-Occupancy Toll Lanes. *CD-ROM: Transportation Research Board 85th Annual Meeting,* 28 pages.

Naik, Bhaven *et al*. (2008). Multivariate analysis of High-Occupancy-Toll lane usage in Houston. *DVD: Transportation Research Board 87th Annual Meeting,* 16 pages.

Ochieng *et al*. (2008). Technologies to measure indicators for variable road user charging. *DVD: Transportation Research Board 87th Annual Meeting*, 18 pages.

Places to Grow – Growth Plan for the Greater Golden Horseshoe (2006). Available online at: www.placestogrow.ca. Accessed October 5, 2009.

Poole, R. (2002). New research on HOT lanes. *Reason Foundation.* Available online at: http://www.reason.org. Accessed April 17, 2009.

Rountree *et al*. (2008). Georgia's approach to congestion with four T's: Tolling, transit, telework, and technology. *DVD: Transportation Research Board 87th Annual Meeting*, 17 pages.

SANDAG FasTrak Website (Metro San Diego, CA). Available online at: http://fastrak.511sd.com/ . Accessed January 26, 2010

Schweitzer, Lisa A and Taylor, Brian D (2007). Just Pricing: Comparing the effects of congestion pricing and transportation sales taxes on low income households. *CD-ROM: Transportation Research Board 86th Annual Meeting*, 27 pages.

Senbil, Metin and Kitamura, Ryuichi (2006). Valuing expressways under time pressures. *CD-ROM: Transportation Research Board 85th Annual Meeting*, 19 pages.

Smith, Brian *et al*. (2008). Enforcement of High-Occupancy-Toll facilities: Simulation-based evaluation methodology. *DVD: Transportation Research Board 87th Annual Meeting*, 14 pages.

Supernak *et al*. (2003).Dynamic value pricing as instrument for better utilization of High-Occupancy Toll Lanes: San Diego I-15 case. *Transportation Research Board 82nd Annual Meeting*, 10 pages.

Ungemah, David and Collier, Tina (2007). I'll tell you what I think!: A national review of how the public perceives pricing. *Transportation Research Record: Vol 1996*, pp. 66 – 73.

Ungemah, David H. *et al.* (2007). Examining incentives and preferential treatment of carpools in managed lane facilities: A state-of-the-practice review. *CD-ROM: Transportation Research Board 86th Annual Meeting*, 26 pages.

Vickrey, W. (1992). Principles of efficient congestion pricing. New York: Columbia University. Available online at: http://www.vtpi.org/vickrey.htm. Accessed January 26, 2010.

Vladisavljevic *et al.* (2008). High-Occupancy Toll Lane experiment on I-15 in Salt Lake City Metropolitan Region: Traffic flow evaluation. *DVD: Transportation Research Board 87th Annual Meeting*, 13 pages.

Washington State DOT SR-167 HOT Lanes (Metro Seattle, WA). Available online at: http://www.wsdot.wa.gov/Tolling/SR167HotLanes/default.htm. Accessed January 26, 2010.

Zhang, Guohui *et al*. (2008). A feedback-based dynamic tolling algorithm for High-Occupancy Toll Lane operations. *Transportation Research Record: Vol. 2065*, pp. 54 – 63.

Zhang, Lei and McMullen, B Starr (2008). Statewide distance-based user charge: Case of Oregon. *DVD: Transportation Research Board 87th Annual Meeting,* 22 pages.

APPENDICES

This chapter contains three sections. Appendix 1 contains the survey instrument and cover letter used to gather data for the stated preference analysis; Appendix 2 is a detailed explanation of the site selection process with descriptions of the sample areas chosen; Appendix 3 is a full write-up of all statistical results not included in the main body of the text.

Appendix 1: Survey instrument and cover letter

Jeremy Finkleman
Masters Candidate
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200 University Ave. W
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VER: 1

How much would YOU pay to escape congestion?

This **5 minute questionnaire** is being conducted to assess how Greater Toronto Area drivers would respond to congestion if a tolled congestion-free alternative were available to them. It is being carried out for academic purposes by Jeremy Finkleman, Masters Candidate in the School of Planning at the University of Waterloo. Completion of this survey constitutes your consent to participate in this study.

The survey team will not be aware of your name or identity. Your results will be combined with those from other participants; results are presented in aggregate.

Survey site: Site 1

HIGHWAY USAGE AND FAMILIARTY

1) For your most frequently travelled trips (i.e. commuting from home to work/school, going shopping, etc.), what mode of transportation do you most often use?

- **a.** I mostly drive by myself
- **b.** I mostly drive with others in the car
- **c.** I'm mostly a passenger in someone's car
- **d.** I mostly travel by public transit
- **e.** I mostly bicycle
- **f.** I mostly walk

2) How often do you travel a Greater Toronto Area (GTA) 400-series highway (limited-access freeway)?

- **a.** Daily
- **b.** At least once a week
- **c.** At least once a month
- **d.** At least once every 6 months
- **e.** Less than once every 6 months
- **f.** I never travel a GTA 400-series highway
  ******If 'f' selected, please end survey here.*

3) Typically, what is your main reason for travelling on the GTA's 400-series network?

- **a.** Commuting to/from work/school
- **b.** Going shopping
- **c.** Travelling to recreation activities
- **d.** Visiting friends/family
- **e.** Business purposes (operating a truck, taxi, delivery service, etc.)
- **f.** The sheer enjoyment of travelling along the GTA's freeways

4) How often do you travel on Toll Highway 407-ETR?

- **a.** Daily
- **b.** At least once a week
- **c.** At least once a month
- **d.** At least once every 6 months
- **e.** Less than once every 6 months
- **f.** I never travel on Hwy. 407-ETR

5) Have you ever been frustrated by congestion or slow moving traffic on a 400-series highway in the GTA?

- **a.** Yes
- **b.** No

6) Other than Hwy. 407, of all the 400-series highways in the GTA, which highway do you travel the most? (please circle one)

a. Hwy. 400
b. Hwy. 401
c. Hwy. 403
d. Hwy. 409
e. Hwy. 410
f. Hwy. 427
g. Don Valley Parkway/Hwy. 404
h. Gardiner Expressway/QEW
i. W.R. Allen Road
NOTE: 407-ETR not included in this study

HOW MUCH IS DRIVING FREE FROM CONGESTION WORTH TO YOU?

The following questions relate to a new market-based approach to congestion-relief already implemented in several cities. Congestion-free toll lanes run adjacent to existing regular lanes on freeways and provide fast and reliable lane-space at a cost to the driver. Tolling is conducted by means of electronic transponders – much like Greater Toronto's 407-ETR. Typically congestion-free toll lanes allow High Occupancy Vehicles (or carpools) to travel in the congestion-free lanes free of charge.

Heavy highway congestion
Traffic speed: 30 km/h

Moderate highway congestion
Traffic speed: 70 km/h

Free flow conditions
Traffic speed: 100 km/h

Picture yourself starting a short **15 km trip** on the GTA's freeway network. At 100 km/h this trip would take **9 min.**

7) Unfortunately today the freeway is heavily congested and moving at a speed of **30 km/h**. You know the road will not speed-up and you'll have to travel the full **15 km trip at 30 km/h** (a total trip time of **30 minutes**).

How much would you be willing to pay to entirely escape congestion and travel in parallel express toll lanes at a speed of 100 km/h?

Please circle a corresponding dollar figure:

Assuming **urgent** circumstances – You are in a rush to get somewhere important (i.e. due at work, late for a scheduled activity):

$0 $0.25 $0.50 $0.75 $1.00 $1.25 $1.50 $1.75 $2.00 // $2.50 $3.00 $3.50 $4.00 $4.50 $5.00 $5.50 $6 // $7 $8 $9 $10

If greater than $10, how much? (please write):

Assuming **non-urgent** circumstances – You are not in a rush or it is not important that you arrive at your intended destination at a particular time (e.g. driving to a recreational activity, driving to a scheduled activity when you have ample time to spare):

$0 $0.25 $0.50 $0.75 $1.00 $1.25 $1.50 $1.75 $2.00 // $2.50 $3.00 $3.50 $4.00 $4.50 $5.00 $5.50 $6 // $7 $8 $9 $10

If greater than $10, how much? (please write):

8) Tomorrow, you set out to make the same 15 km trip once more but this time the road is only moderately congested and moving at a speed of **70 km/h.** You know the road will not speed-up and you'll have to travel the full **15 km trip at 70 km/h** (a total trip time of **13 minutes**).

How much would you be willing to pay to entirely escape congestion and travel in parallel express toll lanes at a speed of 100 km/h?

Assuming **urgent** circumstances:

$0 $0.25 $0.50 $0.75 $1.00 $1.25 $1.50 $1.75 $2.00 $2.50 $3.00 $3.50 $4.00 $4.50 $5.00 $5.50 $6 $7 $8 $9 $10

If greater than $10, how much? (please write):

Assuming **non-urgent** circumstances:

$0 $0.25 $0.50 $0.75 $1.00 $1.25 $1.50 $1.75 $2.00 $2.50 $3.00 $3.50 $4.00 $4.50 $5.00 $5.50 $6 $7 $8 $9 $10

If greater than $10, how much? (please write):

Picture yourself starting a long **40 km trip** on the GTA's freeway network. At 100 km/h this trip would take **24 min.**

9) Unfortunately today the freeway is heavily congested and moving at a speed of **30 km/h.** You know the road will not speed-up and you'll have to travel the full **40 km trip at 30 km/h** (a total trip time of **1 hour and 20 minutes**).

How much would you be willing to pay to entirely escape congestion and travel in parallel express toll lanes at a speed of 100 km/h?

Assuming **urgent** circumstances:

$0 $0.25 $0.50 $0.75 $1.00 $1.25 $1.50 $1.75 $2.00 $2.50 $3.00 $3.50 $4.00 $4.50 $5.00 $5.50 $6 $7 $8 $9 $10

If greater than $10, how much? (please write):

Assuming **non-urgent** circumstances:

$0 $0.25 $0.50 $0.75 $1.00 $1.25 $1.50 $1.75 $2.00 $2.50 $3.00 $3.50 $4.00 $4.50 $5.00 $5.50 $6 $7 $8 $9 $10

If greater than $10, how much? (please write):

10) Tomorrow, you set out to make the same 40 km trip once more but this time the road is only moderately congested and moving at a speed of **70 km/h.** You know the road will not speed-up and you'll have to travel the full **40 km trip at 70 km/h** (a total trip time of **34 minutes**).

How much would you be willing to pay to entirely escape congestion and travel in parallel express toll lanes at a speed of 100 km/h?

Assuming **urgent** circumstances:

$0 $0.25 $0.50 $0.75 $1.00 $1.25 $1.50 $1.75 $2.00 $2.50 $3.00 $3.50 $4.00 $4.50 $5.00 $5.50 $6 $7 $8 $9 $10

If greater than $10, how much? (please write):

Assuming **non-urgent** circumstances:

$0 $0.25 $0.50 $0.75 $1.00 $1.25 $1.50 $1.75 $2.00 $2.50 $3.00 $3.50 $4.00 $4.50 $5.00 $5.50 $6 $7 $8 $9 $10

If greater than $10, how much? (please write):

IMPLEMENTATION PREFERENCE AND IMPACT ON CARPOOLING & TRANSIT USE

11) Choose one of the following three options:

a. I would prefer to see some **existing regular lanes converted** to congestion-free toll lanes/carpool-free lanes and pay on average **$0.10 per km** to use the lanes

b. I would prefer to see **freeways expanded** to include **new** congestion-free toll lanes/carpool free lanes without removing any existing regular lanes and pay on average **$0.20 per km** to use the lanes

c. These types of lanes should not be added to the GTA's freeways – they're a bad idea

12) Assuming vehicles with 2 or more persons would be able to travel in the congestion-free toll lanes free of charge, would this affect your willingness to carpool?

a. Yes
b. No

13) Assuming fast, frequent, and reliable bus service operated in the congestion-free lanes and connected major activity centres with local transit services and park and ride lots, would this affect your willingness to take public transit?

a. Yes
b. No

ABOUT YOU

14) How old are you?

a. 18 – 24
b. 25 – 34
c. 35 – 44
d. 45 – 54
e. 55 – 64
f. 65 +

15) Your gender:

a. Male
b. Female

16) What is your postal code (please write)?

______-______

17) What is your average **annual** household income?

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

Thank you for your participation. Have a great day! ☺

-----------------PLEASE DETACH THIS PAGE PRIOR TO MAILING THE QUESTIONNAIRE-----------------

Jeremy Finkleman
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DATE OF PRINTING

Dear respondent:

You are invited to participate in a brief, anonymous questionnaire being conducted to assess how much travellers would be willing to pay to escape highway congestion along Greater Toronto's freeway network. This study is being conducted by Jeremy Finkleman as part of the requirements for a Masters Degree and is being carried out under the supervision of Dr. Jeffrey Casello.

The purpose of this study is to investigate the magnitude of the public's desire to pay to escape highway congestion, to examine what factors contribute to differences in willingness to pay, to assess public support for High Occupancy/Toll (HOT) lanes along Toronto's freeway-network, and to investigate the impact of HOT lanes on potential shifts to carpool or high-order bus travel arrangements.

High Occupancy/Toll lanes:

- Provide an alternative to regular lanes, allowing vehicles to travel free of congestion for a fee
- Run-parallel to normal lanes
- Are accessible free of charge to carpools or vehicles with high occupancies
- Are tolled by electronic transponder, like Hwy. 407, eliminating the need for staffed toll-booths
- Are priced depending on real-time congestion levels in normal flow lanes to ensure maximum flow
- Are already in existence in several cities

As a participant in this study, you will complete a brief five-minute questionnaire centring on how much you would be willing to pay per trip to avoid congestion along Greater Toronto's freeway network.

Completion of the questionnaire constitutes your consent to participate in this study. Your participation is strictly voluntary, you may leave unanswered any question you prefer not to answer, and you may withdraw your participation at any time. Please note that this questionnaire maintains respondent anonymity and does not ask you to reveal personal information such as your name, address, or telephone number. Data gathered from questionnaires will be aggregated and individual questionnaires will be confidentially shredded after one year.

Survey responses must be mailed by May 15, 2009 to be included in the study.

An executive summary of findings gathered from the analysis will be posted by July, 2009 at: http://transporttomorrow.blogspot.com/. If you have any questions about participation in this study please feel free to ask the survey administrator or contact the researcher at jfinklem@uwaterloo.ca.

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

Once again thank you for your participation.

Kindest regards,

Jeremy Finkleman, Masters Candidate
School of Planning, University of Waterloo

Appendix 2: Site selection process and sample area description

Sample sites were required to fulfill the following criteria:

1. Sample sites were required to be within 2.5 km of a 400-series highway;
2. At least one sample site was required to be within 2.5 km of Hwy 407-ETR;
3. To increase driver demographic and trip purpose heterogeneity, each sample site had to be near:
    a. A library
    b. A school
    c. A house of worship
    d. A bank
    e. A medical clinic
    f. A site of leisure
    g. A restaurant or pub
    h. A retail establishment/store
4. Excluding the Downtown Toronto sample site, one sample site had to be selected from each of four concentric zones.

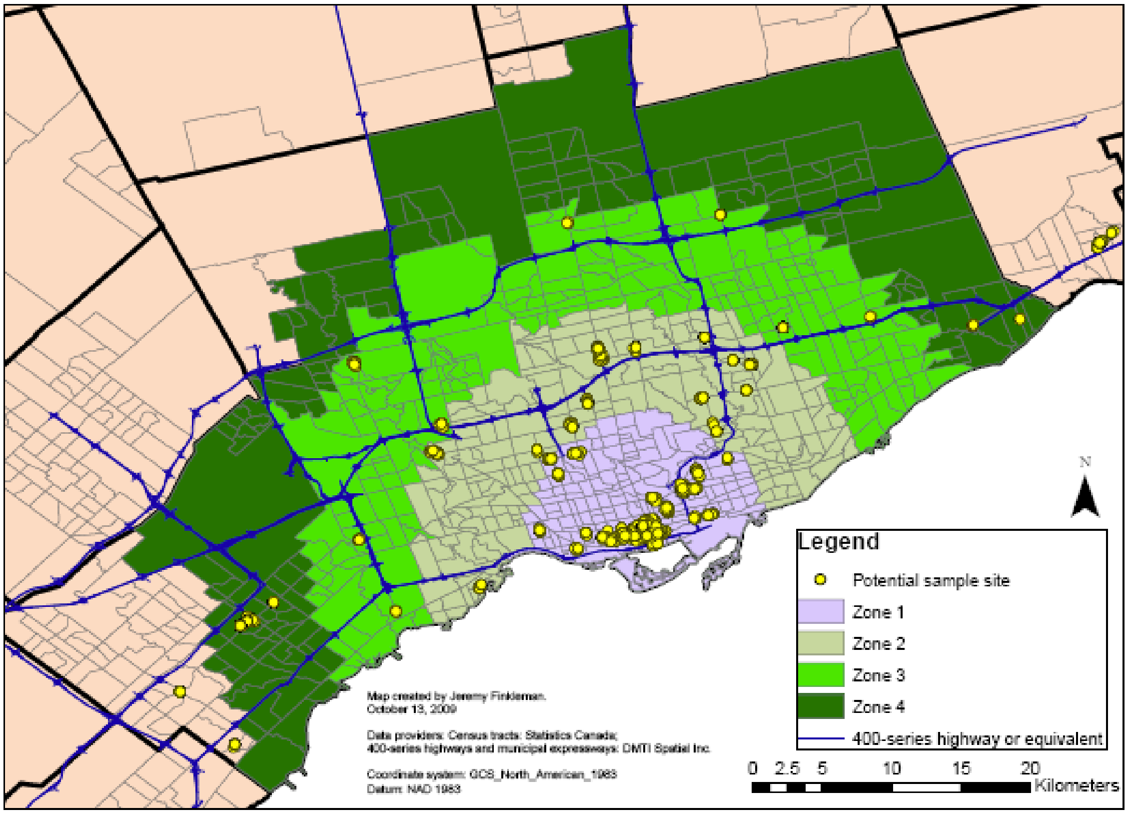


Figure 8.1: Spatial shortlist of sample sites

The study divided the GTA into four 8-km concentric zones radiating from Downtown Toronto. Census tracts whose centroids (CTC) were located 0 to 8 km from Downtown Toronto were classified zone 1, CTCs located 8.1 to 16 km from Downtown were classified zone 2, CTCs located 16.1 to 24 km from Downtown were classified zone 3, and CTCs located 24.1 to 32 km from Downtown were classified zone 4 (see Figure 8.1). Zone-based sampling ensured that participants would be drawn from a variety of different locations and geographies in the metropolitan region.

The 8 km interval was chosen because it generally corresponds with the GTA's built-form and land-use patterns. Zone 1 is predominantly urban in character. This zone developed prior to the popularization of the automobile; its land-use patterns heavily reflect the influence of the streetcar. It is currently well served by public transit. Zone 1's road network is based on a grid-arterial pattern; the two expressways that traverse the zone (Don Valley Pkwy and Gardiner

Expy) are designed more to shuttle traffic in and out of the CBD from further zones than to satisfy zone 1 O-D trips.

By contrast, Zone 2 is of a more suburban character. Though still well served by transit, most of Zone 2 has been designed for the automobile. Much of Zone 2 is characterized by wide superblock-oriented arterial roads and small curvilinear neighbourhood streets. The geography includes sprawling single-detached neighbourhoods, utilitarian apartment building groupings, and large shopping complexes. Zone 2 is served by a more extensive freeway network than Zone 1, including Hwy 401.

Zones 3 and 4 are auto-centric in design. Both zones have an extensive freeway network, large-scale separation of land-uses, typical suburban neighbourhood designs, and highway-oriented industrial areas. Hwy 407-ETR transects the northern sections of Zones 3 and 4. While Zone 3 is entirely within the GTA's built-up area, much of the northern and eastern sections of Zone 4 are agricultural.

GIS spatial analysis

GIS spatial analysis was used to identify concentric zones and shortlist sample sites. A census tract shapefile was used to delimit concentric zones. Zones were determined by CTC distance from a reference Downtown Toronto census tract bordered by Queen (N), Yonge (E), Front (S), and Simcoe (W) streets.

A shortlist of sample sites within concentric zones was obtained by eliminating sites that did not adhere to the criteria (see Figure 8.1). First, Ontario Enhanced Points of Interest (EPOI) shapefiles were used to map the location of all banks, retail establishments/stores, sites of leisure, libraries, medical clinics, restaurants and pubs, elementary and secondary schools, and colleges and universities in the GTA. Then, these shapefiles were filtered in a step-by-step manner to create zone-based spatial shortlists.

Sample site spatial shortlists represented *retail establishments/stores* within:

- 2.5 km of a 400-series highway;
- 1 km of a library;
- 1 km of a school;
- 1 km of a place of worship;
- 250 m of a bank;
- 250 m of a medical clinic;
- 250 m of a site of leisure;
- 250 m of a restaurant or pub;

Chosen sample sites and sample areas

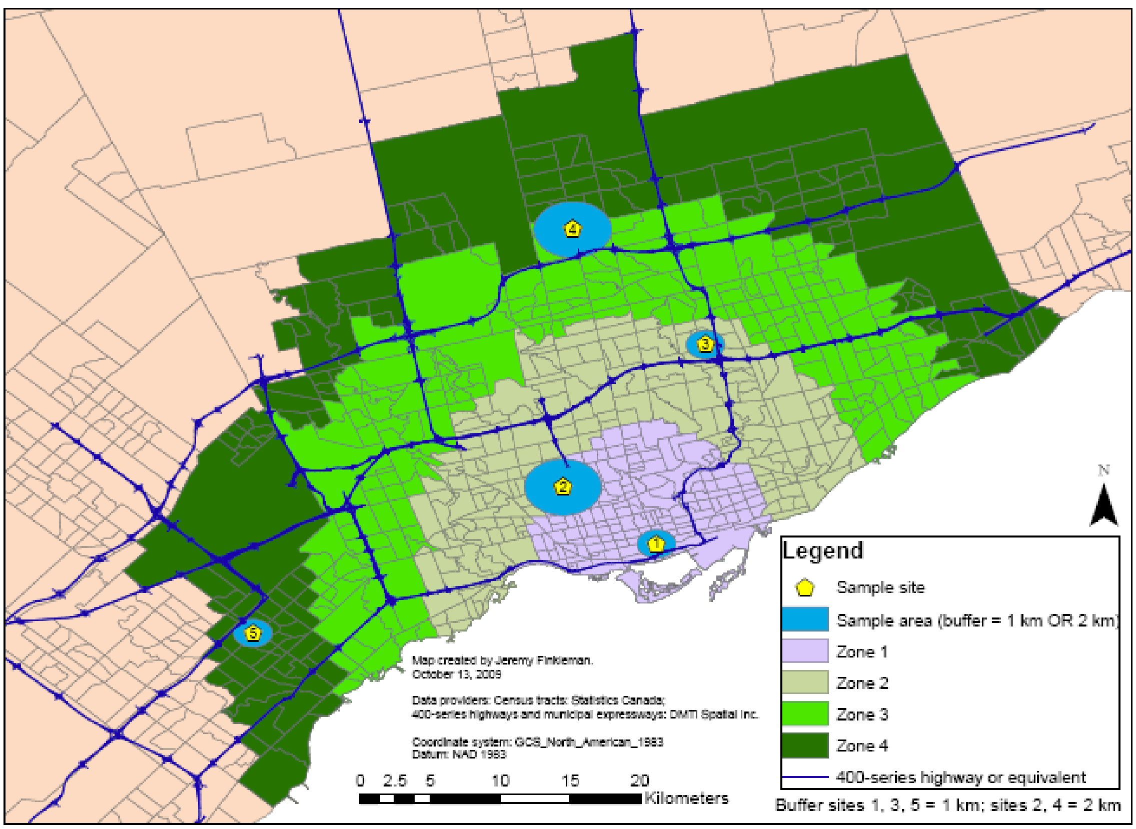


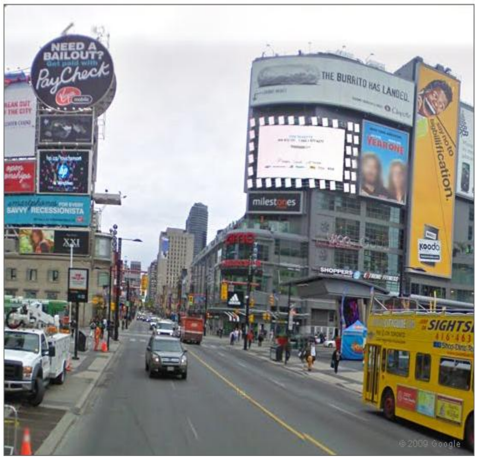
Figure 8.2: Location of sample sites

In addition to Downtown Toronto, one sample site was chosen from each concentric zone's shortlist (see Figure 8.2). The five specific sample sites selected were chosen because they were considered to be located in areas of significant regional convergence that attract individuals from a wide range of household types and socio-demographic groups.

Since sample sites were merely retail establishments/stores that fulfilled all required criteria, it was necessary to establish broader corresponding sample areas where surveys could be distributed. Sample areas comprised all land within either 1 or 2 km of each chosen sample site. The size of the sample area was related to neighbourhood design and service concentration. Sample sites 1, 3, and 5 had corresponding sample area buffers of 1 km while sample sites 2 and 4 had corresponding sample area buffers of 2 km.

Chosen sample sites/areas were as follows:

Sample Area 1: Downtown Toronto



- Sample site was located at the corner of Adelaide and Yonge Streets, Toronto.
- 1 km radius sample area buffer encompassed most of Central Toronto including key landmarks such as City Hall, Dundas Square, St. Lawrence Market, Osgoode Hall, and the city's Central Business District.

Sample Site 1 and 1 km Sample Area Buffer

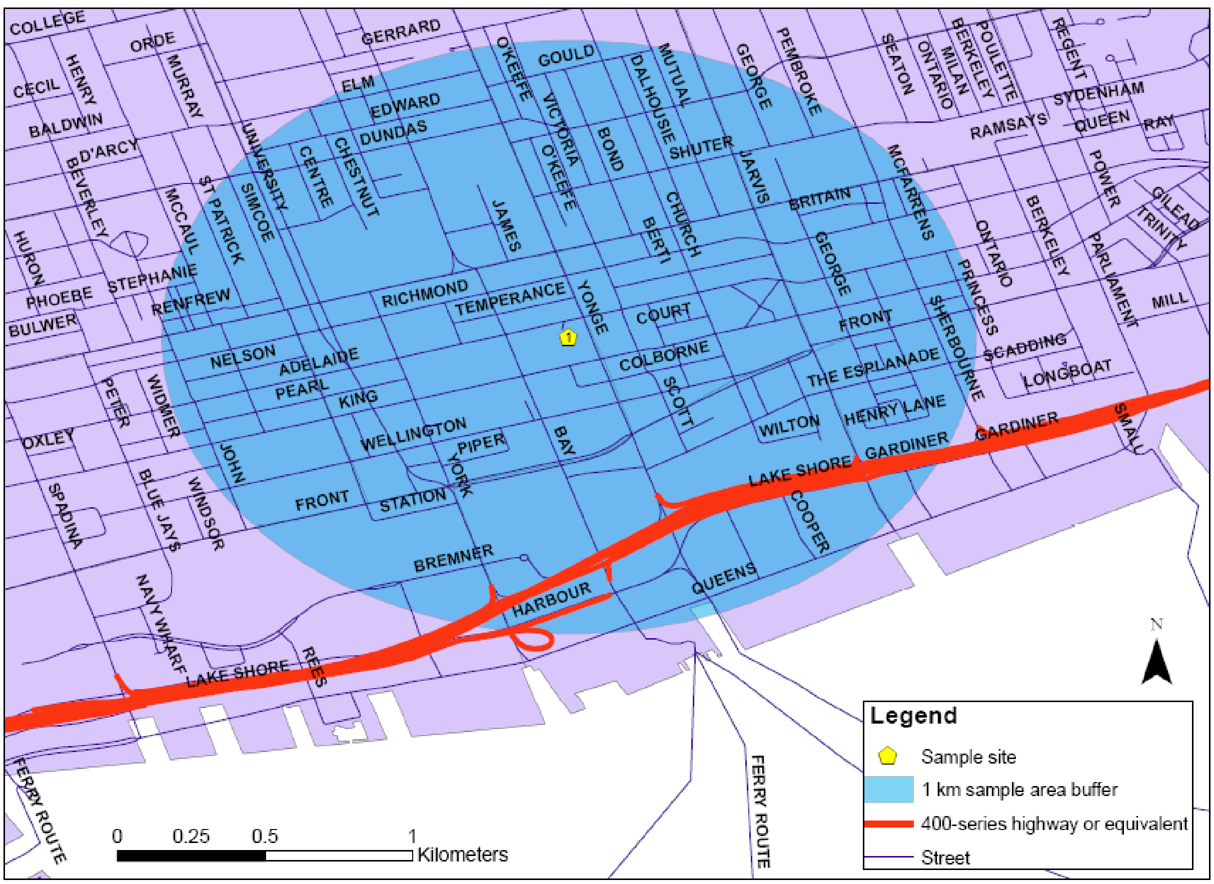
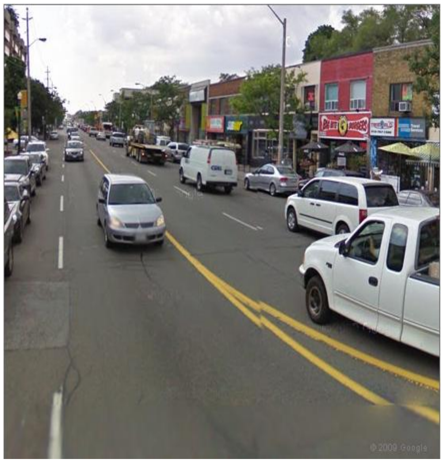


Figure 8.3: Map of sample area 1 / Downtown Toronto

Sample Area 2: Midtown Toronto West



- Sample site was located at the corner of Holland Park and Oakwood Avenues, Toronto, in an established and predominantly residential neighbourhood.
- 2 km radius sample area buffer included major arterials such as Eglinton Ave. from Bathurst St. (E) to Caledonia Rd. (W), Bathurst St. from Eglinton Ave. (N) to south of St Clair Ave. (S), St Clair Ave. from Spadina Rd. (E) to Caledonia Rd. (W), and Dufferin St. from Dupont St. (S) to north of Eglinton Ave (N), as well as smaller residential streets.
- A 2 km radius was necessary for sampling due to the area's linear and anodal urban form.

Sample Site 2 and 2 km Sample Area Buffer

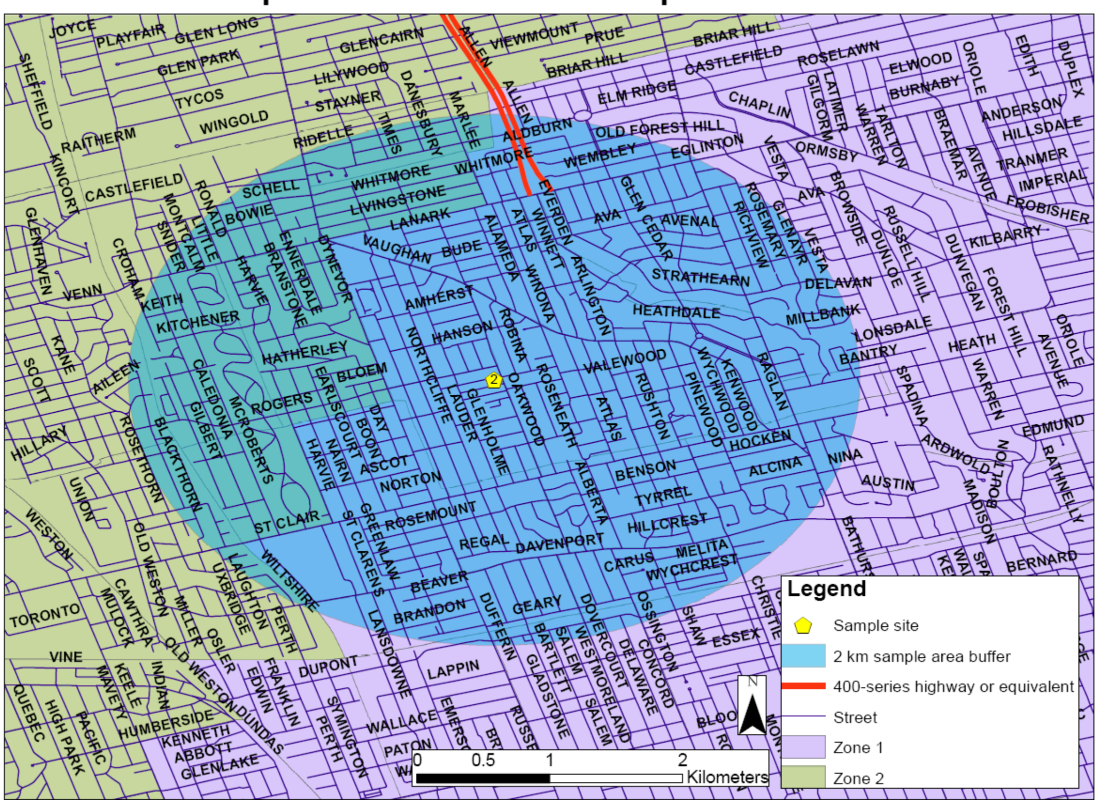


Figure 8.4: Map of sample area 2 / Midtown Toronto West

Sample Area 3: Willowdale-Fairview

- Sample site was located at the corner of Don Mills Rd. and Sheppard Ave., Toronto (North York).
- 1 km radius sample area buffer included a number of older residential high-rise towers, Fairview Mall, Toronto Public Library-North York, and several smaller street-oriented shopping plazas.

Sample Site 3 and 1 km Sample Area Buffer

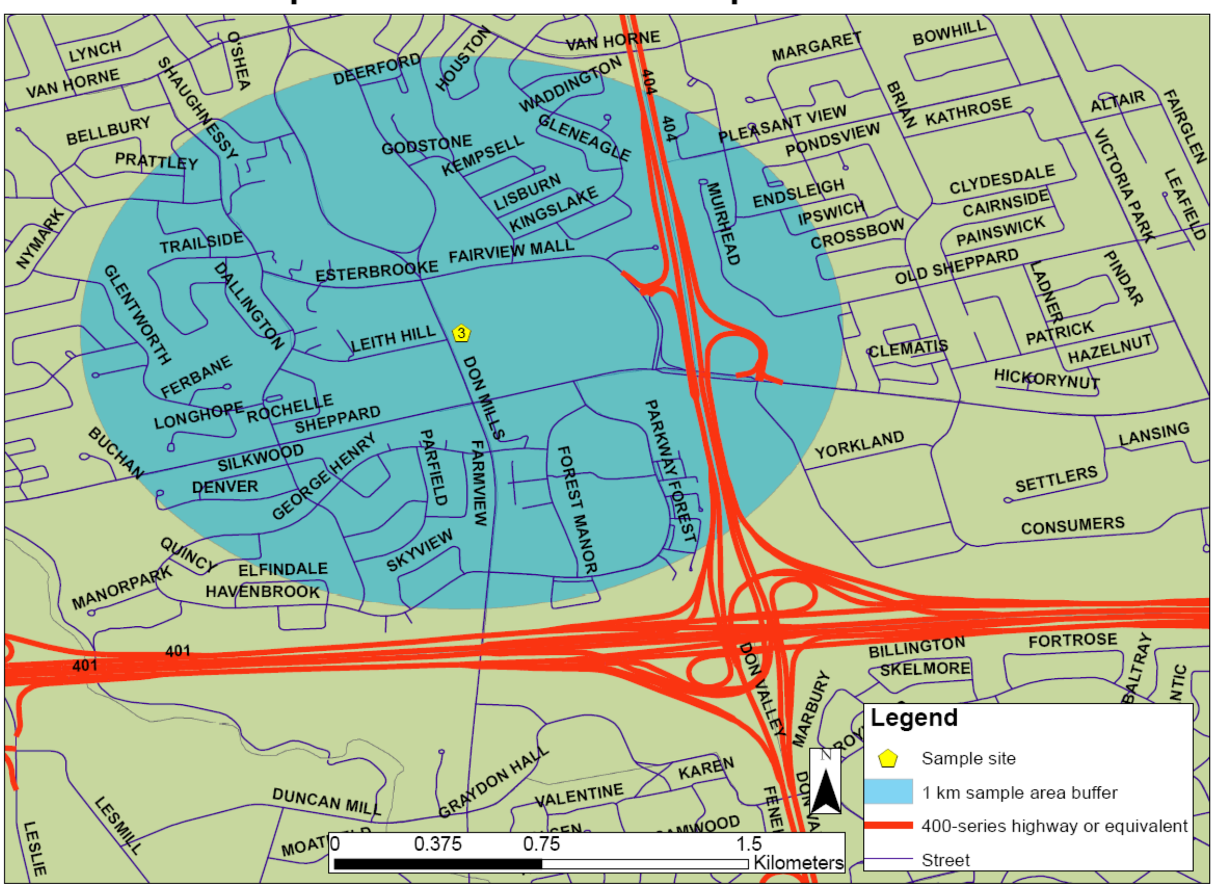
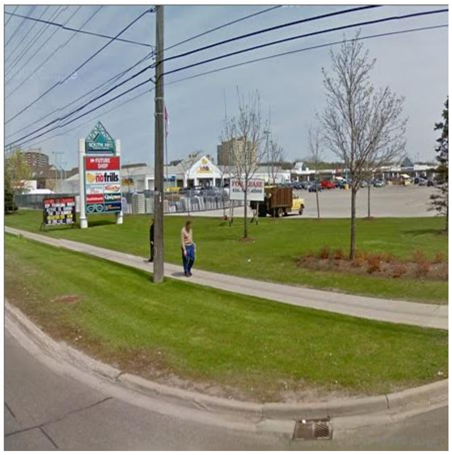


Figure 8.5: Map of sample area 3 / Willowdale-Fairview

Sample Area 4: Richmond Hill-Hillcrest



- Sample site was located at the corner Oak Ave. and Yonge St., Richmond Hill (near the corner of 16th Ave./Carrville Rd. and Yonge St.).
- 2 km radius sample area buffer included a mix of single-detached housing and auto-oriented strip and nodal commercial establishments. Several main arterials traversed the sample area: Yonge St., Carrville Rd. – 16th Ave., and Highway 7. Three major shopping complexes were located in the area.
- A 2 km radius was necessary for sampling due to the area's dispersed urban form and high degree of land-use separation.

Sample Site 4 and 2 km Sample Area Buffer

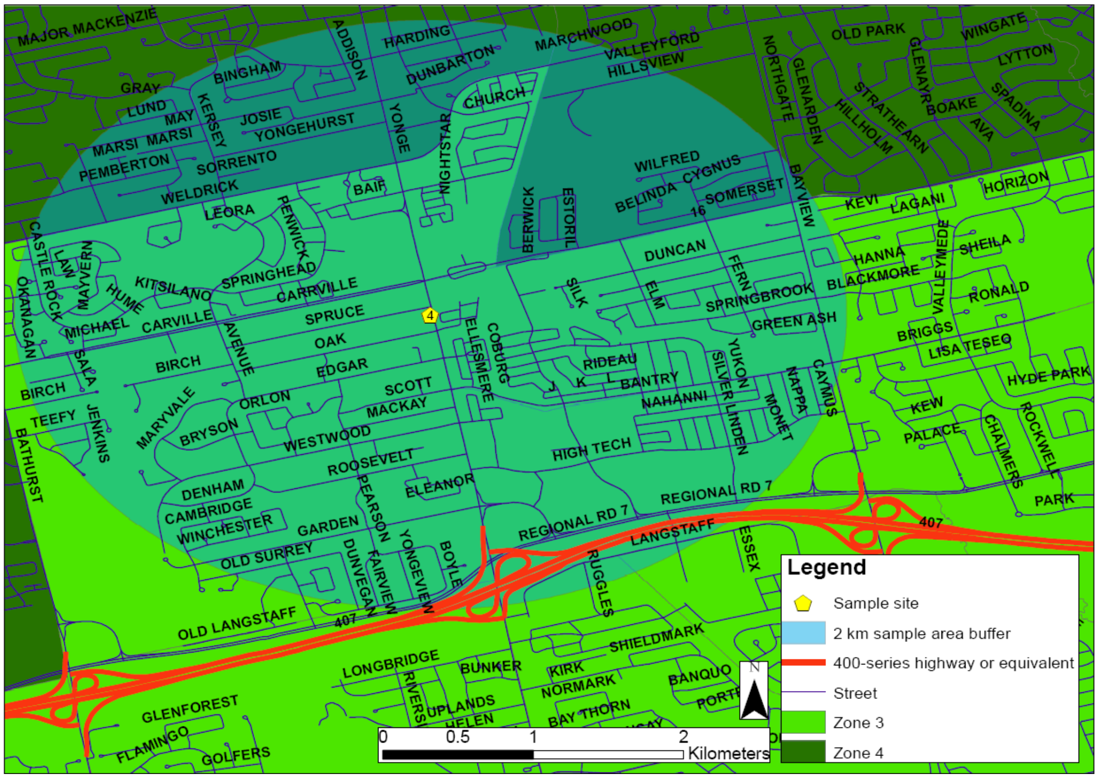
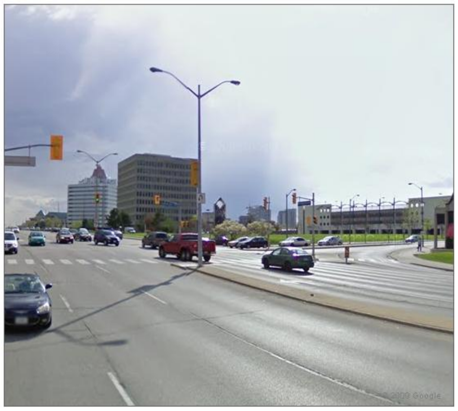


Figure 8.6: Map of sample area 4 / Richmond Hill-Hillcrest

Sample Area 5: Mississauga Centre



- Sample site was located at the corner of City Centre Dr. and Kariya Gate, Mississauga (near the corner of Burnhamthorpe Rd. W and Hurontario St.).
- 1 km radius sample area buffer included Mississauga City Hall, a number of office buildings, a YMCA recreation centre, various residential high-rise towers, and the Square One shopping complex.

Sample Site 5 and 1 km Sample Area Buffer

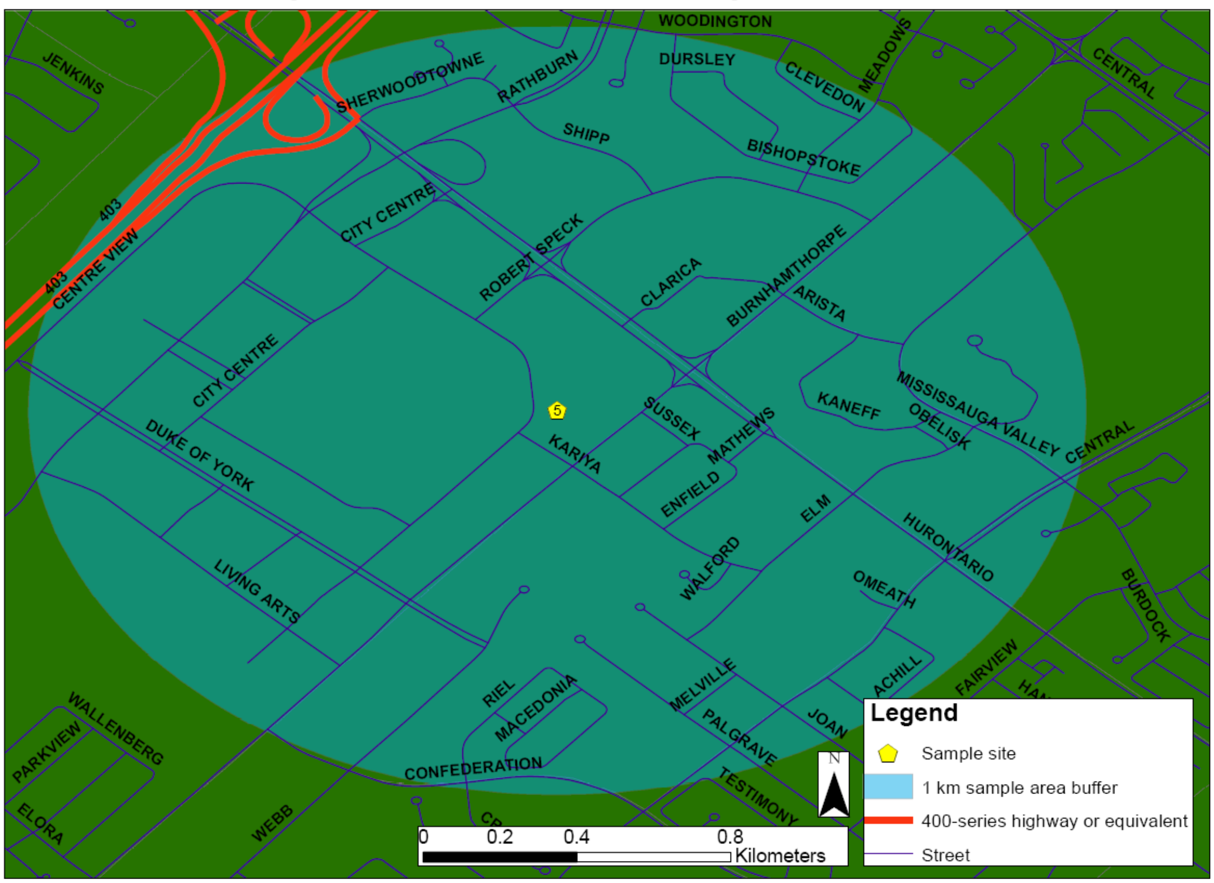


Figure 8.7: Map of sample area 5 / Mississauga Centre

Appendix 3: Full statistical results

The results of statistical tests not included in the main body of the paper are written-up here.

Research Question 2: Additional statistical results

The main effects of urgency, speed, and distance were found to be statistically significant indicators WTP. Interactions did not reveal significant results. A full write-up of the results of speed and distance as well as all interaction results is presented here. A write-up of the results of urgency is found in Section 5.3.1. For an overview of all factorial ANOVA statistical results for this subsection see Table 5.8.

Traffic speed

The impact of traffic speed on WTP to escape congestion was determined by comparing the WTP mean to escape trips with 30 km/h traffic speeds (trips 1, 2, 5, 6) with the WTP mean to escape trips with 70 km/h traffic speeds (trips 3, 4, 7, 8). The WTP mean to escape trips with 30 km/h traffic speeds was derived from 127 cases and the WTP mean to escape trips with 70 km/h traffic speeds was derived from 125 cases.

There was a significant main effect of speed on willingness to pay, F (1) = 17.195 at significance $p < .001$, $\eta = .236$ ($\eta^2 = .056$ / 5.6%). Respondents travelling at slow traffic speeds (30 km/h) were willing to pay significantly more to escape congestion than respondents travelling at moderate traffic speeds (70 km/h). This finding validated the hypothesis and was congruent with results from value-of-time-based research.

400-series trip distance

The impact of trip distance on WTP to escape congestion was determined by comparing the mean WTP for 15 km trips (trips 1, 2, 3, 4) with the mean WTP for 40 km trips (trips 5, 6, 7, 8).

The mean WTP for 15 km trips and the mean WTP for 40 km trips were each derived from 126 separate cases.

There was a significant main effect of distance on willingness to pay, F (1) = 11.029 at significance p = .001, η = .189 (η^2 = .036 / 3.6%). Respondents were willing to pay significantly more to escape congestion for medium-long distance 400-series trips (40 km) than they were for short distance 400-series trips (15 km). This finding validated the hypothesis and was congruent with results from past research.

Urgency and speed

The interaction effect of urgency and speed on WTP to escape congestion was determined by comparing four WTP means: the means of high urgency/30 km/h trips (trips 1, 5), high urgency/70 km/h trips (trips 3, 7), low urgency/30 km/h trips (trips 2, 6), and low urgency/70 km/h trips (trips 4, 8).

A significant interaction effect between urgency and speed was not found, F (1) = .738 at significance p > .05, η = .049 (η^2 = .002 / 0.2%). There was no statistical difference between the effects of urgency on WTP to escape congestion at 30 km/h and 70 km/h. Likewise, there was no statistical difference between the effects of speed on WTP to escape congestion for high urgency trips and low urgency trips. The hypothesis that predicted that the effect of trip urgency on WTP would be more pronounced in trips with 30 km/h traffic speeds than in trips with 70 km/h traffic speeds was proven incorrect.

Urgency and distance

The interaction effect of urgency and distance on WTP to escape congestion was determined by comparing four WTP means: the means of high urgency/15 km trips (trips 1, 3), high urgency/40 km trips (trips 5, 7), low urgency/15 km trips (trips 2, 4), and low urgency/40 km trips (trips 6, 8).

A significant interaction effect between urgency and distance was not found, F (1) = .280 at significance $p > .05$, $\eta = .030$ ($\eta^2 = .001$ / 0.1%). There was no statistical difference between the effects of urgency on WTP to escape congestion for 15 km trips and 40 km trips. Likewise, there was no statistical difference between the effects of distance on WTP to escape congestion for high urgency trips and low urgency trips. The hypothesis that predicted that the effect of trip urgency on WTP would be more pronounced in 40 km trips than in 15 km was proven incorrect.

Speed and distance

The interaction effect of speed and distance on WTP to escape congestion was determined by comparing four WTP means: the means of 30 km/h/15 km trips (trips 1, 2), 30 km/h/40 km trips (trips 5, 6), 70 km/h/15 km trips (trips 3, 4), and 70 km/h/40 km trips (trips 7, 8).

A significant interaction effect between speed and distance was not found, F (1) = .016 at significance $p > .05$, $\eta = .007$ ($\eta^2 = .000$ / 0.0%). There was no statistical difference between the effects of speed on WTP to escape congestion for 15 km trips and 40 km trips. Likewise, there was no statistical difference between the effects of distance on WTP to escape congestion at 30 km/h and 70 km/h. This finding validated the hypothesis.

Urgency, speed, and distance

The interaction effect of urgency, speed and distance (combined) on WTP to escape congestion was determined by comparing all eight trip condition means.

A significant interaction effect between urgency, speed, and distance was not found, F (1) = 1.222 at significance $p > .05$, $\eta = .063$ ($\eta^2 = .004$ / 0.4%).

Research Question 3: Full statistical results

A full write-up of all Research Question 3 statistical results is presented here. Results are categorized by driver factor.

Annual household income

The number of cases in each income group per trip condition is presented in Table 8.1.

Table 8.1: Cases per income group

Trip condition (Urg, Spd, Dist)	$0 - $59,999	$60,000 - $119,999	$120,000+	Total
Trip 1 (H, 30 km/h, 15 km)	60	106	70	236
Trip 2 (L, 30 km/h, 15 km)	60	106	70	236
Trip 3 (H, 70 km/h, 15 km)	60	107	70	237
Trip 4 (L, 70 km/h, 15 km)	60	107	69	236
Trip 5 (H, 30 km/h, 40 km)	60	107	70	237
Trip 6 (L, 30 km/h, 40 km)	60	106	69	235
Trip 7 (H, 70 km/h, 40 km)	60	107	70	237
Trip 8 (L, 70 km/h, 40 km)	60	107	70	237

The statistical significance and effect size of annual household income on WTP was assessed for each trip condition. Planned contrasts revealed the impact of income on WTP between different item levels. See Table 5.9 for a summary of results.

<u>Trip 1 (High urgency, 30 km/h, 15 km):</u> Assume homogeneity of variances (Levene's test: F (2,233) = 1.823 at significance $p > .05$). There was a significant effect of income on WTP to escape congestion, F (2,233) = 3.553 at significance $p < .05$, $\eta = .172$ ($\eta^2 = .030$ / 3%).

Planned contrasts comparing the mean of the low income group with the mean of the high and middle income groups (MEAN-low income vs. MEAN-middle income+high income) did not reveal a significant effect of income, t(233) = 1.859 at significance $p > .05$, $r = .121$ ($R^2 = .015$ / 1.5%). Planned contrasts of the mean of the middle income group and the mean of the high income group revealed a significant effect of income (respondents with high incomes were willing to pay significantly more to escape congestion than respondents with middle incomes), $t(233) = -2.095$ at significance $p < .05$, $r = .136$ ($R^2 = .018$ / 1.8%).

<u>Trip 2 (Low urgency, 30 km/h, 15 km):</u> Assume heterogeneity of variances (Levene's test: $F(2,233) = 9.788$ at significance $p < .001$). There was a significant effect of income on WTP to escape congestion, $F(2,135.599) = 7.398$ (Welch-correction) at significance $p = .001$, $\eta = .274$ ($\eta^2 = .075$ / 7.5%).

Planned contrasts comparing the mean of the low income group with the mean of the high and middle income groups (MEAN-low income vs. MEAN-middle income+high income) revealed a significant effect of income (respondents with middle and high incomes were willing to pay significantly more to escape congestion than respondents with low incomes), $t(158.184) = 3.644$ at significance $p < .001$, $r = .278$ ($R^2 = .077$ / 7.7%). Planned contrasts of the mean of the middle income group and the mean of the high income group revealed a significant effect of income (respondents with high incomes were willing to pay significantly more to escape congestion than respondents with middle incomes), $t(100.581) = -2.858$ at significance $p < .01$, $r = .274$ ($R^2 = .075$ / 7.5%).

<u>Trip 3 (High urgency, 70 km/h, 15 km):</u> Assume heterogeneity of variances (Levene's test: $F(2,234) = 10.700$ at significance $p < .001$). There was a significant effect of income on WTP to escape congestion, $F(2,139.568) = 8.055$ (Welch-correction) at significance $p < .001$, $\eta = .228$ ($\eta^2 = .052$ / 5.2%).

Planned contrasts comparing the mean of the low income group with the mean of the high and middle income groups (MEAN-low income vs. MEAN-middle income+high income) revealed a significant effect of income (respondents with middle and high incomes were willing to pay significantly more to escape congestion than respondents with low incomes), $t(170.441) = 4.021$ at significance $p < .001$, $r = .294$ ($R^2 = .087$ / 8.7%). Planned contrasts of the mean of the middle income group and the mean of the high income group did not reveal a significant effect of income, $t(111.473) = -1.827$ at significance $p > .05$, $r = .171$ ($R^2 = .029$ / 2.9%).

Trip 4 (Low urgency, 70 km/h, 15 km): Assume heterogeneity of variances (Levene's test: $F_{(2,233)} = 5.794$ at significance $p < .01$). No significant effect exists, $F_{(2,135.420)} = 2.265$ (Welch-correction) at significance $p > .05$, $\eta = .164$ ($\eta^2 = .027$ / 2.7%).

Trip 5 (High urgency, 30 km/h, 40 km): Assume homogeneity of variances (Levene's test: $F_{(2,234)} = 1.332$ at significance $p > .05$). There was a significant effect of income on WTP to escape congestion, $F_{(2,234)} = 3.713$ at significance $p < .05$, $\eta = .175$ ($\eta^2 = .031$ / 3.1%).

Planned contrasts comparing the mean of the low income group with the mean of the high and middle income groups (MEAN-low income vs. MEAN-middle income+high income) did not reveal a significant effect of income, $t(234) = 1.277$ at significance $p > .05$, $r = .083$ ($R^2 = .007$ / 0.7%). Planned contrasts of the mean of the middle income group and the mean of the high income group revealed a significant effect of income (respondents with high incomes were willing to pay significantly more to escape congestion than respondents with middle incomes), $t(234) = -2.530$ at significance $p < .05$, $r = .163$ ($R^2 = .027$ / 2.7%).

Trip 6 (Low urgency, 30 km/h, 40 km): Assume heterogeneity of variances (Levene's test: $F_{(2,232)} = 4.141$ at significance $p < .05$). There was a significant effect of income on WTP to escape congestion, $F_{(2,140.445)} = 5.633$ (Welch-correction) at significance $p < .01$, $\eta = .213$ ($\eta^2 = .045$ / 4.5%).

Planned contrasts comparing the mean of the low income group with the mean of the high and middle income groups (MEAN-low income vs. MEAN-middle income+high income) revealed a significant effect of income (respondents with middle and high incomes were willing to pay significantly more to escape congestion than respondents with low incomes), $t(161.918) = 3.148$ at significance $p < .01$, $r = .240$ ($R^2 = .058$ / 5.8%). Planned contrasts of the mean of the middle income group and the mean of the high income group revealed a significant effect of income (respondents with high incomes were willing to pay significantly more to escape congestion than respondents with middle incomes), $t(122.485) = -2.067$ at significance $p < .05$, $r = .184$ ($R^2 = .034$ / 3.4%).

Trip 7 (High urgency, 70 km/h, 40 km): Assume heterogeneity of variances (Levene's test: $F(2,234) = 8.881$ at significance $p < .001$). There was a significant effect of income on WTP to escape congestion, $F(2,134.544) = 4.949$ (Welch-correction) at significance $p < .01$, $\eta = .217$ ($\eta^2 = .047$ / 4.7%).

Planned contrasts comparing the mean of the low income group with the mean of the high and middle income groups (MEAN-low income vs. MEAN-middle income+high income) revealed a significant effect of income (respondents with middle and high incomes were willing to pay more to escape congestion than respondents with low incomes), $t(142.942) = 2.918$ at significance $p < .01$, $r = .237$ ($R^2 = .056$ / 5.6%). Planned contrasts of the mean of the middle income group and the mean of the high income group revealed a significant effect of income (respondents with high incomes were willing to pay significantly more to escape congestion than respondents with middle incomes), $t(110.864) = -2.156$ at significance $p < .05$, $r = .201$ ($R^2 = .040$ / 4.0%).

Trip 8 (Low urgency, 70 km/h, 40 km): Assume heterogeneity of variances (Levene's test: $F(2,234) = 5.678$ at significance $p < .01$). There was a significant effect of income on WTP to escape congestion, $F(2,138.870) = 5.088$ (Welch-correction) at significance $p < .01$, $\eta = .204$ ($\eta^2 = .042$ / 4.2%).

Planned contrasts comparing the mean of the low income group with the mean of the high and middle income groups (MEAN-low income vs. MEAN-middle income+high income) revealed a significant effect of income (respondents with middle and high incomes were willing to pay significantly more to escape congestion than respondents with low incomes), $t(165.730) = 3.152$ at significance $p < .01$, $r = .238$ ($R^2 = .057$ / 5.7%). Planned contrasts of the mean of the middle income group and the mean of the high income group did not reveal a significant effect of income, $t(107.384) = -1.877$ at significance $p > .05$, $r = .178$ ($R^2 = .032$ / 3.2%).

Respondent age

The number of cases in each age group per trip condition is presented in Table 8.2.

Table 8.2: Cases per age group

Trip condition (Urg, Spd, Dist)	18 – 34	35 – 54	55+	Total
Trip 1 (H, 30 km/h, 15 km)	71	111	69	251
Trip 2 (L, 30 km/h, 15 km)	71	111	69	251
Trip 3 (H, 70 km/h, 15 km)	71	111	70	252
Trip 4 (L, 70 km/h, 15 km)	71	111	69	251
Trip 5 (H, 30 km/h, 40 km)	71	111	70	252
Trip 6 (L, 30 km/h, 40 km)	71	109	70	250
Trip 7 (H, 70 km/h, 40 km)	71	111	70	252
Trip 8 (L, 70 km/h, 40 km)	71	111	70	252

The statistical significance and effect size of respondent age on WTP was assessed for each trip condition. Planned contrasts revealed the impact of age on WTP between different item levels. See Table 5.10 for a summary of results.

<u>Trip 1 (High urgency, 30 km/h, 15 km):</u> Assume homogeneity of variances (Levene's test: $F(2,248) = .258$ at significance $p > .05$). No significant effect exists, $F(2,248) = 1.062$ at significance $p > .05$, $\eta = .092$ ($\eta^2 = .008$ / 0.8%).

<u>Trip 2 (Low urgency, 30 km/h, 15 km):</u> Assume homogeneity of variances (Levene's test: $F(2,248) = .858$ at significance $p > .05$). No significant effect exists, $F(2,248) = 1.043$ at significance $p > .05$, $\eta = .091$ ($\eta^2 = .008$ / 0.8%).

<u>Trip 3 (High urgency, 70 km/h, 15 km):</u> Assume homogeneity of variances (Levene's test: $F(2,249) = .197$ at significance $p > .05$). No significant effect exists, $F(2,249) = 1.686$ at significance $p > .05$, $\eta = .116$ ($\eta^2 = .013$ / 1.3%).

Trip 4 (Low urgency, 70 km/h, 15 km): Assume homogeneity of variances (Levene's test: $F_{(2,248)} = 1.238$ at significance $p > .05$). No significant effect exists, $F_{(2,248)} = .578$ at significance $p > .05$, $\eta = .068$ ($\eta^2 = .005$ / 0.5%).

Trip 5 (High urgency, 30 km/h, 40 km): Assume homogeneity of variances (Levene's test: $F_{(2,249)} = .259$ at significance $p > .05$). No significant effect exists, $F_{(2,249)} = 2.413$ at significance $p > .05$, $\eta = .138$ ($\eta^2 = .019$ / 1.9%).

Trip 6 (Low urgency, 30 km/h, 40 km): Assume homogeneity of variances (Levene's test: $F_{(2,247)} = .834$ at significance $p > .05$). No significant effect exists, $F_{(2,247)} = 1.579$ at significance $p > .05$, $\eta = .112$ ($\eta^2 = .013$ / 1.3%).

Trip 7 (High urgency, 70 km/h, 40 km): Assume homogeneity of variances (Levene's test: $F_{(2,249)} = .280$ at significance $p > .05$). No significant effect exists, $F_{(2,249)} = 1.294$ at significance $p > .05$, $\eta = .101$ ($\eta^2 = .010$ / 1.0%).

Trip 8 (Low urgency, 70 km/h, 40 km): Assume homogeneity of variances (Levene's test: $F_{(2,249)} = .783$ at significance $p > .05$). No significant effect exists, $F_{(2,249)} = .927$ at significance $p > .05$, $\eta = .086$ ($\eta^2 = .007$ / 0.7%).

Respondent gender

The number of male and female cases per trip condition is presented in Table 8.3.

Table 8.3: Cases by gender

Trip condition (Urg, Spd, Dist)	Male	Female	Total
Trip 1 (H, 30 km/h, 15 km)	132	119	251
Trip 2 (L, 30 km/h, 15 km)	132	119	251
Trip 3 (H, 70 km/h, 15 km)	133	119	252
Trip 4 (L, 70 km/h, 15 km)	132	119	251
Trip 5 (H, 30 km/h, 40 km)	133	119	252
Trip 6 (L, 30 km/h, 40 km)	132	118	250
Trip 7 (H, 70 km/h, 40 km)	133	119	252
Trip 8 (L, 70 km/h, 40 km)	133	119	252

The statistical significance and effect size of respondent gender on WTP was assessed for each trip condition. See Table 5.11 for a summary of results.

<u>Trip 1 (High urgency, 30 km/h, 15 km):</u> Assume homogeneity of variances (Levene's test: F (249) = .897 at significance p > .05). No significant effects exists, t(249) = .911 at significance p > .05, r = .058 (R^2 = .003 / 0.3%).

<u>Trip 2 (Low urgency, 30 km/h, 15 km):</u> Assume homogeneity of variances (Levene's test: F (249) = 3.543 at significance p > .05). No significant effects exists, t(249) = 1.865 at significance p > .05, r = .117 (R^2 = .014 / 1.4%).

<u>Trip 3 (High urgency, 70 km/h, 15 km):</u> Assume heterogeneity of variances (Levene's test: F (250) = 5.634 at significance p < .05). No significant effects exists, t(234.433) = 1.811 at significance p > .05, r = .117 (R^2 = .014 / 1.4%).

<u>Trip 4 (Low urgency, 70 km/h, 15 km):</u> Assume heterogeneity of variances (Levene's test: F (249) = 8.494 at significance p < .01). There was a significant effect of gender on WTP to escape

congestion (males were willing to pay significantly more to escape congestion than females), t(209.620) = 2.529 at significance $p < .05$, r = .172 (R^2 = .030 / 3.0%).

Trip 5 (High urgency, 30 km/h, 40 km): Assume homogeneity of variances (Levene's test: F (250) = .243 at significance $p > .05$). No significant effects exists, t(250) = .532 at significance p > .05, r = .034 (R^2 = .001 / 0.1%).

Trip 6 (Low urgency, 30 km/h, 40 km): Assume heterogeneity of variances (Levene's test: F (248) = 4.500 at significance $p < .05$). There was a significant effect of gender on WTP to escape congestion (males were willing to pay significantly more to escape congestion than females), t(234.725) = 2.283 at significance $p < .05$, r = .147 (R^2 = .022 / 2.2%).

Trip 7 (High urgency, 70 km/h, 40 km): Assume heterogeneity of variances (Levene's test: F (250) = 10.429 at significance p = .001). There was a significant effect of gender on WTP to escape congestion (males were willing to pay significantly more to escape congestion than females), t(236.396) = 2.428 at significance $p < .05$, r = .156 (R^2 = .024 / 2.4%).

Trip 8 (Low urgency, 70 km/h, 40 km): Assume heterogeneity of variances (Levene's test: F (250) = 11.099 at significance p = .001). There was a significant effect of gender on WTP to escape congestion (males were willing to pay significantly more to escape congestion than females), t(218.706) = 2.869 at significance $p < .01$, r = .190 (R^2 = .036 / 3.6%).

400-series travel frequency

The number of cases in both 400-series travel frequency categories per trip condition is presented in Table 8.4.

Table 8.4: Cases by 400-series travel frequency category

Trip condition (Urg, Spd, Dist)	Daily 400-series users	Less-than daily 400-series users	Total
Trip 1 (H, 30 km/h, 15 km)	106	145	251
Trip 2 (L, 30 km/h, 15 km)	106	145	251
Trip 3 (H, 70 km/h, 15 km)	107	145	252
Trip 4 (L, 70 km/h, 15 km)	107	144	251
Trip 5 (H, 30 km/h, 40 km)	107	145	252
Trip 6 (L, 30 km/h, 40 km)	106	144	250
Trip 7 (H, 70 km/h, 40 km)	107	145	252
Trip 8 (L, 70 km/h, 40 km)	107	145	252

The statistical significance and effect size of 400-series travel frequency on WTP was assessed for each trip condition. See Table 5.12 for a summary of results.

<u>Trip 1 (High urgency, 30 km/h, 15 km):</u> Assume homogeneity of variances (Levene's test: F (249) = 1.217 at significance $p > .05$). No significant effects exists, t(249) = 1.859 at significance $p > .05$, r = .117 (R^2 = .014 / 1.4%).

<u>Trip 2 (Low urgency, 30 km/h, 15 km):</u> Assume homogeneity of variances (Levene's test: F (249) = .021 at significance $p > .05$). No significant effects exists, t(249) = .610 at significance $p > .05$, r = .039 (R^2 = .001 / 0.1%).

<u>Trip 3 (High urgency, 70 km/h, 15 km):</u> Assume homogeneity of variances (Levene's test: F (250) = .261 at significance $p > .05$). No significant effects exists, t(250) = .362 at significance $p > .05$, r = .023 (R^2 = .001 / 0.1%).

Trip 4 (Low urgency, 70 km/h, 15 km): Assume homogeneity of variances (Levene's test: F (249) = 1.882 at significance $p > .05$). No significant effects exists, t(249) = .786 at significance $p > .05$, r = .050 (R^2 = .002 / 0.2%).

Trip 5 (High urgency, 30 km/h, 40 km): Assume homogeneity of variances (Levene's test: F (250) = .2.617 at significance $p > .05$). There was a significant effect of 400-series travel frequency on WTP to escape congestion (less-than-daily 400-series users were willing to pay significantly more to escape congestion than daily 400-series users), t(250) = 2.460 at significance $p < .05$, r = .154 (R^2 = .024 / 2.4%).

Trip 6 (Low urgency, 30 km/h, 40 km): Assume homogeneity of variances (Levene's test: F (248) = .597 at significance $p > .05$). No significant effects exists, t(248) = 1.107 at significance $p > .05$, r = .070 (R^2 = .005 / 0.5%).

Trip 7 (High urgency, 70 km/h, 40 km): Assume heterogeneity of variances (Levene's test: F (250) = 4.048 at significance $p < .05$). No significant effects exists, t(245.008) = 1.706 at significance $p > .05$, r = .108 (R^2 = .012 / 1.2%).

Trip 8 (Low urgency, 70 km/h, 40 km): Assume homogeneity of variances (Levene's test: F (250) = .067 at significance $p > .05$). No significant effects exists, t(250) = .401 at significance $p > .05$, r = .025 (R^2 = .001 / 0.1%).

Exposure to Hwy 407-ETR

The number of cases with and without previous Hwy 407 exposure per trip condition is presented in Table 8.5.

Table 8.5: Cases with and without previous Hwy 407 exposure

Trip condition (Urg, Spd, Dist)	Previous Hwy 407 exposure	No previous Hwy 407 exposure	Total
Trip 1 (H, 30 km/h, 15 km)	152	98	250
Trip 2 (L, 30 km/h, 15 km)	152	98	250
Trip 3 (H, 70 km/h, 15 km)	153	98	251
Trip 4 (L, 70 km/h, 15 km)	152	98	250
Trip 5 (H, 30 km/h, 40 km)	153	98	251
Trip 6 (L, 30 km/h, 40 km)	152	97	249
Trip 7 (H, 70 km/h, 40 km)	153	98	251
Trip 8 (L, 70 km/h, 40 km)	153	98	251

The statistical significance and effect size of previous exposure to Hwy 407-ETR on WTP was assessed for each trip condition. See Table 5.13 for a summary of results.

<u>Trip 1 (High urgency, 30 km/h, 15 km):</u> Assume heterogeneity of variances (Levene's test: F (248) = 3.977 at significance $p < .05$). There was a significant effect of Hwy 407 exposure on WTP to escape congestion (respondents who have been exposed to Hwy 407-ETR were willing to pay significantly more to escape congestion than respondents who have never been exposed to the highway), t(228.230) = 3.414 at significance $p = .001$, r = .220 (R^2 = .049 / 4.9%).

<u>Trip 2 (Low urgency, 30 km/h, 15 km):</u> Assume heterogeneity of variances (Levene's test: F (248) = 16.426 at significance $p < .001$). There was a significant effect of Hwy 407 exposure on WTP to escape congestion (respondents who have been exposed to Hwy 407-ETR were willing to pay significantly more to escape congestion than respondents who have never been exposed to the highway), t(228.773) = 4.985 at significance $p < .001$, r = .313 (R^2 = .098 / 9.8%).

Trip 3 (High urgency, 70 km/h, 15 km): Assume heterogeneity of variances (Levene's test: F (249) = 7.836 at significance $p < .01$). There was a significant effect of Hwy 407 exposure on WTP to escape congestion (respondents who have been exposed to Hwy 407-ETR were willing to pay significantly more to escape congestion than respondents who have never been exposed to the highway), t(244.018) = 4.275 at significance $p < .001$, r = .264 (R^2 = .070 / 7.0%).

Trip 4 (Low urgency, 70 km/h, 15 km): Assume heterogeneity of variances (Levene's test: F (248) = 20.427 at significance $p < .001$). There was a significant effect of Hwy 407 exposure on WTP to escape congestion (respondents who have been exposed to Hwy 407-ETR were willing to pay significantly more to escape congestion than respondents who have never been exposed to the highway), t(196.151) = 3.851 at significance $p < .001$, r = .265 (R^2 = .070 / 7.0%).

Trip 5 (High urgency, 30 km/h, 40 km): Assume homogeneity of variances (Levene's test: F (249) = 1.688 at significance $p > .05$). There was a significant effect of Hwy 407 exposure on WTP to escape congestion (respondents who have been exposed to Hwy 407-ETR were willing to pay significantly more to escape congestion than respondents who have never been exposed to the highway), t(249) = 3.336 at significance $p = .001$, r = .207 (R^2 = .043 / 4.3%).

Trip 6 (Low urgency, 30 km/h, 40 km): Assume heterogeneity of variances (Levene's test: F (247) = 7.527 at significance $p < .01$). There was a significant effect of Hwy 407 exposure on WTP to escape congestion (respondents who have been exposed to Hwy 407-ETR were willing to pay significantly more to escape congestion than respondents who have never been exposed to the highway), t(241.391) = 4.213 at significance $p < .001$, r = .262 (R^2 = .069 / 6.9%).

Trip 7 (High urgency, 70 km/h, 40 km): Assume heterogeneity of variances (Levene's test: F (249) = 7.337 at significance $p < .01$). There was a significant effect of Hwy 407 exposure on WTP to escape congestion (respondents who have been exposed to Hwy 407-ETR were willing to pay significantly more to escape congestion than respondents who have never been exposed to the highway), t(239.724) = 4.468 at significance $p < .001$, r = .277 (R^2 = .077 / 7.7%).

Trip 8 (Low urgency, 70 km/h, 40 km): Assume heterogeneity of variances (Levene's test: F (249) = 17.970 at significance $p < .001$). There was a significant effect of Hwy 407 exposure on WTP to escape congestion (respondents who have been exposed to Hwy 407-ETR were willing to pay significantly more to escape congestion than respondents who have never been exposed to the highway), $t(247.674) = 4.198$ at significance $p < .001$, $r = .258$ ($R^2 = .066$ / 6.6%).

Research Question 4: Full statistical results

A full write-up of all Research Question 4 statistical results is presented here. Results are categorized by driver factor.

Effect of income

Results of One-way ANOVA: Assume heterogeneity of variances (Levene's test: $F(2,231) = 4.015$ at significance $p < .05$). There was a significant effect of income on willingness to take transit, $F(2, 136.707) = 6.016$ (Welch-correction), at significance $p < .01$, $\eta = .224$ ($\eta^2 = .050$ / 5.0%).

Planned contrasts comparing the mean of the low income group with the mean of the high and middle income groups (MEAN-low income vs. MEAN-middle income+high income) revealed a significant effect of income on willingness to take transit (respondents with low incomes were more willing to take transit than respondents with middle or high incomes), $t(106.369) = 2.496$, at significance $p < .05$, $r = .235$ ($R^2 = .055$ / 5.5%). Moreover, planned contrasts comparing the mean of the middle income group with the mean of the high income group also revealed a significant effect of income on willingness to take transit (respondents with middle incomes were more willing to take transit than respondents with high incomes), $t(146.311) = 2.692$, $p < .01$, $r = .217$ ($R^2 = .047$ / 4.7%).

Effect of age

Results of One-way ANOVA: Assume heterogeneity of variances (Levene's test: $F (2,246) = 35.192$ at significance $p < .001$). There was a significant effect of age on willingness to take transit, $F (2, 149.678) = 9.282$ (Welch-correction), at significance $p < .001$, $\eta = .248$ ($\eta^2 = .061$ / 6.1%).

Planned contrasts comparing the mean of the young group (18 – 34 years of age) with the mean of the middle-aged (35 – 54) and older group (55+) (MEAN-young group vs. MEAN-middle-aged+older groups) revealed a significant effect of age on willingness to take transit (younger respondents were more willing to take transit than middle-aged and older respondents), $t(148.641) = 4.318$, at significance $p < .001$, $r = .334$ ($R^2 = .111$ / 11.1%). Planned contrasts comparing the mean of the middle-aged group with the mean of the older group did not reveal a significant effect of age on willingness to take transit (the means of middle-aged and older respondents were not significantly different), $t(141.579) = .671$, at significance $p > .05$, $r = .056$ ($R^2 = .003$ / 0.3%).

Research Question 5: Full statistical results

A full write-up of all Research Question 5 statistical results is presented here. Results are categorized by driver factor.

Effect of income

Results of One-way ANOVA: Assume heterogeneity of variances (Levene's test: $F (2,231) = 8.212$ at significance $p < .001$). There was a significant effect of income on willingness to carpool, $F (2,137.470) = 5.120$ (Welch-correction) at significance $p < .01$, $\eta = .201$ ($\eta^2 = .040$ / 4.0%).

Planned contrasts comparing the mean of the low income group with the mean of the high and middle income groups (MEAN-low income vs. MEAN-middle income+high income) revealed a significant effect of income on willingness to carpool (respondents with low incomes were more willing to carpool than respondents with middle or high incomes), t(106.183) = 3.148, at significance $p < .01$, r = .292 (R^2 = .085 / 8.5%). Planned contrasts comparing the mean of the middle income group with the mean of the high income group did not reveal a significant effect of income on willingness to carpool (the means of middle and high income groups were not significantly different), t(149.249) = .928, at significance $p > .05$, r = .076 (R^2 = .006 / 0.6%).

Effect of age

<u>Results of One-way ANOVA:</u> Assume heterogeneity of variances (Levene's test: F (2,246) = 7.353 at significance p = .001). There was a significant effect of age on willingness to carpool, F (2, 149.395) = 5.717 (Welch-correction), at significance $p < .01$, η = .207 (η^2 = .043 / 4.3%).

Planned contrasts comparing the mean of the young group (18 – 34 years of age) with the mean of the middle-aged (35 – 54) and older group (55+) (MEAN-young group vs. MEAN-middle-aged+older groups) revealed a significant effect of age on willingness to carpool (younger respondents were more willing to carpool than middle-aged and older respondents), t(133.249) = 3.336, at significance p = .001, r = .278 (R^2 = .077 / 7.7%). Planned contrasts comparing the mean of the middle-aged group with the mean of the older group did not reveal a significant effect of age on willingness to carpool (the means of middle-aged and older respondents were not significantly different), t(146.174) = .995, at significance $p > .05$, r = .082 (R^2 = .007 / 0.7%).

Effect of 400-series travel frequency

<u>Results of Independent t-test:</u> Assume homogeneity of variances (Levene's test: F (247) = .053 at significance $p > .05$). No significant effect exists, t(247) = .125 at significance $p > .05$, r = .008 (R^2 = .000 / 0.0%).

Research Question 6: Full statistical results

A full write-up of all Research Question 6 statistical results is presented here. Results are categorized by driver factor.

Effect of income

<u>*Results of One-way ANOVA:*</u> Assume heterogeneity of variances (Levene's test: $F(2,229) = 32.502$ at significance $p < .001$). There was a significant effect of income on HOT-lane desirability, $F(2, 136.285) = 6.554$ (Welch-correction) at significance $p < .01$, $\eta = .216$ ($\eta^2 = .046$ / 4.6%).

Planned contrasts comparing the mean of the low income group with the mean of the high and middle income groups (MEAN-low income vs. MEAN-middle income+high income) did not reveal a significant effect of income on HOT-lane desirability (the mean of the low income group and the combined mean of the middle and high income groups were not significantly different), $t(92.811) = 1.442$, at significance $p > .05$, $r = .148$ ($R^2 = .022$ / 2.2%). Planned contrasts comparing the mean of the middle income group with the mean of the high income group revealed a significant effect of income on HOT-lane desirability (respondents with high incomes were more likely to desire HOT-lanes along the 400-series network than respondents with middle incomes), $t(163.904) = 3.330$, at significance $p = .001$, $r = .252$ ($R^2 = .063$ / 6.3%). Findings validated hypotheses.

Effect of age

<u>*Results of One-way ANOVA:*</u> Assume heterogeneity of variances (Levene's test: $F(2, 242) = 6.429$ at significance $p < .01$). There was a significant effect of age on HOT-lane desirability, $F(2, 145.940) = 4.004$ (Welch-correction), at significance $p < .05$, $\eta = .184$ ($\eta^2 = .034$ / 3.4%).

Planned contrasts comparing the mean of young respondents (18 – 34 years of age) with the mean of middle-aged (35 – 54) and older respondents (55+) (MEAN-young respondents vs.

MEAN-middle-aged+older respondents) did not reveal a significant effect of age on HOT-lane desirability (the mean of young respondents and the combined mean of middle-aged and older respondents were not significantly different), t(133.171) = 1.905, at significance $p > .05$, $r = .163$ ($R^2 = .027$ / 2.7%). Planned contrasts comparing the mean of middle-aged respondents with the mean of older respondents revealed a significant effect of age on HOT-lane desirability (middle-aged respondents were more likely to desire HOT-lanes along the 400-series network than older respondents), t(138.231) = 2.375, at significance $p < .05$, $r = .198$ ($R^2 = .039$ / 3.9%). Findings validated hypotheses.

Effect of 400-series travel frequency

Results of Independent t-test: Assume homogeneity of variances (Levene's test: F (243) = .277 at significance $p > .05$). No significant effect exists, t(243) = .266 at significance $p > .05$, $r = .017$ ($R^2 = .000$ / 0.0%).

Effect of Hwy 407 exposure

Results of independent t-test: Assume heterogeneity of variances (Levene's test: F (242) = 22.238 at significance $p < .001$). There was a significant effect of Hwy 407 exposure on HOT-lane desirability (respondents with previous Hwy 407 exposure were more likely to desire HOT-lanes along the 400-series network than respondents without previous Hwy 407 exposure), t (181.515) = 3.629, at significance $p < .001$, $r = .260$ ($R^2 = .068$ / 6.8%).

Revealed traffic volume analysis: Full results tables

Revealed traffic volume results tables are presented here. Results are categorized by direction and day of travel.

Eastbound traffic

Tables 12.6 and 12.7 display trip urgency (low, moderate, high), Highway 401 volume (low, moderate, high), expected Hwy 407 throughput share, and calculated averaged Hwy 407 throughput share at each hour of the day for eastbound traffic at the screenline. Table 8.6 displays average weekday values and Table 8.7 displays average Saturday/Sunday/holiday values. Expected Hwy 407 throughput share values were based on urgency and Hwy 401 volume levels (see Section 5.8).

Weekday:

Table 8.6: *Eastbound weekday* Hwy 407 throughput share E of Dufferin St./Allen Rd.

Hour Ending	Trip urgency	Hwy 401 congestion	Hypothesis	Hwy 407 throughput share
1:00 AM	Low	Low	Low	8.97%
2:00 AM	Low	Low	Low	8.57%
3:00 AM	Low	Low	Low	7.23%
4:00 AM	Low	Low	Low	7.82%
5:00 AM	Low	Low	Low	9.01%
6:00 AM	High	Low	Moderate-low	11.35%
7:00 AM	High	Moderate	Moderate-high	17.00%
8:00 AM	High	High	High	27.22%
9:00 AM	High	High	High	32.44%
10:00 AM	Moderate	High	Moderate-high	26.27%
11:00 AM	Moderate	Moderate	Moderate	22.79%
12:00 PM	Moderate	Moderate	Moderate	23.11%
1:00 PM	Moderate	High	Moderate-high	23.06%
2:00 PM	Moderate	High	Moderate-high	23.39%
3:00 PM	Moderate	High	Moderate-high	25.52%
4:00 PM	High	High	High	31.62%
5:00 PM	High	High	High	42.14%
6:00 PM	High	High	High	45.62%
7:00 PM	High	High	High	31.39%
8:00 PM	Low	Moderate	Moderate-low	20.40%
9:00 PM	Low	Moderate	Moderate-low	16.44%
10:00 PM	Low	Moderate	Moderate-low	14.65%
11:00 PM	Low	Low	Low	12.32%
12:00 AM	Low	Low	Low	10.37%

Saturday/Sunday/holiday:

Table 8.7: *Eastbound Sat/Sun/hol* Hwy 407 throughput share E of Dufferin St./Allen Rd.

Hour Ending	Trip urgency	Hwy 401 congestion	Hypothesis	407 share of total throughput
1:00 AM	Low	Low	Low	11.42%
2:00 AM	Low	Low	Low	10.33%
3:00 AM	Low	Low	Low	10.03%
4:00 AM	Low	Low	Low	8.62%
5:00 AM	Low	Low	Low	8.07%
6:00 AM	Low	Low	Low	8.06%
7:00 AM	Low	Low	Low	9.76%
8:00 AM	Low	Low	Low	11.79%
9:00 AM	Low	Low	Low	13.58%
10:00 AM	Low	Moderate	Moderate-low	14.08%
11:00 AM	Low	Moderate	Moderate-low	14.90%
12:00 PM	Low	Moderate	Moderate-low	15.74%
1:00 PM	Low	High	Moderate	16.26%
2:00 PM	Low	High	Moderate	16.23%
3:00 PM	Low	High	Moderate	16.47%
4:00 PM	Low	High	Moderate	17.08%
5:00 PM	Low	High	Moderate	17.09%
6:00 PM	Low	High	Moderate	16.19%
7:00 PM	Low	High	Moderate	14.43%
8:00 PM	Low	Moderate	Moderate-low	13.55%
9:00 PM	Low	Moderate	Moderate-low	13.74%
10:00 PM	Low	Moderate	Moderate-low	13.02%
11:00 PM	Low	Moderate	Moderate-low	11.26%
12:00 AM	Low	Low	Low	11.36%

Westbound traffic

Tables 12.8 and 12.9 display trip urgency (low, moderate, high), Highway 401 volume (low, moderate, high), expected Hwy 407 throughput share (hypothesis), and calculated average Hwy 407 throughput share at each hour of the day for westbound traffic at the screenline. Table 8.8 displays average weekday values and Table 8.9 displays average Saturday/Sunday/holiday values.

Weekday:

Table 8.8: *Westbound weekday* Hwy 407 throughput share E of Dufferin St/Allen Rd

Hour Ending	Trip urgency	Hwy 401 congestion	Hypothesis	407 share of total throughput
1:00 AM	Low	Low	Low	6.59%
2:00 AM	Low	Low	Low	5.24%
3:00 AM	Low	Low	Low	4.49%
4:00 AM	Low	Low	Low	6.52%
5:00 AM	Low	Low	Low	9.50%
6:00 AM	High	Low	Moderate-low	12.76%
7:00 AM	High	High	High	20.34%
8:00 AM	High	High	High	32.69%
9:00 AM	High	High	High	35.50%
10:00 AM	Moderate	High	Moderate-high	27.52%
11:00 AM	Moderate	Moderate	Moderate	23.16%
12:00 PM	Moderate	Moderate	Moderate	22.33%
1:00 PM	Moderate	High	Moderate-high	21.63%
2:00 PM	Moderate	High	Moderate-high	21.73%
3:00 PM	Moderate	High	Moderate-high	22.19%
4:00 PM	High	High	High	24.81%
5:00 PM	High	High	High	28.82%
6:00 PM	High	High	High	30.00%
7:00 PM	High	Moderate	Moderate-high	22.69%
8:00 PM	Low	Moderate	Moderate-low	15.71%
9:00 PM	Low	Moderate	Moderate-low	12.89%
10:00 PM	Low	Low	Low	11.19%
11:00 PM	Low	Low	Low	9.92%
12:00 AM	Low	Low	Low	8.32%

Saturday/Sunday/holiday:

Table 8.9: Westbound Sat/Sun/hol Hwy 407 throughput share E of Dufferin St/Allen Rd

Hour Ending	Trip urgency	Hwy 401 congestion	Hypothesis	407 share of total throughput
1:00 AM	Low	Low	Low	9.07%
2:00 AM	Low	Low	Low	8.00%
3:00 AM	Low	Low	Low	7.62%
4:00 AM	Low	Low	Low	7.51%
5:00 AM	Low	Low	Low	8.25%
6:00 AM	Low	Low	Low	9.76%
7:00 AM	Low	Low	Low	12.77%
8:00 AM	Low	Low	Low	15.03%
9:00 AM	Low	Low	Low	15.67%
10:00 AM	Low	Moderate	Moderate-low	15.70%
11:00 AM	Low	Moderate	Moderate-low	15.70%
12:00 PM	Low	Moderate	Moderate-low	15.74%
1:00 PM	Low	High	Moderate	15.92%
2:00 PM	Low	High	Moderate	15.27%
3:00 PM	Low	High	Moderate	14.90%
4:00 PM	Low	High	Moderate	14.76%
5:00 PM	Low	High	Moderate	14.84%
6:00 PM	Low	Moderate	Moderate-low	14.02%
7:00 PM	Low	Moderate	Moderate-low	13.39%
8:00 PM	Low	Moderate	Moderate-low	12.48%
9:00 PM	Low	Moderate	Moderate-low	11.72%
10:00 PM	Low	Moderate	Moderate-low	10.48%
11:00 PM	Low	Low	Low	9.44%
12:00 AM	Low	Low	Low	8.48%