Quantitative TDM Assessment in a Large Metropolitan Area

GREATER TORONTO AND HAMILTON AREA

DRAFT

prepared by:

WPTI
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Leslie Woo
Chief Planning Officer, Planning and Policy
Metrolinx
97 Front Street West,
Toronto ON M5J 1E6

28 October, 2015

Dear Ms. Leslie Woo:

I wish to express my sincere gratitude for the opportunity to conduct research for Metrolinx related to Transportation Demand Management in the Greater Toronto and Hamilton Area. The enclosed report summarizes the research conducted. We have first defined Transportation Demand Management and explored the academic and professional literature around TDM. Next, we developed and implemented a method of analysis to determine for several corridors which TDM measure, if any, has the potential to improve transportation system performance in the GTHA.

Our results show that significant intervention will be necessary to achieve meaningful change. Specifically, there are several corridors we have analyzed where combinations of economic signals – typically road pricing – and improvements in alternative modes – typically transit – will be necessary to successfully influence transportation demand in the region.

We certainly welcome your feedback, comments and questions about methods, findings and conclusions. We would also value the opportunity to present our work to you and your colleagues if you wish for us to do so.

As I believe I have communicated to you earlier, a distilled version of this report was submitted to the Transportation Research Board conference to be held in January of 2015. That paper was accepted. I will be presenting our work in Washington DC early next year.

On behalf of my students, Kitty Chiu and Kevin Yeung who were instrumental in preparing this report and the work that informs it, I wish to thank you again for this opportunity.

Kind regards,

Jeffrey M. Casello

Jeffrey Casello
Associate Professor – Transportation Planning and Engineering
University of Waterloo

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Executive Summary

Urban areas around the world are attempting to improve transportation system performance – reducing delay, increasing mobility, enhancing safety, and maximizing accessibility. The methods by which system performance can be improved include: the construction of new, capacity-increasing infrastructure; the introduction of operational changes incrementally increase capacity; and the management of demand such that situations modal capacities are exceed occur less frequently.

The purpose of this report is to explore the potential for Transportation Demand Management to improve the transportation system performance in the Greater Toronto and Hamilton Area (GTHA). The approach taken is to assess the possibility of shifting demand in time, in space and between modes. In each case, the analysis identifies periods where demand exceeds capacity and assesses the feasibility of shifting some of this demand to a time period, an alternative path, or an alternative mode when or where unused capacity exists. Methodologically, the analysis presented here can be repeated in any corridor of interest using readily available data, to identify which intervention, if any, can produce meaningful changes in system performance.

We first analyze potential shifts in time along sections of four main corridors in the GTHA: Highway 401; Queen Elizabeth Way (QEW); the Gardiner Expressway (GEX); and the Don Valley Parkway (DVP). The results of our analysis show that some potential exists to shift demand in time on the DVP northbound in the am peak period. More limited potential exists to improve the flows on either the 401 or QEW, due to extended periods of congestion.

Next we analyze the possibility of shifting demand in space. For this analysis, we consider a number of origin-destination (OD) pairs, and evaluate the relative travel costs (using a combination of time and out of pocket expenses) for several, alternative paths between them. The report presents an analysis of travel between several "Mobility Hubs" defined by Metrolinx, including: Union Station and the intersection of Leslie Avenue and Highway 407; Mississauga City Centre and Markham Centre; and Downtown Oshawa and Pearson Airport in Mississauga. The full analysis contained additional OD pairs, but these are presented in the report as representative corridors that demonstrate the application of the analysis method.

The results suggest that shifts in space are not a particularly viable TDM measure for travel in these corridors. In most cases, the current, highest-demand paths remain the lowest cost alternative, despite experiencing congestion. In other words, no traveler in these corridors has a motivation to choose an alternative, less congested corridor, because switching paths would *increase* that traveler's cost. There are some exceptions. In the afternoon peak, some travelers could improve their northbound travel time between Union and Leslie if they were to use Bayview Avenue in lieu of the Highway 404 / DVP.

Interestingly, there are several OD pairs in our analysis for which Highway 407 presents significantly shorter travel times but, because of the toll charges, this path remains uncompetitive for travelers. As a result, congestion remains very high on the un-tolled freeways, while excess capacity exists on the 407. One such example is travel between Mississauga and Markham. Our recommendation in this case is to *introduce a toll charge* *on the currently "free" highway option – Highway 401.* The implementation of this toll would encourage some travelers to shift to Highway 407, thereby reducing congestion and improving travel time for those who remain on the 401, without producing a similar increase in congestion on the 407. *In other words, introducing this toll would decrease the total system delay and improve conditions – shorter travel times and greater reliability – for all travelers in this corridor.* The toll would also generate significant revenue for the appropriate agencies in the GTHA. Several other corridors in our analysis would also benefit from the introduction of a similar toll.

We then analyze the potential to shift travelers between modes. Using the same origin destination pairs identified above, we compare the travel costs of completing trips by the shortest auto path and the best transit path. For travel to Union Station (southbound from Leslie), transit is very competitive. High frequency, direct transit service, coupled with auto parking charges in the Union Station area, make transit a less expensive alternative to driving. In this case, there is strong potential to shift demand from auto travel to transit simply through improved information provision to travelers. Similarly competitive transit service exists in this corridor traveling northbound in the pm peak. The presence of competitive transit southbound in the am peak and northbound in the pm peak makes transit a viable option for commuters in this corridor. Few other bi-directional opportunities exist with current transit service.

To understand which system modifications must be made to successfully implement TDM measures, we conducted sensitivity analysis. The question we asked was: by how much would auto charges need to be increased or alternative costs decreased in order to make TDM and system improvements feasible. The answers vary considerably, from only modest changes in some corridors to other situations where the disparity is so large that no reasonable intervention is possible.

The GTHA presents a somewhat challenging environment to change system performance due to the complexity of jurisdictions. Transport in the region is influenced by the City of Toronto, the Toronto Transit Commission, numerous municipal transit providers, the Province of Ontario, the private ownership of Highway 407, and the various divisions of Metrolinx (including GO). Given this complexity, we include some comments on jurisdictional interactions that we believe are necessary to achieve change.

The conclusions of the report are that if Metrolinx and other agencies in the GTHA wish to improve transportation system performance through TDM, specifically shifts in time, space or mode, then several interventions are necessary. First, auto pricing may be necessary along those corridors that are currently suffering recurring congestion. Second, significant investment in alternatives specifically transit in some corridors will be necessary to provide competitive service such that travelers will be motivated to change their behaviour.

Introduction

Metrolinx has been charged with the planning, design and in some cases operation of the transportation systems serving the Greater Toronto and Hamilton Area (GTHA). Currently, the transportation network in the region suffers extreme, recurring congestion that has negative implications on the region's economy, its environment, and its residents' quality of life (OECD, 2009)

One commonly identified method to improve transportation system performance is through transportation demand management (TDM). This concept involves providing information or economic incentives (and potentially disincentives) to shift trips in time, space, and mode from facilities (or time periods) where demand exceeds capacities to facilities (or times) where existing capacity is underutilized (Cervero and Hall, 1989). The results of successful TDM strategies include decreased delays and higher utilization of previously underperforming facilities.

The goal of this report is to assess the potential for TDM initiatives in the Greater Toronto and Hamilton Area. More specifically, this report evaluates the possibility to achieve improved transportation system performance – reduced congestion, lower delays, more reliable and predictable travel times, fewer environmental impacts, etc. – through TDM. The approach taken is to identify common corridors, origins and destinations (ODs) in the GTHA – locations defined by Metrolinx as mobility hubs – and to assess the possibilities of shifting demand in time, space and mode.

To identify opportunities to shift demand in time, we ask the following question: do periods of time exist when the roadway segment(s) operate well (i.e. without congestion) immediately before or after heavily congested time periods? If so, can some of the demand from the congested period be shifted to the uncongested period? To assess this quantitatively, we graph the volume to capacity (v/c) ratios as a function of time for major roadway segments.

Similarly, to identify possible shifts in space, we ask the following question: for roadway segments that are operating poorly, are there parallel roadway segments on which unused capacity exists? If so, can some of the demand from the congested roadway be shifted to the uncongested facility? Quantitatively, we assess the changes in generalized cost – a linear combination of out of pocket expenses and travel times – that a traveler would experience if she were to change from the primary route to an alternative.

Finally, to identify possible shifts in mode, we select travel paths that are performing poorly for which competitive, parallel transit services exist. Quantitatively, we compare the generalized costs of completing a trip on the congested roadway and by the parallel transit service. Corridors where transit competes well are identified as possibilities to shift demand in mode.

Using these three techniques, we identify several corridors in the GTHA for which TDM initiatives have the potential to improve system performance.

The remainder of the report is organized as follows. We first define TDM more fully. We then review the literature and present a summary of current scholarly and professional literature related to TDM and best practices. Next, we describe more completely the methods used in the assessment of possible TDM corridors. Following the explanation of methods, we apply the techniques and report the results for the GTHA. For completeness, we estimate the sensitivity of our findings to various inputs. Finally, we recognize that transportation infrastructure and operations in the GTHA are governed by a number of agencies. As such, we conclude with an assessment of jurisdictional challenges that may be encountered if TDM initiatives are to be implemented.

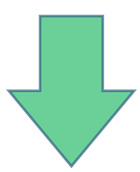
What is TDM?

Transportation Demand Management is a cohesive set of designs and policies to influence individuals to travel (if necessary) by modes and paths, and at times of day such that the demand does not exceed the capacity of transportation infrastructure. To this end, TDM initiatives may:

- Make travelers aware of (or provide economic incentives to choose) different departure times during which excess capacity exists, allowing travelers **to change departure times** to avoid (creating) congestion;
- Make travelers aware of (or provide economic incentives to choose) paths on which excess capacity exists, allowing travelers **to reroute** and avoid (creating) congestion;
- Make travelers aware of (or provide economic incentives to choose) alternative modes on which excess capacity exists, allowing travelers **to change modes** and avoid (creating) congestion;
- Provide opportunities (or economic incentives) for auto travelers to increase **their vehicle occupancy rates**, thereby completing equivalent person-travel with less vehicle-travel;
- **Provide alternatives to travel**, through improved communications technology and other means, that ultimately **reduce the total demand for travel**;
- Design facilities that **incentivize** (or provide disincentives) **appropriate** (incompatible) **transportation activities**.

TDM initiatives, then, can be classified as those that intend to:

- Shift demand in time;
- Shift demand in space to alternative routes;
- Shift demand in space to alternative modes;
- Change behavior through education or economic incentives.



Suppress Demand

Where the demand for trips, particularly discretionary trips can be minimized

Shift in Time

Where capacity exists within the same route, during a different time

Shift in Space

Where capacity exists within the same system, on other routes

Shift in Mode

Where capacity exists within a different, but comparable service

These initiatives can also be classified based on the spatial scales of implementation. TDM measures may be at the:

- neighborhood level, designed to influence local behaviors. Some examples include traffic calming, traffic engineering, network connectivity breaks, etc.
- city level, designed to influence urban transportation behavior and patterns. Examples include employer initiatives, cordon pricing, parking charges, transit incentives, active transportation infrastructure, etc.
- regional level, designed to influence both transportation behavior and land use markets. Examples include toll highways, regional or intercity transportation services, taxation, etc.
- provincial or national level. Examples include restricted auto ownership or operations, broader tax (dis)incentives, etc.

Naturally, the **effectiveness of TDM measures** depends upon several factors. The "strength" of the metropolitan area in terms of attracting and retaining residents and jobs is very important to consider. In some areas, **where firms or residents have great mobility, implementing TDM at the urban level may produce an unintended out-migration of activity**. Where urban centers remain the dominant location, it is easier to implement TDM without producing negative impacts. Further, the presence of viable alternatives (paths, modes, times, or no travel) is critical to assess prior to implementing TDM strategies. **In areas with multiple alternatives, managing demand is more easily accomplished**. In (urban) areas with few alternatives, implementing TDM measures, especially disincentives, can be seen as penal and reducing equity.

For the purposes of this report, we narrow the scope of analysis in several ways. We limit the set of TDM initiatives to shifting in time, space or mode. We do not consider the possibility of changing auto occupancy or reducing overall demand through technological (communication) interventions. We conduct our analysis on the Regional scale – for mid- to long-range travel in the GTHA which typically would include the use of 400 series highways, or high-speed, high-volume urban arterials.

We also enter into the analysis with the assumption that the GTHA has sufficiently strong appeal – in terms of residential, commercial and institutional location choice – that the implementation of TDM initiatives will not negatively impact the region's economic competitiveness. Finally, we do not specifically address equity issues in our analysis. We do not attempt to quantify the social impacts of the changes in behavior (or the economic signals that motivate them) that are necessary to achieve improved system performance.

Literature Review

The concept of Transportation Demand Management arose as a result of worsening congestion and a recognition that increases in capacity were becoming more difficult. The most often-cited definition of TDM is from Meyer (1997): “any action or set of actions aimed at influencing people's travel behavior in such a way that alternative mobility options are presented and/or congestion is reduced”. As noted above, the TDM initiatives in this report concentrate on shifts in time, space and mode. The following sections summarize literature – both scholarly and professional – related to TDM initiatives in these three categories.

Shift in Time

To shift travel in time, one of the most common approaches is to manage commuters’ travel by staggering work hours. Jovanis (1983) was amongst the first to discuss the concept. Cervero and Hall (1989) mention an application of flexible work hours at a growing employment center east of San Francisco. Picado (2000) assessed the uptake of flexible work hours amongst employees at the University of California Berkeley; while utilization was low – less than 25% – reasonable travel time savings were observed for those who did commute in off-peak periods.

A unique case of flexible work hours is the so-called compressed work week (CWW), where employees work their total hour requirements in fewer work days. Sundo and Fujii (2005) in a study of CWW in the Philippines determined that commuters saved travel time but also incurred changes in scheduling their household activities. The provision of a CWW is usually under the jurisdiction of the employer. Many employers do allow for flexible work hours or compressed work weeks. Government agencies can also show leadership by enabling these work arrangements for their own employees, as is the case in the City of Hamilton (2009) and the Public Works and Government Services Canada (2015).

Economic signals may also shift travel demand in time. One such example is from Lee County, Florida. Variable road pricing was implemented on several bridges; the results demonstrate that significant demand was shifted from peak periods (where the price was highest) to the shoulders of the peak (Cain et al, 1999). Similar before and after studies were done for (amongst others) Singapore (Olszewski and Xie, 2005), the New Jersey Turnpike (Ozbay et al., 2006) and the New York City metropolitan area (Holguin-Veras et al., 2011).

Shift in Space

Shifting demand in space – to parallel routes where excess capacity exists – is most commonly referred to as dynamic route guidance. Boyce (1988) and Ben-Akiva et al. (1991) have assessed the feasibility and impacts of these systems. The driver’s response to such dynamic route guidance has been tested by Adler (2001). In this study, Adler found that there are significant short-term advantages to providing information to unfamiliar drivers; however, the effect diminishes as drivers become more familiar with the route.

One form of dynamic route guidance is already in place along Highway 401 through the centre of the Greater Toronto Area. Changeable message signs are placed along the highway prior to interchanges where drivers may select the express or collector lanes along the highway. A study of three years of traffic data on Highway 401 revealed that these signs may increase the diversion rate between the express and collector lanes by up to 5% of traffic, or the equivalent of 300 vehicles per hour (Foo and Abdulhai, 2006). The authors noted that the effects diminished over the years, which supports the findings from Adler (2001). The limited impact of the changeable message signs over time may be a result of a lack of trust for the information provided by the signs by the drivers who have become familiar with the route.

With the prevalence of smartphones, crowdsourced data are emerging as a potential tool to improve dynamic route guidance. Smartphone applications such as Waze, Inrix, or Google Maps are able to provide real-time information based on the travel times and speeds of users in the roadway network. Users may also provide information regarding incidents or construction to the application, which will be disseminated to other users of the application. Increased use of these applications will improve the data that are available to all users, and may increase the effectiveness of dynamic route guidance.

Shift in Mode

Shifting travelers between modes typically involves introducing economic signals. Research suggests that automobile travel may be reduced when there are systematic incentives for transit travel combined with disincentives for automobile travel (Wachs, 1990; Meyer, 1999; Vuchic, 1999). Examples of such driving disincentives include high occupancy toll lanes / express lanes, zone-based pricing or parking pricing.

High Occupancy Toll or Express Lanes

High-occupancy toll (HOT) lanes or express lanes are a pricing strategy that applies a charge for a single occupancy vehicle (SOV) to access a particular separated lane of the roadway, but allows High Occupancy Vehicles (HOV) to enter without charge. The toll rates may vary based on the time-of-day or the amount of congestion on the roadway; generally, the price is set to maintain a higher level of service or speed than the adjacent generic lanes that are not tolled.

These lanes have been implemented in several American jurisdictions. Examples include State Route 91 Express Lanes in Orange County, CA; I-15 HOT Lanes in San Diego, CA; I-10 / Katy Freeway HOT Lanes in Houston, TX; I-394 HOT Lanes in Minnesota; and I-25 Express Lanes in Denver, CO. In each of these examples, a toll is charged for single-occupancy vehicles to access these express lanes. The toll can range up to $10.00 depending on the level of congestion on the roadway, and the distance travelled on the lanes.

To ensure equity and to provide alternatives, transit services were provided along or parallel to these express lane corridors. Often, the revenues from the HOT or express lanes would support the provision of these transit services. However, the success of this measure on encouraging a shift to other alternative modes in the corridor has been limited. Significant mode share changes along express lane corridors were not experienced in Orange County, Houston, Minnesota or Denver; however, the improved service in San Diego from express lane revenues have led to an overall 25% increase in bus ridership (Federal Highway Administration, 2009).

Zone-Based Pricing

Zone-based pricing is a strategy that applies a charge to any vehicle that is operating within a designated area in a municipality. Three cities have successfully implemented zone-based pricing: London, Stockholm and Singapore. In London, a congestion charge is applied to a vehicle if it is driven into, out of or within the Congestion Charging Zone between the hours of 7:00am and 6:00pm Monday to Friday. The charge is £11.50 / day ($23.00 / day) (Transport for London, 2014a).

Since its implementation in 2003, the congestion charge in London has been effective in reducing automobile traffic within the centre of the city. Traffic is 27% lower in the Congestion Charge zone than pre-charging conditions; this is equivalent to 80,000 few cars entering the zone (Transport for London, 2014b). Levels of cycling in the zone have also increased by 66% since the introduction of the charge. Furthermore, this charge has generated a net annual revenue of £139 million ($278 million) for transport investments (Transport for London, 2014a).

In Stockholm, a congestion charge is applied to a vehicle if it enters the inner core of the city between the hours of 6:30am and 6:30pm Monday to Friday. The charge ranges between €1 and €2, depending on the time of day. This charge was introduced as a pilot project in the first half of 2006, and then reintroduced in the summer of 2007. In the first five years since the introduction, there has been an 18-21% reduction in traffic entering the charge area compared to prior to the charge in 2005. The data suggest that much of the volume of travel has been diverted to public transport (Börjesson et al., 2011).

In Singapore, zone-based pricing has been in place since 1975. It was originally known as the Area Licensing Scheme (ALS), which was a daily flat-rate charge for vehicles that drove within a defined "restricted zone" of the city. Since 1998, the Area Licensing Scheme was changed to Electronic Road Pricing. Under this new scheme, a charge is applied to vehicles that use certain congested roadways and expressways, plus a charge is applied to vehicles that enter the restricted zone. This charge depends on the size of the vehicle and the time of the day. During peak periods, the price is dynamically adjusted to ensure acceptable speeds are achieved on roadways and expressways. The rates range up to $6 SGD per entry ($5.75 CAD per entry).

The implementation of zone-based pricing has had significant impact on roadway utilization in Singapore's restricted zone. The initial area licensing scheme led to a 44% reduction in total traffic between March 1975 (pre-ALS) and October 1975 (post-ALS), and on some roadways, the charge led to an underutilization of the roadway capacity (Phang and Toh, 2004). The introduction of Electronic Road Pricing allowed Singapore to adjust the prices towards an optimal and efficient use of infrastructure (Phang and Toh, 2004). This zone-based pricing has been one of many strategies in Singapore that have been effective in shifting demand by mode: only 29% of trips in the city are by private transport, whereas 44% of trips are made by public transit (Land Transport Authority, 2011).

Parking Charges
Parking vehicles requires the allocation of high value space to temporarily store vehicles. This practice is an example of what economists call an “opportunity cost” – the use of a scarce resource with a value less than its optimal use. Based on this observation, Shoup (1997a) argued in his seminal paper that users should pay to offset the cost of providing a parking space at destinations. Introducing parking pricing may also act as an economic signal to commuters to consider a shift in mode from driving to transit.

Charging for parking is relatively common in central business districts of cities; moreover, some cities have introduced more pervasive parking levies across the city. Two Australian cities, Syndey and Melbourne, charge $2260 AUD ($2120 CAD) and $950–$1350 AUD ($890–$1270 CAD) respectively for annual parking levies (NSW Government, 2015; State Revenue Office Victoria, 2015). These charges are often passed from the owners onto the users of the space. In Vancouver, Canada, a 21% parking tax is applied to the price of parking (Translink, 2015).

While these forms of parking pricing strategies are effective in increasing revenue for transportation projects, their effects on mode shares have been mixed. Empirically, Bianco (2000) studied the impact of on-street parking charges on mode choice in an employment district Portland Oregon. After on-street meters were put into effect, the district experienced a 7% decrease in single-occupancy vehicles, with a significant increase in high occupancy vehicles. Other research has indicated that parking demand is inelastic to the parking price, which means that the number of vehicles utilizing a parking facility would only decrease marginally for an increase in the parking fee (Vaca and Kuzmyak, 2005).

Another method to change the economics of parking is known as parking cash-out. Employers often offer free-parking as a subsidy to their employees. With parking cash-out, employees instead receive a cash payment equal in value to the cost of paying for parking. If the employee wishes to continue to park, she simply continues her behavior. But, if the employee has other options, walking, cycling or transit, then any cost savings realized by this change in mode results in increased income for the employee.

Such a strategy was tested with eight employers in Los Angeles with approximately 1700 employees within these firms. From these tests, the use of single occupancy vehicles dropped by 17% with parking cash-out. Many of these commuters shifted to carpools, with mode share for transit increasing by 3% (Shoup,1997b).

Based on this literature review, we take the following approach to our analysis. We attempt to identify corridors or origin-destination pairs for which unused capacity exists over time, in space or on alternative modes. In cases where this capacity is available, we assess the necessary education or economic signals that are necessary to motivate travelers to change their behaviour, such that improved system performance can be realized. The following section describes the methods used in the analysis.

Methods

As noted above, the TDM initiatives on which this paper is focused include shifting demand in time, in space and between modes. The methods of analysis for each of these techniques are presented in this section.

Shifts in Time

Travel demand on urban freeways typically fluctuates over the course of a day, often demonstrating significant peaks during which congestion is more severe. Where peaks in travel demand are heavily concentrated over a short period of time, excess roadway capacity may be available in the “shoulder” periods that immediately precede or follow the peak.

TDM Initiatives that aim to shift travel demand in time by encouraging travel outside of these peak periods are most effective under situations where the typical demand pattern is such that excess capacity is available within a “reasonable” amount of time before or after the peak. The standard by which reasonable is defined can certainly vary. In cities where flexible work hours are the norm, a longer time, up to one hour may be reasonable. Conversely, in cities where flexible work hours are unusual, or where employment is concentrated in low-flexibility sectors, then only 15 minutes may be reasonable.

In Figure 1, the travel demand profile to the left exhibits pronounced peaks, representing a situation where opportunity exists for travel demand to shift from the two peaks to the abutting shoulder periods. On the contrary, the travel demand profile on the right exhibits consistently congested conditions throughout the majority of the day, representing a situation where little opportunity exists for shifting of travel demand across time.

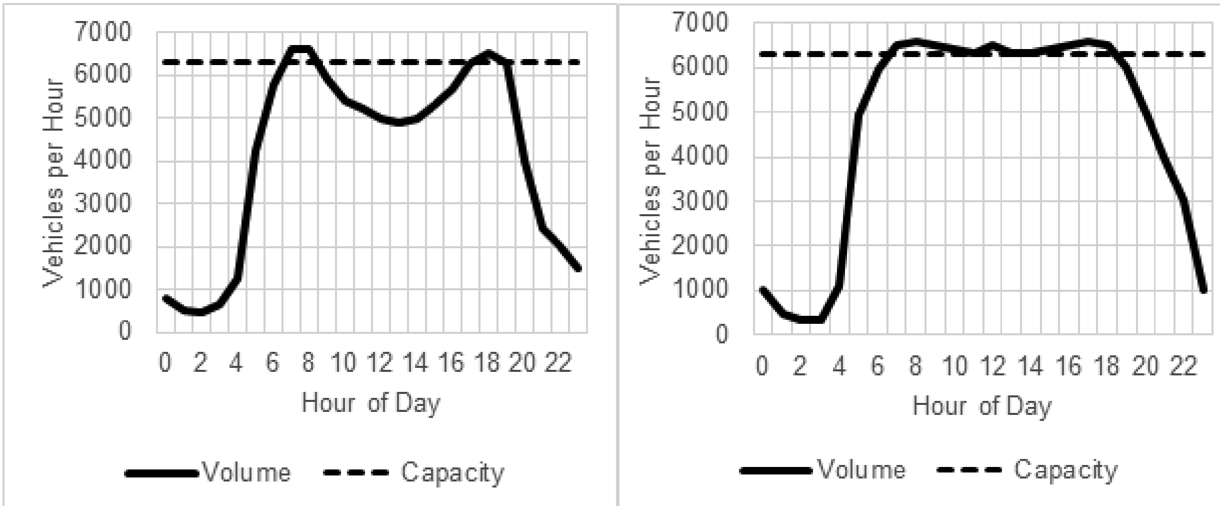


Figure 1 Demand profiles that have high potential (left) and low potential (right) for shifts in time

The objective of the shift in time analysis is to identify corridors within the GTHA freeway network where TDM initiatives that aim to shift demand in time are viable. This can be achieved through a comparison of available roadway capacity and travel demand for different periods of the day using volume-to-capacity (V/C) ratios, a common metric for roadway performance.

The approach to the analysis is as follows. First, we gather data on roadway utilization. These data are often presented as Annual Average Daily Traffic (AADT) – or the number of vehicles using a roadway segment on average over a 24-hour period. While these data are useful, for our purposes we require hourly volumes. As such, the second step in the analysis is to convert AADT volumes to hourly volumes. Next, we calculate volume to capacity ratios. The capacities of roadway segments are derived from common standards; for example, capacity on freeways is often assumed to be between 2000 and 2400 vehicles per hour per lane. To explore the possibility of shifting demand in time, we plot the v/c ratios for roadway segments as a function of time. From these graphs, we are able to identify roadways for which TDM-time shift is possible.

Each of these steps is described in more detail below.

1. *Conversion of Annual Average Daily Traffic (AADT) volumes to hourly volumes.*

The Ontario Ministry of Transportation (MTO) regularly reports traffic volumes in AADT format for all sections of roadway under its jurisdiction. However, in order to observe fluctuations over the course of a day, it is necessary to convert these AADTs into hourly volumes. Across the GTHA highway network, hourly volumes are available only for a limited set of locations, collected either by MTO through the Commercial

Vehicle Survey (CVS), and by the City of Toronto for points along the Don Valley Parkway (DVP). Under the assumption that the temporal distribution of traffic volumes at these select data collection points is representative of nearby highway segments, these data has been used to convert the AADT volumes to estimated hourly volumes. For locations where hourly volume data were available, time-of-day volume conversion factors were calculated for each hour (t) and direction (d) using the following equation:

$$f_{t,d} = \frac{Hourly\ Volume_{t,d}}{24\ Hour\ Two\ Way\ Volume}$$

This factor represents the proportion of the total 24 hour two way traffic volume that occurred during hour (*t*) in direction (*d*) at the data collection points. Based on these factors, and the AADT volumes available for each of the highway segments (*s*), hourly traffic volumes were calculated using the following equation:

$$V_{t,d,s} = f_{t,d} AADT_s$$

2. Estimation of roadway capacity.

Capacity on freeway facilities can be easily estimated using standard values of maximum throughput per lane (HCM 2010). The number of lanes on each segment of highway (*s*), separated by direction (*d*) was determined visually through 2015 satellite imagery of the GTHA. Each lane of travel was assumed to have a throughput of 2200 vehicles per hour per lane.

$$C_{d,s} = Vehicle\ throughput\ per\ lane \times Number\ of\ Lanes_{d,s}$$

3. Calculation of hourly volume-to-capacity (V/C) ratio.

Volume-to-capacity ratios for each segment of the facilities in this study were calculated based on the previously calculated hourly volumes ($V_{t,d,s}$) and roadway capacities ($C_{d.s}$) using the following equation:

$$V/C\ Ratio = \frac{V_{t,d,s}}{C_{t,d,s}}$$

4. ***Classification of highway segments by opportunity to shift in time.***

   Opportunity to shift in time on each segment of the highway was based on a classification of available capacity throughout the day. At a V/C ratio of 0.8 or greater, some level of congestion is typically experienced. For each highway segment, we classified the states of congestion during the peak period (7am–9 am and 4pm–6pm) and the peak shoulders (the hour preceding and following the peak period). Based on these classifications, we identify whether or not opportunities exist on each segment of the highway to shift travel demand in time.

Shifts in Space and Mode

In urban transportation networks, redundancy of infrastructure and services makes it possible to travel between origins and destinations through multiple paths and modes. Highly redundant and connected networks are inherently more reliable, as travelers are provided with many alternatives when certain parts of the network perform poorly.

It is often assumed that travelers, over time, have a tendency to distribute themselves evenly across the transportation system such that travel on any routes between two points results in a similar travel time or user cost. There are, however, some known limitations to this assumption. A lack of spatial awareness or incorrect pricing of resources can lead to imbalance and ultimately heavier congestion on certain parts of the network. In previous periods, a lack of spatial knowledge of the network and uncertainty about conditions on alternative routes or modes often limited a traveler’s willingness to shift routes due to congestion (Adler, 2001). Given the availability of navigation systems and real-time traffic information, contemporary travelers may be more willing to shift routes or modes in a redundant network to save travel time, and to reduce congestion (Tsirimpa, 2015).

TDM initiatives and measures that encourage people to shift their travel across space or modes often aim to incentivize travel on lesser-used alternate paths, or to dissuade travel on heavily used routes as a way to adjust the relative competitiveness between route and mode options. The objective of the shift in space and mode analysis is to identify corridors of travel where the existing path or mode, despite heavy congestion, remains a better alternative than a parallel path or mode on which excess capacity exists. In these cases, shifting some volume from the heavily congested route to the parallel route or mode produces a benefit – reduced travel time – for those who remain on the existing route.

The challenge is to motivate individual travelers to change their behaviors such that this benefit can be realized. An increase in user costs – a toll for example – on the heavily used path may be sufficient to produce a desired change. The magnitude of the economic signal necessary depends on the relative competitiveness of the chosen path and alternative paths.

In this analysis, user costs during different times of the day are examined for multiple paths and modes that connect a selection of origin-destination pairs. Here, user cost (or generalized cost) is used as a metric for competitiveness, and a basis of direct comparison to the costs of other routes and modes in the same corridor. The tasks involved in the analysis are as follows.

To complete the analysis, we first need a method to represent users' perceptions of costs of travel. Typically, this is done using a technique known as generalized costs (GC) – a linear combination of out of pocket expenses (tolls, parking and fuel – measured in dollars) and travel time (measured in minutes). The travel time is converted from minutes to dollars using value of time – $/hour. Estimates of value of time are derived from local salary information.

Once the generalized cost equation is formulated, the GCs between various origins and destinations (ODs) can be quantified for all available modes. The cost of completing the trip by auto along the most likely path can be compared against completing the trip by alternative parallel roadway paths, or by available parallel transit service. This is often done using ratios of alternative generalized costs to shortest path generalized costs; values of less than 1 represent lower cost alternative routes, while values greater than one represent an increased cost for shifting path or mode.

Once the ratios have been calculated, the competitiveness of paths and modes to the shortest auto path can be directly observed. An interesting extension of the analysis is to determine by how much the cost of the shortest path would need to increase, or by how much the alternative path cost would need to decrease, in order to make alternatives more competitive. This exercise is known as sensitivity analysis.

Each of the steps in the analysis is further explained here.

1. Quantification of user costs.

To quantify user costs for a given OD pair, we employ the concept of generalized cost (GC) – a combination of time and out of pocket expenditures necessary to complete a trip (Evans, 1973). In GC calculations, the time elements of the trip are converted to dollars using a value of time (VOT), typically some function of the average regional wage. In this analysis, a value of $12/ hour was used, which is approximately half the average hourly wage for individuals living in Ontario in 2014 (Statistics Canada, 2015). The following outlines the generalized cost formulas developed for auto and transit:

Auto Travel

We define the generalized cost of using an automobile with the following equation:

$$\boldsymbol{GC_{auto} = time\ cost + fuel\ cost + toll\ charges + parking\ charges}$$

$$GC_{auto} = (VOT * t_{IV}) + d_{trip,r} * e_{fuel,r} * C_{fuel} + (B_{toll} + (d_{toll} * C_{toll})) + C_{parking}$$

where,

$$VOT = Value\ of\ Time\ (\$/min)$$
$$t_{IV} = in - vehicle\ time\ (min)$$
$$d_{trip} = trip\ distance\ (km)$$
$$e_{fuel} = fuel\ economy\ (L/km)$$
$$C_{fuel} = fuel\ cost\ (\$/L)$$
$$r = roadway\ type\ (local\ or\ highway)$$
$$B_{toll} = base\ toll\ (\$)$$
$$d_{toll} = toll\ distance\ (km)$$
$$C_{toll} = toll\ charge\ (\$/km)$$
$$C_{parking} = parking\ charge (\$)$$

Auto travel time consists primarily of the in-vehicle time (t_{IV}) the values of which were sourced from Google Maps. The data are presented in ranges representing historical performance for each roadway. In our analysis, we elected to use nearly the upper bound of the range to account for unreliability of travel time.

Fuel costs associated with auto travel were calculated based on the trip distance measured in Google Maps. This distance was converted into a dollar amount based on the fuel economy of an average full sized sedan in either local or highway driving conditions (9 L/100km and 7.4 L/100km respectively), and the average fuel cost at the time of analysis ($1.30/L). The fuel efficiency data are reported by the Canadian Automobile Association.

In the GTHA, there is currently only one tolled facility, the 407 Express Toll Route (407ETR). For trips that include at least some length of travel on this facility, a toll charge based on the highway's pricing scheme was applied. At the time of analysis, each trip on the 407ETR cost a flat rate base toll of $0.80, plus an additional per distance charge of $0.3020/km during the AM and PM peaks, and $0.2406/km during the midday. The toll distance (d_{toll}) was estimated through the trip segment measurements provided by Google Maps.

Finally, parking charges were applied according to the average rate for all day parking at each destination point, assuming commuter parking. As an example, auto trips destined for Toronto Union Station include a $10 parking charge.

Table 1 Assumed Values in Calculating Automobile Generalized Costs

Variable	Definition	Value
VOT	Value of Time	\$12/ hour
t_{IV}	In-Vehicle Travel Time	Varies
e_{fuel}	Fuel Efficiency	7.4L/km (highway); 9.0L/km (local)
C_{fuel}	Fuel Price	\$1.30/L
D_{toll}	Distance on Toll Route	Varies
C_{toll}	Toll Rate	AM / PM Peak Rate: \$0.80 base rate + \$0.30/km Midday Rate: \$0.80 base rate + \$0.24/km
$C_{parking}$	Parking Rate	Varies depending on location

<u>Transit Travel</u>

We define the generalized cost of using transit with the following equation:

$$\boldsymbol{GC_{transit} = time\ cost + fare\ cost + driving\ to\ access\ cost + parking\ charges\ at\ access}$$
$$GC_{transit} = [VOT * (t_{access} + t_{wait} + t_{IV} + t_{egress})] + C_{fare} + (d_{trip} * e_{fuel} * C_{fuel}) + C_{parking}$$

where,

$$VOT = Value\ of\ Time\ (\$/min)$$
$$t_{access} = access\ time\ from\ the\ trip\ start\ point\ to\ the\ transit\ stop\ (min)$$
$$t_{wait} = wait\ time\ at\ the\ transit\ stop (min)$$
$$t_{IV} = in - vehicle\ time\ (min)$$
$$t_{egress} = egress\ time\ from\ the\ transit\ stop\ to\ final\ destination\ (min)$$
$$C_{fare} = fare\ cost\ (\$)$$
$$d_{trip} = trip\ distance\ (km)$$
$$e_{fuel} = fuel\ economy\ (L/km)$$
$$C_{fuel} = fuel\ cost\ (\$/L)$$
$$C_{parking} = parking\ charges (\$)$$

In addition to in-vehicle travel time, transit travel time includes time spent waiting, as well as accessing and egressing the beginning and end of the transit trip. In-vehicle travel time was estimated using scheduled transit travel times provided by the transit operators, and converted to a travel cost by applying the VOT. In cases where the travel time for a specified stop location was not available from system timetables, trip planning tools such as Google Maps and TripLinx were used.

Wait times were calculated as half the sum of the scheduled time headways that precede each leg of the trip to approximate an average wait time. For the initial wait period before the first leg of the transit trip, headways were capped at a maximum of 20 minutes, as travelers are more likely to time their arrival at the first leg of the trip accordingly when headways are longer.

Calculations for time spent accessing and egressing transit services differ depending on the assumed access mode. For access to transit, it was assumed that travelers have the option to either walk or drive to the starting point of the transit trip. On the other hand, for egress from transit, walking was assumed to be the only mode available. In scenarios where walking was the access or egress mode, travel times were calculated from an average walking speed of 1.4m/s and the walk distance provided by the trip planning tools. In scenarios where access to transit by auto is required, access time was estimated using Google Maps, and the GC formulation for auto travel is applied in that segment of the trip, assuming local driving conditions.

Fare charges included in all transit GC calculations were based on the cost of an adult fare, using the Presto farecard. Although the Presto farecard is not yet universally used across the GTHA, it more closely aligns with the price that would be paid by frequent travelers such as commuters. Fare charges vary depending on the operator, and have been listed in the following table.

Table 2 Assumptions for Calculating Transit Generalized Costs

Variable	Definition	Value
VOT	Value of Time	$12/ hour
t_{access}	Time to Access Transit	Access Distance / Average Walking Speed (1.4m/s)
t_{wait}	Waiting Time	Half of the scheduled transit headways to a max. of 20 min.
t_{IV}	In-Vehicle Travel Time	Varies based on times scheduled by transit agency
t_{egress}	Egress Time	Egress Distance / Average Walking Speed (1.4m/s)
C_{fare}	Adult Fare Cost with Presto Farecard	Local Transit System: Toronto Transit Commission (TTC): $2.80/ trip Mississauga Transit/miWay (MT): $2.90/trip Brampton Transit/Zum (BT): $2.80/trip York Region Transit / VIVA (YRT): $3.30/trip Durham Region Transit (DRT): $3.00/trip GO Transit: Variable Fare based on zones Co-Fare for GO Transit connections: - YRT, BT, DRT: $0.75 /trip + GO Transit fare - MT: $0.80/trip + GO Transit Fare

For each OD pair, generalized costs were examined for three alternative scenarios:

1. **Auto – Highway**, which is a route by automobile, generally with the majority of travel on a highway. This alternative may include use of tolled routes.
2. **Auto – Local / Alternate Highway**, which is a route by automobile, using either a different highway, or major arterials and local streets. This alternative does not use tolled routes.
3. **Transit**, which is the most direct route by bus or by rail, using all local and regional transit services available.

Generalized costs for each alternative were calculated for three time periods:

AM Peak: arrival at destination at approximately 8:00 am
Midday: arrival at destination at approximately 1:00 pm
PM Peak: arrival at destination at approximately 5:00 pm

In total, nine generalized cost values were generated for each origin destination pair examined in this analysis.

2. Calculation of a relative competitiveness ratios.

Evaluation of the relative competitiveness of an alternative path or mode requires that some baseline alternative (designated as *b*) be established as a point of comparison. Given the relatively high auto mode share in the GTHA, the baseline alternative for each OD pair, which is assumed to be the primary choice for most travelers, was selected between the two auto alternatives, Auto – Highway and Auto – Local/Alternate Highway.

In corridors where the most logical paths of auto travel do not include the use of a tolled route, alternative 1, Auto-Highway, was designated as the baseline alternative, *b*. In corridors where the most logical paths of auto travel do include use of a tolled route, or where no highway travel is required at all, alternate 2, Auto – Local/Alternate Highway, was designated as *b*.

The relative competitiveness of the two remaining alternatives was quantified as the ratio of the generalized cost of those options (*m*) to the generalized cost of the baseline alternative *(b*) using the following equation:

$$Competitiveness\ Ratio_m = \frac{GC_m}{GC_b}$$

3. Classification of corridors by relative competitiveness between alternatives

Existing opportunities to shift travel demand in space and in mode can be revealed through the competitiveness ratios calculated for each alternative, with a competitiveness ratio of 1 indicating that the alternative is equally competitive. The competitiveness ratios can be interpreted as follows:

0 to 1: More or equally competitive. Travel demand may be shifted in space or mode through improved awareness of alternatives, or increased transit service capacity.

1 to 2: Less competitive, but with opportunity for TDM. Travel demand may be shifted in space or mode with the introduction of modest TDM initiatives.

2 +: Not competitive. Travel demand is unlikely to shift in space or mode without drastic changes to pricing structure, service provision, or infrastructure.

4. ***Sensitivity analysis of relative competitiveness ratios in response to TDM initiatives.***

To estimate the magnitude of the economic signals required to motivate a shift in behaviour, a sensitivity analysis was performed on each travel scenario. The introduction of an additional parking charge at destinations was used as a test case to exemplify the potential for shift between auto and transit with increased cost to auto travel. Incremental charges of $0.50 were added to the generalized costs of both auto-based alternatives, and the competitiveness ratios were subsequently recalculated.

Under scenarios where transit at present is less competitive than auto, this sensitivity analysis tests the point - in an approximate dollar amount - at which economic disincentives to auto are likely to make transit equally competitive (where the competitiveness ratio reaches a value of 1.0).

Application of Methods to the GTHA

The methods described were applied to the GTHA, with an emphasis on key freeway facilities, as well as origins and destinations located in the central portion of the region. This represents the part of the region where congestion is most pervasive, and also where the introduction of TDM initiatives is anticipated to have the greatest impact.

The following sections describe several detailed applications of this assessment to exemplify our analysis and interpretation of the results. A summary of findings is presented in a subsequent section.

Opportunities for Shift in Time

The shift in time analysis was applied to portions of the GTHA highway system for which representative time of day profile data was available. The points at which these data were available from MTO through the commercial vehicle survey are shown in Figure 2, along with the roadway segments for which the time of day volume profiles apply.

Figure 2 Sections of GTHA highways evaluated for shifts in time

Case 1: Highway 401 West

The diagram shown in Figure 3 represents the volume to capacity ratio calculated for various segments of Highway 401 West – those segments west of the City of Toronto. On the left side of the figure, the v/c ratios are presented for eastbound travel on segments from highway 427 to highway 403; from highway 403 to Mavis Road; from Mavis Road to Highway 407; and from Highway 407 to Highway 25. The v/c ratios are calculated hourly over a 24 hour period, from midnight until 11:00pm. Similarly, on the right side of the figure, the v/c ratios are presented for the same segments traveling westbound. The results are color coded. Volume to capacity ratios near to 0 (free-flow travel) are shown in green; the color for a segment changes from green to yellow to orange to red as v/c ratios increase or exceed 1.0.

Eastbound

	12:00AM	1:00AM	2:00AM	3:00AM	4:00AM	5:00AM	6:00AM	7:00AM	8:00AM	9:00AM	10:00AM	11:00AM	12:00PM	1:00PM	2:00PM	3:00PM	4:00PM	5:00PM	6:00PM	7:00PM	8:00PM	9:00PM	10:00PM	11:00PM
Highway 427																								
	0.1	0.1	0.1	0.1	0.2	0.5	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.5	0.4	0.3	0.3	0.2	0.2
Highway 403																								
	0.1	0.1	0.1	0.1	0.2	0.6	1.1	1.0	0.9	0.9	0.8	0.8	0.8	0.7	0.8	0.8	0.9	0.9	0.7	0.5	0.4	0.4	0.3	0.2
Mavis Road																								
	0.1	0.1	0.1	0.1	0.2	0.5	0.9	0.9	0.7	0.7	0.7	0.7	0.6	0.6	0.7	0.7	0.7	0.7	0.6	0.4	0.4	0.3	0.3	0.2
Highway 407																								
	0.1	0.1	0.0	0.1	0.1	0.4	0.7	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.4	0.3	0.3	0.2	0.2	0.1
Highway 25																								

Westbound

	12:00AM	1:00AM	2:00AM	3:00AM	4:00AM	5:00AM	6:00AM	7:00AM	8:00AM	9:00AM	10:00AM	11:00AM	12:00PM	1:00PM	2:00PM	3:00PM	4:00PM	5:00PM	6:00PM	7:00PM	8:00PM	9:00PM	10:00PM	11:00PM
Highway 427																								
	0.1	0.1	0.1	0.1	0.1	0.2	0.5	0.6	0.6	0.5	0.5	0.5	0.6	0.6	0.7	0.8	0.9	0.9	0.7	0.6	0.4	0.4	0.3	0.2
Highway 403																								
	0.1	0.1	0.1	0.1	0.1	0.2	0.4	0.6	0.6	0.5	0.5	0.5	0.6	0.6	0.7	0.8	0.8	0.8	0.7	0.6	0.4	0.4	0.3	0.2
Mavis Road																								
	0.2	0.1	0.1	0.1	0.1	0.2	0.5	0.7	0.7	0.6	0.6	0.6	0.6	0.7	0.8	0.9	1.0	1.0	0.8	0.6	0.5	0.4	0.4	0.2
Highway 407																								
	0.1	0.1	0.1	0.1	0.1	0.2	0.4	0.5	0.5	0.4	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.7	0.6	0.5	0.4	0.3	0.3	0.2
Highway 25																								

Figure 3 Volume to capacity ratios for segments of Highway 401

The interpretation of Figure 3 is as follows. Highway 401 West experiences the highest v/c ratios (and, as a result the greatest congestion) on the segment between Highway 403 and Mavis Road in the eastbound direction in the hours between 6:00 and 7:00 am. Similar v/c ratios are observed between Mavis Road and Highway 407 in the westbound direction in the afternoon, between 4:00 and 6:00pm. The volume tends to be substantially lower than capacity on the segment between Highway 25 and Highway 407 throughout the day, in both directions.

As described above, the potential to shift demand in time is highest when v/c ratios of less than 1.0 occur in periods preceding or following high congestion. In Figure 3, shifting traffic demand is possible for the eastbound direction during the morning peak along much of the facility, with the exception of the portion between Highway 403 and Mavis Road. This is a point of constraint on the facility that may warrant further study. Based on the available data, it is known that the capacity on this part of the facility is reduced to approximately 6600 vehicles per hour from segments of much higher capacity. This reduction in lanes and capacity may be a potential cause for the extensive delay experienced in this segment.

In the westbound direction, congestion exists only in the PM peak and spans for a period of about 3 hours from 3 pm to 5 pm. Some shift in demand over time may be possible for this facility in the westbound direction, particularly to the shoulder that follows this peak if a typical 9 am to 5 am schedule is assumed.

Case 2: 404-DVP

Northbound

	12:00AM	1:00AM	2:00AM	3:00AM	4:00AM	5:00AM	6:00AM	7:00AM	8:00AM	9:00AM	10:00AM	11:00AM	12:00PM	1:00PM	2:00PM	3:00PM	4:00PM	5:00PM	6:00PM	7:00PM	8:00PM	9:00PM	10:00PM	11:00PM
Major Mackenzie Drive																								
	0.2	0.1	0.1	0.0	0.0	0.2	0.4	0.7	0.7	0.5	0.5	0.6	0.6	0.7	0.9	1.0	1.1	1.1	1.1	0.9	0.7	0.6	0.5	0.3
Highway 7																								
	0.1	0.1	0.0	0.0	0.0	0.1	0.4	0.6	0.6	0.5	0.5	0.5	0.6	0.6	0.8	0.9	1.0	1.0	1.0	0.8	0.6	0.6	0.4	0.3
Steeles Avenue																								
	0.1	0.1	0.0	0.0	0.0	0.1	0.4	0.6	0.6	0.5	0.5	0.5	0.6	0.6	0.8	0.9	1.0	1.0	1.0	0.8	0.6	0.6	0.4	0.3
Sheppard Avenue																								
	0.2	0.1	0.1	0.0	0.0	0.2	0.5	0.8	0.8	0.6	0.6	0.7	0.7	0.8	1.0	1.2	1.3	1.3	1.3	1.0	0.8	0.7	0.6	0.4
Highway 401																								
	0.3	0.2	0.1	0.1	0.1	0.2	0.5	0.8	0.9	0.8	0.7	0.7	0.8	0.8	0.8	0.9	0.8	0.6	0.8	0.9	0.8	0.7	0.7	0.6
Eglinton Avenue																								
	0.3	0.2	0.1	0.1	0.1	0.1	0.4	0.7	0.9	0.7	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.5	0.7	0.8	0.8	0.7	0.7	0.6
Gardiner Expressway																								

Southbound

	12:00AM	1:00AM	2:00AM	3:00AM	4:00AM	5:00AM	6:00AM	7:00AM	8:00AM	9:00AM	10:00AM	11:00AM	12:00PM	1:00PM	2:00PM	3:00PM	4:00PM	5:00PM	6:00PM	7:00PM	8:00PM	9:00PM	10:00PM	11:00PM
	0.1	0.0	0.0	0.0	0.1	0.5	0.8	0.5	0.6	0.7	0.7	0.6	0.6	0.5	0.5	0.6	0.7	0.6	0.5	0.4	0.3	0.2	0.2	0.1
	0.1	0.0	0.0	0.0	0.1	0.4	0.7	0.5	0.5	0.7	0.6	0.6	0.5	0.5	0.5	0.6	0.6	0.6	0.4	0.3	0.3	0.2	0.2	0.1
	0.1	0.0	0.0	0.0	0.1	0.4	0.7	0.5	0.5	0.7	0.6	0.6	0.5	0.5	0.5	0.6	0.6	0.6	0.4	0.3	0.3	0.2	0.2	0.1
	0.1	0.1	0.0	0.0	0.1	0.7	1.2	0.8	0.9	1.1	1.0	0.9	0.9	0.8	0.8	0.9	1.0	0.9	0.7	0.6	0.4	0.4	0.3	0.2
	0.2	0.1	0.1	0.1	0.1	0.4	1.0	0.9	0.8	0.8	0.8	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.8	0.7	0.6	0.5	0.3
	0.2	0.1	0.1	0.1	0.1	0.3	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.8	0.9	0.9	0.8	0.5	0.5	0.4	0.3

Figure 4 Volume to capacity ratios for the Don Valley Parkway - Highway 404 corridor

Highway 404-DVP is a major north-south facility that connects northern GTHA municipalities to Downtown Toronto. In the northbound direction, during the AM peak, congestion occurs for a short period between 8:00 and 9:00 am from the Gardiner Expressway to Sheppard Avenue. TDM incentives to shift demand one hour earlier or later have the potential to reduce congestion and improve overall system performance. During the afternoon peak, this congestion shifts northward towards the area between Sheppard Avenue and Major Mackenzie drive, and extends over a much longer period. Given the consistent congestion levels, there exists limited to no opportunity to shift demand, as congestion already extends outside the afternoon peak period.

In the opposing southbound direction, the facility is consistently congested throughout the day from Sheppard Avenue down to the Gardiner Expressway, while the northern segments of the facility operate uncongested for much of the day. TDM incentives that aim to shift demand in time will not be effective as there is little excess capacity available to accommodate the demand.

Case 3: QEW

Eastbound

	12:00AM	1:00AM	2:00AM	3:00AM	4:00AM	5:00AM	6:00AM	7:00AM	8:00AM	9:00AM	10:00AM	11:00AM	12:00PM	1:00PM	2:00PM	3:00PM	4:00PM	5:00PM	6:00PM	7:00PM	8:00PM	9:00PM	10:00PM	11:00PM
Third Line																								
	0.2	0.1	0.1	0.1	0.1	0.2	0.4	0.8	0.8	0.7	0.7	0.7	0.7	0.8	0.8	0.9	0.9	1.0	0.9	0.7	0.6	0.5	0.4	0.3
Highway 403																								
	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.6	0.6	0.5	0.5	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.7	0.5	0.4	0.4	0.3	0.2
Mississauga Road																								
	0.2	0.1	0.1	0.1	0.1	0.2	0.4	0.8	0.8	0.7	0.7	0.7	0.7	0.8	0.8	0.9	0.9	0.9	0.9	0.7	0.6	0.5	0.4	0.3
Dixie Road																								
	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.6	0.6	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.6	0.4	0.4	0.3	0.2
Highway 427																								

Westbound

	12:00AM	1:00AM	2:00AM	3:00AM	4:00AM	5:00AM	6:00AM	7:00AM	8:00AM	9:00AM	10:00AM	11:00AM	12:00PM	1:00PM	2:00PM	3:00PM	4:00PM	5:00PM	6:00PM	7:00PM	8:00PM	9:00PM	10:00PM	11:00PM
	0.1	0.1	0.1	0.1	0.1	0.6	0.9	0.9	0.9	0.9	0.8	0.7	0.7	0.7	0.8	0.8	0.9	0.8	0.7	0.5	0.5	0.4	0.3	0.2
	0.1	0.1	0.0	0.1	0.1	0.4	0.7	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.6	0.6	0.6	0.6	0.5	0.4	0.3	0.3	0.2	0.2
	0.1	0.1	0.1	0.1	0.1	0.6	0.9	0.9	0.9	0.8	0.8	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.7	0.5	0.5	0.4	0.3	0.2
	0.1	0.1	0.0	0.1	0.1	0.4	0.7	0.7	0.7	0.7	0.6	0.6	0.5	0.6	0.6	0.6	0.7	0.6	0.6	0.4	0.4	0.3	0.2	0.2

Figure 5 Volume to capacity ratios on the QEW

Travel demand on the QEW peaks in both the morning and afternoon at two key segments, between Third Line and Highway 403, and Mississauga Road and Dixie Road. For the eastbound direction, the AM peak approaches capacity for about 2 hours between 7:00 and 9:00 AM, but does not exceed it. In the PM Peak, the facility at both of these points becomes much more congested, with heavy demand spanning the period between 3:00 and 7:00 PM. TDM initiatives that aim to shift demand in time may be applied to prevent the AM peak traffic from worsening, but is likely to have little effect on the PM peak traffic as there is no available capacity in the shoulders.

In the westbound direction, the facility peaks similarly in the same two segments, spanning the periods between 6:00 to 10:00 AM and 3:00 to 6:00 PM. This may be indication that the congestion is caused at least in part by physical limitations of the facility. TDM initiatives may be able to shift some of this excess demand into the shoulder periods, but may not completely eliminate pressures at these two points.

Opportunities for Shift in Space and in Mode

Major traffic flows in a large region can be characterized by the movements between key activity centres. For this study, 11 Metrolinx designated Mobility Hubs were selected to represent the origins and destinations of movements across the region. The Mobility Hubs shown in Figure 6 were selected to provide a representation of the major directional flows that occur in the most congested central part of the GTHA.

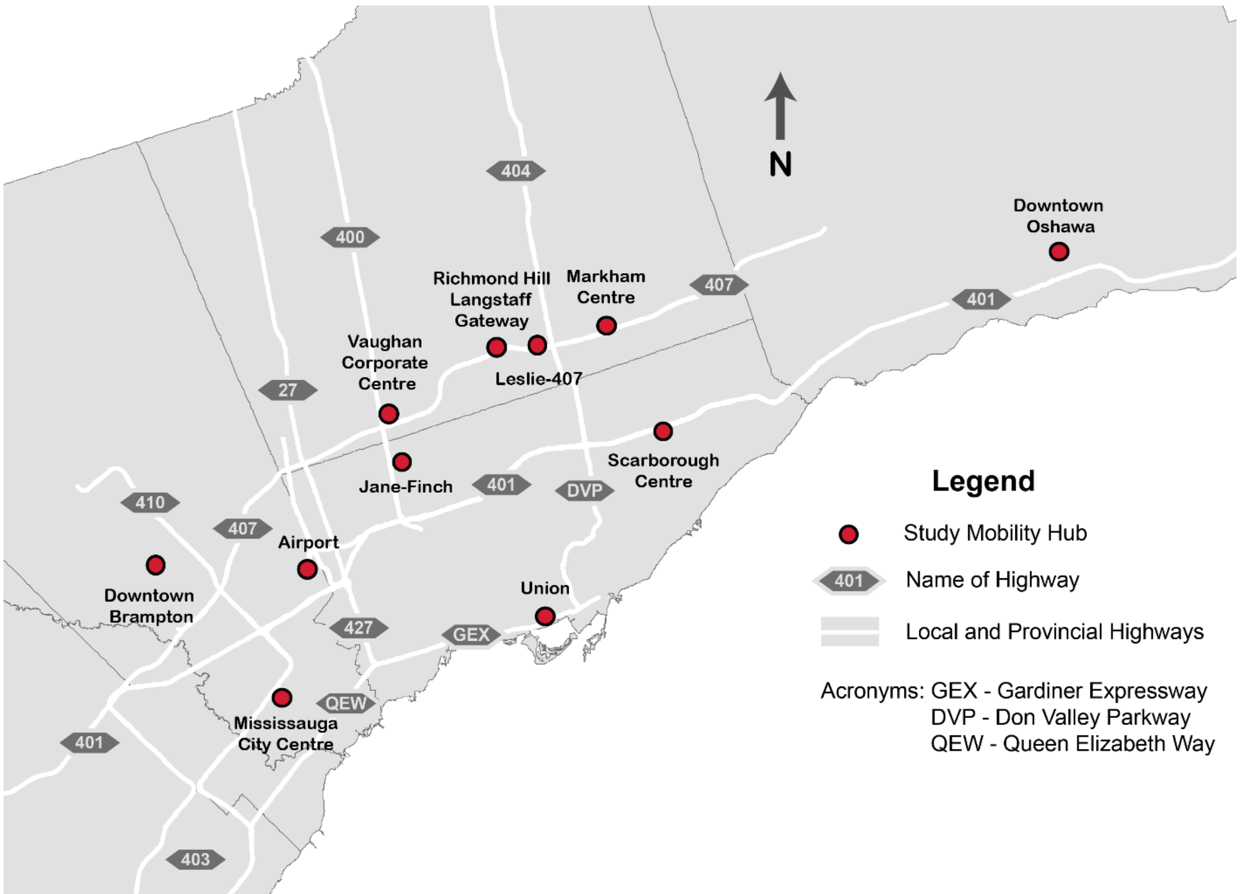


Figure 6 Location of Metrolinx Mobility Hubs analyzed in this report

Case 1: Leslie/407 and Union

The Union Mobility Hub is a major transport terminal located in the central business district of downtown Toronto. Close to 130,000 jobs are located within an 800 metre radius of the station. This mobility hub is well-served by existing transit including all GO Transit rail lines and the TTC's Yonge-University-Spadina Line.

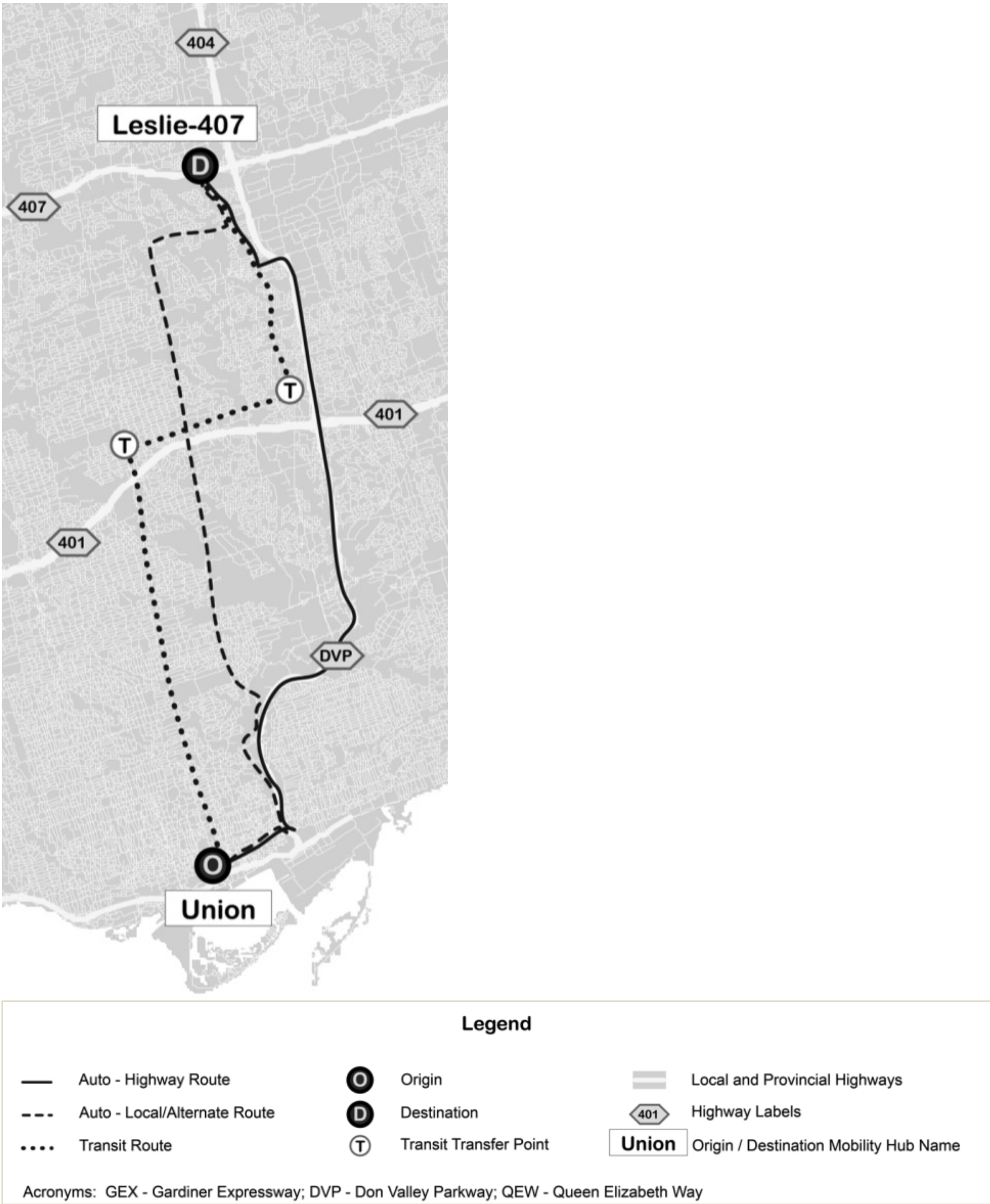


Figure 7 Union and Leslie / 407 Mobility hub locations and paths evaluated

The Leslie / 407 Mobility Hub is located north of the City of Toronto within the neighboring City of Markham. It is a major suburban employment centre with 4,800 jobs located within an 800 meter radius of the hub location.

Travel between the Leslie/407 and Union Station Mobility Hubs represents the north-south movements through the centre of the region. The most commonly used path for this travel is the congested Highway 404 / Don Valley Parkway corridor. This area is also proximate to Highway 407. The local transit agency – York Region Transit – provides both local and rapid bus service to the Leslie mobility hub. The distance between these two mobility hubs is approximately 30 kilometers.

Figure 7 illustrates the location of the mobility hubs and the three routes that were defined in this analysis case. For trips from Leslie / 407 to Union, the Auto – Highway alternative primarily uses Highway 404 and Don Valley Parkway. The Auto – Local alternative uses Bayview Avenue, a major arterial, for the majority of the route. The Transit alternative uses the local YRT bus to Don Mills Station, then two subway routes to Union. The alternatives follow the same routes in the reverse direction for trips from Union to Leslie / 407. In this case, the Auto – Highway is the baseline auto mode for comparison. Note that the typical commuting demand in this corridor is southbound in the am peak and northbound in the pm peak.

The results of the generalized cost analysis are presented in Table 3 for trips between Leslie / 407 and Union.

Table 3 Costs of travel between mobility hubs

Southbound: Leslie / 407 – Union						
Period	**Travel Time (min)**			**Generalized Cost ($)**		
	Auto – Highway	**Auto – Local/Alternate**	**Auto – Highway**	**Auto – Local/Alternate**	**Local**	**Transit**
AM Peak	60	55	67	24.83	24.35	19.45
Midday	45	45	66	21.83	22.35	19.25
PM Peak	40	50	71	20.83	23.35	20.35
Ratio of $GC_{Alternative}$ / $GC_{Highway}$					**Auto – Local/ Alternate**	**Transit**
AM Peak					0.98	0.78
Midday					1.02	0.88
PM Peak					1.12	0.98

Northbound: Union – Leslie / 407						
Period	**Travel Time (min)**			**Generalized Cost ($)**		
	Auto – Highway	**Auto – Local/Alternate**	**Transit**	**Auto – Highway**	**Auto – Local/ Alternate**	**Transit**
AM Peak	55	65	58	13.30	15.64	18.15
Midday	45	60	65	11.30	14.64	19.71
PM Peak	100	90	68	22.30	20.64	19.60
Ratio of $GC_{Alternative}$ / $GC_{Highway}$					**Auto – Local/ Alternate**	**Transit**
AM Peak					1.18	1.32
Midday					1.29	1.68
PM Peak					0.93	0.86

Based on the results outlined in Table 3 for the southbound direction, there exist strong possibilities to shift travel demand in terms of space and mode in this corridor. The competitiveness ratio for the Auto – Local alternative is below 1 in the am peak, which suggests that the generalized costs are similar between the two auto alternatives, but the Bayview path is actually less expensive. In the pm peak, the ratio is slightly below 1 in the northbound direction for the return trip. Providing information regarding travel times on the parallel local routes may motivate travelers to switch paths and alleviate travel demand on the highway in this corridor.

Similarly, transit costs are 78% of the generalized cost for highway in the am peak. This ratio is a result of the existing parking charge in downtown Toronto, estimated as $10. For the return trip, transit remains more cost effective, with a competitiveness ratio of 0.86 for the northbound direction in the pm peak. Providing information on transit departures, connections and costs may have the desired effect of shifting travelers from auto to transit in this corridor.

For those who are reverse commuting, traveling northbound in the am peak, transit costs are 32% higher than the highway alternative. This difference in cost results not from travel time – the difference between the two modes is only 3 minutes – but rather due to the multiple fares that must be paid across multiple agencies. To motivate a mode shift in this direction, two complementary TDM initiatives could be designed. The first is fare integration to reduce the total cost of travel by transit in this corridor. The second is the use of pricing measures such as a road toll along the DVP / 404 corridor or a parking charge in the Leslie / 407 Mobility Hub.

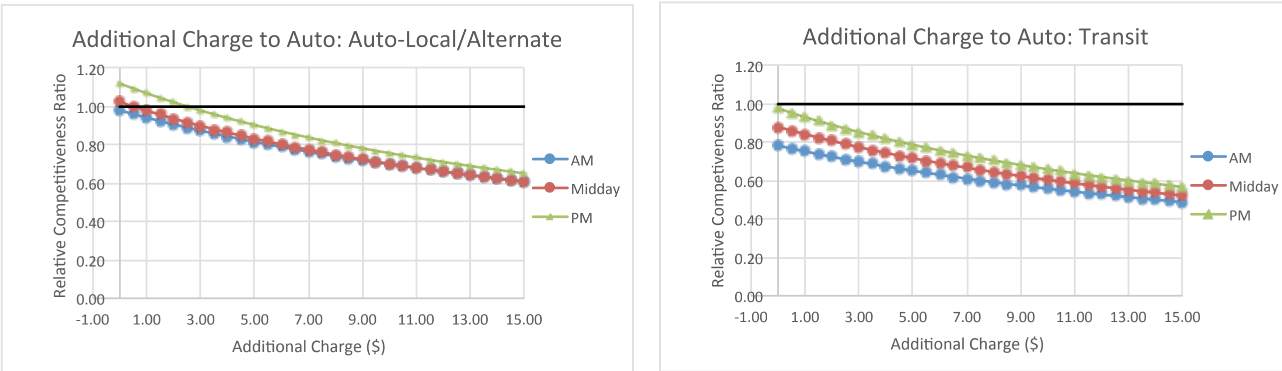


Figure 8 Sensitivity analysis of generalized costs for Leslie / 407 to Union Station (SB)

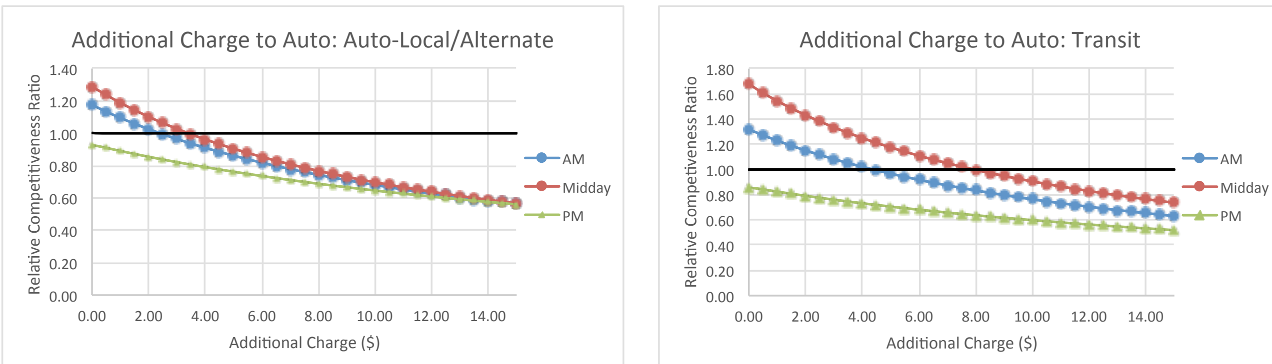


Figure 9 Sensitivity analysis of generalized costs for Union Station to Leslie / 407 (NB)

As noted earlier, we completed a sensitivity analysis to determine the magnitude of the economic signals that would be necessary in order to motivate changes in travel behavior. The method of analysis is to increase the cost of one element of the lowest cost path or mode such that the alternatives become cost competitive. We generate a plot of competitiveness – the ratio of generalized costs – as a function of the additional costs.

In this case, the sensitivity analysis (Figure 9) shows that an additional cost to travel on the DVP / 404, such as a road toll of about $3, is necessary to make the cost of travel on local alternative roads equally competitive. Likewise, an increase of about $4 to $8 to the cost of driving from Union Station and Leslie / 407 would help to make transit more competitive in this corridor. A proportionate decrease to the cost of transit through other initiatives such as improved fare integration would have a similar effect.

Case 2: Mississauga City Centre and Markham Centre

The second case compares the competitiveness of cross-regional trips by using mobility hubs that are located outside of the City of Toronto. The two mobility hubs selected for this case include Markham Centre and Mississauga City Centre.

The Markham Centre Mobility Hub is located at Unionville GO Station. While this site is largely undeveloped at present, there are plans for a mixed-use development with residential, office and retail spaces. The area is located in close proximity to Highway 407. GO Transit provides peak-period train service to downtown Toronto, off-peak bus service to downtown Toronto along Highway 404 and all-day bus service to York University along Highway 407. York Region Transit also services this station with its local and rapid bus transit routes.

The Mississauga City Centre Mobility Hub contains significant employment and retail spaces. Over 8,000 jobs are located within 800 meters of the hub. This area is well served by local and regional transit. GO Transit provides bus service to many Ontario universities and downtown Toronto from its Square One Terminal. Mississauga Transit also provides local and express bus service to this location. The distance between these two mobility hubs is approximately 50 kilometers.

Figure 10 illustrates the three routes that were defined for this analysis case. For trips westbound from Markham Centre to Mississauga City Centre, the Auto – Highway alternative uses the Highway 407 tolled route, as well as the non-tolled Highways 410 and 403. The Auto – Local / Alternate Highway alternative uses local roads to Highways 404, 401 and 403. The Transit alternative uses GO Transit's Highway 407 Express Bus service from Unionville GO to Square One, with a required transfer at York University. The alternatives follow the same routes in the reverse direction for trips eastbound from Mississauga City Centre to Markham Centre.

The results of the generalized cost analysis are presented in Table 4. In these tables, the Alternate Highway is used as the baseline auto alternative.

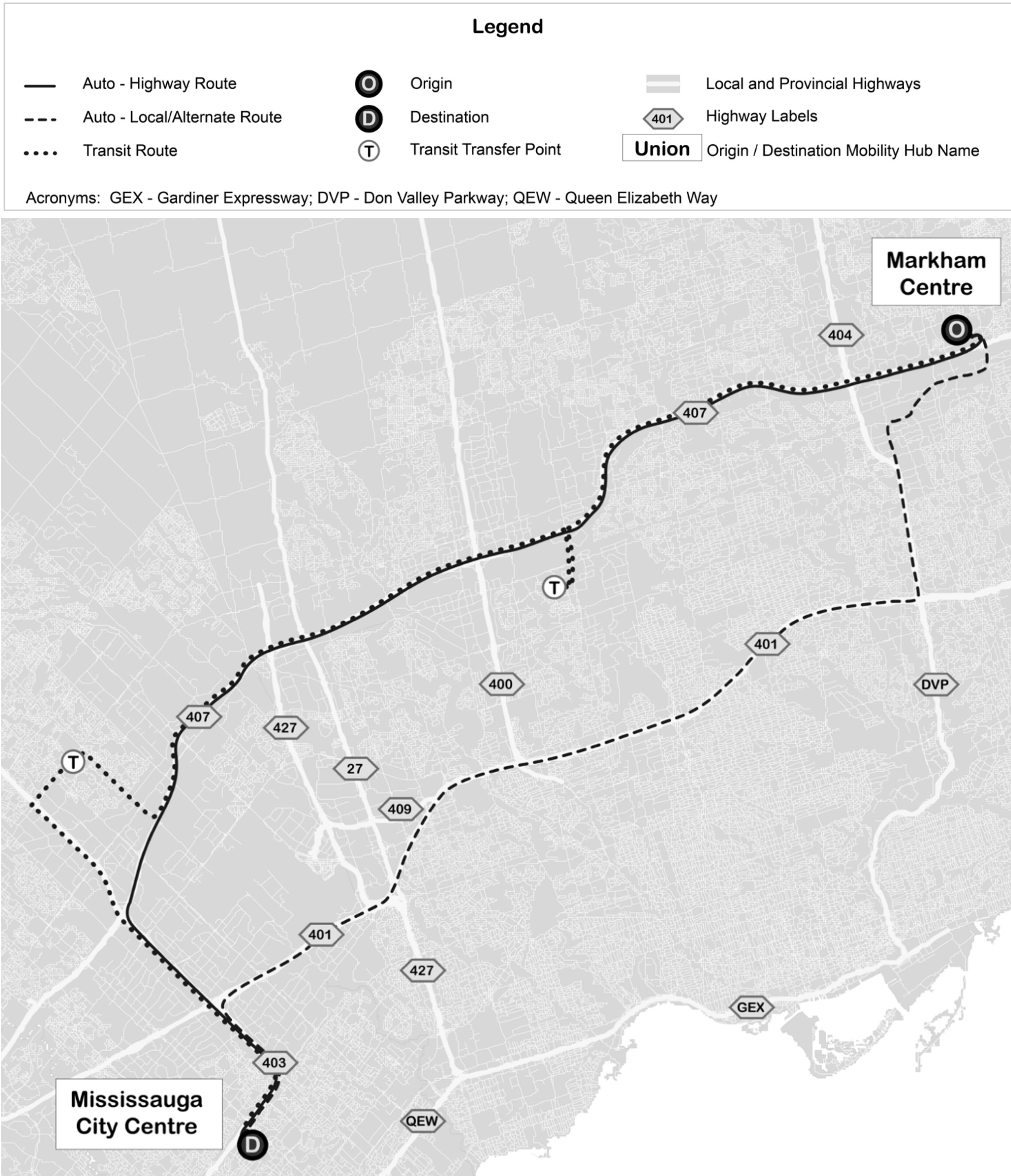


Figure 10 Mississauga City Centre and Markham Centre Mobility Hubs with connecting paths and modes

Table 4 Costs of travel between Mississauga City Centre and Markham Centre mobility hubs

Westbound: Markham Centre – Mississauga City Centre						
Period	**Travel Time (min)**			**Generalized Cost ($)**		
	Auto – Highway	**Auto – Local/Alternate**	**Transit**	**Auto – Highway**	**Auto – Local/Alternate**	**Transit**
AM Peak	45	65	91	26.86	19.14	24.80
Midday	45	60	73	24.45	17.92	21.30
PM Peak	55	90	81	28.86	23.92	22.80
Ratio of $GC_{Alternative}$ / $GC_{Alternate\ Highway}$					**Auto – Highway**	**Transit**
AM Peak					1.40	1.30
Midday					1.36	1.19
PM Peak					1.21	0.95
Eastbound: Mississauga City Centre – Markham Centre						
Period	**Travel Time (min)**			**Generalized Cost ($)**		
	Auto – Highway	**Auto – Local/Alternate**	**Transit**	**Auto – Highway**	**Auto – Local/Alternate**	**Transit**
AM Peak	40	70	72	26.01	19.90	21.00
Midday	40	55	74	23.57	16.90	21.50
PM Peak	60	100	92	30.03	25.90	25.00
Ratio of $GC_{Alternative}$ / $GC_{Alternate\ Highway}$					**Auto – Highway**	**Transit**
AM Peak					1.31	1.06
Midday					1.39	1.27
PM Peak					1.16	0.97

In this corridor, in both the eastbound and westbound directions, the Auto Highway and Transit alternatives are generally not cost competitive to the baseline auto alternative. The tolled highway offers significant travel time savings over the other options, though these travel time savings are offset by the toll charge – approximately $12 in the peak period. Travel by transit is comparable in cost to the baseline auto alternative during the PM peak, but less so in the AM peak and midday.

Since the travel time for the tolled highway is significantly less than the alternate highway, excess capacity may be available on Highway 407. In this case, the non-tolled highways are significantly underpriced compared to the tolled Highway 407 route. Information may assist in shifting demand by space; however, there is no economic incentive to induce this shift. The introduction of a toll on Highway 401, which runs parallel to Highway 407, would further encourage travel demand to shift from Highway 401 to Highway 407. A sensitivity analysis was conducted to determine the price point at which the two highway alternatives are equally competitive. The results of this analysis are illustrated in Figures 11 and 12.

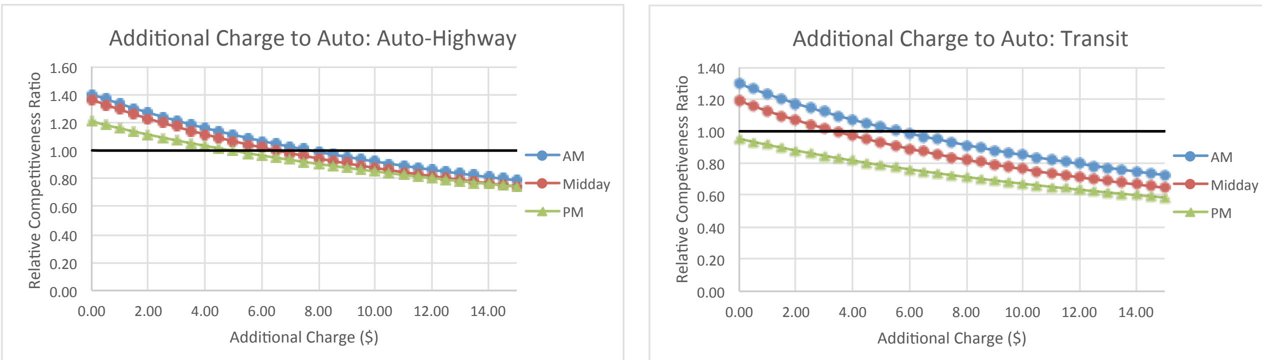


Figure 11 Sensitivity analysis of generalized costs for Markham Centre to Mississauga City Centre (WB)

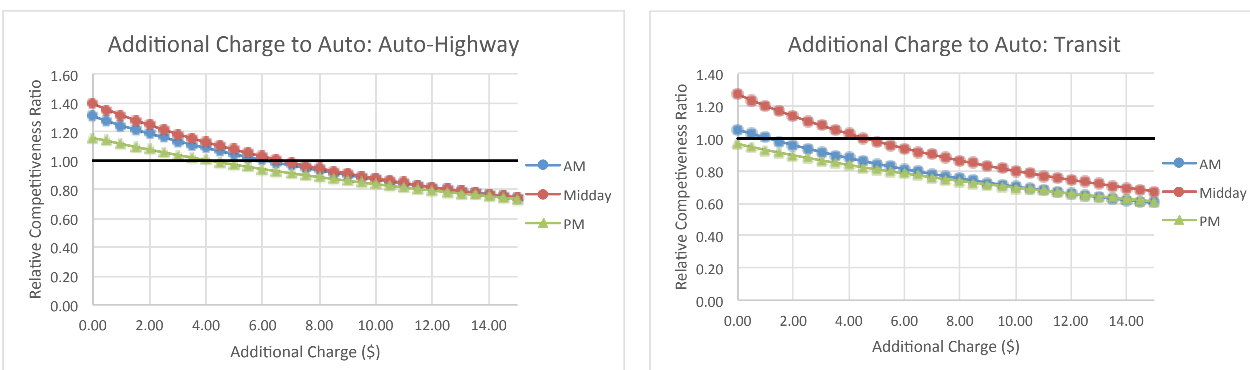


Figure 12 Sensitivity analysis of generalized costs for Mississauga City Centre to Markham Centre (EB)

In both the westbound and eastbound directions, the sensitivity analyses in Figures 11 and 12 show that an additional cost of approximately $6 to the price of driving on Highway 401 produces a competitiveness ratio of about 1.0, or equal generalized cost to that of driving on Highway 407. This additional cost may address the current underpricing of travel on Highway 401, and encourage a shift in travel demand to use the excess capacity available on the tolled highway. Similar changes to the cost ratio between transit and auto driving, as well as improved provision of information, may also motivate shift towards transit. Further analysis of the capacity available on competing transit alternatives will be needed to fully understand the feasibility of this shift.

Case 3: Downtown Oshawa and Airport

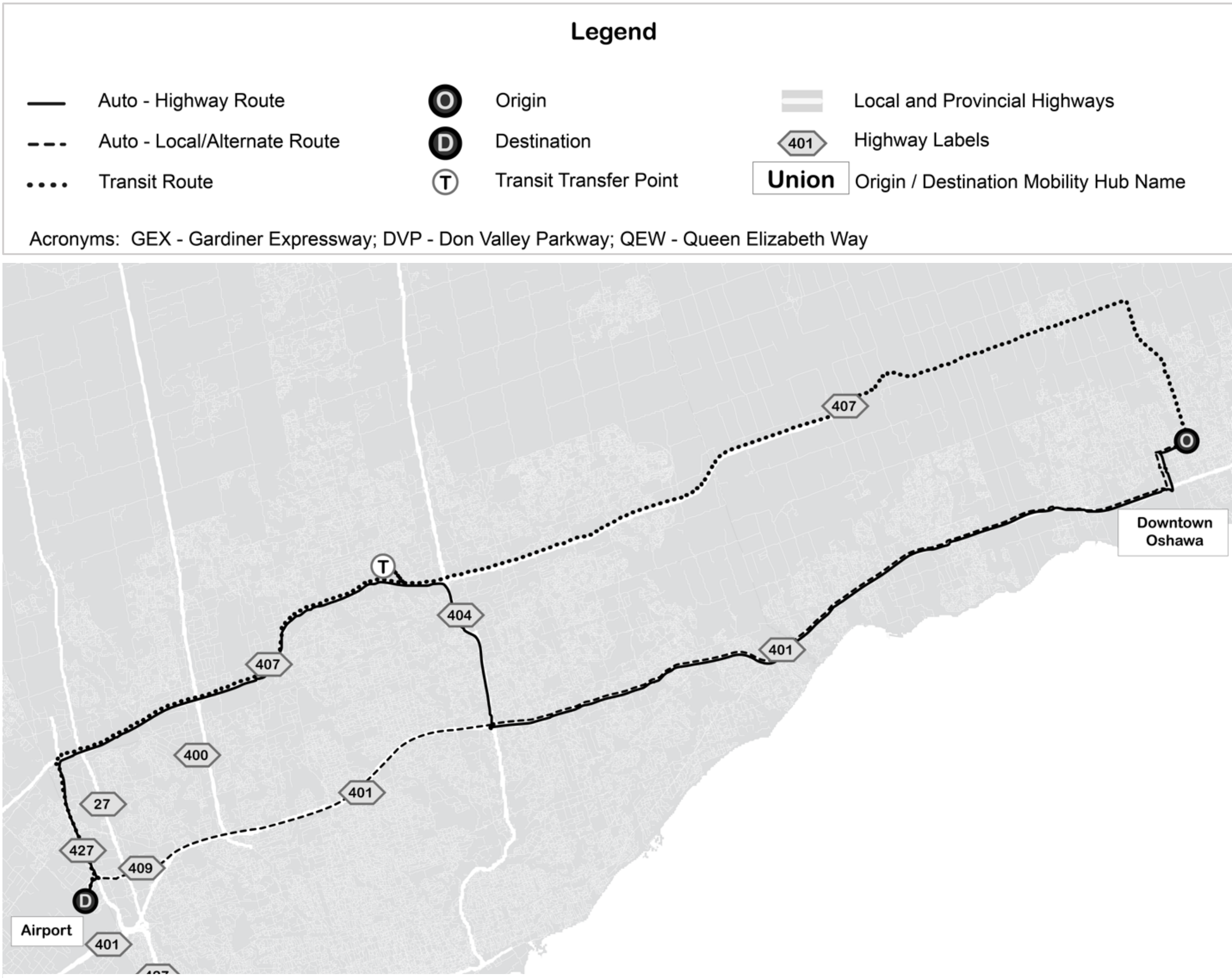


Figure 13 Downtown Oshawa and Airport Mobility Hubs with connecting paths and modes

The third case looks at another cross-regional trip between Downtown Oshawa and the Airport. The Downtown Oshawa mobility hub is located near King and Centre Streets, and is an area that has been designated for growth. Oshawa is home to three post-secondary institutions, including Durham College, Trent University Durham, and the University of Ontario Institute of Technology. The city is also a centre for manufacturing, and a growing centre for information technologies. The hub is located in the historic centre of the City of Oshawa, and the Oshawa Bus terminal is located within the immediate vicinity of the hub. The Oshawa Municipal Airport is located just outside of the downtown to the North, and the Oshawa GO Rail Station is immediately south of the hub. Though Downtown Oshawa is relatively small, there is a large residential population located outside the downtown and in the neighbouring communities. The area is in close proximity to Highway 401, and will be serviced by the extension of Highway 407 Express Toll Route in the near future.

The Airport mobility hub includes Pearson International Airport and the employment district that surrounds it. Aside from being home to the busiest airport in Canada, the Airport mobility hub is also a major employment centre for manufacturing, warehousing and distribution.

The routes analysed are shown in Figure 13 above. The Auto-Local/Alternate route has been designated as the baseline alternative, and uses Highways 401 and 409 for the majority of travel. The Auto-Highway alternative is a tolled alternative using a combination of Highway 401, Highway 404, Highway 407, and Highway 427. The Transit alternative includes GO Transit's 407 East express service, route 52, which connects to the Hamilton / Richmond Hill Pearson Express GO Bus at Richmond Hill Centre. The routing of alternatives is the same for both directions of travel.

Table 5 Costs of travel between Downtown Oshawa and Airport mobility hubs

Westbound: Downtown Oshawa – Airport						
Period	**Travel Time (min)**			**Generalized Cost ($)**		
	Auto – Highway	**Auto – Local/Alternate**	**Transit**	**Auto – Highway**	**Auto – Local/Alternate**	**Transit**
AM Peak	120	120	128	40.33	32.17	35.68
Midday	65	55	123	27.85	19.17	34.68
PM Peak	75	70	138	31.33	22.17	37.68
Ratio of $GC_{Alternative}$ / $GC_{Alternate\ Highway}$					**Auto – Highway**	**Transit**
AM Peak					1.25	1.11
Midday					1.45	1.81
PM Peak					1.41	1.70
Eastbound: Airport – Downtown Oshawa						
Period	**Travel Time (min)**			**Generalized Cost ($)**		
	Auto – Highway	**Auto – Local/Alternate**	**Transit**	**Auto – Highway**	**Auto – Local/Alternate**	**Transit**
AM Peak	80.00	70.00	113.57	39.54	22.28	32.79
Midday	75.00	60.00	126.57	30.01	20.28	34.81
PM Peak	100.00	110.00	134.57	43.76	30.28	36.41
Ratio of $GC_{Alternative}$ / $GC_{Alternate\ Highway}$					**Auto – Highway**	**Transit**
AM Peak					1.77	1.47

Midday	1.48	1.72
PM Peak	1.44	1.20

The results of the generalized cost analysis, shown in Table 5, suggest that neither alternative is currently competitive in cost with the baseline scenario of travelling between the two hubs using Highway 401 and Highway 409. In all directions and periods of the day, the Auto-Highway alternative not only costs more, but also adds to the time that is needed. This is likely because use of the Highway 407 Express Toll Route between these two hubs requires additional north-south travel on Highways 427 and 404, lengthening the path of travel and amount of exposure to congested roadways, as well adding to the cost through through toll charges. While the travel time of the tolled route is comparable to the untolled option during AM peak going westbound, and the PM peak going eastbound, the added cost makes it less desirable. Transit travel in this corridor is also not competitive in either cost or travel time.

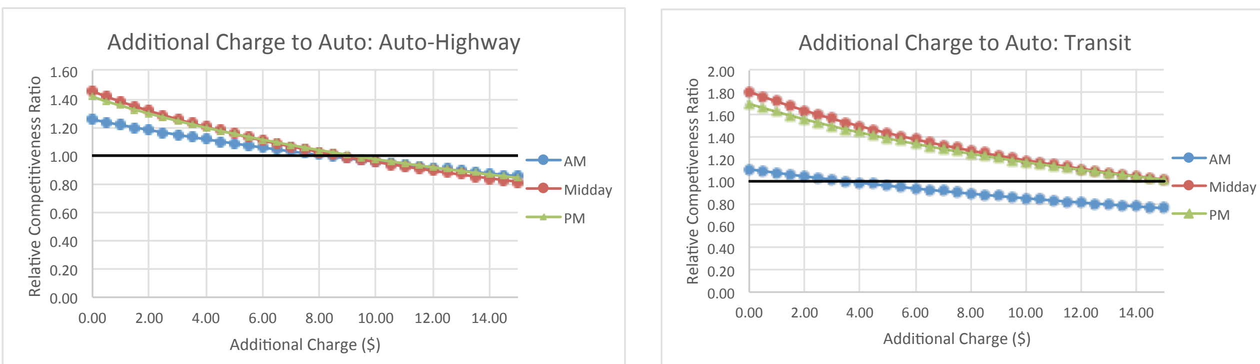


Figure 14 Sensitivity analysis of generalized costs for Downtown Oshawa to Airport (WB)

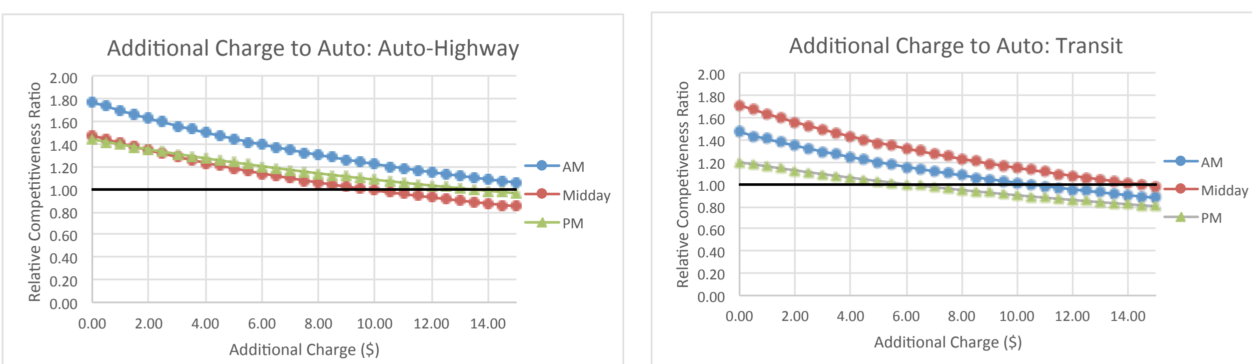


Figure 15 Sensitivity analysis of generalized costs for Airport to Downtown Oshawa (EB)

The sensitivity analysis shown in Figures 14 and 15 shows that significant charges to the auto baseline scenario would be needed to make either alternative more viable. For transit, this comes at a cost of approximately $15, which is about 50-80% of the total trip cost for the baseline. As this represents a significant increase to the cost, other measures such as improvement of the travel time, frequency, and pricing of the transit alternative would be recommended before considering this increase to the cost of auto travel.

Summary of Opportunities and Jurisdictional Challenges

The analysis described provides a high-level overview of the opportunities available to manage travel demand in the GTHA at a regional level. Two approaches were taken: an assessment of the opportunity to shift demand in time across major facilities in the GTHA; and the possibility to shift travel demand between major nodes across alternative routes and modes. The following provides a summary of the opportunities found, and provides discussion of how Metrolinx and its partners may approach some of the recommendations provided.

Summary of Opportunities to Shift in Time

Using data available for the GTHA, a total of five major highway facilities were analysed for the Shift in Time analysis. The results of this analysis have been highlighted in Figure 16.

At least some opportunity to shift travel demand in time exists on all the facilities studied in this analysis. On Highway 404 / DVP, the most congested corridor, opportunities exist only in the northbound direction during the AM peak. At other times of the day and for the entire day in the opposing direction, other demand management strategies, such as those that aim to shift demand in space and in mode, should be considered.

On Highway 401, the eastern portion is largely uncongested for much of the day, except for two sections in the eastbound direction during the afternoon. In the western portion of Highway 401, the facility is congested in the eastbound direction for the morning, and the westbound direction in the afternoon. This suggests that commuting patterns in the western part of the region are strongly unidirectional, with greater travel demand in the inbound direction during the morning, and in the outbound direction for the afternoon. Employer based initiatives that improve awareness and greater flexibility of work hours may be effective here.

In the remaining corridors, QEW and the Gardiner Expressway, congestion persistently occurs at the same short segments of the facility. While TDM initiatives may provide some relief to these pressure points, this type of congestion may be indicative of issues related to the physical geometry or management of information on the highway facility. More study into these specific pressure points in the facility may be needed.

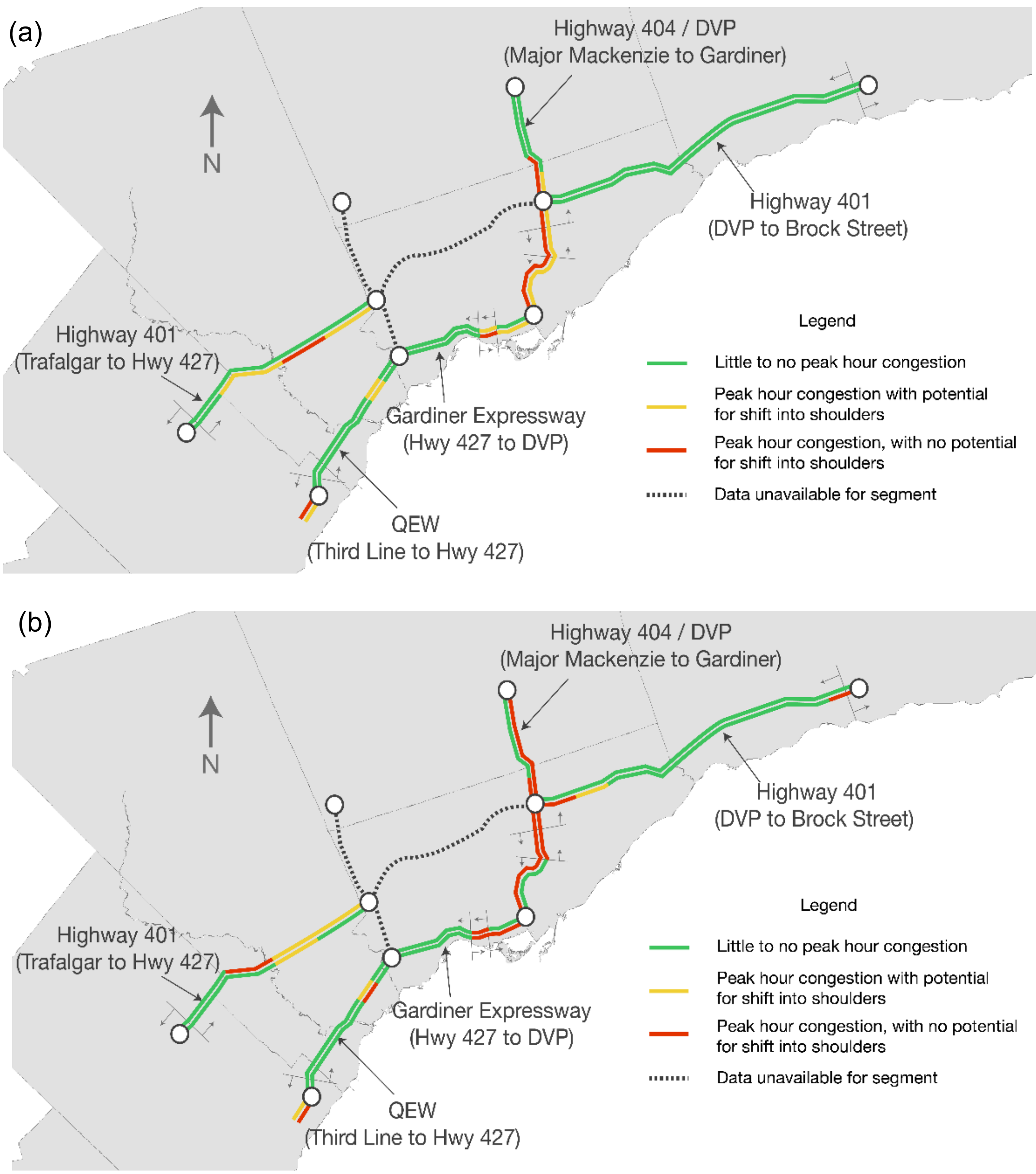


Figure 16 Summary of opportunities to shift travel demand in time for morning (a) and afternoon (b)

Summary of Opportunities to Shift in Space and Mode

Level of Potential for TDM Success	High Potential	Moderate Potential	No Potential
Number of Cases	181	559	49
Percent of Cases	23%	71%	6%

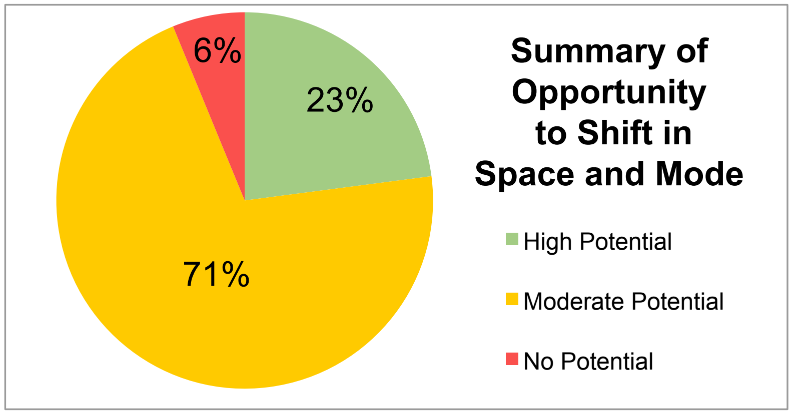


Figure 17 Summary of Opportunity to Shift in Space and Mode

For the generalized cost analysis, a total of 1185 scenarios were tested. This includes all time-of-day and mode scenarios for each origin-destination pair among the 11 chosen mobility hubs, plus 2 additional origin locations, Yonge and Bloor, and Port Credit, which were included as secondary nodes.

The scenarios analysed were classified by the level of potential for TDM success. Where the competitiveness ratios of the scenario to the baseline case were between 0 to 1, the scenario was considered to have high potential for shift. Those with competitiveness ratios of 1 to 2 were considered to have moderate potential. Lastly, those with a competitiveness ratio of greater than 2 were considered not competitive at all and classified as having no potential for TDM success.

The analysis found that about 23% of the scenarios tested were competitive in cost to the respective base case scenario, and had high potential for TDM success. Under these conditions, greater awareness of the competing alternatives, and further study into the available capacity of the individual alternatives is needed. Since the cost is already comparable, little to no financial triggers should be needed to motivate the shift if travelers are made aware of the time or cost saving benefits.

Approximately 71% of the cases were found to have moderate potential for TDM success. This segment of the scenarios were found to be not competitive in cost to the respective base case scenario, but could be made more competitive with an adjustment to the costs. Financial incentives and disincentives that aim to rebalance the relative competitiveness ratios may be most effective here. To motivate shift in space between different roadway facilities, TDM initiatives such as road pricing are likely to have the most direct impact. Where transit is concerned, service improvements that hep to decrease travel or wait times, and decreases to fare costs can help to lower overall costs, and make it a more competitive alternative. At the same time, adjustments to destination parking policies and prices have the potential to decrease driving and motivate a shift in travel demand to other modes such as transit.

Lastly, about 6% of the scenarios tested yielded competitiveness ratios of greater than 2 and were considered in this analysis to be not competitive. In these scenarios, the cost of the alternative is more than double the cost of the baseline alternative, and only drastic, and likely unrealistic, adjustments to the relative costs would be able to make the travel costs more competitive.

Where these cases exist, improvements to infrastructure or transit service provision may be warranted. Out of all the scenarios in this classification, only 2 come from the shift in space analysis. The remainder represents scenarios in the shift in mode analysis where the transit alternative is significantly more costly than the baseline.

Figure 18 shows the shift in mode scenarios classified by level of potential for each destination mobility hub. Locations that are well served by transit, such as Toronto Union Station, suggest that transit is nearly always competitive. On the other hand, Pearson Airport as well as Jane and Finch had many scenarios that were not competitive, suggesting that these nodes are still lacking in transit connections from some of the other Mobility Hubs selected.

Prior to introducing pricing schemes intended to shift travel demand, proper transit connections must be provided so that viable alternatives are available. Adjustments to fare charges in the region through fare integration should also be made a priority as the higher cost of transit in many of the scenarios tested were found to be a result of double fares charged from crossing between the services of different service providers.

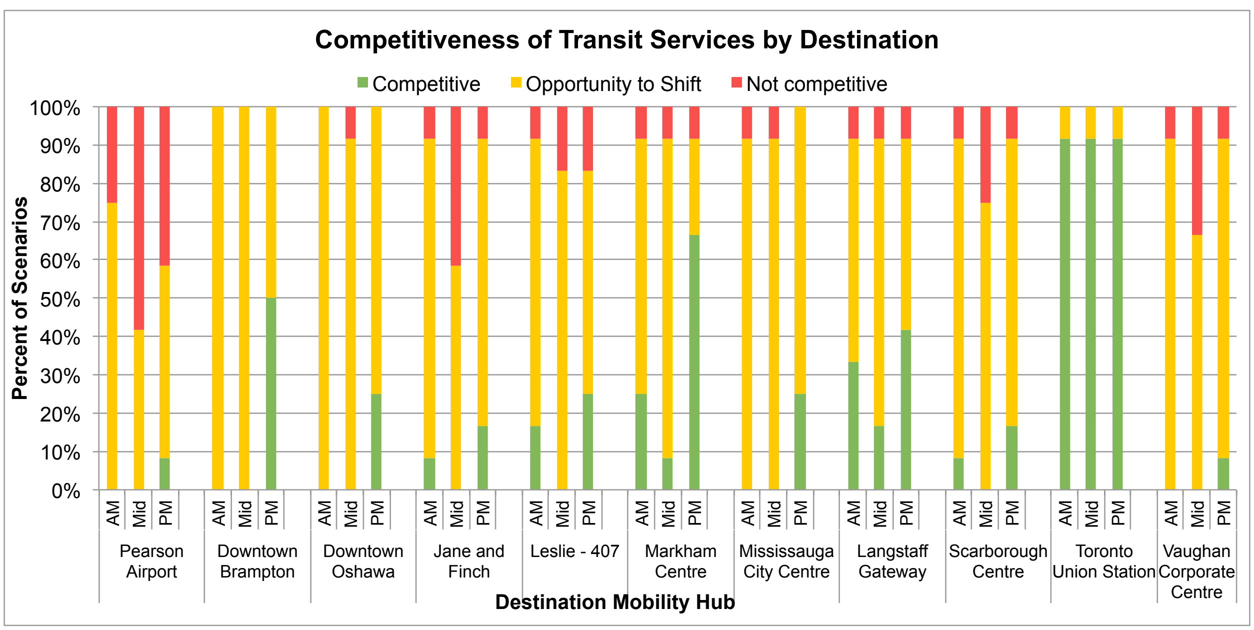


Figure 18 Competitiveness of Transit Services by Destination

Jurisdictional Challenges

Providing relief for regional travel flows will require extensive regional coordination. In most of the road-based scenarios assessed in this analysis, we assumed that the cross-regional movements use freeway facilities under the jurisdiction of the Ministry of Transportation, 407ETR, and The City of Toronto in the case of the DVP and Gardiner Expressway. Should a TDM initiative such as a dynamic road-pricing scheme be introduced, the facilities to which it would be applied would likely be under the jurisdiction of the Ministry of Transportation. But, the impact of the traffic diverted from the roadway would have implications for local roads which are managed by the municipalities. The potential for jurisdictional challenges to arise is quite high. We also recognize that Metrolinx has limited jurisdictional control over roadways in the GTHA; that being said, as a Regional Transportation Planning Agency, Metrolinx does have the capacity to help facilitate the dialog necessary to achieve regional objectives.

TDM initiatives such as parking charges or reductions to the cost of transit may be most effective to generate shifts in mode. However, these programs require agreement among multiple municipalities and transit service providers in order to be most effective. Current co-fare agreements between transit agencies in the GTHA and GO Transit represent a positive first step towards a fare system that better represents the nature of the commuter trips taken. Further progress on Metrolinx' vision for regional fare and service integration would help to make the transit system a more viable option for travel across the region.

Metrolinx currently has a strong program for employer-based TDM. Smart Commute is primarily focused on spreading awareness, and encouraging employers to adopt policies and practices such as flexible hours or telecommuting to allow employees the opportunity to shift their travel behaviour as needed. This should continue to be an integral part of any TDM strategy moving forward.

Expanding Metrolinx's capacity to implement advanced TDM initiatives, particularly those that require changes in economic signals, can be achieved in one of two ways. Metrolinx can continue as the regional planning agency and, in this capacity, work to coordinate across the multiple jurisdictions – the Province, the City of Toronto and adjacent municipalities – to introduce new pricing models. An alternative, more robust model, would be to reconsider the jurisdictional definitions in the region, with a goal of allowing Metrolinx more direct control of Provincial Highway operations – including the implementation of pricing.

It is recommended that the mandate set out for Metrolinx be revisited by the provincial government to ensure that the regional transportation agency has the appropriate authority to carry out strategies on a regional scale. For regional TDM initiatives to succeed, Metrolinx needs to be given greater access and authority over the roadway system. This would allow for improved monitoring of the freeway network, and provide a clearer picture of the true opportunities for demand management on the ground. Greater oversight over the the roadway system would also enable Metrolinx to manage travel demand in the region from a more holistic perspective that includes both the road and transit systems.

Conclusions and Recommendations

This report has presented a method of analysis for critical facilities in the Greater Toronto and Hamilton Area to determine the feasibility of implementing TDM initiatives. The potential to shift demand in time was assessed for sections of Highways 401 and 404, as well as the Gardiner Expressway, The Don Valley Parkway and the Queen Elizabeth Way. The results suggest that there are few to moderate opportunities to shift demand from a time with congestion to an adjacent time period where excess capacities exist. Even with improved information or economic signals, shifts in time do not appear to be a particularly impactful TDM measure for the GTHA.

The report has also presented a method of analysis for travel between critical activity centres, or Mobility Hubs, in the GTHA. The costs (including time and out of pocket expenses) of travel by the most direct automobile path were compared to completing the same trip by an alternative auto path, or the best alternative transit connection. The results suggest that in some cases, parallel arterials exist for which excess capacity exists and, as a result, a shift of volume from the freeway to the arterial may produce a net reduction in congestion for the system. The only TDM initiative that may be necessary in this case is information to drivers about the potential travel time savings.

Similarly, there are several origin and destination pairs for which transit currently provides a lower cost alternative than travel by auto. Again, in order to promote improved transportation system performance, information can be provided to travelers about the presence of transit, and its lower costs compared to auto.

Unfortunately, the number of cases where information provision is all that is necessary to improve the system performance is very small; only about 6% of the origins and destinations we analyzed present these characteristics.

Far more prevalent are cases where the current pricing of auto travel makes one path singularly attractive, concentrating demand into a single corridor and producing significant traffic congestion. For these origin destination pairs, economic signals – increased prices on the lowest cost alternative – are necessary to influence individual travelers to other routes or modes. While increasing the cost of travel, these economic signals have the potential to improve system performance and to generate significant revenues for new infrastructure investments in the GTHA.

The primary recommendation from this report is to prioritize corridors in terms of the magnitude of economic signals necessary to produce the most significant mode shift and, as a result, the greatest positive impact on system performance. The secondary recommendation is for Metrolinx to coordinate amongst its partner agencies – MTO, the City of Toronto, or other municipalities – to develop a schedule and implementation strategy for the introduction of these economic signals.

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