METROLINX

TRANSPORTATION SYSTEMS MANAGEMENT

Background Paper to the
Draft 2041 Regional Transportation Plan

Prepared for Metrolinx
by IBI Group
2017

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Draft Report

Transportation Systems Management

Regional Transportation Plan Background Paper

IBI

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Executive Summary

This report provides background information about Transportation System Management (TSM) principles and how they can be applied within the framework of the Metrolinx Regional Transportation Plan (RTP). To this end, the report builds a case for the TSM approach, identifies gaps in TSM deployment in the Greater Toronto and Hamilton Area (GTHA), and suggests strategic directions for consideration.

What is Transportation System Management (TSM)?

Transportation Systems Management (TSM) refers to **operational strategies that improve the performance of existing infrastructure** through the implementation of technology, services, and processes. It is a “supply side” intervention in that it involves adjustments to the transportation network to improve performance and thereby reduce congestion and/or delays. This includes, but is not limited to, Intelligent Transportation Systems (ITS) technologies that can be applied to achieve TSM goals. In short, TSM can include nearly any operational intervention that improves performance without the construction of new infrastructure capacity. Some of the most common and effective techniques include:

- Traffic management;
- Traveller information;
- Transit technology;
- Traffic signal adjustments; and
- Managed lanes.

These techniques are complementary to the investments in new infrastructure prescribed by The Big Move, 2008 and the updated Draft RTP, and can help to ensure that existing infrastructure is being used to its full potential. Inherently holistic in its approach, TSM offers the opportunity to rethink the way our transportation system is operated in order to make the most out of past and future capital investments.

The Case for TSM

TSM measures are attractive because they **deliver operational improvements without large capital expenditures**. They are particularly useful in addressing issues that are not caused by a lack of transportation capacity, such as incidents or construction.

Return on investment

Although return on investment varies substantially depending on the number of trips affected and the sophistication of the measures employed, TSM interventions are typically highly cost effective and can improve reliability, reduce congestion, or improve safety to a degree that is substantially greater than the cost of implementation. Signal retiming, for example, can produce economic benefits that are dozens of times higher than the cost of implementation.

Non-recurring congestion

According to the US Federal Highways Administration, as much as 60% of congestion delays are a result of “non-recurring” sources, such as incidents, events, adverse weather, and construction. Adding new capacity does not directly address these sources of congestion and it is therefore up to transportation operators to mitigate their impact using a variety of approaches, including TSM measures.

Network optimization

The application of TSM can optimize the capacity of existing infrastructure by improving efficiency and by intelligently allocating road space to maximize throughput. This is an important consideration in urban environments where property and geographic constraints limit the ability to expand infrastructure capacity.

Proven methods

The concept of TSM has been around for many years, and its techniques have been deployed with great success all around the world. This includes numerous existing deployment in the GTHA, including the Ministry of Transportation's HOV/HOT lanes, the City of Toronto's real-time adaptive signal control system, and York Region's schedule-based traffic signal priority scheme for its Viva BRT routes.

TSM Gaps in the GTHA

Although there have been isolated implementations of TSM in the GTHA for many years, **there is significant room for improvement in the sophistication, dissemination, and coordination of these measures**:

- **Traffic management,** including improved data sharing between agencies, coordinated operations, and complementary technologies;
- **Traveller information,** including movement towards open data standards, and improved sharing with other public and private sector entities;
- **Transit technology,** including fully leveraging the availability of data to improve operations, improved coordination between transit agencies and with traffic operators, and compliance with AODA regulations;
- **Traffic signals,** including improving interoperability of signal priority and signal coordination across municipal boundaries, developing a consistent hierarchy for different road users, and ensuring appropriate data availability to support retiming and coordination; and
- **Managed lanes,** including the establishment of a connected network of managed lanes throughout the GTHA and deploying effective enforcement strategies to curb misuse.

Strategic Directions

The following directions will set the stage for improvements to the operation of the GTHA transportation network through innovative and progressive TSM strategies. They also provide a catalyst for the development of a coordinated plan for the deployment of TSM in the GTHA.

Work Together to Manage Operations

Improving interoperability and communication between the GTHA's transportation agencies will be one of the most important elements of any TSM plan for the region. This could include, for example, the development of a GTHA-wide operations strategy and the creation of regional operations working groups.

Adapt Infrastructure to Suit Changing Needs

Evolving travel behaviour and new technologies have a direct effect on how existing infrastructure is used. This is especially prevalent as roadway space becomes scarce in congested regions such as the GTHA. TSM strategies can potentially add more capacity to the network, through measures such as improved enforcement, adapting transit operations to leverage available data, and the prioritization of road space for key travel markets.

Keep the Public Informed

Traveller information is one of the most powerful ways to influence mobility. By making information about the transportation system available, trip makers can make more informed decisions about how, when, or if they want to travel. These decisions can be influenced by increasing the amount and sophistication of available data, and ensuring that the data is available to third party developers.

Embrace Data-Driven Decision Making

The vast quantities of information being generated by the GTHA's transportation system present a tremendous opportunity to improve transportation operations. If properly collected and interpreted, this data has the potential to streamline operational decisions, predict the impact of major operational interventions to the transportation network, and provide a greater evidence base for operational decisions.

Set Targets and Monitor Performance

Setting a goal is the first step towards improvement, and the best way to track progress towards this goal is to monitor performance at each step. A GTHA Transportation Systems Management Master Plan that sets performance metrics and develops monitoring schedule could be the first step towards creating a culture and practice of continuous operational improvement.

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1 Introduction

1.1 What Is Transportation Systems Management (TSM)?

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A different technique known as Travel Demand Management (TDM) has the objective of modifying travel behaviour to achieve the same goals of congestion and delay reduction. TSM and TDM are complimentary, but whereas TDM seeks to modify demand to improve network conditions, TSM improves network conditions for a given level of demand.

Given its broad scope, there are many different examples of TSM measures that are currently implemented in practice. Some of the most common and effective techniques include:

- **Traffic management**, including:
  - **Integrated corridor management** and deployment of interventions (e.g. variable speed limits, traveller information, signal timing) in response to changing conditions;
  - **Incident and emergency management:** Operational responses to traffic incidents, major events, and adverse weather conditions to minimize the impact of non-recurring congestion and delays.
- **Traveller information:** The dissemination of information about network conditions and operations to influence route choice or driving behaviour. This includes real-time information (e.g. the location of current incidents or congestion), predictive information (e.g. a prediction of future conditions on the basis of current conditions and historical norms), or trip-planning information (e.g. a suggested route between origin and destination).
- **Transit Technology:** The application of location monitoring, dispatching, and fare technologies to improve transit network operations and information dissemination.
- **Traffic signal adjustments,** including:
  - **Traffic signal priority and pre-emption:** The prioritization of one traffic movement over another in response to the presence of transit or emergency vehicles;
  - **Traffic signal optimization:** The re-timing of traffic signals to maximize corridor or network throughput.
- **Managed lanes:** The allocation of dedicated road space to a select group of vehicles, such as high-occupancy vehicles, transit vehicles, or toll customers.

1.2 TSM and the Regional Transportation Plan

The Regional Transportation Plan (RTP) establishes a critical long-term vision for transportation in the Greater Toronto and Hamilton Area (GTHA), outlining goals to be achieved in the future and identifying the transportation initiatives needed to meet these goals. The Draft Plan continues in the tradition of The Big Move by recommending a significant investment in regional transit infrastructure, along with supporting policies.

New transportation capacity is clearly necessary to alleviate the transportation issues currently being faced in the GTHA. TSM is complimentary to these new investments and can help to ensure that existing infrastructure is being used to its full potential.

Policy supportive of TSM is at the heart of The Big Move, Metrolinx's first Regional Transportation Plan. Among the plan's 13 goals, one is dedicated to "(optimizing) the use of resources and provid(ing) better value to households, businesses, and governments", with subsidiary objectives to improve the value of transportation investments and increase the productivity of the transportation system.

L. **Efficiency and Effectiveness:** The transportation system will be designed to optimize the use of resources and provide better value to households, businesses and governments. Greater emphasis will be placed on moving people and goods, rather than vehicles.

28. Increased prevalence of Transportation Demand Management practices

29. Improved value of transportation investment and spending for households, businesses and governments

30. Optimized use of all travel rights-of-way by commercial vehicles through a range of incentives and disincentives

31. Increased productivity of the transportation system

The inclusion of an objective within The Big Move specific to the optimization of infrastructure is a reflection of the importance that key policy makers within the Region attached to the efficiency of transportation network operations moving forward. These types of objectives are the domain of TSM, which has the aim of optimizing system operations without new transportation capacity. In short, the goals of the The Big Move cannot be achieved solely by building new and improved infrastructure. There is a need to rethink the way our transportation system is operated in order to make the most out of past and future capital investments.

1.3 About this Report

The purpose of this report is to outline a long-term strategy for TSM and how the GTHA can best leverage this approach to improve system and corridor performance. The report:

- Articulates the benefits of TSM (Section 2);
- Assesses the state of TSM in the GTHA today, with a particular focus on identifying gaps (Section 3);
- Identifies key trends impacting the deployment of TSM in the GTHA and elsewhere (Section 4); and
- Provides strategic direction for future TSM studies and initiatives (Section 5).

2 The Case for TSM

2.1 Network Optimization

As transportation demand in the GTHA has increased, congestion has worsened and the competition for road space has increased. The application of TSM measures can optimize the capacity of existing infrastructure by improving efficiency and by intelligently allocating road space to maximize throughput. For example, signal optimization can maximize corridor throughput for different traffic conditions at different times of day. A focussed signal retiming effort has been recently undertaken in Toronto, resulting in travel time savings of upwards of 4% in many corridors. This is illustrated in the table below.

Exhibit 2.1: Measures of Corridor Performance Before and After Signal Coordination (2012–2015)

Metric	Before	After	Difference	% Difference
Total Travel Time (h)	59,111,000	56,496,000	- 2,615,000	- 9%
Total Delay (h)	29,603,000	26,948,000	- 2,655,000	- 4%
Average Speed (km/h)	28.4	29.5	1.1	+ 4%

Source: City of Toronto Transportation Services: *Signal Optimization (Coordination)*[1]

Other TSM measures used to optimize network performance include:

- **Signal priority** to reduce delay for transit vehicles carrying large numbers of passengers; and
- **Managed lanes** to give preferential treatment to transit, high-occupancy vehicles, or trucks. This can come in the form of technology to adjust lane restrictions (changing from HOV3+ to HOV2+ for instance) based on time of day, network conditions, or other factors. Today's technology can also optimize toll levels in near real time, which can in turn increase network capacity.

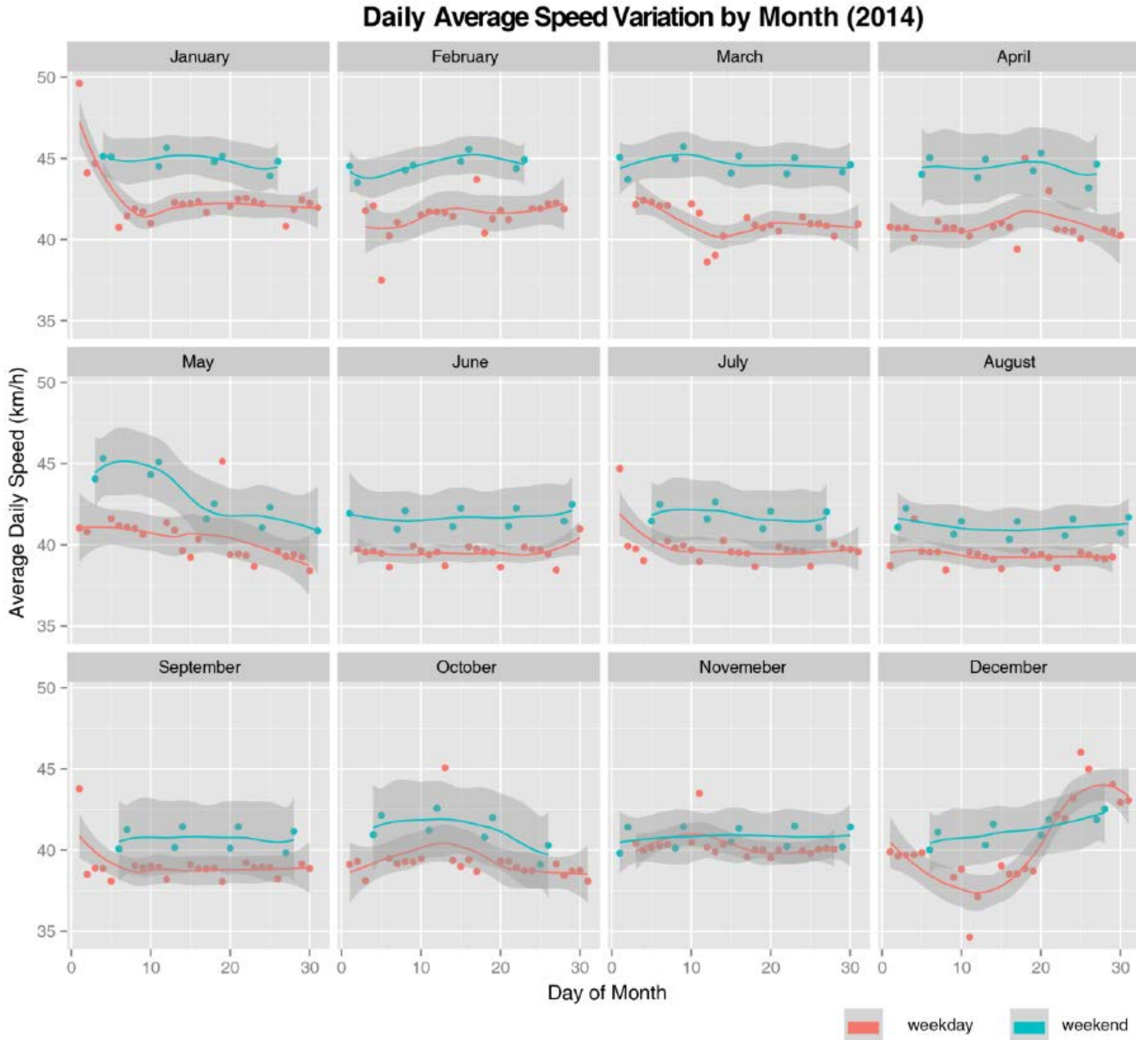
2.2 Non-Recurring Congestion

It is natural to think that the primary cause of congestion is too much demand for the amount of available capacity. However, according to the U.S. Federal Highways Administration, as much as 60% of congestion delays are a result of "non-recurring" sources, such as incidents, events, adverse weather, and construction. Adding new capacity does not directly address these sources of congestion; it is up to transportation operators to mitigate their impact using a variety of approaches.

Recent investigations by the City of Toronto's Big Data Innovation Team have shown that the magnitude and timing of congestion is extremely variable, and that all of the City's most congested days can be attributed to non-recurring sources of delay.

[1] https://www1.toronto.ca/wps/portal/contentonly?vgnextoid=0c9d9325bd1ec410VgnVCM10000071d60f89RCRD&vgnextchannel=9452722c231ec410VgnVCM10000071d60f89RCRD

Exhibit 2.2: Average Daily Speed Variation on Toronto Arterial Roadways in 2014



Source: City of Toronto Transportation Services: *Congested Days in Toronto*[2]

The application of TSM measures can support and enhance the resiliency of transportation network by improving responses to changing operational conditions. Examples of such responses include:

- **Real-time information** about current travel conditions to enable trip makers to make more informed decisions about their route;
- **Incident detection and response** procedures to reduce the amount of time that disabled vehicles impede the flow of traffic; and
- **Real-time operational responses** such as ramp metering, road closures, or additional transit vehicles to adjust transportation supply in response to changing conditions.

[2] https://www1.toronto.ca/City%20Of%20Toronto/Transportation%20Services/Big%20Data%20Innovation/Download%20FIles/McMaster-SummaryPresentation_2015-11-02_FINAL.pdf

2.3 Return on Investment

One of the most attractive features of TSM measures is that they typically generate a substantial amount of benefit in relation to their cost—particularly in comparison to the construction of new infrastructure. Although return on investment varies substantially depending on the number of trips affected and the sophistication of the measures employed, TSM interventions can improve reliability, reduce congestion, or improve safety to a degree that is well worth the cost of implementation.

For example, the investment in retiming traffic signals may result in a decrease in travel time from between 5% to 10% for a corridor at a small fraction of the cost of roadway widening. Recent signal coordination contracts for the City of Toronto's urban corridors have cost approximately $12,000/km. This combination of low cost and tangible benefit has resulted in benefit-to-cost ratios ranging from 55:1 to 75:1[3]. By comparison, urban arterial lane widenings can cost between $1,000,000 and $2,000,000 per km (exclusive of property costs) and, while delivering greater time savings, do not result in the same level of benefit relative to cost.

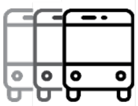
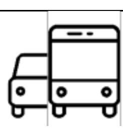
2.4 TSM in Practice

This section provides an overview of various types of TSM implementations as an illustration of the proven effectiveness of TSM techniques. The first part of the section provides a "toolkit" of the most commonly applied TSM measures and a description of how they are typically used in practice. While the toolkit is not intended to be exhaustive, the measures listed have been successfully applied and proven in jurisdictions throughout North America. A TSM implementation typically includes a combination of measures as part of an integrated package that are customized to the characteristics of a corridor or an area to best satisfy the transportation objectives.

The subsequent part of the section then presents some case studies that demonstrate how various measures identified in the toolkit can be integrated into a particular TSM application. The case studies include managed lanes, smart corridors, priority bus and the 2015 Toronto Pan Am/Parapan Am Games, and are provided with a description of the implementation, the TSM measures applied, its key features and some success metrics.

[3] City of Toronto Transportation Services: *Signal Optimization (Coordination)* (https://www1.toronto.ca/wps/portal/contentonly?vgnextoid=0c9d9325bd1ec410VgnVCM10000071d60f89RCRD&vgnextchannel=9452722c231ec410VgnVCM10000071d60f89RCRD)

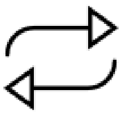
The TSM "Toolkit"

 **centralized vehicle monitoring**	Transit dispatchers and supervisors can make use of Computer-Aided Dispatch/Automated Vehicle Locating (CAD/AVL) systems to monitor operations in real-time. Combined with appropriate standard operating procedures and interventions, this facilitates the provision of more reliable transit service.
 **data sharing**	Since there are often multiple stakeholders operating transportation facilities and services in urban corridors, some regional agencies have invested in formal data-sharing systems that facilitate the sharing of operational data to enabled more coordinated responses to incidents and congestion.
 **frequent service**	The frequency of transit vehicles is a major determinant of service quality and is complementary to infrastructure upgrades that improve speed. Many transit agencies define "frequent transit networks" consisting of routes running at intervals of 10 minutes or less.
 **HOV lanes**	High-occupancy vehicle (HOV) lanes are reserved for vehicles carrying more than one person. They may be reserved for vehicles with 1+ passengers or 2+ passengers, and restrictions may vary by time of day or day of week.
 **incident management**	Incident management systems detect disruptions resulting from traffic incidents and facilitate a coordinated response to restoring normal operations.
 **multi-modal management**	In corridors in which multiple modes of transportation operate (e.g. regional buses on freeways, rail park-and-ride stations adjacent roadways), coordinated multi-modal management systems disseminate travel information about current conditions across modes to influence travel behaviour.
 **quality stations**	Many bus rapid transit (BRT) and priority bus systems are designed with high-quality station infrastructure to make the experience of taking transit more pleasant. Typical features include next-bus arrival notifications, off-line ticketing, and heated shelters, among others.
 **queue jumps**	Queue jump lanes are traffic lanes reserved (or partially reserved) for buses to skip to the front of traffic queues at intersections. In many jurisdictions, queue jumps are implemented via the use of right turn bays at major intersections.

The TSM “toolkit” (continued)

ramp metering

Ramp metering is a process by which access to freeways is controlled in response to current traffic conditions. For example, if congestion along a particular segment of freeway is extremely congested, the operator of the road may elect to reduce the number of vehicle entering an on-ramp. This control is typically achieved via traffic signals or physical gates.



reversible lanes

Reversible lanes carry traffic travelling in opposing directions at different times of day or in response to changing traffic conditions. The direction of traffic flow is typically indicated by overhead signage or, in some cases, by a moveable barrier.

signal coordination and priority

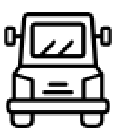
Traffic signal coordination refers to traffic signal timing plans that consider the timing and location of upstream and downstream signals in an attempt to minimize the amount of red time experienced along a given corridor. Traffic signal priority refers to measures that give green priority to certain types of vehicles, especially transit vehicles.

toll/HOT lanes

High-occupancy toll (HOT) lanes and toll lanes impose a fee for some or all users. In the case of toll lanes, the fee is imposed on all users as a flat or variable charge. In the case of HOT lanes, the charge is only imposed on vehicles falling below a set number of occupants.

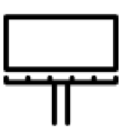
transit priority

Transit priority lanes are those that are reserved (or partially reserved) for buses or other types of transit vehicles. This priority may vary by type of day and be shared with other travel modes (e.g. taxis or HOVs)



truck priority

Truck priority lanes are similar to transit priority lanes except that priority is allocated to commercial vehicles.



variable message signs

Variable message signs provide drivers with information about current travel conditions in order to influence route choices in response to current traffic conditions. In Toronto, for example, variable message signs provide information about current travel times to major destinations in real time.

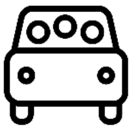
variable speed limits

Variable speed limit systems are typically deployed as a safety measure to ensure that traffic flows at a speed appropriate for current conditions. For example, speed limits may be reduced during heavy snow, or in specific lanes in response to a downstream incident.

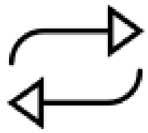
Managed Lanes

The capacity to move people and goods on roadways can be increased by dedicating road space to certain vehicles. These “managed” lanes have most commonly been implemented by allocating lanes to high-occupancy vehicles and buses, but now with improved intelligent transportation technologies, other strategies can be implemented such as toll, high-occupancy toll, and reversible lanes. These different managed lanes strategies have resulted in reduced travel times and have increased the throughput of people for the corridors where they have been implemented.

TOOLKIT


HOV lanes


toll/HOT lanes


reversible lanes


transit priority


truck priority


El Monte Managed Lanes (LA)

Features

- 17 kilometres in length
- 2 bi-directional lanes dedicated to busway and HOT operations
- Electronic toll system
- 3 Bus Stations
- Over 8,000 vehicles in one direction during the peak hour

Successes

- Up to 56% travel time reduction on HOT lanes compared to GPLs
- HOT travel times remained the same while total traffic volumes increased over the years
- Up to 59% ridership increase on some transit routes

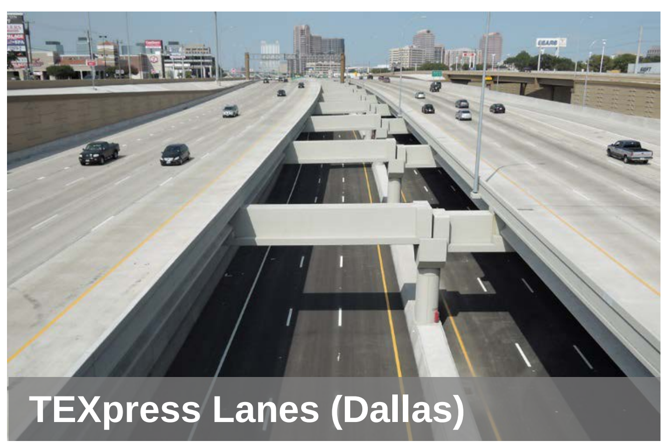
Source: https://ntl.bts.gov/lib/jpodocs/repts_te/13692.html

Features

- 15 kilometres in length
- Fully separated 3 lane bi-directional HOT lanes
- Electronic toll system
- Accepts payments from multiple state wide toll systems

Successes

- The average speed in the westbound direction increased by 10%
- General purpose lane congestion reduction by up to 60%
- HOT lanes operate at or above the speed limit at all times of day


TEXpress Lanes (Dallas)

Source: http://www.texpresslanes.com/faq-page

Smart Corridors

Smart Corridors refer to the application of advanced and coordinated technologies and strategies in a transportation corridor. These corridors leverage new intelligent transportation systems in order to maintain acceptable levels of service and improve safety through better road space management, intersection optimization, and incident management. These technologies and strategies are typically a fraction of the cost when compared to road widening schemes and other infrastructure upgrades.

TOOLKIT

ramp metering

variable message signs

variable speed limits

multi-modal management

incident management

signal coordination

data sharing

managed lanes

I-15 ICM (San Diego)

Features

- 32 kilometres in length
- Real-time modelling recommends responses
- Messaging system to support detours and incident management
- Integrated with San Diego 511 service

Successes

- 246,000 person-hours annual travel time savings
- Travel time reliability improvement of 10%
- Over 320,000 gallons of fuel saved annually
- 3,100 tons/year of mobile emissions saved

Source: http://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/SummID/B2011-00736

US-75 ICM (Dallas)

Features

- Responsive traffic signal system
- Integrated ITS to support all modes and 511 services
- HOV lane network management
- Information sharing between agencies

Successes

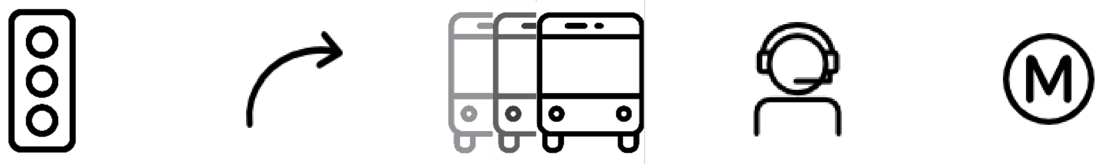
- 740,000 person-hours annual travel time savings
- Travel time reliability improvement of 3%
- Over 981,000 gallons of fuel saved annually
- 9,400 tons/year of emissions saved

Source: http://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/SummID/B2011-00757

Priority Bus

Recent experience has shown that large rapid transit projects are not the only means of improving transit service quality and increasing ridership. In the appropriate environment, a number of operational strategies and intelligent transportation system technologies can deliver substantial benefit without substantial capital investment or disruptive construction. These strategies—known collectively as "priority bus" measures—have been shown to help reduce travel times by transit, improve service reliability, and increase ridership.

TOOLKIT



signal priority	queue jumps	frequent service	centralized monitoring	quality stations

Los Angeles Metro Rapid

Features

- Signal priority at 1,500 intersections
- Average station spacing 1.1 km
- Mixed traffic and dedicated lane operations
- Branded stations and vehicles

Successes

- 20-30% reduction in running time
- Up to 49% increase in corridor ridership
- Reduction in bus bunching
- Negligible impact on traffic operations

Source: https://www.transit.dot.gov/research-innovation/metro-rapid-demonstration-program-evaluation-report-operating-speed-ladot

Features

- Off-line fare payment
- Wayside traveller information system
- Branded stations and vehicles
- Dedicated lane and mixed-traffic operations
- Schedule-based signal priority

Successes

- Near-term corridor ridership growth up to 40%
- Majority of ridership gains in Highway 7 corridor from new riders
- Up to 11% reduction in running times

York Region Transit Viva

Source: dmg.utoronto.ca/pdf/reports/research/ridership_viva_bus.pdf

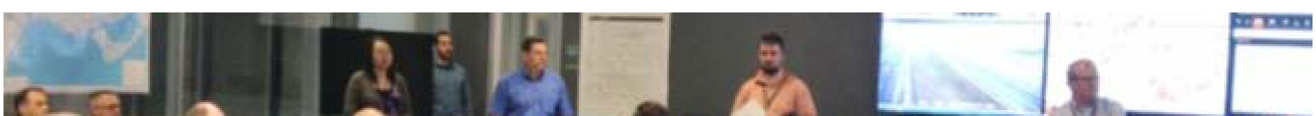
2015 Toronto Pan Am/Parapan Am Games

The 2015 Toronto Pan Am/Parapan Am Games was the largest sporting event ever held in Canada. In order to provide adequate transportation for the Games, as well as to keep the rest of the GTHA moving, a number of TSM measures were put into place. The combination of these measures ensured that no athlete arrived late at their venue and allowed 95% of athlete trips to arrive within their target travel times.

Temporary High Occupancy Vehicle (HOV) lanes *were one of the key TSM measures implemented to ensure the reliability of the transportation network. These managed lanes gave access to HOV and Games-accredited vehicles to minimize delays and increase reliability when travelling to and from Games venues. On average, the "Games Lanes" reduced highway travel times in those lanes by more than **6 minutes** during the afternoon peak period, while delaying general purpose lane traffic by only 2 minutes.The Games Route Network connecting the Athletes' Village and venues included traffic operational improvements to over 1,500 km of roads and 235 km of Temporary HOV lanes.*

Signal retiming and improvements *were implemented across the GTHA on key Games and spectator routes in order to optimize traffic flow in response to expected Games traffic conditions. This also provided the opportunity for some municipalities to upgrade existing signal infrastructure while improving the operations, connectivity and reliability at some traffic signals. Over 350 traffic signals were modified.*

*A **traveller information system** provided advice through three different channels. This included a web-based system and mobile phone application that provided users with a multi-modal travel planner. In addition to this, many road-side variable message signs provided road users with information. The traveller information system influenced as many as 13,500 trips a day over the course of the Games.*



*A **Unified Transportation Control Centre** to coordinate and manage transportation during the Games. The UTCC had representatives from jurisdictions across the GTHA and supported the coordination of the different modes of transportation, managed incidents, and provided traveller information as needed. The UTCC acted as the "starting point" for major operational decisions that were made during the games, including additional transit trips, enforcement levels, and traveller information. Continuous monitoring of road conditions in a centralized facility also enabled early detection, and clearance of incidents.*

3 TSM in the GTHA

This section identifies gaps that are limiting operational performance and provides an overview of existing TSM initiatives currently in place in the GTHA. The table below summarizes these gaps as they relate to the five categories of TSM identified earlier in this report, with the remainder of the section providing background work completed for the GTHA ITS strategy and additional information about each TSM category.

TSM Gaps

1. Traffic Management

1.1: Coordination and Data Sharing: Improved communication and interoperability.

1.2: ATMC Hours of Operation: Longer and more consistent operating hours

1.3: Technology: Advanced and compatible technology deployed across the GTHA

2. Traveller Information

2.1: Use of Legacy Systems: Embracing open data standards to help make traveller information available to a wider audience at a lower cost.

2.2: Standardization: With the emergence of the private sector and the need for coordination between multiple agencies, standardization of shared data has become more important.

2.3: Data Sharing and Procurement: Leverage data sharing and joint procurement to drive down the cost requirements for data procurement.

2.4: Functionality: Provide more information to improve traveller experience and accessibility.

3. Transit Technology

3.1: Coordination between Agencies: Improve coordination of cross-regional operations.

3.2: Untapped Potential of Transit Technology: Leverage data to improve transit operations.

3.3: AODA Compliance: Ensure AODA requirements are met within the legislated timeframe.

4. Traffic Signal

4.1: Interoperability: Separate systems lead to lost efficiency and congestion.

4.2: Hierarchy of Priority: Determine a consistent vehicular hierarchy to focus efforts of intersection operations.

4.3: Data Availability: Data availability varies significantly between jurisdictions, limiting traffic signal coordination capabilities in some locations.

5. Managed Lanes

5.1: Corridors in Isolation: A connected network of managed lanes maximizes benefits.

5.2: Enforcement and Technology: Focussing on compliance helps maintain performance.

3.1 ITS Strategy

Metrolinx's **ITS Strategy for the GTHA**, published in January 2017, identifies a set of goals and initiatives to help to advance the state of ITS in Greater Toronto and Hamilton. The strategy focuses on the value of a regional perspective, emphasizing the importance of collaboration and identifying initiatives that are best managed and coordinated at a regional level.

ITS is at the heart of many of the TSM measures described in this report, and it is important to understand how these technologies can be applied to accomplish TSM goals. The table below summarizes the ITS Strategy's recommended initiatives and links them to the TSM gaps identified subsequently in this section.

	Goal	Initiative	Identified TSM Gap
TRAVELLER INFORMATION	Integrated multi-modal traveller information	Develop a strategy to clarify the role of various data providers in planned and real-time information.	2.3: Data Sharing and Procurement
	Timely accurate real-time transit information	Provide enhancements and features to Triplinx.	2.4: Functionality
	Wayside and on-board information delivery on connecting transit services	Develop an approach to disseminate real-time information of adjacent transit services at stations/stops and on vehicles.	2.4: Functionality
	A consistent regional wayfinding tool for travellers with vision loss	Identify a regional wayfinding tool to be used by travellers with vision loss.	2.4: Functionality
OPERATIONS	Integrated GTHA paratransit booking tools	Introduce tool allowing paratransit customers to book multi-agency paratransit trips.	3.1: Coordination between Agencies
	Coordinated multi-agency transportation incident response	Develop an approach to support shared information and coordinated response between transit agencies.	1.1: Coordination and Data Sharing
	Interoperable transit signal priority	Develop regional guidelines and standards to provide TSM interoperability	4.1: Interoperability
	Cross-boundary signal coordination	Establish cross-boundary coordination between neighbouring jurisdictions to coordinate traffic control	4.1: Interoperability
DATA AND INFORMATION	Single regional source of planned and unplanned road closure data	Develop a single source for up-to-date information on planned road closures and restrictions throughout the GTHA to help inform and coordinate road events.	1.1: Coordination and Data Sharing
	Comprehensive pedestrian and cycling facility data	Update and improve accessibility, infrastructure, and amenity information sources.	1.1: Coordination and Data Sharing
	Park-and-ride lot occupancy information	Identify a practical solution to provide occupancy data for park-and-ride lots in real time.	3.2: Untapped Potential of Transit Technology
	Traffic condition information for arterial roads	Provide enhanced data on arterial roads including traffic conditions and travel times.	1.3: Technology
	Crowdsourced traffic data	Develop a regional approach to acquire and use crowdsourced traffic data.	1.3: Technology

3.2 Traffic Management

GTHA Highlights

- **MTO Traffic Management Centre:** In 2015, MTO consolidated its traffic operations at a new control centre adjacent to Highway 400 (near Finch). This new centre provides a centralized location for moniting MTO roads across MTO's Centre Region, which covers the GTHA. The facility is the hub for Transportation Management and Emergency Operations for the Central Region Highways, and was the central traffic operations centre for the Pan-Am/Para Pan-Am Games
- **City of Toronto Transportation Management Centre:** The City of Toronto operates a traffic management centre to manage movements on the Expressways and arterial roads under the City's control. This includes management of incidents, congestion and signals on the network. Increasingly, the TMC is taking a holistic focus to its traffic management function, recognizing the various classes of users of Toronto's expressway and road network..
- **Transportation Network Management in the Regions around Toronto:** Most of the Regional Municipalities and cities around Toronto operate a transportation management centre, at least on an extended business hours basis. Several of these organizations (e.g., Durham Region, York Region) have recently upgraded or are in the process of upgrading the systems and technologies used by staff within these centres.

The past few years have seen significant investment by GTHA road/highway authorities to enhance their traffic management capabilities, with several existing Traffic Management Centres (TMCs) being overhauled and new centres being built.

The Ministry of Transportation Ontario (MTO) Central Region opened a new TMC in 2015 to consolidate their highway traffic management capability that was previously split between Burlington and Downsview. This facility manages the provincial road network throughout the GTHA and beyond through a variety of tasks that includes:

- Incident management;
- Construction management;
- Traffic monitoring;
- Traveller information (including during emergencies);
- Weather advisories for conditions that may affect roadway operations (ex. road surface conditions, visibility, etc.); and
- Coordination with emergency services.

The MTO centre uses a variety of tools such as providing traveller information through Variable Message Signs (VMSs) and connection to the Ontario 511 system, while also performing traffic monitoring through CCTV cameras and other detection technologies. These systems are integrated and operated using a combination of automatic alert logic and operator monitoring 24 hours a day, seven days a week.

Other jurisdictions in the GTHA have similar control centres capabilities:

- The City of Toronto is investing heavily in its 24/7 traffic management capability, including a major upgrade to its Advanced Traffic Management System software and significant deployments of CCTV and Bluetooth travel time sensors. It has also made significant investments in its traffic signal system and optimization of timing plans. In addition, the City is investigating the potential for new applications within integrated corridor management, managed lanes and traveller information.

- Beyond Toronto, the Regions of York and Durham and cities of Mississauga and Hamilton are in the process of making significant improvements to their traffic management software, field infrastructure and operational capabilities.

The variety of ATMC capabilities are dependent on jurisdictional priorities and available funds. The hours of operation also vary depending on the jurisdiction, with some operations centres operating regular business hours while others operate a 24 hour a day, seven days a week operation. Therefore, while some of these centres have the technology to respond to issues and continue the improve network operations, the fact that the system does not operate around the clock may limit their ability to respond to traffic management issues.

Remaining Traffic Management Gaps

1.1: Coordination and Data Sharing: Many centres across the GTHA operate individually with limited coordination and data sharing between centres—including with emergency services and transit centres within the same jurisdiction. This lack of coordination and data sharing leads to inefficiencies in operations, managing incidents, and redundant procurement.

1.2: ATMC Hours of Operation: Numerous centres across the GTHA have hours of operation that are limited to extended business hours. This limits the ability of these centres respond to issues and manage the network. This is especially true at times when the impact of an ATMC can be substantial, such as during special events, incidents, and emergencies. Further study is needed to assess how and if hours of operation can be better coordinated between agencies.

1.3: Technology: While some centres have state-of-the-art facilities that manage traffic and provide traveller information, others have limited capabilities, especially for data collection and traveller information. An improvement of these functionalities in certain centres will provide improved network management, especially during special events, incidents, and emergencies.

3.3 Traveller Information

GTHA Highlights

- **Ontario 511:** The Ontario Ministry of Transportation operates this telephone and web information service that provices up-to-date information on the status of road closures, road conditions, traffic conditions, and construction projects. The Ministry is currently out to tender for a major upgrade to its current 511 software.
- **Triplinx:** Triplinx is a regional transit trip planner operated by Metrolinx that provides an integrated trip planner across 11 transit agencies within the GTHA. The Triplinx service is available through both a website and mobile app and is used by customer service operators from the participating transit agencies to provide customer advice.

Traveller information systems in the GTHA are provided by a number of different public and private sector entities. The systems provide information through a variety of media, including through fixed and portable variable message signs (VMS), 511 phone systems, mobile phone applications, and websites.

Public Sector

MTO provides traveller information through its Ontario 511 system and fixed and portable VMS on its network. The VMS signs provide information that is pushed from the MTO TMC, which includes reports regarding traffic conditions, travel times, incidents, and special events. In addition to the roadside VMS, the Ontario 511 system also publishes information on its map-based website. This includes information on traffic conditions, incidents, construction information, provincial services, managed lanes, and road/weather conditions. This information is also available through a 511 phone system with voice recognition.

Other local jurisdictions provide this information through their own traveller information services, including websites and fixed and portable VMS. Most transit agencies also publish real-time vehicle location data for next-vehicle prediction by in-house or third party systems.

Metrolinx, in conjunction with the other transit agencies in the GTHA, has also developed the Metrolinx Regional Trip Planner (Triplinx). Triplinx is available on a web-based platform and mobile phone applications such as iOS or Android. This trip planner allows users to plan trips across the GTHA, providing the user information on which routes to take to complete the trip and the cost. As well, this trip planner allows users to access information about the different transit agencies in the GTHA, including agency information and schedules, as well as GTHA Transportation Demand Management initiatives such as Smart Commute. Many transit agencies in the GTHA also have their own websites that provide traveller information, however, if the trip requires the use of multiple agencies, Triplinx provides this information in one platform. The next upgrade for Triplinx plans to integrate real-time vehicle arrival data from additional transit agencies as well as the capability to issue real-time service alerts.

Private Sector

Over the past decade, the private sector has developed a variety of different traveller information applications and websites. The sources of information vary depending on the service. For traffic conditions, many third-party private firms collect information and display travel information and congestion on their own map-based platform. This includes the Google Maps online and mobile platforms and TomTom's in-vehicle GPS devices. For transit information, private firms are also leveraging the available open data to provide information on next vehicle arrival and schedules through General Transit Feed Specification (GTFS) information. Applications such as Google Maps, Transit App, and Citymapper are a few of the applications now providing these services. The standardization of transportation data has allowed these and other private traveller information systems to emerge, leading to an increasingly rich array of traveller information being made available.

Remaining Traveller Information Gaps

2.1: Use of Legacy Systems: The use of closed legacy traveller information systems limits the dissemination and interoperability of data and increases costs. Embracing open data standards will help make traveller information available to a wider audience at a lower cost.

2.2: Standardization: With the emergence of the private sector and the need for coordination between multiple agencies, standardization of shared data has become more important.

2.3: Data Sharing and Procurement: Many agencies are using data in order to better inform their ATMC and provide traveller information. Much of this data is procured and collected separately by each of the jurisdictions. The increase in sharing and joint procurement of larger datasets across the GTHA can drive down the cost requirements for data procurement.

2.4: Functionality: There remain technological and cost impediments towards providing the types of information that travellers require to make fully informed decisions, including the multi-operator fare information, connecting transit information aboard vehicles, and accessibility tools for those with vision or hearing loss.

3.4 Transit Technology

GTHA Highlights

- **PRESTO**: PRESTO is the GTHA's transit fare card system that is now in operation on all of the GTHA's major transit agencies. Work is ongoing to deploy improved Add-Value Machines (AVMs) and new Ticket Vending Machines (TVMs) to improve and automate fare payment in Toronto.
- **GO Automatic Vehicle Location System Upgrade**: Metrolinx is deploying a new Computer Aided Dispatch / Automatic Vehicle Location system to better track service schedule adherence, disseminate customer information, and monitor vehicle status to improve preventative maintenance, driver training, and passenger safety.
- **TTC Conventional and Specialized Transit Technologies**: The TTC is deploying various technologies to improve service delivery for their bus, streetcar, and Wheel-Trans services. The technologies deployment for bus and streetcar will allow TTC to better manage schedule adherence and headways improving service delivery to customers. Changes to the Wheel-Trans booking system will allow customers to book multi-modal trips using a single platform.

Over the past decade, the GTHA has seen a substantial improvement in transit technology capabilities with a rapid deployment of new technologies, including Computer-Aided Dispatch (CAD) and Automated Vehicle Location (AVL) systems, fare payment technologies, and Automated Stop Announcement (ASA) systems. These systems are helping to support the operation of demand-response and fixed-route transit services, but further work is necessary to leverage their full potential.

CAD/AVL systems enable service providers to identify potential scheduling and operations issues and facilitate the day-to-day decisions made by transit dispatchers and inspectors. The deployment of CAD/AVL systems is also critical to the provision of real time transit arrival data in order to support traveller information such as the Metrolinx Regional Trip Planner (Triplinx) and other transit technologies. At present, all transit systems in the GTHA have a CAD/AVL system controlled through their own transit control centres or office workstations. However the capabilities and level of usage vary by agency and, in some localities, data is not being leveraged to improve operations. For example, a common feature of CAD/AVL systems enables inspectors and dispatchers to monitor schedule adherence and/or headways in real-time and make adjustments accordingly. Despite the availability of this information, some agencies perform such adjustments on an *ad hoc* basis with minimal use of vehicle and schedule tracking. Leveraging this wealth of information has the potential to improve reliability and reduce running times, thereby making transit services more attractive to riders.

Another important technology that has supported the operations of the GTHA's transit agencies through better integration is the development of the contactless smartcard system Presto. This system has allowed users to travel on multiple transit systems while using only one form of payment, making transit easier to use, while providing a more cost effective fare payment solution due to the benefits of joint procurement. The next logical step for this technology is incorporation into business intelligence (BI) tools so that travel patterns can be analyzed for planning and operational purposes. Although this data is beginning to be put to use, there remains opportunity to improve service provision using this information.

The development and implementation of the Accessibility for Ontarians with Disabilities Act (AODA) has also had an impact on transit technology. An important requirement of the AODA is that transit vehicles and stops must be accessible. This has required the implementation of automated stop announcement (ASA) systems and traveller alerts to support users that are vision or hearing impaired respectively. Though these systems have been deployed across the GTHA, the information provided through these systems varies depending on the agency and the level of maturity of the technology. The level of compliance with the AODA requirements also varies depending on the agency, limiting the technology's ability to relay information to certain transit users

Remaining Transit Technology Gaps

3.1: Coordination between Agencies: Best practices and data sharing of services are disjointed across the GTHA, with many transit agencies operating their own transit control centres, with limited connection to other ATMCs and transit management centres. This issue can result in missed opportunities for coordinated service and joint procurement.

3.2: Untapped Potential of Transit Technology: Though many transit agencies in the GTHA have transit technology integrated into their systems, the level which some of these systems is used varies depending on the agency. These systems have many advanced functions to support planning, scheduling, and dispatch, but there remains significant untapped potential to support operations.

3.3: AODA Compliance: All transit agencies meet some form of AODA compliance for next stop announcement, however in many cases, other service announcements and information do not meet these requirements. This means some critical service announcements and other information are inaccessible to some users.

3.5 Traffic Signals

GTHA Highlights

- **Toronto Signal Optimization Program:** The City of Toronto has adjusted the timing of 1,275 signals since 2012 in order to improve traffic flow along major arterials. Benefits of the coordination studies include reduction in the frequency of vehicle stops, increased safety, and reduction on auto impacts to the environment.
- **Bus Signal Priority –** Many authorities within the GTHA have some form of bus signal priority on their network. This provides preferential treatment to buses in terms of extended / early green times in order to help them maintain schedule adherence.
- **VivaNext Temporary Construction Signal Timing:** In order to minimize traffic impacts resulting from VivaNext construction projects, temporary signal timing plans have been put into place at various sites during each phase of construction.

One of the main challenges of operating traffic signals is determining which modes or movements should be given priority under a given set of operating conditions. This hierarchy of priority is typically established at a jurisdictional level, and can vary depending on the location and use of the intersection.

Traffic signals in the GTHA are generally operated by the jurisdictions that hold ownership over the intersection controlled by the signal. The jurisdiction is also responsible for updates to signal timings to provide better coordination, implementation of special operations such as Transit Signal Priority (TSP) and Emergency Vehicle Pre-emption (EVP), and providing real time signal timings for incidents and special events. This local operation results in a lack of interoperability of signal technology between jurisdictions due to differences in operational structures, technology, and policies. This is a major issue in the GTHA as many critical arterial roads cross municipal boundaries, leading to increased delay and reduced reliability of the transportation network at these locations due to a lack of interoperability and coordination.

Despite having the potential to improve reliability and reduce delay, advanced signal operations such as TSP and EVP are limited to a few jurisdictions. The application of TSP is limited to only certain corridors within larger transit agencies, including Toronto, Durham Region, Brampton, and York Region. While TSP is expanding, EVP deployment is limited in the GTHA, and is dependent on the policies put forward by the jurisdiction. Currently EVP is only deployed in Peel Region, Durham Region, York Region, Halton Region, and City of Toronto (at limited locations). Though these technologies are deployed on a jurisdictional level, there is limited consistency across municipal boundaries.

Remaining Traffic Signal Gaps

4.1: Interoperability: Signal and TSP operations across jurisdictional boundaries are limited across the GTHA. This leads to lost efficiency due to a lack of coordination crossing jurisdictional boundaries, varying policies, and incompatible technologies.

4.2: Hierarchy of Priority: Intersections serve a large number of road user and modes. Determining a consistent hierarchy is important to focus efforts of intersection operations.

4.3: Data Availability: Data is vital to the coordination of traffic signals and the operation of more advanced systems. Data availability varies significantly between jurisdictions, limiting traffic signal coordination capabilities in some locations.

3.6 Managed Lanes

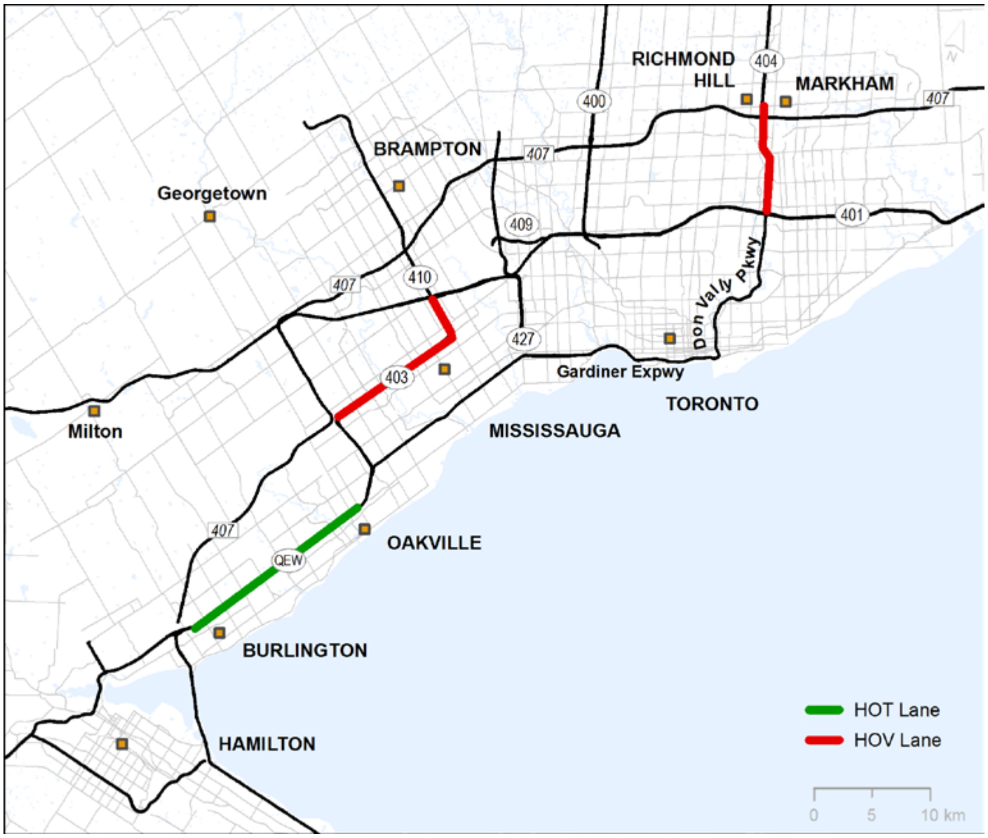
GTHA Highlights

- **MTO HOT and HOV Lanes:** The Ministry of Transportation reserves lanes on sections of Highway 404 and Highway 403 for high-occupancy vehicles, and a section of the QEW for use by high-occupancy vehicles and toll-paying single occupant vehicles. A network of HOT lanes is planned to be implemented on freeways in the GGH in the coming years.
- **Toronto Transit Priority Lanes:** The City of Toronto maintains transit priority lanes on short sections of its arterial road and freeway network, including on the Don Valley Parkway, Bay Street, Dufferin Street, and King Street.

Over the course of many years, transportation operators in the GTHA have converted general purpose traffic lanes to “managed” lanes to increase efficiency and to curb single occupancy vehicle (SOV) usage. These managed lanes include High Occupancy Vehicle (HOV), High Occupancy Toll (HOT), reversible lanes, and transit-only lanes. HOV lanes are lanes reserved for HOV (vehicles with more than a certain number of passengers), while HOT lanes are similar except, SOV who pay a toll can use these lanes. In Ontario, there are a number of vehicles that can use these lanes regardless of occupancy, including green license plate vehicles, buses, and taxis and limos (until June 2018). Reversible lanes are managed lanes that change direction depending on the time of day, while transit only lanes are lanes reserved to transit vehicles either all day or for a particular time of day.

The use of HOV and HOT lanes have become more prevalent in recent years in the GTHA. MTO has deployed HOV lanes on portions Highway 403, Highway 404, and the Queen Elizabeth Way (QEW), as illustrated in Exhibit 3.1. In addition, there are HOV lanes in a few local jurisdictions including the City of Toronto and York Region. HOT lanes started operation in Ontario in 2016, with a segment of the QEW HOV lane being designated as HOT for a pilot project. This system allows users to buy a permit to use the HOV lane as a SOV. However, in order to increase the usage of these lanes, a number of improvements are needed. This includes an expanded network to connect isolated operating segments, improved enforcement, and more advanced HOV and SOV detection technology.

Exhibit 3.1: HOV and HOT Lanes in the GTHA



Reversible lanes are uncommon in the GTHA, with only the City of Toronto employing it on their Jarvis Street corridor. There are currently no plans to expand this managed lane concept to other roadways in the GTHA. In addition, transit-only lanes and transit-only roadways have become more common in the GTHA, especially in York Region, Peel Region, Durham Region, and the City of Toronto. These are usually employed in rapid transit corridors and transit route corridors that experience significant delay and high ridership. Though these have improved travel times and reliability for transit vehicles, they are also found in isolation and at times disconnected from the rest of the transit network. As well, there are enforcement issues on these managed lanes that lead to further delays for transit vehicles. There are currently plans to expand these types of managed lanes with the development of Light Rail Transit and Bus Rapid Transit across the GTHA.

Remaining Managed Lane Gaps

5.1: Corridors in Isolation: The application of managed lanes are done in isolation across the GTHA, minimizing network benefits. The creation of a continuous managed lane network will increase effectiveness and improve attractiveness.

5.2: Enforcement and Technology: Managed lanes require enforcement support from ATMCs and police resources. Application of more advanced technology would also lower violation rates and maximize the effectiveness of managed lanes. More advanced technology will also open managed lanes-and specifically HOT lanes-to a larger user base.

4 Key Trends

A number of technological and transportation trends are changing the way people move. These trends have a direct impact on TSM, providing improved data and tools to understand travel, and the technology to further enhance TSM strategies. Future transportation operators in the GTHA will need to take advantage and account of these trends that are discussed in the section below.

4.1 Technology

Big Data

The creation and proliferation of structured information has increased dramatically since the turn of the century, with the total "digital universe" roughly doubling in size every two years[4]. This pace of change has spawned the term "Big Data", which refers to large datasets that can be analyzed to better understand the operations of a system through data mining and analysis.

Data has always been a large part of transportation planning and operations and is evolving as new technology emerges. Manual counts and telephone surveys have given way to more advanced technologies such as probe data and video recognition software. With the advancement of these technologies, the sample size and resolution of the data has improved considerably. Operators now have the ability to gain access better information to make more informed planning and operational decisions. This can improve network management, which will continue to develop as the technology matures.

How jurisdictions deal with storage and interpretation of Big Data will be important over the coming years. As they collect more data, this will need to be stored, leading to a larger emphasis on data warehousing. Furthermore, data visualization and business intelligence will play a larger role in transportation planning and operations as analyzing the large magnitude of data can be difficult. Data dissemination to the public will change as well. With the emergence of Open Data, government agencies are becoming data regulators and providers, while the private sector is leveraging this Open Data to play a larger role in providing services to the public to disseminate data through internet and mobile applications.

Internet of Things

The Internet of Things (IoT) is a term to that describes how everyday devices are now being connected to the internet and being integrated with computers. These everyday items include consumer items such as home appliances, leading to affordable connectivity and new features that were unavailable in the past with unconnected devices. This trend is growing rapidly, with some forecasts estimating that there will be 8.4 billion connected things in 2017, with a growth to 20.4 billion by 2020[5]. Though some transportation network field equipment is connected and has been for decades, this was typically costly and limited to certain devices. However, the evolution of the IoT has enabled low-cost methods of connecting in-field devices and retrofitting existing infrastructure.

The ubiquity of connected in-field transportation devices will have an impact on how TSM is delivered and managed, as elements of the transportation network become smarter and better connected. This includes many components used in the transportation network, especially with traffic signals and transit vehicles. As this evolves, their capabilities will improve, providing improved functionality and allowing them to provide more information to other devices and operators of the transportation network. With the improvement of the communication between

[4] The Digital Universe of Opportunities. IDC. April, 2014. Web. 11 May 2017.
[5] Gartner Says 8.4 Billion Connected "Things" Will Be in Use in 2017, Up 31 Percent From 2016. "Gartner Press Release ". Egham. United Kingdom, 2017. Web. 8 May 2017.

devices and the operators, efficiencies through better network information can help focus TSM efforts and strategies. At the same time, however, additional resources will have to be dedicated to ensuring the security of these devices in order to mitigate the potential for unauthorized parties to disrupt the transportation system through an organized attack.

Cost of Communications

The growth of the mobile phone market and the IoT has driven the cost of communication down considerably[6]. Coupled with the increase in consumer demand for data-enabled devices, data bandwidths and speeds will likely improve. These enhancements have occurred even more rapidly for wireless forms of data transfer, and continues to improve with the spread of Long-Term Evolution (LTE) telecommunication networks. These trends have had a direct impact on transportation infrastructure, and have also helped drive Big Data and IoT trends.

Increases in bandwidth have allowed higher resolution data to be collected from in-field and crowd-sourced devices. With falling communication costs and bandwidth increases, the resolution of the data collected will only improve. With the improvement of wireless technologies, connected ITS devices to support network management and TSM initiatives have been able to reach more remote locations in the network that were at a time cost prohibitive to connect to. This has allowed for rapid expansion of certain systems that were costly in the past. An example of this is the growth of the CCTV camera networks across the GTHA, especially in areas where older communication methods would have been cost prohibitive.

4.2 Transportation Service Delivery

Mobility as a Service

Mobility as a Service (MaaS) describes an emerging paradigm shift away from auto ownership and towards a variety of platforms that sell transportation on a per-trip or subscription basis. These services provide access to a shared transportation resource that replaces an owned vehicle and can include ride hailing (Uber, Lyft, Halo, etc.) and vehicle sharing (car, bike, etc.). The growth of MaaS has been enabled by improvements in communication technologies, as well as market penetration of smartphones and mobile computing.

Recent studies[7] have shown that the number of car-free households is increasing, suggesting a growing market for MaaS. With the increase of popularity of MaaS, and the new modes of transportation it provides to users, car ownership may continue to decline. As a result, TSM strategies will be able to leverage the increasing centralization of service provision, allowing for improved modal integration and increased efficiency of the transportation network as a whole.

Connected and Autonomous Vehicles

Connected and Autonomous Vehicles (CAV) combine two technologies. Connected vehicles communicate with infrastructure and other vehicles, while autonomous vehicles are vehicles that can drive themselves with minimal to no human interaction.

These technologies have the potential to revolutionize the transportation industry, including TSM. CAV proponents have claimed to offer fewer collisions, narrower lane widths, vehicle-to-vehicle warnings of upcoming hazards, and increases in free time as just some of the benefits. A future combination of MaaS and CAVs coupled with proper rapid transit development, could change mobility needs and future cityscapes, with rapid transit providing long distance travel while CAVs providing last mile transit services on demand. With the increasing technological

[6] Worldwide Smartphone Forecast Update, 2015-2019. December 2015. "International Data Corporation Abstract ". 2015. Web. 8 May 2017.
[7] 2011-2015 American Community Survey 5-Year Estimates. “Selected Housing Characteristics”. 2015. Web. 8 May 2017

advances in CAVs, the way roadways are planned and repurposed will likely change, prompting an impact to TSM strategies and implementations in the future.

Growth of Private Sector Services

The private sector has emerged as a significant provider of traveller information and advice in recent years. Some examples of this include traveller information dissemination such through platforms like Google Maps and Citymapper. To facilitate this, new standards such as GTFS have emerged that now define how some agencies publish their data.

Looking forward, the growing amount of data generated and purchased by firms promises to increase private sector involvement in transportation operations. This may present an opportunity to complement data collected and provided by public sources, or change the role of the public sector in transportation operations altogether. What is certain, however, is that TSM strategies will have to incorporate sources of data from private and public sources. Cooperation rather than competition will improve outcomes for the travelling public.

4.3 Traveller Expectations

Data Ubiquity

With the availability of consistent traveller information now common, users expect data to be accurate and provided in real time. This data comes from a combination of private and public sector sources which continue to become more accurate and available. This improvement is mostly driven by user demand for traveller information.

The improvement to this data can come in a variety of forms, including standardization to facilitate data dissemination across agencies, and improved data collection to create more robust and reliable data. The improvement of data collection, especially for crowd-sourced data will continue through a number of means including user reporting (such as incidents published in Waze) and probe collection (such as speed data published in Google Maps). This will improve operational and planning decisions, including those influencing TSM. As well, users will continue to expect real time accurate data for the road network, and data collection methodologies and dissemination will improve to meet those needs.

Sustainability and Community Development

As infrastructure expansion continues around the GTHA, planning, construction, and change to communities can lead to contention with major capital infrastructure projects. This can cause drawn out planning phases for necessary capacity increases to the network. In addition, during the construction of these projects, a loss of network capacity sometimes occurs. As this occurs more often, strategies to mitigate the impact and maintain the expectations of the road users are needed in order to ensure sustainable community development. With TSM, major infrastructure project construction can be mitigated leveraging existing right of ways, limiting the impact on the existing communities. This is required more than ever with the rapid expansion of transportation infrastructure in the GTHA.

5 Strategic Directions

As a first step towards developing a cohesive plan for TSM in the GTHA, this section identifies potential strategic directions that can be adopted by Metrolinx and other transportation operators. These directions will set the stage for improvements to the operation of the GTHA transportation network through innovative and progressive TSM strategies that will lead to considerable travel time savings for regional travellers as well as more efficient movement of commercial vehicles.

5.1 Work Together to Manage Transportation Operations

One overarching gap that has emerged throughout this study is the interoperability and communication between the many agencies in the GTHA. This is essential to ensure that the TSM strategies that are implemented achieve the goals from an agency and region wide level. Some strategies on a regional level that could be undertaken in order to maintain the goals and focus from a region wide level include:

- **Foster collaboration:** Working groups between different agencies across the GTHA could facilitate collaboration on transportation operations projects and provide opportunities for joint procurement. These could be supported by a GTHA Regional ITS/TSM Steering Committee that would oversee the implementation of shared technologies and practices.
- **Get on the same page:** Developing plans, objectives, and standards for the region will improve interactions between modes and operations at regional boundaries.
- **Work together in real time:** Leveraging existing technologies to improve communication between centres can improve operations management and coordination. This improved communication between adjacent jurisdictions can as well improve the operations of corridors that cross jurisdictional boundaries.

5.2 Adapt Infrastructure to Suit Changing Operational Needs

The continuing change in travel trends and the evolution of travel modes have a direct effect on how existing infrastructure is used. This is especially prevalent as congestion and cities grow, impacting infrastructure, especially roadway space as it becomes scarcer. Changing how existing infrastructure is used through TSM strategies can potentially add more capacity to the network, relieving some of the congestion in the GTHA. Moving forward, some of the strategies in order to adapt our infrastructure for the better include:

- **Get more out of the road network:** Defining regional guidelines to repurpose and prioritize road space will be important as road space becomes scarce. Dedicating road space to modes such as high-occupancy vehicles, transit vehicles, freight, cyclists, and CAVs is a powerful policy tool that can help to achieve regional congestion and environmental goals.
- **Leverage technology to improve transit:** Service concepts like Priority Bus (“BRT-lite”) are relatively low-cost, may be deployed rapidly, and leverage advanced technologies to make public transit more desirable and promote increased ridership.
- **Keep roads clear:** Creating enforcement strategies to address the impact of traffic (recurrent and non-recurrent) and parking violations on operations will help clear roads clear, especially during peak periods where illegal parking has been a problem in the major centres.
- **Ensure accessibility for all:** Adapting and improving existing infrastructure to meet AODA compliance will be important, especially with the region’s aging population.

5.3 Keep the Public Informed

Traveller information is one of the most powerful ways to influence mobility. By making information about the transportation system available, trip makers can make more informed decisions about how, when, or if they want to travel. This can, in turn, facilitate improved transportation network performance through the following actions:

- **Influence travel decisions:** Publishing operational data on travel time, incidents, parking, outages, construction, etc. in real-time can help the public make informed travel decisions.
- **Provide information proactively:** Employing predictive analytics to disseminate traveller information in advance of departures can provide the public with more information to avoid congestion and problem areas.
- **Enable innovation through open data:** Publishing operational data publicly empowers researchers and third-party developers to provide innovative solutions to transportation problems.

5.4 Embrace Data-Driven Decision Making

The vast quantities of information being generated by the GTHA's transportation system present a tremendous opportunity to improve transportation operations. If properly collected and interpreted, this data has the potential to streamline operational decisions, predict the impact of major operational interventions to the transportation network, and provide a greater evidence base for operational decisions. This level of advancement is dependent on the following initial steps:

- **Use new technology to broaden data sets:** Expanding the quality and quantity of data collected from the transportation system will simplify future planning and operations work. It is important to leverage public and private sources as many agencies and companies now collect and store data.
- **Stay open and flexible:** Adopting established and flexible communication and data standards are important to ensure data sharing between agencies in the present and flexibility to take advantage of future innovations in the industry.
- **Look to the past:** Archiving performance and operational data for analytical and planning activities provides critical lessons for future planning and operations. This is especially important in regards to data archiving as data sets get larger.

5.5 Set Targets and Monitor Performance

Setting a goal is the first step towards improvement, and the best way to track progress towards a goal is to monitor performance at each step. The following measures present initial direction towards creating a culture of continuous improvement for transportation system operations:

- **Create a yardstick**: Developing a plan to monitor performance and identify successes is important for present and future planning. This can be supported by developing a GTHA Transportation Systems Management Master Plan that sets performance metrics and develops monitoring schedule.
- **Connect Planning and Operations:** Sharing operational monitoring data with long-range planning divisions ensures that planners are able to leverage accurate and current sources of information when making decisions about the future of the transportation network.