



Traffic Management Systems

Volume 1

THE PROBLEM OF URBAN CONGESTION IN CANADA

The recent CAA study *Grinding to a Halt: Evaluating Canada's Worst Bottlenecks* took a new perspective on a problem that Canadians know all too well: urban congestion is a growing strain on our economy and well-being. Canada's worst traffic bottlenecks are almost as bad as bottlenecks in Chicago, Los Angeles and New York. Bottlenecks affect Canadians in every major urban area, increasing commute times by as much as 50%.

This CAA briefing on investments in active transportation is one in a series that explore potential solutions to the problem of urban congestion in Canada. These briefings delve into solutions not only to highway congestion, but also to congestion on urban streets. Taken together the solutions explored in these briefings represent a toolkit to address this problem. The objective is to inform policy makers and the public about options to reduce congestion and key considerations for when and where a particular solution might be the right fit.

Traffic management systems (TMS) are technologies designed to improve traffic flow and safety, reducing congestion. These technologies can apply to both urban streets and freeways. In many cases, TMS have been around for a long time, but may have not been adopted to their full potential in Canada. Common TMS include various techniques for improving traffic signals (lights), traffic management centres,¹ variable speed limits, temporary use of paved shoulder lanes, lane-specific signalling, reversible lanes, freeway ramp metering, variable message signs, and automated enforcement such as red light cameras. TMS can work in isolation or as a system, with varying levels of coordination and technological sophistication.

Under the right conditions, TMS can be a low-cost means of getting more capacity out of existing infrastructure and so avoiding far more costly investment in new or expanded roads or transit. But TMS do not affect the underlying demand for using roads and highways.

This briefing explores three types of TMS that offer broadly applicable, practical and generally underexplored solutions to the problem of urban congestion in Canada.

¹ Some congestion solutions that could be considered TMS, such as incident management systems, congestion charges and high occupancy toll or high occupancy vehicle lanes are explored in other briefings.

PROBLEM: CONGESTION ON URBAN STREET

POTENTIAL SOLUTION: IMPROVING TRAFFIC SIGNALS

How does it work & what are the benefits? Improving traffic flow by re-timing signals or applying sensors and software to make traffic signals more responsive to traffic conditions. Traditionally improving signals was costly as manual traffic counts or physical detector loops embedded in pavement were required. **Examples** Toronto Traffic Signal Re-Timing Program, adaptive traffic signal control in Colorado.

Signal re-timing in Toronto has saved the public \$64 in time, fuel and air pollution for every \$1 spend on signal re-timing.

CONSIDERATIONS:

- Improving signals requires good quality data on traffic and signal performance. The costs of gathering these data have been falling thanks to remote connectivity (of traffic signals to central monitoring), vehicle detection and software tools, but only 50% of traffic signals in North America currently have remote connectivity.
- Benefits are greater when a whole corridor can be equipped with improved signals, but this may run into coordination issues if a road runs through multiple jurisdictions.
- Traffic signal improvements can be implemented with little or no disruption to traffic flow.
- Depending on infrastructure requirements, costs can range from roughly \$5,000 per intersection for basic re-timing to \$220,000 to \$1.3 million or more for a 6-km corridor for the latest signal control, which avoids the need for further periodic re-timing.

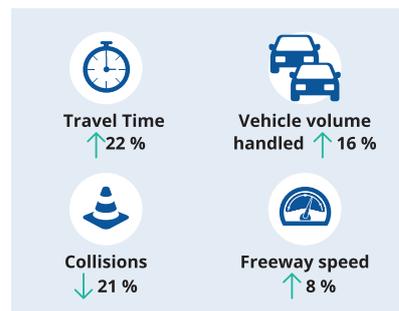
PROBLEM: CONGESTION ON URBAN STREET

POTENTIAL SOLUTION: RAMP METERING

How does it work & what are the benefits? Smooth the flow of vehicles entering a freeway by placing traffic signals on ramps. **Examples** Extensive use in the United States and Europe. For example, in Minneapolis/St. Paul an evaluation of ramp metering estimated the following impacts and overall benefits of \$15 for every \$1 spend on metering.

CONSIDERATIONS:

- Ramp metering requires sufficient space for deceleration and acceleration on either side of the signal. This can be a particular issue on older freeways that may have less space.
- Ramp metering can cause traffic to back up on to connecting city streets, causing congestion.
- Coordinating ramp metering throughout a freeway network, as is done in Minneapolis/ St. Paul for example, can bring greater benefits, but also greater cost and complexity.
- Public acceptance of ramp metering can also be an issue, particularly if the benefits are not clearly communicated or there are problems of traffic backing up on to connecting streets.
- Typical installation costs per ramp range from \$60,000 to \$120,000 and hardware costs from \$10,000 to \$20,000. There are also ongoing operating costs for maintenance, and with more advanced systems, management.



PROBLEM: CONGESTION ON URBAN STREET

POTENTIAL SOLUTION: ACTIVE TRAFFIC MANAGEMENT (INCLUDING VARIABLE SPEED LIMITS AND TEMPORARY SHOULDER USE)

How does it work & what are the benefits? The temporary use of paved shoulders and variable speed limits can help to smooth out traffic flow in peak periods and to increase the capacity of a freeway, alleviating congestion. **Examples** German autobahns, Smart Motorways (United Kingdom), Interstate 66 Active Traffic Management (Virginia).

Interstate 66 active traffic management has helped to improve weekday travel times off-peak by 2-6% and weekend peak period travel times by 10%.

CONSIDERATIONS:

- Variable speed limits are broadly applicable on any freeway. They require installation of electronic speed limit signs at frequent intervals.
- Variable speed limits can be used to slow traffic upstream from an incident or bottleneck or in periods of adverse weather to avoid stop-and-go traffic that creates further congestion and collisions.
- Temporary shoulder use, almost always paired with variable speed limits, requires usable paved shoulders, which may be a particular challenge in urban areas with older freeways that may be space constrained.
- Any implementation of temporary shoulder use would need to achieve acceptable levels of safety, which could involve additional costs for the construction of emergency refuge areas or other infrastructure as well as more aggressive incident management.
- Cost would vary based on infrastructure requirements. In one US example, freeway shoulders were converted for us at a cost of \$1.3 million per km.

IMPROVING TRAFFIC SIGNALS

Improving traffic signals can reduce congestion by speeding up traffic, increasing reliability and reducing collisions. Much of these benefits result from a smoother, more continuous flow of traffic through coordinated green signals, with fewer stops and starts.² Upgrades can involve installing new equipment, re-timing signals and coordinating and interconnecting signals. Many Canadian cities have adopted or are testing improved traffic signals of varying levels of sophistication.

As a city's population and the economy grow and change over time, so do traffic patterns. In the short term a variety of factors like seasons, weather, incidents and construction also shape traffic flows. In order to keep traffic moving, traffic signals have traditionally been retimed periodically. For example, in the United States traffic signals are typically retimed every 3-5 years at a cost of \$5,600 per intersection.^{3,4} Traffic detection technology, like detectors embedded in pavement, has also been around for some time, and has allowed some responsiveness to traffic patterns. Today, adaptive signals (sometimes called smart signals) can detect traffic patterns and adjust timing to improve flow on an ongoing basis, with less hard infrastructure than in the past. The most advanced systems coordinate across intersections and even learn from historical patterns, potentially reducing delay by up to 40%.⁵

EXAMPLES

The City of Toronto's Traffic Signal Re-Timing (Signal Optimization) Program

The City of Toronto has undertaken a program of signal re-timing, spending \$850,000 per year from 2012 to 2015. Analysis shows that for every dollar spent, the public saved \$64 worth of time, fuel and air pollution.⁶ A return of \$64 for every dollar spent is quite rare, suggesting that traffic signal re-timing, if it has not been done recently, offers governments a quick win that could potentially reduce congestion. In 2017 the City of Toronto also launched a pilot project to install adaptive signals at 22 intersections.

² Texas A&M Transportation Institute (n.d.)

³ US Department of Transportation (2017)

⁴ All dollar amounts in this briefing are in Canadian Dollars. US-Dollar amounts have been converted to Canadian Dollars at a rate of \$1.25 Canadian Dollars per US Dollar. Estimates should be considered approximate given other differences between Canada and the United States.

⁵ Texas A&M Transportation Institute (n.d.)

⁶ City of Toronto (2017)

Figure 1: Traffic Signals



Source: Pexels

Adaptive Traffic Signal Control in Colorado⁷

The Colorado Department of Transportation installed two different adaptive signal control systems along 6-km stretches of highways in Greeley, a city of roughly 100,000, and in Woodland Park, a town of 7,000. Adaptive signal control responds in real time to conditions to optimize traffic flow. Traffic conditions were studied before and after implementation. Results showed a 6-9% decrease in travel time on weekdays and an 11-19% reduction on weekends. The amount of time motorists spent stopped dropped by 13-15% on weekdays and by 37-54% on weekends. Installation costs were \$1.3 million in one case and \$220,000 in the other. Roughly two-thirds of the difference in cost was the result of more work required, because existing infrastructure could not accommodate the new system.

The Colorado Department of Transportation estimated the benefits of the projects to be 1.58 times costs in one case and 5.64 times costs in the other. Benefits were measured in terms of travel time savings (almost 90% of the dollar value of the benefit in both systems), fuel consumption and reduced maintenance cost (no more periodic re-timings because the signals adapt continuously). It is notable that there was a cost in increased travel time for motorists on intersecting side streets who on average saw their travel times increase. However, given lower volumes of traffic, these costs were only between 20% and 45% of the time savings for motorists on the primary roads.

TECHNICAL FEASIBILITY, LIMITATIONS AND TRENDS

Without good data, re-timing costs are higher, since modelling or expensive manually collected data are required.⁸ Current technology involves automatic data collection which allows transportation agencies to monitor signal performance and address issues before they become user complaints.⁹ Traffic data are increasingly available thanks to remote connectivity (from signals to central monitoring), vehicle detection and software tools.¹⁰

Supporting infrastructure can be a barrier to improving signals.¹¹ Typically, the latest generation of technology is required to gather detailed data, and only 50% of traffic signals in North America have remote connectivity. Smaller transportation agencies can lack the technical capacity to maintain systems for data processing and the traffic engineering capacity to interpret outputs of these systems.

Where major roads cross jurisdictional boundaries, coordination is required, potentially a barrier to full implementation of a beneficial project.

The greatest benefits from improving signals are achieved along busy streets with high volumes of traffic.¹² Improving signals also has a significant benefit over congestion solutions such as adding lanes or constructing public transit, as it can be implemented with little to no disruption.¹³

⁷ US Department of Transportation (2015)

⁸ US Department of Transportation (2017)

⁹ US Department of Transportation (2017). Free software is available from the US Federal Highways Administration Open Source Application Development Portal and a number of vendors offer complete solutions.

¹⁰ Miovision (n.d.)

¹¹ Miovision (n.d.)

¹² Texas A&M Transportation Institute (n.d.)

¹³ Texas A&M Transportation Institute (n.d.)

While costs might be lower than expanding infrastructure and the benefits proven, upgrading traffic signals can fall into a category of congestion solutions that are less visible and do not provide the ribbon-cutting opportunities of new infrastructure. This can be disadvantageous in attracting funding.

FREEWAY RAMP METERING

Freeway ramp metering (sometimes called ramp flow control) is the use of traffic signals and sometimes moveable barriers that release vehicles onto a freeway smoothly and evenly. The objective is to reduce congestion (including congestion caused by stop-and-go traffic and collisions) through smoother merging and by limiting how many vehicles in total can enter the freeway. Part of the benefit is that vehicles already on the freeway do not need to slow down to allow vehicles to merge, maintaining the speed of the freeway. The fact that drivers must wait to enter a freeway may by itself deter trips at peak times or divert trips away from congested freeways. Ramp metering can be turned off during times of the day or week when congestion is not a problem.

EXAMPLES

In Canada, ramp metering is uncommon. One example, is on a portion of the QEW highway in Ontario. Below are two examples of large scale ramp metering.

Minneapolis/St. Paul: Flow Signal Evaluation

Freeways in Minneapolis/St. Paul have 433 ramp flow control signals, among the most extensive systems in the United States.¹⁴ An evaluation in 2000 that investigated eliminating the signals found that ramp metering increased freeway speeds by 8%, reduced travel times by 22%, increased the volume of vehicles handled by 16% and reduced collisions by 21%.¹⁵ In total, a benefit-cost analysis, which monetizes these benefits and compares them to installation and operating costs, found that the benefits outweighed the cost by 15 to 1.¹⁶

Figure 2: Ramp Metering Signals in Auckland, New Zealand



Source: Public domain image

France: Paris Freeway Ramp Metering

The region surrounding Paris tested ramp metering from 2007 to 2010. The results were a time savings of 15%, an increase in average traffic speed of 10 km/h in peak periods, a 20% reduction in collisions and a 30% reduction in air pollution. Based on this successful pilot, 75 ramps will be equipped with ramp metering by 2018. Vehicles wait no longer than 30 seconds at the ramp signals, and sensors ensure that

the queue is released before it reaches connecting streets.¹⁷

¹⁴ US Department of Transportation (2014a)

¹⁵ Texas A&M Transportation Institute (n.d.b)

¹⁶ US Department of Transportation (2014a)

¹⁷ Direction des routes île-de-France (2016)

TECHNICAL FEASIBILITY, LIMITATIONS AND TRENDS

The major option with ramp flow control signals is the degree to which they operate in isolation or are coordinated with each other and the degree to which they adapt to traffic and queue conditions. Today, adaptive ramp metering can also be centrally managed to optimally respond to congestion and weather conditions. Such a system is the most costly and complicated to operate. Pre-timed non-connected ramp metering is simple and lower cost, and so is more appropriate for localized congestion issues. Adaptive ramp metering can be important if queues become long and begin to disrupt the operations of connecting streets. This type of spillover effect may also create opposition from local municipalities and residents who may see their road networks affected.

The biggest hurdle to implementing ramp metering is space constraints. Sufficient space must be provided for vehicles to accelerate and decelerate on either side of the signal.¹⁸ This means that ramp metering may be less feasible on ramps that are space constrained, which tends to be the case with ramps on older freeways.

Public acceptance can also be an issue. The study noted in the Minneapolis/St. Paul case study presented above was undertaken because the legislature was considering shutting down ramp metering.¹⁹ When signals operate to limit flow because of down-stream congestion, not visible to drivers waiting in line, the public may question the utility of ramp metering, and compliance may even drop. Public education can be helpful in improving acceptability. Equity issues can also arise as some see ramp metering as favouring those entering freeways further away from areas that are typically congested, such as suburban residents commuting into a city centre.²⁰

Ramp flow control tends to be a low-cost congestion solution. Typical installation costs range per ramp from \$60,000 to \$120,000 and hardware costs from \$10,000 to \$20,000.²¹ There are also ongoing operating costs for maintenance, and with more advanced systems, management.

¹⁸ Texas A&M Transportation Institute (n.d.b)

¹⁹ Texas A&M Transportation Institute (n.d.b)

²⁰ US Department of Transportation (2014a)

²¹ Texas A&M Transportation Institute (n.d.b). Estimates should be considered approximate given other differences between Canada and the United States.

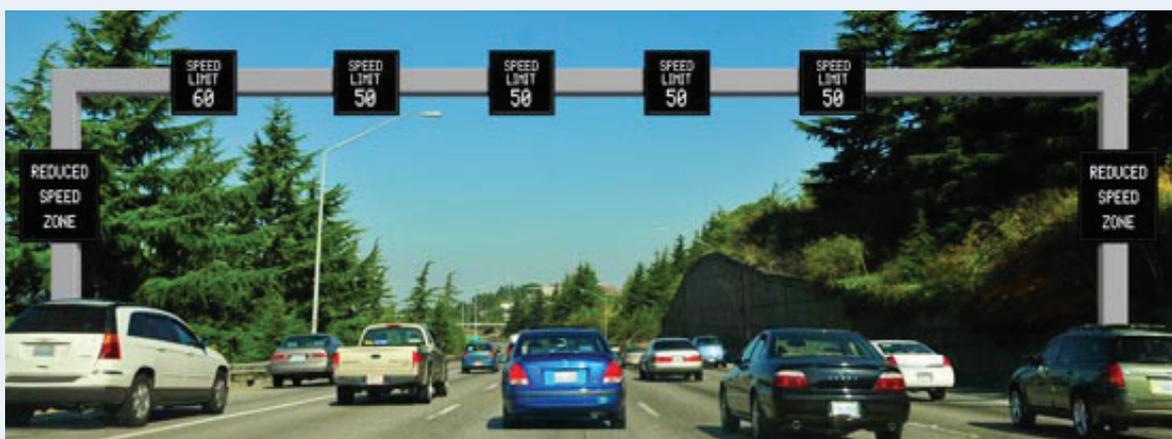
ACTIVE TRAFFIC MANAGEMENT: VARIABLE SPEED LIMITS AND TEMPORARY SHOULDER USE

Active traffic management is a series of TMS typically applied to a freeway. The objective is to increase the capacity of a freeway by smoothing traffic flow and reducing collisions, alleviating congestion. While specific combinations of TMS used vary, typical elements include variable speed limits (VSL), temporary shoulder use (at times of high traffic volume and in conjunction with reduced speed limits), lane use control signs, queue warning systems and dynamic message signs.

VSL²² are systems that reduce speed limits (e.g. with dynamic signage as pictured in Figure 3) when traffic congestion is imminent. VSL can be either mandatory or advisory. Typically sensors detect when congestion (or weather conditions that can cause congestion) exceeds predefined levels and then lowers speed limits in increments of 5-15 km/h. VSL can thereby significantly reduce or delay the onset of congestion and associated stop-and-go traffic and rear-end collisions, which further compound the problem. Benefits arise because the increase in travel time from the lower speed limits should be less than the reduction in speed that congestion would cause.

British Columbia has implemented variable speed limits on Highways 1, 5 and 99. The stated intent is safety improvement in adverse weather conditions. The City of Edmonton had a pilot project to implement advisory VSL on Whitemud Drive, which ended in 2015. The City of Lethbridge, AB, implemented variable speed limits on a 3.5-km section of Whoop-Up Drive in 2016, also specifically targeted at improving winter safety. The speed limit is reduced from 90 km/h to 60 km/h. Since it was implemented in 2014, the section saw collisions during severe snow events reduced from a significant number to zero when the 60-km/h limit is in effect.²³

Figure 3: Variable Speed Limits



Source: Washington State Department of Transportation

²² Also known as harmonization or dynamic speed limits.

²³ City of Lethbridge (n.d.) "Variable Speed Limits on Whoop-Up Drive."

Temporary shoulder use allows all vehicles, or in some cases only transit vehicles (sometimes called a bus by-pass lane/shoulder), to use the paved shoulder of a freeway during peak periods to alleviate congestion. Temporary shoulder use is typically accompanied by a reduced speed limit. In the Vancouver area, shoulder use (not temporary) is in place on the Highway 99 corridor, as it is on the Don Valley Parkway and Highway 403 in Ontario. On the Don Valley Parkway the lanes are only used when traffic speed drops below 60 km/h and buses are only permitted to travel 20 km/h faster than traffic in other lanes.

EXAMPLES

Germany: Autobahns

VSL are in use in a number of high traffic freeways (autobahns) in Germany, usually in combination with other variable message signs that display information on road conditions, weather and incidents. On some sections VSL are paired with shoulder use.²⁴ Roads with VSL have seen travel times reduced by 5-15% and the number of collisions reduced by 30%. At the same time volume of traffic handled has risen by 5%.²⁵

United Kingdom: Smart Motorways

The UK has an extensive network of what are called smart motorways. A smart motorway has four key elements: shoulder use, VSL, emergency refuge areas and signals and dynamic message signs. An evaluation of the first smart motorway (M42) with shoulder use showed increased throughput of 7-9%, reduction in travel time of 3-8% at peak times, reduction in travel time variability of 27% and reduced occurrence of severe congestion.²⁶ This experience also showed that low speed limits (40 mph – 65 km/h) resulted in much lower compliance than when the limit was set at 50 mph (80 km/h) or 60 mph (97 km/h).²⁷

Virginia: Interstate 66 Active Traffic Management

Completed in September 2015, this active traffic management system aims to increase capacity on Interstate 66 (I-66) with a combination of advisory VSL, queue warning systems, lane-use control signs and shoulder use. In order to assess the impact of this project, the Virginia Department of Transportation did a before-and-after study. In this case, the shoulders were already being used in peak periods, and so the impact at peak times was limited. However, weekday travel times did improve by 2-6% at midday and in the off-peak direction of travel during peak periods. During the weekend peak period, travel times and reliability improved by about 10%.²⁸

²⁴ Geistefeldt (2011)

²⁵ Texas A&M Transportation Institute (n.d.a)

²⁶ Van Vuren et al. (n.d.)

²⁷ Texas A&M Transportation Institute (n.d.a)

²⁸ US Department of Transportation (2017a)

TECHNICAL FEASIBILITY, LIMITATIONS AND TRENDS

Requirements for VSL include sufficient overhead space available for installation of gantries (for the signs) and dynamic message signs at frequent intervals. Typically, VSL is applicable to freeways, but may also be applicable along certain high volume roads.

Compliance is also a key driver of the effectiveness of VSLs. Communication with the public and enforcement can support this. As illustrated in the M42 example, compliance will drop if VSLs are not seen by motorists to have a benefit.²⁹

Temporary shoulder use is also a relatively low-cost solution, if suitable paved shoulders are in place. However, in many urban settings, physical space constraints, such as bridge clearances on the Don Valley Parkway in Toronto (illustrated in Figure 4) or conflict points at interchanges make shoulder use not feasible. Shoulder use is more costly to implement if emergency refuge areas must be built (as disabled vehicles would otherwise block the shoulder lane).

From a safety perspective, generally there is a safety benefit from reducing congestion, but a safety cost in terms of losing the use of the shoulder as a place to stop in emergencies, a means of access for emergency vehicles, and potentially a narrower lane.³⁰ The overall impact on safety depends on specific circumstances. Achieving an acceptable level of safety at reasonable cost can be a limitation to temporary shoulder use.

VSL do require ongoing operating costs including adjustments for periods of construction. The cost of converting shoulders for temporary use is highly dependent on specific conditions. For example, the Washington State Department of Transportation was able convert freeway shoulders for use at a cost of \$1.3 million per km.³¹

Figure 4: Some Major Infrastructure Constraints to Shoulder Use on Toronto's Don Valley Parkway



Source: CPCS

²⁹ Texas A&M Transportation Institute (n.d.a)

³⁰ US Department of Transportation (2016)

³¹ Texas A&M Transportation Institute (n.d.c)

TRENDS AFFECTING COSTS AND BENEFITS

Technological development is the overriding trend affecting the costs and benefits of TMS. The table below describes two key aspects.

| TREND | WHAT IS IT | POTENTIAL IMPACT ON TMS |
|--|--|--|
| Falling cost of technology and increased availability | The costs of implementing advanced traffic management technologies are dropping, including because of wireless systems and off-the-shelf software. | Traffic management systems will become increasingly accessible to smaller municipalities and for use on lower volume corridors in larger municipalities that might not have been worth upgrading in the past. |
| Increasing connectivity of vehicles | Increasing connectivity of vehicles with wireless networks and infrastructure can allow for increased communication and data gathering. | Connected vehicles can make TMS work better. For instance, adaptive traffic signals can use wireless signals from vehicles to detect traffic and optimize traffic flow. The use of wireless technologies can help to reduce infrastructure cost, including costs associated with maintaining traditional sensors, such as detectors embedded in pavement, which are frequently damaged by construction. |

While it is difficult to predict the speed of technological progress, it seems likely that the cost of implementing TMS will continue to fall, making these technologies more feasible for smaller communities and for lower volume routes within urban areas that may experience localized congestion. TMS are already feasible, subject to constraints noted in this briefing, in congested urban areas.

CONCLUSION

Individual TMS technologies rarely operate in isolation. So what would a large and coordinated effort to promote a package of these solutions look like in terms of their total benefits? Benefits would be greatest in areas of greatest congestion, such as the bottlenecks identified in the CAA study *Grinding to a Halt: Evaluating Canada's Worst Bottlenecks*,³² and where no or outdated TMS are currently in use.

TMS can be a low-cost and effective solution to the problem of urban congestion in Canada. For city streets, improved traffic signals merit study for any area experiencing congestion. For freeway congestion, ramp metering, variable speed limits and temporary shoulder use can help to alleviate congestion. However, these systems can be limited by physical constraints such as space to install ramp meters or the absence of suitable paved shoulders. TMS are also limited because they do not change the underlying demand for using roads and highways. Nonetheless, they are a practical and generally underexplored solution to the problem of urban congestion in Canada.

³² CAA (2017)

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