Initiatives by the Ministry of Transportation of Ontario to Reduce the Delay Cost Associated with Major Highway Incidents

Rob Pringle P.Eng., Senior Project Manager, WSP|MMM Group Ltd.
Goran Nikolic P.Eng. Head, Traffic Planning, Ministry of Transportation, Ontario

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ABSTRACT

A major incident on a 400-series highway in the Greater Toronto Area has the potential to result in significant costs related to delay with respect to both passenger and commercial travel. Such incidents might involve collisions requiring police investigation or truck roll-overs, fires, or major spills, and could result in partial or full highway closures over multiple hours. In addition, significant delay would be anticipated on “diversion” routes used by drivers to circumvent the incident, as well as delay incurred during the system recovery period once the highway has been re-opened. Since traffic flows on major highways can range from 5,000 vehicles/hour to between 10,000 and 15,000 vehicles per hour over much of the typical day, the total delay cost from a single incident can run into the millions of dollars without even considering the implications for the broader economy.

The Ministry of Transportation of Ontario (MTO) is in the process of reviewing response strategies to major incidents in two contexts. First, prior to the 2015 Pan Am/ParaPan Am Games, the Ministry developed traffic management plans to address major incidents affecting the highways accommodating the temporary High-Occupancy Vehicle (HOV) lanes implemented for the Games. These plans were designed to be more proactive than ambient incident response protocols. The use of the plans on several occasions during the Games created a generally favourable impression of the potential to reduce the impacts of traffic incidents. Secondly, the potential benefit associated with reducing the amount of time required to clear truck roll-overs and similar incidents has been investigated. We also note that ongoing expansion of the use of advanced traffic management systems (ATMS) by the Ministry enhances the toolbox available for incident-related traffic management.

This paper describes the process used to develop more pro-active traffic management protocols for major incidents and provides an evaluation of some of the potential benefits of reducing the time required to clear truck roll-over incidents.

INTRODUCTION

Over a period of 8 days, between March 8, 2017 and March 16, 2017, three large-vehicle roll-overs occurred on Provincial 400-series highways in the Greater Toronto Area:

- On Wednesday March 8, a multiple-unit truck rolled-over on the Burlington Skyway, reportedly due to high winds, blocking the Toronto-bound lanes of the Skyway between approximately 12 noon and 5 p.m.
- On Friday, March 10, a multiple-unit truck rolled over on the ramp from southbound Highway 427 to westbound Highway 401, resulting in the closure of this ramp, the ramp from northbound Highway 427 to westbound Highway 401, and the westbound Highway 401 collector lanes, between approximately 12 noon and 5 p.m.
- On Thursday, March 16, a bus rolled over on the westbound Highway 401 near Allen Road, blocking all westbound collector lanes between approximately 9:30 a.m. and 2:30 p.m.

Fortunately, these incidents did not result in any fatalities. However, in all three cases, the highway and ramp closures were in effect for approximately five hours. During these closures, the number of vehicles that would typically pass through the closed lanes on an average weekday would be approximately 23,000 for the Burlington Skyway, 19,000 for the ramps and collector lanes at the Highway 427/Highway 401 interchange, and 17,000 for the Highway 401 westbound collector lanes near the Allen Road. These numbers do not include vehicles affected during the "recovery" period following re-opening of the closed lanes and ramps, vehicles on alternative routes affected by diverted vehicles (including the express lanes where the incident occurred on the collector lanes), vehicles affected upstream that would not otherwise have passed through the incident locations, and vehicles in adjacent lanes affected by slowing due to "rubbernecking". Obviously, the road user costs related to delay that result from such incidents are significant. However, these costs do not include the broader economic impact related to the impacts of delay such as those incurred at workplaces or at industrial operations operating with "just-in-time" shipments, missed personal appointments, and disrupted transit schedules.

MTO defines "major" incidents as those involving closure of one or more lanes of a highway for at least 30 minutes. These closures may result from collisions or non-collision-related events. For 2013, MTO reported that 360 such incidents occurred on Central Region expressways (approximately one per day on average) while an additional 132 incidents occurred on expressway ramps. Central Region includes the Greater Toronto Area, Hamilton, and Simcoe and Niagara Regions. The average duration of the expressway closures was 3.4 hours while that for the ramp closures was 3.8 hours. In all, the freeway closures totaled 51 days while the ramp closures totaled an additional 21 days.

This paper describes analysis undertaken in support of two initiatives by the Ministry of Transportation of Ontario (MTO) to reduce the delay and economic cost resulting from major incidents on their highway system. The first initiative discussed involves the pursuit of legislation to reduce incident clearance times by allowing large commercial vehicles which have rolled over to be moved from the active lanes without first being restored to an upright attitude, a potentially complex and time-consuming process. Legislation related to liability does not currently allow this, although it is noted that the trailer involved in the Skyway incident was separated and towed from the Skyway without up-righting, likely due to concern that the high winds would topple it again.

The second initiative involved the development of traffic management plans by MTO for the 2015 Pan Am/ParaPan Am Games to reduce the traffic impact of major incidents on highways accommodating the temporary High-Occupancy Vehicle lanes (HOVL) implemented for the Games. These traffic management plans were designed to be more pro-active than the standing protocols typically implemented either by first-responders or by MTO.

EVALUATING THE POTENTIAL BENEFITS ASSOCIATED WITH REDUCED CLEARANCE TIMES FOR TRUCK ROLL-OVERS

Overview

An assessment of the benefit of reducing the clearance time for roll-over incidents from six hours or four hours to two hours was undertaken. Four to six hours was considered to be representative of the duration of highway closures needed under existing clearance protocols (all of the incidents described above involved closures of approximately five hours) while two hours was assumed to be an appropriate closure duration under the proposed protocol. This assessment included consideration of reductions in both delay and air emissions.

Methodology

Delay and air emissions were evaluated using the Aimsun traffic simulation model developed for the evaluation of temporary High-Occupancy Vehicle (HOV) lanes for the 2015 Pan Am/ParaPan Am Games. This simulation model covers the Greater Toronto Area south of Highway 407 between Ajax and Burlington. This is a “hybrid” model with the key highway corridors operating at the microscopic level and the remainder of the network operating at the mesoscopic level. The available travel demand inputs, covering the period from 2 p.m. to 10 p.m., were adjusted to remove trip layers that reflected Games-specific travel. Traffic demand is representative of a typical weekday under average seasonal traffic conditions in 2015.

Three case-study incident locations were selected for evaluation from a list of critical locations identified for the development of traffic management plans for the Pan Am/ParaPan Am Games:

- Westbound Highway 401 collector lanes near Keele Street;
- Westbound Queen Elizabeth Way approaching Trafalgar Road;
- Ramp from northbound Highway 427 to the westbound Highway 401 collector lanes.

Interestingly, these locations bear a strong resemblance to those for the real-life incidents described previously. A “baseline” scenario, without incident-related lane closures, was also evaluated.

At each location, the relevant lanes were closed at 3 p.m. and remained closed for either two, four, or six hours. Highway, ramp, and transfer closures were implemented to ensure that vehicles on the closed lanes would not be trapped without an escape route. Vehicles trapped initially by a closure were allowed to use the shoulder to “escape”. No other traffic management measures were implemented. Vehicles on lanes adjacent to the closed lanes were slowed to approximately 60 km/h to emulate “rubbernecking”.

Travel time, and therefore delay relative to the baseline scenario, were measured both on the highway affected by the incident and across the entire model network. However, air emissions could only be measured for the highways operating in microscopic mode – those accommodating temporary HOV lanes during the 2015 Pan Am/ParaPan Am Games.

To convert travel time or delay into an equivalent cost, several alternative values for the value of time were considered as shown in Table 1. We are assuming willingness to pay and the value of time to be interchangeable: proposed theoretical differences are ignored for the purposes of this analysis. We note that the values of time in use for MTO’s HEIR evaluation tool have not been updated since 2007 although we have ignored the influence of increases in wage and price levels that have occurred over the intervening period.

Results – delay and cost of delay

Figure 1 summarizes the additional delay per vehicle, measured on the affected highway, resulting from the incidents at hourly intervals for the different clearance times and shows the effect of queue accumulation and dissipation. The additional delay is relative to conditions without incident. The maximum delays for the 6-hour clearance time are 78 minutes for the Highway 401 incident (traffic in the collector lanes), 166 minutes for the Highway 427 ramp incident (traffic in the express lanes), and more than 502 minutes for the QEW incident (traffic on Highway 403). In the latter case, queue dissipation would extend beyond the modelled time period. On the other hand, maximum delays for the 2-hour clearance time range from 27 to 34 minutes, a significant reduction.

Delay for the Highway 401 westbound incident is relatively lower than for the other incident locations due to the availability of the express lanes as an immediate escape route. On the other hand, delay for the QEW westbound incident is relatively much higher since the immediate escape route is through the Ford Drive off-ramp and ramp terminal intersection. Furthermore, the QEW and Highway 403 merge upstream of the incident site, resulting in queuing and delay on both highways, and traffic diverting from both highways is competing for the same limited number of off-highway alternative routes. In the case of the incident on the ramp from northbound Highway 427 to westbound Highway 401, the lanes leading to northbound Highway 427 provide an immediate "escape" route although both the express and collector lanes on Highway 427 are affected and off-highway alternative routes are limited, largely due to the presence of the airport.

In terms of queue lengths related to the 6-hour clearance time, the maximum queue length experienced as a result of the Highway 401 incident was approximately 9 km. Queue length was similar in both the collector lanes and express lanes although the queue in the collector lanes was virtually static while that in the express lanes was dynamic with vehicles continuing to move, albeit at relatively slow speeds. The maximum queue length resulting from the Highway 427/401 ramp incident was 5.5 km and occurred in the express lanes. For the QEW incident, the maximum queue length was approximately 14 km. on the QEW and 15 km. on Highway 403 although it is possible that these queues grew even longer after the modelled period.

Figure 2 summarizes the total cost associated with delay related to the three incident locations, accumulated across the modelled network, under the two alternative value-of-time assumptions. These costs are significant; using the HEIR values of time, the total delay costs for a 6-hour clearance time are $3.1 million for the QEW incident, $1.4 million for the Highway 427/401 ramp incident, and $2.5 million for the Highway 401 incident. By contrast, the total delay costs for a 2-hour clearance time are $1.1 million for the QEW incident, $1.2 million for the Highway 427/401 ramp incident, and $2.0 million for the Highway 401 incident. If the surveyed willingness-to-pay values are used, rather than the HEIR values, as the value of time in the calculation of delay costs, the total delay costs increase by 27%-47%.

Figure 3 summarizes the potential cost savings resulting from reducing the incident clearance time from either 4 hours or 6 hours to 2 hours. These cost savings are based on the network-wide delay costs as discussed in connection with Figure 2. Using the HEIR values of time, the potential cost savings associated with reducing the clearance time from 6 hours to 2 hours are $2.0 million (65%), $0.2 million (14%), and $0.5 million (20%) for the QEW, Highway 427/401 ramp, and Highway 401 incidents respectively. Potential cost savings achieved by reducing the clearance time from 4 hours to 2 hours are $1.3 million (54%), $0.1 million (8%), and $0.2 million (9%) for the QEW, Highway 427/401 ramp, and Highway 401 incidents respectively.

Sensitivity

Considering the results obtained across the various incident case-study locations, it is apparent that the delay cost and potential savings are sensitive to incident location. The following discussion explores sensitivity of the delay costs and potential savings to the timing of the incident.

The timeframe of the analysis as undertaken, with the incidents assumed to occur at 3 p.m., was constrained by the extent of the available travel demand inputs which covered the period from 2 p.m. to 10 p.m. In fact, an incident occurring at 5 a.m. would be expected to result in longer queues and delays and higher delay costs. Traffic volumes on the highway system remain relatively high and close to capacity levels during the period between the morning and afternoon peak periods. For example in the westbound Highway 401 collector lanes, hourly traffic volumes between the peak periods typically represent 80%-95% of peak hour volumes. Consequently, queues that accumulate during the morning peak period following an incident at 5 a.m. would not be able to dissipate to any significant extent during the day (if at all) and would accumulate again during the afternoon peak period. Traffic on the surface street system during the day may not remain as close to peak levels as traffic on the highways but many surface streets lose capacity to on-street parking during the day.

Using the incident in the westbound Highway 401 collector lanes as an example, and based on the delay per vehicle for traffic on Highway 401, as shown on Figure 1, and a 6-hour clearance time, a profile for an incident occurring at 5 a.m. and clearing at 11 a.m. was estimated. This profile is shown on Figure 4 and is considered to be conservative, both in assuming queue dissipation between the morning and afternoon peak periods and in assuming limited incremental queue growth during the afternoon peak period. Using this profile and other reasonable but conservative assumptions, we estimate that an incident occurring at 5 a.m. in the Highway 401 westbound collectors at Keele Street, with a 6-hour clearance time, would result in total delay costs more than four times higher than for the same incident occurring at 3 p.m. Consequently, the potential delay cost savings could reasonably be at least four times higher than the values shown on Figure 3, producing potential savings ranging up to $8 million for a single incident using the HEIR values of time and $11 million using value of time based on surveyed willingness to pay..

Emissions

Emissions impacts associated with the incident-related closures were obtained from the traffic simulation model although, as noted previously, these statistics were only available for the 400-series highways modelled at the microscopic level. The emissions produced by vehicles diverted to the surface street system were not assessed. Keeping this limitation in mind, Figure 5 summarizes the changes associated with different closure durations for four key classes of emissions:

- Carbon dioxide (CO_2);
- Mono-nitrogen oxides (NO_x);
- Volatile organic compounds (VOC); and,
- Particulate matter (PM).

It is seen from Figure 5 that changes in the production of emissions as a result of an incident varies by emission type, closure duration, and location but there is no clear pattern to these variations and no obvious relationship between closure duration and the associated change in emissions. This result is not entirely unexpected as the relative contribution of the factors that determine the production of the different emissions, namely speed and acceleration, varies by the type of emission. For example, while acceleration plays a significant role in the generation of CO_2, it does not play a significant role in the generation of the other emissions. Furthermore, among the various locations and closure durations, there will be differences in the traffic volume affected and in the extent to which traffic diverts from the highways in question. Dynamic queuing will involve both higher speeds and more extended acceleration periods while more intense or static queuing will involve slower speeds and brief acceleration periods.

Overall, the emissions implications as assessed do not contribute helpfully to the relative assessment of the 2-hour vs. 4-hour or 6-hour clearance times.

THE DEVELOPMENT OF TRAFFIC MANAGEMENT PLANS TO ADDRESS MAJOR INCIDENTS DURING THE PAN AM/PARAPAN AM GAMES

Overview

In contrast to the previous discussion of the benefits associated with reducing the length of time highways are closed due to a major incident, the following discussion focuses on managing traffic following a major incident to reduce the queuing and delay impacts.

Based on historical records of major incidents on the highway system, the Ministry expected that there would be at least one major incident during the 2015 Pan Am/ParaPan Am Games that would require complete closure over multiple hours of one of the highway sections accommodating the temporary High-Occupancy Vehicle lane (HOVL) network implemented for the Games. It was therefore considered prudent to develop a traffic management strategy to reduce the impact of such incidents, both on Games-related travel, and on background traffic already constrained by the conversion of traffic lanes to create a temporary HOVL network.

MTO decided at the outset that the proposed strategy should be more pro-active than ambient protocols for dealing with such traffic incidents. Local management of the incident scene would continue in accordance with standing police and Emergency Management Services (EMS) protocols although incident clearance times were expected to be reduced, where possible, through enhanced resourcing. It was also expected that the movement of Games-accredited vehicles would be maintained during incident-related closures, either by attempting to keep the temporary HOVLs open or by escorting or detouring these vehicles around the incident location via alternative routes. The proposed strategy was oriented to incidents resulting in complete closure of the highway for a period of at least two hours. Partial closures or closures of lesser duration could advantageously be managed through "slowed down" or partial application of the strategies developed for complete closures.

MTO proposed that individual traffic management plans be developed for 35 critical locations on the expressway corridors (mainline and ramp locations) accommodating the temporary HOVLs or on adjacent highway sections where major incidents would still have a significant effect on these HOVLs. The focus was to be on significant incidents; those resulting in closure of all or most of the lanes of a highway (or of the express or collector lanes), in one or both directions, for a period of two hours or more.

A generic strategy for the management of traffic in response to major incidents on MTO expressways consists of the following steps:

- Detection and verification of an incident, in this case based on monitoring of COMPASS video feeds and reports by field personnel and the public;
- Notification and dispatch of first responders, including emergency services resources, and initiation of localized incident scene management;

- Assessment of the incident and its potential impact, including severity, extent of local closures required, and potential duration;
- Implementation of a traffic management strategy; and,
- In the case of long-duration closures, ongoing monitoring of the situation and the effectiveness of the strategy implemented and, if necessary, modification of the strategy.

The focus of this discussion is the development of the traffic management strategies which were to be in the form of a catalogue of strategies oriented to each of the critical locations – the other steps were centralized within the Unified Traffic Control Centre, an integrated inter-agency and inter-service traffic management function established for the Games.

Selection of 35 critical locations for the development of tailored traffic management plans

The 35 "critical" locations for which traffic management plans would be developed were chosen and prioritized using the following criteria:

- The frequency and severity of past incidents at or near the location, based on MTO's records;
- The availability or non-availability of suitable alternative routes relevant to the location;
- The anticipated level of congestion at the location, based on previous traffic simulations of the temporary HOVL network;
- The potential impact of the location on Games "village to venue" routes and travel times; and
- Combinations of the above.

Figure 6 depicts the locations selected for the development of traffic management plans.

Traffic management objectives, menu of traffic management measures, and supporting analysis

To scope the analysis, the potential impacts and the benefits that might result from effective traffic management, and the potentially necessary traffic management strategies, selected incidents and related closures were modelled using traffic simulation and the evolution of queuing and congestion across the network was tracked.

The following fundamental objectives were framed to guide the development of traffic management strategies:

- To avoid entrapment of vehicles;
- To provide information to drivers concerning the location of the incident and the related queue(s) to facilitate diversion. However, consistent with standard MTO practice, specific alternative routes are not identified;
- To reduce the entry of vehicles to an obstructed highway;
- To facilitate the exiting of vehicles from an obstructed highway;
- To minimize operational disturbances that would reduce the detour capacity of the remaining unblocked lanes, primarily in an express/collector context; and,
- To ensure that traffic management measures were in place when required.

The analyses described below were undertaken to evaluate potential measures to achieve these objectives and to guide the structure of the traffic management plans.

With the help of traffic micro-simulation, it was determined that during peak traffic periods on the highways involved, queues grew at a rate of approximately two kilometres (or from one interchange to the next in most cases) every 15 minutes, on average. It was therefore decided to structure the traffic management strategies around an implementation schedule based on 15-minute intervals. It was assumed that most individual traffic management measures could be implemented within 15 minutes following notification. To ensure timely implementation, the timing of notification for individual measures was set to be 15 minutes before they were actually required.

Using MTO's Greater Golden Horseshoe macroscopic (EMME) travel demand model, it was determined that 50 per cent of drivers on most sections of the highways involved exit at or before the third interchange downstream of their point of entry (fourth interchange in the case of the F.G. Gardiner Expressway and the Queen Elizabeth Way). It was concluded that it would be beneficial to close the on-ramps (including highway-to-highway on-ramps) between the incident and the third on-ramp upstream of the last available off-ramp upstream of the back-of-queue. The number of vehicles that would be added to the queue on the affected highway would be reduced significantly, slowing queue growth. The volume of traffic competing for limited exit capacity at off-ramps and ramp terminals (or transfers) would also be reduced easing the overload at these bottlenecks.

Drivers by-passing an incident on the surface street system may attempt to re-enter the highway as soon as possible once they have passed the incident location. In the case of a closure of the express lanes, it was observed, using traffic simulation, that the capacity of the collector lanes to accommodate bypassing traffic could be increased by 60 per cent by eliminating the merging disturbance at the first one or two on-ramps downstream of the incident location. If there is a collector-to-express transfer downstream of the incident location, such closures would not be necessary downstream of the transfer.

Based on the objectives and the analyses discussed above, a menu of potential traffic management measures was established. Guidelines were also developed to assist in the selection and detailing of appropriate measures for different situations including simple highways, express and collector lanes of complex highways, and highway-to-highway ramps. The menu is summarized below along with a sample of the many explanatory notes accompanying the guidelines.

• Driver information by remote means (MTO website, television, radio, internet/navigation/ social media feeds)	• Implementation assumed but not specifically included in traffic management plans

• Driver information by means of Variable Message Signs (VMS)	• Additional/temporary VMS would be deployed
	• Provide closure location and back-of-queue location (i.e. very slow beyond…)
	• Alternating messages required in many cases
	• Provide messaging upstream:
	  • within 10 km. of incident
	  • in advance of "strategic" interchanges providing access to expressway route alternatives
	  • on intersecting highways

• On-ramp, highway-to-highway on-ramp, or transfer closures to avoid vehicle entrapment	• Avoid trapping vehicles without escape access to an off-ramp or transfer*
• On-ramp, highway-to-highway on-ramp closures	• Close on-ramps upstream from incident to third interchange (or fourth for some highways) beyond last available off-ramp beyond back-of-queue*

• On-ramp closures downstream of the incident location (only for closures of express lanes)	• Close up to two on-ramps between incident in express lanes and next downstream collector-to-express transfer*
• Modification of traffic signal phasing/timing at off-ramp terminals and intersections along primary diversion routes	• Provide extended green time to facilitate traffic leaving highway at off-ramp terminals (and on primary diversion routes near these terminals • Alternatively, increase cycle length by 15% • Agencies operating signals may have alternate plans in place to account for highway-related problems

* *Where relevant, account for imminent blockage of ramps or transfers by growing queues as well as lane-changing distance required to reach off-ramps or transfers.*

Figure 7 presents a sample of the guidelines for an incident on a “simple” highway (no express/collector system). These guidelines are organized consistent with the evolution of an incident– immediately following incident detection, once a queue has formed, as the queue grows, and once the incident has been cleared and the queue has begun to dissipate.

Traffic management plan development

To facilitate the development of traffic management plans, enhancements to the Aimsun traffic simulation software were specified and implemented to allow interactive operation. These enhancements allowed the analyst to instruct the simulation to pause at pre-set intervals, in this case every 15 minutes, to allow a visual review of queue development and traffic congestion hotspots on-screen. These enhancements also provided the analyst with the option of adding, modifying, or removing traffic management measures based on that review, changes which would then be in effect when the simulation was re-started. This allowed the analyst to develop a traffic management plan for a specific incident location within one interactive simulation replication, rather than having to run multiple replications from the start to complete each plan. The Aimsun model used was that developed for the evaluation of the temporary HOVLs implemented for the Games, covering the Greater Toronto Area north to 407/ETR. Each plan was organized around a synchronized timeline and back-of-queue location based on the traffic simulation. For each 15-minute interval, traffic management measures were identified for implementation. Although the timeline provided, in effect, a provisional traffic management implementation schedule, it was intended that in practice, implementation would be tied to observed queue evolution rather than time. Figure 8 presents a sample traffic management plan.

The traffic management plan catalogue for the 35 selected critical incident locations was housed within a Google Earth application. Each plan was cross-referenced to the location on the aerial for that particular incident. For incidents at other locations or for incidents with significantly different characteristics, the following guidelines were proposed:

- For an incident near one of the catalogued locations for which a traffic management plan had been developed, that traffic management plan could be adapted on-the-fly.
- For an incident at a location remote from any of the catalogued locations or a situation significantly different from a nearby catalogued location, the guidelines could be used to develop a traffic management plan on-the-fly.

- For an incident involving closure of only a portion of the available lanes or an incident of less than two hour duration, an available traffic management plan could be implemented partially and/or implementation could be "slowed down".
- For an incident involving closures of more than five hours, it was proposed that the traffic simulation model used for traffic management plan development could be utilized, essentially in real time, to develop a traffic management plan. This capability was not available for the 2015 Games. To achieve the full benefit of real-time traffic planning, the traffic simulation model would have to be integrated with ongoing traffic monitoring.

In practice, no traffic management plan can account for all eventualities and judgement will often be required to modify

Application in practice

The traffic management plans were applied on several occasions during the Games. Due to various circumstances, such as the incidents and related closures not being as severe as assumed for traffic management plan development, the plans were only partially applied. Nonetheless, it was apparent from comments made by those coordinating traffic, that the measures applied assisted in reducing queue lengths and in speeding up system recovery following clearing of the incident. The traffic management plans developed for the Games represent a legacy of the Games that could be used as a starting point for a more permanent protocol to be applied to significant highway incidents on an ongoing basis.

CONCLUSIONS

Major incidents requiring lane closures occur on Provincial expressways in MTO's Central Region with surprising frequency, on average one such incident every day of the year. Even more significant incidents resulting in highway or multiple lane closures over an extended period do not occur nearly as often although it is noted that three such incidents occurred recently within an 8-day period. Incidents in this latter group can result in significant delays and delay costs due to the number of vehicles affected, analysis presented here estimating a cost of up to more than $10 million per incident, not including the broader economic cost. The delay cost resulting from an incident was found to be sensitive to the location of the incident and the time of day at which it occurs.

It makes sense to attempt to reduce these costs and this paper covers two initiatives designed to contribute to achieving this objective. The estimates of delay cost referenced above were developed in support of a current proposal to reduce the clearance time for truck rollovers on Provincial expressways by allowing the trucks to be dragged off the travelled way without first uprighting them. A second initiative involved the development of pro-active traffic management plans to reduce the impact of significant incidents on the expressways accommodating temporary High-Occupancy Vehicle lanes during the 2015 Pan Am/ParaPan Am Games. In both cases, the analysis undertaken and the lessons learned can be used in the development of a longer-term solution.

ILLUSTRATIONS

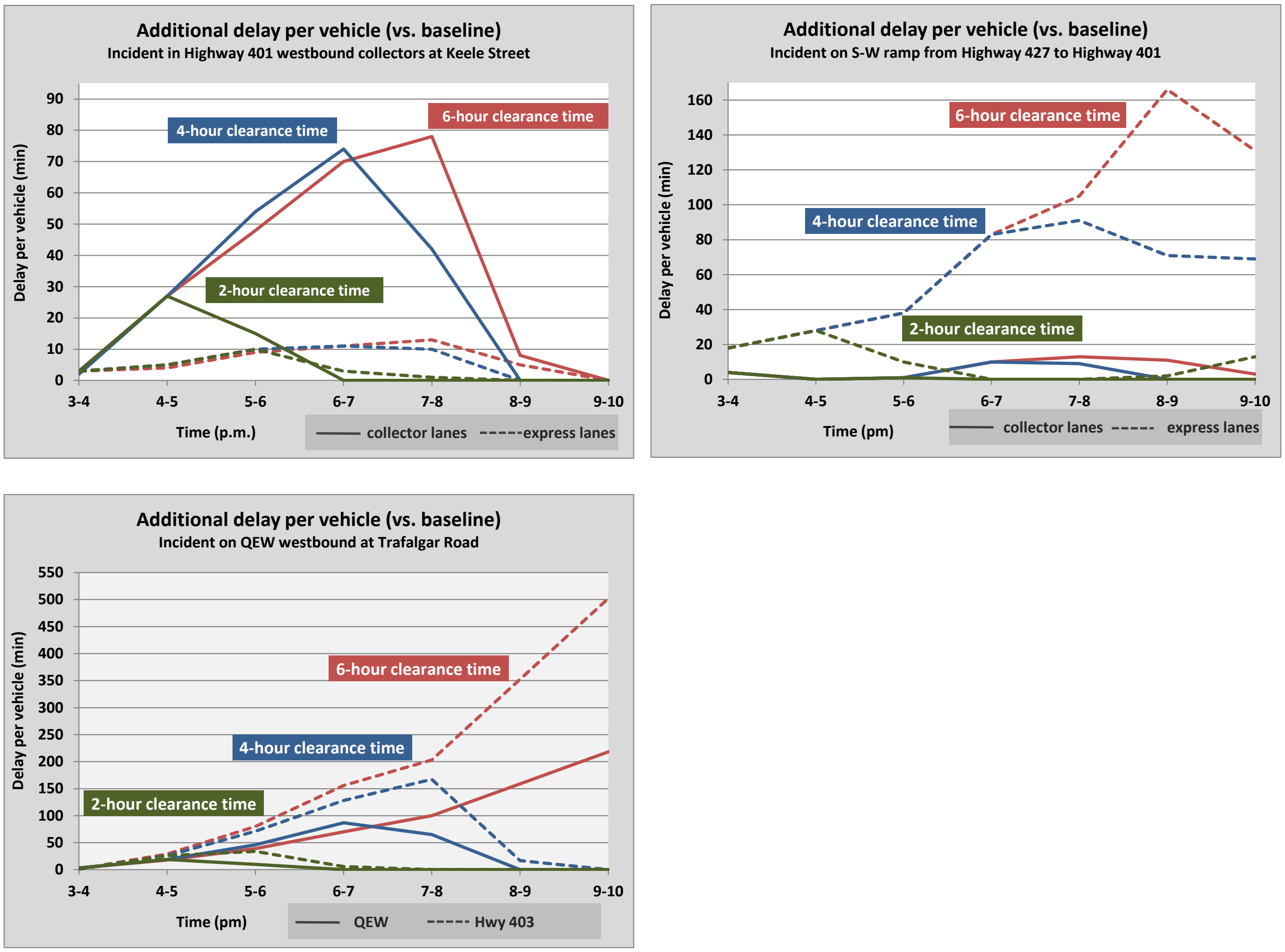


Figure 1: *Additional delay per vehicle – 3 incident locations*

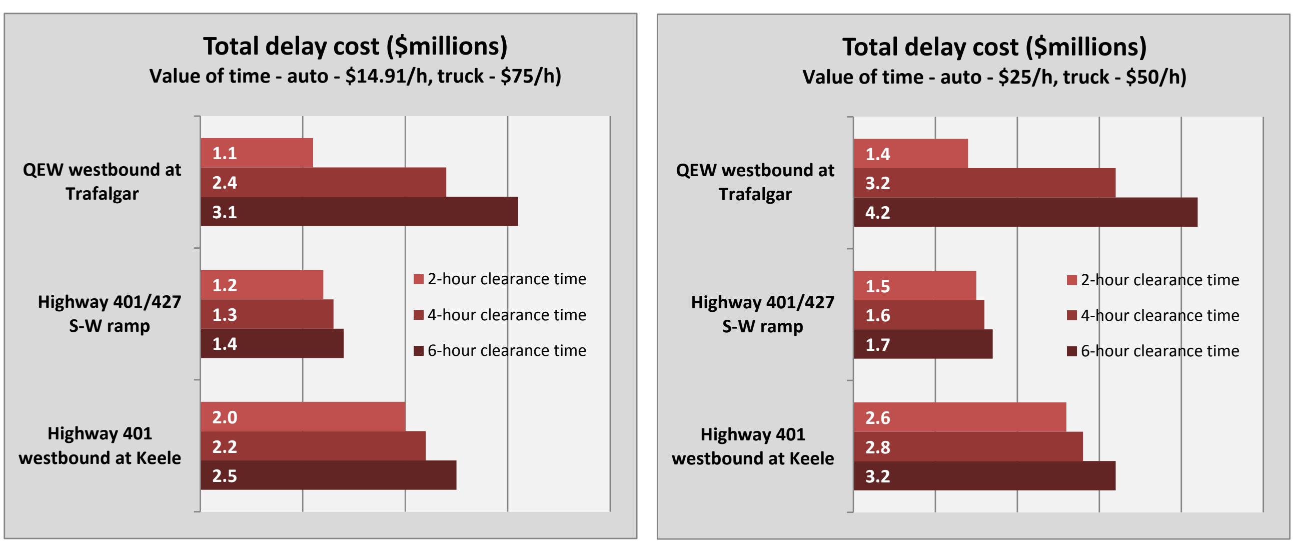


Figure 2: *Total delay cost – 2 value-of-time alternatives*

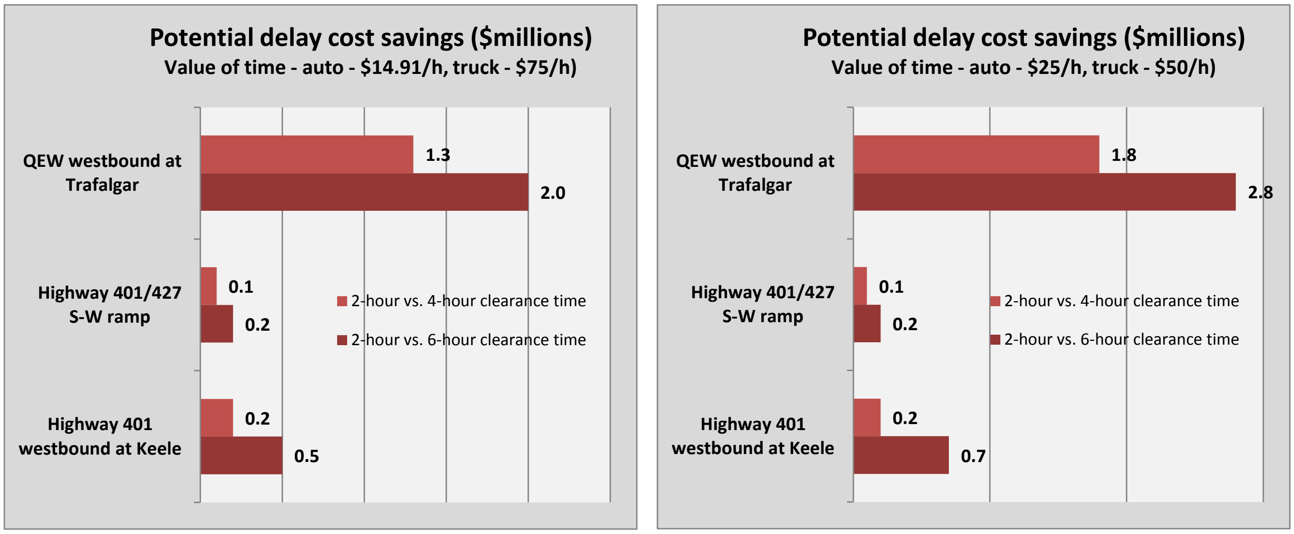


Figure 3: *Potential delay cost savings – 2 value-of-time alternatives*

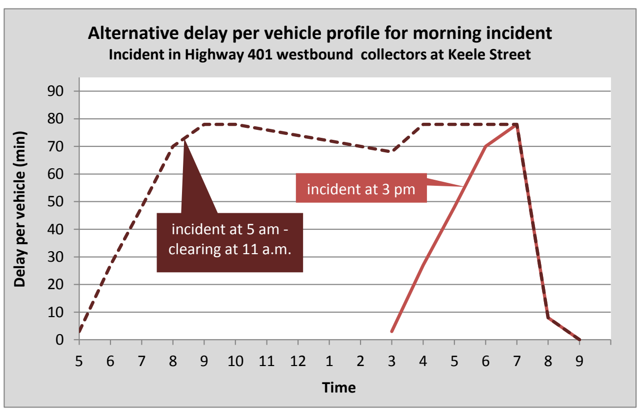


Figure 4: *Alternative profile for additional delay per vehicle based on an incident occurring at 5 am*

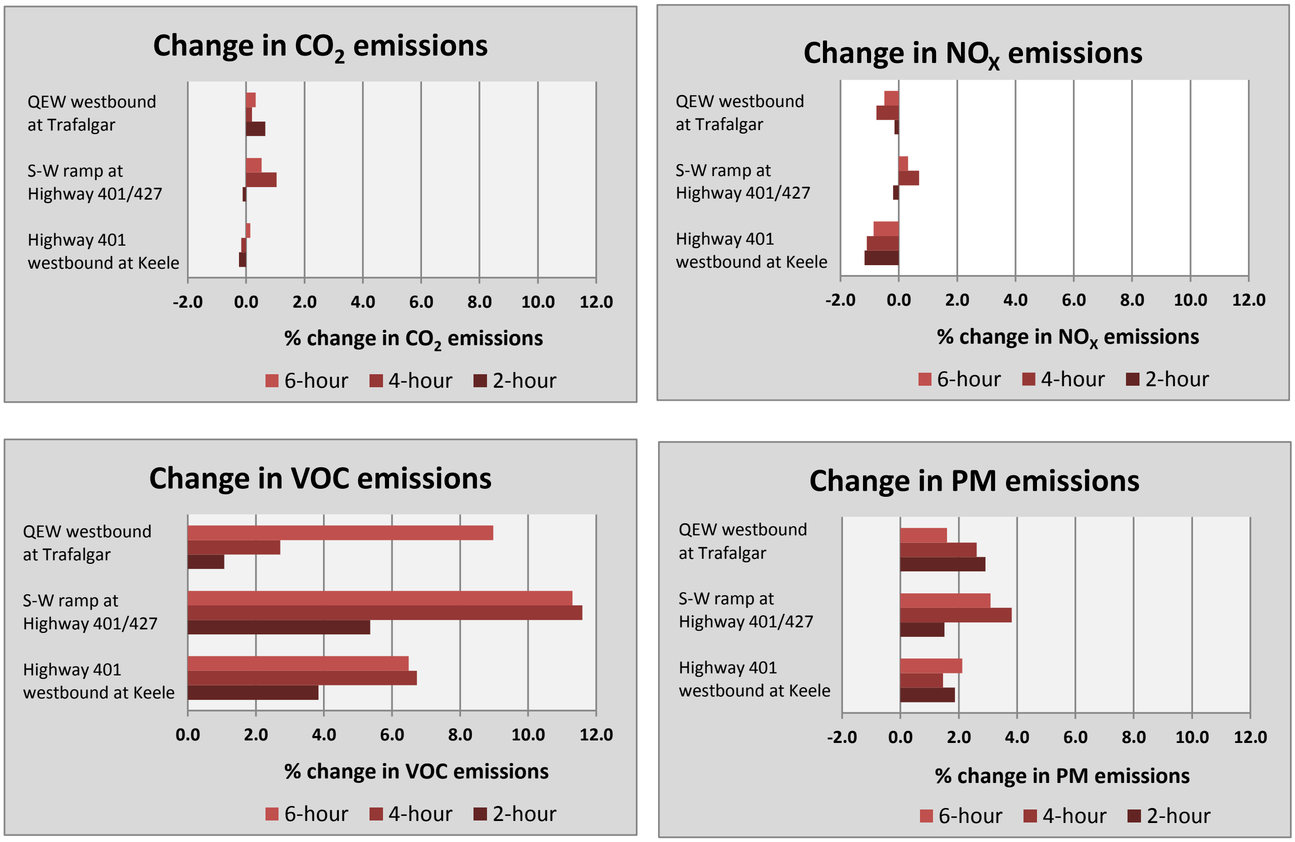


Figure 5: *Percentage changes in production of four key classes of emissions*

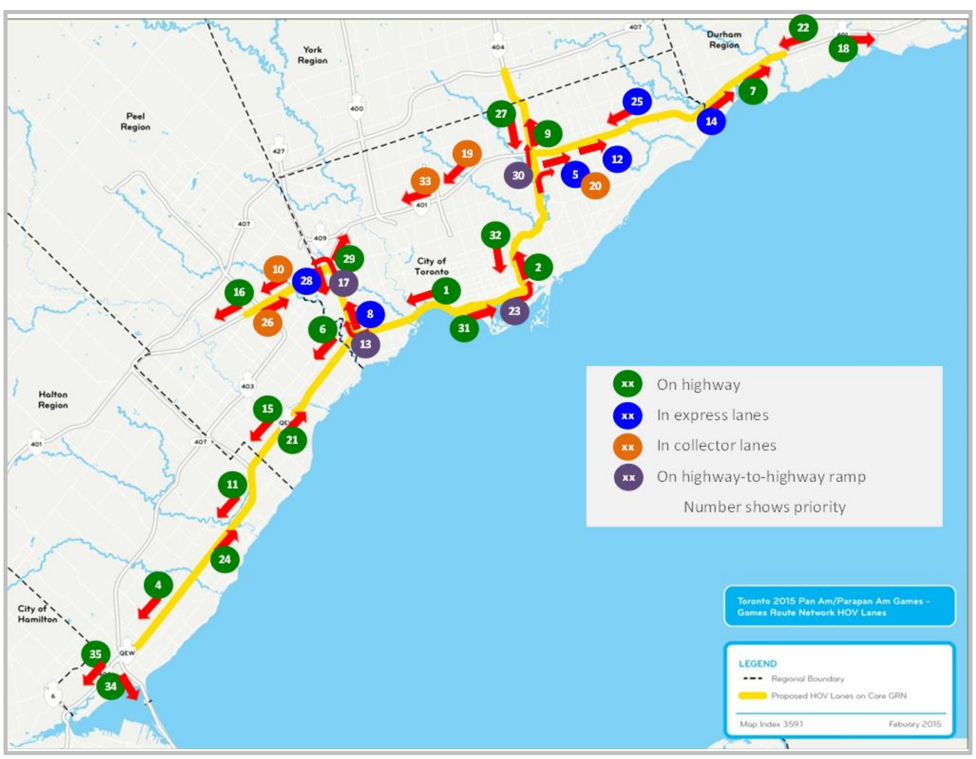


Figure 6: *Critical incident locations and priorities*

GUIDELINES FOR AN INCIDENT RESULTING IN FULL BLOCKAGE OF A SIMPLE HIGHWAY

Note that the strategies shown are in addition to local traffic management implemented by first responders (OPP, MTO, EMS) at the incident site.

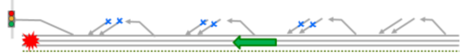
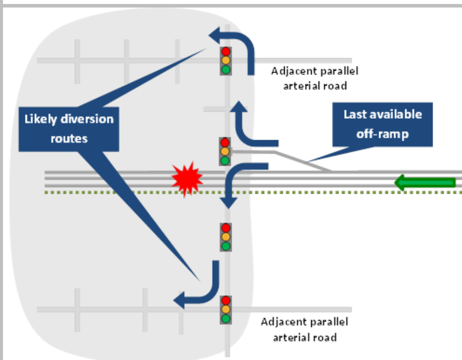
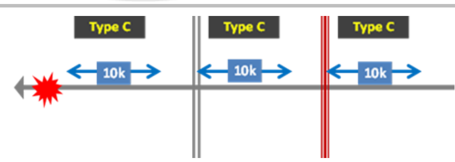
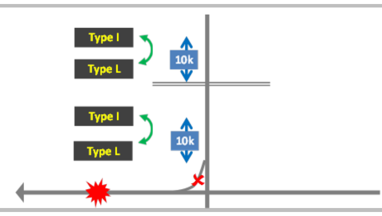
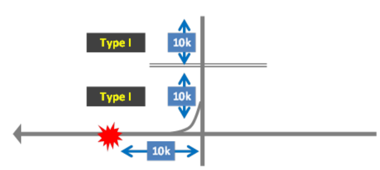
ACTION	SCHEMATIC	NOTES/VMS TYPES
1 Immediately following incident detection…		
A Close on-ramps at 3 interchanges (4 for QEW, FG Gardiner) upstream of last available off-ramp upstream of incident location.	 ***On-ramps to be closed at 4 upstream interchanges for the QEW and FG Gardiner – 3 interchanges for all other highways.***	Two ramps are shown on the schematic at each interchange (loop and direct ramps for a Parclo A interchange) – these may be combined in some fashion, depending on the interchange configuration.
B Implement traffic signal plan modifications at last available off-ramp terminal upstream of incident location - plus adjacent signals as required and practical.		Suggested traffic signal plan modifications are included in the individual traffic management plans with respect to the ramp terminal for the last available off-ramp upstream of the incident. It is suggested that regional/municipal staff consider additional signal timing changes to facilitate traffic on likely diversion routes (see shaded area of schematic at left). Such changes may be included as part of a pre-existing plan to manage traffic in the event of an incident on the highway. Changes may involve changes in signal splits, factors applied to signal splits or, as a fallback, an increase of 15% in the cycle length. Signal timing changes may be implemented remotely or may be implemented by on-scene OPP or municipal/regional police.
C Implement VMS messaging on blocked highway: • Upstream, within 10 km of incident • Upstream, within 10 km of relevant highway-to-highway interchange(s)[1] • Upstream, within 10 km upstream of relevant strategic interchange(s)[2]		**Type C message** **VMS:** Highway blocked beyond Yonge **PVMS:** Hwy blocked beyond Yonge ***In the case of a blocked highway that continues physically under a different name (ie. Highway 404/DonValley Parkway, Queen ElizabethWay/F.G. Gardiner Expressway) OR a situation where a "strategic" VMS is at a location not on the blocked highway, a Type I message should be used rather than Type C.*** **Type I message** **VMS:** QEW eastbound blocked beyond Dixie **PVMS:** QEW eastbd blocked beyond Dixie
D Implement VMS messaging on an intersecting highway **IF** connecting ramp is one of those closed by **A** above. **OR** **D** Implement VMS messaging on an intersecting highway **IF** interchange with the blocked highway is within 10 km of incident **AND** connecting ramp is not one of those closed by **A** above.	 	**Type I message** **VMS:** QEW eastbound blocked beyond Dixie **PVMS:** QEW eastbd blocked beyond Dixie **Type L message** **VMS:** Ramp to Highway 401 eastbound closed **PVMS:** Ramp to 401 eastbd closed
2 Once a queue has formed…		
E Close additional on-ramp(s) as required so that on-ramps are closed at 3 interchanges (4 for QEW, FG Gardiner) upstream of last available off-ramp **AND** the last available off-ramp is at least 1 km upstream of back-of-queue.	 ***On-ramps to be closed at 4 upstream interchanges for the QEW and FG Gardiner – 3 interchanges for all other highways.***	Two ramps are shown on the schematic at each interchange (loop and direct ramps for a Parclo A interchange) – these may be combined in some fashion, depending on the interchange configuration. The 1 km buffer beyond the ramp bull-nose provides an opportunity for the "last" vehicles using an on-ramp (before it is closed) to reach the last available off-ramp before it is blocked by the growing queue.

Figure 7: *Sample guidelines for the development of traffic management plans – only a portion of the guidelines for a "simple" highway (no express/collector system) is shown*

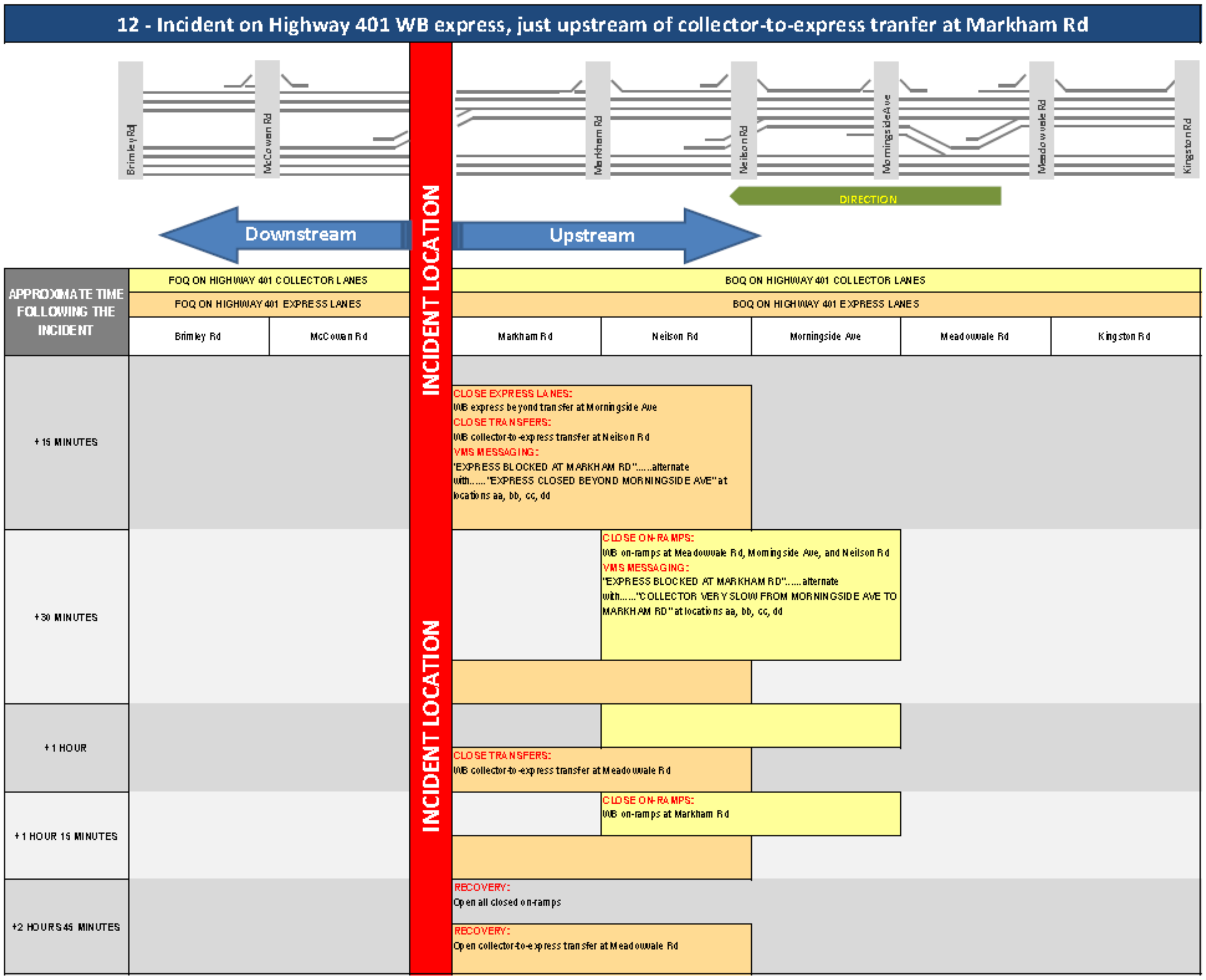


Figure 8: *Sample traffic management plan*

TABLES

Table 1: *Alternative values of time*

Source	$/hour for autos	$/h for trucks
MTO's Highway Element Investment Review (HEIR) methodology for conducting economic analysis	$14.91	$75
Recent stated-preference surveys assessing willingness to pay for time saved through use of a High-Occupancy/Toll (HOT) lane	$25	$50*
** The survey only included auto travel. The value for trucks was assessed as twice that for autos based on a literature review.*		