Get me to the track on time! – Traffic management for the 2015 PanAm/ParaPanAm Games in the Greater Toronto Area

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Abstract

The 2015 PanAm/ParaPanAm Games are scheduled for July and August 2015 in the Greater Toronto Area. Due to the overall level of congestion on area highways and the fact that the Games venues are distributed across a wide area, with the Athlete's Village being located on the Toronto Waterfront, travel time reliability for athletes and officials is a key issue. The Ministry of Transportation of Ontario was assigned the responsibility of planning and implementing a traffic management strategy to ensure that athletes and officials could be at their venues "on time" while minimizing the impact on the travelling public.

To facilitate the development and evaluation of traffic management strategies, a large multi-level traffic simulation model was developed using AIMSUN. While the "macro" and "meso" levels of the model were used at various stages in the process, the principal tool for operational analysis was the "hybrid" level, featuring "micro" operation on key expressway corridors and "meso" operation on the remaining expressways and arterial roads. The model includes 345 kilometres of expressways, 135 interchanges, approximately 2,000 km of surface streets, and 920 signalized intersections. In addition to the evaluation of Transportation Systems Management (TSM) strategies, the simulation model was used to evaluate the potential role of Travel Demand Management (TDM) in mitigating the traffic impacts of the Games.

This project was a significant undertaking led by the Ministry of Transportation and involved three firms – MMM Group Ltd., CIMA Canada Inc. and TSS-Transport Simulation Systems Inc. We would like to acknowledge those who played a significant role in bringing the project to fruition:

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1) Introduction

The 2015 PanAm and ParaPanAm Games are being held in July and August, respectively, in the Greater Toronto Area. The venues are distributed across the Greater Toronto Area and beyond while the Athletes' Village is located on the Toronto waterfront in the downtown area. One of the requirements associated with hosting the Games is the assurance that reliable travel times will be ensured for athletes and Games officials between the Village and the various Games venues. The Ministry of Transportation proposed that a network of temporary HOV lanes be implemented during the Games to facilitate travel by athletes and officials. This temporary HOV lane network incorporates existing sections of permanent HOV lanes on portions of three expressways in the Greater Toronto Area along with temporary conversions of general-purpose lanes to HOV lanes on other expressway sections.

The objectives of the current project included:

- providing support to Ministry decision-makers with respect to the planning and evaluation of the temporary HOV lanes;
- evaluating the potential role of Travel Demand Management (TDM) strategies in minimizing the impact of the Games on day-to-day travel, and;
- providing traffic/incident management support for the temporary HOV lane network.

To assist in achieving these objectives, a large traffic simulation model was developed and applied using the AIMSUN traffic simulation package. This model was used to evaluate various temporary HOV lane options and to develop traffic management strategies to assist in dealing with major incidents affecting the expressway corridors.

The current paper focuses on the development and application of the traffic simulation model. It does not report on the results and subsequent decisions made with respect to the temporary HOV lane network and its operation since these had not been finalized at the time of writing.

Where innovative techniques have been employed, these are identified. These are defined as innovations relative to typical local practice and may or may not be innovations from a more general perspective.

2) Developing the traffic simulation model

The traffic simulation model covers a significant part of the urbanized portion of the Greater Toronto Area and includes approximately 345 kilometres of expressway, 135 interchanges, more than 2,000 kilometres of arterial and collector roads, and approximately 920 signalized intersections. It is one of the larger traffic simulation models in existence. The model does not include most local and collector streets and most unsignalized intersections. The study area was designed to include all highways identified for possible temporary HOV lane implementation and extend some distance beyond to accommodate re-routing of trips. The extent of the traffic simulation model is shown on Figure 1.

> ***Innovation – Operation of the traffic simulation model in "hybrid" mode.***

The simulation model is designed to operate in "hybrid" mode. Vehicles using corridors of interest for a given evaluation will operate in "microscopic" mode, at a high level of detail, while vehicles using the remainder of the network operate in "mesoscopic" mode, at a lower level of detail. For the evaluation of the temporary HOV lane network, the highways accommodating temporary HOV lanes were designated for "microscopic" operation. For the evaluation of traffic management strategies to mitigate the impact of major incidents, the highway(s) directly affected by the incident was (were) designated for "microscopic" operation. The use of "hybrid" mode significantly reduces computation time relative to full-on "microscopic" mode.

The basic road network for the model was created by importing a GIS database/shape file describing the real-life network from the Ontario Land Information System. A significant amount of checking and cleaning up was required to ensure the appropriate connectivity between links and to make sure that link attributes, such as directionality, the number and configuration of lanes, posted speed, etc. were correct. Purpose-built scripts were used to set up intersection controls and basic signal timing plans. Existing signal timing plans were imported from other models or were input, using scripts, from information supplied by the regional and municipal traffic signal operators.

Innovation – A GIS database was used to set up the basic road network.

3) Estimating travel demand

The overall travel demand structure required to address the objectives of the study consisted of a number of different elements and adjustments as shown on Figure 2.

Typically, travel demand inputs for a simulation model would be based on subarea (traversal) matrices extracted from a travel demand forecasting model such as the Ministry's Greater Golden Horseshoe (EMME) Model (GGHM). However, these matrices are typically for a single peak or off-peak hour. Since it was considered necessary to allow for multi-hour operation to fully capture the dynamic effects of congestion, it was decided to extract matrices comprising 30-minute "slices" for the period between 2 p.m. and 10 p.m. from the 2011 Transportation Tomorrow Survey (TTS), a home-interview travel survey of 5% of the households in the greater Toronto Area, conducted each Census year. Separate matrices for single-occupant vehicles and high-occupancy vehicles (HOV2 and HOV3+) were created based on auto driver and auto passenger information. Matrices for light, medium, and heavy trucks were extracted from the GGHM for the peak hours and matrices for the remainder of the analysis period were developed using typical time-of-day distributions based on observed data.

Innovation – Use of time-sliced travel demand matrices from the Transportation Tomorrow Survey.

Since the matrices described above represented an "average" day in 2011, it was necessary to adjust them to represent July conditions in 2015 using growth factors and seasonality factors to compensate for school summer closures and vacationing.

The extraction of subarea matrices for a multi-hour period requires that adjustments be made to account for the fact that trips were assigned to the 30-minute matrices based on their trip start time. Since those trips may actually arrive at the study area boundary in a subsequent 30-minute period, a matrix of inter-zonal travel times was used at the macroscopic level to shift the start times of those trips originating outside the study area appropriately.

Innovation – Time-shifting of trips from origin to arrival at subarea boundary.

Additional travel demand layers were developed to represent trips by athletes and officials between the Athletes' Village and the venues, spectator trips, trips by workers at the venues, and additional trips by workers at non-venue locations. These demand elements had been estimated through the Games planning process for the day during the Games with the heaviest schedule based on the number of spectators expected. Adjustments were required to account for the conversion of commuting trips to spectator or workforce trips, accounting for the likely increase in average auto occupancy through such conversion. Since the entries in these matrices representing trips destined to the Games venues were assigned to a time slice according to their arrival time at the venues, they had to be "back-timed" to their point of entry to the study area so they would not be "late" for the event being attended. This was accomplished using interzonal travel times at the macroscopic level.

> ***Innovation – Time-shifting of trips from venue arrival time to subarea entry time.***

A final set of layers was developed to account for trip reductions due to varying levels of travel demand management "success" during the Games. Such trip reductions often accompany major events as commuters work at home, schedule their vacation, or change their travel behaviour in expectation of increased congestion. Various strategies were considered through the Games planning process with the objective of reducing the number of "background" auto trips on the road system.

By the time all of the demand and adjustment layers had been represented, based on six vehicle classes and sixteen time slices, there were over 1,700 matrices to be combined in different ways according to individual scenarios.

4) Calibrating and validating the travel demand inputs

Calibration and validation of the traffic simulation model was targeted to average 2011 conditions, represented by data from May, June, and September, 2011. However, as noted below, the traffic volume control data could not practically be limited to this window. Calibrating and validating the travel demand model of this size, particularly given the generally congested network conditions, presents a number of significant challenges.

- Due to the size of the network, there are many control points for which data observations were available. In this case, the original control database contained over 1,300 locations. However, only a limited number of these locations had the desired class-level information for the 30-minute bins. The collection of new data was not considered to be practical for this project.
- The individual classes of vehicles suggested separate calibration by class. Since only a limited number of observations were available with the required class distinction, calibration and validation were undertaken with respect to total vehicles and the results separated once again into classes using the original proportions.
- The use of sixteen, 30-minute time slices meant that hourly observations had to be broken down into 30-minute bins and that the calibration and validation had to be oriented to the individual time slices.
- On a large network such as this, demand adjustments made at the origin-destination level have, at best, only an indirect effect on the traffic volume actually realized at a given point on the network. Furthermore, due to protracted travel times resulting from congestion, the impact is often delayed.
- Restricting the control data to that observed during May, June, and September 2011 would have reduced the number of control points unacceptably. Therefore, the available data observations were spread across different years, different seasons, and different days with different conditions related to collisions, weather, and other factors. This led to inconsistencies across the network and significant discrepancies were noted between adjacent sections of the same

highway in some cases, requiring some of the offending control points to be removed from the database.
- As noted previously, demand observations tied to trip start time at the origin required time-shifting to the time at which the trip actually crossed the network boundary.
- On a congested network, the demand cannot always be compared directly to the observed traffic volumes, which reflect the effect of queuing, delay, and traffic metering.

For this project, calibration of the travel demand was undertaken using the matrix adjustment procedures in AIMSUN, with adjustments to the process and the control database made to address the issues listed above. Given the potential scope and impact of these issues, the validation results were considered acceptable. Validation was assessed based on the correspondence plots between simulated and observed traffic volumes at detector locations corresponding to the available control data points and was measured by the standard deviation. The correspondence plots and standard deviations are shown for several cases on Figure 3. During the calibration process, various parameters were adjusted to improve the approximation of actual trip-making, while recognizing computation time implications.

5) Calibrating and validating driver behaviour

It was decided at the outset, given the tight schedule, that detailed calibration of driver behaviour would be focused on the corridors accommodating the temporary HOV lanes as it was these corridors that would be operating in "micro" mode during application. These corridors were calibrated with respect to speed and congestion patterns with the appropriate adjustment of variables related to the car-following, lane-changing, overtaking, look-ahead, and on and off-ramp models. For the remainder of the network, which would be operating in "meso" mode, calibration was oriented to the observation of real-time outputs, including density and speed. This enabled locations where operation or the level and patterns of congestion were suspect to be identified and the underlying factors addressed.

In the past, driver behaviour has been calibrated by comparing simulated traffic speeds and congestion patterns; including queue extent, timing, and duration, with results from biennial travel time surveys, previously conducted using traditional floating car surveys in conjunction with location determination using hand-held Global Positioning System (GPS) units. For calibration and validation of the current simulation model, speed data for the 2011 calibration target was obtained from TomTom for the relevant sections of highway making up the temporary HOV lane corridors. We note that the Ministry is also converting to a similar methodology for their biennial travel time survey.

Innovation – Use of crowd-sourced travel time and speed information from TomTom for calibration of driver behaviour.

6) Application of the traffic simulation model for the planning and evaluation of the temporary HOV lane network.

The traffic simulation model was first applied in support of decisions made with respect to the configuration and operation of the proposed temporary HOV lane network.

One key parameter that required evaluation was the eligibility criterion for these lanes. Existing HOV lanes operated by the Ministry on highways in the Greater Toronto Area are available to autos with two or more persons (HOV2+). However, with the addition of vehicles transporting athletes and officials, although a relatively small number, higher-occupancy vehicles transporting spectators, and high ambient HOV volumes on some sections of highway, it was thought that the travel times being targeted for the athletes and officials might be jeopardized through over-utilization of the lanes. On the other hand, restricting use of the lanes to autos with three or more persons (HOV3+) could result in relative under-utilization of these lanes accompanied by increased demand and congestion in the general-purpose lanes. The micro-simulation model was applied to estimate various performance measures, including HOV and general-purpose lane utilization, average speed and travel time by section, and travel times for the portion of the village-to-venue trips occurring on the temporary HOV lane network. As a result of this evaluation, the decision was made to operate the temporary HOV lanes as HOV3+ lanes during the PanAm Games and as HOV2+ lanes after the PanAm Games and extending through the ParaPanAm Games. A brief familiarization and debugging period is planned with the revised eligibility criteria coming into force approximately two weeks before the Games actually begin.

Also required was a review of the proposed extent of the temporary HOV lanes. The proposed network was reviewed to assess the expected benefit to Games Client Group travel arising from implementation of a temporary HOV lane vs. the implications for operation of the general-purpose lanes. On two sections of highway towards the east (Highway 401) and west (Highway 403) extremities of the network, this evaluation led to the conclusion that the benefit estimated to be gained from the temporary HOV lanes was limited and outweighed by the negative impact on traffic in the general-purpose lanes. Consequently, these sections were removed from the proposed network.

The proposed configuration of the lanes was assessed. Existing HOV lanes operated by the Ministry on highways in the GTA are separated from the general-purpose lanes by painted buffer zones, with access to and egress from the HOV lanes being restricted to clearly marked zones generally spaced at two kilometre intervals, similar to interchanges. However, for a temporary situation within restricted pavement widths, such a configuration was considered to be impractical and costly. It was therefore necessary to assess the implications of operating these lanes with more-or-less continuous access and egress, the lanes being identified by temporary signs and pavement markings. Evaluation using the traffic simulation model, in conjunction with previous similar evaluations, did not demonstrate any critical operating issues with respect to the proposed operational configuration.

Finally, the implications of achieving different levels of trip reduction through Travel Demand Management (TDM) were assessed to provide guidance in the development of trip reduction objectives and strategies.

7) Application of the traffic simulation model for the development of traffic management plans to mitigate the impact of major incidents

Based on recorded collision history, it is anticipated, with reasonable likelihood, that a major incident would occur on the highways accommodating the temporary HOV lane network at some point during the Games. A major incident, in this case, is considered to be one where all or most of the lanes of a highway are blocked for at least several hours. It was therefore decided to develop traffic management plans designed to mitigate the impacts of such incidents in terms of both the scale and the duration of these impacts.

In the context of an overall framework to manage traffic impacts due to incidents (see Figure 4), this project focused on network traffic management, including the framing of traffic management principles and their application to the development of a “catalogue” of traffic management plans to address incidents at priority locations. In the event of an extreme incident, such as the damage inflicted on the structure of the Burlington Skyway by a truck in 2014, leading to closure of the Toronto-bound lanes for four days, the traffic simulation model could be mobilized in conjunction with real-time data collection, to assist with the development and testing of traffic mitigation strategies.

The traffic management "principles" were developed for the application of a "menu" of traffic management measures. These measures included closures of lanes, ramps, or transfers, driver information provided by variable message signs (VMS), and temporary pre-emption or modification of traffic signal operation. The principles were oriented to the following objectives:

- Avoid drivers becoming trapped with no way out;
- Reduce the number of vehicles entering a blocked highway;
- Facilitate exit from a blocked highway;
- Provide driver information to promote route diversion;
- Maintain the capacity of residual unblocked lanes; and,
- Expedite system recovery once the incident is cleared and the highway re-opened.

Background analyses were undertaken to support the development of these principles. For example, through traffic simulation, it was found that during peak traffic conditions, the queue on a completely blocked highway would grow at a rate of approximately four interchanges (eight kilometres) per hour. This information was used as a guide as to the required implementation timing of management measures. From travel patterns considered at the macroscopic level, it was estimated that for highways in the GTA and under normal conditions, one half of the drivers entering the highway planned to exit again at or before the third interchange downstream (or fourth interchange for some highways). Based on this information, it was proposed to close three on-ramps upstream of the back-of-queue associated with an incident to reduce by 50 per cent the number of drivers entering the highway who would normally still be on the highway through the incident location. From traffic simulation, it was determined that, if an incident blocked the express lanes in the case of an express/collector configuration, closing several on-ramps downstream could generate significant benefit by eliminating merging disturbance and preserving the capacity of the collector lanes.

The timing of implementation of the traffic management measures was predicated on the availability of real-time information provided by the video cameras and monitoring protocols of the Ministry's COMPASS system, temporarily enhanced by additional camera coverage. The time dimension of the traffic management plans was tied to real-time monitoring of the back-of-queue resulting from an incident although traffic simulation provided supplementary estimates of elapsed time. Closures of the mainline, transfers, or ramps were timed in recognition of the progressive blockage of exit opportunities by growing queues and to account for the travel and manoeuvering time and space required by the last vehicles through before a closure was implemented.

To supplement existing policies and procedures with respect to VMS messaging which typically includes only information on the number and location of lanes blocked by an incident, it is proposed to include information on the location of the back-of-queue to assist drivers in choosing an alternative route.

The choice and prioritization of incident locations to include in the catalogue of pre-developed management plans was based on the following factors:

- Locations on the highways accommodating temporary HOV lanes, although other locations were included if they had the potential to affect these highways. These corridors were considered critical due to the additional burden placed on them by the temporary HOV lanes;

- Frequency and severity of previous incidents based on the Ministry's major incident log;
- Level of traffic congestion;
- Locations affecting the priority direction of Games-related travel (village-to-venue);
- Bottleneck potential due to lack of alternative routes.

The initial set of traffic management plans developed for the catalogue was based on complete highway, express, or collector closures for a period of four hours during the afternoon peak period at the 35 prioritized locations. The direction of additional plans to be developed is still under discussion at the time of writing of this paper.

Using the stock version of AIMSUN, the development of traffic management plans such as those proposed would be time consuming given that individual runs typically require 24 to 48 hours and that a process of multiple, trial-and-error, runs would likely be required. An enhanced version of AIMSUN was developed, incorporating the ability for the analyst to pause the simulation at regular intervals (15 minutes or the approximate time required for a queue to grow by one interchange of two kilometres), review the extant traffic conditions and queue evolution, and implement traffic management measures, based on the principles, to be implemented or removed for the following time interval. Use of this version meant that a traffic management plan could normally be developed interactively during a single simulation run. In contrast to the planning and evaluation component of the study, discussed previously, multiple simulation replications were not run during the traffic management plan development process.

Innovation – Enhanced version of AIMSUN to allow interactive development of traffic management plans.

An electronic catalogue of traffic management plans is currently under construction using the Google Earth platform. Each incident location included in the catalogue is represented on the Google Earth screen by a clickable area linked to the appropriate traffic management plan. A sample portion of a traffic management plan is shown as Figure 5.

8) Computational aspects

The size of the traffic simulation model described here, in terms of physical extent and the number of vehicles in operation at any given time, led to a number of issues with hardware and data handling processes which had to be resolved along the way. An initial upgrade to workstations including 128 GB of RAM proved to be insufficient as crashes still occurred on a regular basis. These crashes were not limited to actual simulation but also occurred in relation to input and output functions. A further upgrade to workstations featuring 512 GB of RAM and two integrated CPUs has apparently resolved issues related to computational capacity.

9) Conclusions

In conjunction with the planning process related to the transportation aspects of the 2015 PanAm/ParaPanaM Games in Toronto, a large AIMSUN-based hybrid traffic simulation model was developed to assist with transportation and traffic planning. A variety of innovative approaches were developed to cope with scale issues, address technical requirements, and improve the efficiency of model development, calibration, validation, and application.

This traffic simulation model was first used to undertake planning and operational evaluation of the temporary HOV network proposed to facilitate travel during the Games. Eligibility criteria and network extent were among the decisions supported by this analysis.

The traffic simulation model, using an enhanced, interactive, purpose-built version of AIMSUN, was also applied to the development of traffic management plans to mitigate the impact of major incidents on the highways accommodating temporary HOV lanes.

This model will have significant legacy value to the Ministry of Transportation of Ontario as they expand their traffic simulation capabilities to address complex and large-scale transportation planning and traffic operations analytical requirements.

Figures

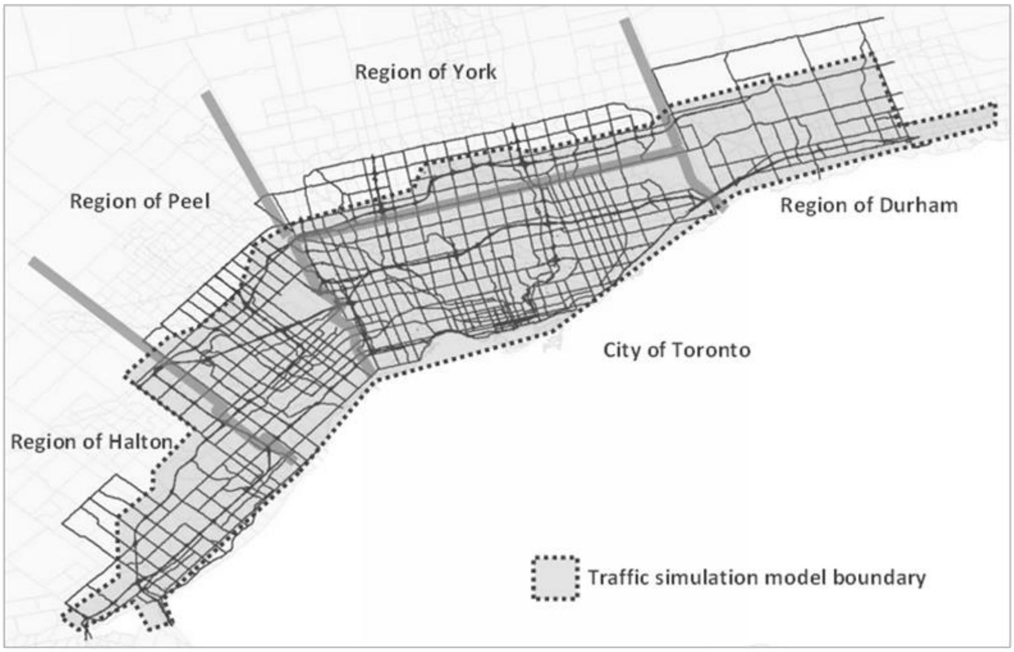


Figure 1: *Traffic simulation model study area*

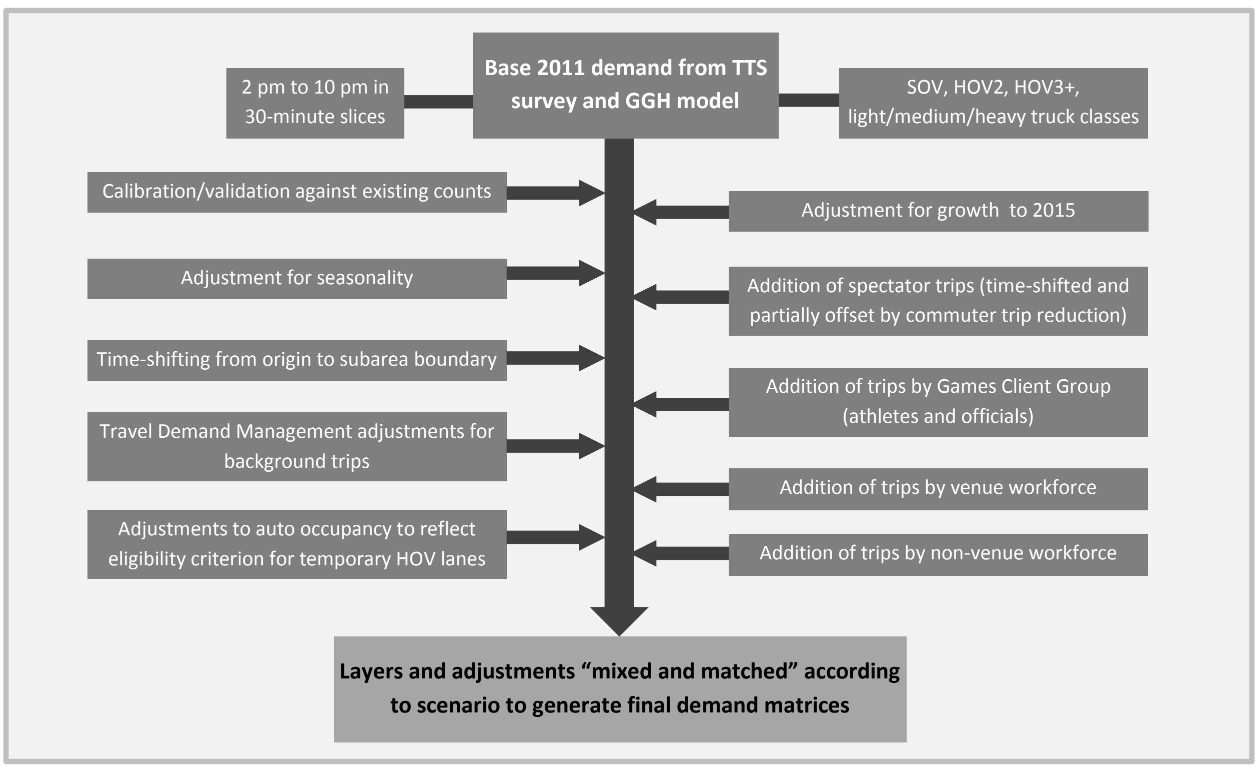
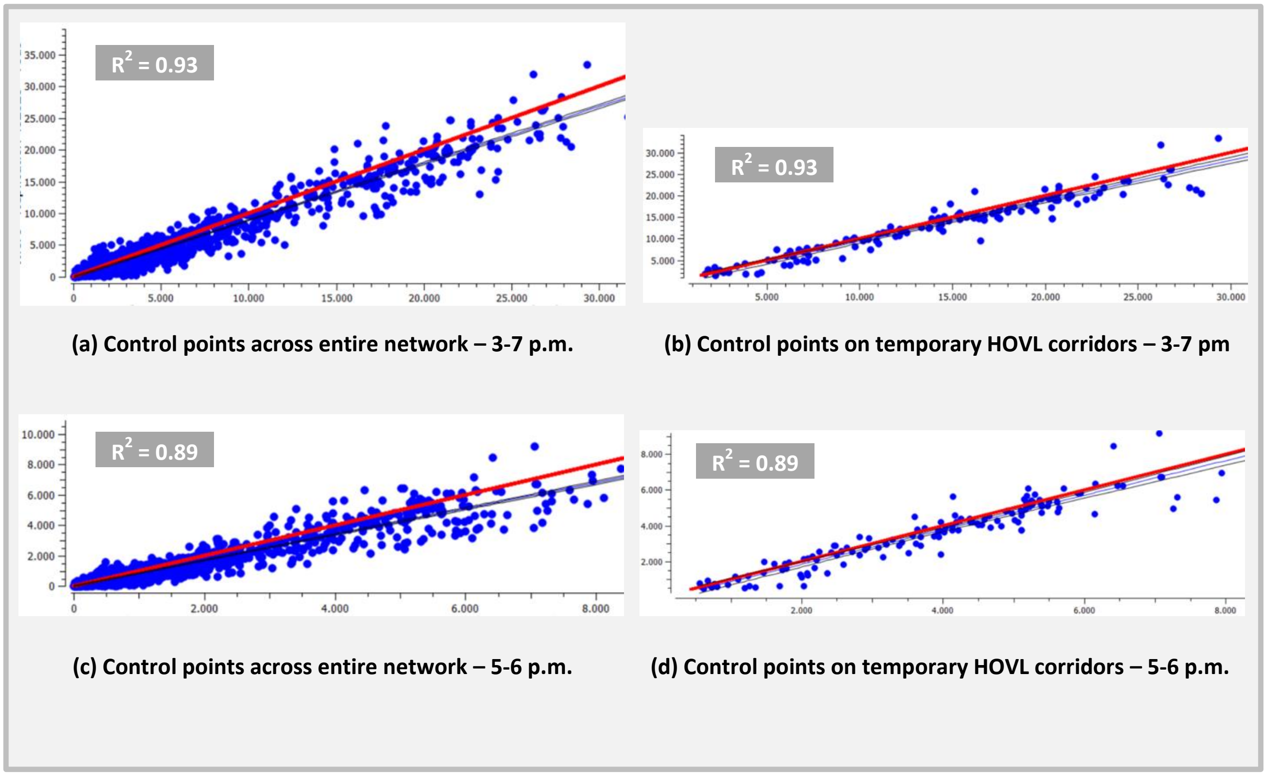


Figure 2: *Structure of travel demand evaluation*



(a) Control points across entire network – 3-7 p.m.

(b) Control points on temporary HOVL corridors – 3-7 pm

(c) Control points across entire network – 5-6 p.m.

(d) Control points on temporary HOVL corridors – 5-6 p.m.

Figure 3: *Selected validation results for calibration of travel demand inputs*

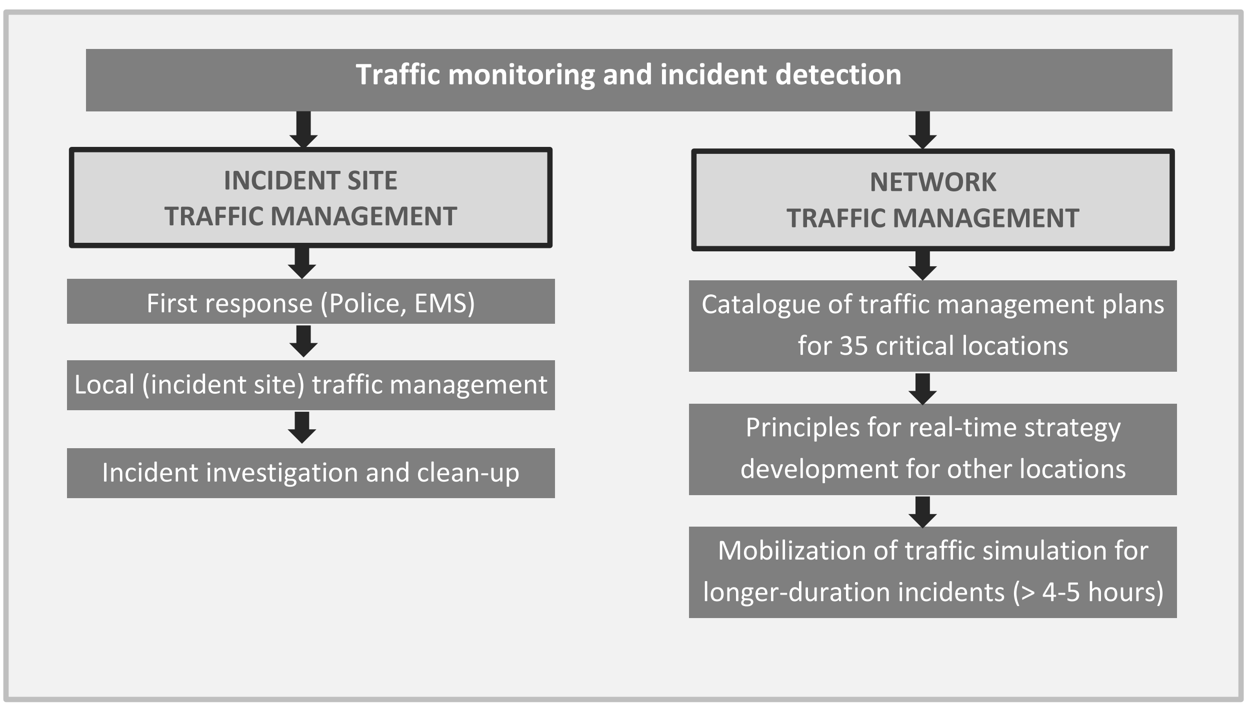


Figure 4: *Traffic management framework for major incidents*