Transportation Modeling for the 2010 Winter Olympic Games

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Introduction

In preparation for the 2010 Winter Olympic Games, the City of Vancouver joined the Olympic and Paralympic Transportation Team (OPTT), a multi-agency organization responsible for the transportation planning and operations of the Games. Consisting of the Vancouver Organizing Committee for the 2010 Winter Olympic and Paralympic Games (VANOC) and several government partners, such as the BC Ministry of Transportation and TransLink (SCBCTA), the OPTT streamlined their process for decision-making by defining specific roles and responsibilities for each of its member agencies. The City of Vancouver took on the responsibility of modeling traffic and projecting travel demand during Games-time in the Greater Vancouver Area (GVA) to assist in the preparation and planning for this world-class event.

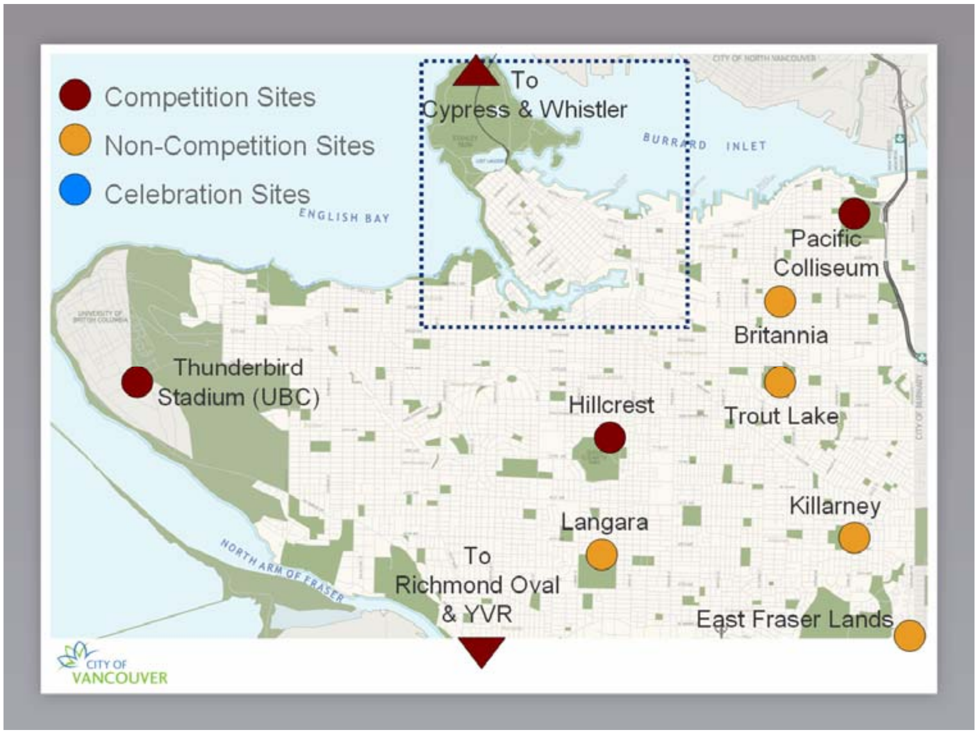
This paper details the development and implementation of three transportation network models created by the City of Vancouver and PTV America, Inc. which were used for decision support and aided in the creation of the Host City Olympic Transportation Plan (HCOTP).

Background

The Vancouver 2010 Olympic and Paralympic Winter Games (2010 Winter Games) present an opportunity to showcase Vancouver as one of the most livable and beautiful cities in the world. Vancouver, the largest city to ever host the Winter Games, will welcome thousands of athletes and team officials from more than 80 countries in February, 2010. Over a 60-day period more than a quarter of a million visitors, 55,000 VANOC staff and volunteers, and 10,000 members of the media are expected. During the Games, Vancouver will be host to numerous competition venues, non-competition venues, and celebration sites. Figures 1 and 2 below illustrate the distribution of competition and non-competition venues within Vancouver.

Figure 1 - Olympic Sites in Downtown Vancouver

Figure 2 - Olympic Sites outside of Downtown Vancouver



The City of Vancouver led the modeling team for the OPTT in developing tools to aid in the decision-making for the planning and management of the 2010 Olympic Games. This effort allowed the OPTT to identify potential issues with the road and transit networks in the region as well as the pedestrian network in downtown Vancouver, evaluate various scenarios, and assist in the development of comprehensive Games-time transportation plans.

More specific goals of the modeling effort included developing tools that allowed for:

- allocation of Olympic client trips to both the road and transit networks;
- systematic projection of demand on the public transport network during the Games period;
- an understanding of impacts to the pedestrian network in the downtown core;
- visualization of the current and anticipated Olympic demand on the public and private transportation network; and
- identification of bottlenecks, capacity constraints, critical time periods, and areas of high congestion.

Three separate network models were developed to address specific components of the system:

1. Olympic Private Transportation Model (OPrT) – includes private forms of transportation (e.g., private vehicles) on the road network;
2. Olympic Public Transportation Model (OPuT) – includes the major transit services in the GVA and connections to VANOC's Olympic shuttle system; and
3. Downtown Vancouver Transportation and Emergency Management System (DVTEMS) – provides a localized pedestrian model for the downtown Vancouver peninsula on the pedestrian network, including sidewalks, pedestrian paths, and venue walkways.

All three models were developed and implemented using the commercial travel demand modeling software, VISUM. Due to the timeline and scope of the modeling efforts, all three models incorporated traffic demand previously established from other sources. None of these models incorporate land use and, therefore, cannot be used to perform re-assignment of traffic on the network. The background traffic demand was established using the existing City of Vancouver EMME/2 model, background transit demand was generated from the TransLink Regional Transit Model (RTM), and the background pedestrian demand was generated from previous City of Vancouver pedestrian studies carried out during the development of the initial DVTEMS model by PTV [Kean Lew et al] and the City of Vancouver [Gordon Foy et al]. The Olympic demand was generated using the VANOC Olympic Transportation Demand Model (OTDM). The OTDM was developed by Bunt and Associates prior to this work and is a spreadsheet-based model estimating the Olympic demand to and from each venue by trip type based on each day of the Olympic Games event schedule.

The development and implementation of each of these network models is discussed separately in the following sections.

The Traffic Model – OPrT

The primary purpose of the OPrT model was to act as a decision support tool in assessing the impacts of additional highway/road network demand generated due to a special event, such as the Olympic Games.

The model was developed to be used for visualization of expected traffic volumes (by various classifications) and performing network assignment of expected Olympic travel demand. This would thus aid in decision making with respect to event scheduling such that the impact on the normal (background demand) travelers would be minimized.

The background demand was incorporated into the model for the primary purpose of adding a level of congestion to the network such that it reflected measured field data. Background congestion on the network was required for the proper functioning of the volume delay functions used for the assignment of Olympic travel demand on the network. Since background demand was developed using a variety of data sources along with a synthetic OD estimation process, it cannot be used in reassignment of background travel demand to model network changes such as roadway closures.

Model Development

The data used for OPrT consisted of two parts, “supply” and “demand”. The supply side of the data consisted of the transportation network (i.e., roadways). The demand side of the data consisted of Origin-Destination matrices for the Auto mode. Data for supply was imported from the City’s existing EMME/2 model while demand data was derived from the City’s EMME/2 model as well as the OTDM.

Transportation Network Details

Links and Nodes

The transportation network imported from EMME/2 contained information about the connectivity of the road network (intersections), the capacities and speeds of roadway sections. These attributes were used in order to calculate shortest paths in the network. Shortest paths were used for allocation of link traffic flows during the assignment process.

Routes for additional transit buses and media buses likely to be running on the transportation network were coded into VISUM as Line Routes so that these volumes could be aggregated on auto links as passenger car equivalents.

Zones and Centroid Connectors

The OPrT model contained a total of 959 zones. The numbering system for these 959 zones was the same as the EMME/2 model used by the City. All centroid connectors were coded with a travel time of 0 seconds. This means that for the large zones such as Richmond/Delta, the travel time estimated by OPrT only represents the portion of travel along the OPrT network to and from the event location and not the entire travel time that would encompass ingress and egress time.

Transportation Modes, Transport Systems, and Demand Segments

VISUM uses a hierarchy of travel defined by a transportation mode, transport systems available to each mode, and demand segments that are allowed to use each transport system.

The OPrT model is a private transportation model (although the model has both Bus and Car modes defined) so assignment was carried out only for the auto component of the model. The inclusion of the Bus mode allowed creation of line routes to reflect Olympic shuttle operations in the network to aid in capacity analysis with the help of visualization features in VISUM.

The Car (PrT) mode included the transportation system "c" representing All Vehicles on the private transportation mode. The Bus (PuT) mode consisted of the Transportation system "b" (Bus) representing the Olympic shuttle bus system. The transport systems are shown below in Table 1.

Table 1: Transport Systems in OPrT

VISUM Transport System Identifier (TSys)	Transport System Name	Transport System Mode
B	Bus	PuT
C	All Vehicles (cars)	PrT

Demand segments in OPrT represented different classifications of passengers using the PrT system. By structuring the demand segments appropriately, OPrT was utilized to assign various demand segments together or alone and track output for each.

The OPrT model utilized 2 demand segments for the PrT mode, as shown in Table 2

Table 2: Demand Segments in OPrT

Name	Description	VISUM Demand Segment (Dseg)	Modes	TSys
All Vehicles	Base (Background) demand for a Weekday period	c	PrT	All Vehicles
Olympic	Additional demand expected for Olympic events	o	PrT	All Vehicles

The first demand segment represents existing base auto demand (derived from the 2007 volumes of the EMME/2 model). The second demand segment represents demand directly related to the 2010 Olympics and is populated automatically into OPrT through the OTDM export utility.

Travel Demand and Trip Matrices

Base Model Demand

The base demand or trip matrices for the model came from matrices imported from the City's EMME/2 model. This base demand was then adjusted to reflect current year demand using TFlowFuzzy. TFlowFuzzy is a synthetic OD estimation tool available in VISUM. In order to estimate a synthetic trip matrix, link traffic count data recorded at key locations in the network was used. TFlowFuzzy performs a synthetic OD estimation based on an extended application of the Willumsen's method. Link counts in the TFlowFuzzy method are represented as fuzzy sets rather than exact values, thus the name TFlowFuzzy. Estimation of OD matrices using TFlowFuzzy is an iterative process repeated until the resulting assignment of the refined OD matrices meets certain calibration criteria.

As a general guideline, a root mean square error value (RMSE) of 35% and Coefficient of Determination (R^2) of 0.7 were used as calibration criteria for the OPrT model. Additionally, while there is no recommended standard, a slope close to one is ideal.

Since the OD matrices were synthetically developed, the OPrT model is not suited to be used for the re-assignment of background traffic to test scenarios such as roadway closures. This is due to the fact that Synthetic OD estimation is a problem that has no unique solution. More specifically, different OD matrices can result in a link volume assignment that matches link counts with no reliable estimate of actual production and attraction totals in a zone. Since the production and attraction totals in a zone are a result of land use activity, only production and attraction totals and thus an OD Matrix arrived at from land use data should be used for the purpose of reassignment.

Additional Travel Demand Due to Olympic Demand

The additional private vehicle demand matrices were created by importing demand data from the VANOC Olympic Transportation Demand Model (OTDM). In order to expedite and automate the process of using OTDM output as OPrT, OPuT, and DVTEMS input, VISUM's muuli matrix editing capabilities were utilized.

Information regarding the number of additional transit buses and media buses running on the network in each of the 24 time periods was provided by the event organizing staff.

Model Procedures

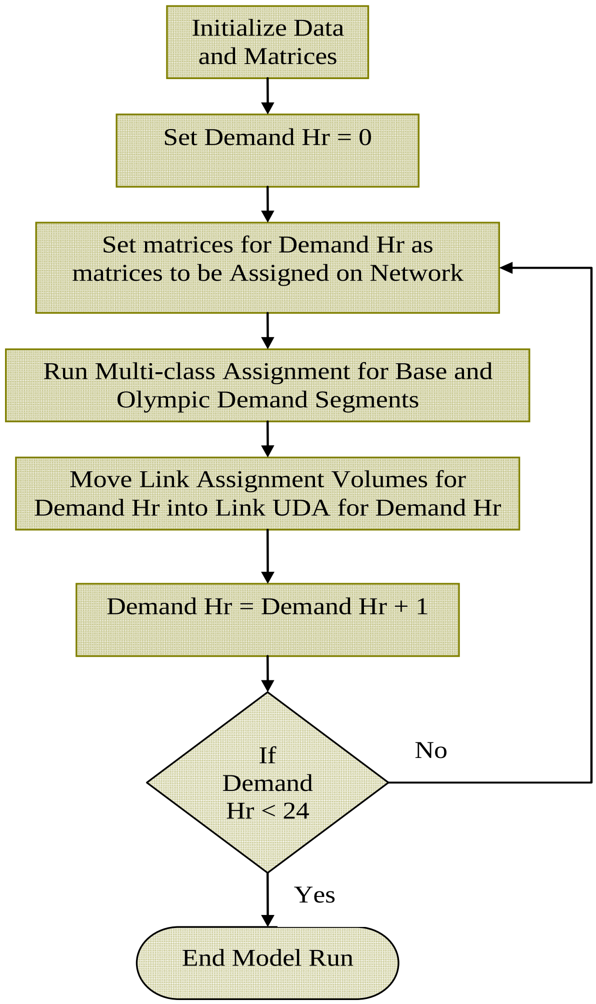
The private vehicle assignment methodology used in the OPrT was Static Multi-class assignment. Two demand segments, viz. Car (Base Demand) and Olympic (Additional Olympic Traffic) were simultaneously assigned on the network.

Additional bus volumes due to additional transit vehicles and media buses were not assigned on the network, but rather aggregated based on number of runs on the links that the lines routes passed through.

Twenty-four model assignments were carried out during the complete model run, the link volumes for all 24 hours of the day were stored in user defined attributes on links. The 24 hour model run was implemented using a python script that automated routine tasks such as moving volumes of the traffic assignment to the corresponding user defined attribute for that time slice, saving out version files for each time period etc.

The flow diagram in Figure 3 below graphically shows the model run steps.

Figure 3: OPrT Model Run Steps in VISUM



Rerouted Traffic

Although the synthetic nature of the demand in the model did not allow for reassignment, the GIS capabilities of the model were used to make rudimentary estimates of how traffic would reroute due to road closures in the downtown. This process mainly consisted of identifying major vehicle routes which used the links affected by closure, then, using City of Vancouver judgment and knowledge of the network, suitable reroutes for the affected vehicles were coded into the model.

Model Outputs

The main outputs of the OPrT model were link volume visualization over the network and export of traffic volume on specific (user specified) links over time. The visualization plots were created using a combination of python scripting and VISUM's built-in visualization features. Examples of the OPrT output are shown below.

Figure 4: OPrT Link Volume Visualization by Demand Segment

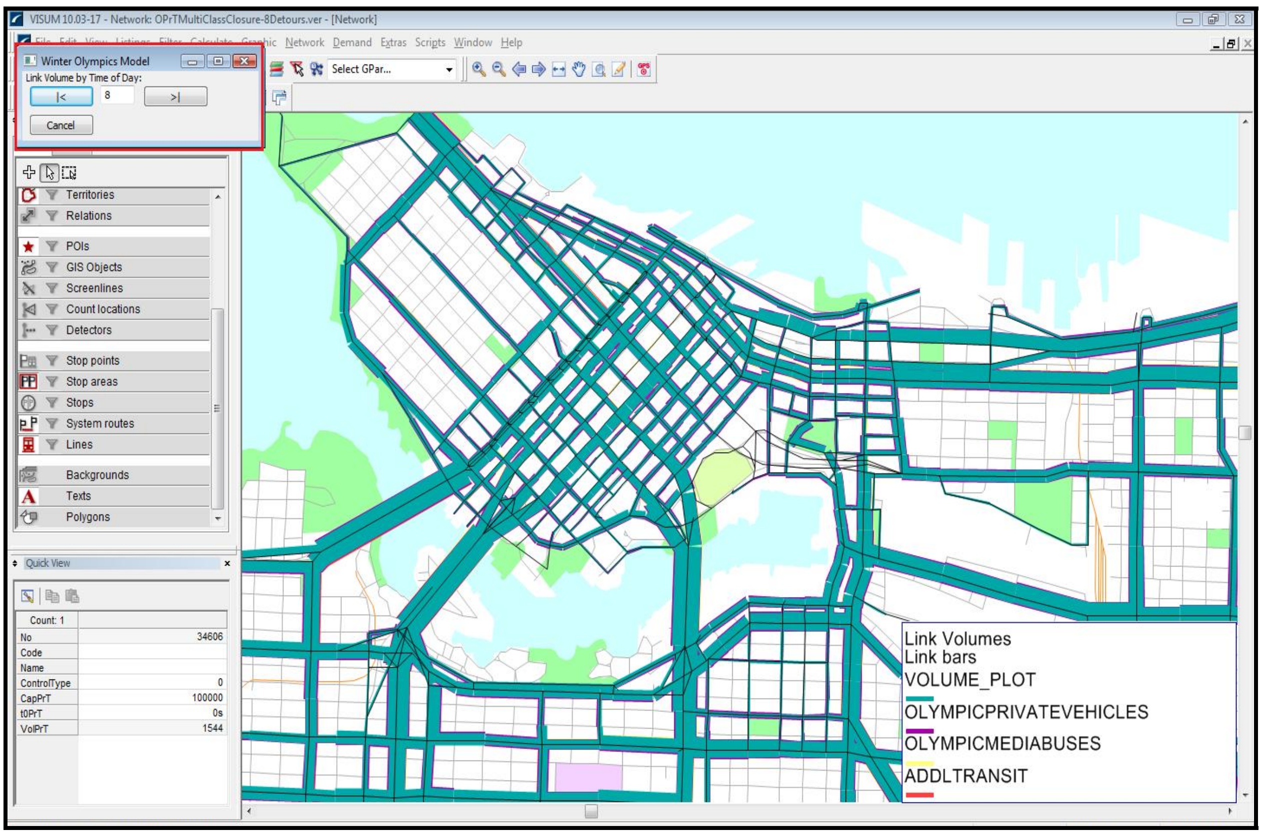
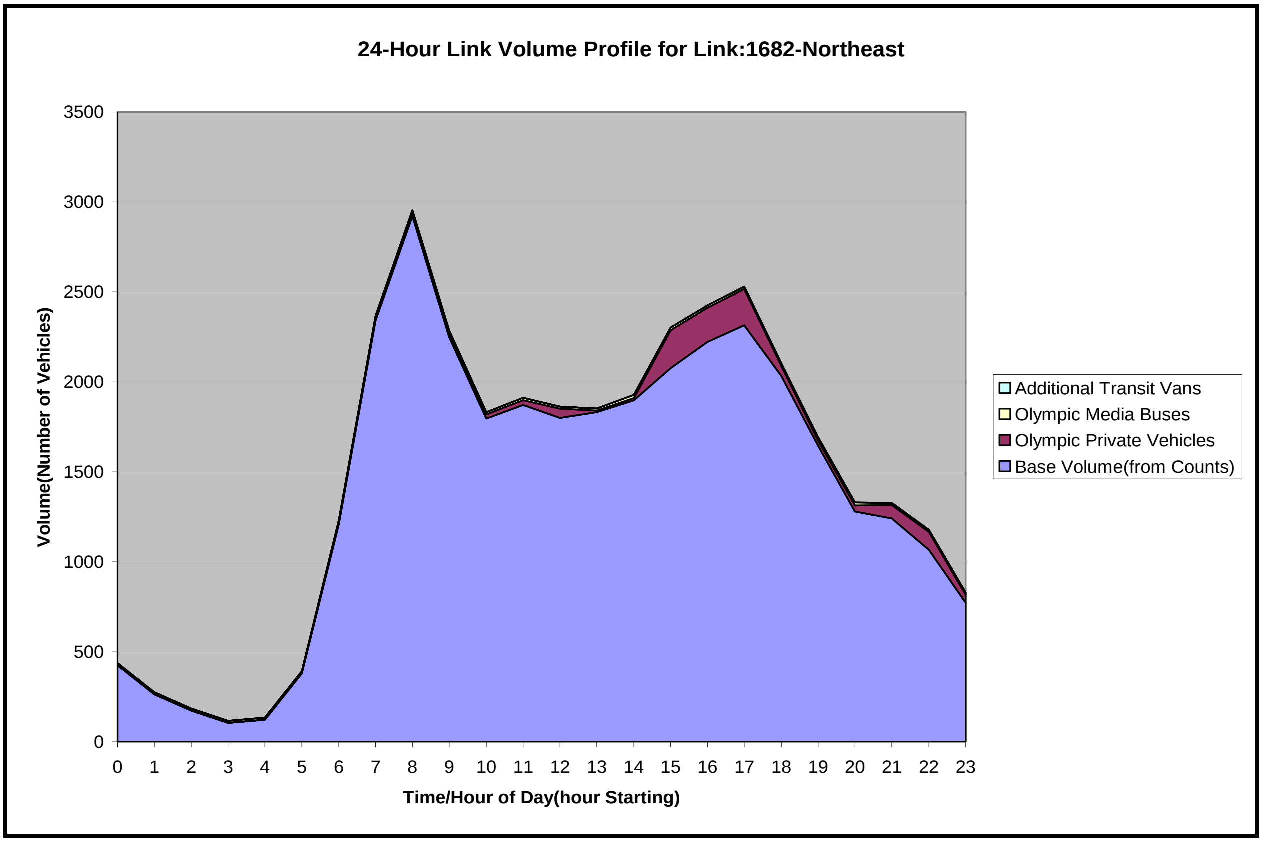


Figure 5: Automatic Link Volume Profile Plot Exported for a Single Link



The OPuT Model

The second of the models was The OPuT Model, this model was constructed from the TransLink Regional Transit Model (RTM), which provides detailed supply and demand for the rapid transit network in the Greater Vancouver Region. RTM Phase A was the basis for the network (supply) and of OPuT. The background demand was developed from the RTM Phase B, which was under development and re-calibrated with the incorporation of the remaining transit network in the region. Additional network elements were added to represent key Olympic-specific transit routes and Olympic demand layered on top of the background demand as provided directly from the Olympic Travel Demand Model (OTDM).

The scope of the base OPuT included one “typical” day during the Olympic Games.

<u>Model Structure</u>

The OPuT model was a transit-only model and did not include any private vehicle or pedestrian traffic. The model carried out network flow assignments for multiple transit modes, better known as Transportation Systems or TSys in VISUM.

The base OPuT model was developed to represent a single 24-hour period. The base model representing one day of network (supply) and demand data have been built into a single VISUM version file (*.ver). During scenario testing, multiple version files were saved to represent different days of Olympic demand and/or different scenarios of supply.

A timetable-based assignment was used in the model. The main goals of the OPuT model were:

1. identifying deficiencies in public transportation service during the 2010 Winter Olympic Games, and
2. providing a rudimentary estimate of travel time to and from each event.

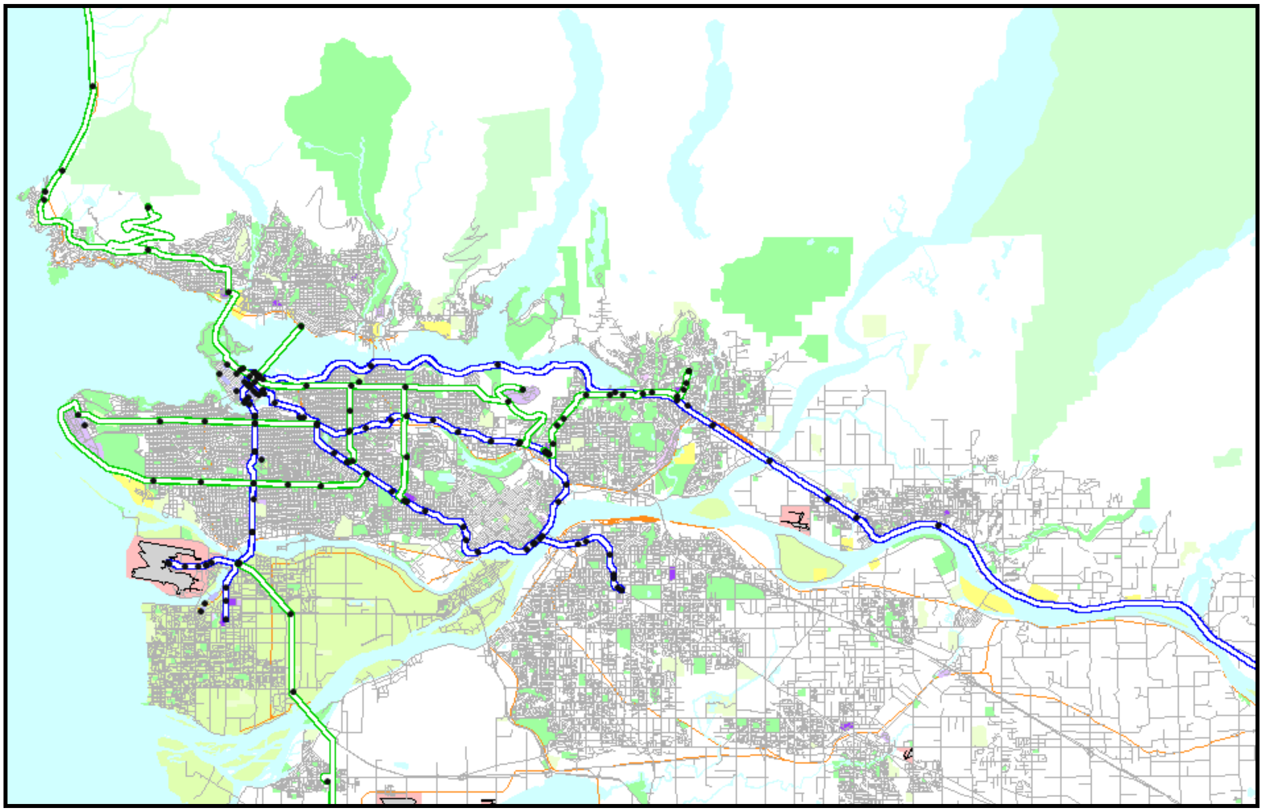
The Olympic demand for OPuT was extracted from the spreadsheet based Olympic Travel Demand Model (OTDM). Olympic demand data from the OTDM was extracted through an Excel-based exporter for a specific day of the event and was used to automatically populate the necessary demand within OPuT model prior to the transit assignment.

The OPuT base supply and demand from RTM covered 24 hours, however, an entire Olympic day is defined as 5:00 AM to midnight on each day.

The OPuT was then broken down into 15-minute intervals and results for specific time periods were obtained as desired by the user.

The most important public transit routes for the Olympic Games were coded into the OPuT model, these which included the SeaBus, critical bus routes, and Olympic shuttles. The network is shown in Figure 6 (rapid transit in blue, non-rapid transit in green).

Figure 6: OPuT Network



The OPuT model contained a total of 104 zones. The numbering system for these 104 zones was adapted to an overall Zone numbering architecture to allow for consistency between the three models DVTEMS, OPrT, and OPuT.

The OPuT model included several transport systems such as SkyTrain, SeaBus, and others and passengers were able to transfer between these systems to allow multi-modal assignment. The transport systems are shown in Table 3.

Table 3: OPuT TSys (modes)

VISUM Transport System Identifier (TSys)	Transport System Name	Transport System Mode
B	Bus	PuT
L	LRT	PuT
M	Metro	PuT
R	Commuter Rail	PuT
S	SkyTrain	PuT
W	Walk	PuT

Demand segments in OPuT represented different classifications of passengers that are using the Transit system. By structuring the demand segments appropriately, OPuT was utilized to assign various demand segments together or alone and track output for each. Additionally, each demand segment was assigned to modes and specific Transport Systems within each mode. These demand segments are shown in Table 4.

Table 4: OPuT Demand Segments

Name	Description	VISUM Demand Segment (Dseg)	Modes	TSys
1_BaseAM	2010 Base (Background) demand for the Weekday AM Peak Period	1_BaseAM	PuT	B,L,M,R,S,W
2_BaseMid	2010 Base (Background) demand for the Weekday Mid-Day Period	2_BaseMid	PuT	B,L,M,R,S,W
3_BasePM	2010 Base (Background) demand for the Weekday PM Peak Period	3_BasePM	PuT	B,L,M,R,S,W
4_BaseEve	2010 Base (Background) demand for the Weekday Evening Period	4_BaseEve	PuT	B,L,M,R,S,W
Olympic	Olympic Demand as Provided from OTDM	O	PuT	B,L,M,R,S,W

OPuT Demand

The travel demand in OPuT was divided into two primary sources: a) base demand, and b) Olympic demand. The base demand was directly extracted from the calibrated RTM Phase B model. An Excel tool was developed to assist in the extraction and input of volumes from RTM Phase B into OPuT.

The Olympic demand in OPuT was automatically populated using the OTDM export utility specifically designed to work with OTDM Version 3.1. In this manner, changes in demand predicted by different scenarios in the OTDM could be quickly incorporated into OPuT.

OPuT Outputs

VISUM provides a wide range of output. The output specifically of interest for the OPuT, however, primarily included volumes, capacity, and travel times.

An example of the results that can be obtained by utilizing the graphics capabilities of VISUM is shown in Figures 7 and 8 below.

Figure 7: Link Volumes over a Day Output from OPuT

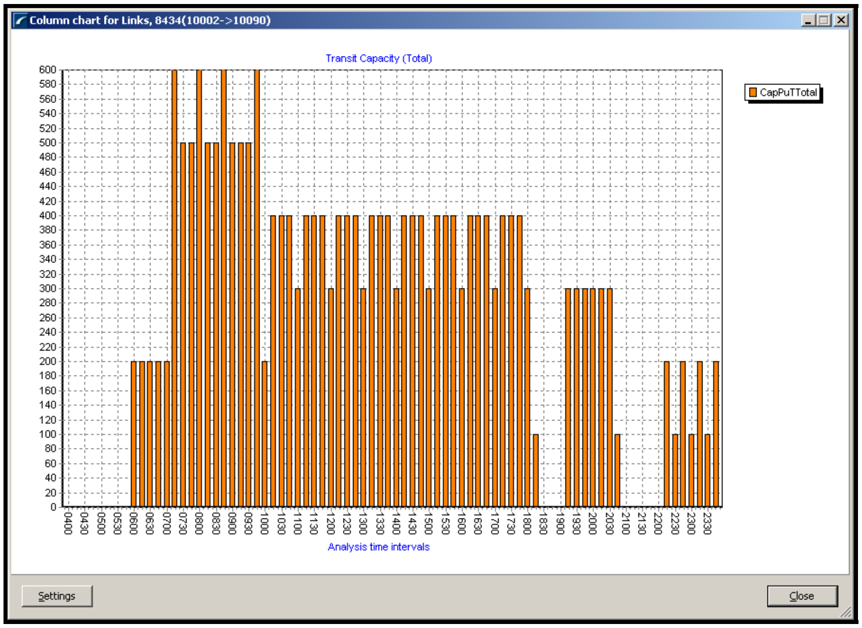
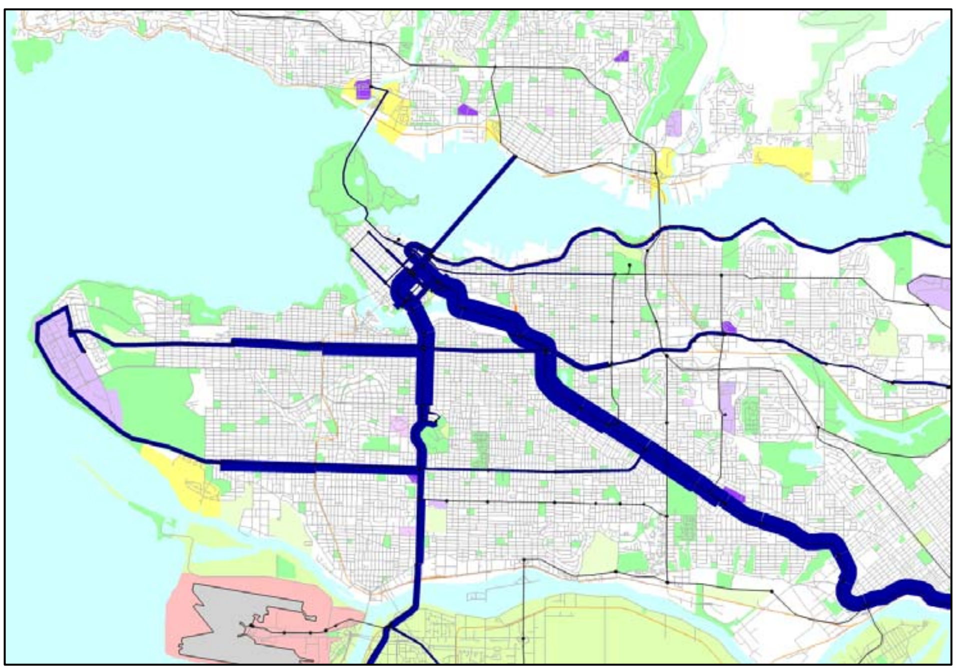


Figure 8: Olympic volumes on the OPuT network during a typical Games-time period



The Pedestrian Flow Model (DVTEMS)

The final of the three models developed was the DVTEMS model, which was an expansion of the DVTEMS model previously developed for the City of Vancouver using the VISUM transportation planning software. The model was a pedestrian flow model that uses Dynamic User Equilibrium (DUE) assignment coupled with custom calculations in order to estimate pedestrian path flows. The application area of this model was restricted to the downtown area where two event venues were located.

There were three primary steps involved in the development of the model:

1. Extraction of Olympic demand from the OTDM;
2. Definition of the Demand model structure; and
3. Network Definition for the base case and scenarios.

Extraction of Olympic Demand from OTDM

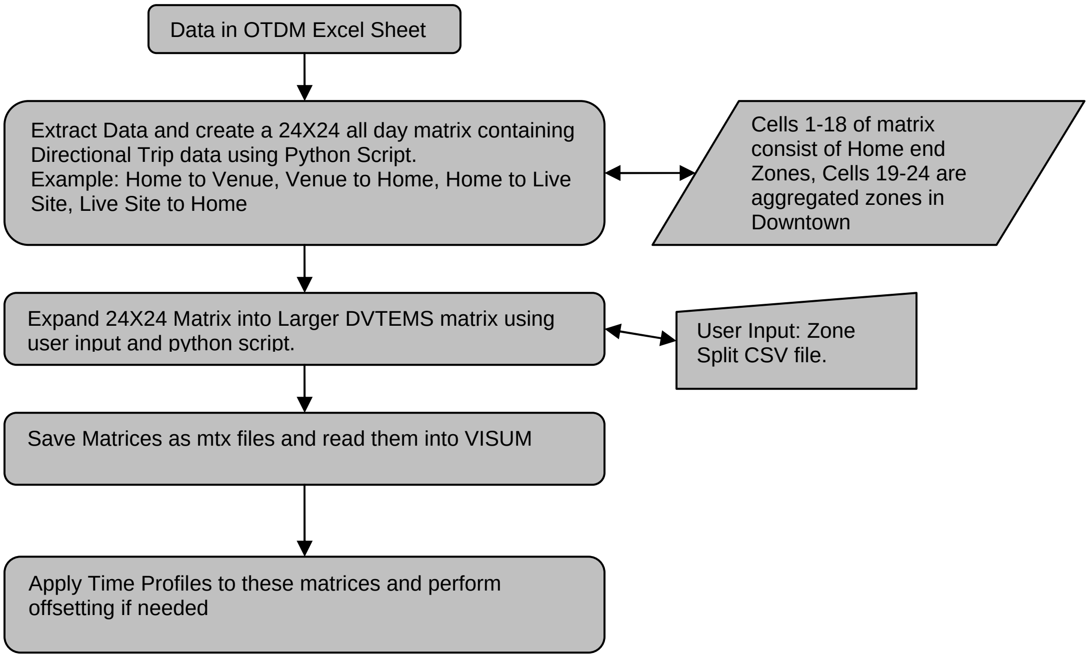
As with OPrT, the demand for DVTEMS was taken directly from the OTDM. This spreadsheet model was a linkage between several spreadsheets and contained the Olympic demand in an aggregated form as activity pairs for 19 hours each Olympic day. The following activity pairs were modeled:

1. Home to Venue
2. Home to Live Site
3. Live Site to Venue
4. Venue to Home
5. Live Site to Home
6. Venue to Live Site

Home represented the residential areas, Live Sites represented the four areas of live Olympic entertainment planned for the downtown core, and Venues represented the two downtown Olympic venues (Olympic Stadium and Canada Hockey Place).

As a result, zones in the DVTEMS model were composed of one or more of the above activity type trip ends. An import utility was created using Python in order to move the demand from the OTDM spreadsheets into an aggregated matrix and then expanding it out to a matrix consistent with the DVTEMS zone structure. The procedure flow involved in the import utility is shown in Figure 9.

Figure 9: Procedure Flow for Importing Spreadsheet Demand Data into VISUM



Once the 19-hour demand was extracted (19 OD Tables for each activity), it was aggregated into a daily demand matrix for each activity type listed above.

Definition of Demand Model Structure

The demand model was structured to be intuitive to a user familiar with the OTDM spreadsheet structure. Definition of the model structure involved three steps.

Step 1: Definition of Demand Segments

A separate demand segment was created for each activity type. As a result the new demand segments created in VISUM were as follows:

- O-Home-LiveSite
- O-Home-Venue
- O-LiveSite-Home
- O-LiveSite-Venue
- O-Venue-Home
- O-Venue-LiveSite

The prefix "O" indicated that the demand segment contained Olympic demand.

In addition to Olympic demand, the existing or base demand was also assigned to the network. This demand was associated to different demand segments as per time of day. These demand segments included:

- PW-AMExisting
- PW-EarlyMorning
- PW-EveExisting
- PW-MidExisting
- PW-NightExisting
- PW-PMExisting

Once all demand segments were defined, aggregate demand matrices were then associated with each of these demand segments.

The definition of demand segments enabled multi-class assignment and storage of link flows for individual demand segments separately for use in further analysis of results.

Step 2: Definition of Standard Time Series

The temporal distribution of travel demand within the analysis period is described by a start time and a time series that is considered during dynamic assignment.

Each Activity Type in the model is an aggregation of sub-activities that are location-specific. These location-specific activity types were defined and associated with standard time series profiles that represented the growth and decay of demand in the network. These profiles were adopted from the OTDM and defined for 15-minute intervals.

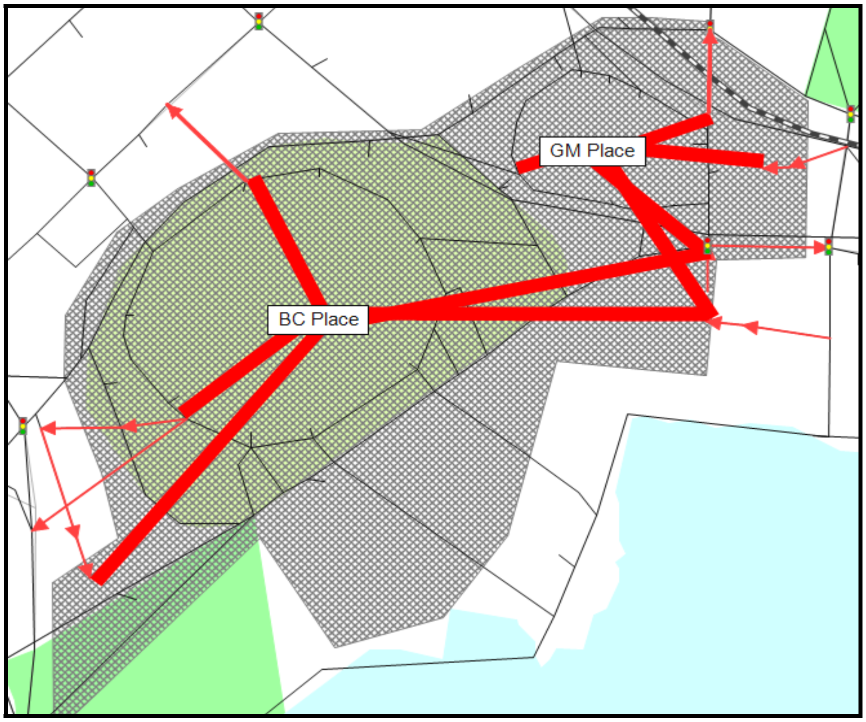
Step 3: Definition of Demand Time Series

A Demand Time Series in VISUM forms a linkage between Standard time series and Demand Segments. Using the time Demand Time Series, it is possible to allocate a different Standard Time Series to an OD pair/relation based on the type of the origin and destination zone. Within Demand Time Series, a Standard Time Series was then assigned to each zone type relation. A number of scenarios with changes in network and Olympic demand data were evaluated using the DVTEMS model. There was one Base Model and two main scenarios. The two main scenarios contained further sub-scenarios that were evaluated separately.

Base Condition

During the 2010 Olympic Games, movement and access around the downtown venue area was planned to be restricted by a security perimeter. As a result, the two downtown venues could be accessed only via certain access points. The network representation shown in Figure 10 reflects a potential layout for the base condition. This used as the modeling and was the basis for the scenario evaluations as well.

Figure 10: Assumed Access and Egress Points for Venues



This layout allowed for ingress access to Olympic Stadium from specific access points and ingress access to Canada Hockey Place from other access points, allowing the flow of event attendees to each venue to remain separated and minimize the crossover flows within the security perimeter. Egress access was provided through separate exit locations, eliminating crossover of entering and exiting pedestrian traffic.

In addition to this layout, time-dependent capacities were used at the entrances and exits of the venue area to reflect specific open and close times of access points. These times were provided as an assumption by VANOC and based on the schedule of events occurring at each of the venues.

Scenarios

The scenarios tested after setting up the base model were as follows:

1) provision of additional entrances;
2) rail station exit closure;
3) provision of additional venue exits;
4) rescheduling of a ceremony; and
5) diversion of pedestrian arrivals from one station location to another.

Model Outputs

Sample outputs from the model consisted of pedestrian arrival and departure profiles at venues gates and other key locations around the venue. This helped in identifying potential bottlenecks and congestion points as a result of event rescheduling, facility closure etc. Some of these graphical outputs have been shown below.

Figure 11: Sample Arrival Profile at Canada Hockey Place (GM Place)

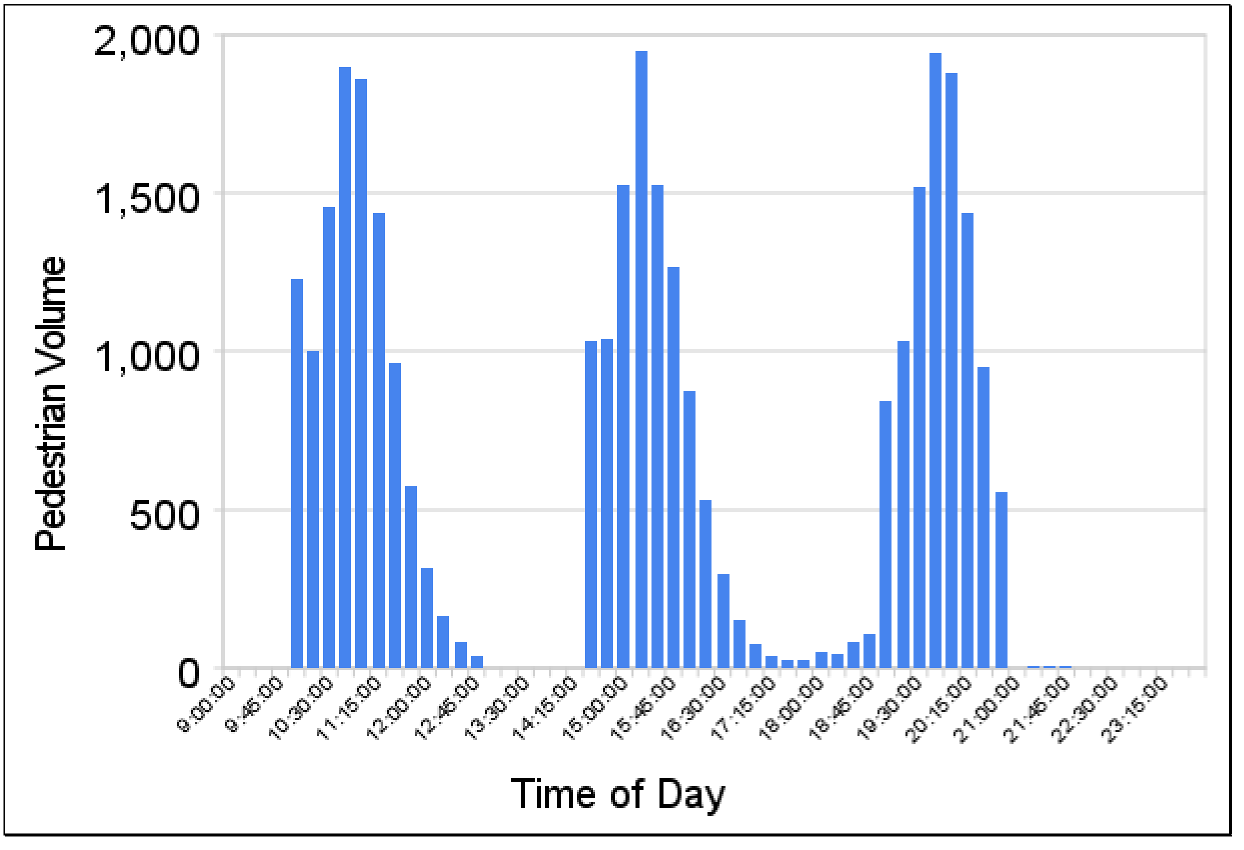
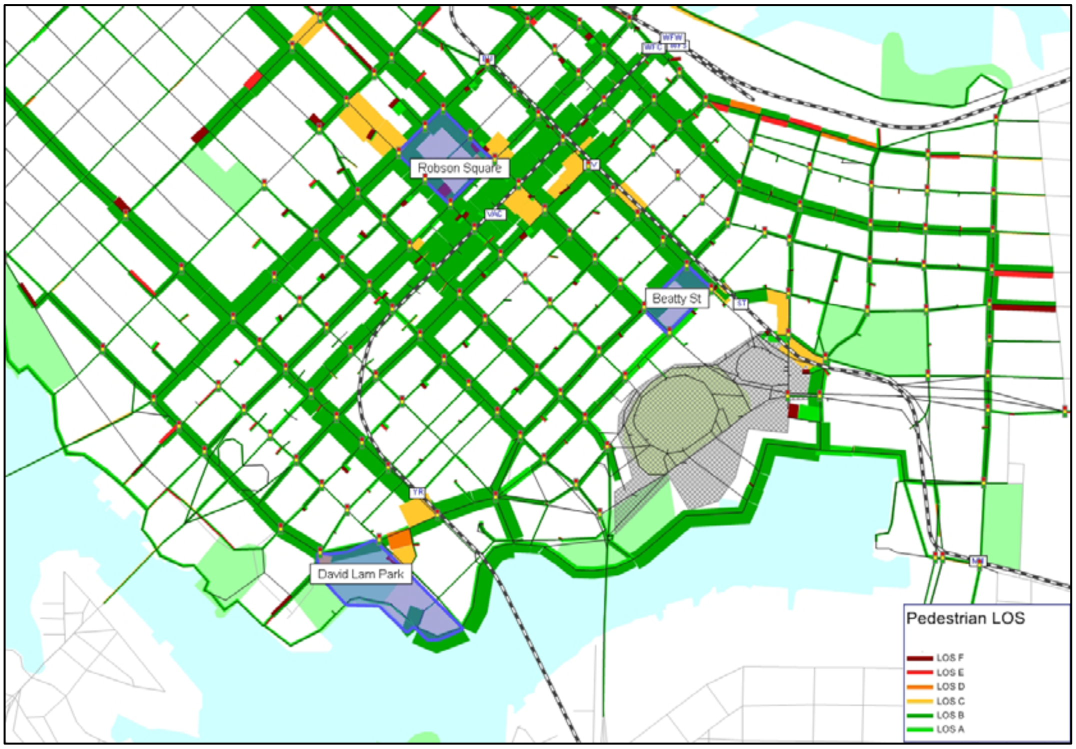


Figure 12: Sample DVTEMS Network Assignment



Summary and Conclusions

The three models developed by the City of Vancouver and PTV America, Inc. described above provided quantitative evaluations of the system under both background and Olympic demand conditions. In addition, the visual output provided by each of these tools allowed decision-makers to systematically project the Olympic demand onto the transportation network, understand the impacts of the Olympic demand on the existing transportation system, and identify network bottlenecks, capacity constraints, and critical time periods and areas of high congestion. This, in turn, assisted the City of Vancouver in the creation of the Host City Olympic Transportation Plan. Additionally, these models supported other OPTT member agencies in the development of their operations and management plans for the 2010 Winter Olympic and Paralympic Games.

Finally, the development of the three models as described above laid out a foundation for a methodology that can be applied to other special event applications to address multi-modal network issues both within Vancouver and other areas.