

Evolution of the Greater Vancouver Transportation Model

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by

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1. Introduction

This paper provides an overview of the evolution of the Greater Vancouver Regional District (GVRD) Transportation Model and focuses on the recent enhancements that were completed in 1998 as part of the GVRD's Transportation Model Enhancement Program. This paper describes how the improvements were identified and prioritized and provides a summary of the model enhancements. The other papers in this session will elaborate on three of the major enhancements (Transit captivity, HOV, Park and Ride).

2. Evolution of the Greater Vancouver Transportation Model

The 1970's

The GVRD has a long history in the development and application of transportation models dating back to the mid-1970's. In 1975, the GVRD's first computer-based transportation model was developed in conjunction with the University of British Columbia (UBC) Computer Science Department. The model consisted of 125 traffic zones, a road and transit network and algorithms to implement a traditional four-step transportation planning model for the morning peak period. Specialized software was written to implement the model on the UBC mainframe computer. The model had limited graphical capabilities, with output consisting primarily of tables of link volumes and other attribute data.

In 1979, the model underwent a significant re-calibration in preparation for the GVRD Rapid Transit Project¹ which was a comprehensive set of studies of future rapid transit lines and technology options for the GVRD. At this time, the traffic zone system was expanded to 152 zones, the transit assignment algorithm was enhanced and the four-step model was re-calibrated. The model was calibrated using travel data from the 1978 North Vancouver Origin-Destination Survey and a series of studies by the City of Vancouver including the 1975 Downtown Vancouver OD Survey, the 1976 Transit Study and the 1977 Cordon Survey.

The 1980's

In 1983, the GVRD conducted a comparative review of transportation modelling software. The GVRD's existing software (developed in-house) was compared with the Federal Highway Administration's Urban Transportation Planning System (UTPS) and INRO Consultants EMME/2. The review committee selected EMME/2 and the GVRD became the second North American site to obtain EMME/2 (Portland, Oregon was the first site).

In 1984 the model was re-calibrated in conjunction with the implementation of EMME/2. The traffic zone system was expanded to 370 zones, road and transit networks were updated and the four-step model was calibrated to 1981 Census data which contained the place of work-place of residence survey. Significant changes to the model structure included the introduction of time-space equations for auto work trips and combined impedance for work trip distribution. At this time, the GVRD purchased the Pixel computer (a 32-bit micro computer) to reduce the high computing costs associated with running the model at UBC. In those days the macro language was not available in EMME/2 and the model equations were entered directly into the matrix calculator (each matrix calculation took about 30 minutes and a 15 iteration assignment required approximately 14 hours of computing time).

In 1985, a comprehensive set of 24 hour travel surveys was conducted to provide a description of travel patterns in the GVRD prior to SkyTrain. The project included a 25,000 household telephone interview survey (a five percent sample of the 522,000 households in the Vancouver CMA), a 1,700

¹ For a description of the technical analysis refer to "Partridge, T., 1980. Report of Technical Studies Greater Vancouver Regional District Rapid Transit Project. City of Vancouver, Planning Department".

household trip diary survey (a 0.3 percent sample), traffic screenline counts, an external cordon survey and a taxi and business travel survey². Data from the household survey is contained in a series of three reports³.

Between 1986 and 1987, the model was re-calibrated to the 1985 survey data. The traffic zone system was increased slightly to 380 zones, networks were updated and the four step model was re-calibrated. The model was then validated to post-Skytrain conditions in 1987. Although several major new facilities had been introduced to the region between 1985 and 1987 (e.g. Skytrain, Alex Fraser Bridge, the East-West Freeway in Richmond), the model compared closely with 1987 screenline counts.

One of the first applications of the new regional model was to examine the impacts of long-term growth on major transportation facilities by the City of Richmond. The findings of this study showed that with current trends land use many of the major river crossings would be at capacity by 1996. This study resulted in an initiative by Richmond council to request that the province lead a comprehensive inter-agency study on land use and transportation for the GVRD.

At the same time, many of the GVRD municipalities began to develop their own sub-area transportation models that contained more detailed zone systems and networks to deal with municipal transportation planning. Burnaby, Surrey, Coquitlam, Richmond and North Vancouver were some of the first municipalities with their own sub-area models. Many of these models were afternoon peak period models as opposed to the GVRD morning peak period model. The sub-area models were run by dialing-in to the GVRD Pixel computer.

In 1988, the City of Vancouver and GVRD conducted a regional trucking survey. Information from this survey was used to calibrate a 24 hour truck model. This model provided information on two categories of truck movements - light trucks with a GVW of 4,500-20,000 kg and heavy trucks with a GVW over 20,000 kg.

Due to increased demands on EMME/2, a decision was made in 1989 to transfer from the Pixel computer to the GVRD VAX computer. A multiple EMME/2 VAX license was purchased from INRO Consultants Inc. which provided municipalities and government agencies with better access to their models. The result was a significant increase in speed and expanded use by various agencies.

A major 1989 study to make extensive use of the regional model was the Freedom to Move - Greater Vancouver Transportation Task Force study⁴. This study, which was sponsored by the Provincial Government and the GVRD, produced an integrated transportation plan for the GVRD to the year 2001.

The 1990s

In 1991, the regional model and truck model were validated to current conditions. The validation process included expanding the traffic zone system to 445 zones, updating the land use inputs and networks and some modifications to the four-step model and significant changes to the truck model structure. During the validation exercise, the GVRD decided to transfer EMME/2 from the VAX to the PC. Again, the reason being lower costs, better access to the models and faster computing time for

² For an overview of the surveys refer to "Peterson, D. and Glover, R. 1987. *ALRT Impact Assessment: Baseline Travel Survey*. Transport Canada Report No. TP 8983E.

³ 1985 Metropolitan Vancouver Origin-Destination Survey, 1. Summary of Household and Travel Demand Statistics, 2. Inter-Municipal Travel Patterns, 3. Vehicle and Passenger Screenline Survey. Greater Vancouver Regional District.

⁴ Freedom to Move - Report of the Greater Vancouver Transportation Task Force. 1989. Volumes 1-5. Province of British Columbia, Ministry of Regional Development and the Greater Vancouver Regional District.

users.

This work was done in preparation for Transport 2021⁵ which was the region's first long-range transportation plan with associated policies on land use, transportation demand management (TDM) and investment priorities for transit and road. Transport 2021 was a two year project that made extensive use of the regional model for testing land use scenarios, TDM strategies and road and transit networks.

In 1992 the GVRD, BC Transit and the Ministry of Transportation and Highways jointly funded a major household travel survey⁶ for the morning peak period (6:00 - 9:00 a.m.). This telephone survey collected data from 15,000 households (a two percent sample of the 690,000 households in the Lower Mainland - Lions Bay to Chilliwack) with information on more than 25,000 morning trips. One of the primary objectives of this survey was to collect data required to re-calibrate the regional model to current morning conditions. This was followed by a 24 hour trip diary survey⁷ in 1994. This was a mail-back survey that collected information from 1,600 households (0.2 percent sample of the 740,000 households in the Lower Mainland) with information on more than 11,000 trips throughout the day. The trip diary was designed to collect baseline information for regional planning purposes, as well as for calibrating an afternoon peak period transportation model.

In late 1994, the Province, GVRD and BC Transit embarked on a follow-up study to Transport 2021 called the South Coast Transportation System Plan. This study was intended to provide a more detailed description of the infrastructure requirements identified in Transport 2021. At about the same time, BC Transit was involved in the development of their 10 Year Plan and in a Multiple Account Evaluation of Rapid Transit Options for the GVRD. Both of these studies made extensive use of the regional model and the GVRD truck model.

In 1995, the GVRD conducted a re-calibration of the model to the 1992 Travel Survey. In summary, the traffic zone system was expanded from 445 zones to 652 zones, the road network was expanded from 7,400 to 13,000 links, the transit network was updated and new intersection-based volume-delay functions were introduced, replacing the old Bureau of Public Roads (BPR) functions.

In 1996, the GVRD established the Transportation Model Enhancement Program to address the evolving needs of the model-users in the region. The first step involved updating the model to 1996 conditions, developing a preliminary PM Transportation Model, collecting additional data and identifying future model enhancements. The identification of future model enhancements involved input from consultants, municipal and provincial staff. This feedback was categorized and prioritized (depending upon need, data availability, difficulty, cost, inter-dependencies, etc.). The result was a short, medium and long-term modelling research program that focuses on model enhancement, model expansion, user support and data collection.

The short-term work program was completed in 1998 and involved the following model enhancements: queue-delay functions; revised transit weight parameters; transit/walk/bike captive model; triple-combined friction factors to include walk accessibility; new walk and bike models; park and ride model; HOV multi-level logit model.

With all of the refinements and added complexity to the model over the last twenty years, it is interesting to note the changes in computing time. In the early 80's a model run took all day to input

⁵ *Transport 2021. A Long-Range Transportation Plan for Greater Vancouver. 1993. Greater Vancouver Regional District and the Province of British Columbia.*

⁶ *1992 Greater Vancouver Travel Survey - Reports no. 1-7, 1994. Greater Vancouver Regional District, Ministry of Transportation and Highways and BC Transit.*

⁷ *1994 Greater Vancouver Trip Diary - Reports No. 1-4. 1995. Greater Vancouver Regional District, Ministry of Transportation and Highways and BC Transit.*

and execute and the assignment took all night. Today, on an AST Pentium II 300 MHz personal computer, a full model run and a 30 iteration multi-class auto assignment takes approximately 40 minutes. This enormous increase in computing efficiency, coupled with a higher level of understanding by the general user, has resulted in tremendous growth in the application of these models for all levels of planning studies - currently there are more than 30 agencies and consultants using EMME/2 and the transportation models for planning studies in the Greater Vancouver area.

3. Identifying and Prioritizing Model Enhancements

As mentioned above, the GVRD established the Transportation Model Enhancement Program in 1996. The goal of this program is to improve our understanding of transportation-related issues and to use these findings to enhance the transportation models and analytical tools available for transportation planning in the GVRD.

One of the first tasks of this program was to determine the current model deficiencies and identify and prioritize research activities to address these deficiencies. Initially, several consultants familiar with the model were asked to prepare papers that identified future research priorities. These papers were discussed in an open forum with the GVRD EMME/2 user group where other ideas and suggestions were identified. Exhibit 1 provides a summary of the research topics that were identified during this process.

The next step was to prioritize these activities according to a set of criteria. The main factors pertaining to the importance and feasibility of the research items were:

- the significance to the model as a whole (both in terms of model functionality and current priority);
- the difficulty in implementing the research (has it been done elsewhere?);
- the dependence from other research issues;
- the resource required (cost and time) in order to undertake the research; and
- the data needed to validate the research (is a specialized survey required?)

For each research topic, a value between 1 and 10 was assigned to each criteria. Exhibit 2 shows the resulting scores which were used as the basis for establishing the future work program.

The research topics can be classified as either an enhancement to the existing model, or an expansion to its capabilities. Additionally, user support and data collection were other general categories identified during the review. Using these general categories and the ranking results, the research topics were organized into short, medium and long-term work programs (see Exhibit 3).

Exhibit 1 - Summary of Research Topics

Research Category	Research Items
Travel Demand	<ul style="list-style-type: none"> • integrated transportation-land use modelling process • investigate use of land use variables for trip generation • investigate use of more detailed demographics • determine optimal traffic zone system • re-calibrate trip distribution model • investigate possibility of constraining the distribution model by spatial allocation of demographics • investigate possibilities of an integrated trip distribution/mode choice model • expand current trip purpose category • external trip matrices re-calibration • define explicit parking capacities
Modal Choice and Vehicle Types	<ul style="list-style-type: none"> • re-calibrate modal split model • refine and calibrate current modal split model to incorporate HOV and park and ride • discrete modelling of captive transit trips in modal split model (auto ownership model) • investigate trip chaining • develop separate pedestrian and bicycle models • develop peak and off-peak truck models • investigate significance of expanding vehicle type categories • incorporate “bus-skipping” penalties on over-capacity transit routes
Assignment	<ul style="list-style-type: none"> • validate VDFs by performing travel time and spot-speed surveys • examine methods of incorporating queuing into model
Network	<ul style="list-style-type: none"> • investigate significance of a more detailed local road network • develop a road classification system agreeable by all agencies • determine significance of the use of topographical information in the transportation model
Time Period	<ul style="list-style-type: none"> • re-calibrate AM and PM models with larger sample travel surveys • develop off-peak models • develop a 24-hour model sensitive to daily variations • develop factors to expand 24-hour model results into annual results
Travel Costs	<ul style="list-style-type: none"> • research value-of-time for different trip purposes • research transit time weights • determine road pricing elasticities by trip purpose and income
User Support	<ul style="list-style-type: none"> • hold training and education seminars and workshops • develop a user group network • develop utilities to assist in model management • investigate model links to micro-simulations
Data Collection/Surveys	<ul style="list-style-type: none"> • develop a detailed data collections strategy and establish a formal on-going program

Exhibit 2 - Results of Priority Rankings

		1	2	3	4	5	
		Significance to model	Difficulty*	Dependence from other items	Resource* (cost and time)	Need for Data*	Score (see note below)
RANK	Weight:	1.5	1	1.5	1	1	
1	examine methods of incorporating queuing into the model	6	4	6	4	4	36
2	validate VDFs by performing travel time and spot-speed surveys	7	4	7	4	7	36
3	research value-of-time for different trip purposes	7	5	7	4	6	36
4	research transit weight times	7	5	7	4	6	36
5	re-calibrate trip distribution model	8	7	8	6	5	36
6	re-calibrate modal split model	8	7	8	6	5	36
7	refine and calibrate current modal split model to incorporate HOV and park and ride	7	6	7	5	4	36
8	discrete modelling of captive transit trips in modal split model (auto ownership model)	7	5	6	4	5	35.5
9	develop a road classification system agreeable by all agencies	5	3	4	3	2	35.5
10	incorporate "bus-skipping" penalties on over-capacity transit routes	6	5	7	3	6	35.5
11	develop separate pedestrian and bicycle models	7	7	7	5	4	35
12	develop a detailed data collections strategy and establish a formal on-going program	4	3	4	3	1	35
13	investigate use of land use variables for trip generation	6	3	5	4	5	34.5
14	investigate use of more detailed demographics	6	3	5	4	5	34.5
15	determine significance of the use of topographical information in the transportation model	5	3	4	3	3	34.5
16	re-calibrate AM and PM models with larger sample travel surveys	8	7	8	6	7	34
17	investigate possibility of constraining distribution model by spatial allocation of demographics	6	5	6	4	5	34
18	determine optimal traffic zone system	5	4	5	4	3	34
19	determine road pricing elasticities by trip purpose and income	7	6	7	5	7	33
20	define explicit parking capacities	5	5	7	4	6	33
21	develop a user group network	4	3	3	4	1	32.5
22	hold training and education seminars and workshops	4	2	4	6	2	32
23	develop off-peak models	8	7	7	7	7	31.5
24	develop a 24-hour model sensitive to daily variations	8	8	7	7	7	30.5
25	develop peak and off-peak truck models	7	7	6	6	6	30.5
26	develop factors to expand 24-hour model results into annual results	7	6	6	6	7	30.5
27	integrated transportation-land use modelling process	8	8	7	8	6	30.5
28	investigate significance of a more detailed local road network	6	6	5	4	6	30.5
29	external trip matrices re-calibration	5	4	4	3	6	30.5
30	expand current trip purpose category	6	5	4	4	6	30
31	develop utilities to assist in model management	5	5	3	6	1	30
32	investigate trip chaining	6	6	5	5	6	29.5
33	investigate possibilities of an integrated trip distribution/mode choice model	7	8	6	5	7	29.5
34	investigate significance of expanding vehicle type categories	5	5	4	3	6	29.5
35	investigate model links to micro-simulations	4	5	3	4	2	29.5

Note: the *lower* the Difficulty, Resource, and Need for Data scores for each item, the *higher* the contribution to priority scores

Exhibit 3 - Modelling Research Work Program

	Short-Term (1998)	Medium-Term (1999-2000)	Long-Term (2001+)
Model Enhancement	<ul style="list-style-type: none"> • examine methods of incorporating queuing into the model • validate VDFs by performing travel time and spot-speed surveys • research value-of-time for different trip purposes • research transit weight times • re-calibrate trip distribution model • re-calibrate modal split model • refine and calibrate current modal split model to incorporate HOV and park and ride • discrete modelling of captive transit trips in modal split model (auto ownership model) • develop a road classification system agreeable by all agencies • incorporate "bus-skipping" penalties on over-capacity transit routes • develop separate pedestrian and bicycle models • investigate use of land use variables for trip generation • investigate use of more detailed demographics 	<ul style="list-style-type: none"> • determine significance of the use of topographical information in the transportation model • re-calibrate AM and PM models with larger sample travel surveys • investigate possibility of constraining distribution model by spatial allocation of demographics • determine optimal traffic zone system • determine road pricing elasticities by trip purpose and income • define explicit parking capacities 	<ul style="list-style-type: none"> • investigate significance of a more detailed local road network • external trip matrices re-calibration • expand current trip purpose category • investigate trip chaining • investigate possibilities of an integrated trip distribution/mode choice model • investigate significance of expanding vehicle type categories
Model Expansion		<ul style="list-style-type: none"> • develop off-peak models • develop a 24-hour model sensitive to daily variations • develop peak and off-peak truck models • develop factors to expand 24-hour model results into annual results 	<ul style="list-style-type: none"> • integrated transportation-land use modelling process
User Support	<ul style="list-style-type: none"> • develop a user group network 	<ul style="list-style-type: none"> • hold training and education seminars and workshops • develop utilities to assist in model management • investigate model links to micro-simulations 	
Data Collection/ Surveys	<ul style="list-style-type: none"> • develop a detailed data collections strategy and establish a formal on-going program • travel time survey • spot-speed survey • queuing survey 	<ul style="list-style-type: none"> • stated-preference survey • truck survey • transit survey 	<ul style="list-style-type: none"> • travel survey • screenline survey

4. Implementing the Short-Term Modelling Program

In the summer of 1997, the GVRD and the British Columbia Ministry of Transportation and Highways (MoTH) agreed to jointly undertake a major restructuring and re-calibration of the transportation model. Using the results from the future research work program, a detailed work program was developed to address the requirements of upcoming planning studies.

The following major activities were identified and sequentially implemented:

1. Road and Transit Network
 - revised volume-delay functions to include a constant signal delay term (validated to travel time surveys)
 - new queue volume-delay functions to improve travel time simulation at bottlenecks
 - revised transit itineraries and transit time functions
2. Travel Costs
 - revised transit time weight parameters (for auxiliary access, waiting, boarding)
 - new value of time for commuting (50 percent of the average hourly wage rate)
3. Trip Generation
 - updated demographics and revised trip generation equations
 - transit/walk/bike captive work trip production
4. Trip Distribution
 - intra-zonal distance/impedance calculation to improve trip distribution in large traffic zones
 - purpose-specific impedance equations (removed parking charges from grade school trips, introduced school district boundary penalties, etc.)
 - gravity models with triple-combined friction factors (reflecting auto, transit and walk impedance)
5. Mode Split
 - nested-logit mode choice model for bike, walk, transit and auto trips
 - park and ride submodel implemented within the nested logit model
 - HOV/SOV submodel implemented within the nested logit model

When implementing significant changes to any model it is important to validate the changes relative to the base model and the original survey data. For this study, a comprehensive list of validation procedures were developed and each improvement was introduced independently to determine the effect on the base model. After each run, the following information was generated and reviewed: trip totals and trip lengths by purpose and mode relative to the survey, aggregated trip tables relative to the survey, auto and transit assignment summary statistics, screenline summaries, and transit itinerary times versus actual transit schedules.

All of the model improvements were calibrated to the 1992 Travel Survey and validated to 1996 conditions using the latest demographics and screenline count information.

The remainder of this paper provides a brief description of some of the key improvements described above. Transit captivity, HOV, and Park and Ride are not described in detail as they are discussed in separate papers in this session.^{8, 9, 10}

⁸ Clement, Basse. *Application of a Transit, Walk and Bike Captive Trip Forecasting Procedure in the Greater Vancouver Transportation Model. 13th Annual EMME/2 Users Group Conference, Houston, Texas. October 1998.*

4.1 Revised Volume-Delay Functions and Queue Functions

In 1996, the GVRD introduced intersection-based volume-delay functions to replace the Bureau of Public Road volume-delay functions.¹¹ These functions offered several advantages including a more straightforward, objective method for coding network links, the ability to reflect minor roadway improvements such as left turn bays and improved travel time results.

Although the simulated travel times were closer to observed times after the introduction of the intersection-based functions, the model times were still faster than the observed times. This was particularly noticeable on uncongested network segments and at bottleneck locations (e.g., bridge approaches) where the model was significantly under-estimating travel times.

With respect to the uncongested network elements, it was found that road users travelling on these segments experienced random delay at intersections associated with “missing the green light”. To address this phenomena, an average delay of 15 seconds (or 0.25 minutes) was added to each volume-delay function which represented a controlled intersection. Functions used to represent free-flow segments were not affected by this modification. As comprehensive travel time data was not available, the constant term was determined by varying it until it produced a close match to the limited observed data.

Below is an example of a typical signal controlled volume-delay function with the new constant term:

$$Vdf_{int} = 0.25 + length \frac{60}{postspeed} + \left(\frac{volau + volad}{800 * lanes} \right)^4$$

The fact that the model underestimates travel time at bottleneck locations is probably due to several factors. For example, the capacity at these locations is affected by merging which is difficult to reflect in the volume-delay functions. Also, a steady-state model cannot address queuing and is calibrated to observed volumes and not demand (demand is represented by the through volume plus the volume in the upstream queue). As a result of these factors, the model tends to underestimate upstream travel times. This makes it difficult to accurately predict the effectiveness of transit and HOV queue-jumpers that are being proposed at many of these locations.

To address this problem, two approaches were reviewed. First, the option of revising the upstream capacity of merging link segments to reflect the downstream capacity was tested. While this is a simple and attractive approach, the user must make an assumption about the volumes on each merging link and downgrade the capacities accordingly. For example, a two-lane freeway (with a nominal capacity of 1,600 vph/lane) merging with a one-lane on-ramp (800 vph/lane) could produce 4,000 vph on the downstream lanes when the nominal capacity is 3,200 vph. To adjust the upstream volume-delay functions, the user could assume that the volume in one of the upstream freeway lanes and the on-ramp must be accommodated by one of the downstream freeway lanes. This could be achieved by factoring the nominal capacity of these lanes by two-thirds (e.g., 1,600/2,400). However, this assumes that both lanes are at capacity (which may not be always be the case) and could produce problems when simulating future conditions. Another approach would

⁹ Hoff, Chris. *Application of a Multi-Level Logit Function HOV/SOV Forecasting Procedure in the Greater Vancouver Transportation Model. 13th International EMME/2 User's Conference, Houston, Texas, October 1998.*

¹⁰ Hull, Edwin. *Application of a Park and Ride Forecasting Procedure in the Greater Vancouver Transportation Model. 13th International EMME/2 User's Conference, Houston, Texas, October 1998.*

¹¹ Partridge, T. and Krajczar, K. *Application of Intersection-Based Volume Delay Functions in Greater Vancouver. 11th International EMME/2 User's Conference, Toronto, Ontario, October 1996.*

be to explicitly reference the downstream link capacity and the volume of the opposing merge link within the volume delay function and adjust the link capacity accordingly. Asymmetric link cost functions which can look upstream and adjust the travel time are in principle possible to implement; however, the method may not converge to a unique solution which is an essential property for any scenario testing.

The second approach was to introduce a special function designed to simulate queue-delay at the bottleneck. Short “dummy” link segments (distance equal to 0.01 kilometres) were added to each bridge or tunnel approach and assigned the following queue function:

$$Vdf_{queue} = \left(\frac{volau + volad}{lanes} - 1900 \right) \times 0.017 \times \left(\frac{volau + volad}{lanes} .ge. 1900 \right)$$

The function was developed based on observations of queue delays and queue lengths at six major water crossings in the region. Assuming a “non-queuing” travel speed of two-thirds the posted speed limit (speed produced by the regular volume-delay function when volume reaches the nominal capacity), the average net delay was determined. The volume in the queue was then estimated giving a demand to capacity ratio. On average, it was found that for every one percent that demand exceeded capacity, the user experienced a 0.32 minute delay associated with queuing. If the volume is below capacity, the conditional argument in the function is “false” and the travel time on the “dummy” link is zero.

In addition to providing more realistic travel times at bottle-necks, this feature can be used to reflect the benefits of queue-jumpers for buses and HOV’s by coding links that bypass the queue link. In order to obtain reasonable travel times, the model is calibrated to the upstream bridge demand. Although this results in higher volumes downstream, the travel times are not significantly affected as the downstream traffic quickly disperses out over the network.

4.2 Intra-zonal Distance/Impedance Calculation

The previous version of the GVRD Transportation Model had a tendency to over-predict walk trips and under-predict auto trips in large rural traffic zones. This became an issue when evaluating future land use scenarios that would allocate significant population growth to these zones. In these scenarios, the proportion of walk trips was unreasonably high and the scenario results had to be manually adjusted.

In areas with large traffic zones, this problem occurred because of the long distances between adjacent zones. The trip distribution model tended to allocate a high proportion of intra-zonal trips because the intra-zonal impedance was small (or even zero) and the next closest traffic zone was several kilometres away. The problem was further compounded by the mode split model which favoured walk over auto on trips with the same impedance (mode bias in favour of walk). As both the walk and auto impedances were zero on intra-zonal trips, a high proportion of walk was being produced within the zone. In reality, the average walk impedance in a large zone would be significantly higher than auto due to the longer trip lengths.

One solution would be to disaggregate the large traffic zones slated for future growth. This would ensure a more realistic distribution of trips and better mode split prediction. However, this approach would be very time consuming as each land use scenario would require the disaggregation of different zones.

Instead, an intra-zonal distance was calculated for each zone and added to the distance matrix which is estimated using the additional demand auto assignment procedure (previously, the distance matrix contained a value of zero on the diagonal). The regular distance matrix is modified as follows:

$$Dist_{ij} = Dist_{ij} + \left(0.067 \times \sqrt{Area(ha)_i} \right) \times (p .eq. q)$$

The distance calculation assumes that the zone is circular and that the average travel distance within the zone is 1.2 times the circle's radius. The area matrix contains the traffic zone areas in hectares up to a maximum of 2,500 hectares (it is unlikely that a large rural zone will develop an area of more than 2,500 hectares within the planning time horizon).

This distance matrix is then used in the auto, transit and walk impedance calculations to produce the appropriate intra-zonal impedances. Note that the auto generalized cost and transit travel time matrices are modified to include an intra-zonal travel time after every assignment, prior to the impedance calculations.

This minor modification has resulted in much better trip distribution and mode split prediction in large traffic zones. Large traffic zones that were previously predicting 60 percent intra-zonal walk trips are on average producing 20 to 25 percent walk trips depending on the predominant trip purposes within the zone.

4.3 Gravity Models with Triple-Combined Friction Factors

Since the early 1980's, the GVRD transportation model has used a gravity model which combines auto and transit impedance in the work friction matrix. This model enhancement was based on the theory that both auto and transit service influence where people live and work. Without this feature, the effects of major transit projects (e.g., the introduction of the SkyTrain ALRT system in 1986) could not be accurately predicted.

During the recent re-calibration work it was observed that in high density areas the model was under-predicting the number of work trips that would stay in the local area. This was a particular problem on the Vancouver downtown peninsula which is home to almost 60,000 people and 140,000 jobs (excluding Stanley Park, this area is less than 500 hectares). A large percentage of people living in this area, work downtown and walk to work (in part, to avoid the high parking charges and transit fares).

To address this issue it was proposed that the walk impedance be added to the friction calculation resulting in a triple-combined friction factor. The previous work friction factor was of the form:

$$Wkf_{ij} = (e^{-.047Autimp_{ij}} + e^{-.047Trnimp_{ij}})(R_{ij})$$

This equation has been modified to include the walk term as follows:

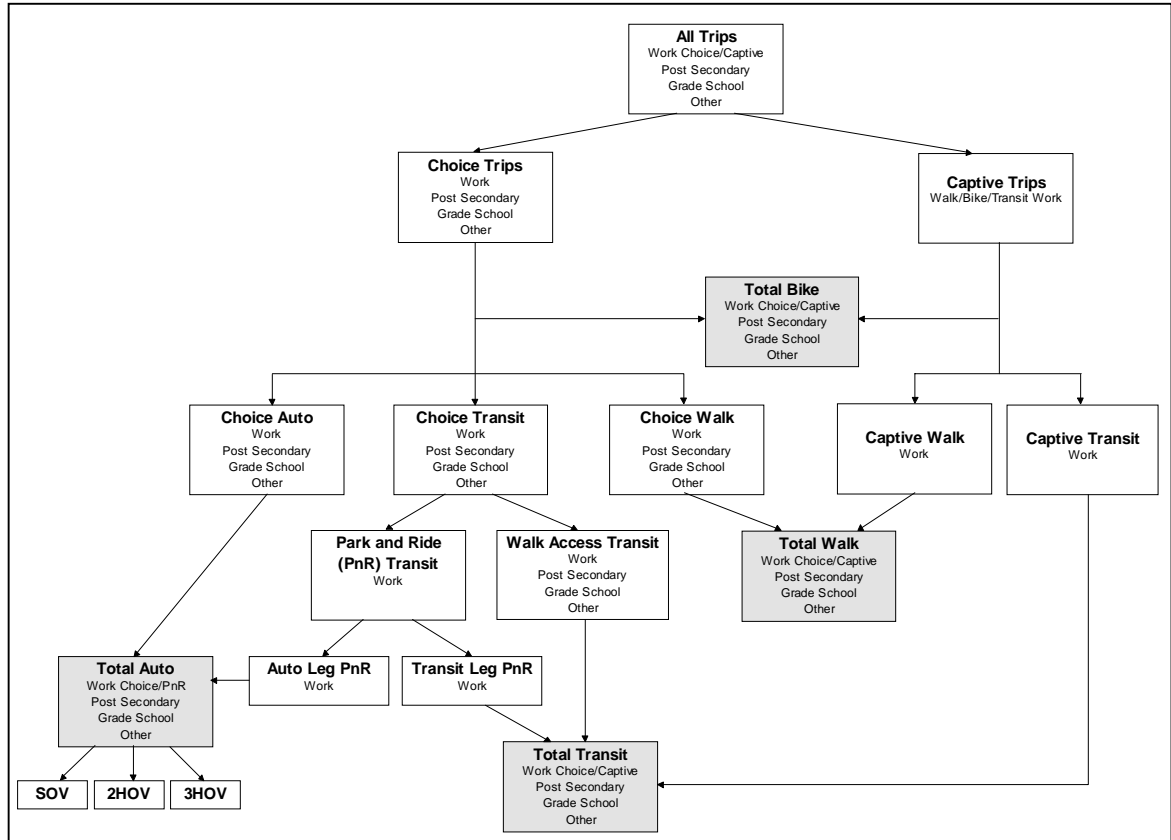
$$Wkf_{ij} = (e^{-.047Autimp_{ij}} + e^{-.047Trnimp_{ij}} + e^{-.047Wlkip_{ij}})(R_{ij})$$

This modification has resulted in significantly better trip distribution within the downtown peninsula and has had no effect in medium or low density areas where walking is not a viable option. The 1992 Travel Survey estimated that there were 5,800 work trips within the downtown peninsula during the morning peak hour. The model was predicting 5,200 trips prior to the improvement, which increased to 5,700 trips with the triple-combined impedance. As would be expected, trips throughout the rest of the region were not affected by this modification.

4.4 Nested-Logit Mode Choice Model Structure

Another major enhancement completed during the re-calibration process was the introduction of a nested-logit mode choice model. Previously, the mode choice model was based on two binomial logit models for each trip purpose that predicted walk trips, followed by transit trips. The introduction of transit captivity, HOV, and park and ride, resulted in the development of a nested-logit framework. Exhibit 4 shows a schematic diagram for the nested-logit structure.

Exhibit 4 - Nested-Logit Mode Choice Structure



The trip distribution models produce five matrices that feed into the nested-logit mode choice model: (i) transit/walk/bike captive work; (ii) choice work; (iii) post secondary; (iv) grade school; and (v) other. Captive trips are predicted at the trip generation stage based on origin zone density and distributed along with choice work trips to a single work attraction vector using the “balmprod” macro.¹² Due to data limitations, captive trips are only predicted for the work trip purpose.

The first step in the mode choice model is the prediction of bike trips which is based on a negative exponential function where distance is the independent variable. This simplistic approach was used as the factors influencing the decision to bike are difficult to predict and these trips only account for one percent of regional travel.

The remaining captive work trips are split into walk and transit trips using a binomial-logit function, while the remaining choice trips are split into auto, transit and walk using a multi-nomial logit model. The park and ride model is then applied to transit choice work trips to determine walk access and

¹² BALMPROD 1.4 - Heinz Spiess, EMME/2 Support Centre, CH-2558 Aegerten

park and ride trips. Park and ride is only applied to work trips as this sub-mode is insignificant for the other trip purposes. The park and ride model produces two matrices: (i) the auto leg from the origin to the parking lot; (ii) the transit leg from the parking lot to the destination. These matrices are incorporated into the overall auto and transit choice matrices.

The final step is the prediction of one person, two person and three or more person vehicle trips. The HOV model predicts these trips for work, post secondary and other trips using a multi-level logit formulation based on the difference in generalized-cost between the sub-modes. Grade school auto trips are split into the three categories based on average vehicle occupancies. These trips are then summed into the three vehicle matrices (e.g., SOV, 2 HOV, 3+ HOV).

The three auto matrices are assigned using a generalized-cost multi-class assignment. The transit matrix is assigned using the multi-path assignment algorithm. Walk and bike matrices are not assigned to the network.

The new nested-logit mode split model provides a significant enhancement over the previous model structure as it enables the prediction of Transit captivity, HOV, and Park and Ride trips. The accompanying papers in this session provide a more detailed description of these enhancements.

5. Conclusions

This paper provides a brief overview of the evolution of the GVRD Transportation Model between 1975 and 1998. Over the years, improved computing efficiencies coupled with better information has led to significant enhancements in the model. Many of these recent enhancements have focused on current policy-related issues (e.g., HOV lanes, park and ride, road pricing, etc.). As a result, the model is now being used by more than 30 agencies throughout the GVRD and the Lower Mainland.

With respect to model enhancements, it is often difficult to agree on improvement priorities - especially in a region with many diverse users. This paper presents one approach to prioritizing research needs and establishing a model enhancement program that meets the needs of the user. Where the needs of a specific user cannot be accommodated within the GVRD work program, the user is encouraged to develop sub-area models or modify the regional model with the help of consultants.

The latest round of work included the introduction of many small-scale modifications (e.g., queue functions, triple-combined impedance) and several major enhancements (e.g., Transit captivity, HOV model, Park and Ride). These changes have improved the accuracy of the model and extended its capabilities to address many of the current-day policy issues.