Application of a Park-and-Ride Forecasting Procedure in the Greater Vancouver Transportation Model

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Introduction

The Vancouver Regional Transportation Model was developed and calibrated in the late 1980's from data collected in a Regional Travel survey undertaken in 1985. The model was substantially re-calibrated in the mid 1990's based on data collected as part of a 1992 telephone interview survey and a 1994 Trip Diary survey.

At the time of the original travel survey and model calibration, there were a limited number of small Park-and-Ride lots in the region primarily serving express bus lines from the inner suburbs. Consequently, no attempt was made in the original calibration to explicitly recognize the effects of Park-and-Ride on transit ridership or to explicitly model local auto trips serving Park-and-Ride users.

The introduction of SkyTrain service (intermediate capacity rail-based rapid transit) in the late 1980's and commuter rail service in the mid 1990's, combined with rapid population growth in the Lower Fraser Valley, has led to increasing development of Park-and-Ride sites to improve access to transit service, particularly in lower density out-lying areas. Today, in the Vancouver region, there are 25 "official" Park-and-Ride lots operated by or on behalf of BC Transit — the Provincial agency responsible for public transit services in the region. The combined capacity of these parking lots is more than 5000 parking spaces. There are also a number of private lots providing paid monthly parking at or near major transit terminals and there is evidence of on street "Hide-and-Ride" in some areas.

This paper reviews the development of Park-and-Ride modelling using EMME/2 in Greater Vancouver and describes the evolution of the model from a site-specific application at individual parking lots to a generic logit function-based procedure using matrix convolutions.

The current procedure was developed and calibrated as part of a major re-structuring and re-calibration of the model undertaken jointly by the Greater Vancouver Regional District and the BC Ministry of Transportation and Highways. The staffs of the Ministry's Lower Mainland Region office and the Regional District's Strategic Planning Department made significant contributions to the development and calibration of the Park-and-Ride model.

The Scott Road Model

The extension of the Vancouver-New Westminster SkyTrain line across the Fraser River to North Surrey in 1990 included a large Park-and-Ride lot at the Scott Road terminus in North Surrey. The 1600-space parking lot reached capacity within a few months of opening and BC Transit began planning an extension. To assist in determining the capacity to be provided, BC Transit commissioned a study to forecast the future use of the lot based on a Park-and-Ride sub-model specifically developed for the project.

The model treated Park-and-Ride as a sub-mode of transit in a nested logit structure. The Park-and-Ride utility or impedance was computed as the sum of auto impedance from origin to Park-and-Ride and the transit impedance from Park-and-Ride to the destination, together with weights and sub-modal biases calibrated to observed use of the 1600-space facility. Implementation of the model in EMME required extensive use of vector ***mo*** and ***md*** matrices. It was found to be necessary to restrict the origins and destinations of trips for which the Pak-and-Ride sub-mode could be considered in order to avoid the creation of illogical trip chains. This was achieved by the subjective identification of Park-and-Ride "catchment areas" at the origin and destination ends of potential trips.

The Northeast Sector Model

BC Transit commissioned additional Park-and-Ride studies during the early and mid-1990's. These involved expanding the site-specific Scott Road model to prepare forecasts of usage at sites with overlapping catchment areas, and for sites served by bus as well as rail-based transit modes. These were used in the planning of the Coquitlam SkyTrain extension to the communities in greater Vancouver's Northeast sector and in planning and designing a commuter rail system to serve the same part of the region.

Modelling several Park-and-Ride sites simultaneously, including locations where more than one site would compete for the same potential users became increasingly complex and cumbersome because of the large number of vector and full matrices required. Consequently, use of the model continued to be restricted to specific projects and the generic regional model did not explicitly model the effects of the increasing number of Park-and-Ride sites being developed in the region.

The Generic Regional Model

The Ministry of Transportation and Highways commissioned Edwin Hull and Associates to work with Ministry and GVRD staff to revise and re-calibrate the model in 1997. The re-calibrated model was to be used for a series of planning studies broadly centred on the Port Mann Bridge which carries the Trans Canada Highway across the Fraser River. The Ministry wished to include a region-wide multiple-site Park-and-Ride model as part of the proposed update.

With 21 identified significant Park-and-ride lots in the region, (see Figure 1) and with some residential areas having reasonable access to five or six alternative lots, this could only be effectively and efficiently achieved using the matrix convolutions module. This allowed the modelling of multiple Park-and-Ride sites with more economical use of matrices and allowed the application of the sub-model procedures to be implemented considerably more efficiently. This combined with construction of additional Park-and-Ride sites throughout the region led to a decision to include the Park-and-Ride procedure in the generic regional model.

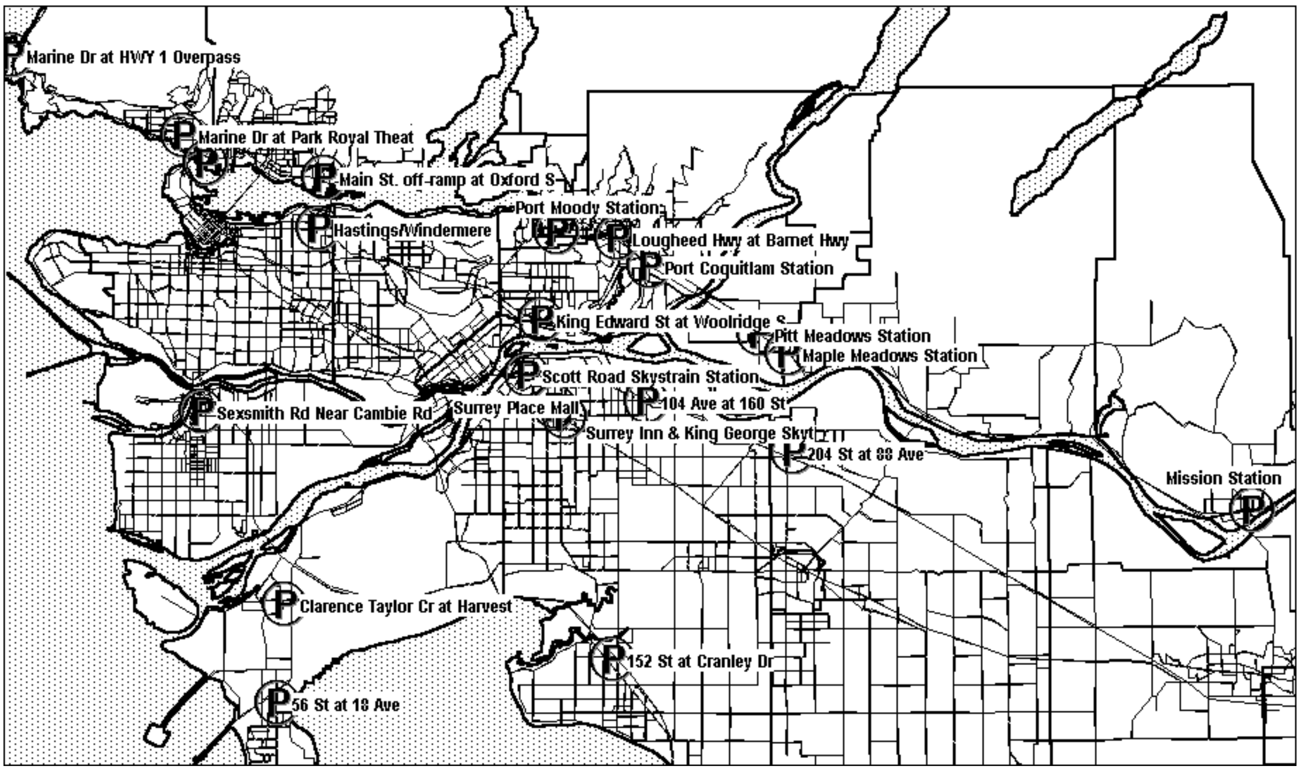

Figure 1 — Major Park-and-Ride Lots in Greater Vancouver

The Park-and-Ride model forms one branch of the nested logit choice model employed in the regional model. The overall model structure and the implementation of other branches of the nested logit model are described in other papers presented at this meeting.

The Park-and-Ride procedure is based on the following assumptions:

1. Transit riders to destinations with abundant free parking will not use Park-and-Ride.
2. Trip makers will not use Park-and-Ride if the transit impedance (generalized cost) from their origin zone to their destination is lower than that from the Park-and-ride lot to their destination.
3. For those trip-makers for whom Park-and-ride is a reasonable mode, the decision on transit access mode can be modelled using a logit-function based on the comparative

generalized costs of the complete transit trip involving the alternative transit access modes.

4. The generalized cost of the Park-and-Ride access mode will include any parking charges collected at the Park-and-Ride lot and, where appropriate, a penalty representing the uncertainty of finding a parking spot at locations where demand is perceived to exceed capacity.

5. Trip makers will be reluctant to use Park-and-Ride unless the travel time and impedance saved justifies the use of the auto. (For example, someone living 200 metres from a transit station is more likely to walk to the station than use a Park-and-Ride lot at the station, even though the Park-and-Ride impedance may be lower than the walk impedance.) This requires the inclusion of a modal penalty or bias in the Park-and-Ride impedance to avoid over-prediction of short auto trips. Modal penalties of 4 minutes at sites served by rail-based transit, and 6 minutes at sites served only by bus provided the best fit to the distribution of trip origins observed in BC Transit surveys.

6. The primary mode of Park-and-Riders is transit. Consequently, the auto leg of the trip will generally be shorter than the transit leg. (This assumption was supported by BC Transit user surveys.) To match the observed distribution of origins of Park-and-Ride trips, it was necessary to apply a weight to the auto leg of the Park-and-Ride trip. This weight was dependent on the transit mode served by the Park-and-Ride lot.

   BC Transit surveys indicated that the mean trip length of the auto leg was longer at rail-based Park-and-Ride sites than at those served only by bus routes. The calibrated weights were 1.25 for sites served by rail-based transit and 1.35 for sites served only by bus.

7. For those trip-makers for whom Park-and-ride is a reasonable mode, the effective transit impedance considered in making decisions about trip distribution and mode split will be lower than for trip makers with no access to Park-and-Ride.

The procedure requires that the database includes:

- “Dummy” zones representing Park-and-Ride lots together with appropriate centroid connectors. For the base year (1996) model, a dummy zone was established to represent each Parking lot indicated in Figure 1.
- A vector (***md***) matrix specifying the estimated peak hour capacity of each lot. Peak hour capacities were estimated from data provided by BC Transit. This included the capacity of each lot and the proportion of total daily users arriving before the peak hour.
- Ensembles to represent the residential catchment area of each Park-and-Ride lot and the logical commercial destinations served by transit service from the Park-and-Ride lot. The “gp” ensemble, illustrated in Figure 2 specified 25 active zone groups, each of

which lay within the catchment area of one or more Park-and-Ride lots. Commercial destinations were identified in a separate "gr" ensemble.

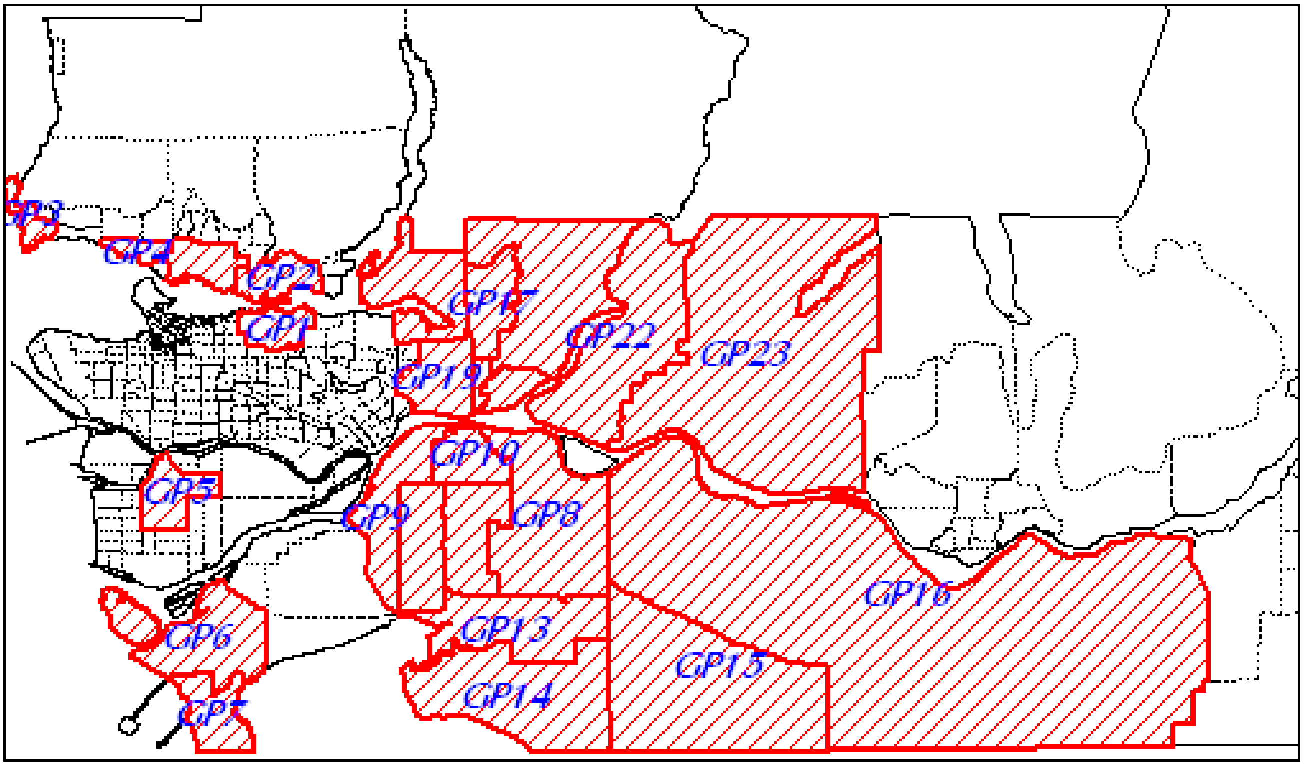

Figure 2 — The "GP" Ensemble

The procedure involved the following steps:

1) Compute Auto & Transit impedances for all zone pairs (including dummy zones representing Park-and-Ride sites.

2) Compute Park-and-Ride Impedance using minimum path based on

   $MIN\ PRI_{(ij)} = \text{Minimum (all k)} (AI_{(ik)} * W^{km} + TI_{(kj)} + P^{km} + SP^{k})$

   Where:

   $MIN\ PRI_{(ij)}$ is the minimum Park-and-Ride Impedance for all logical paths i-k-j.

   $AI_{(ik)}$ is the Auto Impedance from origin "i" to Park-and-Ride lot "k" including any parking charge collected at "k."

   W^{km} is an Auto Impedance weight applied to all trips to "k" — the value of the weight depends on the transit mode "m" served by Park-and-ride lot "k."

   $TI_{(kj)}$ is the transit impedance from Park-and-Ride lot "k" to destination "j."

   P^{km} is a penalty or modal bias applied to all Park-and-Ride trips to "k" — the value of the penalty depends on the transit mode "m" served by Park-and-ride lot "k."

SP^k is an additional penalty (or shadow price) applied to all trips to "k" determined by an iterative procedure to ensure that parking demand at "k" does not exceed the available capacity. (Note that where un-suppressed demand is less than capacity, SP^k is set to zero.)

3) Calculate "enhanced transit impedance" for origin destinations with access to Park-and-Ride based on:

$$ETR_{(ij)} = (\ln (\exp (- \beta * TI_{(ij)}) + \exp (- \beta * PRI_{(ij)}))) / (- \beta)$$

Where:

$ETR_{(ij)}$ is the "enhanced transit impedance"

β is a calibrated exponent used in the Park-and-Ride sub-mode split logit model.

4) Run the distribution and auto/transit mode split using $ETR_{(ij)}$ as the transit impedance

5) Split forecast choice transit trips into walk and Park-and-Ride access modes using a logit function with the calibrated exponent (β) and the respective impedances – $TI_{(ij)}$ and MIN $PRI_{(ij)}$.

6) Compute Park-and-Ride Impedance for each logical path based on

$$PRI_{(ikj)} = AI_{(ik)} * W^{km} + TI_{(kj)} + P^{km} + SP^k$$

7) Distribute forecast Park-and-Ride trips among competing Park-and-Ride lots based on a multinomial logit function of the form:

$$PRT_{(ikj)} = PRT_{(ij)} * \exp (- \beta * PRI_{(ikj)}) / \Sigma_{(k)} (\exp (- \beta * PRI_{(ikj)}))$$

8) Compare $T_{(ikj)}$ with the estimated peak hour capacity of the parking lot "k" and adjust SP^k for "overloaded parking lots.

9) Recalculate MIN $PRI_{(ij)}$ and $PRI_{(ikj)}$ for all "k" and repeat steps 5 through 8 until constrained demand at overloaded lots has converged to a value approximately equal to capacity.

10) Separate forecast Park-and-Ride trips ($PRT_{(ikj)}$) into their auto ($AT_{(ik)}$) and transit ($TT_{(kj)}$) components.

11) Subtract forecast Park-and-Ride trips ($PRT_{(ij)}$) from the transit trip matrix, add the auto leg of Park-and-Ride trips ($AT_{(ik)}$) to the auto trip matrix and add the transit leg of Park-and-Ride trips ($TT_{(kj)}$) to the transit trip matrix.

12) Assign auto and transit trip matrices to the network.

Implementation in EMME/2 of the matrix computations required for the procedure involved use of modules 3.12, 3.21, 3.22 and the matrix convolutions module 3.23. Our application of the matrix convolutions procedure broadly followed the example provided in pages 4-304 to 4-307 of the EMME/2 User's Manual

Implementation based on the matrix convolutions module required use of twelve ***mf*** matrices, three ***md*** matrices and no ***mo*** matrices. Without the matrix convolutions module, implementation of the procedure for 21 Park-and-Ride lots with overlapping catchment areas would likely have required use of more than 15 ***mf*** matrices, up to 20 ***md*** matrices and more than 15 ***mo*** matrices. This would have been impractical and would have precluded inclusion of comprehensive modelling of Park-and-Ride trips from most applications of the regional model.

Results

Forecast peak hour demand for 1996 was generally within 10% of observed peak hour usage at those sites where usage data was available. In addition, where data on the origins and destinations of Park-and-Ride users was also available, the model forecasts appeared satisfactory. Most importantly, the fit of forecast to observed passenger volumes for transit routes served by Park-and-Ride was improved by the introduction of the Park-and-ride forecasting procedure.

Conclusions

In urban areas with significant use of Park-and-Ride facilities, it is appropriate to include a procedure to model Park-and-Ride trips in a travel demand model.

It is desirable to identify origins and destinations of potential users for each Park-and-Ride site in order to avoid modelling illogical trip paths.

Based on the observed origins of Park-and-Ride trips in the Vancouver Region, it is necessary to include an auto time or auto impedance "weight" to ensure that trips from "distant" origins are not over-predicted.

Based on the observed origins of Park-and-Ride trips in the Vancouver Region, it is also necessary to include a Park-and-Ride penalty or bias to ensure that trips from origins within a reasonable walking distance are not over-predicted.

Both the auto time/impedance weight and the sub-modal bias appear to vary based on the transit mode served by the Park-and-Ride site. Lower values for these variables appear to apply for services operating within an exclusive right-of-way and/or offering higher travel speeds and service that is more reliable.

"Shadow pricing" is an effective way to model competition for parking spaces at "over-loaded" Park-and-Ride lots.

The matrix convolutions module provides an elegant and practical way in which to implement Park-and-Ride modelling within EMME/2 with efficient use of matrices.