MODELING WITH PUBLIC TRANSPORT

Task Order 15.4, Final Report

prepared for

**Metropolitan Washington Council of Governments/
National Capital Region Transportation Planning Board**

prepared by

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as subcontractor to

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Table of Contents

1. Introduction

1.1. **Background**

The Metropolitan Washington Council of Governments/National Capital Region Transportation Planning Board (COG/TPB) staff is considering changing in its transit network modeling software from the Cube Voyager TRNBUILD (TB) module to the Public Transport (PT) module. Both modules are Citilabs products. The change is being considered because The PT module is newer and offers added functionalities, such as path-based fare development. PT offers the option of single-route or multiple-route transit skimming/assignment procedures. Moreover, the TRNBUILD module is no longer being developed by Citilabs.

Previously, TPB staff contracted with AECOM to assist with a transition to PT software. AECOM indicated that PT use would require revisions to existing TRNBUILD-based transit network coding procedures. AECOM devised updated transit network coding conventions, including a process to generate a set of non-transit "legs" for various transit access modes.[1] The AECOM team also prepared a preliminary set of PT model scripts for the transit skimming/assignment process.[2] TPB staff has recently revised its transit network coding conventions and has refined AECOM's PT scripts. While the PT network building and path skimming procedures were implemented as prescribed by AECOM, the resulting paths were neither fully tested nor thoroughly validated.

In this task order, the TPB recruited a consultant team comprising the technical staff from Cambridge Systematics (CS) and Gallop Corporation (GC) to evaluate the current PT network modeling process. The main objectives of this task order were to:

- Examine the validity and reasonableness of the transit skimming and transit assignment process, including model parameters and model results;

- Adjust existing path-building parameters in PT based on analysis of observed travel data collected in the Metrorail passenger survey; and

- Refine and integrate the PT script files for within the existing TPB modeling process.

The 2012 WMATA Metrorail Passenger Survey[3] was the primary source of survey data used for validating the PT network modeling results. WMATA conducts the rail passenger survey periodically with the primary objective to "estimate the percentage of total ridership residing in each jurisdiction" for subsidy allocation purposes. The survey provides information about Metrorail passengers and their trip characteristics, including the home location, origin and destination station, trip purpose, and access/egress modes to/from the Metrorail system. This information can be used to assess the accuracy of transit paths developed by the PT module.

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[1] In the path-building terminology used in PT, a "leg" is super link composed of one or more links from the transit network. Specifically, a transit leg is a trip segment, from a boarding point to an alighting point, that uses a single transit line. Similarly, a non-transit leg is the segment of a trip between a zone centroid and the boarding point of a transit trip.

[2] AECOM, *FY 2014 Final Report, COG Contract 12-006: Assistance with Development and Application of the National Capital Region Transportation Planning Board Travel Demand Model* (National Capital Region Transportation Planning Board, Metropolitan Washington Council of Governments, August 18, 2014).

[3] WB&A Market Research, *2012 WMATA Metrorail Passenger Survey*, Final Report (Washington Metropolitan Area Transit Authority, November 27, 2012).

This technical report documents the work conducted in support of this task order. This introductory chapter outlines the scope of work of this task order and provides a brief overview of the technical approach of the study. Chapter 2 presents a review of the PT model scripts and revisions made to refine existing PT scripting. Chapter 4 describes the processing of the Metrorail Passenger Survey file which was necessary for deriving travel path-related characteristics. Chapter 5 presents the technical process for generating relevant PT model skimming and assignment data. A comparison of PT model generated data and observed passenger trip data, as well as summaries of the revision to some PT model parameters, is presented in Chapter 6. Finally, Chapter 7 describes major conclusions of the task and outlines next steps for implementing the PT model within the MWCOG travel demand model.

1.2. Scope of Work

The scope of work established for this task order covered the following activities:

- Review and test the latest PT process developed by AECOM and TPB staff.

- Examine and validate the PT path building and transit assignment results.

- Evaluate the PT-generated transit results with that of the 2012 Metrorail Passenger Survey. Specifically, the consultant should use the survey data to:

  a. Evaluate the consistency of PT walk access and drive access legs with respect to observed behaviour.

  b. Evaluate the parameters used by PT to develop non-transit legs.

  c. Evaluate the path-building parameters used by PT for walk access and drive access trips.

- Adjust path-building parameters based on the evaluation results.

- Document the analysis as performed in this task order.

1.3. Technical Approach

This task order involved two aspects of technical work: 1) PT network modeling process; and 2) a comparative analysis of Metrorail survey data and PT network model data. This task order was carried out in four activities as listed below.

1. **A Review of Existing PT-Model Scripts**: This task element involved the examination of the PT-scripts to ensure that the previously implemented PT model scripts function properly.

2. **Processing of Metrorail Survey Data**: The Metrorail Survey data was processed to generate relevant information reflecting the travel characteristics of Metrorail passengers. This included travel data of the access segment and the line-haul segment of Metrorail passenger trips.

3. **Processing of PT-Model Data**: The revised PT model scripts developed (in activity 1) were executed with the Metrorail Survey trip tables (derived in activity 2). Various transit skimming and transit assignment data were generated. These PT model data were processed to derive modeled travel characteristics data in formats that were comparable with the survey data.

4. **Evaluation of PT-Model Data and Results**: The survey trip data and the model estimated PT data are summarized for comparison to examine the reasonableness of the revised PT

model. In addition, a set of revised PT model parameters were derived based on the evaluation of the PT model results.

2. Review and Test of PT-Process

2.1. Review and Test of PT-Scripts

The consultant team obtained various data and documentation that were recently developed by AECOM and TPB staff. These included PT model script files, PT model data sets for the AM and off-peak periods, data processing flowcharts and other relevant technical reports. The consultant executed the latest developed PT procedures that were provided by the TPB staff. The consultant confirmed that the process was sound and the results were consistent with those provided by the TPB staff.

The consultant team reviewed the PT scripts and all the outputs. The review was focused on the following aspects:

- Parameters of the skimming process;

- Keywords of the script files;

- Coding of the transit network;

- Generation of non-transit linkages (e.g., walk access legs, PNR legs, KNR legs and walk transfer legs); and

- Skim matrix file data.

The review of the PT script files and model data revealed several minor issues that were easily resolved. These include:

1. The PNR-lot-to-Station connection links (mode 15 links) were coded with speed of 30 mph. The connection links represent the walk movements between PNR lots and Metrorail stations and should be coded with walk speed of 3 mph. This error was corrected in the script used to build the transit network ("V2.3_PTNet_Build.S").

2. In the existing TRNBUILD model, the walk time of the "PNR lot-to-station" walk links (mode 15 links) are assumed to be a function of both PNR parking capacity and parking cost.[4] However, in the PT model, the impedance of the PNR lot connection links is coded strictly as walk time. Therefore, the impedance of the mode 15 links was re-coded in the script used to build the transit network to reflect both the time and cost as originally specified. The PNR parking cost information was obtained from the station file ("STATION.DBF"), which is a standard input to the existing MWCOG travel demand model.

3. The non-transit "leg" generation (GENERATE) process was specified to create a maximum of 5 access connections from TAZs to PNR and KNR lots. The maximum of 5 was deemed overly restrictive. The maximum was increased to 10 by altering the keyword

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[4] Ronald Milone, Mark Moran, and Meseret Seifu, *User's Guide for the MWCOG/NCRTPB Travel Forecasting Model, Version 2.3, Build 57: Volume 1 of 2: Main Report and Appendix A (Flowcharts)* (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, October 17, 2014), 191.

MAXNTLEGS. Specifically, the keyword was specified as "MAXNTLEGS=10" in the "NT_KNR_LEGS.S" script and "MAXNTLEGS=10*10" in the "NT_PNR_LEGS.S" script.

The consultant team discovered problems associated with PT's generation of non-transit legs associated with PNR lots. An examination of the output skim matrix files revealed the PNR connection walk times and PNR parking costs (matrices #15 and #16) were uniformly zero. While the PNR lot connection impedance values (i.e., composite time comprising the walk connect time and parking cost) are coded on the PNR lot-to-station connection links (mode 15 links), the PT-process does not read the impedance and parking cost data associated with the PNR lot connection links.

The problem reflects how PT path-building process operates. Unlike the TRNBUILD-based process, which allows for path-building to occur over a sequence of non-transit links between zones and stations, the PT path-building process requires all such links between the zone centroid to the access station to be combined into a single non-transit "leg." A non-transit leg is a virtual link that represents a direct connection to the zone centroid and the access station (it is made up of one or more links from the underlying transit network). The PT process requires that all such non-transit "legs" be generated.

Figure 1 depicts the PNR access coding of Metrorail stations in the transit network and the generated non-transit legs. As shown in the transit network, the movement from a zone centroid to an access Metrorail station travel through following links:

- A zone centroid connector link coded as a road network link;

- A series of road segments coded as road network links;

- A PNR driveway link coded as mode 11 link;

- A PNR to station walk access link coded as mode 15 link.

As shown in Figure 1, in the PT model, the non-transit leg generation process creates a virtual PNR access zone-to-station leg coded as mode 19 for a single zone-to-station connection. The impedance of the mode 19 leg is intended to reflect the sum of the impedances of all traversed links of the access path. It was determined that the impedances found on mode 19 legs generated by the existing PT scripting did not generate the PNR-to-station times and parking costs associated with mode 15 links.

Figure 1   Coding of PNR Access Links of Metrorail Stations
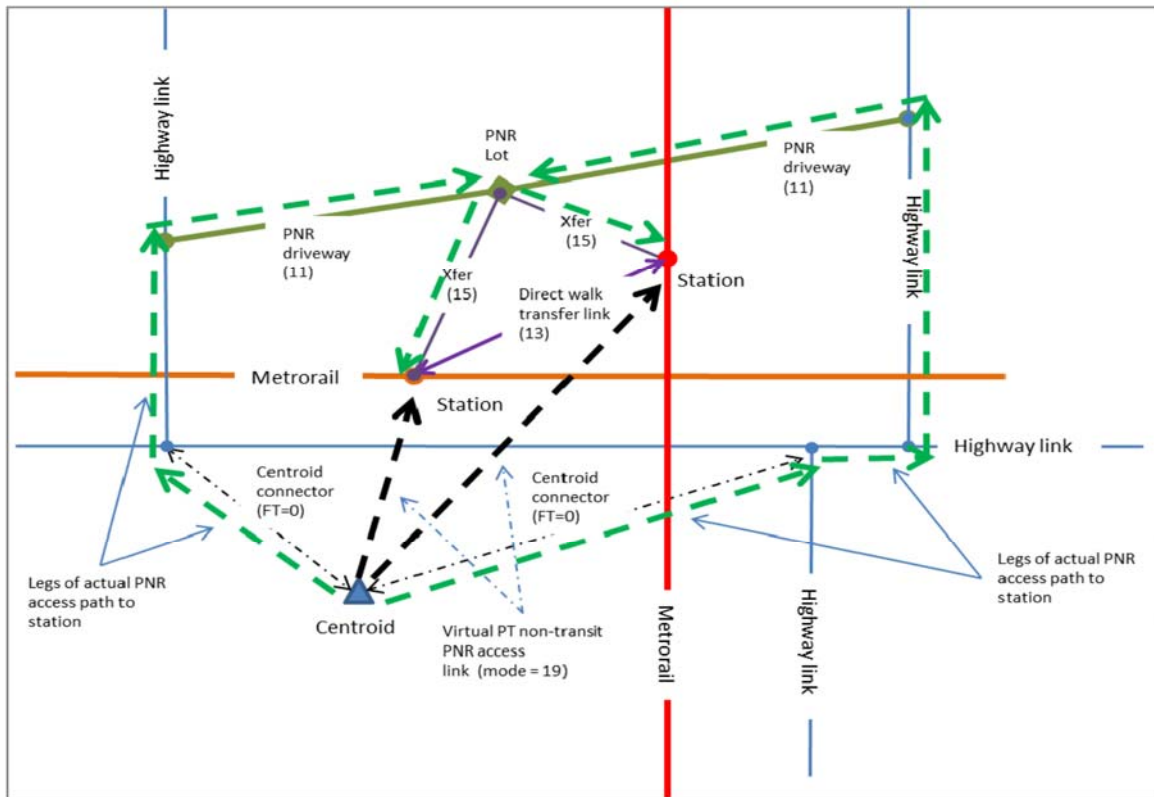
Source: AECOM. FY 2014 Final Report, COG Contract 12-006: Assistance with Development and Application of the National Capital Region Transportation Planning Board Travel Demand Model. August 18, 2014, Fig. 6-17.

In addition, the existing TRNBUILD skimming process develops PNR-to-station impedances as a composite time that includes walking time and an additional time increment that accounts for parking costs and capacities. Again, the existing PT skimming did not account for this impedance provision. Consequently, a "post-skimming" script was created to address these issues. The script ("PT_SKIM_UPDATE_AM_BM_PNR.S") basically updates the initial skim matrix file and writes out the skim file in the same format as that generated by the existing TRNBUILD process. The script undertakes following tasks:

1. Performs another skimming process to output the access and egress rail station node numbers of individual O/D pairs and put the data into two additional matrices (matrices #19 and #20) of the skim file.

2. Retrieves the PNR lot-station composite impedance and PNR parking cost data from a lookup table based on the access station node of individual O/D pairs.

3. Calculates the PNR-station walk access time and PNR parking cost for individual O/D pairs and writes the data in matrices #13 and #14 of the skim file.

The "post-skimming" script generates a revised skim matrix file with the same format as the existing TRNBUILD model. The script also creates revised skim files for KNR and Walk access

conditions. The updated KNR- and Walk-access files include initial skim information as well as two additional matrices reflecting access and egress rail station numbers.

These modifications resulted in PT-based transit skim matrices that were more compatible with those generated from the existing TRNBUILD-based procedures. Further revisions of the script files and parameter values of the PT process were made with other analyses that are discussed below.

Appendix A presents a flowchart and technical details of the updated PT-skimming process. The boxes highlighted with a grey background in the flowchart denote revised and newly developed scripts. The following are the new scripts that are added to the original skimming process:

- "RAIL_STATION_G.S": to generate a PNR station look up table to store PNR connection walk time and PNR parking cost;

- "PT_SKIM_UPDATE_???_G.S": to update the skim matrix file for various access modes as discussed above.

2.2. Examination of PT-Generated Paths

The PT skimming process and the generated PT paths were examined for reasonability. A number of O/D pairs were selected and their associated paths and impedance values were assessed. The examination performed in two steps. First, the paths of the selected O/D pairs were traced using Cube-based on-screen viewing. This on-screen transit trace function allows one to visually examine selected paths but path impedances are not displayed (as shown in Figure 2). The second step of examination was a review of a detailed path-tracing listings for selected O/D pairs. Figure 3 lists one such example listing. The detailed impedance information of the transit path allows to verify the values of the generated skim matrices. The examination focused on the following path components for each selected path:

- Access stations;

- Access times;

- Rail in-vehicle time (IVT);

- Number of transfers;

- Transfer penalties; and

- Total actual travel times and perceived times.

Figure 2   On-Screen Transit Path Trace of Select O/D Pair
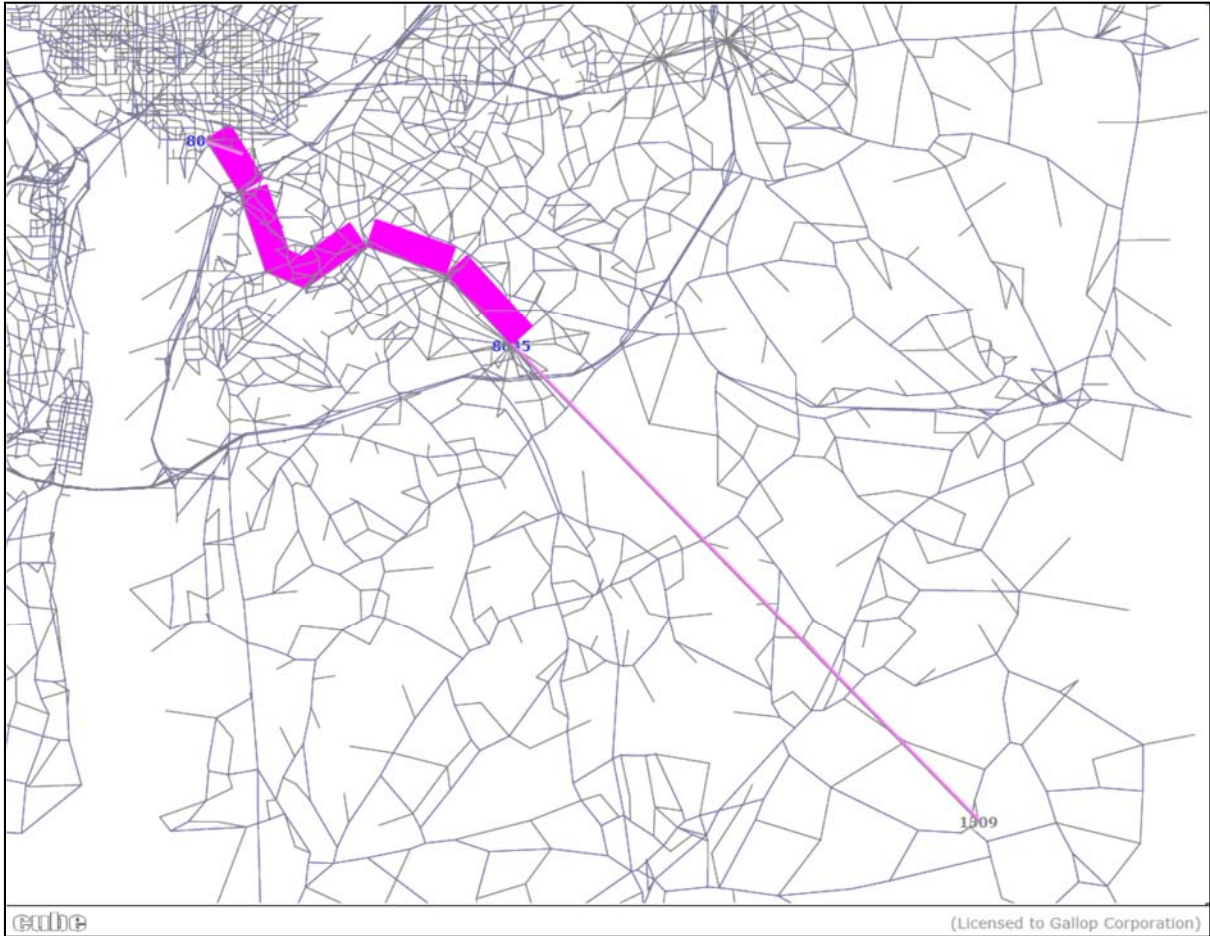
Figure 3   List of Transit Path Trace Information

```
REval Route(s) from Origin 1309 to Destination 364

N:  1309 Mode  WaitA  TimeA Actual B/XPen Percvd   Dist  Total  Lines(weight)
->  8045   11     -   28.06  28.06     -   42.09  14.03  14.03
->  8039    3   3.00  16.28  47.34   2.00  67.87   7.91  21.94  WMGRNA-(1.000)
->   364   20     -   14.60  61.94     -   97.07   0.73  22.67
Mode  TimeA   Dist IWaitA XWaitA
   3  16.28   7.91   3.00   0.00
  11  28.06  14.03
  20  14.60   0.73
```

The transit path examination revealed two main issues. First, unreasonably long zone-to-PNR linkages were observed to stations with no PNR parking costs (e.g., the Reston Town Center and the Stadium Armory stations). Given that PNR costs at other stations are $4.00 or more for the peak period (implying 12 to 15 minutes of added out-of-vehicle time) it was clear that these unreasonably long PNR connections would be eliminated by imposing defaults parking costs at all stations where zero costs existed. Default values were defined as $4.00 for the peak period and $1.00 for the off peak period.

The second issue was related to the net boarding/transfer penalties for Metrorail-Metrorail transfers, which were found to be negative. The net transfer/boarding penalty values should logically be positive. The problem was associated with the boarding and transfer penalty settings in the existing PT scripting. The boarding and transfer penalties were initially specified in the transit factor file ("AM_TRN.FAC") as follows:

```
        BRDPEN= 2*5.0, 3*2.0, 5*5.0
        XFERPEN=3.0,  from=1-10, to=1-2, 6-9
        XFERPEN=-2.0, from=3, to=3
        XFERFACTOR=2.5, from=1-10, to=1-10
```

This above setting implies that a penalty of 2.0 minutes is applied to boarding a Metrorail train. Also a penalty of -2.0 minutes is applied to a Metrorail-Metrorail transfer, with the intention of cancelling out the boarding penalty. However, the transfer-penalty is weighted by 2.5, while the boarding penalty is not weighted. It should be noted that the transfer weight factor ("XFERFACTOR") is applied only to transfer penalty ("XFERPEN"), not to boarding penalty ("BRDPEN"). As a result, the net perceived penalty of a Metrorail-Metrorail transfer is negative (i.e., 2 + 2.5*(-2) = -3.0). To address this problem, the XFERPEN value for Metrorail-Metrorail transfer was revised to -0.99 minutes. The revised setting basically cancels out the net penalty of Metrorail-Metrorail transfer, and also allows for keeping track of the total numbers of Metrorail-Metrorail transfers for a transit path (by retrieving the second decimal point value of the net penalty value, which is stored in matrix #11 in the skim matrix file). The modified transit factor file is shown below:

```
;Boarding and Transfer Penalties
 BRDPEN= 2*5.0, 3*2.50, 5*5.0    ; Changed boarding penalties for rail modes,
Gallop

 XFERPEN=3.0,  from=1-10, to=1-2, 6-9      ;gallop
 XFERPEN=1.0,  from=1-2, 6-9, to=3-5       ;gallop

 XFERPEN=-.99, from=3, to=3    ; revised rail internal transfer penalties to
                               ; to check the number of internal transfers,
Gallop
```

3. Processing of Survey Metrorail Trip Data

3.1. Processing of Survey Trip Records

The consultant team was provided with the processed 2012 Metrorail Passenger Survey file ("Met_svy12.dbf"). The survey data was processed in a trip record format. The details of the

processing and contents of the dataset are documented in a technical memorandum prepared by Hamid O. Humeida[5] of MWCOG. The dataset contains basic travel information of surveyed rail trips, including boarding/alighting stations, modes use for access/egress, home address, trip purpose, and time period. The file was geocoded to the 3,722-TAZ area system. In addition, the dataset included "production" and "attraction" information for each trip record.

It should be noted that the survey did not include complete zonal origin and destination information. Trip geography was constrained to the home location, boarding and alighting stations only. For the purpose of analyzing access characteristics of Metrorail trips for this study, only the home-based trip records were considered in the analysis. These home-based trip records provide information to examine the access travel characteristics (such as access time, access mode use) from home locations to access stations. For the non-home (attraction) ends of the survey trips, it is assumed that destinations are the attraction end stations.

In this study, the home-based trip records were selected from the survey dataset and were processed into a home-based trip record table in "production-attraction" format. The trip record table can be used to examine the frequency distributions of various trip attributes such as access time, station access volumes, and transfer ratios. The major attribute data fields of the trip record included:

- Home zone
- Production end station number
- Production end station zone
- Attraction end station number
- Attraction end station zone
- Access mode used to the production end station
- Transferring station
- Time period
- Trip record expansion factor

3.2. **Processing of Survey Trip Characteristics Data**

The processed Metrorail trip record data was used to analyze the following three travel characteristics:

- Station Boarding Volumes
- Frequency distributions of access time
- Metrorail System Internal Transfers

The station boarding volumes were summarized directly from the survey trip records. These station volume data were used to validate the PT model estimated transit volume results. For

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[5] Hamid O. Humeida, "Processing/Documentation of the 2012 Metrorail Passenger Survey", March 7, 2014.

model validation purpose the station volumes are summarized at station group level, using the station group definition in the MWCOG travel demand model.

To generate the frequency distribution data of access time of Metrorail trips, access time information was attached to the survey trip records. The access time data were derived from the PT-model transit network. A special PT-model procedure was performed to generate access links of all possible zone-to-station connections for the various access modes (direct walk access, PNR access and KNR access). The distance and travel times of these access links were then attached to the trip records, based on the reported home zone number, access station number and access mode.

For bus access Metrorail trips, bus access time data were derived differently. In the PT model, bus is considered as a transit mode, not an access mode. Thus no direct access links are generated for bus access movements. Thus bus access time was determined on the basis of skim data. To determine the zone to station bus access time, a special bus-only skim process was perform to generate a zone-to-zone bus travel time skim matrix. The zone-to-zone bus time data were attached to the bus access Metrorail trip records based on the home zone number and access station zone number.

With the attached access time data, the frequency distributions of access time could then be summarized. These frequency distribution curves were used not only to validate the model estimated access times, but also to set some of the PT model parameters, such as the maximum cost/time of access links for various access modes.

The Metrorail system internal transfers were summarized from the Metrorail trip record data. The system internal transfer data was used to adjust the transfer penalty parameters in the PT skimming process.

The procedure of analyzing the survey trips was implemented in a series of Cube scripts and dbase programs. Appendix B presents program flowcharts and technical details of the survey trip analysis process.

4. Processing of PT-Model Data

4.1. Development of Survey Rail Passenger Trip O/D Tables

Using the processed trip record data file, a number of Metrorail trip tables were generated. These trip tables were used to test the PT model. For example, the trip tables were assigned to the transit network to examine the model estimated transit volumes on the transit network. In this study, the following two sets of trip tables were derived from the survey trip record data file:

1. **Home zone to destination station zone trip tables by access mode and by time period:** These trip tables were used to analyze the access characteristics of the rail trips, such as the frequency distributions of access time of various access modes.

2. **Production station zone to destination station zone trip tables by time period:** These trip tables were generated for the analysis of the model estimated travel characteristics on-board Metrorail vehicles, such as frequency distribution of Metrorail in-vehicle travel time, Metrorail system internal transfers, etc.

As mentioned earlier, only the home-based trip tables in "production-attraction" format were derived for the analysis.

4.2. Analysis of PT Model Assignment Results

To analyze the PT-model trip data, a special transit assignment procedure was performed using the "home-zone to destination station zone" rail trip tables derived from the survey data. The assignment procedure was performed for three types of access mode separately: walk/bus access, PNR access and KNR access. The assignment procedure generates a set of "loaded" link data files, which contain the loaded transit volumes and associate link data (e.g., distance, travel time, etc.) for all transit links and non-transit links of the transit network. These link data files serve as the primary datasets for analyzing the PT model results.

Similar to the analysis of survey trip data, the analysis of PT model data focuses on following three types of travel characteristics:

- Station Boarding Volumes
- Frequency distributions of access time
- Metrorail System Internal Transfers

For comparison purpose, the PT model generated travel characteristics data were organized in the same format as the survey trip data discussed in Section 3.2. The station boarding volumes are summarized directly from the loaded link data files by extracting the volume data of access links (walk access, bus access, PNR access and KNR access) associated to the Metrorail stations.

The data of the frequency distribution of access time were also developed from the loaded link files. For direct walk access, PNR access and KNR access modes, their frequency distribution data were summarized using the access link data associated to these three access modes. For bus transfer access, the process of generating the access time data is different, since bus mode is not considered as access modes in the PT model and no direct zone-station bus access links are generated in the PT model, as described earlier. Instead, bus access time frequency distribution data were generated using the bus access Metrorail trip table and walk-to-bus/rail transit skim matrix file. A special Cube-Matrix procedure was performed to derive the trip length frequency of the bus access trips against bus In-vehicle time. It should be noted the in a home-zone to destination station zone interchange, no bus transfer is required for the destination end. If the skim matrix file indicates that both the bus IVT and rail IVT values are positive for a home zone to destination station zone interchange, the bus IVT value would represent the bus access time for the interchange.

The Metrorail system internal transfer data were generated using the Metrorail trip table files and transit skim matrix files. The values of the 2nd decimal point of the matrix #11 in the skim files represent the number of rail internal transfers of the transit paths between individual home zone to destination station zone interchanges. A Cube-Matrix procedure was performed to summarize the number of bus access trips with 0, 1 and 2+ transfers. The procedure was performed separately for different access types: i.e., walk/bus access, PNR access and KNR access.

Processing of the PT model trip data was implemented in a series of Cube scripts and dbase programs. Appendix C presents the program flowcharts and technical details of the analysis process. The results of the PT-model trip characteristic data will be presented in Chapter 5.

5. Evaluation of PT-Process Data and Results

5.1. Comparison of PT-Model Trip Data with Survey Trip Data

Station Access Connections

For the transit skimming and assignment procedures, the PT-model generated large numbers of access links between origin/destination zones to access/egress stations, for various access/egress modes. The model generated access links greatly affect the model estimated results regarding the transit paths and transit volume assignments on the transit network. Thus, the model generated access links were examined against observed access connections derived from the survey trip data. Figures 4 to 6 illustrate the observed and model generated access links for various access modes.

Figures 4-a and 4-b demonstrate walk access connections for the survey trips and PT-model trips respectively. The figures reveal that, in general, the model generated walk access links were consistent with those of survey trips. In suburban areas, the figures indicate that some of survey walk access links are not generated by the PT-model. This is due to a number of reasons. First, the traffic zones in the outskirt area are usually large and only small part of traffic zones are walk accessible to rail stations. The PT-Model does not build walk access links from those zones. Second, the home locations of the survey trips records were not precisely geocoded due to missing address information. The home zone numbers of some trip records were "estimated" based on partial home address information. This may result in miscoding the home locations of the trip records to neighboring traffic zones, not the actual home zones of the passengers being surveyed.

Figures 5-a and 5-b show the PNR access connections of survey trips and PT-model trips respectively. Figure 5-a reveals some long distance drive access connections reported in the survey. These movements may be made for some special reasons, for example for conducting other activities before or after making rail trips. These long distance connections should not be considered in the PT-model. Figure 5-b illustrates the PNR connections of the PT-model trips. The model generated PNR access connections looks very reasonable and in general compatible with the connections of the survey trips.

For the KNR trips, Figures 6-a and 6-b reveal similar connection patterns as those for the PNR trips. The model generates fewer long distance connections than those reported in the survey. Like the PNR trips, the survey trips reveal some very long distance KNR connections, probably due to some special activities associated with the survey rail trips. In summary, Figures 4-6 reveals that access links generated from the PT model are reasonable and comparable with those of the survey trips.

Figure 4   Walk Access Connections of Survey Trips and PT-Model Trips
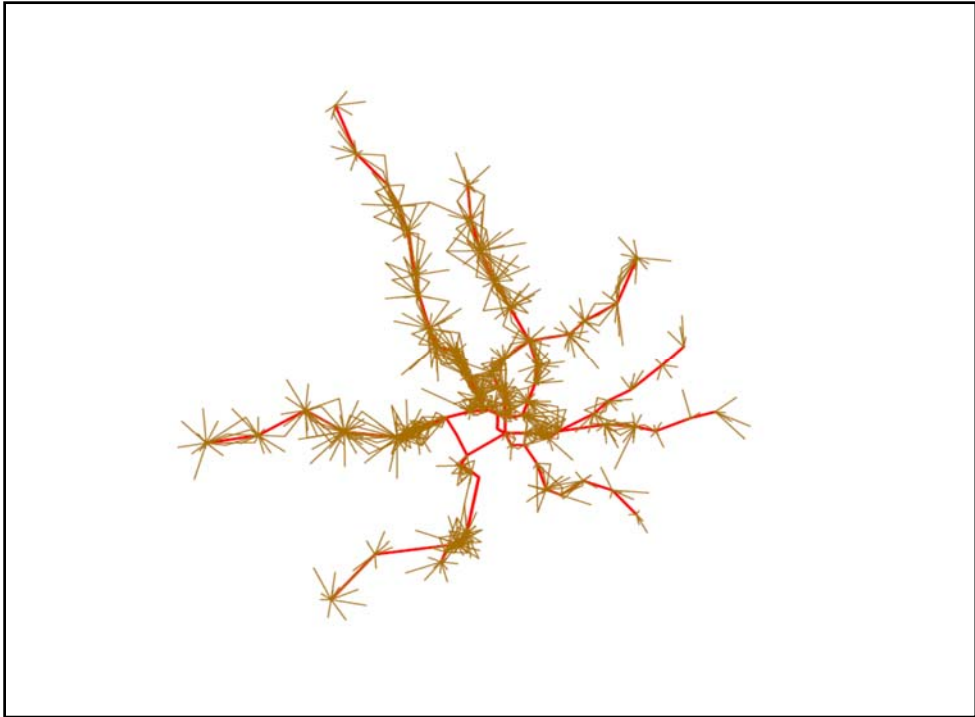
a) Survey Trips
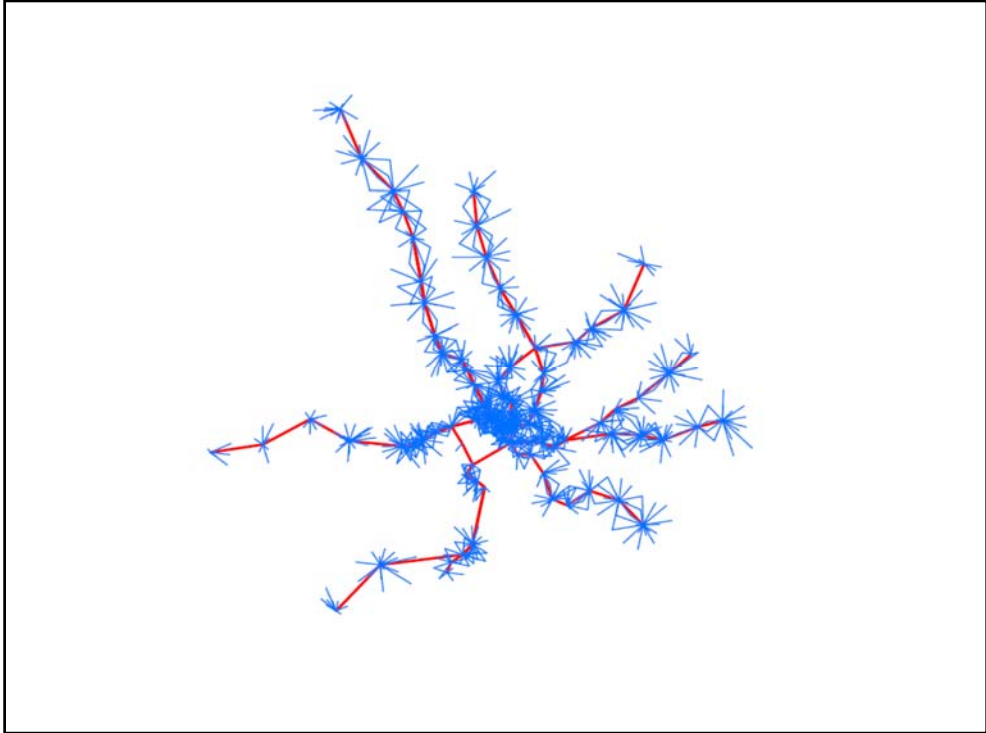
b) PT-Model Trips

Figure 5   PNR Access Connections of Survey Trips and PT-Model Trips
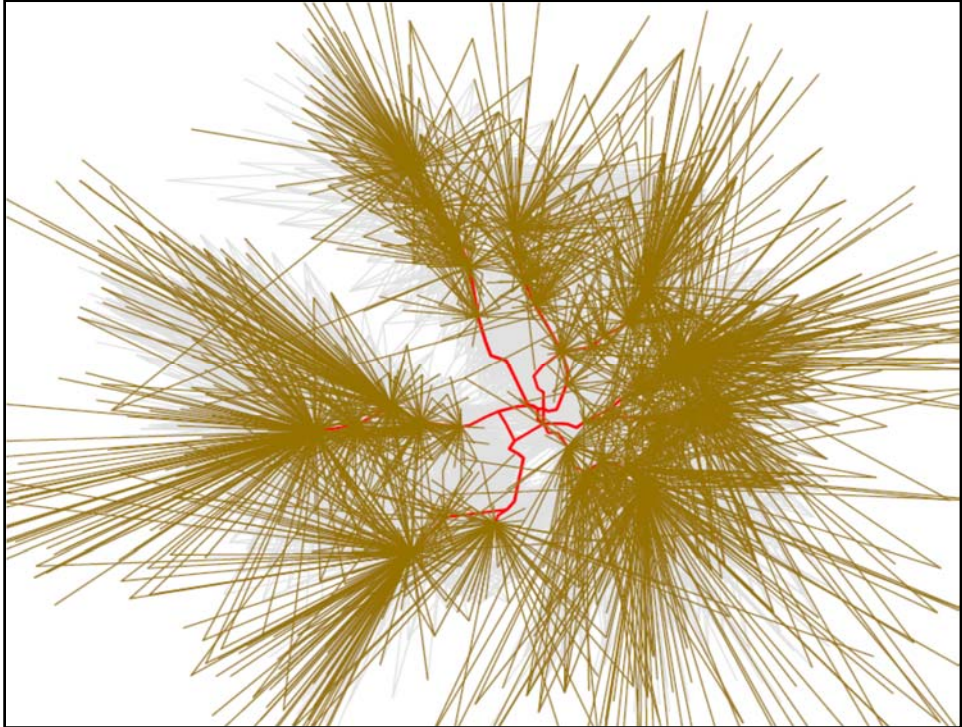
a) Survey Trips
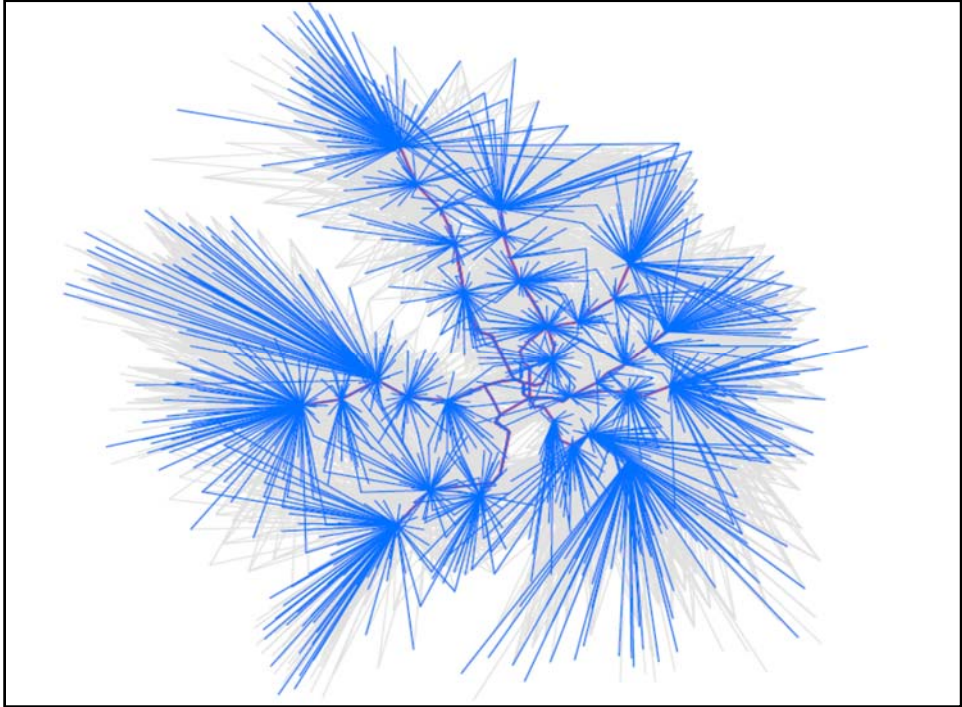
b) PT-Model Trips

Figure 6   KNR Access Connections of Survey Trips and PT-Model Trips

a) Survey Trips
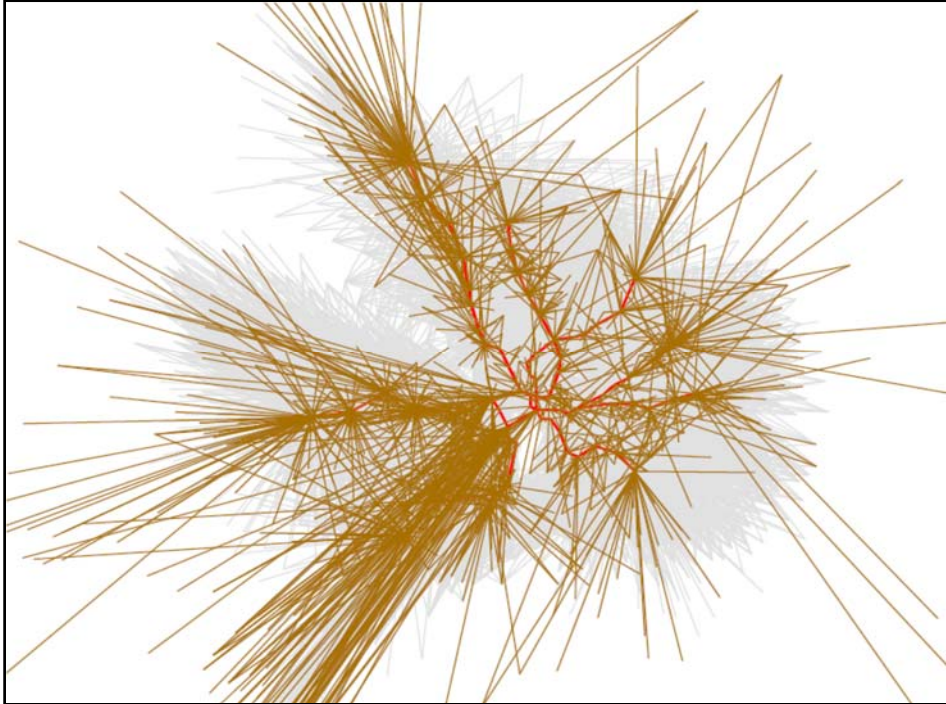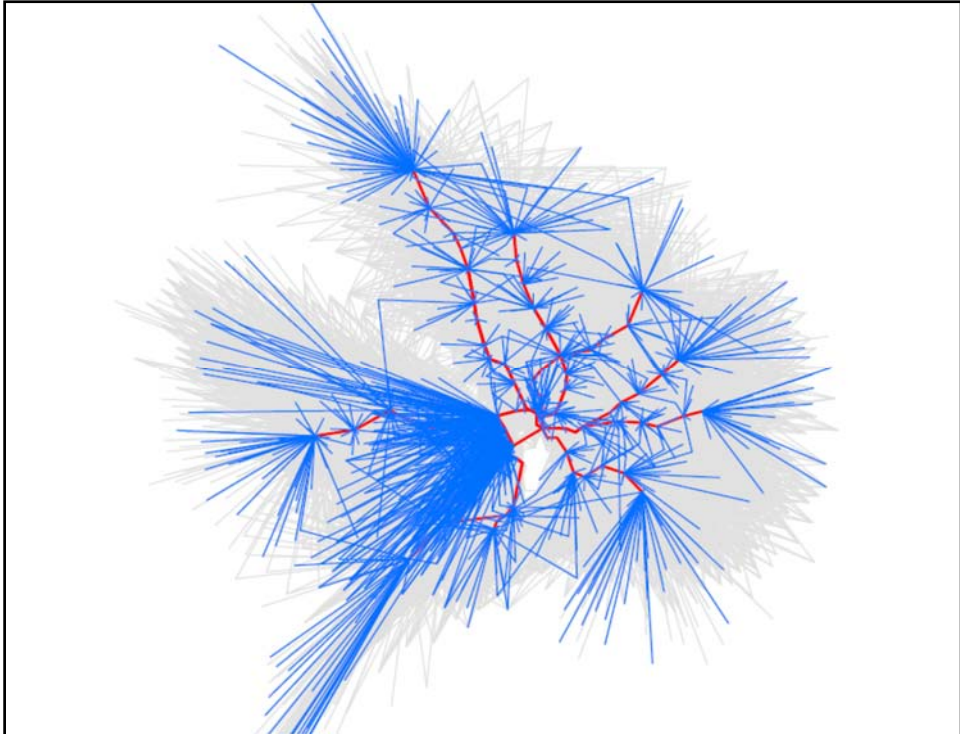
b) PT-Model Trips

Station Boarding Volumes

Table 1 summarizes the survey reported and PT model estimated Metrorail boardings of various access modes by station group. The table indicates that the total number of model trips is about 13% lower than that of survey trips (314,843 vs 361,849). This implies that about 13 percent of the survey trips cannot be assigned to the transit network for no transit paths are being generated from the PT model. Some of the surveyed rail trips cannot be assigned to the transit network because the access distances of these trips are longer than the maximum allowable access distances as specified in the PT-model for the reported access modes. The excessively long access distances as reported in the survey could be due to a number of reasons, such as coding errors; picking up people on the way to rail stations; accessing to the terminus stations; etc. The number of unassignable survey trips can be reduced by appropriately increasing the maximum allowable access distance as specified in the PT-model, in particular for the PNR and KNR access trips to the end-of-line rail stations.

Among various access modes, the highest percent difference is with the walk access mode (-18.6%). This is partly due to the geocoding issue of home zone location as mentioned earlier. The geocoding issue affects walk access trips the most as a small coding error (e.g., geocoding to a neighboring zone instead of actual home zone of the passenger being surveyed) would result in the walk access distance exceeding the maximum allowable walk access distance as specified in PT- skimming process.

Table 1 also reveals that the model underestimates total PNR and KNR access boardings substantially. This is due to some reported rail trips with very long drive access distance for some special reasons, as shown in Figure 2-a and Figure 3-a. These long distance drive access connections cannot be generated by the PT-model. Although the table indicates major estimation differences for some station group segments, the model in general performs quite reasonably for most of the travel segments, in particular, for those segments with large numbers of reported Metrorail trips.

Combining all access modes, the percent differences for most of station groups are within 20%, given the fact that about 13% of the survey rail trips cannot be assigned to the transit network. If the number of those unassignable trips is reduced, for example, by refining some of the PT model parameters as mentioned above, the percent differences for most station groups would be much lower, probably within 10%.

For individual access modes, Table 1 indicates that large percent differences occur for some station groups, in particular for KNR access trips. Given the small numbers of KNR access trips and survey records, it is not expected that the model estimated results match with observed data well. For PNR access trips, the percent differences are basically within 15% for station groups in suburban areas with large numbers of PNR access trips.

Table 1 also indicates that large percent differences occur for walk and bus access trips for some station groups. This is primarily due to the degree of reliability of model estimated bus skim data (i.e., in-vehicle time, wait time, walk access time, etc) in the transit network. In the transit assignment process, walk access and bus access trips are grouped together and assigned to the bus/rail transit network. Thus the reliability of estimated bus skim data would affect walk and bus access volumes greatly. For a regional model, it is not expected that the coded bus routes in the

model can accurately reflect the actual operation conditions, in terms of route alignments, bus stop locations, and coded run times.

The results shown in Table 1 reveal that the PT-model can be further improved, for example, by fine-tuning some model parameters and enhancing the process for generating the access legs. These improvements should aim to reduce the numbers of unassigned trips and increase of reliability of model results for various types of access modes.

Table 1   Comparison of Observed and PT-Model Estimated Access Volumes by Station Group

Station Group	Observed Volumes					Estimated Volumes					Percent Difference				
	Walk	Bus	PNR	KNR	All	Walk	Bus	PNR	KNR	All	Walk	Bus	PNR	KNR	All
Red Line - 'A' route MD outside Beltway	7,482	6,043	13,412	3,237	30,175	8,362	4,323	11,530	2,954	27,168	11.8%	-28.5%	-14.0%	-8.8%	-10.0%
Red Line - 'A' route MD inside Beltway	6,916	2,646	1,600	1,096	12,258	7,413	1,976	1,598	798	11,784	7.2%	-25.3%	-0.1%	-27.3%	-3.9%
Red Line - 'A' route DC non-core	14,732	1,637	795	581	17,745	13,598	3,842	0	702	18,142	-7.7%	134.7%	n/a	20.8%	2.2%
Red Line - DC core	13,788	3,805	1,341	852	19,785	9,411	7,767	0	520	17,698	-31.7%	104.1%	n/a	-39.0%	-10.6%
Red Line - 'B' route DC non-core	7,979	8,051	2,607	1,403	20,039	6,602	6,527	2,640	1,546	17,314	-17.3%	-18.9%	1.2%	10.2%	-13.6%
Red Line - 'B' route MD	9,821	4,432	7,481	2,226	23,960	9,185	4,554	9,817	2,549	26,104	-6.5%	2.8%	31.2%	14.5%	8.9%
Green Line - 'E' route MD	3,758	2,762	8,105	1,726	16,351	3,406	2,715	5,283	1,402	12,805	-9.4%	-1.7%	-34.8%	-18.8%	-21.7%
Green Line - 'E' route DC non-core	13,869	1,444	243	219	15,774	6,147	867	0	8	7,022	-55.7%	-40.0%	n/a	-96.3%	-55.5%
Green Line - DC core	5,161	1,515	366	382	7,425	5,066	831	0	194	6,091	-1.8%	-45.2%	n/a	-49.3%	-18.0%
Green Line - 'F' route DC non-core	5,444	3,986	1,048	480	10,957	3,614	2,043	1,576	938	8,171	-33.6%	-48.8%	50.5%	95.4%	-25.4%
Green Line - 'F' route MD	1,996	6,520	10,900	2,139	21,556	4,506	3,109	9,774	1,930	19,318	125.7%	-52.3%	-10.3%	-9.8%	-10.4%
Blue/Yellow Line - VA Fairfax	3,346	3,517	11,829	3,962	22,654	2,755	3,841	11,624	2,111	20,332	-17.6%	9.2%	-1.7%	-46.7%	-10.2%
Blue/Yellow Line - VA Alexandria	6,381	1,883	459	1,352	10,075	5,500	2,068	0	576	8,144	-13.8%	9.8%	n/a	-57.4%	-19.2%
Blue/Yellow Line - VA Core	9,413	9,411	1,663	3,392	23,879	7,086	8,265	0	3,563	18,914	-24.7%	-12.2%	n/a	5.0%	-20.8%
Orange Line - VA Fairfax	3,970	10,153	13,099	2,463	29,686	2,879	8,709	12,263	1,513	25,364	-27.5%	-14.2%	-6.4%	-38.6%	-14.6%
Orange Line - VA Arlington non-core	16,486	2,270	2,540	1,733	23,029	13,883	3,121	3,106	246	20,357	-15.8%	37.5%	22.3%	-85.8%	-11.6%
Orange/Blue Line - VA/DC core	10,614	4,029	802	1,263	16,708	6,434	6,722	0	4,584	17,741	-39.4%	66.8%	n/a	263.0%	6.2%
Orange/Blue Line - DC non-core	7,365	1,476	540	242	9,623	3,562	540	599	169	4,871	-51.6%	-63.4%	10.8%	-30.3%	-49.4%
Orange Line - DC/MD	1,614	3,283	8,325	1,806	15,028	2,127	2,439	5,177	1,750	11,493	31.8%	-25.7%	-37.8%	-3.1%	-23.5%
Blue Line - DC/MD	3,186	2,955	7,239	1,762	15,142	3,267	2,749	7,993	1,640	15,650	2.6%	-7.0%	10.4%	-6.9%	3.4%
Total	153,318	81,818	94,395	32,318	361,849	124,804	77,007	82,980	29,692	314,483	-18.6%	-5.9%	-12.1%	-8.1%	-13.1%

Metrorail System Internal Transfer Ratio

Table 2 compares the percent of Metrorail trips making 0, 1 and 2+ internal transfers between the survey trips and model trips, by access mode. The table reveals that the PT model estimates the transfer ratios reasonably well. The estimated percent trips with transfer are slightly higher than the percent of survey trips.

Table 2   Percent of Rail Trips by Numbers of Internal Rail Transfers

	Survey Rail Trips					Model Rail Trips			
	Walk	Bus Xfer	PNR	KNR	All	Walk/Bus Xfer	PNR	KNR	All
0-xfer	71.8%	70.8%	70.2%	69.2%	70.9%	67.8%	66.5%	68.1%	67.5%
1-xfer	27.6%	28.8%	29.3%	30.0%	28.6%	31.0%	32.4%	31.1%	31.4%
2+xfer	0.5%	0.3%	0.5%	0.8%	0.5%	1.2%	1.1%	0.8%	1.1%
All	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Frequency Distribution of Access Trips

Figures 7 to 10 illustrates the access time frequency distributions of survey trips and observed trips for various access modes. These figures indicate that the frequency distribution curves of model estimated trips match very well with the curves of survey trips, for all access modes. These distribution figures were used to refine the maximum access distance parameters as specified in the PT model.

Figure 7 Walk Access Time Frequency Distribution Curves
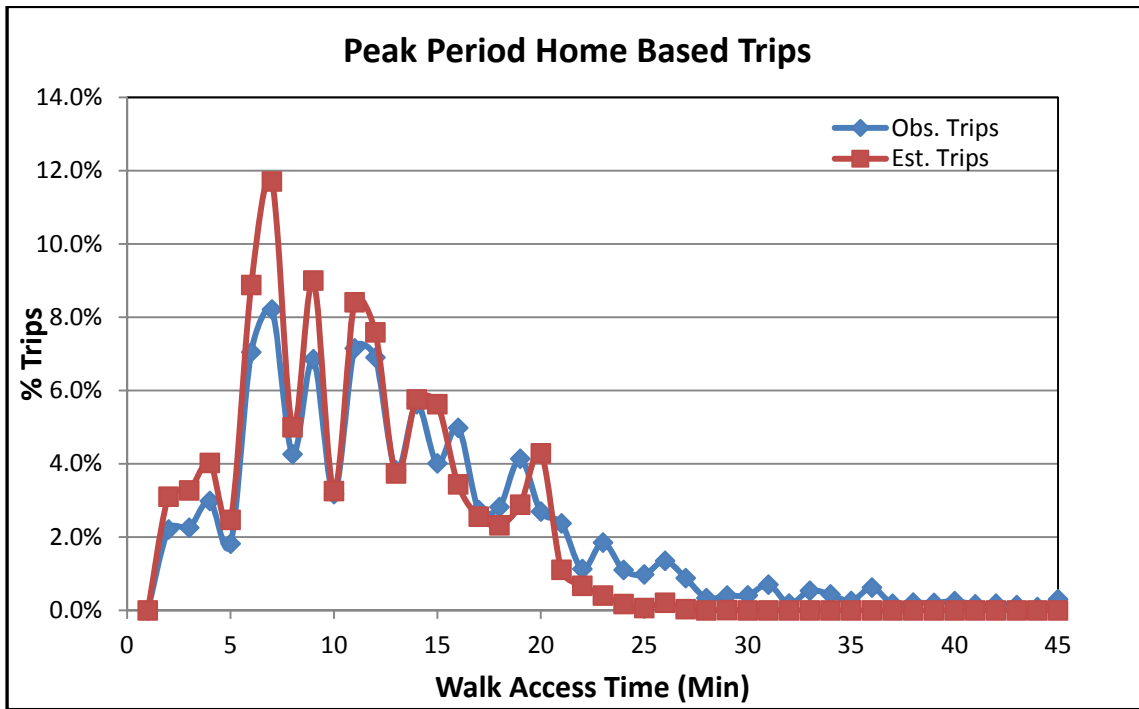
Figure 8 Bus Access Time Frequency Distribution Curves
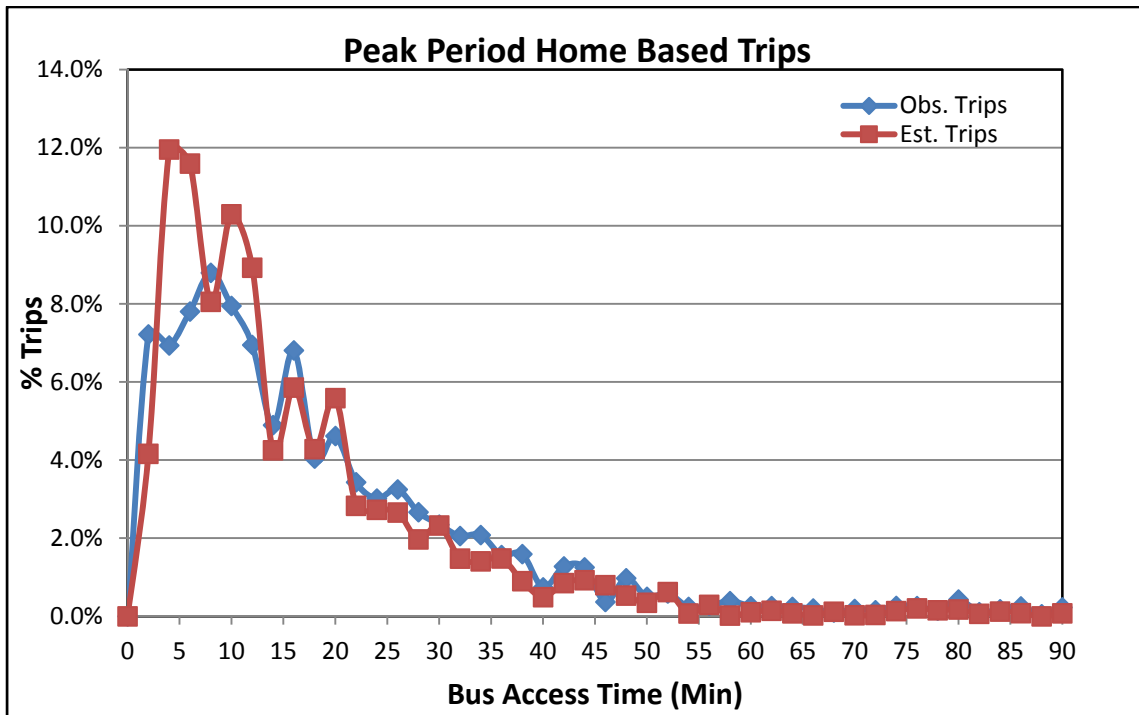
Figure 9   PNR Access Time Frequency Distribution Curves
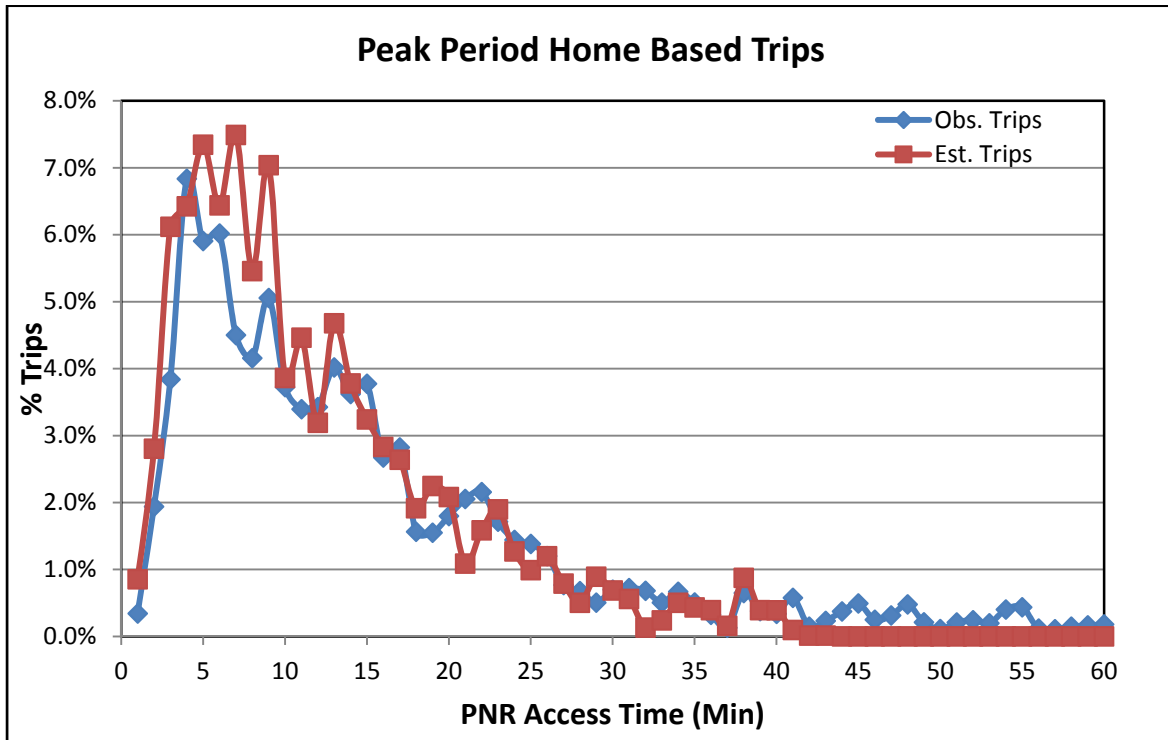
Figure 10   KNR Access Time Frequency Distribution Curves
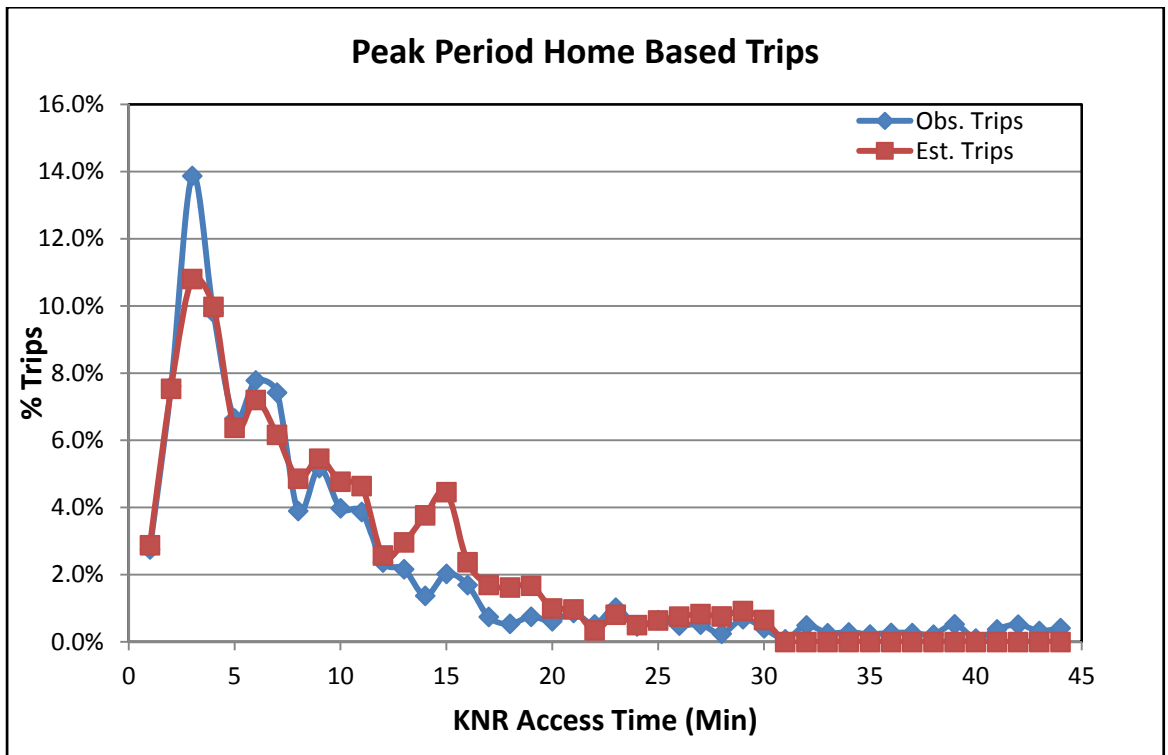
5.2. **Adjustments of PT-Model Parameters**

The model estimated travel characteristics data shown in the figures and tables in the previous section represent the results after several iterations of PT model runs with adjustments made to relevant PT-model parameters. Table 3 summarizes the changes made to parameter values in the PT process.

The maximum costs of access NT legs were adjusted according to the access time distribution curves shown in Figures 7-10. It should be noted that the parameter value of the maximum link cost for PNR access leg is composite time which is the weighted sum of drive access time and parking cost. Thus a parameter value of 60 minutes implies that the maximum actual drive access time is about 40-50 minutes, depending on the parking charge associated to the PNR lot. The values of "slack values" were adjusted with the increase of the parameter values of the maximum costs of access NT legs.

The boarding penalty and transfer penalty were adjusted partly based on the comparison of the access volumes by access modes. Table 3 indicates that a transfer penalty of 1 minute was added for bus to Metrorail transfer. This parameter was introduced because it was found that the model overestimated bus-access boardings in the original parameter settings. With the weighting factor of the transfer penalty being 2.5, the bus-Metrorail transfer incurs a perceived penalty of 2.5 minutes in the skimming process.

As described in Section 2.2, the Metrorail to Metrorail transfer penalty was adjusted from -2.0 to -0.99, considering different weighting factors for boarding penalty and transfer penalty. The original value of Metrorail-to-Metrorail transfer penalty of -2.0 resulted in negative net penalty.

Table 3   Adjustment of PT-Model Parameters

Parameter	Original Value	Adjusted Value	Keyword/PT Model File
Max. Cost (actual min.) for KNR Access NT Leg	15	30	MAXCOST=10*30
			NT_KNR_Legs.S
Max. Cost (composite min.) for PNR Access NT Leg	30	60*	MAXCOST=10*60 * composite time including walk time & PNR parking cost
			NT_PNR_Legs.S
"Slack" value of Walk Access NT Leg to Bus Stops	5	10	SLACK = 10*10
			NT_WLK_Acc_Egr_Legs.S
"Slack" value of Walk Access NT Leg to Rail Stations	5	10	SLACK = 10*10
			NT_WLK_Acc_Egr_Legs.S
Boarding Penalties for rail mode (actual min., with weighting factor of 1.0)	2	2.5	BRDPEN= 2*5.0, 3*2.50, 5*5.0
			AM_TRN.FAC
Xfer Penalty from bus to rail mode (actual min., with weighting factor of 2.5)	0	1	XFERPEN=1, from=1-2, 6-9, to=3-5
			AM_TRN.FAC
Xfer Penalty between Rail Lines (actual min., with weighting factor of 2.5)	-2	-0.99	XFERPEN=-0.99, from=3, to=3
			AM_TRN.FAC

6. Conclusions and Further Work

In this task order, the PT model developed and implemented by AECOM and MWCOG/TPB staff was examined, tested and validated with the Metrorail survey data. The review and test of PT scripts revealed that the PT model is implemented properly and is capable of generating reasonable transit skimming and assignment results. Revisions and refinements of the PT-scripts, primarily related to the PNR access links, were made. Also, PT skimming process was revised to generate skim matrix files in the same format as the existing TRNBUILD model.

The PT model was further validated by comparing the model generated trip data with the observed trips data derived from the 2012 Metrorail Passenger Survey. The validation effort involved processing the survey trip data and the PT model generated trip data to examine the travel characteristics between the survey trips and modeled trips. The validation results revealed that the PT model performs reasonably well, generating travel data that match the survey trip data. Based on the survey trip data and the validation results, some of the PT model parameters were revised.

In summary, the study conducted in this task order demonstrates that the revised PT model performs properly and generates reasonable results. It is thus feasible to move forward to convert the existing TRNBUILD model to the PT model. However, the conversion to PT model requires substantial amount of effort. Therefore, the following further studies are recommended:

First, even though this study demonstrates the robustness of the PT model, there are still several areas of the PT model that needs enhancement to improve the effectiveness and reliability of the model. These include:

- Enhance the PNR access legs generation process, for example, reduce the backtracking of PNR connections and drive connections to end of line stations;

- Improve the reliability of station boarding estimations at the station group level; and

- Include the effect of transit fare in path building process.

Second, the PT model developed so far is limited to the skimming process of bus/rail transit mode. There are several other transit modes considered in the MWCOG Regional Travel Demand Model: bus only, Metrorail only, Light Rail, and Commuter Rail. The conversion process should expand to include these transit modes. This requires collecting travel data for these transit modes, such as the operation and ridership data for the bus mode and commuter rail mode.

Third, the PT script files should be consolidated to be implemented, maintained and integrated efficiently, as part of the existing MWCOG regional model system.

Finally, once the PT model is implemented for the entire transit system, covering different transit modes, a comprehensive validation of the PT model has to be conducted. The comprehensive validation effort involves not only examining the skimming procedure of various transit modes but also applying the actual MWCOG model data to the transit assignment process to validate the model estimated transit volumes against observed ridership data.

Appendix A. PT Model Flowcharts

PT Skimming Process Flowchart

```
┌─────────────────────────┐
│     Rail_Stations_G.s    │
└─────────────────────────┘
            ↓
┌─────────────────────────┐
│    V2.3_PTNet_Build_G.s  │
└─────────────────────────┘
            ↓
┌─────────────────────────┐
│    Combine_Trn_Lines.s   │
└─────────────────────────┘
            ↓
┌─────────────────────────┐
│    NT_Wk_Acc_Egr_Legs.s  │
└─────────────────────────┘
            ↓
┌─────────────────────────┐
│   NT_Wk_Xfer_Legs_Rev.s  │
└─────────────────────────┘
            ↓
┌─────────────────────────┐
│     NT_KNR_Legs_Rev.s    │
└─────────────────────────┘
            ↓
┌─────────────────────────┐
│   NT_PNR_Legs_Rev_G.s    │
└─────────────────────────┘
            ↓
┌─────────────────────────┐
│  Combine_NT_Wk_Legs_Rev.s│
└─────────────────────────┘
            ↓
┌─────────────────────────┐
│   PT_Skims_AM_BM_WK_G.s  │
└─────────────────────────┘
            ↓
┌─────────────────────────┐
│  PT_Skims_AM_BM_KNR_G.s  │
└─────────────────────────┘
            ↓
┌─────────────────────────┐
│  PT_Skims_AM_BM_PNR_G.s  │
└─────────────────────────┘
            ↓
┌─────────────────────────┐
│    PT_Skims_Update_G.s   │
└─────────────────────────┘
```
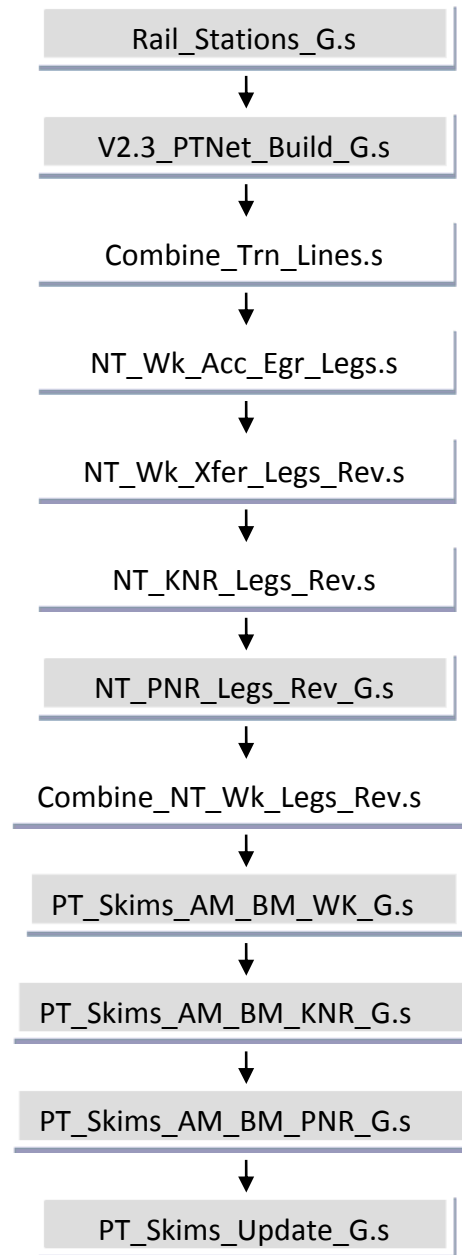
Generate Metro Rail Station Data File

STATION.DBF	→	Rail_Stations_G.s	→	_RAILSTATIONS.TXT
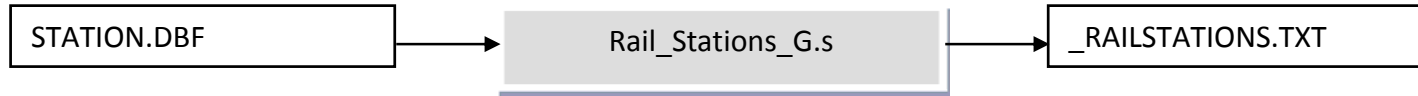
Description:

- The script generates a Metrorail station file storing the PnR lot walk access time and parking cost of Metrorail stations with PnR lots.
- The input file "STATION.DBF" is the basic input file of the standard MWCOG model.
- The script reads in parking capacity and parking cost data from the input file, calculates the PnR walk access time and parking cost for peak and off peak periods, and then outputs the data in text file format.

Update Transit Network

| AM_PT_Net.Net
_RAIL_STATIONS.TXT
RAIL_LINKS.DBF | → | V2.3_PTNet_Build_G.s | → | PT_Net.Net |
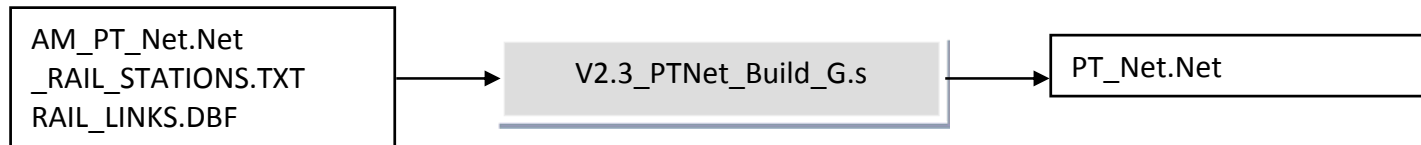
Description:
- Update link impedance/cost attributes for various modes of the transit network.
- Major changes:
    - Revise the link distance and link time data for Metrorail links (mode 3 links) based on data stored in the file "RAIL_LINKS.DBF", which is used in the existing "TRNBUILD" model.
    - Revise the link impedance attribute for PnR connecting links (mode 15) as the composite time consisting of walk time and PnR parking cost - the same calculations as used in the PARKER.S script of the existing TRNBUILD model.
- Major parameters and assumptions
    - Minimum parking cost is set as $2.00 round trip (instead of $1.00 assumed in the existing "TRNBUILD" script).
    - Value of time is set to $10.00/Hr.
    - Walk distance from PnR lot to station is a function on parking capacity.

Generate PnR Non-Transit Legs

```
PT_Net.Net
TSYSD.PTS
AM_TRN.FAC

AM_Bus_Lines.lin
AM_MR_LRT_Lines.lin
Mode4AM.lin
```
→ NT_PNR_Legs_Rev_G.s → PNR.LEG
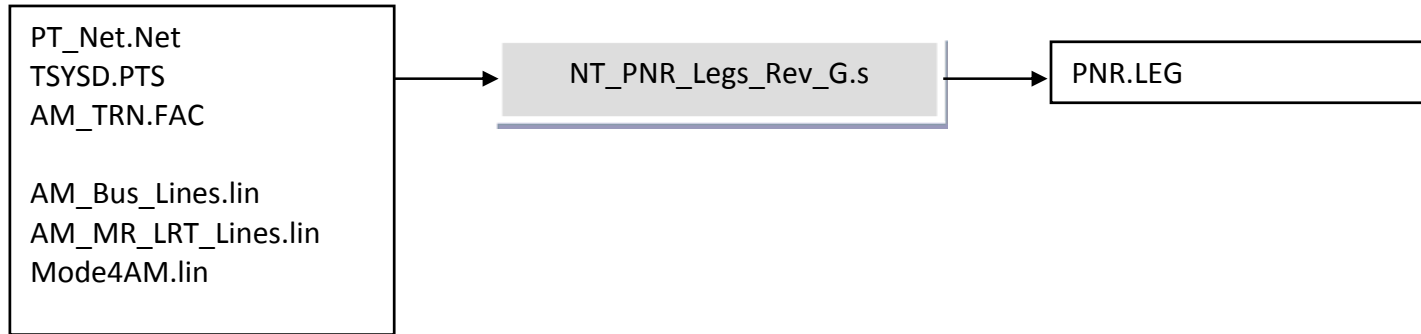
Description:
- Generate the PnR Non-Transit legs (mode 19 direct links) from zone centrals to rail stations.
- The impedance of the PnR NT legs represents the composite cost consisting the follow three elements:
  - Driving distance from zone central to PnR lot;
  - Walk time from PnR to rail station;
  - One-way PnR parking cost.
- Major change of script
  - Increase the maximum impedance of PnR NT legs from 60 minutes (from original 30 minutes), partly to take into account that the impedance include parking cost and PnR connection walk time, in addition to drive time.

Transit Skimming Process

```
┌─────────────────────────┐
│ PT_Net.Net              │
│ TSYSD.PTS               │          ┌──────────────────────┐      ┌────────────────────────┐
│ AM_TRN.FAC              │   ──→    │ PT_Skim_AM_BM_WK_G.s │ ──→  │ AM_BM_WK_SKM.TMP       │
│                         │          └──────────────────────┘      │ AM_BM_WK.NET           │
│ Walk_Acc_Legs.LEG       │                                        │ AM_BM_WK.RTE           │
│ Walk_Egr_Legs.LEG       │                                        └────────────────────────┘
│ Walk_Transfer_Legs.LEG  │          ┌──────────────────────┐      ┌────────────────────────┐
│ KNR.LEG*                │   ──→    │ PT_Skim_AM_BM_PNR_G.s│ ──→  │ AM_BM_PNR_SKM.TMP      │
│ PNR.LEG**               │          └──────────────────────┘      │ AM_BM_PNR.NET          │
│                         │                                        │ AM_BM_PNR.RTE          │
│ AM_Bus_Lines.lin        │                                        └────────────────────────┘
│ AM_MR_LRT_Lines.lin     │          ┌──────────────────────┐      ┌────────────────────────┐
│                         │   ──→    │ PT_Skim_AM_BM_KNR_G.s│ ──→  │ AM_BM_KNR_SKM.TMP      │
│ Filter_Trip_Mat.TRP***  │          └──────────────────────┘      │ AM_BM_KNR.NET          │
│                         │                                        │ AM_BM_KNR.RTE          │
└─────────────────────────┘                                        └────────────────────────┘
```
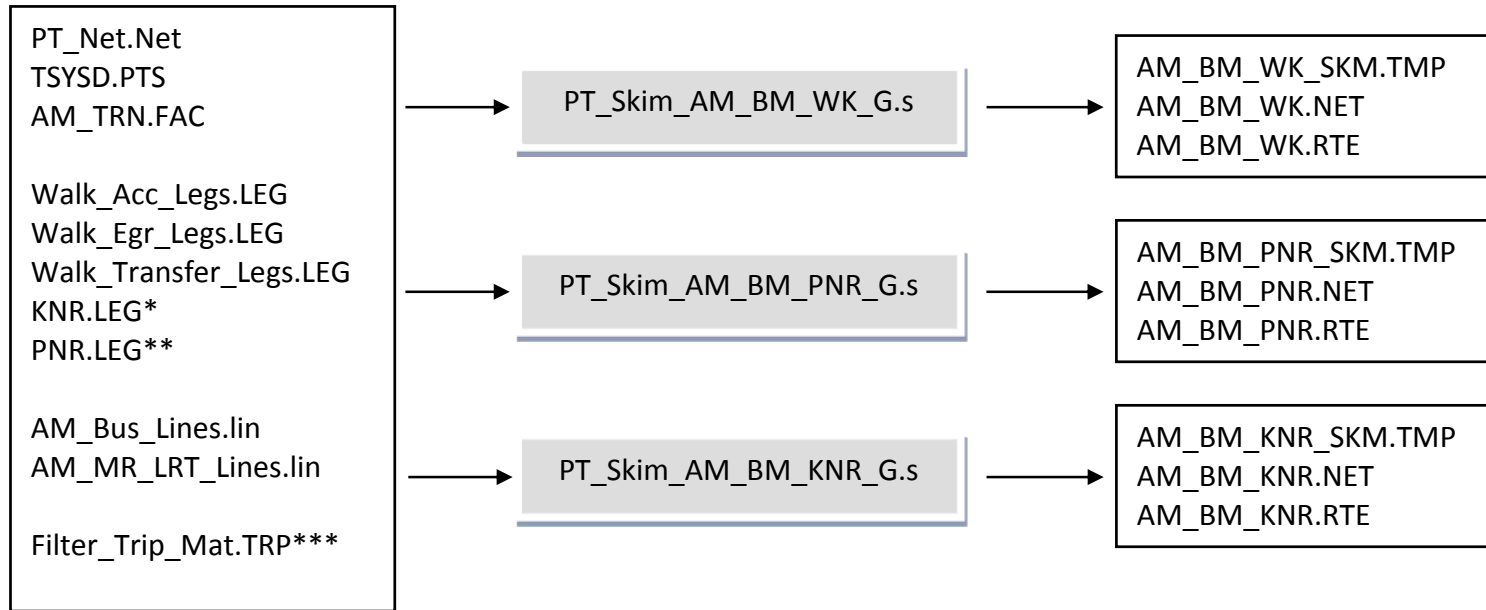
* For KNR access skim process only
** For PNR access skim process only
*** Derived from person trip tables

Description:
- The script performs transit skimming process and generates a set of transit skim matrix files.
- Three sets of skim matrix files are generated:
    - Walk/Bus Access
    - PnR Access
    - KnR Access

Changes:
- The process also generates the "network" file and "route" files that can be used for transit assignment process in a later stage of the model process.

Update PT Skim Matrix Files

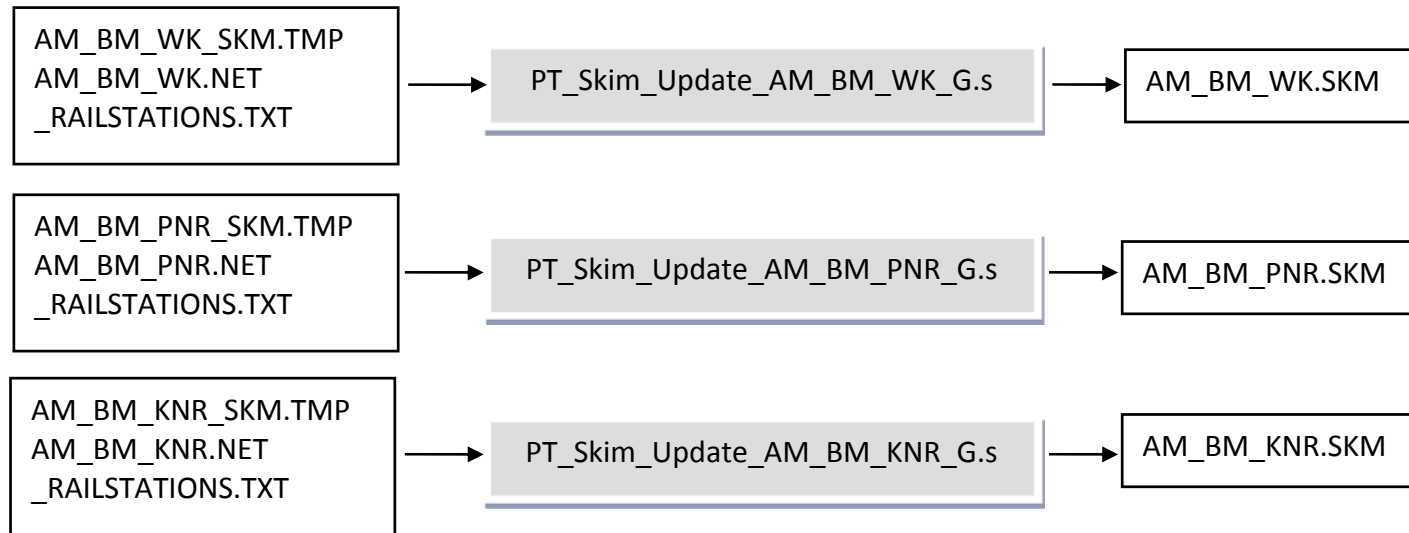|		
AM_BM_WK_SKM.TMP AM_BM_WK.NET _RAILSTATIONS.TXT	→ PT_Skim_Update_AM_BM_WK_G.s →	AM_BM_WK.SKM
AM_BM_PNR_SKM.TMP AM_BM_PNR.NET _RAILSTATIONS.TXT	→ PT_Skim_Update_AM_BM_PNR_G.s →	AM_BM_PNR.SKM
AM_BM_KNR_SKM.TMP AM_BM_KNR.NET _RAILSTATIONS.TXT	→ PT_Skim_Update_AM_BM_KNR_G.s →	AM_BM_KNR.SKM

Description:
- This script updates the skim matrix files generated from PT skimming procedure to make the skim files in similar format as the existing "TRNBUILD" model
- The script basically makes the following updates to the skim matrices:
  - PNR walk time from PNR lot to rail station (table 13) – for PNR access skim only;
  - PNR parking cost (table 15);
  - Attach additional tables identifying boarding and egress rail station numbers (tables 19 and 20).
- The update involves a 3-Step process for each skim matrix file as follow:
  i. Generating a filter matrix with value of 1 for i-j pairs with rail IVT >0;
  ii. Conducting a special transit assignment process to generate a station-station matrix in "dbf" format storing the boarding and alighting rail station node number of each i-j pair in the filter matrix;
  iii. Updating the transit matrix file generated from the previous transit skimming process.

PT Assignment Procedure Flowchart

Assemble_Trn_Trip_Mat_G.s

PT_Asgn_AM_BM_G.s
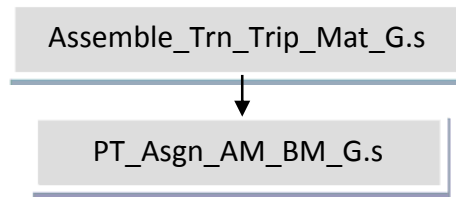
Assemble Transit Trip Matrix File

```
┌─────────────────┐      ┌────────────────────────┐      ┌─────────────────┐
│  I4_AMMS.TRP    │ ───▶ │ Assemble_Trn_Trip_Mat_G.s │ ──▶ │ Trn_Trips_AM.TRP │
└─────────────────┘      └────────────────────────┘      └─────────────────┘
```
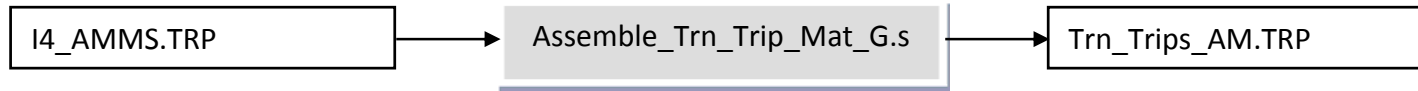
Description:
- This script assembles the transit trip matrices from the MWCOG Mode Choice Model output file into a transit matrix file for the transit assignment process.
- It generates a transit trip matrix file consisting of following three trip tables:
  - Walk/Bus access
  - PnR Access
  - KnR Access

Transit Assignment Process

AM_BM_WK.NET AM_BM_WK.RTE AM_BM_PNR.NET AM_BM_PNR.RTE AM_BM_KNR.NET AM_BM_KNR.RTE Trn_Trips_AM.TRP	→ PT_Asgn_AM_BM_G.s →	AM_BM_WK_LINK.DBF AM_BM_WK_S2S.DBF AM_BM_PNR_LINK.DBF AM_BM_PNR_S2S.DBF AM_BM_KNR_LINK.DBF AM_BM_KNR_S2S.DBF
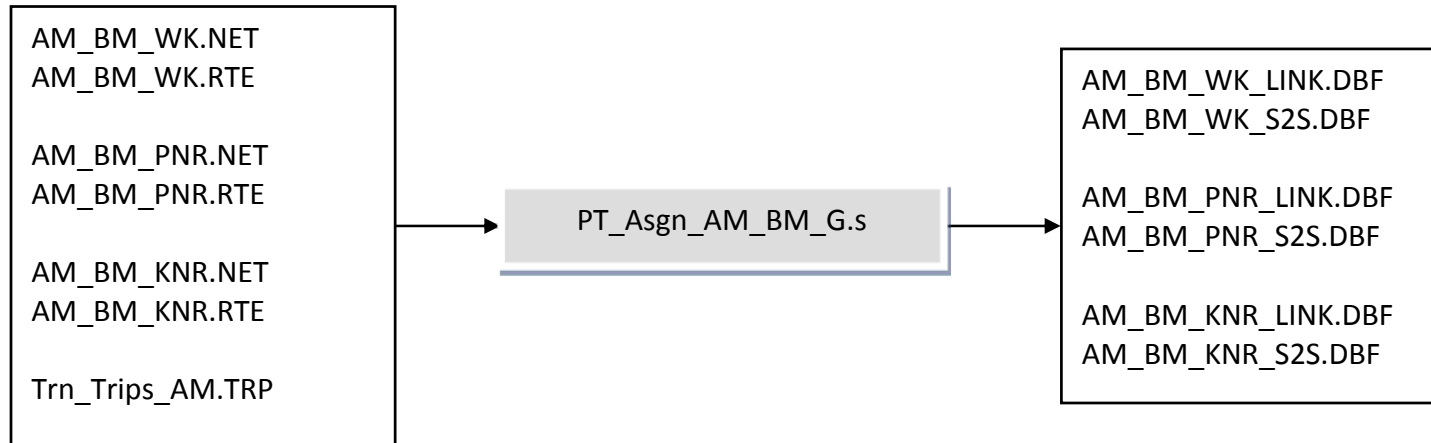
Description:

- The script conducts transit assignment for 3 types of Metrorail trips separately:
  - Walk/bus access
  - PnR access
  - KnR access
- The inputs of the process include:
  - Transit trip matrix file (from mode choice model) consisting of 3 trip tables (Walk/bus access, PnR access, KnR Access);
  - Transit network files and route files generated in the transit skimming process.
- The major outputs of the process are:
  - Link volume data file (dbf format);
  - Station-station volume data file (dbf format).

Appendix B. Survey Trip Data Process Flowcharts

Survey Trip Data Process
Analysis Components

Special Transit Skim Process

↓

Survey Rail Trips Tabulation
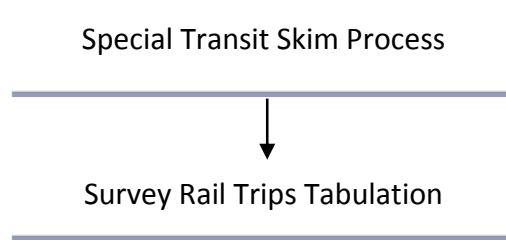
Description:
- This analysis component is to analyze the Metrorail Survey Dataset regarding the following travel characteristics related to the transit skimming procedure:
  - Rail trips by access mode (walk, bus, PnR and KnR);
  - Access time distribution of rail trips by various access modes;
  - Number of internal transfer of Metrorail trips.
- The analysis is conducted based on home zone and access station information as recorded in the Metrorail Survey dataset.
- The access time and access distance data are obtained from the access link (non-transit leg) as coded in the transit network.

Survey Trip Data Process
Special Transit Skim Process ("Special_Transit_Skim_Process.BAT")

```
┌─────────────────────────────────────┐
│  NT_Wk_Acc_Egr_Leg_Survey.s         │
└─────────────────────────────────────┘
              ↓
┌─────────────────────────────────────┐
│  NT_Wk_Xfer_Legs_Survey.s           │
└─────────────────────────────────────┘
              ↓
┌─────────────────────────────────────┐
│  NT_KNR_Legs_Survey.s               │
└─────────────────────────────────────┘
              ↓
┌─────────────────────────────────────┐
│  NT_PNR_Legs_Survey.s               │
└─────────────────────────────────────┘
              ↓
┌─────────────────────────────────────┐
│  Combine_NT_Wk_Legs_Survey.s        │
└─────────────────────────────────────┘
              ↓
┌─────────────────────────────────────┐      ┌─────────────────────────────────┐
│  PT_Skims_AM_BM_WK_Survey.s         │ ───→ │  AM_BM_WK_LINK_SURVEY.DBF       │
└─────────────────────────────────────┘      └─────────────────────────────────┘
              ↓
┌─────────────────────────────────────┐      ┌─────────────────────────────────┐
│  PT_Skims_AM_BM_KNR_Survey.s        │ ───→ │  AM_BM_KNR_LINK_SURVEY.DBF      │
└─────────────────────────────────────┘      └─────────────────────────────────┘
              ↓
┌─────────────────────────────────────┐      ┌─────────────────────────────────┐
│  PT_Skims_AM_BM_PNR_Survey.s        │ ───→ │  AM_BM_PNR_LINK_SURVEY.DBF      │
└─────────────────────────────────────┘      └─────────────────────────────────┘
              ↓
┌─────────────────────────────────────┐      ┌─────────────────────────────────┐
│  PT_Skims_AM_BUS_WK_Survey.s        │ ───→ │  AM_BUS_WK.SKM                  │
└─────────────────────────────────────┘      └─────────────────────────────────┘
```
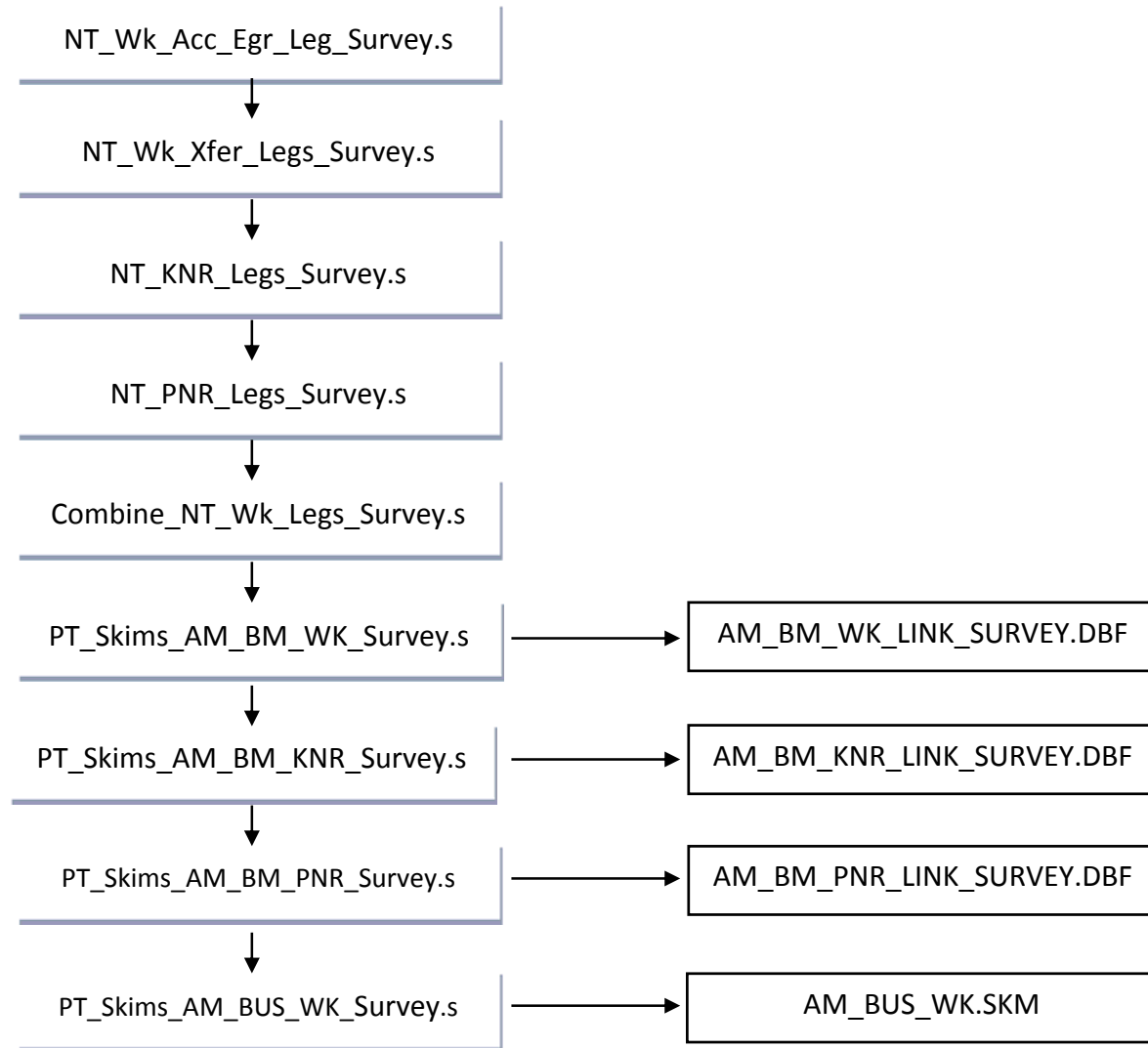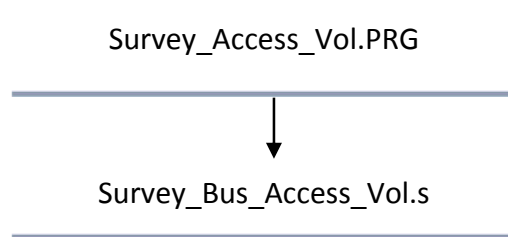
Survey Trip Data Process
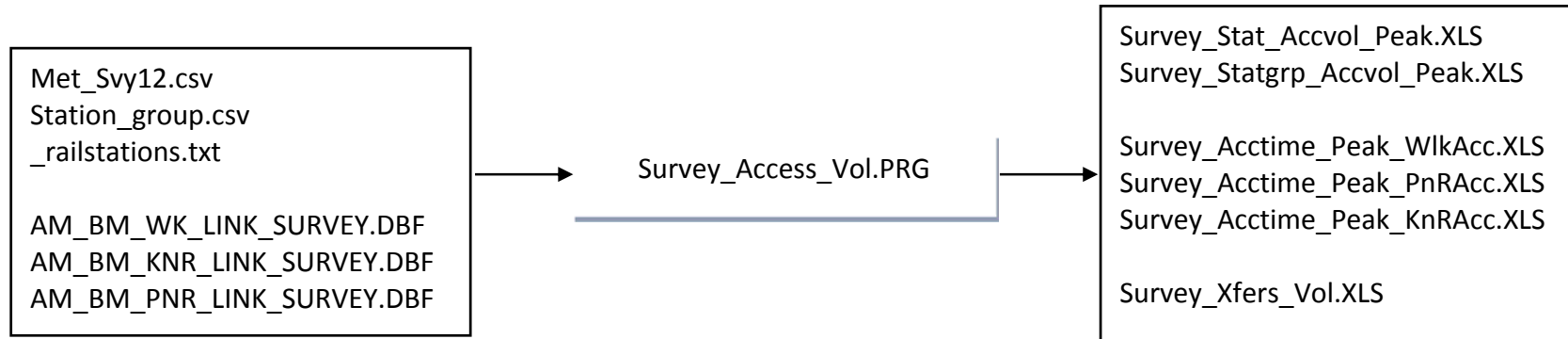## Special Transit Skim Process

Description:
- The main purpose of this special transit skim process is to output a set of transit link data files (in "dbf" format) that store the travel time and travel distance information of access links (from zone centroids to rail stations).
- This special skimming process tries to generate as many as possible the access links (walk-access, PnR-access and KnR-access links) so that most of "zone-to-access stations" movements as recorded in the survey can be covered. Some parameters of the skimming procedure (e.g., maximum access distance, maximum number of access links, etc.) are thus adjusted in the procedure.
- This process also conducts a special "walk access bus-only" skimming procedure and outputs a "walk to bus-only" skim matrix file.* This file will be used to derive the bus-access time from home-zones to access rail stations.
- This process can be executed by running the batch file "Special_Transit_Skim_Process.BAT"

* The bus-access movement is handled differently from other access movement since the bus-access movement is represented as a series of "transit legs," instead of "non-transit legs" for other access movements.

Survey Trip Data Process
## Survey Rail Trips Tabulation
Program Components

Survey_Access_Vol.PRG

Survey_Bus_Access_Vol.s

Survey Trip Data Process
Survey Rail Trips Tabulation

| Met_Svy12.csv
Station_group.csv
_railstations.txt

AM_BM_WK_LINK_SURVEY.DBF
AM_BM_KNR_LINK_SURVEY.DBF
AM_BM_PNR_LINK_SURVEY.DBF | → | Survey_Access_Vol.PRG | → | Survey_Stat_Accvol_Peak.XLS
Survey_Statgrp_Accvol_Peak.XLS

Survey_Acctime_Peak_WlkAcc.XLS
Survey_Acctime_Peak_PnRAcc.XLS
Survey_Acctime_Peak_KnRAcc.XLS

Survey_Xfers_Vol.XLS |

Description:

- This DBF program is to process the Metrorail Survey Dataset.
- The input files of the program include the Metrorail Survey dataset, station group definition and rail station data file (generated from the PT Skimming process).
- The program generates following output files:
  - Survey_Stat_Accvol_Peak.XLS - Rail trips by access station and access mode (walk, bus, PnR and KnR);
  - Survey_Statgrp_Accvol_Peak.XLS – Rail trips by station group and by access mode;
  - Survey_Acctime_Peak_WlkAcc.XLS – Walk access time and access volumes between individual home zone-rail station pairs;
  - Survey_Acctime_Peak_PnRAcc.XLS - Walk access time and access volumes between individual home zone-rail station pairs;
  - Survey_Acctime_Peak_KnRAcc.XLS - Walk access time and access volumes between individual home zone-rail station pairs ;
  - Survey_Xfers_Vol.XLS – Number of rail trips with 0, 1, and 2+ system internal transfers.

Survey Trip Data Process
Survey Rail Trips Tabulation

| Am_Bus_Wk.SKM Hmtaz_Pstataz_Peak_Bus.CSV	→	Survey_Bus_Access_Vol.s	→	Survey_Bus_Access_Vol_Time.CSV
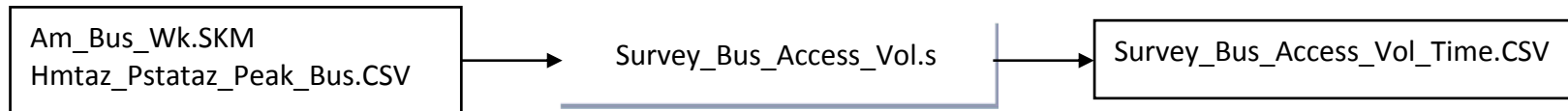
Description:
- This Cube-script program is to derive the bus access times for the reported bus access rail trips in the Metrorail Survey data.
- The bus access time cannot be obtained from the access link data (as for the walk-access, PnR-access and KnR-access trips) because this access movement is considered as "transit mode" (not "access mode") in Cube transit network.
- The bus access time data are obtained from the "walk access bus-only skim" file, based on home zone and access rail station zone as reported in the Metrorail Survey Dataset.
- The output file of the program summarizes the bus access time and bus access volumes between individual home-zone and access station pairs (in Cube transit node number system).

Appendix C. PT Model Trip Data Process Flowcharts

PT-Model Trip Data Process
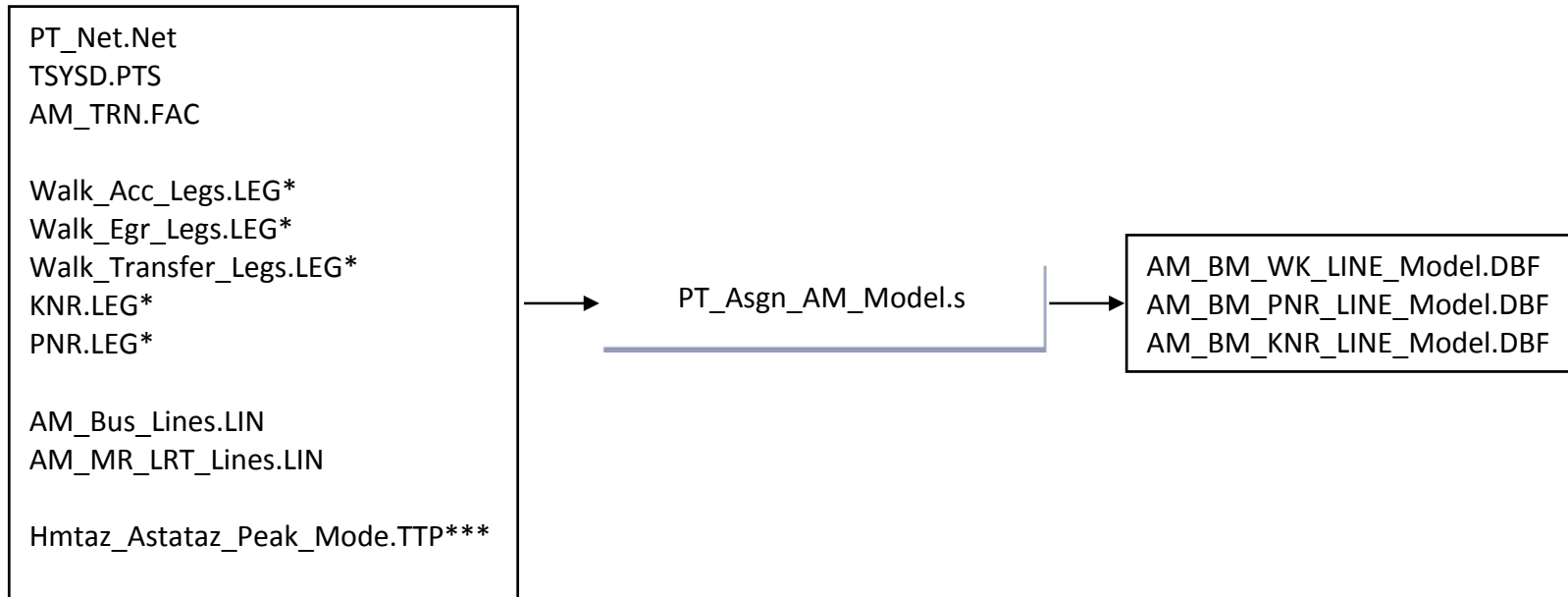## Analysis Components

Special Transit Assignment Process

↓

Model Rail Trips Tabulation
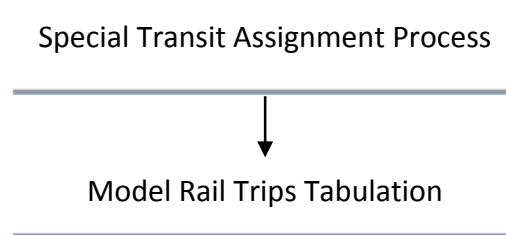
Description:
- The function of this analysis component is to perform a transit assignment process using the "home-zone – destination station zone" rail trip tables and to examine how the rail trips are assigned to access rail stations. The examination of these rail access movements serves as a way to evaluate the reasonableness of the transit skimming and assignment procedure as implemented in the PT-model.
- This analysis component consists of two parts:
  - Conducting a special transit assignment process which assigns the "home zone – destination station zone" trip tables derived from the Metrorail Survey Dataset to the transit network;
  - Summarizing the station access volume and station access times by various access modes based on the link data files generated from the special transit assignment process.
- The analysis generates similar outputs as the survey data analysis, including:
  - Rail Trip by access mode (walk, bus, PnR and KnR);
  - Access time distribution of rail trips of various access modes;
  - Number of internal transfer of Meterorail trips.

PT-Model Trip Data Process
Special Transit Assignment Process

```
PT_Net.Net
TSYSD.PTS
AM_TRN.FAC

Walk_Acc_Legs.LEG*
Walk_Egr_Legs.LEG*
Walk_Transfer_Legs.LEG*
KNR.LEG*
PNR.LEG*

AM_Bus_Lines.LIN
AM_MR_LRT_Lines.LIN

Hmtaz_Astataz_Peak_Mode.TTP***
```

→ PT_Asgn_AM_Model.s →

```
AM_BM_WK_LINE_Model.DBF
AM_BM_PNR_LINE_Model.DBF
AM_BM_KNR_LINE_Model.DBF
```
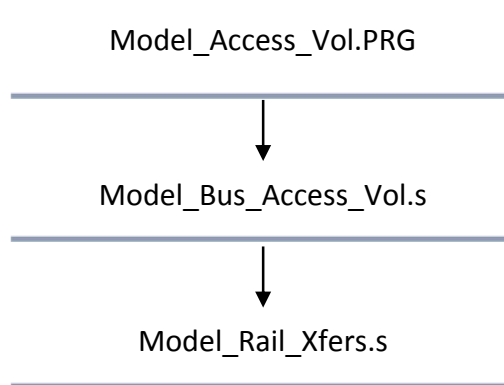
* Generated from the regular PT skimming process
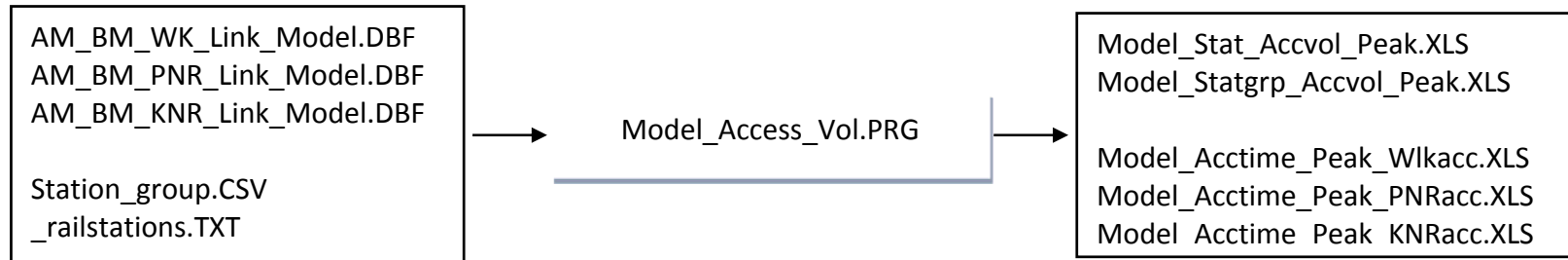** Derived from survey rail trip dataset

Description:
- This Cube script program performs a series of transit assignments using the "home zone – destination station zone" rail trip tables for various access modes (walk/bus-access, PnR-access, KnR-access).
- The output of this assignment process is a set of link data files which store the link distance, travel time, and assigned transit volume of each link (both transit and non-transit links) in the transit network.
- The data of the access links will be used to summarize the access volume and access time for various access modes.

PT-Model Trip Data Process
## Model Rail Trips Tabulation
Program Components

Model_Access_Vol.PRG

Model_Bus_Access_Vol.s

Model_Rail_Xfers.s

PT-Model Trip Data Process

```
AM_BM_WK_Link_Model.DBF
AM_BM_PNR_Link_Model.DBF
AM_BM_KNR_Link_Model.DBF

Station_group.CSV
_railstations.TXT
```

Model_Access_Vol.PRG

```
Model_Stat_Accvol_Peak.XLS
Model_Statgrp_Accvol_Peak.XLS

Model_Acctime_Peak_Wlkacc.XLS
Model_Acctime_Peak_PNRacc.XLS
Model_Acctime_Peak_KNRacc.XLS
```

Description:
- This DBF program is to process the transit link data files output from the transit assignment process.
- The program read in the link data files generated from the special transit assignment process, as well as the station group definition file and the rail station PnR connection data file.
- The program generates following output files:
    - Model_Stat_Accvol_Peak.XLS - Rail trips by access station and access mode (walk, bus, PnR and KnR);
    - Model_Statgrp_Accvol_Peak.XLS – Rail trips by station group and by access mode;
    - Model_Acctime_Peak_WlkAcc.XLS – Walk access time and access volumes between individual home zone-rail station pairs;
    - Model_Acctime_Peak_PnRAcc.XLS - Walk access time and access volumes between individual home zone-rail station pairs;
    - Model_Acctime_Peak_KnRAcc.XLS - Walk access time and access volumes between individual home zone-rail station pairs.

PT-Model Trip Data Process

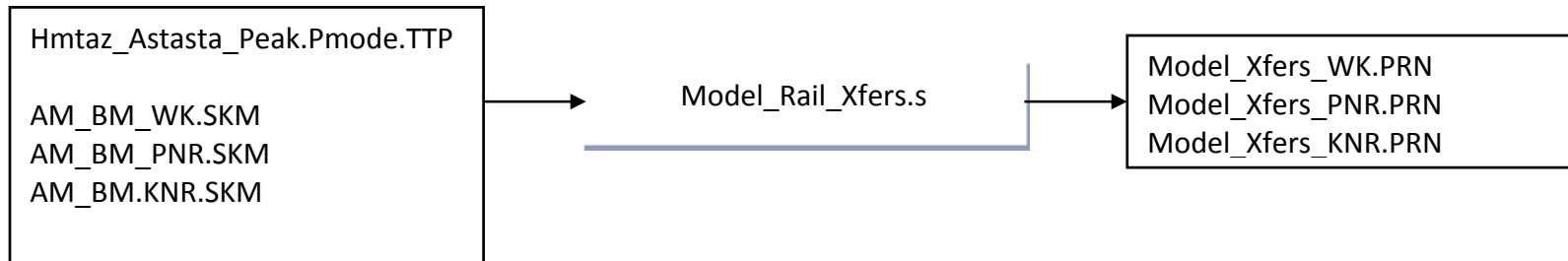| AM_BM_WK.SKM
hmtaz_astataz_peak_mode.CSV | → | Model_Bus_Access_Vol.s | → | Model_bus_access_vol_time.CSV |
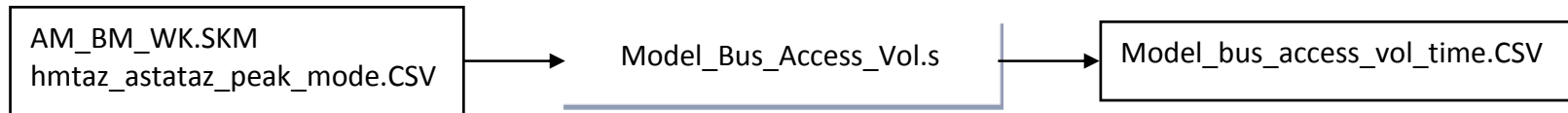
Description:
- This Cube-script program is to derive the model estimated bus access volumes and access times for the rail trip tables derived from the Metrorail Survey Dataset.
- The bus access time cannot be obtained from the access link data (as for the walk-access, PnR-access and KnR-access trips) because this access movement is considered as "transit mode" (instead of "access mode") in the Cube transit network.
- The rail trips tables considered in this analysis are the "walk-access" and "bus-access" rail trips as reported in the Metrorail Survey Dataset. This is because in the Cube transit model, walk-access and bus-access Metrorail trips are grouped together in the assignment process.
- The bus access time data are obtained from the "AM_BM_WK.SKM" file derived from the regular PT skimming process. The bus skim matrix provides the bus travel times (IVT) among "home zones-rail station zones" pairs.
- The rail trips are considered to have bus access time if the skim matrix file indicates both Rail-IVT and Bus-IVT are non-zero for the associated o/d pair. Also, the total bus IVT value is considered as the bus access time for the o/d pair.*
- The output file of the program summarizes the bus access time and bus access volumes between individual home-zone and destination station pairs (in Cube transit node numbers).

* It is assumed that no bus-IVT occurs at the destination end. As the rail trip tables in the analysis represent trips from home zones to destination station zones, no bus-transfer is required at the destination end.

PT-Model Trip Data Process

```
┌─────────────────────────────────┐                                    ┌──────────────────────────┐
│ Hmtaz_Astasta_Peak.Pmode.TTP    │                                    │ Model_Xfers_WK.PRN       │
│                                 │        Model_Rail_Xfers.s          │ Model_Xfers_PNR.PRN      │
│ AM_BM_WK.SKM                    │    ──►                        ──►  │ Model_Xfers_KNR.PRN      │
│ AM_BM_PNR.SKM                   │                                    │                          │
│ AM_BM.KNR.SKM                   │                                    └──────────────────────────┘
│                                 │
└─────────────────────────────────┘
```

Description:
- This Cube script program summarizes the number of rail trips with 0, 1, and 2+ system internal transfers for various rail access modes.
- The script program performs the calculation for three rail trips tables separately (walk/bus-access, Pnr-access, KnR-access).
- The calculation is conducted using data in the transit skim matrix files. The values of the 2nd decimal point of matrix #12 in the skim file represent the number of rail internal transfer of individual o/d pairs.
- The numbers of rail trips with 0, 1 and 2+ internal transfers can be obtained from the Cube Program "PRINT" files, by retrieving the matrix totals of the following working matrices:
    - MW[2] – Total number of rail trips assigned to the transit network;
    - MW[3] – Total number of rail trips with 1 transfer;
    - MW[4] – Total number of rail trips with 2+ transfers.

PT-Model Trip Data Process
Program Components

Acc_Time_Comparison_WalkAcc.XLSX

Acc_Time_Comparison_PnRAcc.XLSX

Acc_Time_Comparison_KnRAcc.XLSX

Acc_Time_Comparison_BusAcc.XLSX

Rail_Trips_Comparison.XLSX

Description:
- This component summarizes the analysis results of the "Survey Rail Trips Analysis" and "Model Rail Trips Analysis" components.
- The results are summarized in a series of excel files to compare the survey reported and model estimated rail trip characteristics, basically covering the following:
  - Access time distributions of various rail access modes
  - Station access rail volumes
  - System internal transfers of rail trips