USER'S GUIDE

For the COG/TPB Gen2/Version 2.4 Travel Demand Forecasting Model

March 15, 2021

National Capital Region
Transportation Planning Board

USER'S GUIDE FOR THE COG/TPB GEN2/VERSION 2.4 TRAVEL DEMAND FORECASTING MODEL

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ABOUT THE TPB

The National Capital Region Transportation Planning Board (NCRTPB or TPB) is the federally designated metropolitan planning organization (MPO) for metropolitan Washington. It is responsible for developing and carrying out a continuing, cooperative, and comprehensive transportation planning process in the metropolitan area. Members of the TPB include representatives of the transportation agencies of the states of Maryland and Virginia and the District of Columbia, 24 local governments, the Washington Metropolitan Area Transit Authority, the Maryland and Virginia General Assemblies, and nonvoting members from the Metropolitan Washington Airports Authority and federal agencies. The TPB is staffed by the Department of Transportation Planning at the Metropolitan Washington Council of Governments.

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The Metropolitan Washington Council of Governments (MWCOG or COG) is an independent, nonprofit association that brings area leaders together to address major regional issues in the District of Columbia, suburban Maryland, and Northern Virginia. COG's membership is comprised of 300 elected officials from 24 local governments, the Maryland and Virginia state legislatures, and U.S. Congress.

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Colophon

This report was created using Microsoft Word and Visio from Office 365 and was converted to a PDF file using Adobe Acrobat DC. In the past, this report was divided into two sections, but the current version of this report is contained in one report. The files for this report can be found in a folder on COG's internal file server (I:\ateam\docum\fy21\Verson24Development\travel_model_user_guide).

1 Introduction

The National Capital Region Transportation Planning Board (NCRTPB or simply TPB) is the federally designated Metropolitan Planning Organization (MPO) for the Washington, D.C. metropolitan area and is also one of several policy boards that operate at the Metropolitan Washington Council of Governments (MWCOG or simply COG). The TPB is staffed by COG's Department of Transportation Planning (DTP). The COG/TPB staff develops and maintains, with consultant assistance, a series of regional travel demand forecasting models that are used for the regional transportation planning process in the Washington, D.C. area. These regional travel demand models are developed under the guidance of the Travel Forecasting Subcommittee (TFS), a subcommittee of TPB's Technical Committee. At any given time, the COG/TPB staff maintains at least two regional travel demand models: an adopted, production-use model and one or more developmental models. The production-use model is the one that is used in planning studies conducted by COG/TPB and is made available to outside parties.[1] The developmental model(s) are the ones that are currently under development by COG/TPB staff, and are generally not made available to outside parties, since they are not yet considered a finished product. Note: As of the Ver. 2.4 Model, TPB staff now provides two production-use travel models (Ver. 2.4 and Ver. 2.3.78). The Data Request webpage provides details on the model transmittal packages for each production-use model.

This report explains how to setup and run the TPB's **Generation-2, or Gen2, Version 2.4 Travel Demand Forecasting Model, which is the latest in a series of regional, trip-based, production-use travel demand models.** The Gen2/Ver. 2.4 Model was derived from the Gen2/Ver. 2.3.78 Model, which was the previous, production-use travel demand model. All the models in the Generation-2 family of models are aggregate, trip-based, four-step travel demand models estimated, calibrated, and validated to conditions in the metropolitan Washington region.

Between 2008 and 2011, the TPB Gen2/Ver. 2.3 Travel Model was calibrated and validated to year-2007 conditions.[2] In 2013, the Ver. 2.3 Travel Model was also validated to year-2010 conditions,[3] with an emphasis on validating the model's highway assignment results. Updates to the model resulting from this validation work were part of the Ver. 2.3.52 Travel Model (a.k.a., Build 52). In 2019, the **Ver. 2.3.75 Model was validated to year-2014 conditions**, mainly to fulfill a federal requirement associated with the air quality conformity (AQC) determination.[4] In November 2019, **staff re-calibrated** the nested-logit

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[1] The procedures for requesting the model can be found on the "Data Requests" webpage (https://www.mwcog.org/transportation/data-and-tools/modeling/data-requests/).
[2] Ronald Milone et al., "Calibration Report for the TPB Travel Forecasting Model, Version 2.3, on the 3,722-Zone Area System," Final Report (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, January 20, 2012), https://www.mwcog.org/transportation/data-and-tools/modeling/model-documentation/.
[3] Ronald Milone to Files, "2010 Validation of the Version 2.3 Travel Demand Model," Memorandum, June 30, 2013, https://www.mwcog.org/transportation/data-and-tools/modeling/model-documentation/.
[4] Specifically, according to federal regulations 40 CFR 93.122(b)(1)(i), "network-based travel models must be validated against observed counts (peak and off-peak, if possible) for a base year that is not more than 10 years prior

mode choice (NLMC) model of the TPB Version 2.3 Travel Demand Model to year-2007 conditions, following recent updates to person-trip calibration targets for commuter rail.[5] In 2020, the TPB Ver. 2.3 Travel Demand Model (Ver. 2.3.85) was re-validated to year-2014 conditions and evaluated for its performance, based on a series of sensitivity tests. Following a series of important updates and recalibration/revalidation efforts, the resulting Ver. 2.3.87 Model was rebranded as Version 2.4.

The user's guide for the Ver. 2.4 Model is contained in one volume. As of the Ver. 2.3.78 Model,[6] the model user's guide no longer includes Volume 2, which had contained appendices of batch files, Cube Voyager scripts, and AEMS Fortran control files (Instead, these files are available via the standard model/network transmittal package[7]).

1.1 Adoption of the regional travel demand forecasting model by the TPB

The TPB does not *explicitly* adopt a specific version of the regional travel demand model. Instead, the adoption is typically made *implicitly* when the TPB adopts both 1) a given version of its Long-Range Transportation Plan (LRTP) and Transportation Improvement Program (TIP); and 2) the findings from an AQC analysis of the financially constrained element of the LRTP and the associated TIP. The LRTP undergoes a major update every four years. The last of these updates was done in 2018 and was known as Visualize 2045.[8] The latest version of the LRTP is known as the 2020 Amendment to Visualize 2045, which was finalized in 2020 and has an out year of 2045. The 2020 Amendment to Visualize 2045 has both a financially constrained element and an aspirational element. The constrained element is what used to be called the Constrained Long-Range Plan (CLRP). The purpose of the AQC analysis is to determine whether the air pollution created by motor vehicles ("mobile emissions") traveling on the transportation network represented in the constrained element of the LRTP (in this case, the 2020 Amendment to Visualize 2045) is consistent with (conforms to) the state air quality implementation plans (SIPs). The *implicit adoption* of a specific model version generally occurs when the TPB adopts an AQC analysis that made use of that model version. For instance, the Ver. 2.3.78 TPB Travel Demand

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to the date of the conformity determination." The year-2014 validation enabled the Ver. 2.3 Model to be used for Air Quality Conformity (AQC) determinations through 2024. Refer to the following document for more details: Feng Xie to Dusan Vuksan and Mark Moran, "Year-2014 Validation of TPB's Version 2.3 Travel Demand Model", Memorandum, March 12, 2019.

[5] Feng Xie, "TPB Version 2.3 Travel Demand Model: Re-Calibrating the Nested-Logit Mode Choice Model Following the Updates to Commuter Rail Person Trip Targets," Memorandum, November 15, 2019.

[6] Ray Ngo, Feng Xie, and Mark Moran, "User's Guide for the COG/TPB Travel Demand Forecasting Model, Version 2.3.78" (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, April 14, 2020), https://www.mwcog.org/assets/1/6/mwcog_tpb_travel_model_v2.3.78_user_guide_v5_full.pdf.

[7] See, for example, Meseret Seifu to Feng Xie and Mark S. Moran, "Transmittal Package: TPB Ver. 2.3.78 Travel Demand Forecasting Model, Transportation Networks, and Land Use Data Associated with the Air Quality Conformity Analysis of the 2020 Amendment to Visualize 2045," Memorandum, April 14, 2020, https://www.mwcog.org/transportation/data-and-tools/modeling/data-requests/.

[8] "Visualize 2045, A Long-Range Transportation Plan for the National Capital Region," Draft (Washington, D.C.: National Capital Region Transportation Planning Board, Metropolitan Washington Council of Governments, September 2018), https://www.mwcog.org/visualize2045/document-library/.

Forecasting Model (TDFM) became the adopted, production-use model on March 18, 2020 when the TPB adopted two resolutions on the 2020 Amendment to Visualize 2045.

Different from the Ver. 2.3.78 Model, which was released to the public following a TPB action, the Ver. 2.4 Model will be released to the public in early 2021 without a TPB action. Instead, the model will be released based on TPB staff's assessment that it is ready for production use. Specifically, TPB staff re-ran all the AQC analysis scenarios in the 2020 Amendment to Visualize 2045 using the Ver. 2.4 Model and verified the reasonableness of the modeling results. Staff also validated the Ver. 2.4 Model to year-2014 conditions.[9] As a result, the Version 2.4 Model will be released as TPB's next production-use regional travel demand model before (rather than after) its use for an AQC of the LRTP update. The next update of the LRTP is expected in 2022 and this will be a quadrennial update (expected around June 2022). Some major updates to the Ver. 2.4 Model will be discussed in Section 1.3.

1.2 History of the production-use Version 2.3 and Version 2.4 Travel Models

The adopted, production-use Generation-2, or Gen2, Version 2.3 Travel Model is a series of model versions ending with Version 2.3.78. The first iteration of the Version 2.3 Model became the adopted regional travel model for the Washington, D.C. metropolitan area on November 16, 2011. In 2012, a newer version of the model (Ver. 2.3.39) was used for the air quality conformity analysis of the 2012 Constrained Long-Range Plan and the FY 2013-2018 Transportation Improvement Plan. In 2013, the Ver. 2.3.52 Model was used for the air quality conformity analysis of the 2013 CLRP and FY 2013-2018 TIP. In 2015, the Ver. 2.3.57a Model became the production-use model. In 2016, 2017, 2018, and 2020 the Ver. 2.3.66, Ver. 2.3.70, Ver. 2.3.75, and Ver. 2.3.78 models became the production-use model, respectively.

The Gen2/Version 2.4 Travel Model is the latest series of the Generation-2 family of model versions. COG staff implemented some major updates to Version 2.3.78 to create Version 2.4. In early 2021, the Version 2.4 Model became the production-use regional travel demand model.

Below is a list of milestones in the development of the TPB regional travel demand model from 2008 to the present:

- March 1, 2008: The TPB Version 2.2 Travel Model was released.[10]
  - The Version 2.2 Travel Model was developed on the 2,191-TAZ area system and most of its component models were estimated and calibrated with data from the COG/TPB 1994 Household Travel Survey (HTS), which included about 4,800 households.
- June 30, 2008: Draft TPB Version 2.3 Travel Model was released.[11]

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[9] Meseret Seifu to Feng Xie, "Year-2014 Validation of TPB Version 2.4 Travel Model," October 29, 2020.
[10] Ronald Milone et al., *TPB Travel Forecasting Model, Version 2.2: Specification, Validation, and User's Guide* (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, March 1, 2008), http://www.mwcog.org/transportation/activities/models/documentation.asp.
[11] Ronald Milone et al., "TPB Travel Forecasting Model, Version 2.3: Specification, Validation, and User's Guide," Draft Report (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, June 30, 2008).

  - At the time when the Version 2.2 Travel Model was released, a parallel effort was also underway to combine a nested-logit mode choice (NL MC) model and revised truck models into the Version 2.2 framework. This development effort proved to be viable and resulted in a release of what was then called the "draft Version 2.3 Travel Model" in June of 2008. The draft Version 2.3 Model, like Version 2.2, was developed on the 2,191-TAZ area system.
  - The draft Version 2.3 Model was not brought into production given that two related events were in motion during 2008. First, a new round of travel data collection was underway, including a major regional household travel survey (the COG/TPB 2007/2008 Household Travel Survey, which included about 11,000 households) and two transit on-board surveys (a bus on-board survey and a Metrorail passenger survey). Second, a new TAZ system was in development. The new zone system was envisioned to be developed over the same geographic area as the 2,191-TAZ system (6,800 square miles), but with smaller average zone sizes. TPB staff ultimately decided that the draft Version 2.3 Travel Model should not become the approved regional travel model until it incorporated the new zone system and the new data from the 2007/2008 Household Travel Survey (HTS) and the on-board transit surveys.
- February 28, 2011: The TPB Version 2.3 Travel Model, Build 9, was released (i.e., Ver. 2.3.9).[12]
  - From 2008 to 2012, TPB staff conducted the following activities:
    - Compiled and cleaned new survey data.
    - Prepared calibration files based on the new 3,722 TAZ system.
    - Estimated and calibrated various sub-models in the regional travel model.
- November 11, 2011: The TPB Version 2.3.36 Model was released.[13] This is the model that became the adopted regional travel model for the for the Washington, D.C. metropolitan area on November 16, 2011.
- December 21, 2011: The TPB Version 2.3.38 Model was released. This model was documented in January 2012.[14]
- July 17, 2013: The TPB Version 2.3.52 Model became the production-use travel model.
- October 15, 2014: The TPB Version 2.3.57 Model became the production-use travel model.
- October 21, 2015: The TPB Version 2.3.57a Model became the production-use travel model.
- November 16, 2016: The TPB Version 2.3.66 Model became the production-use travel model.
- October 18, 2017: The TPB Version 2.3.70 Model became the production-use travel model.
- October 17, 2018: The TPB Version 2.3.75 Model became the production-use travel model.

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[12] Ronald Milone et al., "TPB Version 2.3 Travel Forecasting Model for the 3,722-Zone Area System: Calibration Report," Draft report (Washington, D.C.: National Capital Region Transportation Planning Board, February 28, 2011).

[13] Ronald Milone et al., "Calibration Report for the TPB Travel Forecasting Model, Version 2.3.36, on the 3,722-Zone Area System," Draft report (Washington, D.C.: National Capital Region Transportation Planning Board, November 18, 2011), http://www.mwcog.org/uploads/committee-documents/aF1fV1xW20111118131827.pdf.

[14] Ronald Milone et al., "User's Guide for the TPB Travel Forecasting Model, Version 2.3, Build 38, on the 3,722-Zone Area System," Final Report (Washington, D.C.: National Capital Region Transportation Planning Board, January 20, 2012), http://www.mwcog.org/transportation/activities/models/documentation.asp.

- March 18, 2020: The TPB Version 2.3.78 Model became the production-use travel model.
- March 15, 2021: The TPB Version 2.4 Model became the production-use travel model.

1.3 Recent changes to the model: From Ver. 2.3.78 to Ver. 2.4

There have been five major updates to the TPB regional travel demand model since the previously adopted model (Ver. 2.3.78). The updates are listed in Table 1 and are described in more detail later in this report.

The TPB Model can have four types of updates: a bug fix, a new feature, a feature enhancement, and updated documentation. Bug fixes are the most important type of update and have the highest priority. Software bugs can be found by either internal or external model users. New or enhanced features bring improvements to the model or make it easier to use. Documentation relates to comments or annotations within scripts or batch files that explain what is occurring in the software code. As shown in Table 1, all five of the model updates associated with the Ver. 2.4 Model were feature enhancements. As will be explained later, all the feature enhancements in Ver. 2.4, with the exception of Update 4, cause some changes in the model results.

Table 1 Updates made to the Ver. 2.4 Model, compared to Ver. 2.3.78

#	Description	Type of update	Further details and benefit(s)	Changes model results?
1	Revised treatment of how external-to-internal (X-I) and internal-to-external (I-X) trips are handled in the trip distribution step	Feature enhancement	To improve the model's representation of observed external-to-internal (X-I) and internal-to-external (I-X) travel patterns within the modeled area. In addition to the changes to the external trip distribution model, this update included three other model changes: • Removed jurisdictional, non-work trip production modification factors (P-mods); • Increased highway free-flow speed look-up values (by 15%); and • Removed consideration of bridge penalties in highway path-building within the traffic assignment process.	Yes
2	Re-calibrated the nested-logit mode choice (NLMC) model to year-2007 conditions, following recent updates to person trip calibration targets for commuter rail	Feature enhancement	The re-calibration was conducted with three main motivations: • This calibration was warranted by recent updates to transit-person trip calibration targets associated with commuter rail. • This calibration reflected recent model changes that TPB staff implemented in a parallel modeling effort to improve the modeling of I-X and X-I auto-person trips (Update 1). • This calibration also included adjustments to model parameters related to commuter rail path building as part of the effort to address the model's under-estimation of commuter rail ridership. The year-2014 validation results of the calibrated model have significantly improved compared to those of the Ver. 2.3.78 Model, although the calibrated model still underestimates the 2014 commuter rail ridership at the regional level.	Yes
3	Restored the number of iterations used in external trip distribution of HBS and HBO trips	Feature enhancement	The revision of the model's treatment of I-X and X-I ("external") travel in Update 1 reduced the trip distribution step's maximum iteration MAXITERS for HBS and HBO trips from 27 to 9 and from 27 to 15, respectively. Update 3 restored the MAXITERS values for these two trip purposes to their original values to maintain a good model convergence.	Yes

#	Description	Type of update	Further details and benefit(s)	Changes model results?
4	Created additional node ranges for each jurisdiction in the modeled area	Feature enhancement	Due to the continuous network enhancements and updates for the TPB Ver. 2.3 Model, allocated node numbers for jurisdictions are running out, especially in Washington, D.C. and Montgomery County. By adding new highway node ranges, the number of nodes reserved for each jurisdiction has been doubled.	No
5	Adjusted volume-to-capacity (V/C) ratio toll-search stopping criteria	Feature enhancement	Staff tested different toll-search stopping criteria (in terms of V/C ranges for stopping) in the toll-setting process to find out which one would produce estimated tolls more comparable to the observed data. Based on the testing, staff recommended that the V/C toll-search stopping range of (0.90-0.95) be implemented in the toll-setting process of the Ver. 2.4 Model.	Yes

1.3.1 Update 1: Revised treatment of trip distribution for trips that begin or end outside the modeled area

This section is largely extracted from a memo documenting the revised process for the trip distribution of external-to-internal (X-I) and internal-to-external (I-X) trips, often called "external" trips, for the Ver. 2.3 Model.[15]

1.3.1.1 Motivation

The need to revisit this component of the model was identified during recent project planning work, where it was found that that the share of external trips crossing the Potomac River was disproportionately large, relative to other internal travel markets. In a subsequent investigation, it was found that external (I-X, X-I) trip lengths in the Version 2.3.78 Model and prior model versions were excessive.

The trip distribution process within the Version 2.3 Travel Demand Model (e.g., Version 2.3.78) addresses internal (I-I) and external (X-I, I-X) trips separately and independently. This "dual" trip distribution approach is used because external trip lengths in the region are substantially longer than those of internal trips. The existing external trip distribution process involves the application of gravity models that are specified by purpose (home-based work [HBW], home-based shop [HBS], home-based other [HBO] and non-home-based [NHB]) and facility type (Interstate freeways and arterial roads).

The way in which external trip-ends are prepared prior to the trip distribution step is essentially as follows:

- Productions and attractions (Ps and As) at external stations are first developed by purpose. Traffic counts (or traffic count extrapolations used in forecast-year scenarios) at each external station are apportioned among modes (auto and truck), movements (X-I, I-X, X-X) and trip purposes. The apportionment is made on a station-by-station basis in accordance with proportions observed in the last TPB Auto External Survey (AES), conducted in 1994.
- Internal (TAZ-level) Ps and As are developed by scaling total internal Ps and As, by purpose, to match the external Ps and As totals calculated above.

The above approach is reasonable since the external ends of the trip are directly consistent with traffic counts observed at each external station (or traffic count projections in the case of a forecast-year scenario). However, one concern with the above approach relates to its treatment of external travel at the internal end of the trip. The approach implies that external travel to/from the modeled region is distributed in the same way that internal Ps and As are distributed. For example, most internal work (HBW) trips in the region are logically attracted to the regional "core" where jobs are most densely concentrated. However, it is not necessarily true that external HBW trips will be similarly oriented toward the regional core area in the same way as internal trips.

[15] Ronald Milone and Meseret Seifu, "External Trip Distribution Model Update," Memorandum, December 4, 2019.

1.3.1.2 Solution

The external trip distribution process has been adjusted using 2014 cellular origin-destination (O-D) data that was purchased from AirSage in June of 2014. Given limitations in the cellular data that have been recognized (and are reviewed below), the adjustment was intentionally undertaken with a focus on jurisdictional trip patterns as opposed to finer (zonal) patterns.

The updated external trip distribution model was developed in the following steps:

- Concerns associated with the existing external trip distribution approach were identified;
- A comparison of total external cellular trip-ends and trip-end data from other observed data sources was presented at the jurisdictional level; The comparison was provided to confirm the reasonability of the cellular data source as a basis for re-calibrating the updated model;
- A comparison of total external trip-ends from the existing travel model and from observed (cellular) trip-ends was presented at the jurisdictional level. The comparison provided insight on problematic external travel patterns that are associated with the existing distribution process;
- The development of the updated trip distribution process involved: 1) adjusting external trip ends to conform to observed patterns at the jurisdictional level prior to the external trip distribution, and 2) the adjustment of friction factors (F-factors) used in the external trip distribution using the adjusted trip-ends;
- Integrated the updates into the model and assessed the resulting impacts on model performance and reasonability.

Update 1 changed five scripts and one supporting file, as listed in Table 2. The modifications made to these files affected the model results.[16]

[16] Ronald Milone and Meseret Seifu, "External Trip Distribution Model Update," Memorandum, December 4, 2019, 11.

Table 2 Affected model components due to Update 1

Purpose	File name	Changes
Revised treatment in the model external travel	*Scripts\Prepare_Ext_Auto_Ends.s*	Revised
	Scripts\Trip_Distribution_External.s	Revised
	Support\Ver23_f_factors.dbf	Revised
Revised trip production modification factors	*Scripts\Trip_Generation.s*	Revised
Updated free-flow highway speeds	*Scripts\hwy_assign_capSpeedLookup.s*	Revised
Removed Potomac river-crossing bridge penalties in the traffic assignment process	*Scripts\Highway_Assignment_Parallel.s*	Revised

Changes made to *Prepare_Ext_Auto_Ends.s*

Figure 1[17] below shows the first section of changes made to the *Prepare_Ext_Auto_Ends.s*. The 6 red and 537 green lines indicate the lines before and after changes. The far-left column shows the line numbers of the scripts before the change and the next column shows the line numbers of the scripts after the change. If a green line is blank, the line is deleted from the batch file. If a green line is added without a prior red line, the green line is simply added to the file.

For example, the original lines 4-6:

```
4   ;  Prepare_Ext_Auto_Ends.s
                              =
5   ;  This process prepares Auto-related external Ps, As for the External Trip
    Distribution Process     =
6   ;  The zonal level internal Ps & As are scaled (or balanced) to match external As
    & Ps, respectively =
```

are removed and replaced by new lines 4-9 in the updated script:

```
4 ;  Prepare_Ext_Auto_Ends.s
                              =
5 ;  This process prepares Auto-related external Ps, As for the External Trip
  Distribution Process      =
6 ;  The zonal level internal Ps & As are scaled (or balanced) to match external As
  & Ps, respectively  =
7 ; 04/26/2018 RJM
                              =
8 ; Added section to adjust scaled external Ps and As to make sure the internal
  distribution of I/X and =
9 ; X/I trips matched jurisdictional distribution indicated by AirSage
  data                              =
```

[17] We have used Sublime Merge to create these figures showing the script differences

Due to the large number of changes (537 new lines) in the script, only two screenshots illustrating the beginning and ending of the changes are presented in this user's guide. An interested user can view the rest of changes by comparing the *Prepare_Ext_Auto_Ends.s* script of the Ver. 2.3.78 Model to that of the Ver. 2.4 Model.

```
Scripts/Prepare_Ext_Auto_Ends.s  -6  +537                                   •••
                                                      Revert hunk   Hunk history
*del voya*.prn
;
;===================================================================================================
;  Prepare_Ext_Auto_Ends.s                 =
;  This process prepares Auto-related external Ps, As for the External Trip Distribution Process     =
;  The zonal level internal Ps & As are scaled (or balanced) to match external As & Ps, respectively =
;  Prepare_Ext_Auto_Ends.s                  =
;  This process prepares Auto-related external Ps, As for the External Trip Distribution Process      =
;  The zonal level internal Ps & As are scaled (or balanced) to match external As & Ps, respectively  =
; 04/26/2018 RJM                            =
; Added section to adjust scaled external Ps and As to make sure the internal distribution of I/X and =
; X/I trips matched jurisdictional distribution indicated by AirSage data                      =
;===================================================================================================
```

Figure 1 First section of changes made to *Prepare_Ext_Auto_Ends.s* in Ver. 2.4

Scripts/Prepare_Ext_Auto_Ends.s -6 +537 ...

```
            ro.SHBO_MtrPs = SA_ZP_IXA[3][zz]
            ro.SNHW_MtrPs = SA_ZP_IXA[4][zz]
            ro.SNHO_MtrPs = SA_ZP_IXA[5][zz]

            ro.SHBW_MtrAs = SA_ZP_XIA[1][zz]
            ro.SHBS_MtrAs = SA_ZP_XIA[2][zz]
            ro.SHBO_MtrAs = SA_ZP_XIA[3][zz]
            ro.SNHW_MtrAs = SA_ZP_XIA[4][zz]
            ro.SNHO_MtrAs = SA_ZP_XIA[5][zz]

            IF (ZZ <= @LastIZn@)
                  ro.NHWIIAs = SA_ZP_XIA[4][zz]
                  ro.NHOIIAs = SA_ZP_XIA[5][zz]
              ELSE
                  ro.NHWIIAs = 0.0
                  ro.NHOIIAs = 0.0
            ENDIF


            WRITE RECO=1
ENDLOOP

ENDRUN

*copy %_iter_%_Prepare_Ext_Auto_Ends1.txt+%_iter_%_Prepare_Ext_Auto_Ends2.txt
%_iter_%_Prepare_Ext_Auto_Ends.txt
*del  %_iter_%_Prepare_Ext_Auto_Ends1.txt
*del  %_iter_%_Prepare_Ext_Auto_Ends2.txt

```

Figure 2 Last section of changes made to *Prepare_Ext_Auto_Ends.s* in Ver. 2.4

Changes made to *Trip_Distribution_External.s*

Note that the user's guide shows only two screenshots, Figure 3 and Figure 4, which illustrate the beginning and ending sections of the changes, respectively. An interested user can view the rest of changes by comparing the *Trip_Distribution_External.s* script of the Ver. 2.3.78 Model to that of the Ver. 2.4 Model.

Scripts/Trip_Distribution_External.s -8 +15

```
;==============================================================================================
; Trip_Distribution_External.s  - Version 2.5 Trip Distribution for External Trips
; RJM, RQN 5/14/2018 - Updated to account for new external trip distribution
process on Ver2.5
; 1= Updated external P/A file from %_iter_%_Ext_Trip_Gen_PsAs.dbf to
%_iter_%_Ext_Trip_Gen_PsAs_Adj.dbf
; 2= Updated Maxiters:  HBS= from 27 to 9, HBO from 27 to 15, and NHBW/O from 9
to 15
; 3= Updated NHB FFactor variable names in the look-up table
;==============================================================================================


; Trip_Distribution_External.s  - Version 2.3 Trip Distribution for External Trips
```

Revert hunk | Hunk history

```
;          NHW_MTR_AS  NHW_NMT_AS  NHW_ALL_AS  NHO_MTR_AS  NHO_NMT_AS  NHO_ALL_AS


ExtPsAs    = '%_iter_%_Ext_Trip_Gen_PsAs.dbf' ; Extl Auto Ps, As
ExtPsAs    = '%_iter_%_Ext_Trip_Gen_PsAs_Adj.dbf' ; Extl Auto Ps, As
;;Variables in dbf file:
; TAZ      SHBW_Mtr_Ps  SHBS_Mtr_Ps  SHBO_Mtr_Ps  SNHW_Mtr_Ps  SNHO_Mtr_Ps
;          SHBW_Mtr_As  SHBS_Mtr_As  SHBO_Mtr_As  SNHW_Mtr_As  SNHO_Mtr_As
```

Figure 3 First section of changes made to *Trip_Distribution_External.s* in Ver. 2.4

```
MAXITERS = 27     ; specify GM iterations
MAXITERS = 15     ; specify GM iterations
MAXRMSE  = 0.0001



;  read friction factors file as lookup table
FileI LOOKUPI[1] = "@FFsFile@"
LOOKUP LOOKUPI=1, NAME=FF,
       LOOKUP[1]  = IMP, RESULT=NHBEI,     ;
       LOOKUP[2]  = IMP, RESULT=NHBEA,     ;
       LOOKUP[3]  = IMP, RESULT=NHBEI,     ;
       LOOKUP[4]  = IMP, RESULT=NHBEA,     ;
       LOOKUP[1]  = IMP, RESULT=NHWEI,     ;
       LOOKUP[2]  = IMP, RESULT=NHWEA,     ;
       LOOKUP[3]  = IMP, RESULT=NHOEI,     ;
       LOOKUP[4]  = IMP, RESULT=NHOEA,     ;
       INTERPOLATE=N,SETUPPER=T,FAIL=0,0,0

;  Establish production and attraction vectors here:

SETPA P[1]=ZI.1.SNHW_MtrAs, P[2]=ZI.1.SNHW_MtrAs, P[3]=ZI.1.SNHO_MtrAs, P[
4]=ZI.1.SNHO_MtrAs
SETPA A[1]=ZI.1.SNHW_MtrAs, A[2]=ZI.1.SNHW_MtrAs, A[3]=ZI.1.SNHO_MtrAs, A[
4]=ZI.1.SNHO_MtrAs

MAXITERS = 9      ; specify GM iterations
MAXITERS = 15      ; specify GM iterations
MAXRMSE  = 0.0001
```

Figure 4 Last section of changes made to *Trip_Distribution_External.s* in Ver. 2.4

Changes made to *Trip_Generation.s*

Figure 5 indicates the removal of non-work production modification factors ("P-mods") corresponding to Prince George's County as part of the adjustment.

```
Scripts/Trip_Generation.s  -1  +2                                                        ...

25   25
26   26  ; 3/13/13  applied 15% and 17% reduction on Loudoun County P,A Trip rates
             respectively
27   27  ; 3/14/13  fixed conditions where the  final non-motor P/A share could exceed 1
     28  ; 9/10/19  removed non-work production adjustments for PG County
28   29  ;=================================================================================
             ===========
29   30  ;Parameters and file specifications:
30   31  ;=================================================================
                                                                  Revert hunk   Hunk history
425  426 R="      0,  1.00,  0.85,  1.20,  1.00,  1.00,",  ;;dc  NONCORE
426  427   "      1,  1.00,  0.85,  1.20,  1.00,  1.00,",  ;;dc  CORE
427  428   "     10,  0.95,  1.00,  1.05,  1.00,  1.00,",  ;;mtg
428        "     20,  1.00,  0.88,  0.97,  1.00,  1.00,",  ;;pg
     429   "     20,  1.00,  1.00,  1.00,  1.00,  1.00,",  ;;pg      ;; 9/10/19 HBS/HBO
           changed from 0.88/0.97 to 1.00/1.00
429  430   "     30,  1.00,  1.11,  1.08,  1.00,  1.00,",  ;;arl NONCORE
430  431   "     31,  1.00,  1.11,  1.08,  1.00,  1.00,",  ;;arl CORE
431  432   "     40,  1.00,  1.00,  1.00,  1.00,  1.00,",  ;;alx
```

Figure 5 Changes made to *Trip_Generation.s* in Ver.2.4

Changes made to *Ver23_f_factors.dbf*

The following two figures illustrate some changes made to the *Ver23_f_factors.dbf* file. Specifically, the update: 1) made changes to HBWEI (HBW external interstate), HBWEA (HBW external arterial), HBSEI, HBSEA, HBOEI, HBOEA columns (Figure 6); 2) removed NHBEI and NHBEA columns and added NHWEI, NHWEA, NHOEI, and NHOEA (Figure 7).

1		HBWEI	HBWEA	HBSEI	HBSEA	HBOEI	HBOEA
2	*	984609	984609	984609	984609	984609	984609
3	*	984609	984609	984609	984609	984609	984609
4	*	984609	984609	984609	984609	984609	984609
5	*	554679	984609	777594	984609	615654	984609
6	*	355325	590136	641659	709738	427667	556119
7	*	246882	388216	543380	539905	317518	348612
8	*	181418	272306	467715	425824	246809	234823
9	*	138887	200170	406863	344544	198396	166714
10	*	109702	152496	356371	284052	163619	123206
11	*	88811	119490	313505	237502	137691	93977
12	*	73343	95778	276499	200729	117780	73538
13	*	61571	78219	244160	171065	102114	58769
14	*	52404	64886	215648	146728	89538	47805
15	*	45127	54546	190357	126484	79269	39474
16	*	39254	46379	167832	109454	70762	33020
17	*	34444	39827	147722	94994	63624	27933
18	*	30457	34498	129747	82624	57568	23864
19	*	27114	30111	113682	71975	52381	20567
20	*	24284	26461	99334	62763	47898	17863
21	*	21868	23394	86539	54761	43995	15623

1	HBWEI	HBWEA	HBSEI	HBSEA	HBOEI	HBOEA
2	64277	64277	59969	59969	280459	280459
3	69593	69593	154834	154834	227428	227428
4	71178	71178	249081	249081	195960	195960
5	71122	71122	330139	330139	173093	173093
6	70164	70164	393513	393513	154989	154989
7	68662	68662	438597	438597	139979	139979
8	66818	66818	466716	466716	127176	127176
9	64759	64759	480081	480081	116048	116048
10	62569	62569	481203	481203	106245	106245
11	60304	60304	472574	472574	97526	97526
12	58005	58005	456492	456492	89712	89712
13	55703	55703	434981	434981	82669	82669
14	53418	53418	409760	409760	76291	76291
15	51166	51166	382253	382253	70493	70493
16	48961	48961	353606	353606	65206	65206
17	46808	46808	324718	324718	60372	60372
18	44716	44716	296276	296276	55943	55943
19	42688	42688	268790	268790	51876	51876
20	40727	40727	242617	242617	48137	48137
21	38835	38835	217996	217996	44693	44693

Figure 6 Sample of changes made to HBWEI, HBWEA, HBSEI, HBSEA, HBOEI, HBOEA columns of *Ver23_f_factors.dbf* in Ver. 2.4

NHWEI	NHWEA	NHOEI	NHOEA	NHBEI	NHBEA
75948	75948	30366	30366	984609	984609
77000	77000	50862	50862	984609	984609
75496	75496	65934	65934	984609	984609
73015	73015	76959	76959	570003	984609
70087	70087	84809	84809	372910	622434
66957	66957	90124	90124	263572	427490
63758	63758	93398	93398	196487	310836
60567	60567	95029	95029	152294	235615

Figure 7 Sample of changes made to NHBEI and NHBEA columns and new NHWEI, NHWEA, NHOEI, and NHOEA columns of *Ver23_f_factors.dbf* in Ver. 2.4

Changes made to *hwy_assign_capSpeedLookup.s*

Figure 8 shows changes made to the highway speed lookup table in the *hwy_assign_capSpeedLookup.s* file, which essentially increase free flow speeds by 15% across the board to better match the jurisdiction-level vehicle miles of travel (VMT) data from the Highway Performance Monitoring System (HPMS) after introducing the update to the external trip distribution process. It is worth noting that, because of this update to the speed lookup table, the "view_from_space.s" summary script for the Ver. 2.4 Model has been updated accordingly. Please refer to Section 7.1 for more detail.

```
Support/hwy_assign_capSpeedLookup.s  -7  +7  ...

;
;             areatp > 1    2    3    4    5    6    fac type
;                     ---  ---  ---  ---  ---  ----    V
SPDCAP      SPEED[01]= 15   15   20   25   30   35    ; cen
SPDCAP      SPEED[11]= 55   55   60   60   65   65    ; fwy
SPDCAP      SPEED[21]= 35   35   45   45   50   50    ; maj
SPDCAP      SPEED[31]= 35   35   40   40   40   45    ; min
SPDCAP      SPEED[41]= 30   30   30   35   35   35    ; col
SPDCAP      SPEED[51]= 45   45   50   50   50   55    ; xwy
SPDCAP      SPEED[61]= 20   20   30   30   35   50    ; rmp
SPDCAP      SPEED[01]= 17   17   23   29   35   40    ; cen
SPDCAP      SPEED[11]= 63   63   69   69   75   75    ; fwy
SPDCAP      SPEED[21]= 40   40   52   52   58   58    ; maj
SPDCAP      SPEED[31]= 40   40   46   46   46   52    ; min
SPDCAP      SPEED[41]= 35   35   35   40   40   40    ; col
SPDCAP      SPEED[51]= 52   52   58   58   58   63    ; xwy
SPDCAP      SPEED[61]= 23   23   35   35   40   58    ; rmp
```

Figure 8 Changes made to *hwy_assign_capSpeedLookup.s* in Ver. 2.4

Changes made to *Highway_Assignment_Parallel.s*

Figure 9 and Figure 10 exhibit the beginning and ending of the changes made to the *Highway_Assignment_Parallel.s* script. The changes indicate the removal of bridge penalties in the construction of path-building within the traffic assignment process. An interested user can view the rest of changes by comparing the *Highway_Assignment_Parallel.s* script of the Ver. 2.3.78 Model to that of the Ver. 2.4 Model.

```
Scripts/Highway_Assignment_Parallel.s  -28  +35

                 incorrectly when the model crash at a certain step
2019-05-20 RQN   Modified to fix the misleading subnodes names by
                 separating AM and MD subnodes to AM, PM, MD, and NT subnodes
2019-08-27 RJM Script has been modified to DISALLOW bridge penalties from being
used within the traffic assigment process
            for example:  This line command:         LW.SOV@PRD@IMP = TIME  +
            LI.TIMEPEN   + (LW.SOV@PRD@TOLL/100.0)* SV@PRD@EQM ;SOV   IMP
                           has been changed to this:  LW.SOV@PRD@IMP =
                           TIME                  + (LW.SOV@PRD@TOLL/100.0)*
                           SV@PRD@EQM ;SOV   IMP
            The change affected 28 line commands in all
```

Figure 9 First section of changes made to *Highway_Assignment_Paralle.s* in Ver. 2.4

```
         LW.SOV@PRD@IMP = TIME   + LI.TIMEPEN + (LW.SOV@PRD@TOLL/100.0)*
         SV@PRD@EQM ;SOV   IMP
         LW.HV2@PRD@IMP = TIME   + LI.TIMEPEN + (LW.HV2@PRD@TOLL/100.0)*
         H2@PRD@EQM ;HOV 2 IMP
         LW.HV3@PRD@IMP = TIME   + LI.TIMEPEN + (LW.HV3@PRD@TOLL/100.0)*
         H3@PRD@EQM ;HOV 3+IMP
         LW.CV@PRD@IMP  = TIME   + LI.TIMEPEN + (LW.CV@PRD@TOLL /100.0)*
         CV@PRD@EQM ;CV    IMP
         LW.TRK@PRD@IMP = TIME   + LI.TIMEPEN + (LW.TRK@PRD@TOLL/100.0)*
         TK@PRD@EQM ;Truck IMP
         LW.APX@PRD@IMP = TIME   + LI.TIMEPEN + (LW.APX@PRD@TOLL/100.0)*
         AP@PRD@EQM ;APAX  IMP
         LW.SOV@PRD@IMP = TIME                + (LW.SOV@PRD@TOLL/100.0)*
         SV@PRD@EQM ;SOV   IMP
         LW.HV2@PRD@IMP = TIME                + (LW.HV2@PRD@TOLL/100.0)*
         H2@PRD@EQM ;HOV 2 IMP
         LW.HV3@PRD@IMP = TIME                + (LW.HV3@PRD@TOLL/100.0)*
         H3@PRD@EQM ;HOV 3+IMP
         LW.CV@PRD@IMP  = TIME                + (LW.CV@PRD@TOLL /100.0)*
         CV@PRD@EQM ;CV    IMP
         LW.TRK@PRD@IMP = TIME                + (LW.TRK@PRD@TOLL/100.0)*
         TK@PRD@EQM ;Truck IMP
         LW.APX@PRD@IMP = TIME                + (LW.APX@PRD@TOLL/100.0)*
         AP@PRD@EQM ;APAX  IMP
```

Figure 10 Last section of changes made to *Highway_Assignment_Paralle.s* in Ver. 2.4

1.3.2 Update 2: Re-calibrated the nested-logit mode choice (NLMC) model to year-2007 conditions, following recent updates to person trip calibration targets for commuter rail

This section is largely extracted from a memo detailing the NLMC recalibration after the updates to person trip targets for commuter rail.[18]

1.3.2.1 Motivation

The nested-logit mode choice (NLMC) model, as part of the TPB Version 2.3 Travel Demand Model on the 3,722-TAZ area system, underwent four major calibrations in the past. An overview of prior NLMC model calibrations was provided in a technical report dated October 2011.[19] In retrospect, the four prior calibrations mainly differed in their auto person trip targets. The first calibration used auto person trip targets developed by loading an observed trip table derived from the COG/TPB 2007/2008 Household Travel Survey (HTS) data onto a year-2007 highway network.[20] All the subsequent calibrations used auto person trip targets derived from simulated trip tables, although origins of those person trip tables differed. In particular, the fourth calibration was conducted after making additional adjustments to simulated high-occupant vehicle (HOV) auto person trip targets based on the data from the 2000 Census Transportation Planning Products (CTPP), and the calibrated NLMC model became a part of the official release of the Version 2.3 Travel Model.[21]

All four prior calibrations, on the other hand, used the same set of transit person trip targets developed from a series of regional transit on-board surveys (TOBSs), namely:

- 2008 Metrorail Passenger Survey
- 2008 Regional Bus Survey (supplemented by the Fairfax Connector Bus Survey)
- 2007/2008 Maryland Transit Administration (MTA) Riders On-Board Survey, which included survey information from riders of the Maryland Area Regional Commuter (MARC) trains, and
- 2005 Virginia Railway Express (VRE) Passenger Survey

In June 2019, TPB staff uncovered a discrepancy related to the observed data used for developing commuter rail calibration targets.[22] Specifically, TPB staff found that the percentage of VRE external

[18] Feng Xie, "TPB Version 2.3 Travel Demand Model: Re-Calibrating the Nested-Logit Mode Choice Model Following the Updates to Commuter Rail Person Trip Targets," Memorandum, November 15, 2019.
[19] Mark Moran, "TPB Version 2.3. Travel Demand Model: Calibrating the Nested-Logit Mode Choice Model after Making Adjustments to HOV Auto Person Trip Targets," Technical Report, October 27, 2011.
[20] Mark Moran, "Using CALIBMS and an Observed Trip Table to Calibrate the Nested-logit Mode Choice Model That Is Part of the TPB Version 2.3 Travel Model on the 3,722-TAZ Area System," Memorandum, January 19, 2011.
[21] Ronald Milone, Mark Moran, Meseret Seifu, Hamid Humeida, Maria Martchouk, "Calibration Report for the TPB Travel Forecasting Model, Version 2.3, on the 3,722-Zone Area System," Final report (Washington, D.C.: National Capital Region Transportation Planning Board, January 20, 2012), http://www.mwcog.org/transportation/activities/models/documentation.asp.
[22] Feng Xie, "Updating the Calibration and Validation Targets for Commuter Rail in TPB's Version 2.3 Travel Demand Model," Memorandum, October 21, 2019.

trips (48.99%) derived from the 2005 VRE Passenger Survey data was unrealistically high. Subsequently, TPB staff revisited the original survey data and found two errors associated with data processing. After making corrections to the survey data, TPB staff updated the calibration and validation targets for commuter rail. Consequently, a new round of model calibration and validation was needed to reflect those updates.

As noted in Section 1.3.1, some model improvements had been implemented to improve the distribution of external travel, including adjusting the distribution of internal trip ends of external trips based on the 2014 AirSage data, re-calibrating friction factors (F-factors) in trip distribution, modifying free-flow speeds on the highway network, removing Potomac River bridge penalties from highway assignment, and removing non-work P-mods for Prince George's County. Due to their demonstrated effects on auto-person trip making, updates to auto-person trip calibration targets were needed to account for these model improvements.

Additionally, underestimation of commuter rail ridership had been a perennial issue with TPB's Version 2.3 Travel Demand Model. The recent validation of TPB's Version 2.3.75 Travel Model, for instance, reported a 40% under-estimation of daily commuter rail ridership in 2014.[23] Recognizing the critical role of commuter rail in the long-distance commute market of this region, TPB staff strived to improve the simulation of commuter rail ridership in the Version 2.3 Model relative to observed data.

The investigation suggested that the model's underestimation of commuter rail ridership may partially be attributed to lack of preferential treatment in the model towards commuter rail travel. It is widely acknowledged that the unique characteristics of commuter rail provide additional amenities (utilities) for commuter rail trips: commuter rail service is schedule-based so riders can minimize their waiting times on the platform based on fixed train schedules; commuter rail trains usually provide a seat to every passenger; the ride is usually fast and comfortable, etc. The transit path-building module of the Version 2.3 Model, however, fails to recognize those advantageous features of commuter rail, thereby under-estimating commuter rail trips in mode choice and transit assignment models.

1.3.2.2 Solution

TPB staff addressed the above issues by conducting the fifth calibration of the NLMC model. As explained above, the justifications of the re-calibration of the NLMC model included the following:

- This calibration was warranted by recent updates to transit person trip calibration targets associated with commuter rail.
- This calibration reflected recent model changes TPB staff implemented in a parallel modeling effort to improve the model's estimation of auto-person trips external to this region.

[23] Feng Xie to Dusan Vuksan and Mark Moran, "Year-2014 Validation of TPB's Version 2.3 Travel Demand Model," Memorandum, March 12, 2019, https://www.mwcog.org/assets/1/28/Year-2014_Validation_of_TPBs_Ver2.3_Travel_Demand_Model_v5_March_12_2019.pdf.

- This calibration also included adjustments to model parameters related to commuter rail path building to improve the underestimation of commuter rail ridership.

TPB staff adopted a more incremental approach to improve the commuter rail ridership at the regional level, making sure that changes to the regional travel model would be minimal and defensible. TPB staff avoided station-specific adjustments (such as changes to exit/transfer times and shadow prices) and focused on adjustments to path-building parameters in favor of commuter rail travel. After evaluating a variety of parameters in preliminary modeling tests, TPB staff selected only three mode-specific path-building parameters, IWAITMAX (commuter rail maximum initial waiting time), MODEFAC (weight of commuter rail in-vehicle travel time) and IWAITFAC (factor of actual waiting time to perceived waiting time), for further sensitivity testing.

As part of the calibration effort, TPB staff tested adjustments to model parameters related to commuter rail path building in different combinations and included the best combination of parameter adjustments, changing commuter rail maximum initial waiting time from 60 minutes to 10 minutes (IWAITMAX[4]: 60 to 10) and weight of commuter rail IVTT from 1 to 0.8 (MODEFAC[4]: 1 to 0.8), in the final calibration.

Update 2 comprises changes made to eight scripts and five AEMS control files, as listed in Table 3. The update changed the model results.[24]

Table 3 Affected model components due to Update 2

Purpose	File name	Changes
New calibrated AEMS control files with re-estimated nesting constants	*controls/hbo_nl_mc.ctl,*	Revised
	controls/hbs_nl_mc.ctl	Revised
	controls/hbw_nl_mc.ctl	Revised
	controls/nho_nl_mc.ctl	Revised
	controls/nhw_nl_mc.ctl	Revised
Updated path building model parameters (weight of commuter rail in-vehicle travel time and maximum commuter rail initial waiting time)	*Scripts/Transit_Skims_AM.s*	Revised
	Scripts/Transit_Skims_BM.s	Revised
	Scripts/Transit_Skims_CR.s	Revised
	Scripts/Transit_Skims_MR.s	Revised

[24] Feng Xie, "TPB Version 2.3 Travel Demand Model: Re-Calibrating the Nested-Logit Mode Choice Model Following the Updates to Commuter Rail Person Trip Targets," Memorandum, November 15, 2019.

	Scripts/Transit_Assignment_AB.s	Revised
	Scripts/Transit_Assignment_BM.s	Revised
	Scripts/Transit_Assignment_CR.s	Revised
	Scripts/Transit_Assignment_MR.s	Revised

As a result of the fifth calibration of the NLMC model, the AEMS control files were updated. Due to the large number of changes made to the AEMS control files, the user's guide presents only a subset of the changes for each file (i.e., the beginning and ending of the list of changes).

Changes made to *controls/hbo_nl_mc.ctl*

There were 256 modified lines of code in *hbo_nl_mc.ctl*, but Figure 11 captures only a subset of the changes. Interested users may view the rest of changes by comparing the updated control files in Ver. 2.4 to those in Ver. 2.3.78.

```
controls/hbo_nl_mc.ctl  -265  +265

HBO OP NESTED LOGIT MC - #DATE:  9/17/2011 #VER:  21
HBO OP NESTED LOGIT MC - #DATE: 11/08/2019 #VER:  21
CHOICE            1>DR ALONE  SR2       SR3+      WK-CR     WK-BUS    WK-BU/MR
WK-MR     PNR-CR    KNR-CR    PNR-BUS   KNR-BUS   PNR-BU/MR KNR-BU/MR PNR-MR
KNR-MR
*
*

* SEGMENT  1
NSTC 10 1GRND TOTAL>
NSTC 11 1AUTO      >       0.5     0.00000
NSTC 12 1TRANSIT   >       0.5     0.45317
NSTC 12 1TRANSIT   >       0.5     0.28880
NSTC 20 1TOTAL TRN >
NSTC 21 1WALK ACC  >       0.5     0.00000
NSTC 22 1PNR ACC   >       0.5    -2.50663
NSTC 23 1KNR ACC   >       0.5    -6.06114
NSTC 22 1PNR ACC   >       0.5    -2.30448
NSTC 23 1KNR ACC   >       0.5    -6.10074
NSTC 30 1WLK TRN
NSTC 31 1WLK CR    >       1.0     0.05410
NSTC 32 1WLK BUS   >       1.0     0.01251
NSTC 33 1WLK BU/MR >       1.0     0.45714
NSTC 31 1WLK CR    >       1.0     0.09148
NSTC 32 1WLK BUS   >       1.0     0.07844
NSTC 33 1WLK BU/MR >       1.0     0.55152
NSTC 34 1WLK METRO >       1.0     0.00000
NSTC 40 1PNR TRN
```

Figure 11 Beginning and ending sections of changes made to hbo_nl_mc.ctl

Changes made to *controls/hbs_nl_mc.ctl*

There were 193 modified lines of code in *hbs_nl_mc.ctl*, but Figure 12 captures only a subset of the changes. Interested users may view the rest of changes by comparing the updated control files in Ver. 2.4 to those in Ver. 2.3.78.

```
▼ controls/hbs_nl_mc.ctl  -193  +193                                                   ...

  1        HBS OP NESTED LOGIT MC - #DATE:  9/17/2011 #VER:  21
        1  HBS OP NESTED LOGIT MC - #DATE: 11/08/2019 #VER:  21
  2     2  CHOICE           1>DR ALONE  SR2       SR3+      WK-CR     WK-BUS    WK-BU/MR
           WK-MR     PNR-CR    KNR-CR    PNR-BUS   KNR-BUS   PNR-BU/MR KNR-BU/MR PNR-MR
           KNR-MR
  3     3  *
  4     4  *

669   669  * SEGMENT  1
670   670  NSTC 10 1GRND TOTAL>
671   671  NSTC 11 1AUTO     >      0.5    0.00000
672        NSTC 12 1TRANSIT  >      0.5   -1.80327
      672  NSTC 12 1TRANSIT  >      0.5    0.73273
673   673  NSTC 20 1TOTAL TRN >
674   674  NSTC 21 1WALK ACC  >     0.5    0.00000
675        NSTC 22 1PNR ACC   >     0.5   -1.74474
676        NSTC 23 1KNR ACC   >     0.5   -5.09216
      675  NSTC 22 1PNR ACC   >     0.5   -3.27490
      676  NSTC 23 1KNR ACC   >     0.5   -6.96103
677   677  NSTC 30 1WLK TRN
678        NSTC 31 1WLK CR    >     1.0    1.24196
679        NSTC 32 1WLK BUS   >     1.0    1.85744
680        NSTC 33 1WLK BU/MR >     1.0    1.90245
      678  NSTC 31 1WLK CR    >     1.0    1.03824
      679  NSTC 32 1WLK BUS   >     1.0    1.71237
      680  NSTC 33 1WLK BU/MR >     1.0    0.73502
```

Figure 12 Beginning and ending sections of changes made to hbs_nl_mc.ctl

Changes made to *controls/hbw_nl_mc.ctl*

There were 286 modified lines of code in *hbw_nl_mc.ctl*, but Figure 13 captures only a subset of the changes. Interested users may view the rest of changes by comparing the updated control files in Ver. 2.4 to those in Ver. 2.3.78.

```
controls/hbw_nl_mc.ctl  -286  +285

HBW AM NESTED LOGIT MC - #DATE:  9/17/2011 #VER:   21
HBW AM NESTED LOGIT MC - #DATE: 11/08/2019 #VER:   21
CHOICE            1>DR ALONE   SR2        SR3+       WK-CR      WK-BUS     WK-BU/MR
WK-MR      PNR-CR     KNR-CR     PNR-BUS    KNR-BUS    PNR-BU/MR KNR-BU/MR PNR-MR
KNR-MR
*
*

* SEGMENT   1
NSTC 10 1GRND TOTAL>
NSTC 11 1AUTO       >       0.5      0.00000
NSTC 12 1TRANSIT    >       0.5      3.72445
NSTC 12 1TRANSIT    >       0.5      2.85474
NSTC 20 1TOTAL TRN >
NSTC 21 1WALK ACC   >       0.5      0.00000
NSTC 22 1PNR ACC    >       0.5     -3.76433
NSTC 23 1KNR ACC    >       0.5     -7.33524
NSTC 22 1PNR ACC    >       0.5     -3.32099
NSTC 23 1KNR ACC    >       0.5     -7.02088
NSTC 30 1WLK TRN
NSTC 31 1WLK CR     >       1.0     -0.80725
NSTC 32 1WLK BUS    >       1.0     -1.44958
NSTC 33 1WLK BU/MR >        1.0     -1.46039
NSTC 31 1WLK CR     >       1.0     -0.74745
NSTC 32 1WLK BUS    >       1.0     -1.37011
NSTC 33 1WLK BU/MR >        1.0     -1.27764
NSTC 34 1WLK METRO >        1.0      0.00000
```

Figure 13 Beginning and ending sections of changes made to hbw_nl_mc.ctl

Changes made to *controls/nho_nl_mc.ctl*

There were 247 modified lines of code in nho_*nl_mc.ctl*, but Figure 14 captures only a subset of the changes. Interested users may view the rest of changes by comparing the updated control files in Ver. 2.4 to those in Ver. 2.3.78.

```
▼ controls/nho_nl_mc.ctl  -247  +247  ...

NHO OP NESTED LOGIT MC - #DATE: 11/08/2019 #VER:  21
CHOICE             1>DR ALONE  SR2        SR3+       WK-CR      WK-BUS     WK-BU/MR
WK-MR      PNR-CR     KNR-CR     PNR-BUS    KNR-BUS    PNR-BU/MR KNR-BU/MR PNR-MR
KNR-MR
*
*

* SEGMENT  1
NSTC 10 1GRND TOTAL>
NSTC 11 1AUTO      >       0.5     0.00000
NSTC 12 1TRANSIT   >       0.5    -2.89068
NSTC 12 1TRANSIT   >       0.5    -0.96877
NSTC 20 1TOTAL TRN >
NSTC 21 1WALK ACC  >       0.5     0.00000
NSTC 22 1PNR ACC   >       0.5    -0.84618
NSTC 23 1KNR ACC   >       0.5    -3.05790
NSTC 22 1PNR ACC   >       0.5    -1.17148
NSTC 23 1KNR ACC   >       0.5    -3.87695
NSTC 30 1WLK TRN
NSTC 31 1WLK CR    >       1.0     0.72167
NSTC 32 1WLK BUS   >       1.0     0.64344
NSTC 33 1WLK BU/MR >       1.0     5.19110
NSTC 31 1WLK CR    >       1.0     0.47551
NSTC 32 1WLK BUS   >       1.0     0.38195
NSTC 33 1WLK BU/MR >       1.0     3.30652
NSTC 34 1WLK METRO >       1.0     0.00000
```

Figure 14 Beginning and ending sections of changes made to nho_nl_mc.ctl

Changes made to *controls/nhw_nl_mc.ctl*

Figure 15 shows the beginning and ending sections of changes made to the nhw_nl_mc.ctl control file.

```
controls/nhw_nl_mc.ctl  -275  +275

NHW OP NESTED LOGIT MC - #DATE:  9/18/2011 #VER:  21
NHW OP NESTED LOGIT MC - #DATE: 11/08/2019 #VER:  21
CHOICE            1>DR ALONE  SR2        SR3+       WK-CR      WK-BUS     WK-BU/MR
WK-MR      PNR-CR     KNR-CR     PNR-BUS    KNR-BUS    PNR-BU/MR  KNR-BU/MR  PNR-MR
KNR-MR
*
*

* SEGMENT  1
NSTC 10 1GRND TOTAL>
NSTC 11 1AUTO      >      0.5     0.00000
NSTC 12 1TRANSIT   >      0.5    -1.70935
NSTC 12 1TRANSIT   >      0.5    75.58862
NSTC 20 1TOTAL TRN >
NSTC 21 1WALK ACC  >      0.5     0.00000
NSTC 22 1PNR ACC   >      0.5    -1.95080
NSTC 23 1KNR ACC   >      0.5    -4.17573
NSTC 22 1PNR ACC   >      0.5    -6.97701
NSTC 23 1KNR ACC   >      0.5   -11.50004
NSTC 30 1WLK TRN
NSTC 31 1WLK CR    >      1.0     0.07631
NSTC 32 1WLK BUS   >      1.0    -1.00068
NSTC 33 1WLK BU/MR >      1.0     4.39187
NSTC 31 1WLK CR    >      1.0    -2.74144
NSTC 32 1WLK BUS   >      1.0    -9.84239
NSTC 33 1WLK BU/MR >      1.0    -7.07500
NSTC 34 1WLK METRO >      1.0     0.00000
```

Figure 15 Beginning and ending sections of changes made to *nhw_nl_mc.ctl*

Changes made to *Transit_Skim_AB.s*

Changes made to the Transit_Skim_AB.s script are shown in Figure 16.

```
Scripts/Transit_Skims_AB.s  -2  +2

;---- factors to convert actual time to perceived time ----

MODEFAC[1]  = 10*1.0  ;---- in-vehicle time
MODEFAC[1]  = 3*1.0,0.8,6*1.0  ;---- in-vehicle time
MODEFAC[11] = 1.50    ;---- drive access time
MODEFAC[12] = 2.00    ;---- transit transfer time
MODEFAC[13] = 2.00    ;---- walk network time

IWAITFAC[1] = 10*2.50
XWAITFAC[1] = 10*2.50
IWAITMAX[1] = 10*60.0
IWAITMAX[1] = 3*60.0,10.0,6*60.0
XWAITMIN[1] = 2*4.0,0.0,4.0,0.0,3*4.0,10.0,4.0

;---- boarding and transfer penalties ----
```

Figure 16 Changes made to the *Transit_Skim_AB.s* script

Changes made to *Transit_Skim_BM.s*

```
Scripts/Transit_Skims_BM.s  -2  +2

;---- factors to convert actual time to perceived time ----

MODEFAC[1]  = 10*1.0  ;---- in-vehicle time
MODEFAC[1]  = 3*1.0,0.8,6*1.0  ;---- in-vehicle time
MODEFAC[11] = 1.50    ;---- drive access time
MODEFAC[12] = 2.00    ;---- transit transfer time
MODEFAC[13] = 2.00    ;---- walk network time

IWAITFAC[1] = 10*2.50
XWAITFAC[1] = 10*2.50
IWAITMAX[1] = 10*60.0
IWAITMAX[1] = 3*60.0,10.0,6*60.0
XWAITMIN[1] = 2*4.0,0.0,4.0,0.0,3*4.0,10.0,4.0

;---- boarding and transfer penalties ----
```

Figure 17 Changes made to the *Transit_Skim_BM.s* script

Changes made to *Transit_Skim_CR.s*

Scripts/Transit_Skims_CR.s -2 +2

```
;---- factors to convert actual time to perceived time ----

MODEFAC[1]  = 10*1.0  ;---- in-vehicle time
MODEFAC[1]  = 3*1.0,0.8,6*1.0  ;---- in-vehicle time
MODEFAC[11] = 1.50    ;---- drive access time
MODEFAC[12] = 2.00    ;---- transit transfer time
MODEFAC[13] = 2.00    ;---- walk network time
```

```
IWAITFAC[1] = 10*2.50
XWAITFAC[1] = 10*2.50
IWAITMAX[1] = 10*60.0
IWAITMAX[1] = 3*60.0,10.0,6*60.0
XWAITMIN[1] = 2*4.0,0.0,4.0,0.0,3*4.0,10.0,4.0

;---- boarding and transfer penalties ----
```

Figure 18 Changes made to the *Transit_Skim_CR.s* script

Changes made to *Transit_Skim_MR.s*

Scripts/Transit_Skims_MR.s -2 +2

```
;---- factors to convert actual time to perceived time ----

MODEFAC[1]  = 10*1.0  ;---- in-vehicle time
MODEFAC[1]  = 3*1.0,0.8,6*1.0  ;---- in-vehicle time
MODEFAC[11] = 1.50    ;---- drive access time
MODEFAC[12] = 2.00    ;---- transit transfer time
MODEFAC[13] = 2.00    ;---- walk network time
```

```
IWAITFAC[1] = 10*2.50
XWAITFAC[1] = 10*2.50
IWAITMAX[1] = 10*60.0
IWAITMAX[1] = 3*60.0,10.0,6*60.0
XWAITMIN[1] = 2*4.0,0.0,4.0,0.0,3*4.0,10.0,4.0

;---- boarding and transfer penalties ----
```

Figure 19 Changes made to the *Transit_Skim_MR.s* script

Changes made to *Transit_Assignment_AB.s*

```
Scripts/Transit_Assignment_AB.s  -2  +2                                   ...

;---- factors to convert actual time to perceived time ----

MODEFAC[1]  = 10*1.0  ;---- in-vehicle time
MODEFAC[1]  = 3*1.0,0.8,6*1.0  ;---- in-vehicle time
MODEFAC[11] = 1.50    ;---- drive access time
MODEFAC[12] = 2.00    ;---- transit transfer time
MODEFAC[13] = 2.00    ;---- walk network time
                                                   Revert hunk   Hunk history

IWAITFAC[1] = 10*2.50
XWAITFAC[1] = 10*2.50
IWAITMAX[1] = 10*60.0
IWAITMAX[1] = 3*60.0,10.0,6*60.0
XWAITMIN[1] = 2*4.0,0.0,4.0,0.0,3*4.0,10.0,4.0

;---- boarding and transfer penalties ----
```

Figure 20 Changes made to the *Transit_Assignment_AB.s* script

Changes made to *Transit_Assignment_BM.s*

```
Scripts/Transit_Assignment_BM.s  -2  +2                                   ...

;---- factors to convert actual time to perceived time ----

MODEFAC[1]  = 10*1.0  ;---- in-vehicle time
MODEFAC[1]  = 3*1.0,0.8,6*1.0  ;---- in-vehicle time
MODEFAC[11] = 1.50    ;---- drive access time
MODEFAC[12] = 2.00    ;---- transit transfer time
MODEFAC[13] = 2.00    ;---- walk network time


IWAITFAC[1] = 10*2.50
XWAITFAC[1] = 10*2.50
IWAITMAX[1] = 10*60.0
IWAITMAX[1] = 3*60.0,10.0,6*60.0
XWAITMIN[1] = 2*4.0,0.0,4.0,0.0,3*4.0,10.0,4.0

;---- boarding and transfer penalties ----
```

Figure 21 Changes made to the *Transit_Assignment_BM.s* script

Changes made to *Transit_Assignment_CR.s*

Scripts/Transit_Assignment_CR.s -2 +2

```diff
 
 ;---- factors to convert actual time to perceived time ----
 
-MODEFAC[1]  = 10*1.0  ;---- in-vehicle time
+MODEFAC[1]  = 3*1.0,0.8,6*1.0  ;---- in-vehicle time
 MODEFAC[11] = 1.50    ;---- drive access time
 MODEFAC[12] = 2.00    ;---- transit transfer time
 MODEFAC[13] = 2.00    ;---- walk network time

 
 IWAITFAC[1] = 10*2.50
 XWAITFAC[1] = 10*2.50
-IWAITMAX[1] = 10*60.0
+IWAITMAX[1] = 3*60.0,10.0,6*60.0
 XWAITMIN[1] = 2*4.0,0.0,4.0,0.0,3*4.0,10.0,4.0
 
 ;---- boarding and transfer penalties ----
```

Figure 22 Changes made to the *Transit_Assignment_CR.s* script

Changes made to *Transit_Assignment_MR.s*

Scripts/Transit_Assignment_MR.s -2 +2

```diff
 
 ;---- factors to convert actual time to perceived time ----
 
-MODEFAC[1]  = 10*1.0  ;---- in-vehicle time
+MODEFAC[1]  = 3*1.0,0.8,6*1.0  ;---- in-vehicle time
 MODEFAC[11] = 1.50    ;---- drive access time
 MODEFAC[12] = 2.00    ;---- transit transfer time
 MODEFAC[13] = 2.00    ;---- walk network time

 
 IWAITFAC[1] = 10*2.50
 XWAITFAC[1] = 10*2.50
-IWAITMAX[1] = 10*60.0
+IWAITMAX[1] = 3*60.0,10.0,6*60.0
 XWAITMIN[1] = 2*4.0,0.0,4.0,0.0,3*4.0,10.0,4.0
 
 ;---- boarding and transfer penalties ----
```

Figure 23 Changes made to the *Transit_Assignment_MR.s* script

1.3.3 Update 3: Restored the number of iterations used in external trip distribution of HBS and HBO trips

1.3.3.1 Motivation

The Version 2.3 Model family uses the gravity model in the trip distribution step. The gravity model in the Ver. 2.3 Model is doubly constrained to ensure that total number of trips leaving each zone will match trip productions (Ps) of this zone (estimated in the trip generation step) and total number trips going to each zone will match trip attractions (As) to this zone. Two parameters, maximum number of iteration (MAXITERS) and maximum root mean square error (MAXRMSE), were used to control the cutoff of the repeated adjustment process of the gravity model. These parameters set criteria that guarantee that the gravity model process will stop when at least one of the conditions is satisfied. Update 1 made some changes to the MAXITERS values for HBS, HBO, NHBW and NHBO trips. Specifically, the MAXITERS value for HBS was dropped from 27 to 9, the HBO value was reduced from 27 to 15, and the NHBW and NHBO values were increased from 9 to 15. During subsequent sensitivity testing, however, staff found that the reduced number of iterations in HBS and HBO external trip distribution resulted in looser model convergence, and thus had adverse effects on the sensitivity of modeling results. Consequently, staff decided to restore the MAXITERS values for HBS and HBO trips to their original values.

1.3.3.2 Solution

Update 3 restored the MAXITERS values of the gravity model from the Ver. 2.3.78 Model, changing the value for HBS trips from 9 to 27 and that for HBO trips from 15 to 27. This change was made in the *Trip_Distribution_External.s* script. Reverting to the original numbers of iterations in the trip distribution resulted in more intuitive directionality of the VMT change in sensitivity testing.[25]

Table 4 Affected model components due to Update 3

File name	Changes
Scripts\Trip_Distribution_External.s	Revised

[25] Meseret Seifu, "Ver. 2.3.85 Travel Model: Technical Updates and Sensitivity Tests," Memorandum, April 14, 2020, p.1.

Changes made to *Trip_Distribution_External.s*

```
Scripts/Trip_Distribution_External.s -2 +2

SETPA P[1]=ZI.3.SHBS_MtrPs, P[2]=ZI.3.SHBS_MtrPs
SETPA A[1]=ZI.3.SHBS_MtrAs, A[2]=ZI.3.SHBS_MtrAs

MAXITERS = 9     ; specify GM iterations
MAXITERS = 27     ; specify GM iterations
MAXRMSE   = 0.0001



SETPA P[1]=ZI.3.SHBO_MtrPs, P[2]=ZI.3.SHBO_MtrPs
SETPA A[1]=ZI.3.SHBO_MtrAs, A[2]=ZI.3.SHBO_MtrAs

MAXITERS = 15     ; specify GM iterations
MAXITERS = 27     ; specify GM iterations
MAXRMSE   = 0.0001
```

Figure 24 Changes made to the *Trip_Distribution_External.s* script in Ver. 2.4

1.3.4 Update 4: Created additional node ranges for each jurisdiction in the modeled area

This section is largely extracted from a memo discussing the effort to create additional node ranges for each jurisdiction in the modeled area.[26]

1.3.4.1 Motivation

Due to the frequent updates to the TPB Travel Demand Model and continuous enhancements to the TPB planning networks that provide inputs to the model, node number ranges allocated for jurisdictions are running out, especially in Washington, D.C. and Montgomery County. For example, Washington, D.C. was allocated 2,000 highway nodes and all the nodes were used by early 2020. The potential insufficiency of reserved node number ranges highlighted the need for larger ranges of nodes for future use.

1.3.4.2 Solution

Staff included additional node numbering ranges by adding 100,000 to existing beginning/ending highway node numbers reserved for each jurisdiction. For example, the highway network in Ver. 2.3 reserved 2000 nodes (20000 to 21999) for Washington, D.C., while the highway network in Ver. 2.4 reserves two sets of nodes for Washington, D.C.: one ranging from 20000 to 21999 and the other ranging from 120000 to 121999. Thus, the number of allocated highway nodes for Washington, D.C. in

[26] Sanghyeon Ko and Feng Xie to Mark Moran, “Node Range Extension for TPB Travel Demand Model and Test Results with Version 2.3.86 Model,” April 16, 2020.

Ver. 2.4 becomes 4,000, which is double what it was in Version 2.3. The existing and additional highway node numbers per jurisdiction in Version 2.4 are shown in Table 5.

Table 5 Node ranges for highway network in Version 2.4

Jurisdiction	Current			Additional (Current + 100000)		
	Beginning Node	Ending Node	Allocated Nodes	Beginning Node	Ending Node	Allocated Nodes
District of Columbia	20000	21999	2000	120000	121999	2000
Montgomery Co., MD	22000	25999	4000	122000	125999	4000
Prince George's Co., MD	26000	29999	4000	126000	129999	4000
Arlington Co., VA	30000	31999	2000	130000	131999	2000
City of Alexandria, VA	32000	33999	2000	132000	133999	2000
Fairfax Co., VA	34000	37999	4000	134000	137999	4000
Loudoun Co., VA	38000	39999	2000	138000	139999	2000
Prince William Co., VA	40000	41999	2000	140000	141999	2000
Frederick Co., MD	42000	43999	2000	142000	143999	2000
Howard Co., MD	44000	45499	1500	144000	145499	1500
Anne Arundel Co., MD	45500	46999	1500	145500	146999	1500
Charles Co., MD	47000	47999	1000	147000	147999	1000
Carroll Co., MD	48000	48999	1000	148000	148999	1000
Calvert Co., MD	49000	49499	500	149000	149499	500
St. Mary's Co., MD	49500	49999	500	149500	149999	500
King George Co., VA	50000	50499	500	150000	150499	500
City of Fredericksburg, VA	50500	50999	500	150500	150999	500
Stafford Co., VA	51000	51999	1000	151000	151999	1000
Spotsylvania Co., VA	52000	52999	1000	152000	152999	1000
Fauquier Co., VA	53000	53999	1000	153000	153999	1000
Clarke Co., VA	54000	54499	500	154000	154499	500
Jefferson Co., WVA	54500	54999	500	154500	154999	500
Reserved Nodes	90000	90999	1000			

Staff performed tests and confirmed that the mechanism of specifying multiple node ranges for a jurisdiction worked in the network database. Staff also updated relevant model scripts to work with the additional node ranges, as shown in Table 6. Modeling tests before and after the update indicated no changes to model results.[27]

[27] Sanghyeon Ko and Feng Xie to Mark Moran, "Node Range Extension for TPB Travel Demand Model and Test Results with Version 2.3.86 Model," April 16, 2020.

Table 6 Affected model components due to Update 4

File name	Changes
Scripts\Walkacc.s	Revised
Scripts\Transit_Skims_MR|AB|CR|BM.s	Revised
Scripts\Transit_Assignment_ MR|AB|CR|BM.s	Revised
Scripts\Autoacc5.s	Revised
Scripts\unbuild_net.s	Revised
Scripts\Parker.s	Revised
Scripts\highway_Assignment_Parallel.s	Revised

The changes made to various Cube Voyager scripts are shown in Figure 25 through Figure 37.

Changes made to *walkacc.s*

```
Scripts/walkacc.s  -1  +1

;;          opposed to using the sequence number as TAZ (K), as notified by AECOM - RJM
;; 04/17/17 - Corrected the distance notes: "tenths" to "hundredths" - DQN
;; Dimensions:
NodeSize     = 60000        ;; Highway node size
NodeSize     = 160000        ;; Highway node size
TAZSTASize   =  7999        ;; TAZ/Sta dimensions
ITAZSize     =  3675        ;; Internal TAZ dimensions
XLinkSize    =  1000        ;; Max. no. of user-defined Add/Del links
```

Figure 25 Changes made to *walkacc.s* in Version 2.4

Changes made to *Transit_Skims_MR|AB|CR|BM.s*

```
Scripts/Transit_Skims_AB.s  -1  +1

RUN PGM=TRNBUILD
 NETI = ZONEHWY.NET
 MATO = transit.temp.ab.skm
 maxnode = 60000
 maxnode = 160000

 HWYTIME = @TIME_PERIOD@HTIME

```

Figure 26 Changes made to *Transit_Skims_AB.s* in Version 2.4

Scripts/Transit_Skims_BM.s -1 +1 ...

```
RUN PGM=TRNBUILD
 NETI = ZONEHWY.NET
 MATO = transit.temp.bm.skm
 maxnode = 60000
 maxnode = 160000

 HWYTIME = @TIME_PERIOD@HTIME

```

Figure 27 Changes made to *Transit_Skims_BM.s* in Version 2.4

Scripts/Transit_Skims_CR.s -1 +1 ...

```
RUN PGM=TRNBUILD
 NETI = ZONEHWY.NET
 MATO = transit.temp.cr.skm
 maxnode = 60000
 maxnode = 160000

 HWYTIME = @TIME_PERIOD@HTIME

```

Figure 28 Changes made to *Transit_Skims_CR.s* in Version 2.4

Scripts/Transit_Skims_MR.s -1 +1 ...

```
RUN PGM=TRNBUILD
 NETI = ZONEHWY.NET
 MATO = transit.temp.mr.skm
 maxnode = 60000
 maxnode = 160000

 HWYTIME = @TIME_PERIOD@HTIME

```

Figure 29 Changes made to *Transit_Skims_MR.s* in Version 2.4

Changes made to *Transit_Assignment_ MR|AB|CR|BM.s*

Scripts/Transit_Assignment_AB.s -1 +1 ...

```
RUN PGM=TRNBUILD
 NETI = ZONEHWY.NET
 MATI = @MATIN@
 maxnode = 60000
 maxnode = 160000

 HWYTIME = @TIME_PERIOD@HTIME

```

Figure 30 Changes made to *Transit_Assignment_AB.s* in Version 2.4

```diff
Scripts/Transit_Assignment_BM.s  -1  +1

 RUN PGM=TRNBUILD
  NETI = ZONEHWY.NET
  MATI = @MATIN@
- maxnode = 60000
+ maxnode = 160000

  HWYTIME = @TIME_PERIOD@HTIME

```

Figure 31 Changes made to *Transit_Assignment_BM.s* in Version 2.4

```diff
Scripts/Transit_Assignment_CR.s  -1  +1

 RUN PGM=TRNBUILD
  NETI = ZONEHWY.NET
  MATI = @MATIN@
- maxnode = 60000
+ maxnode = 160000

  HWYTIME = @TIME_PERIOD@HTIME

```

Figure 32 Changes made to *Transit_Assignment_CR.s* in Version 2.4

```diff
Scripts/Transit_Assignment_MR.s  -1  +1

 RUN PGM=TRNBUILD
  NETI = ZONEHWY.NET
  MATI = @MATIN@
- maxnode = 60000
+ maxnode = 160000

  HWYTIME = @TIME_PERIOD@HTIME

```

Figure 33 Changes made to *Transit_Assignment_MR.s* in Version 2.4

Changes made to *Autoacc5.s*

Scripts/Autoacc5.s -3 +3 ...

```
;;--------------------------------------------------------------------------------
     IF (PentTAZ[I] > 0 && j = pentsta)

         Print Printo=1 list = ' SUPPLINK N=',I(5),'-',Pentnode(5),' DIST=',AMDIST(6),
         Print Printo=1 list = ' SUPPLINK N=',I(5),'-',Pentnode(6),' DIST=',AMDIST(6),
                      ' ONEWAY=Y MODE=11 SPEED=',AMSPD(4)

         Print Printo=2 list = ' SUPPORT N=',I(5),'-',Pentnode(5),' DIST=',AMDIST(6),
         Print Printo=2 list = ' SUPPORT N=',I(5),'-',Pentnode(6),' DIST=',AMDIST(6),
                      ' ONEWAY=Y MODE=11 SPEED=',AMSPD(4)


         Print Printo=3 list = ' SUPPORT N=',I(5),'-',Pentnode(5),' DIST=',OPDIST(6),
         Print Printo=3 list = ' SUPPORT N=',I(5),'-',Pentnode(6),' DIST=',OPDIST(6),
                      ' ONEWAY=Y MODE=11 SPEED=',OPSPD(4)
     ENDIF
;;  end  AM/OP Pentagon Links-------------------------------------------
```

Figure 34 Changes made to *Autoacc5.s* in Version 2.4

Changes made to *unbuild_net.s*

Scripts/unbuild_net.s -1 +1 ...

```

linko= @basepath@\@out_link@,
  format=DBF,
  include=a(5),b(5),distance(7.2),spdclass(7),capclass(7),jur(7),Screen(5),ftype(7),toll(
  9),tollgrp(5),
  include=a(6),b(6),distance(7.2),spdclass(7),capclass(7),jur(7),Screen(5),ftype(7),toll(
  9),tollgrp(5),
           amlane(3),amlimit(3),pmlane(3),pmlimit(3),oplane(3),oplimit(3),edgeid(10),linkid
           (10),netyear(8),Shape_Leng(7.2),
           projectid(10)

```

Figure 35 Changes made to *unbuild_net.s* in Version 2.4

Changes made to *Parker.s*

Scripts/Parker.s -10 +10

```
        _time  = _walkpk + STAPKSHAD + (@MinPerDoll@  * _parkam)
        _xtime = _time/100.0

        Print printo =1   list = 'SUPPLINK N=',STAP(5),'-',STAT(5),' ONEWAY=Y MODE=15',
        Print printo =1   list = 'SUPPLINK N=',STAP(6),'-',STAT(6),' ONEWAY=Y MODE=15',
                                 ' DIST= ',_parkam(5),' TIME= ', _Xtime(8.2)

        _time  = _walkop + STAOPSHAD + (@MinPerDoll@  * _parkop)
        _xtime = _time/100.0

        Print printo =6   list = 'SUPPLINK N=',STAP(5),'-',STAT(5),' ONEWAY=Y MODE=15',
        Print printo =6   list = 'SUPPLINK N=',STAP(6),'-',STAT(6),' ONEWAY=Y MODE=15',
                                 ' DIST= ',_parkop(5),' TIME= ', _Xtime(8.2)
ENDIF

        _time  = _walkpk + STAPKSHAD + (@MinPerDoll@  * _parkam)
        _xtime = _time/100.0

        Print printo =2   list = 'SUPPLINK N=',STAP(5),'-',STAT(5),' ONEWAY=Y MODE=15',
        Print printo =2   list = 'SUPPLINK N=',STAP(6),'-',STAT(6),' ONEWAY=Y MODE=15',
```

Figure 36 Changes made to *Parker.s* in Version 2.4

Changes made to *Highway_Assignment_Parallel.s*

Scripts/Highway_Assignment_Parallel.s -2 +2

```

    ; PRINT TO check

print LIST=A(5),' ',B(5),DISTANCE(7.2),' ',@PCTADT@(4.3),' ',@prd@LANE(2.0),' ',
print LIST=A(6),' ',B(6),DISTANCE(7.2),' ',@PCTADT@(4.3),' ',@prd@LANE(2.0),' ',
    @prd@HRLKCAP(5.0),' ',@prd@HRLNCAP(5.0),' ',
    %_iter_%@prd@VOL(8.2),' ',
    %_iter_%@prd@ffspd(5.1),' ',%_iter_%@prd@VC(6.4),' ',%_iter_%@prd@VDF(6.4),' ',

    ; PRINT TO check

print LIST=A(5),' ',B(5),DISTANCE(7.2),' ',@PCTADT@(4.3),' ',@prd@LANE(2.0),' ',
print LIST=A(6),' ',B(6),DISTANCE(7.2),' ',@PCTADT@(4.3),' ',@prd@LANE(2.0),' ',
    @prd@HRLKCAP(5.0),' ',@prd@HRLNCAP(5.0),' ',
    %_iter_%@prd@VOL(8.2),' ',
    %_iter_%@prd@ffspd(5.1),' ',%_iter_%@prd@VC(6.4),' ',%_iter_%@prd@VDF(6.4),' ',
```

Figure 37 Changes made to *Highway_Assignment_Parellel.s* in Version 2.4

1.3.5 Update 5: Adjusted volume-to-capacity (V/C) ratio toll-search stopping criteria

This section is largely extracted from a memo[28] documenting the recommendation for the use of new toll-search stopping criteria in the toll setting process of the Version 2.4 Model based on the testing of various tolling scenarios.

1.3.5.1 Motivation

According to prior investigations, the toll estimates from the toll-setting algorithm in the Version 2.3 Model family were considerably lower than the observed tolls on high occupancy toll (HOT) lanes.[29] The core component of the toll setting process is a toll searching algorithm that incrementally raises the tolls on HOT lane facilities until target Volume-to-Capacity (V/C) ratios that would ensure both free-flow conditions and an optimal vehicle throughput are achieved. The toll-search stopping criteria in the toll setting algorithm of the Ver. 2.3 Model were defined by the target V/C range of (0.95 - 1.01).

Through testing, TPB staff realized that the four updates discussed in the preceding sections (Section 1.3.1 to Section 1.3.4) would have led to even lower toll estimates from the toll-setting algorithm in the Ver. 2.3 travel models. In response, staff carried out diagnostic tests to identify the toll-search stopping criteria that would provide a better match of the estimated tolls to the observed data while maintaining a reasonable vehicle throughput on HOT lanes.

It is important to note that most external users of the travel model do not execute the toll setting steps of the model (including the toll setting "pump prime" model run).

1.3.5.2 Solution

Staff carried out three tests with three different target V/C ranges of (0.80-0.85), (0.85-0.90) and (0.90-0.95). Staff compared year 2019 and 2045 testing results to the corresponding results from the Base2019 and Base2045 model runs carried out with the inputs from the 2020 Amendment to Visualize 2045 modeling analysis and using the existing target V/C range of (0.95-1.01). It's worth noting that the current toll searching algorithm does not utilize the lower-end value of the threshold range since that value is used only when tolls are allowed to be reduced during toll searching.

The comparison shows that the test with the target V/C range of (0.9-0.95) produced lower but reasonable tolls than two other tests with the target V/C ranges of (0.80-0.85) and (0.85-0.90), while producing a vehicle throughput that is higher than the other two tests and closer to Base2019. Staff also found the V/C range of (0.90-0.95) more desirable as it corresponds to the speed range of 45 to 55 miles per hour based on the volume-delay function. These speeds are considered to be minimum speeds to ensure free-flow conditions on managed lanes.

---

[28] Anant Choudhary and Dusan Vuksan to Files, "Toll Setting Process Recommendation for the Version 2.4 Travel Demand Model," Memorandum, October 16, 2020.

[29] Anant Choudhary, "Sensitivity Tests Using Lower Toll Setting Process Stopping Criteria V/C Threshold Range of (0.90–0.95)," Memorandum, April 15, 2016; Feng Xie, "Access to Historical Toll Data," December 17, 2015.

Based on the evaluation of testing results, staff recommended that the target V/C range of (0.90-0.95) be used as the new toll-search stopping criteria in the toll-setting process of the Version 2.4 Model. With this lower (and more stringent) target in toll searching, internal (COG) model users will experience longer run times when conducting model runs that include the toll setting process (e.g., those for future air quality conformity assessments).

Since most external (non-COG) users do not execute the toll setting steps of the model (including its pump prime run), the changes due to Update 5 will not affect their modeling exercises. For model users who have to run the toll setting process, this update affects three scripts, as shown in Table 7.

Table 7 Affected model components due to Update 5

File name	Changes
Scripts\TS_V23_AM.S	Revised
Scripts\TS_V23_MD.S	Revised
Scripts\TS_V23_PM.S	Revised

Changes made to *TS_V23_AM.S*

Figure 38 shows the first few changes that were implemented to the *TS_V23_AM.S* script.

```
Scripts/TS_V23_AM.S  -8  +8

 26   26 MAXTGRPS =  %MAXTGRPS%;  Maximum toll group number
-27      VC_UW    =  1.0100; VC RATIO UPPER BOUND
+     27 VC_UW    =  0.9500; VC RATIO UPPER BOUND
 28   28 PRD      = 'AM'    ;
 29   29
 30   30 pr       =      3  ;  iteration index

134  134 ;
135  135
136  136      LOOP K=1,@MAXTGRPS@
-137               IF (TG_@PRD@AVC[K] > 1.01
                   00)                                                  ; CASE 1: when VC >
                   1.01 ADD TOLL
-138                    IF(D_@PRD@VC[K] > 0.10
                        00)                                                 ;
+     137          IF (TG_@PRD@AVC[K] > 0.95
                   00)                                                  ; CASE 1: when VC >
                   0.95 ADD TOLL
+     138               IF(D_@PRD@VC[K] > 0.16
                        00)                                                 ;
139  139                   TG_@PRD@X[K]   = TG_@PRD@OTL[K] +
                           1*50.0*@CONV_VAL@/20.0               ;            50 CENTS INCREASE
140  140                   TG_@PRD@DT[K] =
                           0                                                       ;
-141                    ELSEIF(D_@PRD@VC[K] =0.0500-0.09
                        99)                                     ;
+     141               ELSEIF(D_@PRD@VC[K] =0.1100-0.15
                        99)                                     ;
```

Figure 38 Sample of changes made to the script *TS_V23_AM.S*

Changes made to *TS_V23_MD.S*

Figure 39 shows the first few changes that were implemented to the *TS_V23_MD.S* script.

```
Scripts/TS_V23_MD.S  -8  +8                                                    ...

CONV_VAL =   20.00;  in current CPI year cents; it is unlikely that a user will need to modify
this variable
MAXTGRPS =   %MAXTGRPS%;  Maximum toll group number
VC_UW     =  1.0100; VC RATIO UPPER BOUND
VC_UW     =   0.9500; VC RATIO UPPER BOUND
PRD       = 'MD'    ;
pr        =     3   ;  iteration index
it        =     4   ;  iteration index
                                                              Revert hunk   Hunk history
; toll setting
;
     LOOP K=1,@MAXTGRPS@
           IF (TG_@PRD@AVC[K] > 1.01
           00)                                                ; CASE 1: when VC >
           1.01 ADD TOLL
                IF(D_@PRD@VC[K] > 0.10
                00)                                                ;
           IF (TG_@PRD@AVC[K] > 0.95
           00)                                                ; CASE 1: when VC >
           0.95 ADD TOLL
                IF(D_@PRD@VC[K] > 0.16
                00)                                                ;
                   TG_@PRD@X[K]   = TG_@PRD@OTL[K] +
                   1*50.0*@CONV_VAL@/20.0                     ;          50 CENTS INCREASE
                   TG_@PRD@DT[K] =
                   0                                                  ;
                ELSEIF(D_@PRD@VC[K] =0.0500-0.09
                99)                                           ;
                ELSEIF(D_@PRD@VC[K] =0.1100-0.15
                99)                                           ;
```

Figure 39 Sample of changes made to the script *TS_V23_MD.S*

Changes made to *TS_V23_PM.S*

Figure 40 shows the first few changes that were implemented to the *TS_V23_PM.S* script.

```
Scripts/TS_V23_PM.S  -8  +8

MAXTGRPS =    %MAXTGRPS%;  Maximum toll group number
VC_UW     =  1.0100; VC RATIO UPPER BOUND
VC_UW     =   0.9500; VC RATIO UPPER BOUND
PRD       = 'PM'       ;
pr        =     3      ;  iteration index
it        =     4      ;  iteration index

; toll setting
;
     LOOP K=1,@MAXTGRPS@
           IF (TG_@PRD@AVC[K] > 1.01
           00)                                                   ; CASE 1: when VC >
           1.01 ADD TOLL
                IF(D_@PRD@VC[K] > 0.10
                00)                                                ;
           IF (TG_@PRD@AVC[K] > 0.95
           00)                                                   ; CASE 1: when VC >
           0.95 ADD TOLL
                IF(D_@PRD@VC[K] > 0.16
                00)                                                ;
                   TG_@PRD@X[K]   = TG_@PRD@OTL[K] +
                   1*50.0*@CONV_VAL@/20.0                   ;          50 CENTS INCREASE
                   TG_@PRD@DT[K]  =
                   0                                                       ;
                ELSEIF(D_@PRD@VC[K] =0.0500-0.09
                99)                                         ;
                ELSEIF(D_@PRD@VC[K] =0.1100-0.15
                99)                                         ;
```

Figure 40 Sample of changes made to the script *TS_V23_PM.S*

2 Overview of the model

The TPB Version 2.4 family of travel models, derived from the Version 2.3 family, is a classic, aggregate, "four-step," trip-based, regional travel demand model. The four steps in a classic travel demand model are:

- Trip generation
- Trip distribution
- Mode choice
- Trip assignment[30]

The first three steps deal with estimating current-year or future-year demand for travel. The last step, trip assignment, where the demand for travel is assigned to a transportation network, represents an equilibration between the transportation demand and the transportation supply. In many models, trip assignment includes only a highway assignment step ("traffic assignment"), where private-use motor vehicles are assigned to a roadway network. In larger urban areas with extensive transit systems, on the other hand, there is often an additional transit assignment component. The TPB Version 2.4 Travel Model includes both a highway assignment and a transit assignment step. So-called "four-step" models are trip based, meaning that trips are the basic unit of analysis, and are also "aggregate," meaning that the model represents aggregate person flows and aggregate vehicle flows between transportation analysis zones (TAZs). In other words, these models do not model trips that happen within an individual TAZ (intra-zonal trips) and they do not simulate the movement of individual people or individual vehicles.

A highway assignment can be conducted at one of three different scales: microscopic, mesoscopic, or macroscopic. The TPB Version 2.4 Travel Model highway assignment is a **macro**scopic, static traffic assignment. This is the standard practice for most four-step model used in the United States. To better understand the meaning of a **macro**scopic traffic assignment, it is useful to understand the two other scales of assignment: microscopic and mesoscopic. In a **micro**scopic traffic assignment, individual vehicles are modeled, using a small time-step, such as every second. In a **meso**scopic traffic assignment, platoons of vehicles are modeled, with a demand that varies through the assignment period (e.g., the AM peak hour demand is higher than the demand found in the shoulder hours of the AM peak period). By contrast, in a **macro**scopic traffic assignment, all traffic moving from one zone to another zone is modeled, but demand does not vary within the assignment period (e.g., a constant demand is assumed for all three hours in the AM peak period). Although it would seem appealing to use a microscopic or mesoscopic assignment in a regional travel demand model, these fine-grained assignments are rarely used in regional travel demand models since they would take too long to run and would require, at the regional level, too much input data (e.g., information about the traffic control devices and signal timings at every intersection). Thus, a macroscopic traffic assignment is usually the norm for regional travel

[30] The Version 2.4 family of travel models actually has six major steps. The two additional steps are "demographic sub-models" and the "time-of-day model." All six of these steps are described in section 2.3 of this report.

demand models. As noted in a 2012 TRB report, "While there is much ongoing research into the use of dynamic assignment and traffic simulation procedures, the state of the practice for regional travel models remains static equilibrium assignment."[31]

2.1 Model inputs

The major inputs and outputs of the regional travel demand model are shown in Figure 41. The travel model requires three major inputs:

- Zone-level land activity forecasts for year/scenario X;
- Transportation networks (both highway and transit) for year/scenario X; and
  Transportation policy assumptions for year/scenario X.

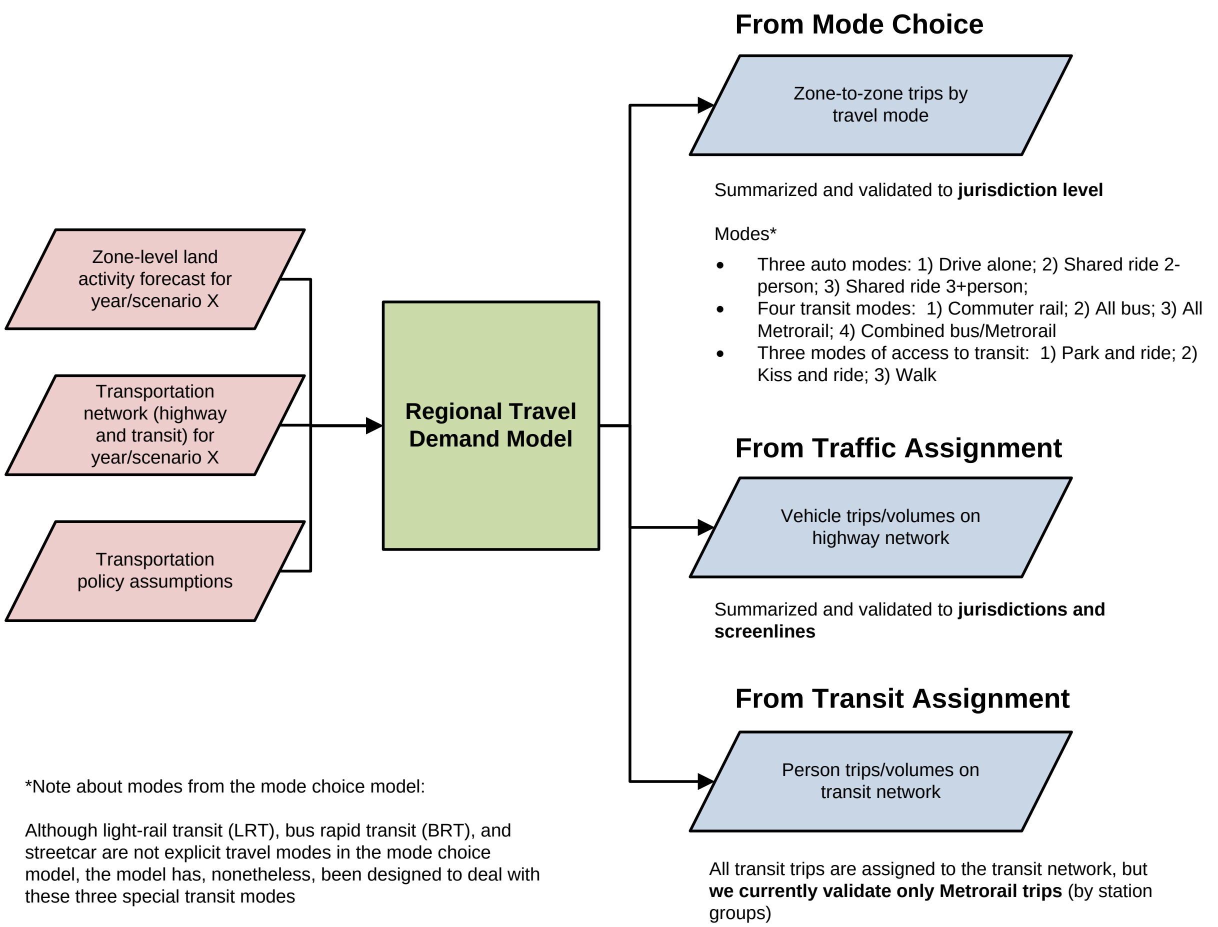

Figure 41 Major inputs and outputs of the TPB Version 2.4 Travel Model

Ref: travel_model_flowchart_overview_v3.vsd

[31] Cambridge Systematics, Inc. et al., *NCHRP Report 716: Travel Demand Forecasting: Parameters and Techniques*, National Cooperative Highway Research Program (Washington, D.C.: Transportation Research Board of the National Academies, 2012), 74, http://www.trb.org/Main/Blurbs/167055.aspx.

The zone-level land activity forecasts are developed by COG's Cooperative Forecasting Program, working through its Cooperative Forecasting and Data Subcommittee.[32] COG does not use a formal land use model. In the early 1970s, COG tried using a land use model called EMPIRIC,[33] but COG staff was not satisfied with its performance, and later abandoned its use.[34] According to a recent screening survey of 68 agencies, 37% do not operate a land use model and do not plan to do so in the near future.[35] This is the current case with COG. Instead of a formal land use model, COG uses a process, often known as an "expert panel"[36] or a "modified Delphi process," which involves reconciling top-down and bottom-up land activity forecasts.[37] The top-down forecasts are regional econometric projections of employment, population, and households. The bottom-up forecasts are also projections of employment, population, and households, but made at the zone level and are based on information from the local governments. These bottom-up forecasts are derived from both building permits (providing short-term information) and comprehensive land use plans (providing long-term information). Each update of the zone-level, land activity forecasts in the Cooperative Forecasting program is called a "round." The latest adopted update is Round 9.1a, but efforts are underway to develop Round 9.2.

Before the zone-level land activity data can be used as an input to the travel model, it must undergo an adjustment process, known as the CTPP-based employment adjustment, which ensures that a consistent employment definition is used by all counties and jurisdictions in the modeled area. The reason for this adjustment is that different jurisdictions in the modeled area, which covers DC, Maryland, Virginia, and one county in West Virginia, use different definitions of employment. For example, jurisdictions in the Baltimore region and several other Maryland jurisdictions develop their base-year employment estimates using data from Bureau of Economic Analysis (BEA). By contrast, most of the jurisdictions in the Washington region develop their base-year employment estimates using data from the Quarterly Census of Employment and Wages (QCEW) collected by the Bureau of Labor Statistics (BLS).[38] The QCEW is a joint federal/state cooperative arrangement between the BLS and state employment security agencies (ESAs). According to Spear, "In lieu of using the publicly available QCEW database, some state

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[32] "Cooperative Forecasting and Data Subcommittee," Metropolitan Washington Council of Governments, 2021, https://www.mwcog.org/committees/cooperative-forecasting-and-data-subcommittee/.

[33] Peat, Marwick, Mitchell and Company, "EMPIRIC Activity Allocation Model: Application to the Washington Metropolitan Region" (Metropolitan Washington Council of Governments, 1972).

[34] Reid Ewing and Keith Bartholomew, "Comparing Land Use Forecasting Methods: Expert Panel Versus Spatial Interaction Model," *Journal of the American Planning Association* 75, no. 3 (2009): 347.

[35] Rolf Moeckel, "NCHRP Synthesis 520: Integrated Transportation and Land Use Models," National Cooperative Highway Research Program, A Synthesis of Highway Practice (Washington, D.C.: Transportation Research Board of the National Academies, 2018), 2, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_520.pdf.

[36] Samuel N. Seskin et al., "The Use of Expert Panels in Analyzing Transportation and Land Use Alternatives," Final Report (Portland, Oregon: American Association of State Highway and Transportation Officials (AASHTO), Standing Committee on Planning, April 2002), http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP08-36%2804%29_FR.pdf.

[37] Metropolitan Washington Council of Governments, "Round 9.1 Growth Trends to 2045," Cooperative Forecasting in the Washington Region (Washington, D.C.: Metropolitan Washington Council of Governments, October 2018), https://www.mwcog.org/documents/2018/10/17/growth-trends-cooperative-forecasting-in-metropolitan-washington-cooperative-forecast-growth--development/.

[38] Robert E. Griffiths to Ronald Milone, "Travel Model Employment Data Adjustment Factors for Round 7.0," Memorandum, August 10, 2005, 1.

DOTs (and even some MPOs) have entered into formal agreements with their state ESAs to obtain access to the enhanced QCEW microdata files that are used by BLS to develop the QCEW… [The QCEW files] are more commonly known in the transportation community as ES-202 data, but this terminology is no longer used by BLS."[39] This year, the most recently developed employment adjustment factors are no longer based on a comparison with CTPP data, so the factors are called "employment definition adjustment factors." The employment definition adjustment factors were used in Round 9.1a, the most recent land activity data.[40]

As for the transportation networks, COG/TPB staff develops a series of highway and transit networks for the air quality conformity analysis, and these networks are often used as the starting point for other planning studies. The highway network consists of all freeways, expressways, and major arterials in the modeled area. It also includes many minor arterials and some collectors, but almost no local roads (centroid connectors represent local roads, but one centroid connector may represent many local roads, so there is not a one-to-one representation like one finds for other link types in the highway network). The highway network forms the base layer for the transit network since buses mostly make use of the highway network. In addition to the highway network, the transit network includes the following elements:

- Transit infrastructure: Transit-only links
- Transfer links
- Transit service
- Transit fares

The latest full-scale documentation of the transportation networks was done in 2020.[41]

Transportation policy assumptions include the following:

- Assumptions about how transportation costs will increase over time, e.g.,
  - Will transit fares rise at the same rate as inflation or a different rate?
  - How will auto operating costs change over time?
- Cost of parking;

[39] Bruce D. Spear, "NCHRP 08-36, Task 098: Improving Employment Data for Transportation Planning" (Washington, D.C.: American Association of State Highway and Transportation Officials (AASHTO), Standing Committee on Planning, September 2011), ES-7, http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP08-36(98)_FR.pdf.
[40] Sanghyeon Ko to Mark S. Moran et al., "Developing Land Use Input Files for the Version 2.3 Travel Model Using Round 9.1a Cooperative Forecasts and the Employment Definition Adjustment Factors," Memorandum, September 17, 2019.
[41] "Highway and Transit Networks Used in the Air Quality Conformity Analysis of the 2020 Amendment to Visualize 2045 and the FY 2021-2024 TIP (Ver. 2.3.78 Travel Model)" (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, April 10, 2020), https://www.mwcog.org/transportation/data-and-tools/modeling/model-documentation/.

  - For drive-access transit trips, the cost of parking is stored in the station file. For park-and-ride (PNR)-to-station transfer links, the walk time is a function of parking capacity and parking cost,[42] but parking cost is not used as part of the transit path-building.
  - For driving trips not involving transit, a parking cost model is used, where parking cost is a function of employment density (see section 21.7.1 "Non-transit-related parking costs").
- Amount of commuting to and from areas outside the modeled cordon.

2.2 Model outputs

The travel model produces many outputs. **Each model run produces about 25 GB of output files**. Since many of these are intermediate files, a clean-up process has been added to the model that moves these intermediate/temporary files to a folder where they can be easily deleted. **Once these are deleted, the amount of output files per model run is about 10 GB**. As stated earlier, the travel model is an "aggregate" model meaning that the model represents aggregate person flows and aggregate vehicle flows between transportation analysis zones (TAZs). Nonetheless, the model produces many fine-grained outputs. These include link-level outputs, such as the number of vehicles traveling on each link in the AM peak period, and zone-interchange-level outputs, such as the number of bus person trips traveling from TAZ X to TAZ Y. However, although the model *produces* these fine-grained outputs, **the model has not been validated to these fine-grained levels, so it is not recommended that one use these fine-grained outputs from the travel model**. A general rule is that, before using or reporting any model outputs, they should be summarized or aggregated to the same, or a higher, level as was used in model validation. For example, although the model produces link-level traffic volumes, this information should be aggregated to the screenline level, jurisdiction level, or regional level, before it is used or reported. Despite this rule, these fine-grained outputs are sometimes used in corridor-level or project-level planning studies, but typically only after the outputs have undergone post-processing (see, for example the classic report NCHRP 255,[43] or its update, NCHRP 765[44]). Given the regional nature of most of the transportation planning studies conducted for the TPB, the COG/TPB staff rarely conducts this type of post-processing work (it is more commonly conducted by consultants working for local governments or state DOTs). In conclusion, when using outputs of the regional travel demand model, one should generally use outputs that have been aggregated or summarized to the following levels:

- Region level, e.g.,
  - The modeled area,
  - The TPB planning area,

[42] Manish Jain to Ronald Milone and Mark Moran, "MWCOG Network Coding Guide for Nested Logit Model (First Draft: September 20, 2007; Updated February 2008 and October 2010)," Memorandum, October 2010, 6.
[43] Neil J. Pedersen and D. R. Samdahl, *NCHRP Report 255: Highway Traffic Data for Urbanized Area Project Planning and Design*, National Cooperative Highway Research Program (NCHRP) (Transportation Research Board, National Research Council, 1982), http://trid.trb.org/view/1982/M/188432.
[44] CDM Smith et al., *NCHRP Report 765: Analytical Travel Forecasting Approaches for Project-Level Planning and Design*, National Cooperative Highway Research Program (NCHRP) (Transportation Research Board of the National Academies, 2014).

  - o The metropolitan statistical area (MSA), or
  - o One of the air quality non-attainment areas, which can vary by pollutant.[45]
- Jurisdiction level
- Jurisdiction-to-jurisdiction level
- For highway assignments: Regional screenlines
- For transit assignments: Metrorail station groups

Figure 41 shows the three major outputs of the travel model, listing both the disaggregate-level output and the more aggregate-level output that is recommended for use. Table 8 adds some detail to the information found in Figure 41.

Table 8 Outputs of the travel model: Disaggregate-level output that is not validated versus aggregate-level output that is validated

Model producing the output	**Disaggregate-level output (Produced by the model, but not recommended for use)**	**Aggregate-level output (recommended for use)**
Mode choice	Zone-to-zone trips by travel mode	• Jurisdiction-to-jurisdiction flows • Jurisdiction-level mode spits • Region-level mode splits
Traffic assignment	Vehicle trips/volumes on the road links	• Jurisdiction-level metrics, such as VMT by jurisdiction • Screenline-level metrics, such as total number of vehicles crossing a regional screenline
Transit assignment	Transit person trips/volumes on transit links	Although all transit person trips are assigned to the transit network, we currently validate only Metrorail trips, and these are validated only by station groups (generally three to four stations per group).

2.3 Modeling steps and the speed feedback loop

The major steps of the Version 2.4 Travel Model, including major inputs and outputs, can be found in Figure 42. As mentioned earlier, the major inputs are the transportation networks, the zonal land use data, and the transportation policy assumptions. The model itself, which is delineated in Figure 42 by a gray, dashed line forming a box, begins with demographic models and ends with traffic assignment and transit assignment. Each of the steps of the travel model is discussed in subsequent chapters of the user's guide.

[45] The modeled area is the largest of these regional areas.

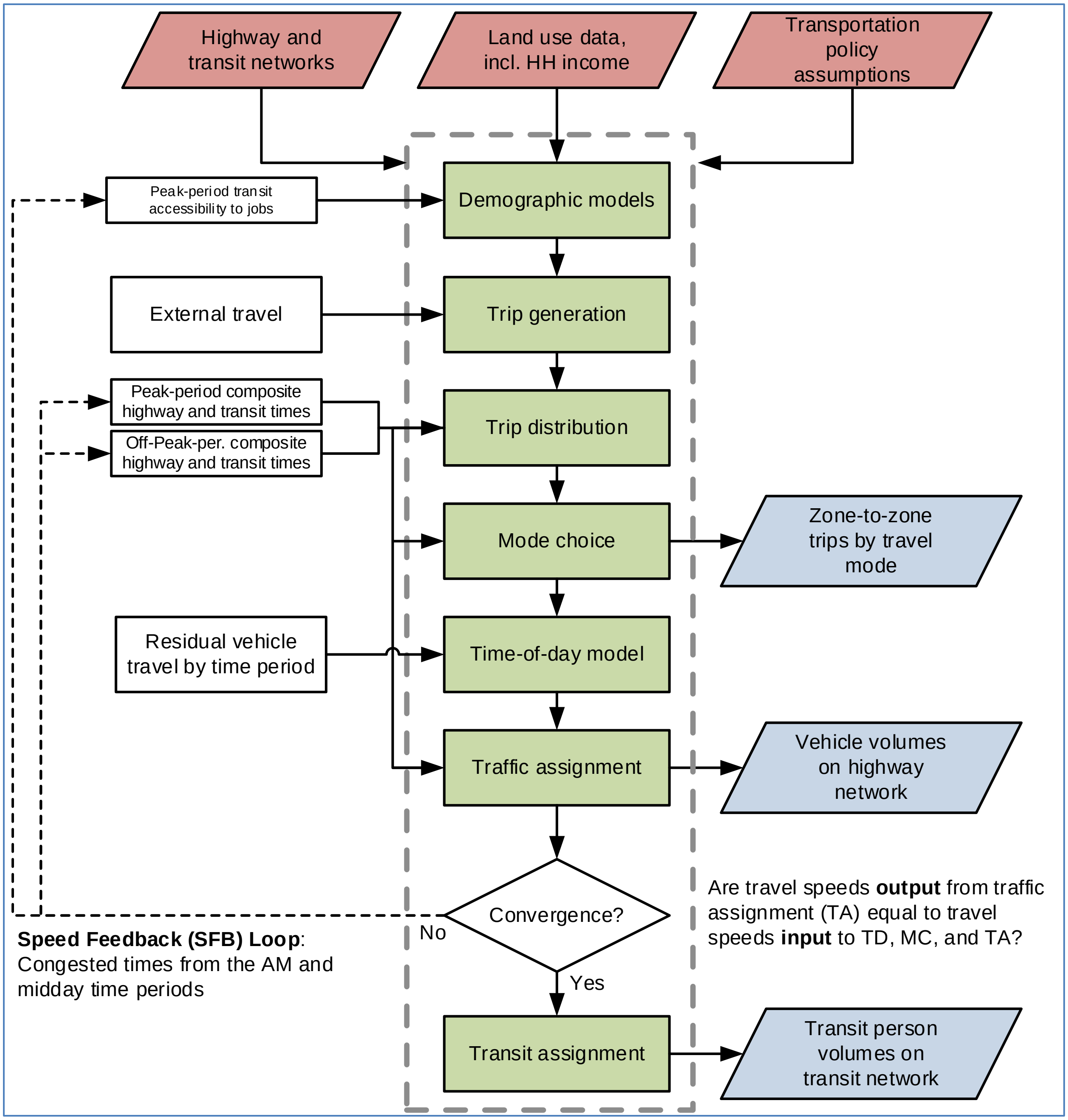

Figure 42 Major steps of the Version 2.4 Travel Model

Ref: six_step_model_ver2.3_v3.vsd

As can be seen in Figure 42, the Version 2.4 Travel Model uses a speed feedback (SFB) loop to ensure that the travel times (and hence speeds) coming out of traffic assignment are consistent with those used as inputs to trip distribution and mode choice. In theory, at the end of each SFB loop, the model would have a test to determine whether convergence has been met. In other words, one could continue running iterations of the speed feedback loop until a convergence stopping criterion has been met.

Currently, however, we do not use a convergence-based stopping criterion. Instead, based on past tests with the regional model, we have determined that the model is sufficiently converged after four SFB iterations.[46] So we simply use a fixed number of SFB loop iterations (five iterations, including the initialization iteration, known as the "pump prime" iteration). In the future, we may use a more formal convergence-based stopping criterion for the SFB loop, such as the percent root-mean-square error (%RMSE) of the travel skims.[47] Nonetheless, in 2011, Cambridge Systematics was unable to find any MPOs that used a formal stopping criterion for the SFB loop.[48] The SFB loop and the volume averaging method used in the SFB loop are discussed in more detail later in this section.

Traffic assignment is discussed both here and in its own chapter (Chapter 23). Like most travel models in the U.S., the Version 2.4 Travel Model uses a user-equilibrium (UE), static traffic assignment (STA), traffic assignment process, which is the generally accepted method for static traffic assignments. Furthermore, the assignment process is a multi-class UE assignment, meaning that separate user classes can be assigned at the same time. The Version 2.4 Model includes six user classes:

1. Single-occupant vehicle (SOV)
2. High-occupant vehicle with two persons (HOV2)
3. High-occupant vehicle with three+ persons (HOV3+)
4. Medium and heavy trucks
5. Commercial vehicles
6. Airport passengers traveling to/from the three commercial airports

Additionally, the Version 2.4 Model includes four time-of-day periods for traffic assignment:

- AM peak period (3 hours: 6:00 AM to 9:00 AM)
- Midday period (6 hours: 9:00 AM to 3:00 PM)
- PM peak period (4 hours: 3:00 PM to 7:00 PM)
- Night/early morning period (11 hours: 7:00 PM to 6:00 AM)

Most MPOs use a UE traffic assignment that relies on an optimization algorithm known as the Frank-Wolfe (FW) algorithm.[49] The FW algorithm is essentially a series of all-or-nothing traffic assignments where flows are combined using weights from an optimization process whose goal is to minimize an objective function. The process stops when a stopping criterion is met. Previously, the Version 2.3 Travel

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[46] Ron Milone, "TPB Models Development Status Report," https://www.mwcog.org/file.aspx?&A=%2fTnLbhiKP7J4dc5BCvLqxHQzO%2bq9WHN4K%2bDGCm64j8s%3d.
[47] See, for example, Caliper Corporation, "Traffic Assignment and Feedback Research to Support Improved Travel Forecasting," Final Report (Washington, D.C.: Federal Transit Administration, Office of Planning and Environment, July 31, 2015), pages 3-2 and 3-4, http://www.fta.dot.gov/documents/traffic-assignment-and-feedback-research-to-support-improved-travel-forecasting.pdf.
[48] Cambridge Systematics, Inc., "Fiscal Year 2010 Task Reports," Final Report (Washington, D.C.: National Capital Region Transportation Planning Board, November 16, 2010), 1–20 to 1–21, https://www.mwcog.org/transportation/data-and-tools/modeling/review-of-travel-modeling-procedures/.
[49] Marguerite Frank and Philip Wolfe, "An Algorithm for Quadratic Programming," *Naval Research Logistics Quarterly* 3, no. 1–2 (1956): 95–110, https://doi.org/10.1002/nav.3800030109.

Model used the following UE stopping criterion: When the relative gap ≤ 10^{-3} OR the number of UE iterations ≥ 300. The relative gap threshold was always intended to be the primary stopping criterion, with the number of UE iterations functioning as a backup criterion. Now, however, in later versions of the Ver. 2.3 Model and also in the Ver. 2.4 Model, we use a "progressive" relative gap stopping criterion. The idea is that, in the early SFB iterations, the UE closure criterion will be relatively loose, but, in the later SFB iterations, the UE closure criterion will tighten, as shown in Table 9.

Table 9 User equilibrium closure criterion (relative gap) varies by speed feedback iteration

Speed feedback iteration	Primary closure criterion for UE traffic assignment	Secondary closure criteria for UE traffic assignment
Pump prime	Relative gap ≤ 10^{-2} (i.e., 0.01)	Number of UE iterations ≥ 1000
1	Relative gap ≤ 10^{-2} (i.e., 0.01)	Number of UE iterations ≥ 1000
2	Relative gap ≤ 10^{-2} (i.e., 0.01)	Number of UE iterations ≥ 1000
3	Relative gap ≤ 10^{-3} (i.e., 0.001)	Number of UE iterations ≥ 1000
4	Relative gap ≤ 10^{-4} (i.e., 0.0001)	Number of UE iterations ≥ 1000

By using the higher value for UE iterations (1000 vs. 300), we were able to ensure that this secondary criterion is unlikely to be used as the stopping criterion. Based on a series of sensitivity tests,[50] we found that the new progressive relative gap scheme resulted in a relatively converged traffic assignment, without the extremely lengthy model run times that would be needed if one were to use a high threshold (e.g., 10^{-4} relative gap) for each of the five SFB iterations. The Version 2.4 Travel Model uses a slight variation of the FW algorithm, called the *bi-conjugate* Frank-Wolfe algorithm, which converges marginally faster than the classic FW algorithm.

Regarding data inputs, the zonal land use data that is input to the travel model (Figure 42) includes information about average household wealth, in the form of an average household income index. This index is the ratio of the zonal median household income to the regional median household income, in year-2007 dollars. So-called "residual vehicle" or exogenous trips are added to the modeling stream at the time-of-day model stage. These trips are composed of the following:

- Through trips (auto and truck), also known as external-to-external, or X-X, trips;
- Taxi trips;
- School trips;
- Visitor/tourist trips;
- Airport passenger trips (i.e., trips by air passengers destined to the three commercial airports in the region).

[50] Mark S. Moran and Ronald Milone, "Status Report on the Version 2.3 Travel Model: Updates to the Model and Year-2010 Validation" (March 22, 2013 meeting of the Travel Forecasting Subcommittee of the Technical Committee of the National Capital Region Transportation Planning Board, held at the Metropolitan Washington Council of Governments, Washington, D.C., March 22, 2013), 7–11.

Figure 43 is another view of the Version 2.4 Travel Model, but with an emphasis on which steps occur *before* the speed feedback (SFB) loop and which steps occur *within* the SFB loop. Before the loop is begun, there is an initialization phase, known as the "pump-prime" iteration. In the pump prime iteration, a first pass of the travel model is performed using *initial* AM and off-peak highway speeds, and *initial* mode choice percentages (i.e., the mode choice model is not executed in the pump prime iteration). The "skimmed" highway times are used to develop drive-access-to-transit (zone-to-PNR-lot) links as part of the transit network. After the transit network is built and skimmed, trip generation and trip distribution are executed. The resulting person trips are converted to vehicle trips based on default zone-level mode choice and car occupancy percentages, and these are assigned to the highway network.

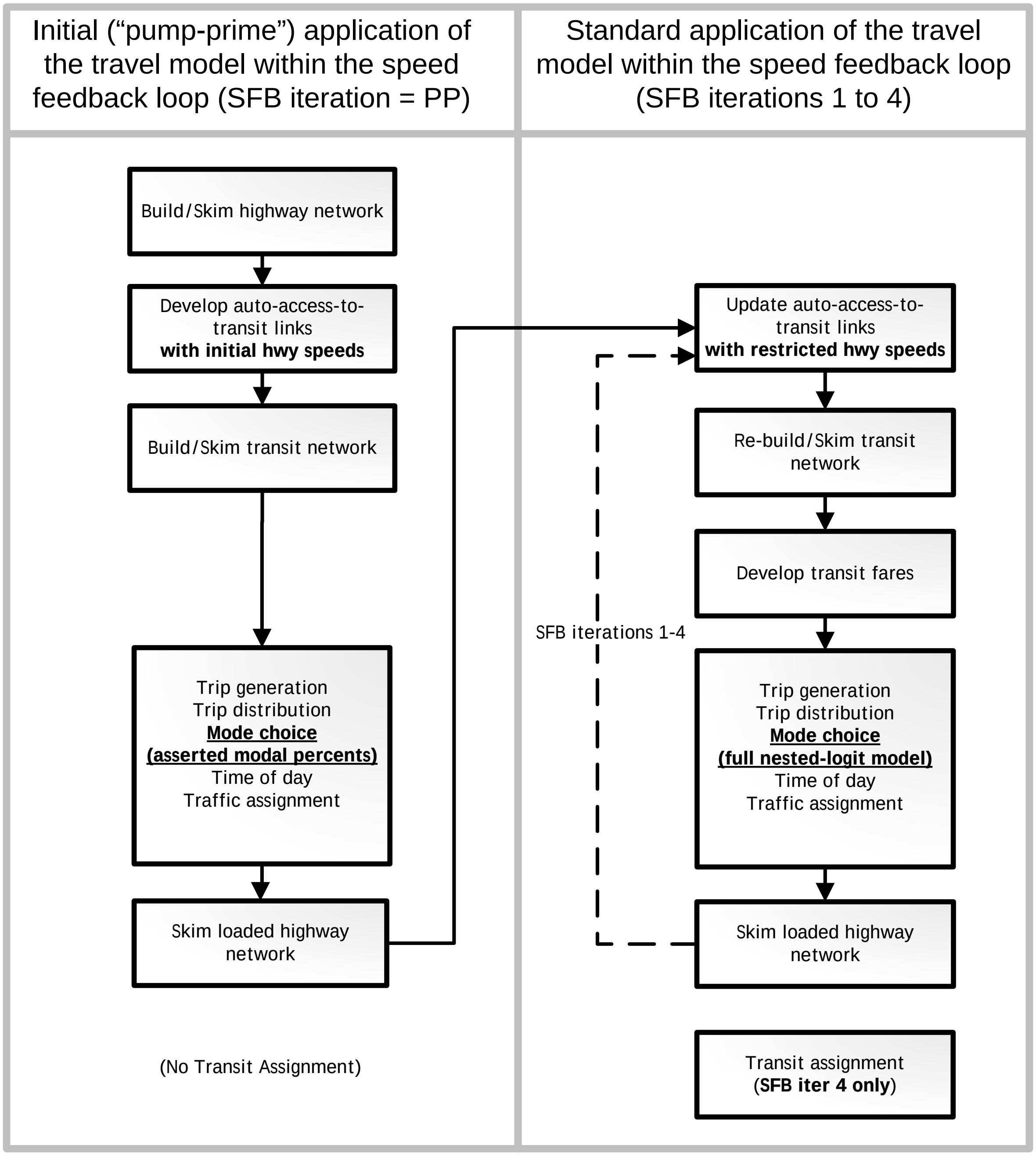

Figure 43 Application process of the Version 2.4 Travel Model

Ref: pumpPrime_vs_other_sfb_iter_v5.vsd

The next series of "standard" SFB iterations (1 through 4) involve the execution of the complete travel model which includes: 1) a mode choice model execution and 2) the use of recycled traffic assignment-based speeds as input. The AM peak and off-peak restrained highway times are used to update the zone-to-PNR link speeds, and the transit network is re-built and skimmed. The highway and transit time skims are used as inputs to the mode choice model. The auto driver trips produced from the mode choice model are processed through the time-of-day model, which apportions the auto drivers among four time-of-day periods: the AM peak period (6 - 9 AM), the midday period (9 AM - 3 PM), the PM peak period (3 - 7 PM), and the night/early morning period (7 PM - 6 AM). The four time-of-day trip tables are subsequently loaded onto the highway network in separate traffic assignment procedures. The loaded-link volumes are successively averaged using the method of successive averages (MSA) to facilitate the convergence of the final link speeds. The averaging occurs individually for each of the four time-of-day periods at the link level, as follows:

- The "final" first iteration link volumes are equal to the "raw" assigned link volumes from the pump-prime iteration.
- The "final" second iteration link volume equals one half of the first iteration link volume plus one half of the second iteration assigned link volume.
- The "final" third iteration link volume equals 2/3 of the "final" second iteration link volume plus 1/3 of the third iteration assigned volume.
- The "final" fourth iteration volume is not averaged -- it is the direct assignment output.

In all the Version 2.2, Version 2.3, and Version 2.4 Travel Models, a fixed number of speed-feedback (SFB) iterations is used. The Version 2.2 model used six speed feedback iterations (in addition to the pump prime iteration). By contrast, the Version 2.3 and Version 2.4 models use four speed feedback iterations (in addition to the pump prime iteration). The Version 2.4 Model, like the Version 2.3 Model, produces **two final loaded network files** called **i4_Assign_Output.net** and **i4_HWY.NET**. The first file (**i4_Assign_Output.net**) is based on the direct trip table output, while **i4_HWY.NET** is based on volume averaging. TPB staff use **i4_Assign_Output.net** to compute the emissions as a part of air quality conformity and work for the state air quality implementation plans (SIPs).

As shown in both Figure 42 and Figure 43, transit assignment is not conducted within each speed feedback loop, but is instead conducted once, after the final feedback iteration is complete. Transit assignment is conducted for two time-of-day periods (peak and off-peak) using trip tables in production-attraction (P-A) format (not origin-destination format, as is the case for highway assignment) and, unlike highway assignment, transit assignment is not capacity constrained. Although both these aspects of transit assignment may seem like shortcomings, the state of the practice for regional transit assignments is P-A assignment without capacity constraint.[51]

2.4 Special modeling procedures used in earlier versions of the travel model

Historically, there have been two transportation phenomena that have required specialized modeling procedures. The two phenomena were 1) Limited capacity on the Metrorail system to handle the demand for travel to and through the regional core and 2) High Occupancy/Toll (HOT) lanes.

The first phenomenon, a limit on Metrorail's peak-period capacity, was modeled using a procedure called the Metrorail constraint to and through the regional core. This modeling technique was used from about 2001 to 2018. In 2018, however, WMATA received new dedicated funding from the District, Northern Virginia, and suburban Maryland, which meant that the transit authority would likely have the

[51] See, for example, Cambridge Systematics, Inc. et al., *NCHRP 716*, 77.

funds to handle its peak volumes to/through the regional core. Thus, in 2018, WMATA requested that this procedure stop being used. The last model to use this procedure was the Ver. 2.3.70 Model.

The second phenomenon, HOT lanes, is still in effect and will be for the foreseeable future, but the technique for modeling it was changed in the Ver. 2.3.75 Model. In the Ver. 2.3.70 Model, and older model versions, a special procedure was used, known as the HOV3+ highway skim replacement (HSR) procedure or the multi-run traffic assignment procedure.

As discussed in Section 1.3 in the previous user's guide,[52] as of the Version 2.3.75 Travel Model, both the Metrorail constraint and the HSR procedure have been eliminated. Nonetheless, the Ver. 2.3.75, Ver.2.3.78, and Ver. 2.4 models still includes two special modeling procedures, which are not used for general application of the model but can be used when the need arises. One is estimating toll values on HOT lane facilities. The other is for performing select-link analyses. Both special procedures are described below.

2.4.1 Toll estimation for high occupancy/toll (HOT) lanes

According to a recent FHWA report, " 'Managed lanes' are defined as highway facilities or a set of lanes where operational strategies are proactively implemented and managed in response to changing conditions….Examples of operating managed lane projects include high-occupancy vehicle (HOV) lanes, value priced lanes, high-occupancy toll (HOT) lanes, or exclusive or special use lanes."[53] Most HOT lane facilities exist on freeways which include one or more adjacent general purpose (GP) lanes that are not managed.

2.4.1.1 HOT lanes which allow free use with 3+ occupants per vehicle

On Nov. 17, 2012, HOT lanes, known as the I-495 Express Lanes, opened on I-495 in Virginia. On this facility, vehicles with three or more occupants (HOV3+) may use the facility for free, but single-occupant vehicles (SOVs) and two-occupant vehicles (HOV2) must pay a toll to use the facility. The toll is dynamically set, every six minutes or so, based on congestion levels. The toll is set such that the HOT lanes will remain free flowing. In December 2014, HOT lanes, known as the I-95 Express Lanes, opened on I-95. This second facility also had the same HOV restriction (HOV3+), so both facilities are HOT3+.

Given the advantageous treatments in favor of HOV3+ traffic, such as the fact that HOV3+ vehicles are not charged tolls like non-HOV3+ (in both mode choice and traffic assignment), staff decided to eliminate the HSR procedure.[54] Obviously, a central modeling objective in representing HOT lanes is to specify detailed toll rates that will result in demand levels that do not degrade the prevailing speed on

[52] Ngo et al., "User's Guide for the COG/ TPB Travel Demand Forecasting Model, Version 2.3.75. Volume 1 of 2: Main Report and Appendix A (Flowcharts)."
[53] FHWA, "Managed Lanes: A Primer" (Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration, 2008), 5, http://www.ops.fhwa.dot.gov/publications/managelanes_primer/managed_lanes_primer.pdf.
[54] Feng Xie and Dusan Vuksan to Files, "Evaluating the Modeling Effects of Eliminating the 'HOV Skim Replacement' Process," Memorandum, March 7, 2018.

the HOT facility. To achieve this objective, the following three steps (reduced from four steps in previous model versions when HSR procedure was used) were implemented as of the Ver. 2.3.75 Model (including Ver. 2.4) on a year-by-year basis to perform toll setting (i.e., estimate toll values) on HOT lanes. Note that the toll-setting procedure is conducted by TPB staff. Thus, many external users of the TPB model never perform this step (since the estimated toll values for future-year networks are provided as part of the model/network transmittal package). For those with an interest in the current toll-setting procedure, please consult the 2018 memo cited here and earlier.[55]

2.4.1.2 HOT lanes which allow free use with 2+ occupants per vehicle

From 2017 to 2020, the Virginia Department of Transportation (VDOT) chose to operate the I-66 HOT lanes inside the Beltway as a HOT2+ facility. Before 2017, the only HOT lane facilities in the region were HOT3+. The Air Quality Conformity Analysis of the 2020 Amendment to Visualize 2045 includes six analysis years: 2019, 2021, 2025, 2030, 2040, and 2045. Among those years, only 2019 contained the HOT2+ facility of I-66 HOT lanes inside the Beltway. Since the HSR procedure has been removed, the similar three steps discussed in section 2.4.1.1 were implemented in Ver 2.3.75 for year-2019 to simulate HOT lanes. The only difference is that HOV2+ traffic is free to operate on HOT2+ facility, thus HOV2+ skims developed in Step 2 were used in Step 3.

Please also see the discussion of the treatment of airport passenger auto driver trips on HOV- and HOT-lane facilities in section 23.3.8 (p. 233).

2.4.2 Select-link analyses

A select-link analysis (SLA) and a select-link assignment are common procedures in travel demand modeling, but these are not part of our standard modeling procedures. There are theoretical reasons why SLAs should not be performed,[56] but COG/TPB staff often get requests for help with running SLAs. COG/TPB staff has developed some SLA procedures for the regional travel demand forecasting model. The most recent update of these procedures, for the Ver. 2.3.70 Model,[57] can also be used for the Ver. 2.4 Model. The SLA procedures may be requested by outside parties by making a request on the Data Request web page (https://www.mwcog.org/transportation/data-and-tools/modeling/data-requests/).

[55] Feng Xie and Dusan Vuksan to Files, "Evaluating the Modeling Effects of Eliminating the 'HOV Skim Replacement' Process," Memorandum, March 7, 2018.
[56] See, for example, Hillel Bar-Gera and Amos Luzon, "Non-Unique Solutions of User-Equilibrium Assignments and Their Practical Implications (Paper # 07-1335)," in *Compendium of Papers CD-ROM* (Transportation Research Board 86th Annual Meeting, held January 21-25, 2007, Washington, D.C., 2007).
[57] Feng Xie to Files, "Select Link Analysis for TPB's Version 2.3.70 Travel Demand Model," Memorandum, September 14, 2018.

3 Hardware and software requirements

This section of the report describes the hardware and software requirements for running the Version 2.4 family of travel models. It also includes a section discussing the hardware used for modeling at COG. In addition to requirements, this section of the report also discusses any recommendations regarding hardware and software.

3.1 Hardware

- Processor/central processing unit (CPU)/chip:
    - Intel or Intel-like processor, e.g., Intel, AMD, with 64-bit architecture ("x64").
    - Number of cores: The Version 2.4 Travel Model has been designed to run some steps in parallel using Cube Cluster and/or multiple command windows running in parallel.
        - During the highway assignment step, there can be up to 8 concurrent program threads running at once, which means that it is recommended that you have a computer with 8 or more cores. Nonetheless, you can run the regional travel model on a computer with only 4 or 2 cores (see instructions found in Table 21 on p. 111), however, due to rounding issues in Cube Cluster, running with fewer than the recommended 8 cores may result in slight differences in modeled results.
        - The two biggest chip manufacturers are Intel and AMD. Some Intel chips feature a technology known as Hyper-Threading. When Hyper-Threading technology is enabled on the chip, the operating system sees double the number of cores. So, if your computer has four cores and Hyper-Threading is enabled, the operating system will see eight virtual cores, thus doubling your CPU capacity. See the section 8.2.1 for more details. COG/TPB staff has executed the Version 2.4 family of travel models on only computers running Intel chips, but the model should run equally well on computers running AMD chips.
    - Chip/CPU speed: While there is no minimum chip speed, we have found that model run time scales inversely with chip speed, so a faster chip/CPU is always preferred. We recommend a chip speed of around 3 GHz.
- Memory: 64-bit versions of Windows can a large amount of memory (e.g., from 128 GB on Windows 10 Home to 2 TB on Windows 10 Pro). However, based on experience, running the Ver. 2.4 Model is not memory intensive, so 3 to 4 GB of RAM should suffice. Some of our current travel mode servers have 32 GB of RAM, but, again, this does not seem to be needed for the current, trip-based model.
- Storage space: We recommend you have at least 500 GB of free space on your computer storage -- hard disk drive (HDD) or solid-state drive (SSD). One modeling scenario/year generates about 25 GB of files (1,600 files) before the clean-up procedure is run, and about 10 GB of files after the clean-up procedure is run. A solid-state drive (SSD) could provide shorter model run times, but in one test we performed on a new travel model server, the SSD

performed no better than the hard drive.[58] This result was unexpected, since one would generally expect an SSD to out-perform an HDD. In this test, the data drive was an SSD and the operating system (O/S) drive was a HDD. We did not, however, have time to test the case where both the data drive and the O/S drive were SSDs.

3.2 Software

- Operating system: Microsoft Windows (64-bit version), such as Windows 10, Windows Server 2008, or Windows Server 2012. To our knowledge, the Ver. 2.4 Model has not been tested at COG using Windows 10, but it should work.
- The Version 2.4 Travel Model: The procedures for requesting the travel model and its input files can be found on the "Data Requests" webpage (https://www.mwcog.org/transportation/data-and-tools/modeling/data-requests/).
- Bentley Systems Cube software (Bentley Systems acquired Citilabs in 2020): The TPB Version 2.4 Travel Model is implemented using Cube software, a proprietary software package, which is produced, licensed, and marketed by Bentley Systems. Thus, to run the regional travel model, you will need to purchase the Cube software from Bentley Systems. COG/TPB staff cannot provide copies of Cube software.
  - Cube Base: Cube Base is the graphical user interface (GUI) for editing transportation networks, matrices, and scripts. In theory, Cube Base can also be used for managing network scenarios (Scenario Manager) and running travel models (Application Manager), but that is not how the Version 2.3/Version 2.4 family of travel models have been implemented. Instead, the Version 2.4 Model is implemented using a command-line interface (CLI), as described later in this report. **Note that Cube Base is 32-bit software (Cube Voyager is 64 bit)**.
  - Cube Voyager: Cube Voyager is the computational engine that powers the Cube suite of software and includes its own proprietary scripting language. The Version 2.4 Travel Model has been developed and applied by COG/TPB staff using **Cube version 6.4.1, so it is generally recommended you use Cube 6.4.1 with the Ver. 2.4 Model**. Nonetheless, some users may want to use a more recent version of Cube. It is possible to do so in only certain circumstances. As noted in Figure 44, the key decision is whether the user intends to make changes to the transit networks (e.g., adding, deleting , or modifying a transit line). If the user plans to make changes to the transit network, then they will need to run the automated, ArcPy transit walkshed process. This process is turned off (commented out in the script) by default. As noted in Figure 44, if the user will not be changing the transit network, there is no need to run the automated, ArcPy transit walkshed process, so the Ver. 2.4 Model is compatible with several versions of Cube (i.e., 6.4.1, 6.4.2, 6.4.3, and 6.4.5). By contrast, if the user will be changing the transit network, there is a need to run the automated, ArcPy transit walkshed process, which

[58] Dzung Ngo and Mark S. Moran to Ronald Milone et al., "Benchmark Tests on Travel Model Server #7 (Tms7) to Determine the Configuration for the Server's Hard Drives and the Potential Use of Cube's 64-Bit Version," Memorandum, February 2, 2016, 8.

means that there is a more limited set of compatible Cube versions. Note that Cube Ver. 6.4.4 is not mentioned in the figure because this version has a bug that causes a crash at the trip generation step of the Version 2.4 Travel Model.

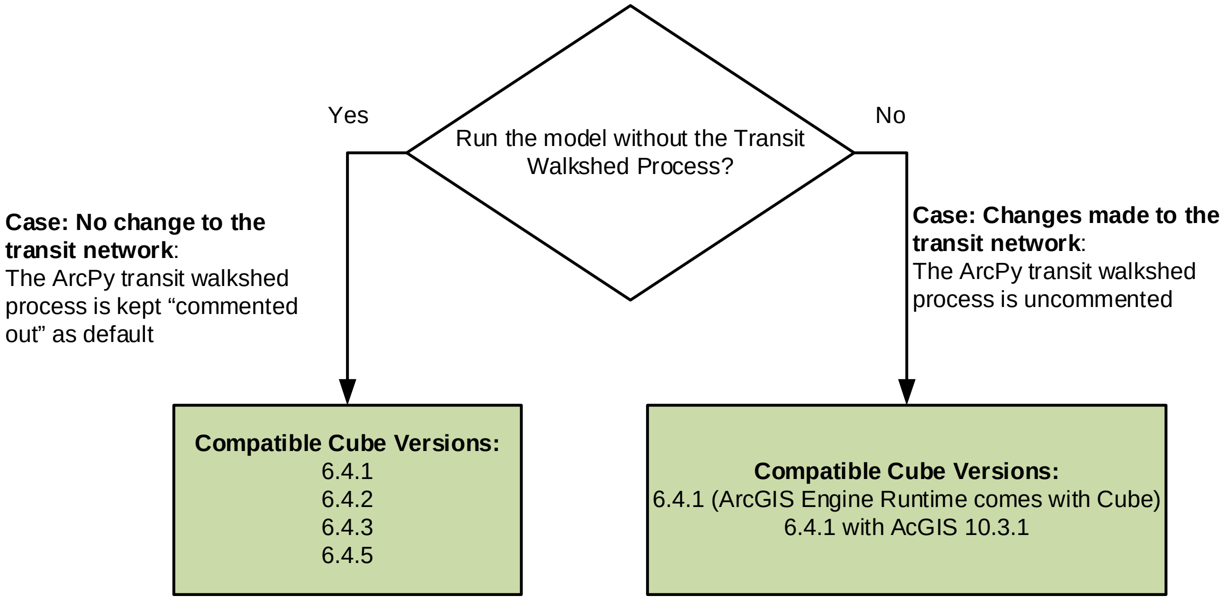

Figure 44 Compatibility between the Gen2/Ver. 2.4 Travel Model and various versions of Cube software

Ref: " I:\ateam\docum\FY20\Verson23Development\travel_model_user_guide\Model_Cube_Version_Decisions.vsd

As noted above, Cube Voyager is 64-bit software. In the past, we noted that Cube Voyager 6.4.2 was less stable when running the ArcPy transit walkshed process.[59] Staff conducted some testing and found that the instability issue also happens with ArcGIS Engine 10.6 included in Cube 6.4.5 and the trip generation step of the model does not work with Cube 6.4.4. For the transmittal version of the Ver. 2.4 Model, we plan to "comment out" the automated ArcPy transit walkshed process as we first did in Ver. 2.3.70,[60] since most users do not need to re-run this step (the output file from this process, areawalk.txt, is delivered with the model transmittal package), unless they make changes to transit stops (e.g., changing the location of an existing transit stop or adding a new stop). Based on our experience, the automated ArcPy transit walkshed process is the modeling step that is most likely to result in the model run stopping prematurely**. If a model user makes changes to the transit network and wants to update the walk sheds, then they need to uncomment the statement that calls this procedure, allowing the procedure to run as one of the first steps of the model.**

[59] Mark Moran, Ron Milone, and Meseret Seifu, "User's Guide for the COG/ TPB Travel Demand Forecasting Model, Version 2.3.70. Volume 1 of 2: Main Report and Appendix A (Flowcharts)," November 28, 2017, https://www.mwcog.org/assets/1/6/mwcog_tpb_travel_model_v2.3.70_user_guide_v7_appA_flowch.pdf.

[60] In the run_ModelSteps_*.bat batch file, the line "call ArcPy_Walkshed_Process.bat %1" should have "REM" at the beginning of the line to comment out this step.

  - Cube TRNBUILD: Currently, Cube has two transit modeling software modules: TRNBUILD and Public Transport (PT). The Ver. 2.4 Model, like the Ver. 2.3 Model, uses Cube's TRNBUILD software module for transit modeling (e.g., transit network building, path development, skimming and assignment). For the TPB's next-generation travel model, the Generation-3, or Gen3, Model, [61] on the other hand, the plans is to switch to PT.
  - Cube Cluster: Cube Cluster is Bentley Systems' implementation of distributed processing, which is a technique for distributing computing jobs across multiple computers or processors, thus reducing model run times by allowing two or more processes to run in parallel. Strictly speaking, Cube Cluster is not required to run the Version 2.4 Travel Model. But it is strongly recommended, in order to keep model run times to a minimum, and, if you choose not to use it, you will have to modify the model setups that are supplied by COG/TPB staff (this is described later in this report).
- ArcGIS Engine Runtime 10.3.1 or ArcGIS 10.1. ArcGIS Engine Runtime 10.3.1 comes with Cube 6.4.1. When installing Cube, the software installation process will check to see if ArcGIS has already been installed on your computer. See Figure 44 on p.59 and Table 22 on p. 127 for more information. The easiest setup would be to install Cube on a computer that does not have ArcGIS.
- A text editor (optional but recommended): The choice of which text editor to use is a personal one. Cube Base includes its own text editor, optimized, obviously, for editing Cube Voyager scripts. In addition to the Cube Base built-in text editor, COG staff uses both Notepad++ (free and open source) and PSPad (free, but not open source).
- Software for comparing or "diffing" text files (not required but recommended). COG staff uses both WinDiff, which is older, and WinMerge, which is newer and has more functionality. Both are available for free.
- Cygwin (optional, http://www.cygwin.com/) is a Linux-like environment for Windows that provides a series of Unix-like command-line tools, such as head, tail, and which. This free and open source software **is no longer part of the model stream, so users no longer need to install this**. Alternatively, Windows now allows one to install Linux on Windows 10.[62]

3.3 Examples of computer hardware used at COG for modeling

COG/TPB staff performs most modeling runs on computer servers that are dedicated for this task, though one can also run the travel model on a standard, desktop computer. COG/TPB staff typically accesses a travel model server (TMS) using a Remote Desktop Connection. We currently have four travel model servers, named tms5, tms6, tms7, and tms8. Tms8 is the most recent travel model server at COG.

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[61] RSG and Baseline Mobility Group, "Gen3 Model Design Plan" (Metropolitan Washington Council of Governments, July 2, 2020), https://www.mwcog.org/file.aspx?&A=UvEp6mZMXIIwbpwr0%2Bd8dmoshHSSA4wFCs7s8AoszaM%3D.

[62] "Install Windows Subsystem for Linux (WSL) on Windows 10," September 15, 2020, https://docs.microsoft.com/en-us/windows/wsl/install-win10.

Currently, tms6 and tms7 are used mainly by COG's Model Applications Group, and tms5 and tms8 are used mainly by COG's Model Development Group.

Table 10 compares the computer specifications ("specs") of the latest travel model servers used by the Model Development Group (tms8) and the Model Applications Group (tms7). Both computers are running 64-bit versions of Windows Server 2012 R2 Standard.

Table 10 Comparison of computer specs between tms7 and tms8

Host Name:	**Tms7**	**Tms8**
OS Name:	MS Windows Server 2012 R2 Standard	MS Windows Server 2012 R2 Standard
OS Version:	6.3.9600 Build 9600	6.3.9600 Build 9600
System Manufacturer:	HP	HP
System Model:	ProLiant DL380 Gen9	ProLiant DL380 Gen10
System Type:	64-bit	64-bit
Number of processors:	2	2
Processor name(s):	Intel Xeon E5-2687W V3	Intel Xeon Gold 6146
Clock speed of processor (GHz):	3.10	3.20
No. of cores/processor:	10	12
No. of threads/processor:	20	24
Total number of cores:	20	24
Total number of threads:	40	48
Hyper-Threading Technology:	Yes	Yes
Total Physical Memory:	24 GB	242 GB[63]
Hard drives for data storage:		Total 6 disks for drives C & F
	Local Disk (C:), 1 TB, RAID 1 (2 disks)	Local Disk (C:), 325 GB, RAID 10
	Data (E:), 3.27 TB, RAID 5 (4 disks)	**Data (F:), 4.04 TB, RAID 10**
	SSD (F:), 186 GB, RAID 0 (for testing)	

Ref: " I:\ateam\docum\fy19\memos\travel_model_server_tms_specs_2018.xlsx"

COG/TPB staff has begun conducting feasibility tests regarding running the travel model in the cloud (i.e., using off-premises servers), but this testing is still in very early stages. Feasibility tests will address both technical and cost feasibility.

On a 64-bit computer with a 64-bit version of windows, some applications are 32-bit applications whereas others are native 64-bit applications, and each type of application has its own installation folder, as shown below:

[63] RAM was recently added to support development of the Gen3 Travel Model.

- Installation location for 64-bit applications: "C:\Program Files"
  - Example: Cube Voyager
- Installation location for 32-bit applications: "C:\Program Files (x86)"
  - Examples: Cube Base, WinMerge

Although both tms7 and tms8 have two processors, tms7 has 10 cores per processor, resulting in a total of 20 physical cores. By contrast, tms8 has 12 cores per processor, resulting in a total of 24 physical cores. Because of Intel's Hyper Threading Technology, each server appears (to the operating system) to have double the number of cores. Thus, tms7 appears to the operating system as 40 virtual cores (which can handle 40 threads of instruction) and tms8 appears to the operating system as 48 virtual cores (which can handle 48 threads of instruction). The processor clock speeds for tms7 and tms8 are 3.1 GHz and 3.2 GHz, respectively. Regarding total physical memory, tms8 has 64 GB of RAM, double the size of tms7's RAM.

One can use the total number of cores in a computer to determine the maximum number of concurrent model runs that can be conducted. Since the Version 2.4 Model is set up to use a maximum of 8 threads/cores, three concurrent model runs require the simultaneous use of 24 (= 3 x 8) cores. Four concurrent model runs could require up to 32 (= 4 x 8) cores. In tests conducted on tms6, which has 32 virtual cores ("threads"), TPB staff found that we could run four concurrent model runs of the Ver. 2.3.57 model (the results should apply to the Ver. 2.4 Model as well). However, In the past, using Cube 6.1 SP1, we had found that, if two or more users tried to launch concurrent model runs, even if there were only two users, each with one model run, then one of the two model runs would often crash.[64] However, **under Cube 6.4.1, we found that two or three users can submit concurrent model runs**.[65] This is one improvement of Cube 6.4.1. For users who are running the automated ArcPy transit walkshed process, it is still necessary to use a 45-minute offset for launching model runs, so that only one instance of ArcGIS is running at a time. Also, based on recent communications with Citilabs (personal communication, 2/6/17), it is better not to overload the processor, so, although a 32-core computer should be able to run 4 concurrent model runs (4 x 8 = 32), it would be better to limit this computer to 3 concurrent model runs. It is hoped that further information about this issue will be added to future Cube documentation.

Travel model servers often have two logical disk drives: one containing the software, usually called "C:", and one used to store data, such as the model runs. Each one of these logical disks could be one or more disks, storage arrays, or, conceivably, solid state drives. The data drives associated with the travel model servers at COG are shown in Table 11.

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[64] Mark S. Moran and Dzung Ngo to Ronald Milone et al., "Stress Tests of Travel Model Server #6 (Tms6) to Determine the Maximum Number of Model Runs That Can Run Concurrently," Memorandum, October 29, 2014.
[65] Dzung Ngo to Mark S. Moran et al., "Testing the COG/TPB Travel Model Servers: 1) Need for Admin Privileges; 2) Ability to Run Two or More Concurrent Model Runs by Two or More Users; 3) Experience with Malware," Memorandum, June 6, 2017, 5.

Table 11 Computer storage drives used for travel demand modeling

Server	UNC Path	Mapped Drive Letter	Size	Drive Setup
nas	\\nas\TMSARCHIVE\MODELAPP	N:	13.9 TB	RAID 5
nas	\\nas\TMSARCHIVE\MODELDEV	O:	13.9 TB	RAID 5
sas	\\sas\dtp_sas$	S:	649 GB	VM. Gets storage from the SAN.
tms5	\\tms5\E	X:	4.5 TB	RAID 5
tms6	\\tms6\ateam	L:	2 TB	RAID 0
tms6	\\tms6\bteam	P:	2 TB	RAID 0
tms6	\\tms6\ateamarray	T:	10 TB	RAID 5 DAS
tms6	\\tms6\bteamarray	V:	10 TB	RAID 5 DAS
tms7	\\tms7\Data	M:	3.3 TB	RAID 5 (4 disks)
tms8	\\tms8\F	Z:	4 TB	RAID 10

Ref: " I:\ateam\docum\fy19\tpb_tdfm_gen2\ver2.3\travel_model_user_guide\mapped_drives_cog_2018.xlsx"

For example, tms5 has one data drive with a capacity of 4.5 TB. This drive is mapped as the E drive when logged on to tms5 and is mapped to the X drive when not logged on to the server. By contrast, tms6 has four data drives. The UNC path for each data drive indicates both the server name (e.g., tms6) and the share name (e.g., ateam). Logical drives that are made of storage arrays consist of multiple physical disk drives, which can be configured in different ways to allow redundancy (using RAID, which stands for Redundant Array of Inexpensive Disks or Redundant Array of Independent Disks). RAID 0 provides no redundancy, but it can often be the fastest configuration. For example, ateamarray and bteamarray have been set up with RAID 5, so they have redundancy in the case of a hard drive crash.

4 Mechanics of the model application process

The Version 2.4 family of travel models, like Ver. 2.3 family, is applied using a command-line interface (CLI), not a graphical user interface (GUI). The model is launched via a single command that is typed or pasted in a single command window (this is covered in the section about running the model). The Version 2.4 Travel Model makes use of the following:

- A series of pre-established batch files, which are used to call a series of Cube Voyager scripts (*.s) and Fortran programs (*.exe);
- A standardized subdirectory system, in which input files, output files, Cube Voyager scripts, and other files are organized; and
- The use of generically named input and output files, which are stored in designated locations in the subdirectory system.

An example subdirectory structure for applying the Version 2.4 Model is shown in Figure 45. The "root" subdirectory appears at the top of the structure. The root subdirectory may exist anywhere on the computer hard drive and may be arbitrarily named by the analyst, but **it is recommended that the name of the root subdirectory include information about both the travel model being used (e.g. Ver2.4) and the modeling project being undertaken**. For example, an analyst performing model runs to support the Air Quality Conformity (AQC) analysis of the 2020 Amendment to Visualize 2045, the TPB's Long-Range Transportation Plan (LRTP) might name the root subdirectory as follows:

`C:\modelRuns\fy20\`**`Ver2.4_aqc_Amend_Vis2045`**

Note that the root subdirectory need not be located directly off the root of the C drive (or D drive, etc.). In the example above, the root subdirectory is below the "fy20" subdirectory. On the left side of Figure 45, there are five specially designated subdirectories under the root that are established:

- SOFTWARE: Fortran executable files and dynamic-link library (DLL) files
- CONTROLS: Control files that are required by the Fortran programs
- SCRIPTS: Cube Voyager scripts
- SUPPORT: General parameter files used by the scripts or other programs, such as AEMS (Fortran) and LineSum (C++)
- SUMMARY: Summary scripts, which are used to summarize the model run

The first four subdirectories are required, but the fifth subdirectory is optional. The SUPPORT subdirectory is reserved for parameter files that generally do not change by modeled scenario such as K-factors, F-factors, and the like. <u>The four required subdirectories must exist under the root, and must be named as shown</u>, although the names are not case sensitive. The optional summary subdirectory may be given any name. Furthermore, the files residing in these four required subdirectories should generally not be altered or renamed.

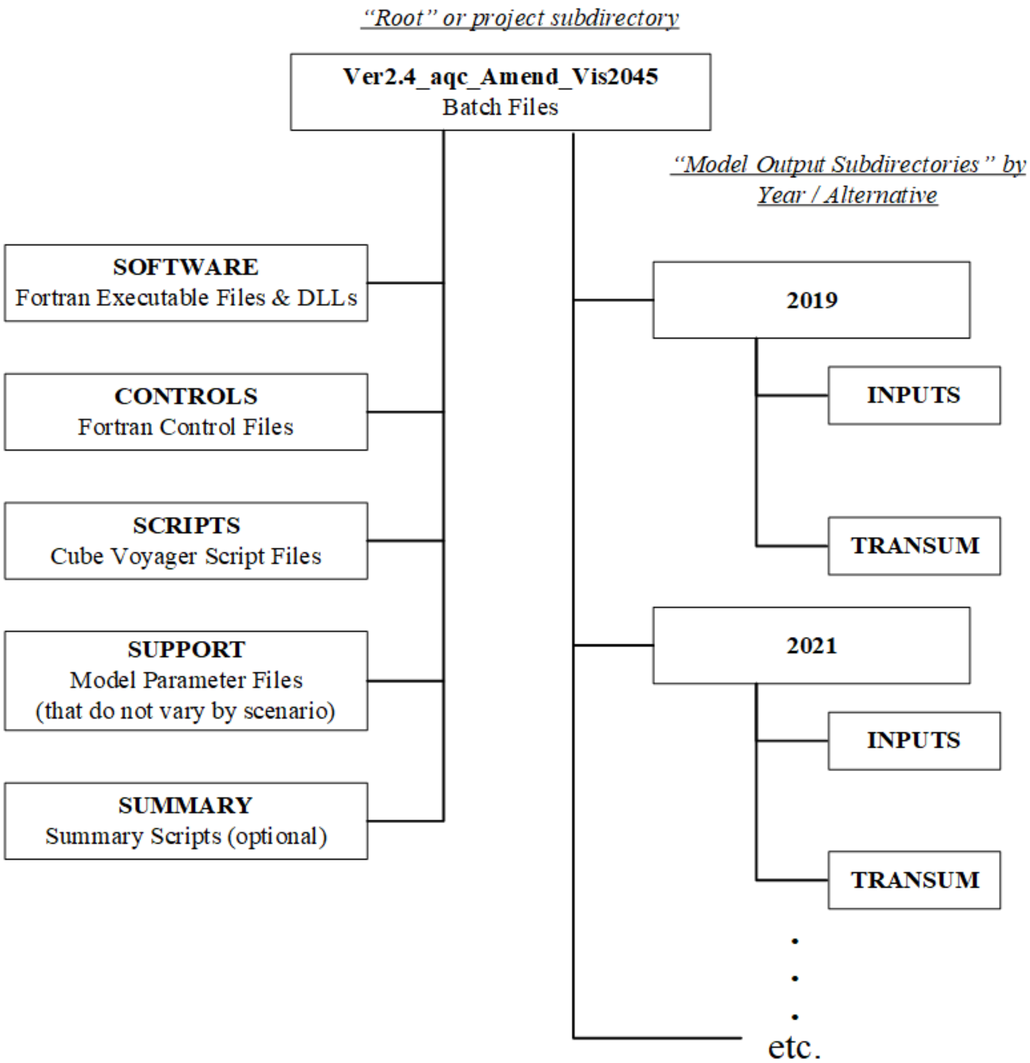


Figure 45 Subdirectory structure for executing the Version 2.4 Travel Model

Ref: " I:\ateam\docum\fy21\Verson23Development\travel_model_user_guide\directoryStruct_v2.4.vsd"

The right side of Figure 45 shows two subdirectories, named "2019" and "2021."[66] These two subdirectories are the output subdirectories (a.k.a. the scenario subdirectories). The user is free to choose any name for output subdirectories. Since travel demand models are best used in a comparative manner, a travel demand modeling project would typically have two or more scenarios or alternatives. Each alternative would get its own output subdirectory for scenario-specific outputs from the travel model.

[66] As of the Ver. 2.3.75 Model, we no longer require two runs of the travel model ("base" and "final") for each scenario modeled. However, some modelers may continue to use the name "final" (e.g., 2021_final), even though there is only one run per scenario.

Under each scenario-specific subdirectory that exists, there need to be two subdirectories, one named "inputs" and the other named "transum." These exact names must be used, but, as stated previously, names are case insensitive. The "transum" subdirectory is for storing summary information about the transit assignment summary. At the beginning of the model run, the "transum" subdirectory will be completely empty, but, at the end of the run, the subdirectory will contain reports from the process (LineSum) that summarizes the transit assignment. The "inputs" subdirectory is where one stores all necessary model inputs that area specific to a modeled scenario (see Table 12). Note that some "inputs" that are common to all modeled scenarios are stored in the "support" subdirectory (see Table 12, which also includes input files stored in the CONTROLS subdirectory). Input files in the "inputs" folder are named generically (e.g., land use data is stored in a file named zone.dbf; network link data is stored in a file named link.dbf, etc.). The user may establish an unlimited number of output subdirectories, as long as each one contains one "inputs" subdirectory and one "transum" subdirectory. Neither the inputs nor transum subdirectories can be shared among more than one alternative. After a model has been run, if the automated transit walkshed process was run with the model, then the "inputs" folder will contain a new subfolder called "Transit_Walksheds_GIS." In the default setup found with the model transmittal package, the automated transit walkshed process is not run (it is commented out). Note that the primary output file from the automated transit walkshed process (areawalk.txt) is now supplied in the inputs folder as part of the model transmittal package, so users need not re-run the process (it is commented out by default) unless users plan to make changes to the transit network, in which case it is recommended that the process be run.

The actual structure of the folders/subdirectories storing the travel model, its input files, and output folders, will be a function of the years/scenarios analyzed, but the list below is representative:

```
+---2019
|   +---Inputs
|   \---transum
+---2021
|   +---Inputs
|   \---transum
+---Controls
+---Docs
+---Scripts
+---Software
+---Summary
+---Support
```

If one is running multiple scenarios, **it is recommended that the analyst set up an electronic spreadsheet to keep track of metadata associated with each model run**. The metadata of importance will vary from study to study, but might contain items such as:

- Run number/ID (a unique sequence number to quickly name a model run)
- Parent run number/ID (indicates the run number of the run that formed the basis for the current run). Useful in figuring which run was derived from which other runs.
- Subdirectory name (i.e., the name of the root folder/subdirectory)

- Key modeling assumption parameters, such as the network year, land use year, land use round (e.g., Round 9.1a), WMATA tariff number, etc.
- Key modeling output parameters, such as model run time, regional VMT, total transit, etc.

Table 12 Input files needed to run the Version 2.4 Travel Model, stored in the CONTROLS, INPUTS, and SUPPORT folders

No.	Folder	Filename	Description	File Type	Category	Modeling step where file is used	Transit/ Non-Transit Mode(s)
1	controls	HBO_NL_MC.ctl	HBO nested-logit mode choice mode control file	Text	Model	Mode choice (MC_Purp.bat & AEMS.EXE)	
2	controls	HBS_NL_MC.ctl	HBS nested-logit mode choice mode control file	Text	Model	Mode choice (MC_Purp.bat & AEMS.EXE)	
3	controls	HBW_NL_MC.ctl	HBW nested-logit mode choice mode control file	Text	Model	Mode choice (MC_Purp.bat & AEMS.EXE)	
4	controls	lineSum_MR_access.ctl	Summary of Metrorail riders by access mode	Text	Summary	LineSum.exe	
5	controls	lineSum_MR_line.ctl	Summary of Metrorail boardings, alightings, and ridership	Text	Summary	LineSum.exe	
6	controls	LineSum_Volume.ctl	Consolidate peak & off-peak vols from transit assignment	Text	Summary	LineSum.exe	
7	controls	NHO_NL_MC.ctl	NHO nested-logit mode choice mode control file	Text	Model	Mode choice (MC_Purp.bat & AEMS.EXE)	
8	controls	NHW_NL_MC.ctl	NHW nested-logit mode choice mode control file	Text	Model	Mode choice (MC_Purp.bat & AEMS.EXE)	
9	controls	station_names.dbf	Contains rail station names (derived from station.dbf)	DBF	Metadata	Created by set_factors.s; Used by LineSum	
1	inputs	airpax.adr	Air Passenger Auto Driver Trips	Binary	Assumptions	Miscellaneous time of day	
2	inputs	AM_Tfac.dbf	AM Toll Factors by Vehicle Type	DBF	Assumptions	Highway skimming and assignment	
3	inputs	areadef3722.prn	Input TAZ-Mode choice district equivalence	Text	Assumptions	Transit fare development (prefarv23.s)	
4	inputs	AreaWalk.txt	Optional. This file is now generated/re-generated by model	Text	Transit network	Generated by automated ArcPy process	
5	inputs	AT_override.TXT	Cases where zones have area-type override values	Text	Assumptions	AreaType_File.s	
6	inputs	Bus_Factor_File.dbf	Local Bus Time Degradation Factors	DBF	Assumptions	transit_skims_??.s	
7	inputs	bus_pnrn.tb	Bus PNR lots	Text	Transit network	transit_skims_??.s	1,2,6-9
8	inputs	BUSFARAM.ASC	AM Bus Fare matrix (Bus fares zones '1' to '21')	Text	Assumptions	mfare2.s	
9	inputs	BUSFAROP.ASC	OP Bus Fare matrix (Bus fares zones '1' to '21')	Text	Assumptions	mfare2.s	
10	inputs	com_bus.tb	Transfer link (walk) between commuter rail station and bus & LRT stop	Text	Transit network	transit_skims_??.s	12
11	inputs	com_link.tb	Commuter rail links	Text	Transit network	transit_skims_??.s	4
12	inputs	com_node.tb	Commuter rail stations	Text	Transit network	transit_skims_??.s	4
13	inputs	com_pnrn.tb	Commuter rail PNR lots	Text	Transit network	transit_skims_??.s	4
14	inputs	CPI_File.txt	Assumed rate of inflation, based on historical CPI	Text	Assumptions	Set_CPI.s	
15	inputs	Ext_PsAs.dbf	External Productions and Attractions	DBF	Observed data	trip_generation.s	
16	inputs	GIS_Variables.dbf	GIS variables used to calculate non-motorized trips	DBF	Observed data	trip_generation.s	
17	inputs	HBO_NL_MC.MTT	Pre-existing mode choice model output	Binary	Assumptions	pp_auto_drivers.s	
18	inputs	HBS_NL_MC.MTT	Pre-existing mode choice model output	Binary	Assumptions	pp_auto_drivers.s	
19	inputs	HBW_NL_MC.MTT	Pre-existing mode choice model output	Binary	Assumptions	pp_auto_drivers.s	
20	inputs	Jur.dbf	Equiv. between juris and river superdistricts: Disallows river crossings for PNR	DBF	Land use	Autoacc5.s	
21	inputs	Link.dbf	Highway network links	DBF	Highway network	V2.3_Highway_Build.s	
22	inputs	lrt_bus.tb	Transfer link (walk) between LRT station and bus stop	Text	Transit network	transit_skims_??.s	12
23	inputs	lrt_link.tb	LRT links	Text	Transit network	transit_skims_??.s	5
24	inputs	lrt_node.tb	LRT stations/stops	Text	Transit network	transit_skims_??.s	5
25	inputs	lrt_pnrn.tb	LRT PNR lots	Text	Transit network	transit_skims_??.s	5
26	inputs	MD_Tfac.dbf	MD Toll Factors by Vehicle Type	DBF	Assumptions	Highway skimming and assignment	
27	inputs	met_bus.tb	Transfer link (walk) between Metrorail station and bus stop	Text	Transit network	transit_skims_??.s	12
28	inputs	met_link.tb	Metrorail links	Text	Transit network	transit_skims_??.s	3
29	inputs	met_node.tb	Metrorail stations	Text	Transit network	transit_skims_??.s	3
30	inputs	met_pnrn.tb	Metrorail PNR lots	Text	Transit network	transit_skims_??.s	3
31	inputs	metlnkm1.tb	Metrorail Links	Text	Transit network	metrorail_skims.s	
32	inputs	metnodm1.tb	Metrorail Nodes	Text	Transit network	metrorail_skims.s	
33	inputs	mfare1.a1	Metrorail Sta XYs scaled to 1/100ths of miles	Text	Transit network	mfare1.s	
34	inputs	mfare1_Sta_Disc.ASC	Metrorail Sta fare discount array in cents	Text	Assumptions	mfare1.s	
35	inputs	MODE1AM,… MODE10AM.tb	AM Transit Line Files	Text	Transit network	transit_skims_??.s	
36	inputs	MODE1OP,… MODE10OP.tb	OP Transit Line Files	Text	Transit network	transit_skims_??.s	
37	inputs	new_bus.tb	Transfer link (walk) between BRT/streetcar stop and bus stop	Text	Transit network	transit_skims_??.s	12
38	inputs	new_link.tb	BRT/streetcar links	Text	Transit network	transit_skims_??.s	10
39	inputs	new_node.tb	BRT/streetcar stations/stops	Text	Transit network	transit_skims_??.s	10
40	inputs	new_pnrn.tb	BRT/streetcar PNR lots	Text	Transit network	transit_skims_??.s	10
41	inputs	NHO_NL_MC.MTT	Pre-existing mode choice model output	Binary	Assumptions	pp_auto_drivers.s	
42	inputs	NHW_NL_MC.MTT	Pre-existing mode choice model output	Binary	Assumptions	pp_auto_drivers.s	
43	inputs	Node.dbf	XY coordinates of nodes in highway network	DBF	Highway network	AreaType_File.s	
44	inputs	NT_Tfac.dbf	NT Toll Factors by Vehicle Type	DBF	Assumptions	Highway skimming and assignment	
45	inputs	Pen.dbf	List of TAZs considered to be in the "slugging" shed of the Pentagon	DBF	Assumptions	Autoacc5.s	
46	inputs	PM_Tfac.dbf	PM Toll Factors by Vehicle Type	DBF	Assumptions	highway_assignment.s	
47	inputs	schl.adr	School Auto Driver Trips	Binary	Assumptions	misc_time-of-day.s	

No.	Folder	Filename	Description	File Type	Category	Modeling step where file is used	Transit/ Non-Transit Mode(s)
48	inputs	StaAcc.dbf	Lookup table: Maximum drive-access-to-transit distances	DBF	Assumptions	Autoacc5.s	
49	inputs	station.dbf	Station file: Metrorail, commuter rail, LRT stations/PNR lots and bus PNR lots	DBF	Transit network	parker.s	
50	inputs	tariff.txt	WMATA tariff policy	Text	Assumptions	mfare1.s	
51	inputs	taxi.adr	Taxi Auto Driver Trips	Binary	Assumptions	misc_time-of-day.s	
52	inputs	tazfrzn.asc	Fare Zone File	Text	Assumptions	prefarv23.s	
53	inputs	Toll_Esc.dbf	Toll escalation assumptions: Highway tolls & deflators	DBF	Assumptions	V2.3_Highway_Build.s	
54	inputs	trnpen.dat	Turn Penalty file to ensure correct Metrorail fares	Text	Assumptions	metrorail_skims.s	
55	inputs	visi.adr	Visitor Auto Driver Trips	Binary	Assumptions	misc_time-of-day.s	
56	inputs	xtrawalk.dbf	Extra walk links that the analyst wishes to include	DBF	Transit network	walkacc.s	13
57	inputs	xxaut.vtt	Auto Driver Through Trips	Binary	Assumptions	misc_time-of-day.s	
58	inputs	XXCVT.vtt	Com/Mtk/Htk through Trips	Binary	Calculated data	misc_time-of-day.s	
59	inputs	Zone.dbf	Land use/land activity data at zonal level, 3722 TAZ	DBF	Land use	AreaType_File.s	
1	support	AM_SPD_LKP.txt	Initial lookup speeds used for highway links, AM period	Text	Highway network	V2.3_Highway_Build.s	
2	support	AttrRates.dbf	Trip Attractions	DBF	Calculated data	trip_generation.s	
3	support	cvdelta_3722.trp	Calibration matrix, or "delta table" for commercial vehicles	Binary	Assumptions	misc_time-of-day.s	
4	support	equiv_toll_min_by_inc.s	Equivalent minutes (min/'07$) by period & income level	Text	Assumptions	trip_distribution.s	
5	support	HBincRat.dbf	HB Income Shares	DBF	Calculated data	trip_generation.s	
6	support	hwy_assign_capSpeedLookup.s	FT x AT Speed & Capacity lookup	Text	Highway network	highway_assignment.s	
7	support	hwy_assign_Conical_VDF.s	Volume Delay Functions file	Text	Highway network	highway_assignment.s	
8	support	MD_SPD_LKP.txt	Initial lookup speeds used for highway links, midday	Text	Highway network	V2.3_Highway_Build.s	
9	support	NMArates.dbf	Non-motorized Trip Attractions	DBF	Calculated data	trip_generation.s	
10	support	NMPrates.dbf	Non-motorized Trip Productions	DBF	Calculated data	trip_generation.s	
11	support	TAZ3722_to_7Mrkts.txt	Equivalency between TAZs and mode choice superdistricts	Text	Assumptions	PP_Auto_Drivers.s	
12	support	tkdelta_3722.trp	Calibration matrix, or "delta table" for med and hvy truck	Binary	Assumptions	misc_time-of-day.s	
13	support	todcomp_2008HTS.dbf	Time of day model/factors	Binary	Assumptions	time-of-day.s	
14	support	toll_minutes.txt	Toll minutes equivalence file by Vehicle Type	Text	Assumptions	Highway_skims.s	
15	support	TPBMod_Jur_Boundary.shp	Jurisdictional boundaries	SHP	Network	Network editing with Cube Base	
16	support	Truck_Com_Trip_Rates.dbf	Truck and Commercial Vehicle Trip Rates	DBF	Calculated data	truck_com_trip_generation.s	
17	support	True_Shape_2040_Nov20.shp	Used to display highway network with True Shape	SHP	Highway network	Network editing with Cube Base	
18	support	Ver23_f_factors.dbf	F-factors for trip distribution	DBF	Calculated data	trip_distribution.s	
19	support	weighted_trip_rates.dbf	Trip Productions	DBF	Calculated data	trip_generation.s	

* This file is created automatically by set_factors.s from the station.dbf file.

Ref: v2.3.75_inputs_v1.xlsx

Pre-established "parent" and "child" batch files for executing the model reside in the root subdirectory. Typically, "parent" batch files are edited to correspond to each modeled scenario, while "child" batch files remain unaltered. The parent batch files can be named as the user likes. The two main parent batch files are the "wrapper" batch file and the "run model steps" batch file (the latter file used to be called the "run all" batch file). Details about these two files can be found in section 6.2 ("Parent batch files") on page 87. The child batch files are the ones that execute individual modeling steps, such as the trip generation step (e.g., Trip_Generation.bat) or the traffic assignment step (e.g., Highway_Assignment_Parallel.bat). Child batch files generally call the Cube Voyager scripts and/or Fortran programs. The child batch files also assign names to report files that result from each model step. Listing files are typically assigned file extensions of RPT or TAB. The former refers to Cube Voyager report or listing files, while the latter refers to a subset tabulation of the report file containing only trip table totals or jurisdictional summaries. Parent batch files are used to string child batch files together so that the entire model execution can be initiated with a single command or batch file. The parent batch files also establish Windows environment variables that are used in the child batch files and Cube Voyager scripts, such as the iteration number, the model year, and the model description.

As stated earlier, all the input files located in the "inputs," "controls," and "support" folders are listed in Table 12. It is the user's responsibility to make sure that the generically named files are appropriate for the modeled scenario and are in the prescribed format (described later). Additionally, almost all the files shown in Table 12 must exist for the model run to complete successfully, with the exception of some files such as the shapefiles used for displaying a highway network in True Shape mode (True_Shape_2040_Nov20.shp). The advantage of using generic filenames is that the input and output filenames referenced in each Cube Voyager script and control file do not need to be tailored to match the different scenarios that are run. The disadvantage of using generic filenames is that, when moving or sharing files, two files with the same name could be quite different (e.g., zone.dbf for the year 2019 has the same name as zone.dbf for the year 2045). Thus, the metadata that describes the scenario name is stored in the name of the output subdirectory (e.g., "2019"), not in the filenames themselves.

The SOFTWARE folder contains two Fortran executable programs (AEMS.exe and extrtab.exe), one C++ executable program (LineSum.exe),[67] and several dynamic-link library (DLL) files, as shown in Table 13.

---

[67] In the future, if we replace AEMS with TRANSIMS ModeChoice, this folder will also include the C++ mode choice application program ModeChoice.exe.

Table 13 Fortran and C++ executable files and dynamic-link library files required for running the Version 2.4 Travel Model

Executable Name	Ver	Date	Size (bytes)	Program Function	Requires a control file?
AEMS.exe		2/13/2012	195,900	Mode choice application program (Fortran, 32-bit)	yes
cw3240.dll		2/13/2012	827,392	Dynamic-link library file associated w/ AEMS.exe	no
DFORMD.dll		2/13/2012	425,984	Dynamic-link library file associated w/ AEMS.exe	no
extrtab.exe		2/13/2012	464,559	Extracts sections from Cube Voyager report files (Fortran, 32-bit)	no
Linesum.exe	6.0.2	3/26/2014	697,344	Creates reports summarizing transit loaded link files (C++, 32-bit)	yes

Note: There are two Cube DLL files needed for running AEMS.exe: Tppdlibx.dll and Tputlibc.dll.[68] These two files come with Cube. **These are not stored in the software folder**, but when AEMS runs, it needs to "see" these two files. This can be accomplished by either 1) placing a copy of these two files in the folder where AEMS runs (the SOFTWARE folder under the root folder of the model run); OR 2) **setting the Windows PATH environment variable to point to the location where these DLL files exist**. **It has been found that the second option is generally the best one**. One complicating factor is the fact that Cube Base is 32-bit and Cube Voyager is 64-bit, and each comes with a version of these two files (see Table 14). **AEMS needs the 32-bit version** (which is stored here: C:\Program Files (x86)\Citilabs\CubeVoyager). For more information about setting the Windows PATH environment variable, see section 5.1 ("Installing software ").

Table 14 Location for Cube DLL files

Cube DLL File	Location for 32-bit version	Location for 64-bit version
TPPDLIBX.DLL	C:\Program Files (x86)\Citilabs\Cube\ C:\Program Files (x86)\Citilabs\CubeVoyager\	none C:\Program Files\Citilabs\CubeVoyager\
TPUTLIBC.DLL	C:\Program Files (x86)\Citilabs\Cube\ C:\Program Files (x86)\Citilabs\CubeVoyager\	none C:\Program Files\Citilabs\CubeVoyager\

A listing of child batch files is provided in Table 15. The table also indicates the programs and/or Cube Voyager scripts that are invoked and the purpose of each batch file. Given the iterative application process of the model, most of the batch files are called multiple times during a model run. The sequence of batch file applications, by iteration, is shown in Table 16. The table indicates that there are 48 batch file steps called during a standard application of the model. Some of the batch files are called once, while others (e.g., *Trip_Generation.bat*) are called during the pump-prime and all four standard iterations. A parent batch file ("*run_ModelSteps*.bat*") is used to string each of the child batch files together during a typical model execution. The parent batch files, like child batch files, reside in the root subdirectory. Two parent batch files are typically prepared for each individual model run. The process for executing a model is addressed in the next section. The remaining chapters address the specific details of each modeling step.

[68] In earlier versions of Cube, the filename of the second file omitted the letter "c": Tputlib.dll

Table 15 Child batch files used to run the Version 2.4 Travel Model

Batch File	Scripts/Programs	Purpose
set_up_model_run_folders.bat	None	Not used in the running of the mode, but can be used to set up folders for a new model run.
ArcPy_Walkshed_Process.bat	MWCOG_Prepare_Inputs_to_Walkshed_Process_PT.s MWCOG_Prepare_Inputs_to_Walkshed_Process_TRNBUILD.s	Run the automated/integrated ArcPy/Python transit walkshed process
Set_CPI.bat	Set_CPI.s Set_Factors.s	Create highway and transit cost deflators. Create K factors and time penalties. Create station_names.dbf file from station.dbf file.
PP_Highway_Build.bat	AreaType_File.s V2.3_higway_build.s	Build highway networks.
PP_Highway_Skims.bat (see also Highway_Skims.bat)	Highway_skims_am.s Highway_skims_md.s Modnet.s CheckStationAccess.s Highway_skims_mod_am.s Highway_skims_mod_md.s Joinskims.s Remove_PP_Speed.s	Create AM/off-peak highway skims. Check whether stations are accessible
Transit_Skim_All_Modes_Parallel.bat	parker.s walkacc.s autoacc5.s transit_Accessibility.s Transit_Skim_LineHaul_Parallel.bat Transit_Skims_AB.s Transit_Skims_BM.s Transit_Skims_CR.s Transit_Skims_MR.s	Create the transit network: • Create transit access links • Create transit network • Skim the four transit submodes Also runs the transit accessibility process.
Transit_Fare.bat	prefarV23.s Metrorail_skims.s MFARE1.s MFARE2.s Assemble_Skims_MR.s Assemble_Skims_BM.s Assemble_Skims_AB.s Assemble_Skims_CR.s	Create transit fares for the current speed feedback iteration.
Trip_Generation.bat	Demo_Models.s Trip_Generation.s Trip_Generation_Summary.s Truck_Com_Trip_Generation.s	Execute daily trip generation.
Trip_Distribution.bat	Prepare_Ext_Auto_Ends.s Prepare_Ext_ComTruck_Ends.s Trip_Distribution_External.s Prepare_Internal_Ends.s Trip_Distribution_Internal.s	Execute daily trip distribution.
Mode_Choice_Parallel.bat	MC_purp.bat => AEMS.EXE mc_NL_summary.s	Execute the daily mode choice model (in P/A format).

Batch File	Scripts/Programs	Purpose
copyBaseMC_to_final_inputs.bat	None	Not currently called as part of a model run. Could potentially be used by modeler to copy pre-existing NL mode choice model output into the input folder for new run.
Auto_Driver.bat	mc_Auto_Drivers.s	Generate initial auto driver trips after mode choice.
PP_Auto_Drivers.bat	PP_Auto_Drivers.s	Generate initial auto driver trips without the use of the mode choice model.
Time-of-Day.bat	Time-of-Day.s Misc_Time-of-Day.s Prepare_Trip_Tables_for_Assignment.s	Convert daily modeled trips to AM, PM, midday, and night. Convert trip tables from P/A format to O/D format.
Highway_Assignment_Parallel.bat	Highway_Assignment_Parallel.s	Execute user equilibrium highway assignment for four time-of-day periods
Average_Link_Speeds.bat	Average_Link_Speeds.s	Compute average link speeds. Run for only speed feedback iterations 2-4
Highway_Skims.bat	Highway_Skims_am.s Highway_Skims_md.s modnet.s Highway_Skims_mod_am.s Highway_Skims_mod_md.s joinskims.s	Build zone-to-zone paths on the highway network and skim the times and costs on each path. Store the skimmed times and paths in matrix files.
Transit_Assignment_Parallel.bat	Combine_Tables_For_TrAssign_Parallel.s Transit_Assignment_LineHaul_Parallel.bat Transit_Assignment_AB.s Transit_Assignment_BM.s Transit_Assignment_CR.s Transit_Assignment_MR.s	Execute the transit assignment (P/A format) for peak and off-peak periods
TranSum.bat	LineSum_*.ctl (such as LineSum_Volume.ctl, or lineSum_MR_access.ctl)	Summarize the transit assignment
dateName.bat	None (used by searchForErrs.bat)	
searchForErrs.bat	None	Searches through log and print files for possible error codes
move_temp_files_v6.bat	None	Moves temporary files to a location where they can be later deleted manual by the modeler.
updating_tpp_dll_files.bat	None	Not used for a model run. In the past, this batch file could be used to put the TP+ DLL files in the correct location, but this file is no longer used.

Table 16 Sequence of the batch files used to run the Version 2.4 Travel Model

		Speed Feedback Iteration				
Batch File	**Scripts/Programs**	**PP**	**1**	**2**	**3**	**4**
ArcPy_Walkshed_Process.bat	MWCOG_Prepare_Inputs_to_Walkshed_Process_PT.s MWCOG_Prepare_Inputs_to_Walkshed_Process_TRNBUILD.s	1				
Set_CPI.bat	Set_CPI.s Set_Factors.s	2				
PP_Highway_Build.bat	AreaType_File.s V2.3_higway_build.s	3				
PP_Highway_Skims.bat (see also Highway_Skims.bat)	Highway_skims_am.s Highway_skims_md.s Modnet.s CheckStationAccess.s Highway_skims_mod_am.s Highway_skims_mod_md.s Joinskims.s Remove_PP_Speed.s	3				
Transit_Skim_All_Modes_Parallel.bat	parker.s walkacc.s autoacc5.s transit_Accessibility.s Transit_Skim_LineHaul_Parallel.bat Transit_Skims_AB.s Transit_Skims_BM.s Transit_Skims_CR.s Transit_Skims_MR.s	5	12	21	30	39
Transit_Fare.bat	prefarV23.s Metrorail_skims.s MFARE1.s MFARE2.s Assemble_Skims_MR.s Assemble_Skims_BM.s Assemble_Skims_AB.s Assemble_Skims_CR.s		13	22	31	39
Trip_Generation.bat	Demo_Models.s Trip_Generation.s Trip_Generation_Summary.s Truck_Com_Trip_Generation.s	6	14	23	32	41
Trip_Distribution.bat	Prepare_Ext_Auto_Ends.s Prepare_Ext_ComTruck_Ends.s Trip_Distribution_External.s Prepare_Internal_Ends.s Trip_Distribution_Internal.s	7	15	24	33	42
Mode_Choice_Parallel.bat	MC_purp.bat => AEMS.EXE mc_NL_summary.s		16	25	34	43
Auto_Driver.bat	mc_Auto_Drivers.s		17	26	35	44
PP_Auto_Drivers.bat	PP_Auto_Drivers.s	8				
Time-of-Day.bat	Time-of-Day.s Misc_Time-of-Day.s Prepare_Trip_Tables_for_Assignment.s	9	18	27	36	45
Highway_Assignment_Parallel.bat	Highway_Assignment_Parallel.s	10	19	28	37	46

		Speed Feedback Iteration				
Batch File	**Scripts/Programs**	**PP**	**1**	**2**	**3**	**4**
Highway_Skims.bat	Highway_Skims_am.s Highway_Skims_md.s modnet.s Highway_Skims_mod_am.s Highway_Skims_mod_md.s joinskims.s	11	20	29	38	47
Transit_Assignment_Parallel.bat	Combine_Tables_For_TrAssign_Parallel.s Transit_Assignment_LineHaul_Parallel.bat Transit_Assignment_AB.s Transit_Assignment_BM.s Transit_Assignment_CR.s Transit_Assignment_MR.s					48
TranSum.bat	LineSum_*.ctl (such as LineSum_Volume.ctl, or lineSum_MR_access.ctl)					49

5 Preparing to run the model

Before the travel model can be run, one must install the necessary software, as described in the next section.

5.1 Installing software and setting the Windows PATH environment variable

Step 1: Make sure you are logged on to your computer with administrator privileges, so you can install software (or ask your IT department to perform the installation).

At COG, you will need to be a member of these two groups: "Administrators" and "SophosAdministrator" (the second group is associated with antivirus software). In other agencies, there may be other requirements. Additionally, based on testing done at COG, the mode choice application program (AEMS.EXE) may not work if you are not part of the Administrators group.

Step 2: Verify that your computer is running a 64-bit version of Windows, since this is needed to install the 64-bit version of Cube Voyager (Cube Base is still 32-bit software).

<Windows key><Pause/Break> will bring up the System Properties window. The "System Type" should be listed as "64-bit Operating System." Alternatively, if you prefer using the command prompt, you can run the command "systeminfo | more":

- If you are running a 32-bit version of Windows, you will see "System Type: X86-based PC". This will not allow you to install the 64-bit version of Cube Voyager, so you will not be able to run the Ver. 2.4 Model.
- If you are running a 64-bit version of Windows, you will see "System Type: x64-based PC".

On 64-bit versions of Windows

- 64-bit software, such as Cube Voyager, is stored here: "C:\Program Files".
- 32-bit software, such as Cube Base, is stored here: "C:\Program Files (x86)".

Step 3: Determine the number of cores on your computer.

Again, <Windows key><Pause/Break> will bring up the System Properties window. Here you can see the CPU type (e.g., "Intel Core i5-4590"). You can perform an internet search with this information to find the number of cores that are contained in your processor.

Also, if you open up the Task Manager (keyboard combination <CTRL><SHIFT><ESC>) and select the Performance tab, you can see the number of cores that the Windows operating system sees, as well as the number of logical processors (see Figure 46).

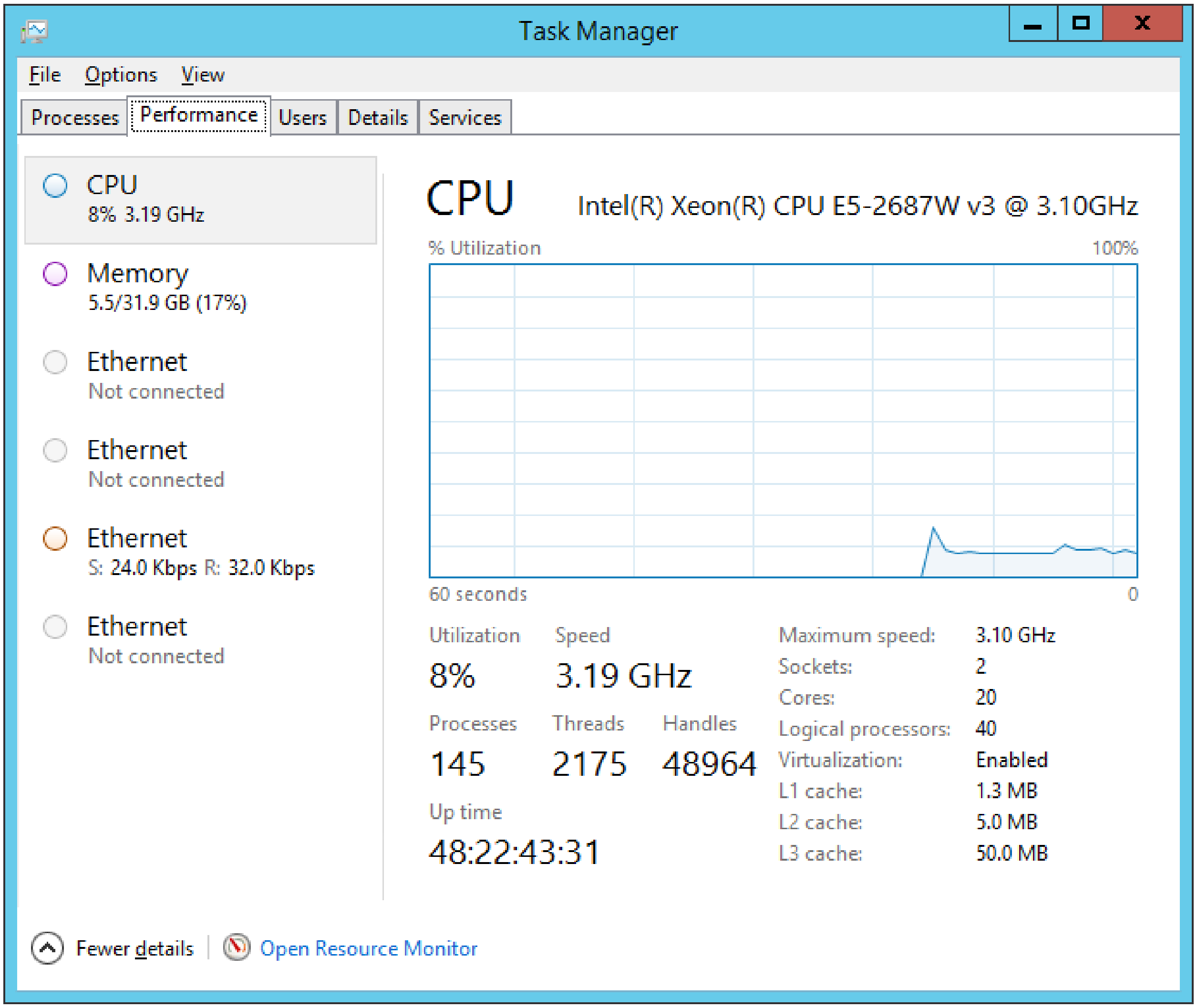


Figure 46 Number of cores and logical processors

In this example, Windows sees 20 cores and 40 logical processors. If the number of logical processors is double the number of cores, this means that Intel's Hyper-Threading Technology is turned on. Intel's Hyper-Threading Technology allows each core to handle two threads, so the operating system (OS) will see twice as logical processors as the actual number of physical cores.

Step 4: Install Bentley Systems Cube Base and Cube Voyager software, according to the vendor's instructions. If you have purchased the license for Cube Cluster, this will also be installed at this point.

Once you have installed Cube Base, you can open it and click on help ("  ") and "About…", which should bring up a window like the following:

Figure 47 Bentley Systems Cube 6.4, "About" message window

From this window, we can see that we have installed Cube Base, version 6.4.1. The maintenance license expires in Feb. 2019. Cube sees 10 processors, even though this is on a computer with 20 cores and 40 logical processors.

If you are running the Ver. 2.4 Travel Model on a computer with fewer than 8 logical processors, you will need to follow the instructions in Table 21 (p. 111) before running the Ver. 2.4 Travel Model.

Determining if you have Cube Cluster: If you wish to determine whether a given computer includes a Cube Cluster license, open Cube Voyager and click the "About Voyager" button. If your computer has a Cube Cluster license, you should see "with Cluster License" (as shown in Figure 48).

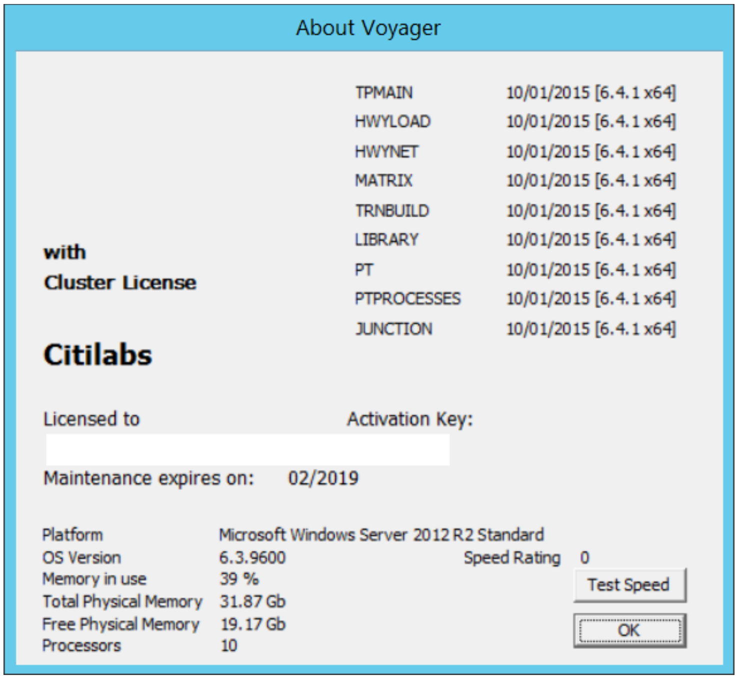


Figure 48 "About Voyager": Presence of Cube Cluster license

According to Citilabs, the "Test Speed" button is no longer active. This window also shows 10 processors, even though this computer has 20 cores and 40 logical processors.

Step 5: Make sure that the version of PowerShell is 3.0 or higher. One may check their PowerShell version by using $PSVersionTable command in Windows PowerShell.

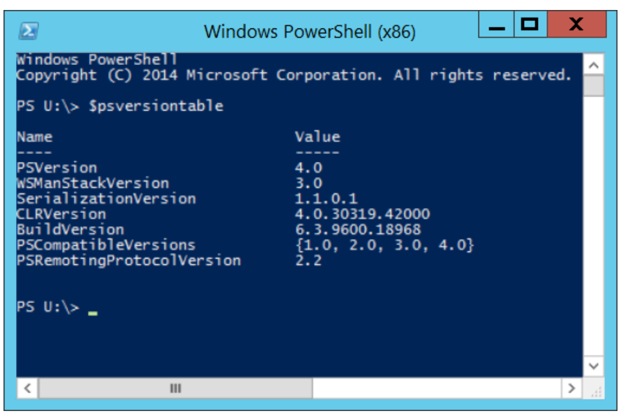


Figure 49 Windows PowerShell version

Most computers will likely be running Windows PowerShell 3.0 (or more recent), which comes preinstalled with Windows operating systems. If the version of PowerShell is 1.0 or 2.0, which may come with older versions of Windows, such as Windows XP or Windows Server 2008 SP1, the framework needs an upgrade to a more recent version. The steps to install a more recent Windows PowerShell version can be found in the Microsoft webpage "https://docs.microsoft.com/en-us/powershell/scripting/setup/installing-windows-powershell?view=powershell-6".

Step 6: If you do not already have one, install the text editor of your choice, such as Notepad++ or PSPad. Notepad++ is free and open source. PSPad is free but is not open source. Each of these text editors has it pluses and minuses, in terms of syntax highlighting, code folding, and other features, such as diffing two text files.

Step 7: (Optional) Install Cygwin (http://www.cygwin.com/). **Like Ver. 2.3.78, the Ver. 2.4 Model does not need this software**. Nonetheless, some users may still choose to install this software, due to its ability to offer various Unix-like utility commands. This is a free, open source software package that provides a Linux-like environment for Windows. It provides a series of Unix-like command-line tools, such as head, tail, and which. Another more recent, and perhaps more integrated way, to get access to Linux commands on a Windows computer is to install the Windows Subsystem for Linux (WSL).

Cygwin comes in two versions: a 32-bit version (setup-x86.exe) and a 64-bit version (setup-x86_64.exe). Normally, we would advise you to install the version that is appropriate for your computer. However, in the past, we have found that, in the 64-bit version of Cygwin, the head and tail commands did not seem to work correctly. **Consequently, if you choose to install Cygwin, we recommend that you install the 32-bit version of the software**.

1. Download the 32-bit version of Cygwin: setup-x86.exe.
2. Double click the setup file to run. It will install a default set of packages. You can always add more in the future by rerunning the setup file.

Do not forget where this file is since you might need to run it in the future to add or remove components from Cygwin. The recommended location is to place the file is in a folder in your "downloads" folder (e.g., C:\Users\<username>\downloads\cygwin). Once you have done this, you should create a shortcut to the setup file on the Windows Desktop so that you can find this file easily in the future. As an alternative, you can also store the setup file directly on the Windows Desktop. The disadvantage with this second location is that, during the installation procedure, Cygwin will place a folder of downloaded files on the Desktop, and this folder may have an odd name, such as "ftp%3a%2f%2fftp.gtlib.gatech.edu%2fpub%2fcygwin%2f".

Step 8: Set the Windows PATH environment variable.

Among other files, the 32-bit software folder (C:\Program Files (x86)\Citilabs\CubeVoyager) contains the following files:

```
10/01/2015  07:11 AM         3,416,528 CLUSTER.EXE
10/01/2015  07:44 AM           111,056 RUNTPP.EXE
10/01/2015  07:44 AM           415,744 TPPDLIBX.DLL
10/01/2015  07:44 AM           152,576 TPUTLIBC.DLL
```

By contrast, the 64-bit software folder (C:\Program Files\Citilabs\CubeVoyager) contains the following files:

```
10/01/2015  07:11 AM         4,206,544 CLUSTER.EXE
10/01/2015  07:45 AM           150,480 RUNTPP.EXE
```

```
10/01/2015  07:45 AM           373,712 VOYAGER.EXE
10/01/2015  07:44 AM           511,488 TPPDLIBX.DLL
10/01/2015  07:44 AM           178,688 TPUTLIBC.DLL
```

AEMS.EXE requires the use of the two TP DLL files in the 32-bit folder (C:\Program Files (x86)\Citilabs\CubeVoyager), so the Windows PATH variable should point to that folder. However, the 32-bit folder contains the wrong version of Cluster and does not contain Voyager.exe at all. Luckily, when Voyager.exe is called using the "start /w" command, Windows knows how to find the correct version of Voyager (in this case, the only version of Voyager). Thus, as a minimum, you will want to add the following path to your Windows PATH environment variable:

64-bit version of Windows	**Reason**
C:\Program Files (x86)\Citilabs\CubeVoyager	Needed so that AEMS can find the two TP DLL files (Tppdlibx.dll and Tputlibc.dll)

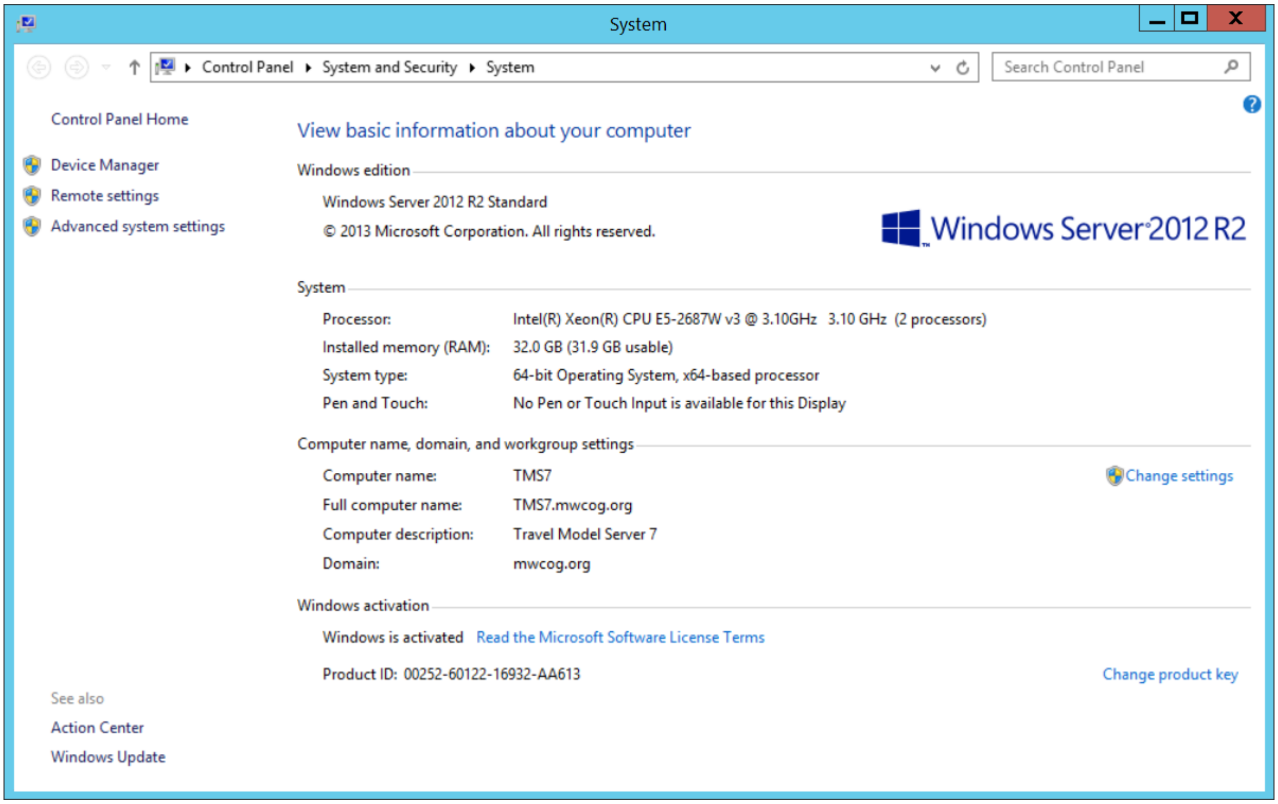
Additionally, the following paths might also be useful additions to your Windows PATH environment variable:

64-bit version of Windows	**Reason**
C:\Program Files (x86)\PSPad editor	To be able to open the PSPad text editor from the command line
C:\Program Files (x86)\WinMerge	To be able to open WinMerge from the command line
C:\cygwin\bin	Needed to run Cygwin from the command line

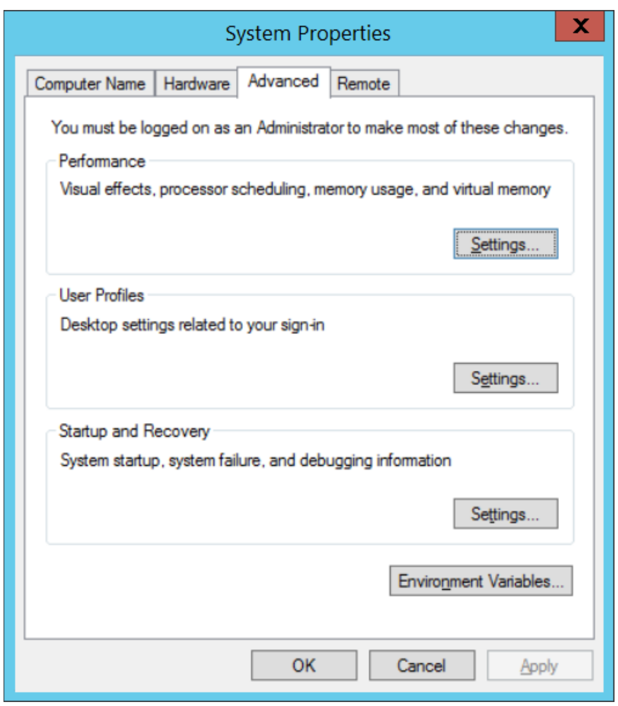
Here are instructions for updating the Windows PATH environment variable:

Hold down these two keys simultaneously to bring up the Windows System Properties window:

<Windows key><Pause/Break key>

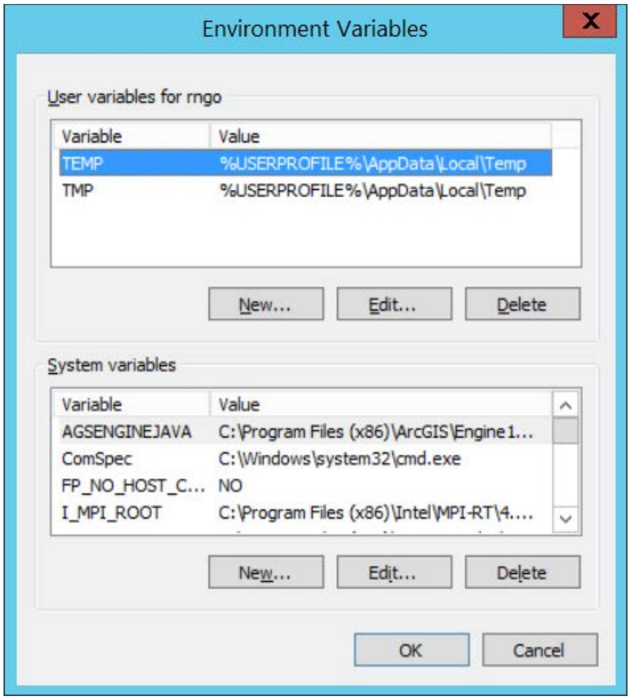


Click "Advanced system settings." Click the "Advanced" tab.

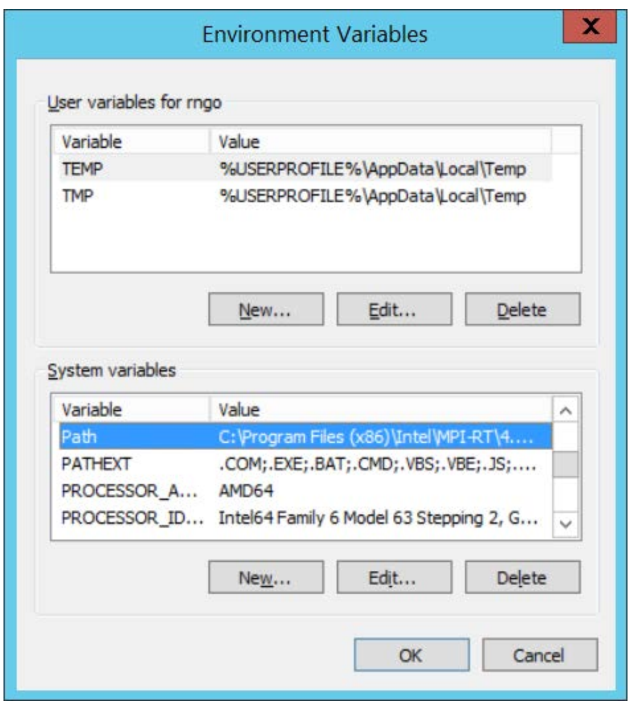


Click the "Environment Variables" button.

The lower half of this window contains "system variables."



Find the "Path" environment variable in the lower half of this window.



Click "Edit."

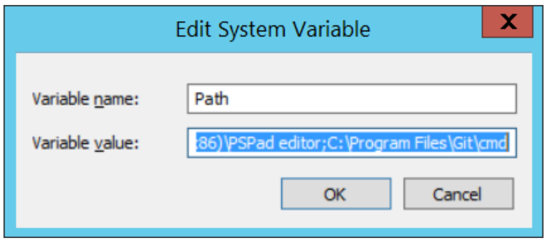
Add the Windows paths that you want. Add these to the end of the Path variable, using a semicolon (";") as the separator.

For example, this path:

```
%SystemRoot%\system32;%SystemRoot%;%SystemRoot%\System32\Wbem;%SYSTEMROOT%\System32\WindowsPowerShell\v1.0\
```

Would become this path:

```
%SystemRoot%\system32;%SystemRoot%;%SystemRoot%\System32\Wbem;%SYSTEMROOT%\System32\WindowsPowerShell\v1.0\;C:\Program Files (x86)\Citilabs\CubeVoyager;C:\cygwin\bin
```



Click "OK" three times.

To test whether Cygwin is working correctly, open a command window and type a Cygwin command, such as

```
which ls
```

Or

```
tail --help
```

To test Cube Voyager, type:

```
start /w voyager
```

Or

```
cluster
```

Step 9: Useful, but not essential: Install Winmerge and update the PATH environment variable to include:

C:\Program Files\WinMerge

Step 10: You may want to associate *.net files with Cube.exe. This will allow the file i4_assign_output.net to be opened in Cube automatically at the completion of a model run. You may also want to associate *.txt and *.rpt files with your preferred text editor. At the completion of a model run, the "run model" batch file tries to open several of these files (such as i4_Highway_Assignment.rpt). By setting up the desired file association, these files will be opened at the end of the model run using the desired text editor (versus the default Windows text editor, which is Notepad).

5.2 Preparing input files and calculating zonal percent-walk-to-transit values

After a person has requested the COG/TPB travel model from COG/TPB staff (https://www.mwcog.org/transportation/data-and-tools/modeling/data-requests/), he or she will be sent a transmittal memo and the actual travel model, including its inputs. If the user wants to simply run the travel model for the years/scenarios that have been supplied by COG/TPB staff, then there is no need to make any changes to the model inputs (This also pre-supposes that the user has required hardware and software, as specified in this user's guide).

In the Ver. 2.3.66 Travel Model and earlier versions, one of the first steps in the run_modelSteps batch file was to run the automated transit walkshed process: "call *ArcPy_Walkshed_Process.bat* %1". Due to instabilities with ArcGIS and the ArcGIS runtime engine that is packaged with Cube, the automated transit walkshed process is one of the model steps that is most likely to fail (premature stop or crash). This is especially true with the ArcGIS runtime engine that comes with Cube 6.4.2. For this reason, when we transmit the model to end users, the automated transit walkshed process is turned off (commented out in the run_modelsteps batch file). This is not a problem for most users since we provide in the inputs folder the primary output file (areawalk) from the automated transit walkshed process. If, however, a user wishes to make changes to the transit network, then we recommend uncommenting this step to allow the automated transit walkshed process to run. The new transit walkshed process is discussed in section 11 ("Building transit walksheds and calculating zonal walk percent") of this report, beginning on p. 123.

6 Running the model

As noted in the "Hardware and software " section, the Version 2.4 Travel Model is implemented using Bentley Systems Cube software (in 2020, Citilabs was acquired by Bentley Systems). Cube Base is the graphical user interface (GUI) for the Cube suite of software. Cube base can be used for editing Cube Voyage scripts, editing transportation networks, viewing matrix files, managing network scenarios (Scenario Manager), and running travel models (Application Manager). However, the Version 2.4 Travel Model is not launched using Cube Base's Application Manager. Instead, the Version 2.4 Travel Model is implemented using a command-line interface (CLI) that is initiated from a Windows command window (also called a DOS command window by some, although DOS no longer exists).

6.1 Updating the Windows PATH environment variable

It is important to update the Windows PATH environment variable, as described in section 5.1 ("Installing software and setting the Windows PATH environment variable").

The next section describes a simple example of how to run the travel model. Following that are two sections that describe the wrapper batch file and the "run model steps" batch file in more detail.

6.2 Parent batch files

To run the Version 2.4 Travel Model, the user must edit two batch files and then run one of the batch files, which, in turn, will call the other file. These two batch files are known as the parent batch files, since they call a series of other batch files (known as the child batch files). The first parent batch file is called the "wrapper" batch file or the "run model" batch file (an example can be seen in Figure 50). The second parent batch file is called the "run model steps" (formerly "run all") batch file (an example can be seen in Figure 51). In computer programming, the term "wrapper function" is used for a function whose main purpose is to call a second function and set up a computing environment for that second function. We are using this term in a similar vein, since the main purpose of our wrapper batch file is to call a second batch file (the "run model steps" batch file) and set up the running environment for the model run. Once the user has edited the two parent batch files with a text editor, the user launches the model run by launching the wrapper batch file either directly or within a command prompt window that is pointing to the root directory. For example, if the root directory is "C:\modelRuns\fy18\Ver2.4.75_aqc_Vis2045", then **the user would open a command prompt window at this location and type the name of the "run model"/wrapper batch file and press Enter to execute it.** This process is described in more detail below, along with some preliminary information needed to make the model run correctly.

There is typically a "run model" batch file and a "run model steps" batch file for each scenario/year that is modeled, e.g.,:

run_Model_2019.bat
run_ModelSteps_2019.bat

run_Model_2021.bat
run_ModelSteps_2021.bat

run_Model_2025.bat
run_ModelSteps_2025.bat

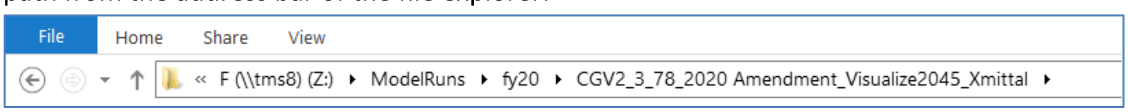
run_Model_2030.bat
run_ModelSteps_2030.bat

run_Model_2040.bat
run_ModelSteps_2040.bat

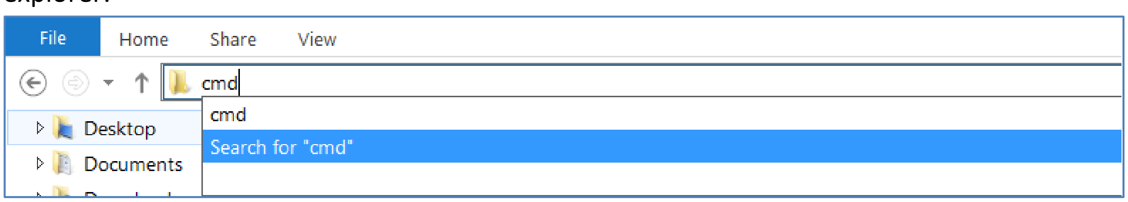
run_Model_2045.bat
run_ModelSteps_2045.bat

To launch a model run, one needs to open a Windows command window that points to the location where you have placed the parent batch files (the so-called "root" folder). One way to do this is to open Windows Explorer (File Explore in some versions of Windows) and navigate to the root folder, and then select the root folder by clicking it once. In earlier versions of Windows, one would select the folder in the left pane, and then, with nothing selected in the right pane, one would use the mouse to **shift-right-click** in the right pane, selecting "Open Command Window Here." However, in newer versions of Windows, this action results in the option to "Open PowerShell window here." Since the model is currently not run under Windows PowerShell, one should not select this option. Instead, one can do one of the following:

- Either, open a command window using the Windows Start button, and change the directory to the desired directory by using the change directory (CD) command. One can copy the desired path from the address bar of the file explorer:



- Or, one can put the cursor in the address bar and type "cmd". This will open a command window whose current path is the path that had been in the address bar of the Windows file explorer:



The main drawback to using the second approach is that after one types cmd in the address box, the address box seems to no longer contain the original path, even though the Windows File Explorer still seems to show this location and the files stored in this location. Thus, after one types "cmd" in the address box, when one clicks in the box a second time, one will see this:

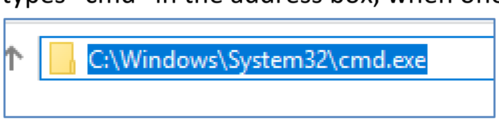


Figure 50 "Run model" batch file for 2019

```
:: File location
```

```
:: Version 2.4
:: 2/10/2020 2:47 PM

set root=.
set scenar=2019
set runbat=run_ModelSteps_2019.bat
:: Environment variables for (multistep) distributed processing:
:: Environment variables for (intrastep) distributed processing:
::     use MDP = t/f (for true or false)
::     use IDP = t/f (for true or false)
::     Number of subnodes:  1-3 => 3 subnodes and one main node = 4 nodes in total
set useIdp=t
set useMdp=t
::  AMsubnode, MDsubnode, PMsubnode, NTsubnode are used in highway_assignment_parallel.bat/s
set AMsubnode=1-4
set MDsubnode=2-4
set PMsubnode=2-4
set NTsubnode=2-4
::  subnode used in transit fare and transit assignment
::  We no longer use IDP in transit skimming, since it would require 16 cores
set subnode=1-3

:: This command will
::  1) time the model run (using timethis.exe and the double quotes)
::  2) redirect standard output and standard error to a file
::  3) Use the tee command so that stderr & stdout are sent both to the file and the screen

timethis "%runbat%  %scenar%" 2>&1 | tee %root%\%scenar%\%scenar%_fulloutput.txt

:: Open up the file containing the stderr and stdout
if exist %root%\%scenar%\%scenar%_fulloutput.txt     start %root%\%scenar%\%scenar%_fulloutput.txt

:: Look four errors in the reports and output files
call searchForErrs.bat  %scenar%
:: Open up the file containing any errors found
if exist %root%\%scenar%\%scenar%_searchForErrs.txt  start %root%\%scenar%\%scenar%_searchForErrs.txt

:: Open up other report files
if exist %root%\%scenar%\i4_Highway_Assignment.rpt   start %root%\%scenar%\i4_Highway_Assignment.rpt
if exist %root%\%scenar%\i4_mc_NL_summary.txt        start %root%\%scenar%\i4_mc_NL_summary.txt
if exist %root%\%scenar%\i4_Assign_Output.net        start %root%\%scenar%\i4_Assign_Output.net
cd %scenar%
start powershell.exe -noexit -Command get-content i4_ue*AM_nonHov*txt -tail 1; get-content i4_ue*AM_hov*txt -tail 1;
get-content i4_ue*PM_nonHov*txt -tail 1; get-content i4_ue*PM_hov*txt -tail 1; get-content i4_ue*MD*txt -tail 1;
get-content i4_ue*NT*txt -tail 1
cd ..
move_temp_files_v6.bat %scenar%

:: Cleanup
set root=
set scenar=
set runbat=
set useIdp=
set useMdp=
set AMsubnode=
set MDsubnode=
set subnode=
```

Figure 51 "Run model steps" batch file for 2019

```
:: Version 2.4
:: 2/10/2020 2:49:21 PM
:: Version 2.4 TPB Travel Model on 3722 TAZ System

set _year_=2019
set _alt_=Ver2.4_2019
:: Maximum number of user equilibrium iterations used in traffic assignment
:: User should not need to change this.  Instead, change _relGap_ (below)
```

```
set _maxUeIter_=1000

:: Not set transit constraint path and files
:: Current year no longer used to set the constraint

set _tcpath_=



:: UE relative gap threshold: Progressive (10^-2 for pp-i2, 10^-3 for i3, & 10^-4 for i4)
:: Set the value below

rem ====== Pump Prime Iteration ==========================================

set _iter_=pp
set _prev_=pp
set _relGap_=0.01

REM call ArcPy_Walkshed_Process.bat %1
call Set_CPI.bat                %1
call PP_Highway_Build.bat       %1
call PP_Highway_Skims.bat       %1
call Transit_Skim_All_Modes_Parallel.bat %1
call Trip_Generation.bat        %1
call Trip_Distribution.bat      %1
call PP_Auto_Drivers.bat        %1
call Time-of-Day.bat            %1
call Highway_Assignment_Parallel.bat     %1
call Highway_Skims.bat          %1

:: rem ====== Iteration 1 ===================================================

set _iter_=i1
set _prev_=pp

call Transit_Skim_All_Modes_Parallel.bat %1
call Transit_Fare.bat           %1
call Trip_Generation.bat        %1
call Trip_Distribution.bat      %1
call Mode_Choice_Parallel.bat      %1
call Auto_Driver.bat            %1
call Time-of-Day.bat            %1
call Highway_Assignment_Parallel.bat     %1
call Highway_Skims.bat          %1

:: rem ====== Iteration 2 ===================================================

set _iter_=i2
set _prev_=i1

call Transit_Skim_All_Modes_Parallel.bat %1
call Transit_Fare.bat           %1
call Trip_Generation.bat        %1
call Trip_Distribution.bat      %1
call Mode_Choice_Parallel.bat      %1
call Auto_Driver.bat            %1
call Time-of-Day.bat            %1
call Highway_Assignment_Parallel.bat     %1
call Average_Link_Speeds.bat    %1
call Highway_Skims.bat          %1

:: rem ====== Iteration 3 ===================================================

set _iter_=i3
set _prev_=i2
set _relGap_=0.001

call Transit_Skim_All_Modes_Parallel.bat %1
```

```
77   call Transit_Fare.bat           %1
78   call Trip_Generation.bat        %1
79   call Trip_Distribution.bat      %1
80   call Mode_Choice_Parallel.bat      %1
81   call Auto_Driver.bat            %1
82   call Time-of-Day.bat            %1
83   call Highway_Assignment_Parallel.bat     %1
84   call Average_Link_Speeds.bat    %1
85   call Highway_Skims.bat          %1
86
87   :: rem ====== Iteration 4 ===================================================
88
89   set _iter_=i4
90   set _prev_=i3
91   set _relGap_=0.0001
92
93   call Transit_Skim_All_Modes_Parallel.bat %1
94   call Transit_Fare.bat           %1
95   call Trip_Generation.bat        %1
96   call Trip_Distribution.bat      %1
97   call Mode_Choice_Parallel.bat      %1
98   call Auto_Driver.bat            %1
99   call Time-of-Day.bat            %1
100  call Highway_Assignment_Parallel.bat     %1
101  call Average_Link_Speeds.bat    %1
102  call Highway_Skims.bat          %1
103
104  :: rem ====== Transit assignment ============================================
105  @echo Starting Transit Assignment Step
106  @date /t & time/t
107
108  call Transit_Assignment_Parallel.bat %1
109  call TranSum.bat %1
110
111  @echo End of batch file
112  @date /t & time/t
113  :: rem ====== End of batch file =============================================
114
115  REM cd %1
116  REM copy *.txt MDP_%useMDP%\*.txt
117  REM copy *.rpt MDP_%useMDP%\*.rpt
118  REM copy *.log MDP_%useMDP%\*.log
119  REM CD..
120
121  set _year_=
122  set _alt_=
123  set _iter_=
124  set _prev_=
125  set _maxUeIter_=
126  set _relGap_=
127
```

6.2.1 Description of the "run model"/wrapper batch file

The first three lines of the "run model" batch file shown in Figure 50 are simply comments. Comments in batch files can be indicated using either a double colon ("::") or the word REM at the start of the line.[69] In line #5, we define a Windows environment variable called "root" and set its value to ".", which simply means the current directory location (i.e., the current directory where one has opened a command prompt). In line #6, we define an environment variable called "scenar" (scenario) and set its value to the

[69] A single colon (":") before a word indicates a label, which is often the target of a GOTO statement.

model scenario/year we want to run (in this case, 2019, but any string may be used, such as "2030_lowGrowth"). In line #7, we define an environment variable named "runbat" which is used to store the name of the "run model steps" batch file that we will use for the year-2019 model run. Lines 13-22 is where one sets the environment variables that control distributed processing. Distributed processing is covered in more detail later in this report.

Line 29 is the actual line that runs the model. The "timethis" command is used to time how long the command takes to run. In this case, the command being timed is the entire model run. The "2>&1" and "tee" sections of line 29 are explained next. When a program is run in a command-line interface, such as the Windows command window, there are two streams of output information: standard output and standard error. Standard output is information that the program supplies to a user while the program is running, such as messages about finishing a step, or the current TAZ number that is being processed. Standard error is information about errors that occur while running a program, for example, "file not found." Normally, both the standard output stream and the standard error stream are sent to the screen (in this case, the Windows command window). However, since model run last many hours, it is not practical for a model user to watch the screen to see what messages occur during the model run. One solution is to redirect these two information streams to a file, instead of the screen, which allows one to review the contents of the file after the model run is completed. The "2>&1" keyword redirects both standard error and standard output to one file (in this case, the file ending with "_fulloutput.txt"). However, the drawback to this approach is that the model user will not see any real-time information on the screen, since all the information is being sent to a file. An alternate approach is to combine the use of "2>&1" with the "tee" command, which splits any stream of information into two streams of identical information. The result of using these two keywords together is that the standard output and standard error streams are sent both to the screen and to a file at the same time. Line 32 simply opens, at the conclusion of the model run, the file containing the standard output and standard error information. The Tee.exe utility program is part of the Windows 2000 Resource Kit.

Line 35 calls a batch file that searches reports and output files for certain errors. Line 35 simply opens this file containing the listing of errors. It should be noted that this file was mainly used for model development, **so it contains little useful information for the average model user. For the average model users, the key file to review is the one that combines the standard output and error information ("_fulloutput.txt")**.

Lines 40 through 42 contain commands which opens other report files, after the model run has completed**. Line 44** (which is so long that it stretches over three lines in Figure 50) contains a PowerShell command that opens a window showing some summary convergence metrics for traffic assignment. **Lastly, line 48 runs the cleanup process**, which divides model output files into two sets: files to keep and temporary files that can be deleted. At the completion of a model run, there are about 26 GB of output files, many of which are temporary or non-final versions of files. The move_temp_files_v6.bat batch file creates the folder "temp_files" and moves about 16 GB of the 26 GB of files to the temp_files folder. **To save disk space, the user can then either delete the temp_files folder or the contents of the temp_files folder** (such as using Windows File Explorer). The advantage of deleting the *contents* of the temp_files folder, but not the folder itself, is that, in multi-user environments, it will be apparent to other model users that the cleanup process has already been run.

6.2.2 Description of the "run model steps" batch files

There is a "run model steps" batch file for each model run scenario/year. Before Ver 2.3.75, these "run model steps" batch files were structured to implement three special modeling procedures:

1. Metrorail constraint to and through the regional core.
2. HOT3+: HOT lanes with free access for HOV3+ (e.g., I-495 and I-95 Express Lanes).
3. HOT2+: HOT lanes with free access for HOV2+ (e.g., I-66 inside the Beltway for 2017-2020).

However, as explained in sections 1.3 and 2.4, starting with the Ver. 2.3.75 model, COG/TPB staff has eliminated the use of the Metrorail constraint to and through the regional core and also the HOV3+ skim substitution technique for modeling HOT lanes. These changes simplify the development of the "run model steps" batch files, since we now use the same batch file structure for all scenarios. The setup now excludes HOV2 and HOV3+ skim replacement and the Metrorail constraint procedures (in the past, the Metrorail constraint procedure required extra attention for modeled years after 2020, which had been the constraint year in the past).

Table 17 shows the key changes in three scenario representatives of Ver. 2.3.70 and Ver 2.4 (the same as Ver 2.3.78). For example, the HOV3+ skim replacement procedure, which was invoked in Ver 2.3.70 in the model run representing year-2019 conditions (since HOT lanes existed in that scenario), is not called in Ver 2.4. Similarly, the Metrorail constraint and the HOV3+ skim replacement components are not invoked in the year-2040 model run from Ver 2.3.75. **Thus, a "base" scenario is not needed; only a "final" scenario is now needed to run any modeled year**. The final scenario can be called "2019". As of Ver 2.3.75, the environment variable "_tcpath_" (transit constraint path) is set to blank/null for all scenarios since the Metrorail constraint path is not needed. Also, the HOV3+ skim substitution/replacement technique is not used in the "run model steps" batch files of all scenarios, this means that the "_HOV3PATH_" environment variable is removed (see Figure 51). Although 2020 is not a conformity year in the Amendment to Visualize 2045, Table 17 still shows the differences between 2020 scenario model-step batch files of these two versions.

Table 17 Summary of differences to the "run model steps" batch files for the years 2019, 2020, and 2045 in Ver 2.3.70 and Ver 2.4 (or Ver 2.3.75, Ver 2.3.78)

	Year / Scenario model runs		**Metrorail constraint through regional core?**		**HOV2+ skim substitution technique for modeling HOT lanes?**		**HOV3+ skim substitution technique for modeling HOT lanes?**	
	V2.3.70	**V2.3.75 V2.3.78 V2.4**	**V2.3.70**	**V2.3.75 V2.3.78 V2.4**	**V2.3.70**	**V2.3.75 V2.3.78 V2.4**	**V2.3.70**	**V2.3.75 V2.3.78 V2.4**
2019	2019_base	**N/A**	Not used (2020 is constraining year) i.e., "set _tcpath_="	N/A	N/A	N/A	No (Base HOV3+ skims are estimated) i.e., "set _HOV3PATH_="	N/A
	2019_final	2019_final	Not used (2020 is constraining year) i.e., "set _tcpath_="	Not used "set _tcpath_="	N/A	N/A	**Yes** (Base HOV3+ skims are used from the "base" run) i.e., "set _HOV3PATH_=..\2019_base"	**Removed**
2020	2020_base	**N/A**	2020 is the year used to set the constraint, but no change is made to batch file i.e., "set _tcpath_="	N/A	No (Base HOV2&3+ skims are estimated) i.e., "set _HOV3PATH_="	N/A	No (Base HOV3+ skims are estimated) i.e., "set _HOV3PATH_="	N/A
	2020_final	2020_final	2020 is the year used to set the constraint, but no change is made to batch file i.e., "set _tcpath_="	Not used "set _tcpath_="	**Yes** (Base HOV2&3+ skims are used from the "base" run) i.e., "set _HOV3PATH_=..\2020_base"	**Removed**	**Yes** (Base HOV3+ skims are used from the "base" run) i.e., "set _HOV3PATH_=..\2020_base"	**Removed**
2040	2040_base	**N/A**	**Yes** e.g., "set _tcpath_=..\2020_final"	N/A	N/A	N/A	No (Base HOV3+ skims are estimated) i.e., "set _HOV3PATH_="	N/A
	2040_final	2045_final	**Yes** e.g., "set _tcpath_=..\2020_final"	**Removed** "set _tcpath_="	N/A	N/A	**Yes** (Base HOV3+ skims are used from the "base" run) i.e., "set _HOV3PATH_=..\2040_base"	**Removed**

Regarding the 2040 scenario, whose "run model steps" batch file is shown in Figure 52, Table 17 shows that starting from Ver. 2.3.75, the model no longer use the Metrorail constraint process. Thus, there are four changes to the batch file shown in Figure 52. These changes are highlighted in yellow. First, the "_tcpath_" environment variable is no longer set to the location containing the Metrorail trips for the constraint year, 2020 (see line 16 in Figure 52). Although we could have removed this command entirely from the batch file, we have chosen to leave it there, but with a blank argument, in case, in the future, there would be a need to re-apply the Metrorail constraint. Second, line 32 of Figure 52 is highlighted to indicate that *PP_Highway_Skims.bat* has been modified to adding a check to ensure that no rail stations are disconnected from the road network. Third, the lines that call the Metrorail constraint mode choice process ("call *Mode_Choice_TC_V23_Parallel.bat*") have been changed to apply the mode choice process without constraint ("call *Mode_Choice_Parallel.bat*"). These changes have been highlighted in lines 50, 65, 82, and 99 in Figure 52. Fourth, regarding the modeling of HOT lanes, Table 17 shows us that, a "final" scenario is no longer needed to apply the HOV3+ skim substitution/replacement technique, so we no longer need to designate the location of the HOV3+ baseline skims. Thus, the "_HOV3PATH_" environment variable is removed and the *Highway_Skims.bat* is used instead of *HSR_Highway_Skims.bat* (see lines 39, 54, 70, 87, and 104 in Figure 52).

Figure 52 "Run model steps" batch file for 2040_final

```
1  :: File location
2  :: Version 2.4
3  :: 2/20/2020 4:53:22 PM
4
5  :: Version 2.4 TPB Travel Model on 3722 TAZ System
6
7  set _year_=2040
8  set _alt_=Ver2.4_2040
9  :: Maximum number of user equilibrium iterations used in traffic assignment
10 :: User should not need to change this.  Instead, change _relGap_ (below)
11 set _maxUeIter_=1000
12
13 :: Not set transit constraint path and files
14 :: Current year no longer used to set the constraint
15
16 set _tcpath_=
17
18
19
20 :: UE relative gap threshold: Progressive (10^-2 for pp-i2, 10^-3 for i3, & 10^-4 for i4)
21 :: Set the value below
22
23 rem ====== Pump Prime Iteration ==========================================
24
25 set _iter_=pp
26 set _prev_=pp
27 set _relGap_=0.01
28
29 REM call ArcPy_Walkshed_Process.bat %1
30 call Set_CPI.bat                %1
31 call PP_Highway_Build.bat       %1
32 call PP_Highway_Skims.bat       %1
33 call Transit_Skim_All_Modes_Parallel.bat %1
34 call Trip_Generation.bat        %1
35 call Trip_Distribution.bat      %1
36 call PP_Auto_Drivers.bat        %1
37 call Time-of-Day.bat            %1
38 call Highway_Assignment_Parallel.bat     %1
39 call Highway_Skims.bat          %1
```

```

:: rem ====== Iteration 1 ===================================================

set _iter_=i1
set _prev_=pp

call Transit_Skim_All_Modes_Parallel.bat %1
call Transit_Fare.bat           %1
call Trip_Generation.bat        %1
call Trip_Distribution.bat      %1
call Mode_Choice_Parallel.bat      %1
call Auto_Driver.bat            %1
call Time-of-Day.bat            %1
call Highway_Assignment_Parallel.bat     %1
call Highway_Skims.bat          %1

:: rem ====== Iteration 2 ===================================================

set _iter_=i2
set _prev_=i1

call Transit_Skim_All_Modes_Parallel.bat %1
call Transit_Fare.bat           %1
call Trip_Generation.bat        %1
call Trip_Distribution.bat      %1
call Mode_Choice_Parallel.bat      %1
call Auto_Driver.bat            %1
call Time-of-Day.bat            %1
call Highway_Assignment_Parallel.bat     %1
call Average_Link_Speeds.bat    %1
call Highway_Skims.bat          %1

:: rem ====== Iteration 3 ===================================================

set _iter_=i3
set _prev_=i2
set _relGap_=0.001

call Transit_Skim_All_Modes_Parallel.bat %1
call Transit_Fare.bat           %1
call Trip_Generation.bat        %1
call Trip_Distribution.bat      %1
call Mode_Choice_Parallel.bat      %1
call Auto_Driver.bat            %1
call Time-of-Day.bat            %1
call Highway_Assignment_Parallel.bat     %1
call Average_Link_Speeds.bat    %1
call Highway_Skims.bat          %1

:: rem ====== Iteration 4 ===================================================

set _iter_=i4
set _prev_=i3
set _relGap_=0.0001

call Transit_Skim_All_Modes_Parallel.bat %1
call Transit_Fare.bat           %1
call Trip_Generation.bat        %1
call Trip_Distribution.bat      %1
call Mode_Choice_Parallel.bat      %1
call Auto_Driver.bat            %1
call Time-of-Day.bat            %1
call Highway_Assignment_Parallel.bat     %1
call Average_Link_Speeds.bat    %1
call Highway_Skims.bat          %1

:: rem ====== Transit assignment ============================================
@echo Starting Transit Assignment Step
```

```
108 @date /t & time/t
109
110 call Transit_Assignment_Parallel.bat %1
111 call TranSum.bat %1
112
113
114
115 @echo End of batch file
116 @date /t & time/t
117 :: rem ====== End of batch file ============================================
118
119 REM cd %1
120 REM copy *.txt MDP_%useMDP%\*.txt
121 REM copy *.rpt MDP_%useMDP%\*.rpt
122 REM copy *.log MDP_%useMDP%\*.log
123 REM CD..
124
125 set _year_=
126 set _alt_=
127 set _iter_=
128 set _prev_=
129 set _maxUeIter_=
130 set _relGap_=
```

All two of the "run model steps" batch files (Figure 51 and Figure 52) apply the progressive relative gap procedure by using the "_relGap_" environment variable. For example, the relGap variable starts at a value of 0.01 (10^-2) on line 27 in Figure 52, and then changes to 0.001 (10^-3) on lines 76, before attaining the final value of 0.0001 (10^-4) on line 93 in speed-feedback iteration 4. This is covered in more detail in the text surrounding both Table 9 and Table 88.

6.3 Running the model: An example

This section provides an example of how to run the travel model for the year 2019 (named "2019") using the travel model package that is typically transmitted to external users. It is assumed that the user has copied the transmitted model into the folder where it will be run and did not modify any input files or folder names. The top-level folder is referred to as the "root" folder and typically has a name referring to the travel model version and the specific modeling project (e.g. "Ver2.4_aqc_Amend_Vis2045"). The root folder contains all the batch files and modeling folders (shown in Figure 45). The folder/subdirectory called "2019" is referred to as the "outputs" folder or the "scenario-specific" folder. It should also be noted that, to follow the steps below, one should have followed all the steps in Chapter 0 ("

Preparing to run the model"). It is also assumed that you are not making any changes to the default parallel processing setup in the model, which requires a computer with eight cores. Otherwise, see instructions found in Table 21 on p. 111.

1. Ensure that the root folder has the two parent batch files:
    a. *run_Model_2019.bat*, which is known as the wrapper batch file or the "run model" batch file.
    b. *run_ModelSteps_2019.bat*, which is known as the "run model steps" batch file.
2. These two batch files are ready to go and should not need any editing for a normal model run. However, the general practice would be to open the wrapper file in a text editor (do not double click it, since this will launch the model run) and check the following:

   a. The "root" environment variable should be set equal to "." (which means the current working directory, i.e., the current folder in your command window)
   b. The "scenar" environment variable should be set equal to "2019"
   c. The "runbat" environment variable should be set equal to "*run_ModelSteps_2019.bat*" (which is the relevant "run model steps" batch file)
   d. Other environment variables, such as those used for distributed processing, are explained in the chapter on parallel processing.
3. Open a command window and navigate to the root folder OR

   Use Windows Explorer/File Explorer to navigate to the root folder using the method described in section 6.2 ("Parent batch files"), which begins on page 87).

4. Type "*run_Model_2019.bat*" (without the quotes) and hit Enter.

The model run should begin, and the user should see numerous commands scrolling in the command window.

7 Summarizing model output and other utilities

7.1 Summary Scripts

In addition to the model, the user can be provided, upon request, with about a dozen summary scripts, which may be helpful in analyzing the model output. These are listed in Table 18.

Table 18 Travel Model Summary Scripts

Summary script	**Description**	**Folder**
COMPARE_NL_MC.S	Compares **estimated** mode choice results between two different model runs.	summary
COMPARE_NL_MC_Cube61vsCube64.S	Compares **estimated** mode choice results between two different model runs.	summary
COMPARE_NL_MC_Expanded_Alt_V23_52_minus_Base_V23_39.S	Compares alternative developed with V2.3.52 and base developed with V.2.3.39. Such a script is needed because naming conventions for output files changed between Build 39 and Build 52.	summary
Compare_Trip_Distribution.s	Compares **estimated** trip distribution to **observed** trip distribution from HTS	summary
Diff_Plots_Rev2.s	Plots volume differences between two input networks	summary
Retrieve_Pros_SubAreas.s	Summarize estimated productions and attractions by purpose and mode.	summary
Screen_Analysis.s	Performs analysis of traffic assignment volumes by screenline	summary
Summarize_2007_2040_Screenlines.s	Compares estimated screenlines volumes in 2007 and 2040	summary
Summarize_Est_Obs_Volume_Daily.s	Compares **estimated** daily traffic volumes on select links to **observed** counts. Also compares **estimated** and **observed** daily screenline volumes.	summary
Summarize_Est_Obs_Volume_Period.s	Compares **estimated** AM, MD, PM, and NT volumes on select links to **observed** counts.	summary
view_from_space.s	Creates global summary of demographic info, trips, and VMT.	summary
RMSE_Calc.s	Creates summaries of link counts and percent root mean squared error between estimated link volumes and observed counts.	assignment_summary
ScreenLine_Summary.s	Merges counts on to a network.	assignment_summary
TVOLDIF_Plot.s	Plots volume differences between two input networks	assignment_summary

Because of the changes to free-flow speeds in the highway speed look-up table in the Ver. 2.4 Model, staff updated the "view_from_space.s" script to work with the new model. The updated script will be included in the \Summary subfolder of the Ver. 2.4 Model transmittal package. It is worth noting that, **the updated "view_from_space.s" script can work with both Ver. 2.3 and Ver. 2.4 Models, while the old script that was created for the Ver. 2.3 Model would generate incorrect summaries if it were used to summarize a Ver. 2.4 model run**.

The summary script Summarize_Est_Obs_Volume_Daily.s is used to compare estimated daily traffic volumes on select links to observed traffic counts. It also compares estimated and observed daily screenline volumes. Most freeway-class HOV lanes are paired with a set of general-purpose lanes. Similarly, most freeway-class HOT lanes are also paired with a set of general-purpose lanes. In the networks used by the travel model, such managed-lane road segments are typically dual coded, meaning that the road segment is represented with four one-way links (e.g., HOV northbound, LOV northbound, HOV southbound, and LOV southbound). Since this script is summarizing estimated daily traffic volumes and observed traffic counts, this script must account for the different ways that the traffic counts are provided by the state DOTs. In some cases, such as the I-95 HOV lanes, the state DOT provides separate counts for the HOV and LOV lanes. In other cases, such as on the Capital Beltway HOT lanes, there are no separate counts – the HOT and LOV counts are grouped together as one set of counts. To process all counts in a consistent manner, the counts on links with separated counts need to be grouped together and placed on the LOV links only. This grouping is done using an LOV/HOV link equivalency file named HOV_Links.txt, which is referenced in the Summarize_Est_Obs_Volume_Daily.s script. Thus, to run this script, a model user needs to ensure that the HOV_Links.txt equivalency file is up to date with the network being summarized.

Figure 53 First five lines of the LOV/HOV link equivalency HOV_Links.txt

```
 40318   40149   40214   40330       ;;<<< LOVA    LOVB    A       B
 40395   40268   40394   40396
 40268   40269   40396   40399
 35182   35183   34881   34883
 34889   35073   34884   34882
```

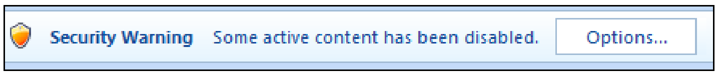
Additionally, the program LineSum.exe is used for summarizing the transit assignment (see Chapter 24 ("Transit Assignment, Including Summary Process (LineSum)").

7.2 Utilities

The Version 2.4 Travel Model requires many input files in various file formats. One of the file formats is dBase or DBF. Compared to space-delimited text files, DBF files have several advantages (e.g., fields do not mistakenly run together when values become large), but DBF files can also have some drawbacks, e.g., they can be difficult to create, and it can be difficult to compare two DBF files. On this second issue, there are several utilities for comparing or "diffing" <u>text</u> files (such as the Unix/Linux `diff` command, WinDiff, WinMerge, PSPad, and Notepad++), but it is more difficult to find programs that allow one to compare <u>DBF</u> files. To facilitate such comparison, a member of the TPB staff, Feng Xie, has developed a utility, known as the DBF Converter (DBF_Converter_v3.2.xls) that enables the user to convert DBF files to text files in comma-separated variable (CSV) format. This conversion can also be done within Cube (using File > Export). Once the files are converted to CSV format, it is easier to compare or "diff" them using other existing utilities. TPB staff is making this DBF converter available to users of the regional travel model to aid in checking/comparing input files.

Using the DBF converter, the user has the option of converting all DBF files in a directory or a select subset of the files. This utility requires Microsoft Office Excel software.

To begin the process, the user double clicks on the converter file/icon (DBF_Converter_v3.2.xls), which will open an Excel spreadsheet. In the center of the spreadsheet, there is a "Start" button. Before clicking on this button, the user has to enable the button by clicking on the "Options…" button:



When prompted, the user will have to click "Enable this content" and "OK":

Now, the user can click on the "Start" button:

This will result in the following pop-up window prompting the user to enter the input folder, output folder, and the file name filter string(s):

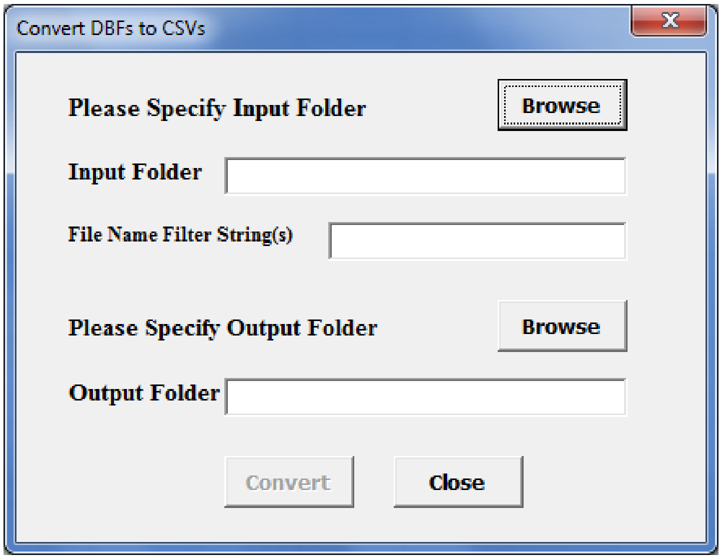
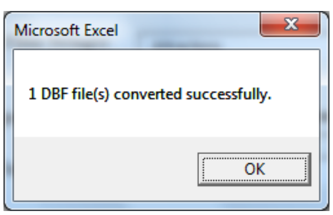


Figure 54 Convert DBFs to CSVs dialog box

The input folder must contain the DBF files that the user wishes to convert. The output folder is the folder where the newly created CSV files will be placed. The Input/Output folders can be specified by either by clicking the "Browse" button or by typing/pasting in the text boxes. Once the user has selected the input and output folders, he or she may wish to specify a file name filter string. The filter string textbox allows multiple filter strings, separated by spaces. If the user would like to convert all DBF files in the input folder, then the "File Name Filter String(s)" field should be left blank.[70] However, if the user wishes to convert only one DBF file or only a subset of DBF files in the input folder, he or she should specify either a full or partial file name. When the fields are filled, the user needs to press the "Convert" button. Once the conversion process is complete, the user will see a pop-up window stating that the DBF file(s) were converted successfully.



Once the converter has run, the user can find the newly created CSV file(s) in the specified output folder.

[70] Note, however, that this can take several minutes, since there are over 100 files.

8 Use of parallel processing to reduce model run times

8.1 Model run times

In the period from 2008 to 2011, when COG/TPB staff had first transitioned from the Version 2.2 Travel Model to the Version 2.3 Travel Model, we noticed that the Version 2.3 Model required much longer run times. For example, using a server bought in 2009 (such as COG's travel model server 3, or tms3), a run of the Ver. 2.2 Travel Model took 15-20 hours, whereas a run of the Version 2.3 Travel Model required about 80-90 hours initially (a factor of 4.5 times or 350%), which was later reduced to about 30 hours in 2012 by using Cube Cluster, Bentley Systems' implementation of distributed processing. On a newer travel model server, such as tms8 or tms7, the model run time is about 12 - 17 hours. Like the Ver. 2.3 Travel Model, the Ver. 2.4 Model also requires longer run times than the Ver. 2.2 Model.

There are several reasons why the Ver. 2.3 Travel Model, when it was first developed, had such long run times, compared to its predecessor, the Ver. 2.2 Travel Model. First, the number of transportation analysis zones (TAZs) increased from 2,191 to 3,722. This represents a 70% increase in the number of TAZs and a 189% increase in matrix sizes used to store trip tables and travel time skims ($3{,}722^2/2{,}191^2$). The other factors causing longer run times are associated mainly with refinements to the Version 2.2 traffic assignment process:

- The number of time-of-day periods went from three (AM, PM, and off peak) to four (AM, midday, PM, night/early morning)
- The number of user classes went from five to six (an explicit commercial-vehicle user class has been added);
- The number of traffic assignments has increased. The Version 2.2 Travel Model had originally used three traffic assignments, one for each time-of-day period (AM, PM, and off peak). Later versions of the Version 2.2 Travel Model split the peak assignments into two groups (HOV3+ and non-HOV3+, the so called "two step traffic assignment"), resulting in the five assignments shown in the left-hand column of Table 19. In the Version 2.3 and Version 2.4 Travel Models, the off-peak period has been further split into two parts: midday and night/early morning. So, the number of traffic assignments has increased from five in Version 2.2 to six in Version 2.3 and Version 2.4.
- Higher convergence thresholds
  - In the Version 2.2 model, all five traffic assignments were run with 60 user equilibrium (UE) iterations. This resulted in a range of relative gaps values, from a low value of 1.10×10^{-4} (0.0001) for the AM HOV3+ assignment to a high of 1.19×10^{-2} (0.0119) for the AM non-HOV3+ assignment.[71] [72]

[71] From a model run representing year-2002 conditions from the air quality conformity determination of the 2009 CLRP/FY 2010-2015 TIP.

[72] The modeler can check the relative gap by consulting the highway assignment report file for the final speed feedback iteration (i.e., i4_Highway_Assignment.rpt). The variable is called RELGAP.

- In the Version 2.3 model, prior to Build 52, all six traffic assignments were run to either a relative gap of 0.001 (1 x 10^{-3}) or 300 user equilibrium iterations, whichever came first. For travel model versions 2.3.52 through 2.4, we use a **progressively tightening relative gap** procedure, which is described in more detail later in this chapter.

Table 19 Five traffic assignments in the Version 2.2 Travel Model became six in the Version 2.3 and Version 2.4 Travel Models

Version 2.2 model: Five assignments	Version 2.3 and Version 2.4 models: Six assignments
AM Non-HOV3+	AM Non-HOV3+
AM HOV3+	AM HOV3+
PM Non-HOV3+	PM Non-HOV3+
PM HOV3+	PM HOV3+
Off peak	Midday
	Night and early morning

8.2 Use of parallel processing to reduce model run times

One way to reduce model run times is to buy quicker hardware. However, there are limits to this approach, given the recent trend of chip makers, such as Intel, to focus less on increasing clock speeds and focus more on increasing the number of cores (i.e., the capacity) of computer processors. As evidence of this trend, one of COG's travel model servers, tms6, has a processor whose clock speed is 16% *slower* than that of its predecessor (travel model server #5, or tms5). By contrast, the number of cores has gone from 12 physical cores (24 virtual cores with Hyper-Threading) in tms5 to 16 physical cores (32 virtual cores with Hyper-Threading) in tms6. Consequently, we have focused on achieving run time reductions via the software side of the equation. COG's newest travel model server, tms8, has a clock speed of 3.2 GHz, has two processors, each with 12 physical cores, which, with Hyper-Threading turned on, appears to the operating system as 48 logical processors (virtual cores), as noted in Table 10.

We use the term "parallelization" to mean running two or more processes or threads in parallel. By running two or more steps in parallel, one can reduce model run time. A common way to achieve this parallelization is by using distributed processing, which essentially distributes the computing load across multiple computer processors or cores. These computer processors/cores could be in separate computers (linked by a local area network or LAN) or could be on one computer that has multiple cores. Bentley Systems has its own implementation of distributed processing called Cube Cluster, which is an add-on component of Cube Voyager. There are two forms of distributed processing available in Cube Cluster:

- "Intrastep distributed processing (IDP): This type of distributed processing works by breaking up zone-based processing in a single step into zone groups that can be processed concurrently on multiple computing nodes. Currently only the Matrix and the Highway programs are available for IDP."[73]

[73] Citilabs, Inc., "Cube Voyager Reference Guide, Version 6.4.1" (Citilabs, Inc., September 30, 2015), 1124–25.

- "Multistep distributed processing (MDP): This type of distributed processing works by breaking up blocks of one or more modeling steps and distributes them to multiple computing nodes to process. This can be used for any program in Cube Voyager as well as user-written programs with the caveat that the distributed blocks and the mainline process must be logically independent of each other."[74]

The Version 2.4. Travel Model uses both IDP and MDP and uses a third method of parallelization that is already part of the Windows operating system: Running programs in parallel using multiple concurrent command windows.

8.2.1 Background and terminology

A computer contains a central processing unit (CPU), which is also known as a chip or processor. Modern CPUs are often divided into two to ten. A core functions as a separate processor, so, to an operating system, a computer with two CPUs is the same as a computer with one CPU divided into two cores. The two biggest chip manufacturers for computers running the Microsoft Windows operating system are Intel and AMD. COG/TPB staff has run the Version 2.4 Travel Model on only computers with Intel chips, but the model should run on computers with any Intel-like chip, such as AMD. Some Intel chips feature a technology known as Hyper-Threading. When Hyper-Threading technology is enabled on the chip, the operating system sees double the number of cores. So, if your computer has four cores and Hyper-Threading is enabled, the operating system will see eight virtual cores (or "logical processors"), thus doubling your CPU capacity. **Thus, a computer with one CPU that contains four cores and has Hyper-Threading enabled, should be able to run the Version 2.4 Travel Model "out of the box" without making changes to the "run model"/wrapper batch file, since such a computer has eight virtual cores**.[75] When a computer executes a task, it uses a process or "thread." In general, one process or thread runs on one processor or core. The operating system (Microsoft Windows) chooses the actual physical core to use when running a process. If one opens the Resource Manager within Windows Task Manager, one can see that the operating system appears to randomly move the task from one core to the next until the process completes, but the user need not focus on this detail. Cube Base documentation does briefly discuss Hyper-Threading.[76]

In Cube Cluster parlance, a set of processors that can be used for a computing task, whether they exist in one computer or a network of computers is called a "cluster." Any individual processor or core is called a "computing node" or simply a "node." Cube Cluster, which is a part of Cube Voyager, allows the nodes in the cluster to communicate, so that they can work together, essentially running in parallel, to accomplish a computing task. Citilabs originally wrote Cube Cluster with the idea that users would want

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[74] Citilabs, Inc., 1125.
[75] According to one external user who had a computer with only four cores (though it was not clear whether these were physical cores or virtual cores), the user found that the model crashed at the mode choice step. This was likely due to the fact that the default configuration of the model is designed to run five concurrent mode choice runs. However, this user was able to follow the procedures listed in Table 21 to get the model to run on the four-core computer.
[76] Citilabs, Inc., "Cube Base Reference Guide, Version 6.4.1" (Citilabs, Inc., September 30, 2015), 10–11.

to harness the power of multiple, run-of-the-mill PCs that were networked together using a local area network (LAN). However, COG/TPB staff has not used Cube Cluster in that way. Instead, COG/TPB staff has harnessed the power of Cube Cluster by running on one computer (server) at a time, by virtue of the fact that the computer contained multiple cores. If you are running Cube Cluster across multiple computers, you would have a main computer, known as the "main node," and one or more helper computers, known as "sub-nodes" (or "subnodes"). When running Cube Cluster in a single computer with multiple cores, the "main node" and "sub-nodes" would then exist within the same CPU. So, continuing with the single-computer scenario, the user can think of a model run as occurring on a "main node" (which is simply one of the cores on the CPU), and the main node can then call upon one or more sub-nodes (other cores on the CPU) to make use of IDP or MDP.

8.2.2 Effect of Cube Cluster on modeled results

It should be noted that **using Cube Cluster can result in numerical rounding which can affect model results**. For instance, COG/TPB staff found that the use of IDP resulted in a very small change in the estimated VMT coming out of the travel model.[77] As part of a series of test conducted in 2011, COG/TPB staff conducted two model runs: 1) a year-2007 traffic assignment with IDP using 4 cores; and 2) a year-2007 traffic assignment without IDP (i.e., one core). COG/TPB staff then calculated the VMT difference between the two runs at the regional level, the jurisdiction level, and the link level. At the regional level, the use of IDP had almost no effect on modeled results – it resulted in only a 1/100th to 3/100ths of a percent drop in estimated VMT (slide 25). At the jurisdiction level, the use of IDP also resulted in almost no difference in estimated VMT – the difference was as large as 9/100ths of a percent for some jurisdictions (slide 27). At the link level, however, the use of IDP resulted in several cases where the VMT difference was above 20% (slide 29). Fortunately, the links with the largest volume differences were the lower-class facilities (e.g., not freeways). Both runs were done as part of the full travel model and both were done using Cube Voyager/Cluster version 5.1.2. Newer versions of Cube Voyager/Cluster are now available (e.g., COG is now using 6.4.1), but COG/TPB staff have not re-tried the sensitivity test with the newer versions of Cube Voyager. COG/TPB staff shared these results with Citilabs and, in 2012, Citilabs updated its documentation to note this rounding phenomenon. For example, in the Cube 6.4.1 Cube Voyager Reference Guide from 2015: "Use of Cluster can have a very small effect on volumes generated by the HIGHWAY program. During the ADJUST phase, when iteration volumes are combined, the final assigned volumes might vary slightly over different numbers of cluster nodes."[78]

8.2.3 History of adding parallelization to the Version 2.3 Travel Models

In Build 16 of the Version 2.3 Travel Model (Ver. 2.3.16), COG/TPB staff added IDP to the highway assignment script. Staff set the travel model up to use four cores, and, based on the findings of various tests, staff recommended that users who wanted to replicate COG results also use four cores. In Builds 20 through 24 of the Version 2.3 Travel Model, COG/TPB staff added IDP to other modeling steps, such

[77] See slides 25-32 of Ronald Milone and Mark S. Moran, "TPB Version 2.3 Travel Model on the 3,722-TAZ Area System: Status Report" (May 20, 2011 meeting of the COG/TPB Travel Forecasting Subcommittee, held at the Metropolitan Washington Council of Governments, Washington, D.C., May 20, 2011).
[78] Citilabs, Inc., "Cube Voyager Reference Guide, Version 6.4.1," 1129.

as *MFARE2.s*, *Time-of-Day.s*, and the transit skimming scripts. In 2012, COG asked for AECOM's assistance to further reduce model run times. AECOM suggested model changes that introduced MDP to the travel model.[79] Now, in addition to using four cores for IDP traffic assignment, the use of MDP allowed two traffic assignments to run in parallel (thus, 8 cores would be in use, but only 4 in each of the two IDP sessions). COG/TPB staff incorporated these AECOM recommendations into Build 40 of the Version 2.3 Travel Model (Ver. 2.3.40), and these same parallelization enhancements, such as the use of both IDP and MDP, also exist in the Version 2.3.52 Travel Model and later models.

8.2.4 Implementation of parallelization in the Version 2.3.52 through 2.4 Travel Models

The Version 2.3.52 Travel Model (and later models, including Ver. 2.4) has three types of parallelization to help minimize run times:

- Cube Cluster intra-step distributed processing (IDP)
- Cube Cluster multi-step distributed processing (MDP)
- Windows operating system: Running programs in parallel using multiple concurrent command windows

IDP is used in three modeling steps:

- Highway assignment (*Highway_Assignment_Parallel.s*)
- Transit fare development (*MFARE2.S*)
- Transit assignment (*Combine_Tables_For_TrAssign_Parallel.s*)

By contrast, MDP is used for only one step: Highway assignment (*Highway_Assignment_Parallel.s*). In other words, **highway assignment uses both IDP and MDP**. The model is set up to use four cores in IDP, and, using MDP, there are two concurrent IDP sessions: A main node, which uses four cores via IDP, and a sub-node, which also uses four cores via IDP. **This combination of IDP and MDP means that highway assignment uses 8 cores concurrently for processing**.

Lastly, running programs in parallel by using multiple concurrent command windows is used for three modeling steps:

- Transit skimming (command windows invoked by *Transit_Skim_All_Modes_Parallel.bat*)
- Mode choice (command windows invoked by *Mode_Choice_Parallel.bat*)
- Transit assignment (command windows invoked by *Transit_Assignment_Parallel.bat*)

IDP, which works only for the MATRIX or HIGHWAY modules of Cube Voyager, is implemented in a Cube Voyager script using **a single line of code**, such as this from the *Highway_Assignment_Parallel.s* script:

```
distributeIntrastep processId='AM', ProcessList=%AMsubnode%
```

[79] For more details, see AECOM and Stump/Hausman Partnership, "FY 2012 Report," chap. 5.

By contrast, **MDP** is implemented in a Cube Voyager script using **an MDP block of code**. The code block begins and ends with code such as the following (from the *Highway_Assignment_Parallel.s* script):

```
DistributeMULTISTEP ProcessID='AM', ProcessNum=1
       (various lines of code)
ENDDistributeMULTISTEP
```

The IDP statement above can be used on its own or within an MDP block. Examples of both of these cases can be found in the *Highway_Assignment_Parallel.s* script.

Table 20 shows the five modeling steps where parallelization is used, noting the method of parallelization (e.g., IDP, MDP, or batch file); the names of the batch files that call each step; the names of the tokens (variables) used to store the number of processing nodes/subnodes to use for IDP/MDP; and the maximum number of simultaneous threads/cores used by the step. For example, in the case of transit skimming, parallelization is achieved by calling multiple simultaneous batch files. The batch file that actually initiates the multiple Windows command windows is *Transit_Skim_All_Modes_Parallel.bat*, and, since this step uses neither IDP nor MDP, there are no associated IDP or MDP tokens. The transit skimming process uses 4 cores. In the highway assignment step, both MDP and IDP are used. Prior to Version 2.3.78, the tokens used for IDP were AMsubnode and MDsubnode (more on this later in this chapter). As of Version 2.3.78, two more tokens, PMsubnode and NTsubnode, are added. Although MDP is used, no tokens are used for MDP. Instead, the subnode for MDP is labeled using a fixed name, "AM1". The highway assignment step can use up to 8 simultaneous nodes/cores, since IDP is implemented with four cores and there are two concurrent IDP sessions, run using MDP. As can be seen in Table 20, modeling steps with parallelization use 4, 5, or 8 cores. Modeling steps without parallelization use only one core at a time.

8.2.4.1 Parallel processing in the "Run model"/wrapper batch file

This section of the report describes how the code in the "run model"/wrapper batch files affects parallel processing implemented in the Version 2.3.52 Travel Model (and used in subsequent versions of the model, such as Ver. 2.4). This section uses the 2019 "run model" batch file (Figure 50 on page 88) as an example. It also describes changes that can be made to the "run model"/wrapper batch files in order run the model on a computer with fewer than the standard 8 cores. The next section of the report, 8.2.4.3 on page 112, describes how parallel processing (specifically IDP and MDP) has been implemented in one script: *Highway_Assignment_Parallel.s*. As noted in Table 20 (p. 109), the number of cores used in each of the parallelized modeling steps varies from 4 to 8 cores. Those steps that do not contain parallelization use only one core at a time. **Thus, to run the Version 2.3.52 Travel Model "out of the box," without making any changes, one needs a computer with eight or more cores**, as was explained in the section 3.1 of the report.

Table 20 Modeling steps where parallelization is used, including the maximum number of threads/cores used

Modeling Step	First-Level "Child" Batch File	Second-Level "Child" Batch File	**Method of Parallelization** (batch file or script which calls parallel process)	Tokens Used for IDP**	Max. No. of Cores
Transit skimming	Transit_Skim_All_Modes_Parallel.bat	TransitSkim_LineHaul_Parallel.bat	**Batch file** (Transit_Skim_All_Modes_Parallel.bat)		4
Highway assignment	Highway_Assignment_Parallel.bat	None	**MDP** & **IDP** (Highway_Assignment_Parallel.s)	AMsubnode MDsubnode PMsubnode* NTsubnode*	8
Transit fare development	Transit_Fare.bat	None	**IDP** (MFARE2.s)	subnode	4
Mode choice	Mode_Choice_Parallel.bat	MC_purp.bat	**Batch file** (Mode_Choice_Parallel.bat)		5
Transit assignment	Transit_Assignment_Parallel.bat	TransitAssignment_LineHaul_Parallel.bat	**Batch file** (Transit_Assignment_Parallel.bat) **IDP** (Combine_Tables_For_TrAssign_Parallel.s)	subnode	4

* As of Version 2.3.78

** MDP as implemented in *Highway_Assignment_Parallel.s* does not use a token. Instead, the subnode name designation is done using a hard-coded value in the script, i.e., "AM1", as is explained later in this chapter.

The "run model"/wrapper batch file makes use of several of user-defined Windows environment variables. Those environment variables that do not deal with distributed processing were discussed in section 6.2.1 ("Description of the "run model"/wrapper batch file") on page 91. By contrast, those environment variables that do deal with distributed processing are discussed in this chapter (Chapter 8).

It is possible to have IDP-related or MDP-related statements in a script, but not use them. Consequently, one of the first Cube Cluster statements in any script that uses Cube Cluster will be a statement that indicates whether Cube Cluster should be used or not. An example of such a statement is shown below:

```
distribute intrastep=t multistep=f
```

The above statement indicates that IDP will be used (since its flag has been set to a value of TRUE or T) and MDP will not be used (since its flag has been set to a value of FALSE or F). In this example, even if there is code for MDP in the Cube Voyager script, the MDP processing will not be executed, since it has been set to FALSE. In our scripts and batch files, we generally use user-defined, Windows environment variables to set these two values. Thus, the statement above appears like this, using two "tokens" or variables to hold the true/false flags:

```
distribute intrastep=%useIdp% multistep=%useMdp%
```

In lines 13 and 14 of the "run model"/wrapper batch file (shown in Figure 50), these two "set" statements simply set the IDP and MDP usage flags to a value of TRUE:

```
set useIdp=t
set useMdp=t
```

The statement "distribute intrastep=%useIdp% multistep=%useMdp%" is used in both *Combine_Tables_For_TrAssign_Parallel.s* and *Highway_Assignment_Parallel.s*.[80] By contrast, in MFARE2.s, which uses IDP, but not MDP, the MDP flag has been hard-coded to FALSE, instead of using the token value set in the wrapper batch file: "distribute intrastep=%useIdp% multistep=f".

The "useidp" environment variable is used in the three steps shown in Table 20 that make use of IDP. As one would expect, the "usemdp" environment variable is used in the highway assignment step, since this step makes used of MDP. However, the "usemdp" environment variable **is also used in *Mode_Choice_Parallel.bat***. Specifically, if the "usemdp" flag is set to TRUE, then parallel processing is used in the mode choice step (via concurrent batch files, not MDP), which means that the five mode choice models (HBW, HBS, HBO, NHW, and NHO) are run in parallel command windows. If the "usemdp" flag is set to FALSE, then the mode choice process assumes that there is only one core available and runs the five mode choice models in sequence.

[80] This same statement is also currently found in the four transit skimming scripts (Transit_Skims_AB|BM|CR|MR.s), but it is no longer being used, so it should eventually be removed. At one point, we had used IDP in transit skimming, but, for the Ver. 2.3.40 model, when parallelization via concurrent batch files was added, the parallelization via IDP was dropped, so that the model would not use more than 8 concurrent cores.

Prior to Version 2.3.78, the distributed processing had only two environment variables (AMsubnode and MDsubnode). As discussed in Section 1.3.1, starting from Version 2.3.78, the model includes two more variables, PMsubnode and NTsubnode. Four environment variables dealing with distributed processing in Version 2.3.78 and Version 2.4 can be found on in lines 16 to 19 of the "run model"/wrapper batch file (Figure 50):

```
set AMsubnode=1-4
set MDsubnode=2-4
set PMsubnode=2-4
set NTsubnode=2-4
```

More discussion on these variables and their usage in IDP and MDP of highway skimming and highway assignment is discussed in Section 1.3.1.1.

Given that we generally have decided upon using four cores for IDP processing in the model (to maintain consistency), one might expect that AMsubnode = MDsubnode = PMsubnode = NTsubnode= 1-4. In other words, one might expect that we would provide Cube Cluster with a list of four nodes (1-4) for both the main branch of IDP processing and the MDP branch of IDP. According to AECOM, the reason for delineating only three subnodes (i.e., "MDsubnode=2-4") and not four, is that "only three slave threads [sub-nodes] are launched since the master uses itself as one of the threads to process the PM highway assignment."[81] Thus, despite the appearance of 3 nodes for MD and 4 nodes for AM, both IDP sessions use 4 nodes. To further clarify this issue, the IDP and MDP processes running in *Highway_Assignment_Parallel.s* have been diagramed in Figure 55 in section 8.2.4.3.

8.2.4.2 Changing the "run model"/wrapper batch file for computers with fewer than 8 cores

The Version 2.4 Travel Model (Ver. 2.3.52 and later) is designed to run on a computer that has 8 or more cores. Table 21 shows the changes that a user should make in order to run the Version 2.4 Model on computers with fewer than 8 cores. See section 8.2.2 ("Effect of Cube Cluster on modeled results") on p. 106 for a discussion about how modeled results can change slightly with the number of cores used.

Table 21 Running the Version 2.4 Travel Model on computers with fewer than 8 cores: Changes that need to be made to the "run model"/wrapper batch file

Number of cores in your computer	Changes needed in the "run model"/wrapper batch file	Result
8 or more	• No changes need be made	The model will run using between 1 and 8 cores, depending on the modeling step. Eight cores are used in highway assignment, due to the use of both IDP and MDP.
4	• Change "useMdp=t" to "useMdp=f"	This change will mean that highway assignment no longer uses MDP, only four cores with IDP. Also, in the mode choice model, sequential processing will

[81] AECOM and Stump/Hausman Partnership, "FY 2012 Report," 5–9 to 5–10.

Number of cores in your computer	Changes needed in the "run model"/wrapper batch file	Result
		be done (i.e., the five models will no longer run in parallel).
2	• Change "useMdp=t" to "useMdp=f" • Change "set AMsubnode=1-4" to "set AMsubnode=1-2" • Change "set MDsubnode=2-4" to "set MDsubnode=2" • Change "set PMsubnode=2-4" to "set MDsubnode=2" • Change "set NTsubnode=2-4" to "set MDsubnode=2"	This should result in only 2 cores being used in IDP.
1	• Change "useMdp=t" to "useMdp=f" • Change "useIdp=t" to "useIdp=f"	This will disable IDP and MDP and will also result in disabling the parallel processing in the mode choice step.

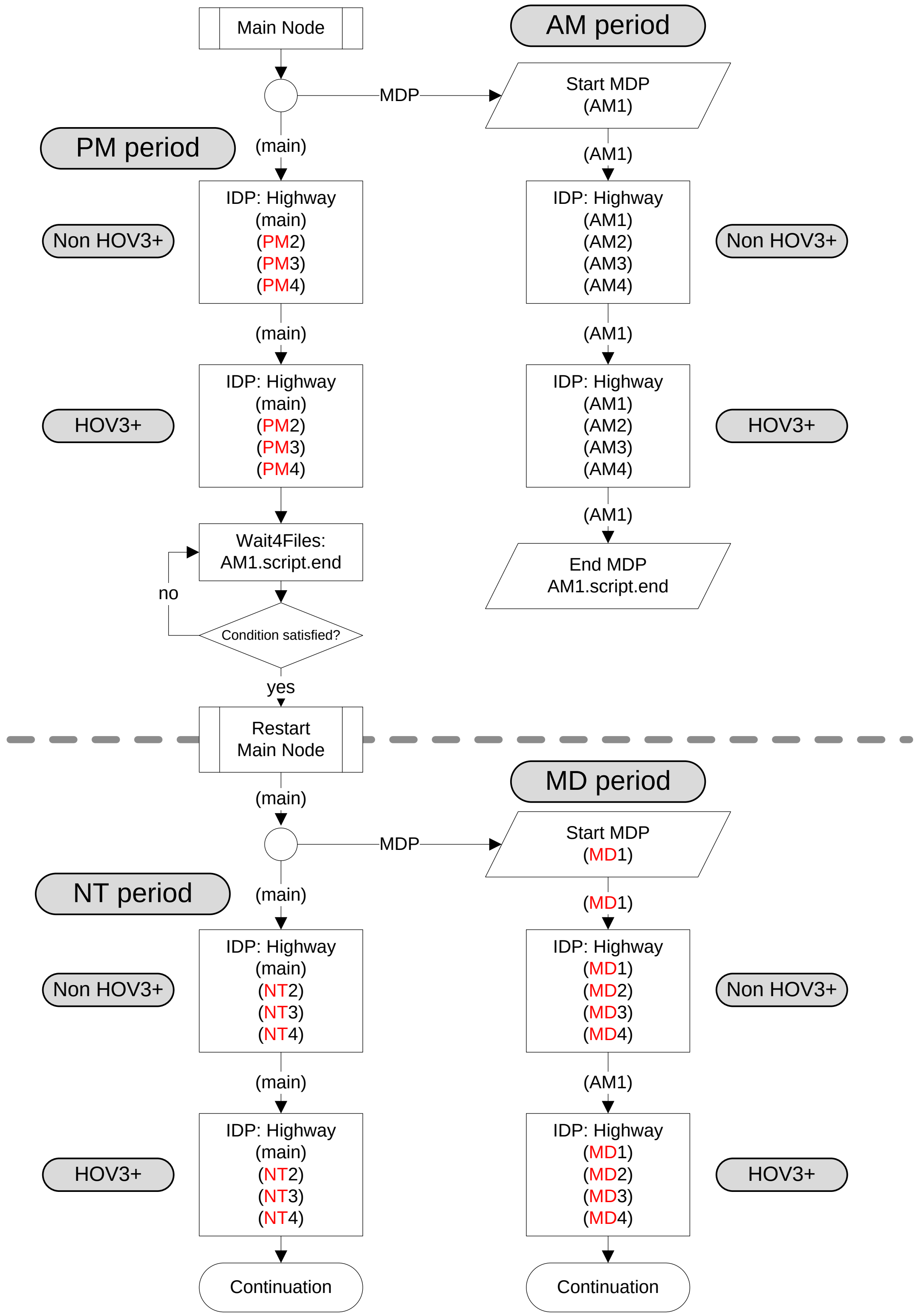
Note that the information in Table 21 is based on testing done by COG/TPB staff using a virtual computer with Cube 6.0.2 installed.

8.2.4.3 Parallel processing in the highway assignment script

The previous section of the report, section 8.2.4.1, described how the code in the "run model"/wrapper batch files affects parallel processing implemented in the Version 2.3 (Ver. 2.3.52 and later) and Version 2.4 Travel Model. This section of the report describes how parallel processing (specifically IDP and MDP) have been implemented in one script: *Highway_Assignment_Parallel.s*. Figure 55 shows a schematic of how IDP and MDP have been implanted in the highway assignment script of Version 2.4, which includes more logical naming conventions (the changed sub-node names are indicated by using red font).

The actual highway assignment script relating to Figure 55 can be found in Appendix C (Volume 2). Since the script has over 2,000 lines of code, we have created an excerpt of the Highway_Assignment_Parallel.s script (about 150 lines), shown in Figure 56, that focuses on the lines that are most relevant to IDP and MDP. Locations where code has been removed are indicated in Figure 56 by a triple ampersand ("&&&"). On line 4 of Figure 56, the statement "distribute intrastep=%useIdp% multistep=%useMdp%" either turns IDP and MDP on or off, based on the value of the two tokens. The code in Figure 56 contains two MDP blocks. Each MDP block begins with the keyword "DistributeMULTISTEP" and ends with the keyword "ENDDistributeMULTISTEP." The beginning and ending of each of the two MDP blocks has been highlighted in green. IDP does not require a block of statements – it simply uses a single statement begun with the keyword "distributeIntrastep." Lines containing this keyword have been highlighted in yellow. For example, the first MDP block includes two IDP statements, but the next two IDP statements occur outside of an MDP block (in other words, they are run from the main node, not a sub-node). As shown in Figure 55, since we have two parallel streams of processes (e.g., one for the AM period and one for the PM period), we need to use a "Wait4Files" keyword, which ensures that the main line of processing stops until the MDP branch completes it work. The Wait4Files keywords have been highlighted in blue in Figure 56. So, as indicated in Figure 55, when the AM period processing is finished a file called AM1.script.end is generated. The Wait4Files tells the main line of processing to stop until it detects that the AM1.script.end file has been generated.

Figure 55 Schematic of IDP and MDP in the highway assignment process of the Ver. 2.4 Travel Model (*Highway_Assignment_Parallel.s*)



Ref: ver2.3.52_hwy_assign_mdp_idp.vsd

Figure 56 Excerpts from the *Highway_Assignment_Parallel.s* script (triple ampersand => code removed)

```
&&&
/*  **** Set up tokens in Voyager Pilot step ***** */
;  useIdp = t (true) or f (false);  this is set in the wrapper batch file
distribute intrastep=%useIdp% multistep=%useMdp%
&&&
;;;*****************************************************************************
;;; Step 1: Execute peak-period traffic assignments (AM & PM)
;;;         AM nonHOV, HOV and PM nonHOV and HOV Assignemnts
;;;*****************************************************************************

itr = '%_iter_%'   ;;
&&&
INPNET = 'ZONEHWY.NET'

DistributeMULTISTEP ProcessID='AM', ProcessNum=1

PRD    =  'AM'        ;
PCTADT =   41.7        ; %_AMPF_%  AM PHF (% of traffic in pk hr of period)
CAPFAC=1/(PCTADT/100)     ;  Capacity Factor = 1/(PCTADT/100)
&&&
in_capSpd = '..\support\hwy_assign_capSpeedLookup.s'         ;;     FT x AT Speed & Capacity lookup
VDF_File  = '..\support\hwy_assign_Conical_VDF.s'            ;;     Volume Delay Functions file

;;;*****************************************************************************
;;; Step 1.1: Assign AM NonHOV3+ trip tables only
;;;           (SOV, HOV2, CV, TRUCK & AIRPORT PASSENGER TRIPS)
;;;*****************************************************************************

  RUN PGM=HIGHWAY  ; NonHOV3+ traffic assignment
distributeIntrastep processId='AM', ProcessList=%AMsubnode%
  FILEI NETI     =  @INPNET@                          ; TP+ Network
&&&
ENDRUN
;;;*****************************************************************************
;;; Step 1.2: Assign AM HOV3+ only
;;;*****************************************************************************

  RUN PGM=HIGHWAY  ; HOV3+    traffic assignment
distributeIntrastep processId='AM', ProcessList=%AMsubnode%
  FILEI NETI     = TEMP1_@PRD@.NET                    ; TP+ Network
&&&
ENDRUN
ENDDistributeMULTISTEP

PRD    =  'PM'        ;
PCTADT =   29.4        ; %_AMPF_%  AM PHF (% of traffic in pk hr of period)

&&&
;;;*****************************************************************************
;;; Step 1.3: Assign PM NonHOV3+ trip tables only
;;;           (SOV, HOV2, CV, TRUCK & AIRPORT PASSENGER TRIPS)
;;;*****************************************************************************

  RUN PGM=HIGHWAY  ; NonHOV3+ traffic assignment
distributeIntrastep processId='PM', ProcessList=%PMsubnode%
  FILEI NETI     =  @INPNET@                          ; TP+ Network
&&&
ENDRUN
;;;*****************************************************************************
;;; Step 1.4: Assign PM HOV3+ only
;;;*****************************************************************************

  RUN PGM=HIGHWAY  ; HOV3+    traffic assignment
distributeIntrastep processId='PM', ProcessList=%PMsubnode%
  FILEI NETI     = TEMP1_@PRD@.NET                    ; TP+ Network
&&&
```

```
ENDRUN

Wait4Files Files=AM1.script.end, CheckReturnCode=T, PrintFiles=Merge, DelDistribFiles=T

;;;*****************************************************************************
;;; Step 2: Execute off-peak-period traffic assignments (midday/MD & night/NT)
;;;         All 6 trip tables are assigned together.
;;;*****************************************************************************

DistributeMULTISTEP ProcessID='MD', ProcessNum=1
            ; Off-Peak Period
PRD    =  'MD'         ;
PCTADT =   17.7        ; %_MDPF_%  Midday PHF (% of traffic in pk hr of period)
CAPFAC=1/(PCTADT/100)                  ; Capacity Factor = 1/(PCTADT/100)
; Turnpen  = 'inputs\turnpen.pen'        ; Turn penalty

  RUN PGM=HIGHWAY  ; Off-peak (midday & evening) traffic assignment
distributeIntrastep processId='MD', ProcessList=%MDsubnode%
FILEI NETI     = @INPNET@                          ; TP+ Network
&&&
ENDRUN

ENDDistributeMULTISTEP

PRD    =  'NT'         ;
PCTADT =   15.0        ; %_NTPF_%  NT PHF (% of traffic in pk hr of period)
CAPFAC=1/(PCTADT/100)                  ; Capacity Factor = 1/(PCTADT/100)

  RUN PGM=HIGHWAY  ; Off-peak (midday & evening) traffic assignment
distributeIntrastep processId='NT', ProcessList=%NTsubnode%
FILEI NETI     = @INPNET@                          ; TP+ Network
&&&
ENDRUN

Wait4Files Files=MD1.script.end, CheckReturnCode=T, PrintFiles=Merge, DelDistribFiles=T

; END OF MIDDAY and OFF PEAK ASSIGNMENT

;;;*****************************************************************************
;;; Step 3: Calculate restrained final Volumes, speeds, V/Cs (No MSA)
;;;*****************************************************************************
;;; Step 3.1: Loop thru 1 (AM) and 2 (PM)
;;;*****************************************************************************

LOOP PERIOD = 1,2  ; Loop thru 1 (AM) and 2 (PM);  Each pk per. includes NonHOV3+ and HOV3+

IF (PERIOD==1)
            PRD    =  'AM'         ;
            PCTADT =   41.7        ;
ELSE
            PRD    =  'PM'         ;
            PCTADT =   29.4        ;
ENDIF
CAPFAC=1/(PCTADT/100)      ; Capacity Factor = 1/(PCTADT/100)

  RUN PGM=HWYNET                 ; Calculate restrained speed/perform MSA volume averaging
&&&
ENDRUN
ENDLOOP            ; Loop thru 1 (AM) and 2 (PM);  Each pk per. includes NonHOV3+ and HOV3+

;;;*****************************************************************************
;;; Step 3.2: Loop thru 3 (MD) and 4 (OP)
;;;*****************************************************************************

LOOP PERIOD = 3,4  ; Loop thru 1 (midday, MD) and 2 (evening/off-peak, OP)
IF (PERIOD==3)
            PRD    =  'MD'         ;
            PCTADT =   17.7
```

```
135 ELSE
136             PRD    =  'NT'         ;
137             PCTADT =   15.0
138 ENDIF
139 CAPFAC=1/(PCTADT/100)      ; Capacity Factor = 1/(PCTADT/100)
140
141   RUN PGM=HWYNET   ; Calculate restrained speed/perform MSA volume averaging
142 &&&
143 ENDRUN
144 ENDLOOP            ; Loop thru 1 (midday, MD) and 2 (evening/off-peak, OP)
145
146 ;;;*****************************************************************************
147 ;;; Step 4: Summarize 24-hour VMT of current AM, PM, MD & NT assignments
148 ;;;*****************************************************************************
149
150 RUN PGM=HWYNET     ; Summarize 24-hour VMT of current AM, PM, MD & OP assignments
151 &&&
152 ENDRUN
```

Ref: Highway_Assignment_Parallel_excerpt2.s

The four periods being processed are AM, PM, MD, and NT, and these are indicated in Figure 56 by pink/purple highlighting. For example, we can see that on line 17, the AM processing starts, and the four IDP sub-nodes for the non-HOV3+ assignment are named AM1, AM2, AM3, and AM4 (line 30 of Figure 56), since %AMsubnode% equals "1-4". After the non-HOV3+ assignment is complete, then HOV3+ assignment occurs, and the four IDP sub-nodes for the HOV assignment are also named AM1, AM2, AM3, and AM4 (line 39 of Figure 56). As of Version 2.3.78, the mislabeled naming of sub-nodes beginning with the PM period assignment starting from line 45 is now corrected. For example, for the PM non-HOV3+ assignment, the sub-nodes are now named PM2, PM3, and PM4 (line 55 of Figure 56), since %MDsubnode% equals "2-4". The same misleading naming convention is fixed for the sub-node names in the PM HOV3+ assignment: PM2, PM3, and PM4 (line 64 of Figure 56), instead of MD2, MD3, and MD4. A similar issue occurs for the midday assignment (beginning on line 78 of Figure 56) and the nighttime assignment (beginning on line 91 of Figure 56).

9 Debugging cases where the model run stops prematurely or crashes

If a model run stops prematurely or crashes, one can use the "full output" text file to determine:

- The speed feedback iteration (e.g., pump prime, iteration 1, …, iteration 4) that was underway when the model stopped
- The modeling step, within a given speed feedback iteration, that was underway when the model stopped (e.g., network building, trip distribution, mode choice, traffic assignment).
- Possible error messages returned by any programs that crash.

An excerpt from one of the "full output" text files can be seen in Figure 57. Additionally, when debugging a model run crash, one should find the latest print file (*.prn) to see any relevant error or warning messages. One can search this file using regular expressions to find any warnings or errors.[82]

In some cases, it is sufficient to review the "full output" text file and the latest print file to determine why a model run stops. As an additional tool, however, one can also scan the "search for errors" text file (e.g. 2019_Final_searchForErrs.txt), which is created by the *searchForErrs.bat* batch file. An example of the "search for errors" text file can be found in Figure 58.

One of the most common causes for a model run crash is a sharing violation, which typically occurs when one launches two or more concurrent model runs in the same root directory at about the same time. **One way to protect against this happening is to ensure there is a time delay (ca. 1 hour) between the start of two model runs that share the same root directory**. Additionally, there is now a second reason to offset model runs by about an hour: As described in Chapter 11 ("Building transit walksheds and calculating zonal walk percent"), with the new process for generating transit walksheds and calculating the percent of each zone within walking distance to transit, it is imperative to use a 45- to 60-minute gap in the start times of two or more model runs on the same computer.

[82] For example, using the text editor PSPad, one can use this regular expression (regex) to find warnings or errors: F\([0-9]*\):|W\([0-9]*\):

Figure 57 An excerpt from an example of the "full output" text file that is created during a model run

```


Z:\ModelRuns\fy20\CGV2_3_78_2020 Amendment_Visualize2045_Xmittal>set _year_=2019

Z:\ModelRuns\fy20\CGV2_3_78_2020 Amendment_Visualize2045_Xmittal>set _alt_=Ver2.4_2019

Z:\ModelRuns\fy20\CGV2_3_78_2020 Amendment_Visualize2045_Xmittal>set _maxUeIter_=1000

Z:\ModelRuns\fy20\CGV2_3_78_2020 Amendment_Visualize2045_Xmittal>set _tcpath_=

Z:\ModelRuns\fy20\CGV2_3_78_2020 Amendment_Visualize2045_Xmittal>rem ====== Pump Prime Iteration
==========================================

Z:\ModelRuns\fy20\CGV2_3_78_2020 Amendment_Visualize2045_Xmittal>set _iter_=pp

Z:\ModelRuns\fy20\CGV2_3_78_2020 Amendment_Visualize2045_Xmittal>set _prev_=pp

Z:\ModelRuns\fy20\CGV2_3_78_2020 Amendment_Visualize2045_Xmittal>set _relGap_=0.01

Z:\ModelRuns\fy20\CGV2_3_78_2020 Amendment_Visualize2045_Xmittal>call ArcPy_Walkshed_Process.bat 2019
    Searching for Python in Path C:\Python27\ArcGIS10.6
    Searching for Python in Path C:\Python27\ArcGIS10.5
    Searching for Python in Path C:\Python27\ArcGIS10.4
    Searching for Python in Path C:\Python27\ArcGIS10.3
    Found Python in Path C:\Python27\ArcGIS10.3

 Using Python from Directory = C:\Python27\ArcGIS10.3



1) Creating Subdirectories ...


2) Preparing Inputs ...

    using TRNBUILD line files

3) Launching ArcPy-based Walkshed Process ...
```

Ref: Z:\ModelRuns\fy20\CGV2_3_78_2020 Amendment_Visualize2045_Xmittal\2019\2019_fulloutput.txt

Figure 58 An excerpt from the "search for errors" file that is created during a model run

```
********** Searching for errors and anomalies after a travel model run **********
Program name: searchForErrs.bat

***** Searching *fulloutput.txt

  *** Searching for cases where a file could not be found


***** Searching report files (*.rpt)
  *** Searching for evidence that TP+ (TPMAIN) is running, instead of Voyager (PILOT)
  *** Searching for evidence of LINKO nodes that do not have XY values
2019\i1_TRANSIT_SKIMS_AB.RPT:W(693): The following LINKO nodes do not have XY values:
2019\i1_TRANSIT_SKIMS_AB.RPT:W(693): The following LINKO nodes do not have XY values:
2019\i1_TRANSIT_SKIMS_AB.RPT:W(693): The following LINKO nodes do not have XY values:
2019\i1_TRANSIT_SKIMS_AB.RPT:W(693): The following LINKO nodes do not have XY values:
2019\i1_TRANSIT_SKIMS_AB.RPT:W(693): The following LINKO nodes do not have XY values:

```

Ref: Z:\ModelRuns\fy20\CGV2_3_78_2020 Amendment_Visualize2045_Xmittal\2019\2019_searchForErrs.txt

10 Known issues related to running the model

10.1 Cube Cluster differences

When using Cube Cluster, the estimated VMT coming from the model can change slightly, depending on how many cores/nodes are used. See section 8.2.2 ("Effect of Cube Cluster on modeled results") on page 106 for more details.

10.2 Model run stops before finishing

We have experienced some cases where a model run will prematurely stop (this is sometimes also referred to as a "crash") for no apparent reason. Sometimes the exact same model run will complete successfully if run on a different computer. While we are still trying to determine the cause of these stoppages, we do, however, have a pragmatic way for dealing with these events. Determine where the model run crashed. Re-launch the model run but comment out all the steps in the "run model steps" that have completed successfully, so that the model runs only the step that crashed and the steps that follow it. This procedure will typically result in a normal model run, even though it requires the analyst to intervene midstream. Please see Chapter 9 ("Debugging cases where the model run stops prematurely or crashes") on page 119.

10.3 Issues with traffic assignment convergence

In the past, we have identified some cases where the gap (but not relative gap) for a given user equilibrium iteration in traffic assignment is equal to exactly zero, as opposed to a small, but non-zero value. We have reported this issue to Citilabs/Bentley Systems, which began an investigation into the matter. However, since the Version 2.4 Model (like its predecessors, e.g., 2.3.57 - 2.3.78) uses the *relative* gap and the number of user equilibrium iterations as stopping criteria, this issue should not affect the running of the model. Nonetheless, a model user could experience convergence issues if they change the model to use a tight stopping criterion. For example, in one test conducted by TPB staff, a stopping criterion of 10^{-6} was used, but the traffic assignment continued, going past 10^{-7}, even though 10^{-6} was specified. This happened for a for a future-year scenario that had variably priced facilities. At this point, we do not have any definitive answers, but we contacted Citilabs, whose staff thought that the difficulty reaching convergence was due to large toll values that dominate the link-cost function. Again, this should not be an issue for standard runs of the travel model, which use progressively tightening relative gap tolerances of 10^{-2}, 10^{-3}, and 10^{-4}.

10.4 Running multiple concurrent model runs on one computer/server

A user may wish to run two or more travel model runs on one computer or server at the same time. To compute the maximum number of concurrent model runs that may be run on a given computer, divide the number of cores (real or virtual, whichever is greater) by the number of cores needed per model run (currently 8, in the traffic assignment step). For example, on a computer like COG's travel model server #6 (tms6), which has 16 physical cores or 32 virtual cores due to Intel's Hyper-Threading Technology, the calculation would be:

(32 virtual cores)/(8 cores needed per model run) = 4 concurrent model runs (maximum)

However, based on our experience at COG, the actual number of concurrent model runs that you can run on a given computer may be less than the maximum number, depending on factors such as the following:

- The number of users launching the model runs: **This no longer appears to be an issue**. In the past, using Cube 6.1 SP1, we had found that, if two or more users tried to launch concurrent model runs, even if it was only two users, each with one model run, one of the two model runs would often stop prematurely or crash. However, **under Cube 6.4.1, we found that two or three users can submit concurrent model runs**.[83]
- Whether one runs the automated ArcPy walkshed process: This is now turned off by default in the model transmittal package, but it can also be uncommented (turned on) by the user if the user is making changes to the transit network and wants to recompute the transit walksheds and their resultant walk percentages.
- Whether one introduces a time delay (lag time) between model runs: For example, **two model runs can be launched at the same time**, or the **modeler can choose to offset the two launch times by a certain amount of time**. Thus, "**concurrent**" can mean that all the runs were started at the same time or that there was some offset between the start times of the model runs.

Finally, as noted in Section 3.3, based on recent communications with Citilabs (personal communication, 2/6/17), it is better not to overload the processor, so, although a 32-core computer should be able to run 4 concurrent model runs (4 x 8 = 32), it would be better to limit this computer to 3 concurrent model runs. Citilabs alludes to this issue in recent documentation: "However, when comparing two processors from the same family, assuming the processors are otherwise identical, an 8-core processor without Hyper-Threading will outperform a 4-core processor with Hyper-Threading, even though both processors are making 8 threads available to the operating system."[84]

[83] Ngo to Moran et al., "Testing the COG/TPB Travel Model Servers: 1) Need for Admin Privileges; 2) Ability to Run Two or More Concurrent Model Runs by Two or More Users; 3) Experience with Malware," June 6, 2017, 5.
[84] Citilabs, Inc., "Cube Base Reference Guide, Version 6.4.1," 10–11.

11 Building transit walksheds and calculating zonal walk percentages

11.1 Overview

One of the inputs to the travel demand model is the percentage of each zone that is within walking distance to transit. Conceptually, one develops a series of transit walksheds, which are then combined geographically with zone boundaries to calculate the percentage of each zone that is within walking distance to transit. This procedure creates point buffers around transit stop nodes and then overlays these point buffers with TAZ boundaries. The process is made more complicated by the fact that two walking distances are differentiated: a short walk (0.5 miles) and a long walk (1.0 miles). See Section 21.4.3 ("Market segmentation by access to transit") beginning on p. 196 for more details.

The model assumes that the area of each TAZ that is within a short-walk or a long-walk to transit is stored in a text file (areawalk.txt). This file is used by the walk access script (*walkacc.s*) to calculate the zonal walk *percentages*, which are then stored in a second text file (NLWalkPCT.txt).[85] This second file is then an input to both the transit fare process (*prefarv23.s*) and the mode choice process.

Note: **For the associated Ver. 2.4 Model transmittal package, the automated transit walkshed process has been turned off** (commented out in the run_modelSteps batch files). This is because:

1. If the user is not changing the transit network, there is no need to rerun this process, since we supply the needed areawalk.txt file with each network scenario;
2. Based on experience, this step is one of the most likely modeling steps to cause a premature stop or a crash, so for most users, it is better simply not to run it automatically. The reasons why the automated transit walkshed process causes a premature stop or a crash are varied, from incompatibilities between Cube Base and ArcGIS (see Table 22 on p. 127), to issues related to the way that the current ArcGIS engine runtime deals with slivers in the buffering process.

11.2 Application Details

The Ver. 2.4 Travel Model continues using an automated/integrated transit walkshed process, which was developed by AECOM. The process is automated in the sense that it is run using a Python/ArcPy script, so it does not require manual intervention from the user. The process is integrated in the sense that it is built into the travel model run: It is now the first step in the "run model steps" batch file ("call *ArcPy_Walkshed_Process.bat* %1"). The new process was developed by AECOM in FY 2014, and is discussed both in AECOM's FY 2014 report.[86] Although this process is turned off, by default, in the version of the model distributed with the model transmittal package, for users who would like to run the

[85] See the modeling flowchart in Appendix A.

[86] 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), chap. 3, http://www.mwcog.org/uploads/committee-documents/Y11YWFZd20140922110646.pdf.

process (perhaps because they have made a change to a transit network), the user can simply uncomment (remove the "REM") the following line in the run_modelSteps batch file:

```
call ArcPy_Walkshed_Process.bat %1
```

As noted by AECOM, "ArcPy was chosen as the basis for development because it provides convenient and powerful access to the GIS functionalities in a (Python) programming environment that is transparent and relatively easy to modify."[87] Another advantage of the new process is that it does not require one to have/purchase ArcGIS. One needs only to have purchased Cube, which comes with the ArcGIS engine runtime and which is already a requirement to run the model. To run the new integrated walkshed process, one must have the following:

- One of the following two ArcGIS software packages:
  - ArcGIS (e.g., version 10.1): Available for purchase from Esri. Some modelers may already have this software; some may not.
  - ArcGIS engine runtime (e.g., version 10.3): Available for free, if you have purchased Cube. All modelers will have purchased Cube, since it is needed to run the model. Cube version 6.4.1 comes with ArcGIS engine runtime 10.3.4959. If you do not have a full installation of ArcGIS 10.1, you will want to install Cube, including the ArcGIS engine runtime.
- Python (e.g., version 2.7): This is free, open-source software. One way to get it automatically is to install Cube "with ArcGIS engine runtime." It may also be included when one installs the full version of ArcGIS.

Notes:

1. As of Ver. 2.3.66, the areawalk.txt file created in the new automated walkshed process is sorted by TAZ.
2. In testing, if two model runs that incorporate the new transit walkshed process were started at the same time, one of the two runs will likely stop prematurely in the walkshed process. This is likely due to a license restriction with the ArcGIS runtime engine. Consequently, it is recommended that multiple model runs with enabled walkshed process on the same computer not be launched at the same time. Instead, **it is recommended that the start times be staggered/offset by 45 to 60 minutes**.[88] Based on a series of recent "stress tests" to see how many concurrent model runs could be completed on one server, it was also found that the 45-60-minute time offset is useful for minimizing the chance of a model run crash (irrespective of whether the new walkshed process is run, since a sharing violation can occur with other modeling steps).
3.

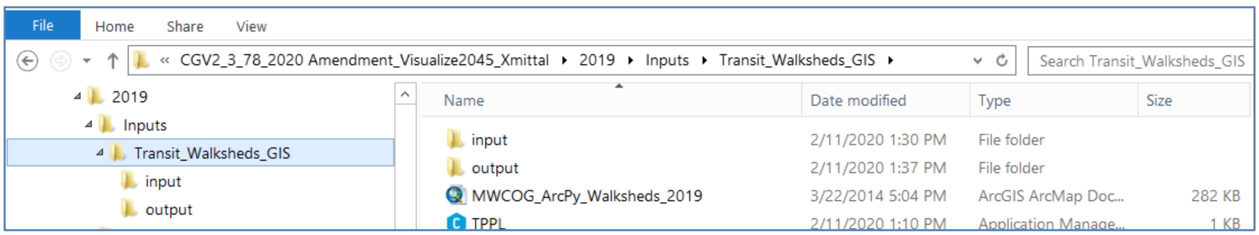
[87] AECOM, 3–2.
[88] AECOM, 3–8.

The new walkshed process appears to give identical results to the previous walkshed process, providing the inputs, such as the transit line files, are identical and correctly coded.[89]

In the model transmittal package, this line has been turned off (commented out), by placing "REM" at the beginning of the line (for the reasons explained earlier in this section).

If this automated transit walkshed process is run, this step occurs at the start of the pump-prime (PP) speed feedback loop. Once the walkshed process has been run, a new folder will be created in the "inputs" folder, named "Transit_Walkshed_GIS," as shown in Figure 59. Within this folder, one can find an ArcGIS map document file (MWCOG_ArcPy_Walksheds_*.mxd) which can be used to visualize the walkshed buffers, as shown in Figure 60.

Figure 59 Folder structure for the automated ArcPy walkshed process



Note that the Transit_Walkshed_GIS folder includes two subfolders, "input" and "output", which should not be confused with the "inputs" folder that is stored within the scenario-specific folder (which, in this case is called 2019). The ArcPy walkshed process creates two files: areawalk.txt and PercentWalk.txt, but only the first file is used by the travel model. If a copy of areawalk.txt already exists in the "inputs" folder, the old copy will be renamed as AreaWalk_Old.txt, before the new areawalk.txt file is created.[90]

11.3 Known issues

Although the new automated transit walkshed generation process has been a benefit to most users of the regional travel model, it has also been the source of many technical assistance calls to the COG/TPB staff when the process crashes for one reason or another. To minimize the likelihood that the automated ArcPy transit walkshed process will crash, we recommend you use versions of Cube and ArcGIS that are compatible. Table 22 shows which versions of Cube Base are **compatible** with ArcGIS, **in terms of the ability to run the automated transit walkshed process**. We have tested four different versions of ArcGIS with Cube Base ver. 6.4.1. Two of these worked (ArcGIS Engine Runtime 10.3 and ArcGIS 10.1) and two of these did not (ArcGIS 10.3.1 and ArcGIS 10.4.1). According to recent Citilabs documentation covering Cube 6.4.2 and 6.4.1, "Cube 6.4.1 includes support for ArcGIS versions 9.3 to

[89] See page 2-3 of Mark S. Moran and Dzung Ngo to David Roden and Krishna Patnam, "Comments on Your Cube/ArcPy-Based Transit Walkshed Process and Its Associated Memo Dated March 25, 2013," Memorandum, May 15, 2014.

[90] 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," 9–2.

10.3.1."[91] However, in our test #3, we found that the "support" was not such that it would allow the automated ArcPy transit walkshed process to run to completion, which is why we have noted that Cube Base 6.4.1 and ArcGIS 10.3.1 are not compatible for running the ArcPy automated walkshed process.

The table also shows two other cases, both for Cube 6.4.2. In test #5, an external user tried using Cube 6.4.2 and ArcGIS 10.4, but the two software packages were incompatible. In test #6, COG/TPB staff tested Cube 6.4.2 with ArcGIS engine runtime 10.4. In this case, the two software packages seemed to be compatible, but, as noted in a footnote to the table below, Cube Voyager ver. 6.4.2 appears to be less stable than Cube 6.4.1 when running the automated ArcPy transit walkshed process. TPB staff experienced several crashes in the ArcPy walkshed process under Cube 6.4.2. When staff upgraded Cube 6.4.1 to Cube 6.4.2 but did not upgrade ArcGIS Engine Runtime from 10.3.4959 to 10.4.1636776 (test #7), the model runs did not crash. The success of test #7 indicates the instability of ArcGIS Engine Runtime 10.4.1636776 coming with Cube 6.4.2 when running the automated transit walkshed process.

Staff recommend using Cube 6.4.1 and its ArcGIS Engine Runtime, Version 10.3.4959, as is shown in **bold** in Table 22.

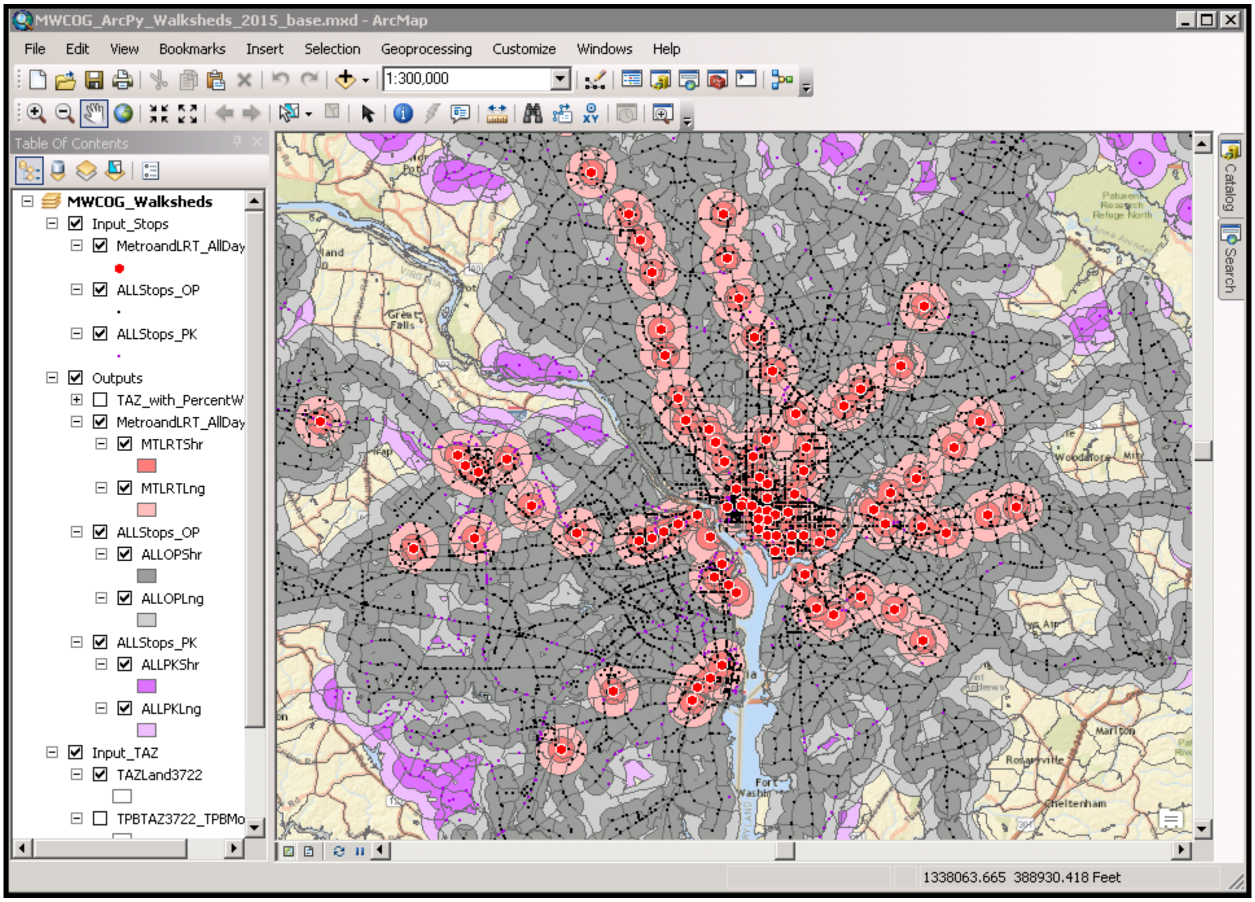
[91] Citilabs, Inc., "Cube Base Release Summary, Version 6.4.2" (Tallahassee, Florida: Citilabs, Inc., September 22, 2016), 4, http://citilabs-website-resources.s3.amazonaws.com/resources/RS_CubeBase.pdf.

Table 22 Compatibility between Cube Base and ArcGIS, in terms of the ability to run the automated transit walkshed process

Version of Cube Base	Version of ArcGIS	Compatible? *	Test Conducted by	Test No.
6.4.1	**10.3.4959 (ArcGIS Engine Runtime**)**	**Yes**	**COG/TPB**	**1**
	10.1 (full version)	Yes	COG/TPB	2
	10.3.1 (full version)	No	COG/TPB	3
	10.4.1 (full version)	No	COG/TPB	4
6.4.2***	10.4 (full version)	No	No. Va. Transportation Commission	5
	10.4.1636776 (ArcGIS Engine Runtime**)	Unstable	COG/TPB	6
	10.3.4959 (ArcGIS Engine Runtime****)	Yes	COG/TPB	7
6.4.3	10.5 (ArcGIS Engine Runtime **)	Yes	Citilabs/Bentley Systems	8
6.4.4	10.6 (ArcGIS Engine Runtime **)	No	COG/TPB	9
6.4.5	10.6 (ArcGIS Engine Runtime **)	Unstable	COG/TPB	10

* "Compatible" means that the tester was able to run the automated ArcPy transit walkshed process using the noted version of Cube and ArcGIS.
** ArcGIS Engine Runtime comes with Cube.
*** Compared to Cube Voyager ver. 6.4.1, Cube Voyager ver. 6.4.2 appears to be less stable when running the automated ArcPy transit walkshed process (TPB staff experienced several crashes in the ArcPy walkshed process under Cube 6.4.2).
**** ArcGIS Engine Runtime coming with Cube 6.4.1 is kept when updating to Cube 6.4.2.

Figure 60 Walkshed buffers for a typical base-year scenario



12 Set-Up Programs and Highway Network Building

12.1 Overview

Following the generation of transit walksheds, the initial modeling steps of the Version 2.4 Model are executed to establish basic modeling parameters to construct a binary (or "built") highway network. The steps are executed using two batch files:

- *Set_CPI.bat*: The batch file calls two Cube Voyager scripts, *Set_CPI.s* and *Set_Factors.s*
- *PP_Highway_Build.bat*: The batch file calls two Cube Voyager scripts, *AreaType_File.s* and *V2.3_Highway_Build.s*

The modeling steps included in these two batch files are shown on pages A-2 and A-3 of the flowchart in *Appendix A. Set_CPI.s* is used to establish deflation factors that are used in subsequent toll-related and transit fare-related steps. *Set_Factors.s* is used to establish K-Factors used in trip distribution and is also used to create the file *station_names.dbf* (used for the transit assignment summary process), which is developed using information pulled from station.dbf. The *Area_Type.s* step establishes zonal area type codes based on land activity densities (see Table 33). The resulting area type file is subsequently used in the highway building step, *V2.3_Highway_Build.s*. These steps are not implemented within the speed feedback loop of the travel model; they are executed only once, in the "pump prime" stage of the travel model. The principal inputs to above modeling steps are listed in Table 23 and detailed in Table 24 through Table 28. The principal outputs are listed in Table 29, and are detailed in Table 30 and Table 31.

Table 23 Inputs to the set-up and highway network building process

File description	File name and location	Format
CPI schedule and parameter file	\Inputs\CPI_File.txt	Text
Zonal land use file	\Inputs\ZONE.DBF	DBF
Node coordinate file	\Inputs\NODE.DBF	DBF
Zonal area type override file	\Inputs\AT_override.txt	Text
Link file	\Inputs\LINK.DBF	DBF
Initial AM and midday hwy. speed lookup files	\Support\AM_SPD_LKP.TXT, \Support\MD_SPD_LKP.TXT	Text
Toll parameter file	\Inputs\Toll_Esc.dbf	DBF

Table 24 Land Use File Format Description (zone.dbf)

Variable name	Description
TAZ	TAZ (1-3722)
HH	Households
HHPOP	Household population
GQPOP	Group quarters population
TOTPOP	Total population
TOTEMP	Total employment

Variable name	Description
INDEMP	Industrial employment
RETEMP	Retail employment
OFFEMP	Office employment
OTHEMP	Other employment
JURCODE	Jurisdiction Code (0-23) *0/DC, 1/MTG, 2/PG, 3/ALR/, 4/ALX,5, FFX, 6/LDN, 7/ PW, 8/(unused), 9/FRD, 10/HOW, 11/AA, 12/CHS, 13/(unused), 14/CAR, 15/CAL, 16/STM, 17/KG, 18/FBG, 19/STF, 20/SPTS, 21/FAU, 22/CLK, 23/JEF*
LANDAREA	Gross land area (square miles)
HHINCIDX	Ratio of zonal HH median income to regional median HH income in tenths (i.e., 10 = 1.0) per the 2007 ACS
ADISTTOX	Airline distance to the nearest external station (whole miles)
TAZXCRD	TAZ X-coordinate (NAD83, whole feet)
TAZYCRD	TAZ Y-coordinate (NAD83, whole feet)

Table 25 Node Coordinate File Format Description (node.dbf)

Variable name	Description
N	Highway node number
X	X-coordinate (NAD83, whole feet)
Y	Y-coordinate (NAD83, whole feet)

Table 26 Base Highway Link File Format Description (link.dbf)

File Name	Variable Name	Description
Link.dbf	A	A-Node
	B	B_Node
	DISTANCE	Link distance (in 1/100ths of miles)
	JUR	Jurisdiction Code (0-23) *0/DC, 1/MTG, 2/PG, 3/ALR/, 4/ALX,5, FFX, 6/LDN, 7/ PW, 8/(unused), 9/FRD, 10/HOW, 11/AA, 12/CHS, 13/(unused), 14/CAR, 15/CAL, 16/STM, 17/KG, 18/FBG, 19/STF, 20/SPTS, 21/FAU, 22/CLK, 23/JEF*
	SCREEN	Screenline Code
	FTYPE	Link Facility Type Code (0-6)
		0/centroids, 1/Freeways, 2/Major Art., 3/Minor Art, 4/Collector, 5/Expressway, 6/Ramp
	TOLL	Toll Value in current year dollars
	TOLLGRP	Toll Group Code
	AMLANE	AM Peak No. of Lanes
	AMLIMIT	AM Peak Limit Code (0-9)

File Name	Variable Name	Description
	PMLANE	PM Peak No. of Lanes
	PMLIMIT	PM Peak Limit Code (0-9)
	OPLANE	Off-Peak No. of Lanes
	OPLIMIT	Off-Peak Limit Code (0-9)
	EDGEID	Geometric network link identifier
	LINKID	Logical network link identifier
	NETYEAR	Planning year of network link
	SHAPE_LENG	Geometric length of network link (in feet)
	PROJECTID	Project identifier
	TRANTIME	Unused place marker
	WKTIME	Unused place marker
	MODE	Unused place marker
	SPEED	Unused place marker

Notes:

- The mode choice model requires that all costs be in 2007 dollars, which was the calibration year.
- Link limit codes are shown in Table 27.

Table 27 Link limit codes

Limit Code	Description and Vehicles Allowed
0	All vehicles allowed
2	HOV 2+ occupant vehicles allowed
3	HOV 3+ occupant vehicles allowed
4	All vehicles allowed, except for trucks
5	Airport passenger auto driver trips allowed
9	Closed link or transit only link. Example use cases: a) Transit only: Link closed to all traffic other than transit vehicles. If no transit routes traverse the link, then it is essentially closed to all vehicle traffic. b) Directional coding of managed-lane facilities, such as HOV and HOT, where some links are effectively closed to vehicles in some directions, during some periods of the day. c) Change in link directionality through time, e.g., if a road is 2-directional in some network years, but changes to a one-way street in the future, then limit 9 is used on the direction that is closed in the future. d) Reversible lanes, e.g., Rock Creek Parkway has limit code 9 in the off-peak direction, since it is closed for travel in that direction. e) Roads that do not exist in early years of the plan but are built in later years. For example, I-270 has future-year improvements in 2030 north of I-370. In the early years, these links are coded as limit code 9, since they do not yet exist.

Table 28 Toll Parameter File (Toll_esc.dbf)

File Name	Variable Name	Description
Toll_Esc.dbf	Tollgrp	Toll group code 1 = Flat toll (pertains to most existing tolled facilities); 2 = Toll that varies by time of day (e.g. ICC), 3+= Tolls that change dynamically based on congestion level (e.g., VA HOT lanes/Express Lanes)
	Escfac	Deflation factor override. Can be used to group various toll policies.
	Dstfac	Distance (per mile) based toll factor in present year cents/dollar (optional)
	AM_Tftr	AM period Toll factor
	PM_Tftr	PM period toll factor
	OP_Tftr	Off-peak period toll factor
	AT_MIn	Area Type minimum override (optional)
	AT_Max	Area Type maximum override (optional)
	TollType	*Toll Type (1=operating in calibration year, 2= operating after calibration year)*

Table 29 Outputs of the set-up and highway network building process

Highway, transit deflator files	Trn_Deflator.txt, Hwy_Deflator.txt	Text
Summary text file of Fare CPI assumptions used	MFARE2_CPI.txt	Text
Zone centroid co-ordinates	TAZ_XYs.dbf	DBF
1-mile floating land use	Floating_LU.dbf	DBF
Area type file	AreaType_File.dbf	DBF
Unloaded/built highway network file	ZONEHWY.NET	Binary
Summary text file of Fare CPI assumptions used	MFARE2_CPI.txt	Text
Zonal K-factors	HBW_K.MAT, HBS_K.MAT, HBO_K.MAT, NHW_K.MAT, NHO_K.MAT	Binary

Table 30 Zonal Area Type File (AreaType_File.dbf)

Variable Name	Description
TAZ	TAZ Number (1-3,722)
POP_10	One-mile "floating" Population density
EMP_10	One-mile "floating" Employment density
AREA_10	One-mile "floating" Area
POPDEN	One-mile "floating" Population density
EMPDEN	One-mile "floating" Employment density
POPCODE	Population density code (1 -7)
EMPCODE	Employment density code (1 -7)
ATYPE	Area Type (1-6)

Ref: "I:\ateam\docum\fy19\tpb_tdfm_gen2\ver2.3\travel_model_user_guide\AreaType_File.xlsx"

The one-mile floating density is calculated by using the TAZ centroids and a one-mile point buffer around these centroids.

Table 31 Unloaded binary highway network file (Zonehwy.net)

File Name	VariableName	Description
zonehwy.net	A	A Node
	B	B Node
	DISTANCE	Link Distance in miles (x.xx)
	SPDC	(Not used)
	CAPC	(Not used)
	JUR	Jurisdiction Code (0-23)
		0/dc, 1/mtg, 2/pg, 3/alr/, 4/alx,5, ffx, 6/ldn, 7/ pw, 8/(unused), 9/ frd, 10/how, 11/aa, 12/chs, 13/(unused), 14/car, 15/cal, 16/stm, 17/ kg, 18/fbg, 19/stf, 20/spts, 21/fau, 22/clk, 23/jef
	SCREEN	Screenline Code (1-38)
	FTYPE	Link Facility Type Code (0-6)
		0/centroids, 1/Freeways, 2/Major Art., 3/Minor Art, 4/ Collector, 5/ Expressway, 6/ Ramp
	TOLL	Toll value in current year dollars
	TOLLGRP	Toll Group Code (1-9999)
	<Period>LANE	<Period> No. of Lanes
	<Period>LIMIT	<Period> Limit Code (0-9)
	EDGEID	Geometry network link identifier
	LINKID	Logical network link identifier
	NETWORKYEA	Planning year of network link
	SHAPE_LENG	Geometry length of network link (in feet)
	PROJECTID	Project identifier
	TAZ	TAZ (1-3,722)
	ATYPE	Area Type (1-6)
	SPDCLASS	Speed Class
	CAPCLASS	Capacity Class
	DEFLATIONFTR	Deflation factor for converting existing year costs to 2007 costs
	<Period>TOLL	<Period>Toll value in current year cents (if applicable)
	<Period>TOLL_VP	<Period>Toll of future, variably priced facility only
	<Period> HTIME	<Period> Highway Time (min)
Key		
<Period>=	AM	AM Peak Period (6:00-9:00 AM)
	MD	Mid Day (9:00 AM - 3:00 PM)
	PM	PM Peak Period (3:00 - 7:00 PM)
	NT	All remaining hours

12.2 Application Details

The *Set_CPI.S* script is used to produce deflation factor files (Trn_Deflator.txt and Hwy_Deflator.txt) which are used to convert present-year costs to constant-year (2007) costs. The deflation parameter files are inputs to the *V2.3_Highway_Build.s* and *MFARE2.S* scripts. This procedure has been established to ensure that cost deflation for highway tolls and transit fares are treated consistently.

The *Set_CPI.S* script reads a preexisting look-up table (\INPUTS\CPI_File.txt) containing historical annualized CPI figures published by the U.S. Bureau of Labor Statistics beginning with the model calibration year, 2007. The CPI figures are based on the U.S. city average of all urban consumers (100 = 1982-84). An example listing of the file appears in Figure 61. Note that in the Version 2.4 Travel Model, the consumer price index file still uses 2018 as the current CPI year, since the model currently uses the model inputs from the 2020 Amendment to Visualize 2045. The CPI file, along with other model inputs, will be updated when the Ver. 2.4 Model is used for the next LRTP update.

Figure 61 Consumer price index file (CPI_File.txt)

```
;; - MWCOG V2.3 Travel Model - Cost deflation Table
;; - 6/20/2019  - RN
;; Data from BLS / All Urban Consumers (CPI-U) US City Avg.1982-84=100.0
;; http://www.usinflationcalculator.com/inflation/consumer-price-index-and-annual-percent-changes-from-1913-to-2008
;; https://www.bls.gov/regions/mid-atlantic/data/consumerpriceindexannualandsemiannual_table.htm

InflationFTR        = 1.0    ; Inflation Assumption (DEFAULT IS 1.0)
Defl_OverRide       = 0.0    ; Deflation Override   (DEFAULT IS 0.0)  If Non-zero it is used as deflator
                             ; Used as deflator IF NON-ZERO
BaseCPIYear         = 2007   ; Base year of the CPI Table
CurrCPIYear         = 2018   ; Current year on  CPI Table
;
;================================================================
; Establish historic CPI table and Deflation Factor            =
;================================================================
;
      LOOKUP Name=CPI_Table,
             LOOKUP[1]   = 1,Result = 2,          ;;  CPI index (from US BLS)
             LOOKUP[2]   = 1,Result = 3,          ;;  Compounded Growth Rate From Base Year
             LOOKUP[3]   = 1,Result = 4,          ;;  Deflation Factor
             Interpolate = N, FAIL=0,0,0,list=Y,
          ;;
          ;;               (((YrCPI/BsCPI)^(1/n))-1.0)*100   BsCPI/YrCPI)
          ;;                      Annual_Avg.                Historic Deflation
          ;; YEAR    CPI          Growth_Rate(%)             Factor
          ;; ----   -----        -----------------          -----------
        R=' 2007,  207.342,          0.00,                  1.0000 ', ; <--- BaseCPIYear
          ' 2008,  215.303,          3.84,                  0.9630 ', ;
          ' 2009,  214.537,          1.72,                  0.9665 ', ;
          ' 2010,  218.056,          1.69,                  0.9509 ', ;
          ' 2011,  224.939,          2.06,                  0.9218 ', ;
          ' 2012,  229.594,          2.06,                  0.9031 ', ;
          ' 2013,  232.957,          1.96,                  0.8900 ', ;
          ' 2014,  236.736,          1.91,                  0.8758 ', ;
          ' 2015,  237.017,          1.69,                  0.8748 ', ;
          ' 2016,  240.007,          1.64,                  0.8639 ', ;
          ' 2017,  245.120,          1.69,                  0.8459 ', ;
          ' 2018,  251.107,          1.76,                  0.8257 '  ; <--- Curr(ent)CPI Year
; --- end of CPI File -----------
; ------------------------------
```

Ref: Z:\ModelRuns\fy20\CGV2_3_78_2020 Amendment_Visualize2045_Xmittal\2019\Inputs\CPI_File.txt

The script computes a cost deflation factor using the CPI table and the parameters *BaseCPIYear*, *CurrCPIYear, InflationFTR* (all specified in the above text file), and **the _*Year*_ environment variable specified in the "Run_ModelSteps" batch file**. These parameters are defined as:

- **BaseCPIYear** = the base (or calibration) year of the travel model
- **CurrCPIYear** = the most recent year for which historical CPI data exists (as reflected in the CPI table)
- **_Year_** = the year of the modeled scenario (as defined in the Run_ModelSteps.bat file)
- **InflationFTR** = Factor reflecting special CPI growth assumptions beyond CurrCPIYear that might be considered in scenario testing. For example, a value of 1.0 indicates future cost escalation is assumed to remain constant with the historical rate of inflation; a value of 2.0 would indicate that the future cost escalation is assumed to be twice the historical rate of inflation; a value of 0.5 would indicate that the future cost escalation is assumed to be one half of the historical rate of inflation, etc. The default value is 1.0.

Under default conditions, if the modeled year (_*Year*_) is less than or equal to *CurrCPIYear*, the CPI factor will equal CPI_{2007}/ $CPI_{\_Year\_}$ from values provided in the CPI table. If the modeled year (_*Year*_) is greater than *CurrCPIYear*, the CPI factor will equal (CPI_{2007}/ $CPI_{CurrCPIYear}$) from values provided in the CPI table. The user may optionally invoke the *InflationFTR* parameter to arrive at a deflation factor that reflects something other than the "historical inflation rate" assumption. In addition to the output deflation factor files mentioned above, the script also writes a text file (Mfare2_CPI.txt) that lists the input and output parameter values used.

The Set_Factors.s script is used to generate a family of K-factors by modeled trip purpose, to be used subsequently by the trip distribution process. The K-factors are jurisdiction-based and have been formulated during the calibration and validation phase of the model development process. Separate K-factor files are produced by purpose as Cube/Voyager binary matrix files (zone-to-zone). These files are currently stored in the Support folder, though there has been some thought of moving these into the inputs folder to prevent sharing violations when multiple model runs are launched concurrently. As of the Ver. 2.3.57a model, *Set_Factors.s* is also used to generate the station names file (station_names.dbf), which is stored in the INPUTS folder, used in the transit assignment summary process, and is derived from information found in the station file (station.dbf, see Table 40).

It is useful to understand the basic elements of the highway and transit networks that are reflected in the highway link input file (link.dbf) to the Version 2.4 Model. The highway elements are shown in Table 32.

Table 32 Elements of the highway network

Highway Network Element	What It Represents	Node No. Ranges	Notes
Zone centroid	Center of activity for the TAZ; Start and end point for trips	1-3722	3676-3722 allocated as external stations. 3723-5000 reserved for TAZ expansion. Established ranges for each jurisdiction. Some TAZs are unused
Station PNR centroid	Location of the station's park-and-ride lot. Used to develop congested highway times between each TAZ and each PNR lot.	5001-7999*	5001-5999 for Metrorail. 6000-6999 for commuter rail. 7000-7999 for LRT, BRT, and streetcar.
Highway node	Highway intersections or junctions, including where zone centroids connect to the highway network	20000-60000 120000-160000 90000-90999**	Established ranges for each jurisdiction.
Zone centroid connectors	Connection from zone centroid to the highway network. One zone centroid connector can represent multiple local roads.		Facility type (FTYPE) = 0
PNR lot connectors	Connection from PNR lot to the highway network		Facility type (FTYPE) = 4
Highway links	Road segments		0 = centroid connectors; 1 = freeways; 2 = major arterials; 3 = minor arterials; 4 = collectors; 5 = expressways; 6 = ramps on freeways and arterials; 9 = transit only;

Notes: * Station PNR centroids (a.k.a. dummy station centroids) are not required for Mode 5 (LRT) or Mode 10 (BRT/streetcar).[92] For the sake of consistency, the current COG coding practice is to refrain from using station PNR centroids for LRT, BRT, and streetcar. In other words, in the station file, the STAC variable is coded with a value of zero.
** Exclusively reserved for Montgomery County.

The network includes two types of centroids: a zonal centroid, which represents the geographic center of land activity within a TAZ, and a park-and-ride (PNR) lot centroid (also known as a "station centroid," "dummy PNR centroid"), which represents PNR lot locations at Metrorail and commuter rail stations. The PNR centroid represents a kiss-and-ride (KNR) drop-off point if no PNR lot exists at a given station. Within the station file (station.dbf), the PNR centroid/station centroid is denoted with the variable name STAC. Each Metrorail station and commuter rail station should have its own unique STAC. The two centroid types are assigned specific numbering ranges. TAZ centroids are numbered 1-3722 and PNR centroids are numbered 5001-7999. The numbering gap between the TAZ and PNR ranges, 3723-5000, are reserved for future TAZ assignments.[93] The two centroid types are employed so that highway level-of-service (LOS) matrices may be built, not only between TAZs, but also between TAZs and PNR lots.

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[92] Jain to Milone and Moran, "MWCOG Network Coding Guide for Nested Logit Model (First Draft: September 20, 2007; Updated February 2008 and October 2010)," October 2010, 6 and 10.
[93] The existing Version 2.3 scripts, inputs, and support files would need to be modified if additional TAZs were added to the highway network.

Highway nodes representing intersections or highway access points from TAZs or PNR lots are assigned a number from the following ranges: 20000 to 60000 and 120000 to 1600000. The unused nodes ranging from 90000-90999 are reserved exclusively for Montgomery County studies where more detailed coding is included to avoid the possibility of using the same node numbers in different locations. Network links (i.e., centroid connectors and highway links) are assigned facility type ("Ftype") attributes ranging from 0 to 6.

The highway network building process -- i.e., the process for creating a binary highway network file which is used in subsequent modeling steps -- is undertaken with two scripts that are executed in sequence: *AreaType_File.s* and *V2.3_Highway_Build.s* (page A-3). The *AreaType_File.s* script, which reads a preexisting zonal land activity file (Zone.dbf) and a highway node coordinate file (Node.dbf), computes the area type code associated with each TAZ. Area type codes range from 1 to 6 and are based on population and employment density, as shown in Table 33.

Table 33 Area type codes, based on population and employment density

One-Mile "Floating" Population Density (Pop/Sq mi)	One- mile "Floating" Employment Density (Emp/Sq mi)						
	0-100	101-350	351-1,500	1,501-3,550	3,551-13,750	13,751-15,000	15,001+
0-750	6	6	5	3	3	3	2
751-1,500	6	5	5	3	3	3	2
1,501-3,500	6	5	5	3	3	2	2
3,501-6,000	6	4	4	3	2	2	1
6,001-10,000	4	4	4	2	2	2	1
10,000-15,000	4	4	4	2	2	2	1
15,001+	2	2	2	2	2	1	1

The *AreaType_File.s* script produces three files which are used as inputs to the *v2.3_highway_build.s* script:

- TAZ_Xys.dbf (zonal coordinates),
- Floating_LU.dbf (a zonal file containing the area, population, and employment within one mile),[94]

[94] TAZ-level floating density is calculated by using the TAZ centroids and creating a 1-mile point buffer around each centroid.

- Areatype_file.dbf (a zonal file containing the associated area type, in accordance with the land activity file)

The *V2.3_Highway_Build.S* script reads the zonal area type file, along with a node file, a link attribute file, a zone file, and four parameter files. The parameter files include initial speed and capacity lookup files (AMSpd.lkp, MDSpd.lkp), both arrayed by facility type and area type. The deflation file created by the SET_CPI.s script (Hwy_Deflator.txt) is also read into the highway building script. Finally, a toll parameter/escalation file (Toll_esc.dbf) is also used by the script. The file contains a number of toll-related parameters that are indexed by a tolled facility code (tollgrp) which is included as a link attribute.

The highway building process consists of the following steps:

1) Each highway link is evaluated against all TAZ centroids to determine its nearest zone (i.e., the TAZ centroid nearest to the airline mid-point of the link a-node and b-node). The nearest zone is then saved to a temporary link file containing the A-node, B-node, and nearest TAZ.
2) The link file, zonal area type file, and link-TAZ (from step 1) are merged to enable the zonal area type of the nearest TAZ to be assigned to each link. The link file contains basic link attributes, including distance, facility code, time-of-day-period-specific (AM, PM, OP) lanes and limit codes, coded tolls, toll group codes, jurisdiction, and screenline codes.
3) Toll parameters are merged to each link based on the tollgrp code.
4) Speed and capacity classes are next defined as a two-digit integer, where the first digit represents the facility type and the second digit represents the area type.
5) Period-specific tolls (AM, PM, and OP) are computed. The general form of the toll computation is:

   <prd>Toll = (Toll + (DstFac$_t$ * Distance * <prd>_TFtr$_t$)) * (EscFac$_t$ if > 0.0; Otherwise: Hdefl)

<u>Where:</u>

<prd>Toll	= period-specific toll coded on link in constant year dollars (e.g., Amtoll)
Toll	= link-coded "Toll" link attribute value
DstFac$_t$	= distance factor (cents/mi) for toll group "t", as specified in Toll_Esc.dbf
Distance	= link-coded distance (miles)
<prd>_TFtr$_t$	= period-specific factor for toll group "t" as specified in Toll_Esc.dbf
Hdefl	= Default highway deflation factor based on CPI assumptions (Set_CPI.s)
Esc_Fac$_t$	= Hwy. deflation factor *override* for toll group "t", as specified in Toll_Esc.dbf

6) A period-specific toll type code (<prd>Toll_VP) is established to distinguish whether the tolled link existed during the model calibration year or the tolled link is a future, variably priced facility. This information is relevant to subsequent toll skimming.
7) Initial AM and OP speeds are assigned, based on facility and area type codes.
8) Midday (MD) and Night (NT) attributes are set to off-peak (OP)-related attributes defined above

The binary network file resulting from the highway network building process is named Zonehwy.net. Variables that are included in the zonehwy.net file are described in Table 34.

Table 34 zonehwy.net file Variables description

Variable Name	Description
A	A-Node
B	B-Node
DISTANCE	Link Distance in miles (x.xx)
SPDC	Not used
CAPC	Not used
JUR	Jurisdiction Code (0-23) *0/DC, 1/MTG, 2/PG, 3/ALR/, 4/ALX,5, FFX, 6/LDN, 7/ PW, 8/(unused), 9/FRD, 10/HOW, 11/AA, 12/CHS, 13/(unused), 14/CAR, 15/CAL, 16/STM, 17/KG, 18/FBG, 19/STF, 20/SPTS, 21/FAU, 22/CLK, 23/JEF*
SCREEN	Screenline Code (1-38)
FTYPE	Link Facility Type Code (0-6) *0/centroids, 1/Freeways, 2/Major Art., 3/Minor Art, 4/Collector, 5/Expressway, 6/Ramp*
TOLL	Toll Value in current year dollars
TOLLGRP	Toll Group Code (1-9999)
<Period>LANE	<Period> No. of Lanes
<Period>LIMIT	<Period> Limit Code (0-9)
EDGEID	Geometry network link identifier
LINKID	Logical network link identifier
NETWORKYEA	Planning year of network link
SHAPE_LENG	Geometry length of network link (in feet)
PROJECTID	Project identifier
TAZ	TAZ (1-3722)
ATYPE	Area Type (1-6)
SPDCLASS	Speed Class
CAPCLASS	Capacity Class
DEFLATIONFTR	Factor for deflating current year tolls to constant year tolls
<Period>TOLL	<Period> Toll Value in current year dollars
<Period>TOLL_VP	<Period> Toll Value in current year dollars - Variably priced tolled facilities only
<Period> HTIME	<Period> Highway Time - based on initial highway lookup speeds
KEY	
<Period>= AM	AM Peak Period (6:00 AM - 9:00 AM)
MD	Midday (9:00 AM - 3:00 PM)
PM	PM Peak Period (3:00 PM - 7:00 PM)
NT	All remaining hours ("nighttime")

13 Highway Skim File Development

13.1 Overview

Highway skimming begins with path building, the process of building minimum-impedance paths from every TAZ to every other TAZ. After paths have been built, the paths can be "skimmed," i.e., the paths are traversed, and key variables are summed over the paths. The variables that are skimmed include travel times, distances, and tolls. The resultant zone-to-zone sums are saved in one or more skim matrices. The input to the skimming process is usually a loaded network with congested travel speeds, generated from a traffic assignment process. Although traffic assignment is conducted for four time-of-day periods (AM peak period, midday, PM peak period, and nighttime), the travel model is set up to use skims for only two time-of-day periods: a peak period (represented by the AM peak period) and an off-peak period (represented by the midday period). Highway skims in the Version 2.4 Model are generated after each traffic assignment step.

Highway skims are generated by time period (AM and Midday), and by highway mode (SOV, HOV 2-occupant, HOV 3+occupant). In addition, truck skims are generated for the midday period only. Mode-specific paths are very important in the Washington, D.C. region, due to special operating restrictions, particularly during the AM peak period.

The TPB's highway skimming is done twice: once to develop zone-to-zone (3722 x 3722) skim matrices and then again to develop zone/PNR lot-to-zone/PNR lot (7999 x 7999) skim matrices. The latter set enables restrained highway speeds and distances to be calculated between zones and PNR lots, thus allowing transit auto-access links to be built. The entire highway skimming process is applied with the scripts named *Highway_Skims_am.s, Highway_Skims_md.s, modnet.s, Highway_Skims_mod_am.s, Highway_Skims_mod_md.s,*[95] *joinskims.s, and Remove_PP_Speed.s*. These are invoked with the *PP_Highway_Skims.bat* file in the initial or pump-prime iteration (see page A-4 of Appendix A) and the *Highway_Skims.bat* file (see page A-11) in the standard iterations. The *Remove_PP_Speed.s* script is executed in the pump-prime iteration only. The principal inputs and outputs are shown in Table 35 and Table 36 , respectively.

Table 35 Inputs to the highway skim file development

Built highway network file	<ITER>_HWY.NET	Binary
Toll minutes equivalent	support\toll_minutes.txt	Text
AM toll factors by vehicle type	Inputs\AM_Tfac.dbf	DBF
MD toll factors by vehicle type	Inputs\MD_Tfac.dbf	DBF

Note: <ITER> =PP, i1…i4   <Prd>= AM and MD

[95] Prior to build 37, there was one script (*Highway_Skims_mod.s*), which had a loop covering the two time periods, AM and midday. However, it was found that this script would crash on some hardware configurations, when running Voyager 5.1.3, resulting in the following errors: 1) Voyager.exe, APPCRASH, TPPDLIBX.DLL; and 2) Voyager, APPCRASH, MSVCR90.DLL. The script was then split into two files (*Highway_Skims_mod_am.s* and *Highway_Skims_mod_md.s*), which eliminated this problem.

Table 36 Outputs of the highway skim file development

Total highway skims	<ITER>_SKIMTOT.TXT	Text
Truck skims	<ITER>_MD_TRK.SKM	Binary
SOV skims	<ITER>_<Prd>_SOV.SKM	Binary
HOV2 skims	<ITER>_<Prd>_HOV2.SKM	Binary
HOV3+ skims	<ITER>_<Prd>_HOV3.SKM	Binary
SOV skims (used by mode choice model)	<ITER>_<Prd>_SOV_MC.SKM	Binary
HOV2 skims (used by mode choice model)	<ITER>_<Prd>_HOV2_MC.SKM	Binary
HOV3+ skims (used by mode choice model)	<ITER>_<Prd>_HOV3_MC.SKM	Binary
AM highway skims	<ITER>_HWY_AM.SKM	Binary
Off peak highway skims	<ITER>_HWY_OP.SKM	Binary
Network with added station centroid connectors	<ITER>_HWYMOD.NET	Binary
Walk access links	WalkAcc_Links.dbf	DBF
	<ITER>_<Prd>_SOV_MOD.SKM	Binary
	<ITER>_<Prd>_HOV2_MOD.SKM	Binary
	<ITER>_<Prd>_HOV3_MOD.SKM	Binary
Highway network with PP speeds removed	ZoneHWY.NET	Binary

Note: <ITER> =PP, i1…i4 <Prd>= AM and MD

13.2 Application Details

The highway skimming process is used to develop time, cost, and toll values between origin/destination (i/j) pairs of zones on a minimum-impedance path. The skimming process reads a highway network input file with preexisting restrained speeds. The restrained speeds used in the pump prime (PP) iteration initially are table look-up values based on time period (AM, Off-peak), facility type, and area type. After the PP iteration is completed (i.e., after the PP traffic assignment process is completed), the highway skimming is accomplished using traffic assignment-based link speeds. The generalized impedance for which paths are developed for highway skimming is defined as follows:

Equation 1 Converting tolls into time-equivalent minutes of impedance

$$(\text{Impedance})_v = (\text{Restrained over-the-network time})_v + (\text{Toll-related time})_v$$

or

$$(\text{Impedance})_v = (\text{Restrained over-the-network time})_v + ([\text{Toll cost}]_v \times [\text{Time rate}]_v \times [\text{Vehicle factor}]_{vf})$$

where

$(\text{Impedance})_v = \text{Restrained over-the-network time}_V + \text{Toll-related Time}_V$

$(\text{Restrained over-the-network time})_v$ = Congested/restrained network travel time (min) for vehicle class "V"

$[\text{Toll cost}]_v$ = Tolls (2007 dollars)paid by vehicle class "V", if a tolled facility was used

$[\text{Time rate}]_{v}$ = Time valuation (min/2007 dollar) of toll costs for vehicle class "V"
$[\text{Vehicle factor}]_{vf}$ = Vehicle class factor for tolled facility "F"

Note: Vehicle classes are: SOVs, HOV2-occs, HOV3+occs, Commercial Vehicles, Trucks, and airport passenger vehicles.

The assumed time rates are provided by vehicle class and time period in toll_minutes.txt (see below), which is located in the Support folder. The values shown are derived from average household income levels and information from the 2007/08 HTS. The values should not be altered.

```
;
;     ==================================================================
;     = Equivalent Toll Minutes by Time Prd & Vehicle Type             =
;     = in minutes per 2007 dollar - rm 1/7/11                         =
;     ==================================================================
;
;    AM Peak          Midday           PM Peak          Night
;---------------  ---------------    --------------     --------------
  SVAMEQM = 2.5     SVMDEQM = 3.0    SVPMEQM = 3.0     SVNTEQM = 3.0 ; <--- SOVs
  H2AMEQM = 1.5     H2MDEQM = 4.0    H2PMEQM = 2.0     H2NTEQM = 4.0 ; <--- HOVs-2 Occ
  H3AMEQM = 1.0     H3MDEQM = 4.0    H3PMEQM = 1.0     H3NTEQM = 4.0 ; <--- HOVs-3+Occ
  CVAMEQM = 2.0     CVMDEQM = 2.0    CVPMEQM = 2.0     CVNTEQM = 2.0 ; <--- Comm Veh
  TKAMEQM = 2.0     TKMDEQM = 2.0    TKPMEQM = 2.0     TKNTEQM = 2.0 ; <--- Trucks
  APAMEQM = 2.0     APMDEQM = 2.0    APPMEQM = 2.0     APNTEQM = 2.0 ; <--- Apaxs
```

The vehicle factors are provided by time period in the inputs files AM_Tfac.dbf and MD_Tfac.dbf. An example of the AM_Tfac.dbf file is shown below. The file is available to allow for the ability to reflect a facility-specific toll policy differential between vehicle classes. The table below specifies the default assumption that tolls do not vary between vehicle classes, except for trucks, which are assumed to pay 2.5 times the toll that an auto would pay.

TOLLGRP	AMSOVTFTR	AMHV2TFTR	AMHV3TFTR	AMCOMTFTR	AMTRKTFTR	AMAPXTFTR
1	1.0000	1.0000	1.0000	1.0000	2.5000	1.0000

Information about the "toll setting" process that is used to estimate reasonable toll values can be found in two technical memos.[96]

The standard zone-to-zone highway skims are developed by the scripts *Highway_Skims_am.s* and *Highway_Skims_md.s*. The scripts produce skim files pertaining to two time periods (AM and midday) and to four mode/path types (SOV, HOV2, HOV3+, and truck). The truck skim file contains one table pertaining to travel time. The SOV and HOV skim files **contain four tables**: 1) time (min), 2) distance in implied tenths of miles, 3) total toll (year-2007 cents), and 4) variably priced tolls (year-2007 cents).

[96] Jinchul Park to Team B Modelers, "Processes Related to Toll Setting in Version 2.3 Model (Draft)," Memorandum, October 12, 2012.

Based on a past analysis of Version 2.2 model forecasts, TPB staff found substantial costs associated with planned variably priced highway facilities (e.g., the Northern Virginia HOT lanes and the ICC) caused counterintuitive mode choice model results. Essentially, the added person trips induced by the HOT lane's accessibility benefit tended to be allocated among non-SOV modes because of the substantial costs for paying SOVs to use the HOT lane costs. The result was not considered reasonable since the objective of the facility was to attract paying SOVs by selling a travel time benefit. Staff speculated that the result may be attributed to the specification of the mode choice model: the "SOV-pay" alternative was not included in the choice set when the model was calibrated (indeed, no such facility had ever operated in the region). It was decided that the potentially extreme costs associated with future-year, variably priced highway facilities should **not** be considered by the mode choice model **as monetary values** in application. **Instead, tolls on variably priced facilities are expressed as equivalent minutes that are added to the highway time**. This approach has been adopted for the Version 2.4 application. Consequently, two sets of SOV and HOV skim files are created, one in which all toll facility costs are skimmed (e.g., <ITER>_AM_SOV.SKM), and another set in which the toll skims reflect base-year toll facilities only **and the time skims reflect highway times and tolls converted to equivalent time** (<ITER>_AM_SOV_MC.SKM). The former is used as an input to the trip distribution model and the latter is used as an input to mode choice.

The *joinskims.s* script is use to merge the six skim files used by the mode choice model into two files, <iter>_HWY_AM.skm and <iter>_HWY_MD.skm, which are read directly into the mode choice model.

Modnet.s reads the built highway network file and creates another modified binary network that includes an expanded set of zone centroids, zone centroids (numbered 1 to 3722) and PNR lot centroids (numbered 5001 to 7999). The expanded network is named <iter>_HwyMod.net. *Modnet.s* also generates a list of highway links that are considered as "walk network links" in the development of sidewalk (mode 13) links for the transit network.

The *Highway_Skims_Mod_am.s* and *Highway_Skims_Mod_md.s* scripts read the expanded network and create an expanded set of highway skims dimensioned 7999 by 7999, which includes highway skims between zone centroids as well as between zone and PNR lot pairs. The latter will be used subsequently to create auto access link attributes. As explained in footnote 95, prior to build 37, there was one script (*Highway_Skims_mod.s*), which had a loop covering the two time periods, AM and midday. However, it was found that this script would crash on some hardware configurations, but not on others. The script was then split into two files (*Highway_Skims_mod_am.s* and *Highway_Skims_mod_md.s*), which eliminated this problem.

The *Remove_PP_Speed.s* script is used to remove the "PP" iteration speed attributes from the highway network. This is necessary in the initial (PP) iteration, when table lookup speeds are to be replaced by traffic assignment speeds in the PP iteration.

14 Auto Driver Trip Development

14.1 Overview

The "auto drivers" step is used to convert daily auto person trip tables by occupant group (1, 2, and 3+) into auto driver trips by occupant group. This step occurs in between the mode choice model and the time-of-day model steps (see pages A-8 and A-14 of Appendix A). The auto driver step uses daily auto person trips estimated by the mode choice model and computes auto driver trips by occupant groups using matrix division. Because the mode choice file output includes only internal-to-internal movements, total external auto person trips produced in the trip distribution step are also used as a basis for developing external auto driver trips by occupant groups. External auto person trips produced by the trip distribution process are not stratified by occupant groups. The auto driver step uses modeled occupant disaggregation curves to develop external auto drivers by occupant groups.

The scripts used are *PP_Auto_Drivers.s*, invoked by the *PP_AutoDrivers.bat* file (see page A-8 of Appendix A) and *MC_Auto_Drivers.s*, invoked by the *Auto_Drivers.bat* file (see page A-14 of Appendix A). The inputs to this step are shown in Table 37. The outputs are shown in Table 38. The outputs consist of five purpose-specific auto driver files, each containing three tables (one for each occupant group). The output files contain both internal and external auto driver movements.

Note that the *PP_Auto_Drivers.s* script uses a pre-existing mode choice model output file that resides in the \inputs subdirectory, while the *MC_Auto_Drivers.s* script reads mode choice model output that is generated within the model execution stream. A pre-existing file must be used in the pump prime iteration in order to provide initial zonal mode choice percentages. TPB staff uses a pre-existing file that is as current and as reasonable for the modeled scenario as possible.

Table 37 Inputs to auto driver trip development

Pre-existing final iteration AEMS mode choice model output modal trip tables	???_NL_MC.MTT	Binary
Pump Prime iteration person trip tables	<iter>_???.PTT	Binary
Current iteration AEMS mode choice model output modal trip tables	???_NL_MC.MTT	Binary

Note: ??? = HBW, HBS, HBO, NHW, and NHO <ITER> =PP, i1…i4

14.2 Application Details

Table 38 Outputs of auto driver trip development

Auto drivers trips by trip purpose (t1= 1-occ. auto drivers, t2= 2-occ. auto drivers, t3 =3+ occ. Auto drivers	<ITER>_???_ADR.MAT	Binary

Note: ??? = HBW, HBS, HBO, NHW, and NHO <ITER> =PP, i1…i4,

15 Pre-Transit Network Processing

15.1 Overview

Prior to transit network building (shown on page A-5), a series of Cube Voyager scripts is executed to generate special transit-access links that are subsequently folded into the transit network, along with highway links, transit links, and transit lines. The scripts include *Parker.s* (used to generate PNR-lot-to-rail-station links), *walkacc.s* (used to develop zonal walk access links), *Adjust_Runtime.s* (to update the RUNTIME values for local bus service to account for worsening congestion), and *Autoacc5.s* (used to generate TAZ-to-station links, a.k.a., auto access links). The automated approach for generating these links has greatly streamlined the transit network coding process. Three of these programs (*Parker.s*, *walkacc.s*, and *Autoacc5.s*) were originally developed as stand-alone Fortran programs developed by AECOM Consult. TPB staff converted these three Fortran programs to Cube Voyager scripts to facilitate the implementation of future enhancements.

The inputs used by the above programs are list in Table 39. Specific file descriptions are shown in Table 40 through Table 43. The output files are shown in Table 44.

Table 39 Inputs to pre-transit network processing

Zonal land use file	Zone.dbf	DBF
Station file	Station.dbf	DBF
Highway node file	node.dbf	DBF
Supplemental walk link file	xtrawalk.dbf	DBF
Sidewalk network links	WalkAcc_Links.dbf	DBF
TAZ area that is within walking distance from transit stops	Areawalk.txt**	Text
Factors used to determine the amount of speed degradation, due to congestion, for local bus routes	Bus_Factor_File.dbf	DBF
Station mode-station type-max access dist. Lookup	StaAcc.dbf	DBF
Jurisdiction code- jurisdiction group lookup	Jur.dbf	DBF
List of zones connected to the Pentagon Metrorail station for the purpose of creating long-distance kiss-and-ride (KNR) links, which represent "slugging" or informal, ad-hoc carpooling	Pen.dbf	DBF
TAZ XY co-ordinates	TAZ_xys.dbf	DBF
SOV AM/Off-peak highway time skims file	AM_SOV_MOD.SKM, MD_SOV_MOD.SKM	Binary

** Areawalk.txt contains information needed to calculate zonal percent-walk-to-transit (PWT) values.

Input File Descriptions and Formats

Table 40 Variables in the transit station file (Station.dbf)

Name	Type	Field Description
SEQNO	N	Sequence Number
MM	C	Mode Code (M=Metrorail, C=Commuter rail, B=Bus, L=Light rail, N= BRT/streetcar)
NCT	**N**	**Access distance code (1, 2, 3, 0, 9, 8)** (See Table 41)
STAPARK	C	Does the station have a park-and-ride lot? (Y=yes; blank=no)
STAUSE	C	Is the station in use for the given year? (Y=yes; blank=no)
SNAME	C	Station Name/PNR lot name
STAC	N	Station centroid number (5001-7999), also known as a park-and-ride (PNR) lot centroid or a dummy PNR centroid"
STAZ	N	For the purposes of path building, the TAZ (1-3722) that represents the location of the station PNR lot. Usually the closest TAZ to the PNR lot.
STAT	N	Station Node (8000-8999, 9000-9999, 10000-10999)
STAP	N	Station park-and-ride (PNR) node number (11000-13999)
STAN1	N	Station bus node #1 (used to generate a station-to-bus-node connector)
STAN2	N	Station bus node #2 (used to generate a station-to-bus-node connector)
STAN3	N	Station bus node #3 (used to generate a station-to-bus-node connector)
STAN4	N	Station bus node #4 (used to generate a station-to-bus-node connector)
STAPCAP	**N**	**Parking capacity (number of spaces at the PNR lot)**
STAX	N	X coordinate of station/PNR lot (MD State Plane, NAD83, feet)
STAY	N	Y coordinate of station/PNR lot (MD State Plane, NAD83, feet)
STAPKCOST	**N**	**Peak period parking cost (daily cost, cents)**
STAOPCOST	**N**	**Off-peak parking cost (hourly cost, cents)**
STAPKSHAD	**N**	**Peak-period shadow price (currently not used)**
STAOPSHAD	**N**	**Off-peak-period shadow price (currently not used)**
FIRSTYR	N	Year of Station/PNR lot Opening (unused by scripts, but used as metadata)
STA_CEND	N	Project ID (Metadata)
	C	Scenario name, or left blank (Metadata)
	C	Comments, if any, regarding the file, since file cannot accept comment lines preceding the data lines

Notes: New variables are shown with bold font. The SEQNO variable does not correspond to the station node (STAT), and, unlike the STAT, cannot be assumed to stay the same over time.

Source: Jain, M. (2010, October). MWCOG network coding guide for Nested Logit Model (First draft: September 20, 2007; Updated February 2008 and October 2010). Memorandum.

The station file (station.dbf) is created by the create-station-file function of COGTools using transit nodes and transfer links. The input files for this procedure[97] are pre-existing transit support files listed at the top of p. A-5. STAN1, STAN2, STAN3, STAN4 represent transit stop nodes, which are used to generate station-to-transit-node connectors. A node could be a bus bay, bus stop, a light rail stop, a light

[97] Meseret Seifu to Files, "Create a Station File," Memorandum, July 20, 2011.

rail station, or a commuter rail station, etc. The information of these nodes is used in four scripts: *Autoacc5.s, Parker.s, Set_Factors.s*, and *Refine_Station_File.s*. One transit station could have STAN1, or STAN1 and STAN2, or STAN1, STAN2, and STAN3. A station with four STANs could have other station connections beyond these four that exist in the network geodatabase, but these are not shown explicitly in the station file. It is worth noting that only the STAN1 information for the bus parking lots ("B") actually get used in the model. All the information contained in "STAN2"-"STAN4" and contained in "STAN1" for non-bus modes in the station file (station.dbf) are not used in the model.

The "access distance code," known as NCT in the autoacc5.s script, is a newly added variable in the station file that controls the number, extent, and directionality of PNR/KNR access links generated for each parking lot (in the case of PNR) or each station (in the case of KNR). Table 41 describes the meaning of each of the six access distance codes.

Table 41 Interpretation of transit access distance codes (NCT): Metrorail, light rail, and bus PNR access distance codes and their meaning for the

Acc Dist Code	Interpretation
1	End-of-the-line station (e.g., Shady Grove Metro)
2	Intermediate station (e.g., Rockville Metro)
3	PNR close to a CBD (e.g., Rhode Island Ave. Metro, Fort Totten)
0	Only KNR-access links generated (e.g., Braddock Road, National Airport, Clarendon)
9	Metrorail sta. in use, but no PNR/KNR access (e.g., Dupont Circle, Farragut North, Metro Ctr.)
8	Pentagon Metro Sta., allows for very long KNR links, to represent "slugging" (informal carpool)

The access distance code, along with the transit mode, determines the maximum link distance for the drive-access-to-transit links generated by autoacc5.s for the TPB nested-logit mode choice model. The maximum link distances for PNR are shown in Table 83. Although not shown in the table, the maximum allowed link distance for KNR links is 3 miles. It is also important to note that the KNR links are generated to Metrorail stations, light rail stations, streetcar stops, and bus stops with parking lots, but not commuter rail stations.

In the autoacc5.s script, the maximum station access distances correspond to the "AccDist" variable in the StaAcc.dbf file and are defined in the autoacc5.s script in an array called "STAD". The following logic is used in autoacc5.s:

1. If a station (k) is not used, then STAD[k]=0.
2. If a station does not have a parking lot (STAPARK[k] != 'Y'), only KNR access links can be generated and STAD[k]=300 (i.e., 3.00 miles).
    a. For stations that do not have a parking lot, the default value of STAD[k] is 300 (i.e., 3.00 miles).

b. NCT=8 is a special NCT code reserved for the Pentagon Metrorail Station. As stated in Table 41, the Pentagon Metrorail Station allows for very long KNR links to represent "slugging." Since the Pentagon station does not have a PNR parking lot for commuter use, its STAD[k]=300. However, the autoacc5.s script generates the KNR access links to this particular station in a separate process, in which there is no limit on the distance of those links (in other words, STAD[k] is not used for this particular station).
c. NCT=9 is a special NCT code reserved for stations that do not have a parking lot and prohibit KNR drop-offs, such as Dupont Circle, Farragut North, and Metro Center. As a result, although STAD[k] for those stations has the default value of 300, the model will not generate any PNR or KNR access link to them (also indicated in Table 41).

3. The model writes out the STAD values for all the stations listed in the station file in a text file called "debug1.asc" for debugging.

Due to the program logic, a model user does not need to worry about the "AccDist" values for stations with NCT=8 or 9 because the model automatically takes care of them: For NCT=8, KNR access links will be generated with no distance limitation and no PNR access links will be generated; for NCT=9, no PNR or KNR links will be generated at all.

Table 42 HBW zonal parking costs/terminal time file (HBWV2a1.dbf)

File Name	Variable Name	Description
HBWV2a1.dbf	TAZ	TAZ (1-3,722)
	PCTWKSH	Percent short walk to transit
	PCTWKLG	Percent long walk to transit
	AREA	in sq. mile

For more information about short walk and long walk to transit, see section 21.4 ("Market segmentation") on page 192.

Table 43 Walk Access Links (WalkAcc_Lnks.dbf)

File Name	Variable Name	Description
WalkAcc_Links.dbf	A	A-Node
	B	B_Node
	DISTANCE	Link distance (in 1/100ths of miles)
	FTYPE	Link Facility Type Code (0-6)
		0/centroids, 1/Freeways, 2/Major Art., 3/Minor Art, 4/ Collector, 5/ Expressway, 6/ Ramp
	TAZ	TAZ (1-3,722)

Table 44 Outputs of pre-transit network processing

Transit support files in inputs subdirectory	met_link.tb, com_link.tb, lrt_link.tb, new_link.tb, met_node.tb, com_node.tb, lrt_node.tb, new_node.tb, bus_pnrn.tb, met_pnrn.tb, com_pnrn.tb, lrt_pnrn.tb, new_pnrn.tb,	

	met_bus.tb, com_bus.tb, lrt_bus.tb, new_bus.tb	Text
Transit network walk link files	sidewalk.asc walkacc.asc support.asc	Text
Percent of TAZ within short/long walk from transit	HBWV2A1.dbf	DBF
	NLWalkPCT.txt	Text
PNR lot to station transfer links	metampnr.tb, comampnr.tb, busampnr.tb, newampnr.tb, lrtampnr.tb, metoppnr.tb, comoppnr.tb, busoppnr.tb, newoppnr.tb, lrtoppnr.tb	Text
Transit access link files	mrpram.asc, mrprop.asc, mrkram.asc, mrkrop.asc, cram.asc, crop.asc, buspram.asc, busprop.asc, buskram.asc, buskrop.asc, lrtam.asc, lrtop.asc, newam.asc, newop.asc, lrtkram.asc, lrtkrop.asc, newkram.asc, newkrop.asc, autoall.asc	Text

15.2 Application Details

It is important to understand the various elements of the Version 2.4 transit network system. The elements are listed in Table 45. The network consists of highway links, transit stops, PNR lots, rail stations, rail links, and transit lines (modes 1-10). The transit network also contains access links relating to zonal access connections including zone-to-transit-stop walking links (mode 16), and zone-to-KNR/PNR auto links (mode 11). The network also includes other walk-related connections such as sidewalk links used in transferring (mode 13), rail station-to-bus stop connections (mode 12), and PNR lot-to-station connections (mode 15). The above scripts are used to develop all of these types of "support" links, with the exception of station-to-bus transfer links which are addressed as part of pre-network development.

The Mode Choice Model chapter of this report addresses the how access links are developed by the *walkacc.s, Parker.s*, and the *Autoacc5.s* programs.

Table 45 Overview of Version 2.3 Transit Network Elements

Transit network element	Description	Numbering	Modes/Nodes
Bus stop nodes	Highway nodes that reflect bus stops	20000-60000 120000-160000	Boarding/alighting locations
PNR lots	Point location representing PNR lot	11001-13999	11001-11999: Metrorail 12001-12999: Commuter rail 13001-13999: LRT/BRT/Streetcar
Station	Point location representing rail stop	8001-10999	8001-8999: Metrorail 9001-9999: Metrorail 10001-10999: Metrorail
Rail links	Fixed guideway segments connecting stations (non-highway transit links)	-	Mode 3 = Metrorail Mode 4 = Commuter rail

			Mode 5 = Light rail
			Mode 10 = BRT, Streetcar
Walk access links	TAZ-transit stop bike/pedestrian connections	-	Mode 16 = TAZ-to-transit stop node Mode 13 = sidewalk links
Auto access links	TAZ-PNR lot driving connections	-	Mode 11
PNR lot-to-station links	Walk transfer links from PNR lot to station		Mode = 15
Station-to-bus transfer link	Walk transfer links between stations & bus stops		Mode = 12
Transit line files	Bus, rail transit line data (line characteristics, node sequence of route)		Mode = 1-10

16 Transit Skim File Development

16.1 Overview

The transit skimming file process involves the development of 22 sets of level-of-service (LOS) skims corresponding to two time-of-day period (peak and off-peak)[98] by four sub-mode groups (Bus only, Metrorail only, Bus-Metrorail combination, and commuter rail) by three access mode (walk, PNR, KNR).[99] As shown on page A-5 of Appendix A, the transit network building and skimming scripts are named *Transit_Skims_CR.s, Transit_Skims_MR.s, Transit_Skims_AB.s, Transit_Skims_BM.s*. These four scripts are launched using two batch files:

- *Transit_Skim_All_Modes_Parallel.bat*
- *Transit_Skim_LineHaul_Parallel.bat*

Additionally, transit accessibility summaries are needed to support the vehicle ownership model. The *Transit_Accessibility.s* script is used for this purpose. The inputs out outputs to transit skimming are shown in Table 46 and Table 47, respectively.

Table 46 Inputs to transit skim file development

Local bus future time degradation factors	Bus_Factor_File.dbf	Binary
Transit line files	MODE1, MODE2AM, … MODE10AM.TB MODE1, MODE2OP, … MODE10OP.TB	Text
Transit path tracing selection criteria	*PATHTRACE.S*	Script block
Binary highway network	ZONEHWY.NET	Binary
Transit support files in inputs subdirectory	met_link.tb, com_link.tb, lrt_link.tb, new_link.tb, met_node.tb, com_node.tb, lrt_node.tb, new_node.tb, bus_pnrn.tb, met_pnrn.tb, com_pnrn.tb, lrt_pnrn.tb, new_pnrn.tb, met_bus.tb, com_bus.tb, lrt_bus.tb, new_bus.tb	Text
Transit network walk link files	sidewalk.asc walkacc.asc support.asc	Text
PNR lot to station transfer links	metampnr.tb, comampnr.tb, busampnr.tb, newampnr.tb, lrtampnr.tb, metoppnr.tb, comoppnr.tb, busoppnr.tb, newoppnr.tb, lrtoppnr.tb	Text
Transit access link files	mrpram.asc, mrprop.asc, mrkram.asc, mrkrop.asc, cram.asc, crop.asc, buspram.asc, busprop.asc, buskram.asc, buskrop.asc, lrtam.asc, lrtop.asc, newam.asc, newop.asc, lrtkram.asc, lrtkrop.asc, newkram.asc, newkrop.asc, autoall.asc	Text

[98] For the calculation of average headways and run times, the peak period is represented by the AM peak hour and the off-peak period is represented by the five-hour midday period.

[99] This should equal 24 (2x3x4), but KNR access to commuter rail mode is not considered by the mode choice model, and so the total number of required path sets equals 22.

Table 47 Outputs of transit skim file development

Commuter rail skim files	SUPL_<Prd>_<AA>_CR.ASC SUPN_<Prd>_<AA>_CR.DBF TRNL_<Prd>_<AA>_CR.DBF <ITER>_*<Prd>_<AA>*_CR.STA <ITER>_*<Prd>_<AA>*_CR.SKM <ITER>_*<Prd>_<AA>*_CR.TTT*	Text DBF DBF Binary Binary Binary
Metrorail support skim files	SUPL_<Prd>_<AA>_MR.ASC SUPN_<Prd>_<AA>_MR.DBF TRNL_<Prd>_<AA>_MR.DBF <ITER>_*<Prd>_<AA>*_MR.STA <ITER>_*<Prd>_<AA>*_MR.SKM <ITER>_*<Prd>_<AA>*_MR.TTT*	Text DBF DBF Binary Binary Binary
All Bus support skim files	SUPL_<Prd>_<AA>_AB.ASC SUPN_<Prd>_<AA>_AB.DBF TRNL_<Prd>_<AA>_AB.DBF <ITER>_*<Prd>_<AA>*_AB.STA <ITER>_*<Prd>_<AA>*_AB.SKM <ITER>_*<Prd>_<AA>*_AB.TTT*	Text DBF DBF Binary Binary Binary
Bus/Metrorail support skim files	SUPL_<Prd>_<AA>_BM.ASC SUPN_<Prd>_<AA>_BM.DBF TRNL_<Prd>_<AA>_BM.DBF <ITER>_*<Prd>_<AA>*_BM.STA <ITER>_*<Prd>_<AA>*_BM.SKM <ITER>_*<Prd>_<AA>*_BM.TTT*	Text DBF DBF Binary Binary Binary
Job accessibility by transit	<ITER>_<Prd>_<AA>_[BM|MR]_JobAcc.dbf	DBF

Note: <Prd>= AM and OP <AA>= WK, DR, KR <ITER> =PP, i1…i4

* TTT files: total transit time skims, which excludes wait time.

16.2 Application Details

16.2.1 Skim file names and list of transit skim tables in the skim files

The skim files developed by the transit skimming process in the Ver. 2.4 travel demand model are shown in Table 48. Each filename is preceded by the speed feedback iteration: pp (pump prime), i1, i2, i3, i4. Each skim file contains 16 tables of information, as shown in Table 49.

Table 48 Skim files developed by the transit skimming process

Submode	Time Period	
	AM Peak Skim Files	**Off-Peak Skim Files**
Commuter Rail	<iter>_AM_WK_CR.SKM <iter>_AM_DR_CR.SKM (no CR KNR file is created)	<iter>_OP_WK_CR.SKM <iter>_OP_DR_CR.SKM (no CR KNR file is created)
Metrorail Only	<iter>_AM_WK_MR.SKM <iter>_AM_DR_MR.SKM <iter>_AM_KR_MR.SKM	<iter>_OP_WK_MR.SKM <iter>_OP_DR_MR.SKM <iter>_OP_KR_MR.SKM
Bus Only	<iter>_AM_WK_AB.SKM <iter>_AM_DR_AB.SKM <iter>_AM_KR_AB.SKM	<iter>_OP_WK_AB.SKM <iter>_OP_DR_AB.SKM <iter>_OP_KR_AB.SKM
Metrorail and Bus	<iter>_AM_WK_BM.SKM <iter>_AM_DR_BM.SKM <iter>_AM_KR_BM.SKM	<iter>_OP_WK_BM.SKM <iter>_OP_DR_BM.SKM <iter>_OP_KR_BM.SKM

Table 49 Skim tables contained in each transit skim file

Table No.	Table Description
1	In-Vehicle Time-Local Bus (0.01 min)
2	In-Vehicle Time-Express Bus (0.01 min)
3	In-Vehicle Time-Metrorail (0.01 min)
4	In-Vehicle Time-commuter rail (0.01 min)
5	In-Vehicle Time-new rail mode (0.01 min)
6	In-Vehicle Time-new bus mode (0.01 min)
7	Initial wait time (0.01 min)
8	Transfer wait time (0.01 min)
9	Walk access time (0.01 min)
10	Other walk time (0.01 min)
11	Added Transfer time (0.01 min)
12	No. of transfers (0 to N)
13	Drive-access time (0.01 min)
14	Drive-access distance (0.01 mile)
15	PNR-to-Station time (0.01 min)
16	PNR Cost (2007 cents)

Ref: Transit_Skim_Specs_2.xlsx

16.2.2 Description of local bus, future time degradation factors

Transit service is represented in the transit network using a series of transit routes, which are stored in transit "line" or "mode" files. There is one set of transit routes for the peak period (represented by AM peak period service) and one set of transit routes for the off-peak period (represented by the midday period). For each of the two time-of-day periods, each transit route has the following:

- Name (such as "WM04AI," or WMATA bus 4A, inbound),
- Flag indicating whether the route is one-way or two-way,
- Mode code (e.g., 1 = local bus),
- Average headway (FREQ[1]= 30, which means the bus comes every 30 minutes), and
- Average run time (i.e., the number of minutes from the start of the route to the end of the route, e.g., RUNTIME= 42 min.).

When developing the transit networks for a base year (i.e., a year close to the current year, such as 2016), the average headways and average run times come directly from the published schedules from the transit providers. These schedules can be in paper format or electronic format, such as GTFS. For a future-year transit network (such as 2040), however, the average headway and run time are unknown, so we use information from the latest published schedule (e.g., 2016). However, simply using the published schedules would likely result in bus speeds that are too fast, since they don't account for the added roadway congestion that is likely to occur in the future, i.e., it is likely that worsening road congestion over time would result in slower bus speeds. In particular, **local** bus service, which travels on local roads, might be slowed more than express bus service, which makes use of freeways and expressways for all or part of its routes. Thus, it would be good to have a relationship that relates future-year, congested road/link speeds to bus speeds. Before 2004, the COG/TPB travel model had no such relationship. In 2004, AECOM recommended that COG develop a relationship between link speeds and bus speeds, but cautioned against developing overly sensitive relationships.[100] For example, if one develops a direct relationship between the link speed and the bus travel times over that link, and if one road link becomes hyper congested, due, say, to excessive traffic or a network coding error, then the bus speed will drop to near zero. Consequently, COG/TPB staff developed a proposed solution that followed what was proposed in the Bruggeman/Woodford memo. The solution was what is known as the local bus, future time degradation factors, which are used to represent the fact that, as the highway network becomes more congested, there will be a slight degradation in **local** bus speeds over time. This technique was first used in the Version 2.1/D Travel Model,[101] and has been retained in the Version 2.2, 2.3, and 2.4 Travel Models. In 2015, the local bus speed degradation factors were re-estimated,[102] and those re-estimated factors were part of the Ver. 2.3.57a travel demand model.

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[100] Jeff Bruggeman and Bill Woodford to Ronald Milone, "Comments on MWCOG Modeling Procedures," Memorandum, June 30, 2004.

[101] Ronald Milone to Files, "Methodology for Linking Future Bus Speeds to Highway Congestion in the Version 2.1/D Model," Memorandum, July 14, 2004.

[102] Meseret Seifu and Ronald Milone, "Update of Local Bus Speed Degradation Model," Memorandum, March 19, 2015.

As of Ver. 2.3.66 Model, the process was significantly updated, as was described in section 1.3.4 of the Ver. 2.3.66 Model user's guide[103] and a technical memo.[104] The major changes are as follows:

1. The text file Lbus_TimFTRS.asc has been replaced with the dBase file Bus_Factor_File.dbf.
2. A new script has been added (*Adjust_Runtime.s*). This script reads in the transit line files associated with the local bus routes (mode codes 1, 6, and 8), adjusts the RUNTIME values by the factors contained in Bus_Factor_File.dbf, and writes out revised mode 1, 6, and 8 files with the revised RUNTIME values. The script *Adjust_Runtime.s* is called from *Transit_Skim_All_Modes_Parallel.bat*.

An example of a local bus route **before** the adjustment of its RUNTIME variable is shown in Figure 62. An example of a local bus route **after** the adjustment of its RUNTIME variable is shown in Figure 63.

```
LINE NAME="ART43N",
OWNER="ART Bus;Crystal City Bay A, S Bell St, SB @ S Hayes St S;Crystal City Bay A, S Bell St, SB @ S Hayes St S;2014;base",
ONEWAY= Y,MODE= 01,FREQ[1]= 20,RUNTIME= 40,
         N=  30247  30666  30279 -30246 -30280 -30243 -30244 -30207  30206,
             30204 -30286 -30316 -30315 -30211  30115  30120 -30115  30116,
             30520  30117 -30122  30123
```

Figure 62 A local bus route before its RUNTIME value is updated

```
LINE NAME="ART43N",
OWNER="ART Bus;Crystal City Bay A, S Bell St, SB @ S Hayes St S;Crystal City Bay A, S Bell St, SB @ S Hayes St S;2014;base",
ONEWAY= Y,MODE= 01,FREQ[1]= 20,RUNTIME=43.9,                          ; Base RUNTIME=      40.00 Time Factor: 1.098 Year: 2040
         N=  30247  30666  30279 -30246 -30280 -30243 -30244 -30207  30206,
             30204 -30286 -30316 -30315 -30211  30115  30120 -30115  30116,
             30520  30117 -30122  30123
```

Figure 63 A local bus route after its RUNTIME value is updated to reflect road congestion predicted to occur in future years

Transit accessibility outputs are listed on Table 50.

[103] Ronald Milone, Mark Moran, and Meseret Seifu, "User's Guide for the COG/TPB Travel Demand Forecasting Model, Version 2.3.66: Volume 1 of 2: Main Report and Appendix A (Flowcharts)" (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, February 13, 2017), 7, https://www.mwcog.org/transportation/data-and-tools/modeling/model-documentation/.
[104] Ronald Milone to Feng Xie et al., "Update to the V2.3.57a Model's Treatment of Bus Speed Factors," Memorandum, March 17, 2016.

Table 50 Job accessibility by transit file format description (<ITER>_<Prd>_<AA>_[BM|MR]_JobAcc.dbf)

Variable Name	Description
TAZ	TAZ (1-3722)
EMP35	Number of jobs accessible, from a given zone, within 35 minutes' travel time
EMP40	Number of jobs accessible, from a given zone, within 40 minutes' travel time
EMP45**	Number of jobs accessible, from a given zone, within 45 minutes' travel time
EMP50	Number of jobs accessible, from a given zone, within 50 minutes' travel time
EMPTOT	Total number of jobs accessible, from a given zone

** Only EMP45 is used from this file.

17 Transit Fare Development

17.1 Overview

Zone-to-zone transit fares are developed for the 22 paths sets described in the transit skimming section (section 16). As shown on page A-12 of Appendix A, the fares are developed using the scripts named Prefarv23.s, Metrorail_Skims.S, Mfare1.s, and Mfare2.s. The inputs to the fare process are shown in Table 51 and the outputs are shown in Table 52. After the fare process is executed, four scripts are used to combine transit skims and fares into consolidated submode files: *Assemble_Skims_CR.s, Assemble_Skims_MR.s, Assemble_Skims_AB.s*, and *Assemble_Skims_BM.s*.

Table 51 Inputs to transit fare development

Zonal transit walk percent	NLwalkPct.txt	Text
Zonal TAZ-to-bus fare zone equivalence	Inputs\TAZFRZN.ASC	Text
Zonal Area Type file	AreaType_File.dbf	DBF
Zonal land use file	zone.dbf	DBF
Zonal TAZ-Mode choice district equivalency	areadef3722.prn	Text
Metro Station Link File	METLNKM1.TB**	Text
Metro Station XY File	METNODM1.TB**	Text
Metrorail turn penalty file	Inputs\trnpen.dat	Text
MFARE1 A1 (Coordinate) File	MFARE1.A1	Text
Metrorail station discount file	Inputs\MFARE1_STA_DISC.ASC	Text
WMATA tariff parameters	Inputs\tarriff.txt	Text
Transit fare deflation factor file	Trn_deflator.txt	Text
	<ITER>_*<Prd>*_*<AA>*_CR.STA <ITER>_*<Prd>*_*<AA>*_CR.SKM <ITER>_*<Prd>*_*<AA>*_MR.STA <ITER>_*<Prd>*_*<AA>*_MR.SKM <ITER>_*<Prd>*_*<AA>*_AB.STA <ITER>_*<Prd>*_*<AA>*_AB.SKM <ITER>_*<Prd>*_*<AA>*_BM.STA <ITER>_*<Prd>*_*<AA>*_BM.SKM	Binary
	<ITER>_*<Prd>*_*<AA>*_CR.FAR <ITER>_*<Prd>*_*<AA>*_MR.FAR <ITER>_*<Prd>*_*<AA>*_AB.FAR <ITER>_*<Prd>*_*<AA>*_BM.FAR	
Peak / Off-Peak MFARE2 Bus Fare Matrix	Inputs\busfaram.asc Inputs\busfarop.asc	Text
Peak /Off-Peak MFARE2 A2 File	FARE_A2.ASC	Text

Notes: <Prd>= AM and OP <AA>= WK, DR, KR <ITER> =PP, i1…i4

** These two files are originally in the Inputs folder, and then are copied to the Output folder in *Transit_Skim_All_Modes_Parallel.bat*

Table 52 Outputs of transit fare development

Summary of walkshed area and walkshed percentage	Prepare_MC_Zfile.txt	Text
Output Zone file for the NL mode choice model	ZONEV2.A2F	Text
A "complete" A2 file for the MFARE2.S	Fare_a2.asc	
Metrorail distance skims	RLDIST.SKM	Binary
Metrorail station to station fares	AM_Metrorail_Fares.TXT OP_Metrorail_Fares.TXT	Text
Zonal fares	<ITER>_*<Prd>*_*<AA>*_CR.FAR <ITER>_*<Prd>*_*<AA>*_CR.FR5 <ITER>_*<Prd>*_*<AA>*_CR.TXT <ITER>_*<Prd>*_*<AA>*_MR.FAR <ITER>_*<Prd>*_*<AA>*_MR.FR5 <ITER>_*<Prd>*_*<AA>*_MR.TXT <ITER>_*<Prd>*_*<AA>*_AB.FAR <ITER>_*<Prd>*_*<AA>*_AB.FR5 <ITER>_*<Prd>*_*<AA>*_AB.TXT <ITER>_*<Prd>*_*<AA>*_BM.FAR <ITER>_*<Prd>*_*<AA>*_BM.FR5 <ITER>_*<Prd>*_*<AA>*_BM.TXT	
Combined time and fare commuter rail skims	<ITER>_TRNAM_CR.SKM <ITER>_TRNOP_CR.SKM	Binary
Combined time and fare Metrorail skims	<ITER>_TRNAM_MR.SKM <ITER>_TRNOP_MR.SKM	Binary
Combined time and fare all bus skims	<ITER>_TRNAM_AB.SKM <ITER>_TRNOP_AB.SKM	Binary
Combined time and fare bus/Metrorail skims	<ITER>_TRNAM_BM.SKM <ITER>_TRNOP_BM.SKM	Binary

Table 53 TAZ/Bus Fare Zone Equivalency File Format Description (TAZFRZN.ASC)

Columns	Format	Field Description
Zonal data (All lines in the file)		
1-8	I4	TAZ Number (1-3,675)
9-16	I4	1st Bus fare zone 1 (currently numbered 1 to 21)
17-24	I4	2nd Bus fare zone 2 (currently numbered 1 to 21)
57-64	I8	Jurisdiction code
65-72	I8	P discount
73-80	I8	A discount
Station data (first 150 lines of the file only)		
1-8	I4	Metrorail Station No. (1-150)
41-48	I4	1st Bus Fare Zone associated with Metro Station (currently numbered 1 to 21)
49-56	I4	2nd Bus Fare Zone associated with Metro Station (currently numbered 1 to 21)

As shown in Table 53 above, the TAZ/Bus Fare Zone Equivalency File (TAZFRZN.ASC) essentially contains two look-up tables: the zonal data table includes all lines in the file, while the station data table includes only the first 150 lines of the file. Both look-up tables use Columns 1-8 as the index column, which represents TAZ Number (1-3675) for the zonal data and represents Station Number (1-150) for the station data. Station information contained in Columns 41-48 and 49-56 are populated in only the first 150 lines of the file (zeros are used as placeholders for Lines 151-3675).

17.2 Application Details

The purpose of transit fare process is to develop a zonal matrix containing total transit costs as expressed in 2007 cents. The core components of the transit fare process are two scripts: *MFARE1.S* which develops Metrorail station-to-station fares and *MFARE2.S* which develops zone-to-zone transit fares using the *MFARE1.S* output. Twenty-two fare matrices are developed sub-mode, time period, and access type, specifically:

- Four sub-modes (Bus Only Metrorail only, Metrorail/ Bus, and Commuter Rail) by;
- Two time periods (AM, off-peak), by;
- Three access types (Walk, PNR, and KNR)

Since commuter rail access is distinguished by walk and auto access only, 22 matrices are developed (instead of 24 which is implied above).

The fare process is executed with a batch file named *Transit_Fare.bat*. The batch file calls four scripts that are used to formulate the zone-to-zone transit fares for each market:

- *PrefarV23.s*: This script reads a zonal transit walk area file (NLWalkPct.txt) which includes walk areas pertaining to Metrorail stations only. It also reads an equivalency file (TAZFRZN.ASC) that equates TAZs to bus fare zones and Metrorail station numbers to bus fare zones. The program essentially merges the Metrorail walk percent information into the zonal equivalency file. The resulting file is named fare_a2.asc. This file is called by the MFARE2.S script and is needed for the zonal transit fare calculation. This script is also used to develop the zonal parking costs that are input into the mode choice model.
- *Metrorail_skims.s*: This script reads a Metrorail link and node file, and then develops Metrorail station-to-station distance skims. The file is need for the Metrorail station-to-station fare calculation.
- *MFARE1.S*: This script calculates the Metrorail station-to-station fares for AM and off-peak periods. The script reads in a fare parameter file that is consistent with WMATA’s latest Metrorail fare policy (tariff.txt), station coordinates (MFARE1.A1), and a station discount file (MFARE1_STA_DISC.ASC). The script writes two text files containing Metrorail fares: AM_Metrorail_Fares.txt and OP_Metrorail_Fares.txt.
- *MFARE2.S*: This script calculates the total transit fare between TAZs for AM and off-peak periods. The script reads in several files:
  - The Metrorail station-to-station fares developed by MFARE1.s,
  - tarrif.txt (transit fare policy parameters contain rail-to-bus discounts)
  - TRN_Deflator.txt (the transit deflation factor)
  - Fare_a2.asc (file containing zonal walk percentages to Metrorail stations
  - BUSFAREAM/OP.ASC: AM and off-peak bus and commuter rail fares between bus fare policy zones. TPB currently uses 21 bus fare zones for the region. While most TAZs fall into a single bus policy zone, the fare calculation also accounts for the possibility that a single TAZ may be straddle 2 bus policy zones
  - Zonal skim files containing Metrorail on/off stations (*.STA) and in-vehicle travel times by transit mode (*.SKM). A set of transit skims must exist for each of the 22 transit paths.

The transit fare files are written to 22 binary file (*.FAR) each containing one table (total transit fare in 2007 cents). The batch file calls four additional scripts (*Assemble_Skims_??.S*) which are used to consolidate the 22 binary fare files into four files associated with each sub-mode. The consolidated files are subsequently used as inputs to the mode choice model.

The fare construction process between zonal pairs essentially consists of blending the Metrorail station-to-station fares with the bus-zone-to-bus-zone fares. The consideration of Metrorail fares is dependent upon individual path characteristics, i.e., whether or not the Metrorail in-vehicle time is greater than zero. If the path is not Metrorail-related, then the fare is developed from the bus fare matrix input. If the path is Metrorail-related, then the transit fare is based on the Metrorail station-to-station fare (from MFARE1), bus access and/or egress fares developed from the bus fare matrix, zonal Metrorail walk potential, and the Rail-to-Bus policy discount. The MFARE2 computation may be explained as a series of four discrete conditions.

Condition 1: Non-Metrorail related path / Single bus fare zone origin to Single bus fare destination zone

Transit fare = Bus Fare(bi1/bj1)

Condition 2: Non-Metrorail related path / Single bus fare zone origin to Double bus fare destination zone

Transit fare = [(Bus Fare(bi1/bj1) + Bus Fare(bi1/bj2)] / 2.0

Condition 3: Non-Metrorail related path / Double bus fare zone origin to Double bus fare destination zone

Transit fare = [(Bus Fare(bi1/bj1) + Bus Fare(b i1/bj2) + (Bus Fare(b i2/bj1) + Bus Fare(b i2/bj2)] / 4.0

Condition 4: Metrorail related paths

Transit Fare = (Bus Access fare * (1.0-Origin Metrorail walk Pct.)) + Metrorail fare(si/sj) +
(Bus Egress fare * (1.0-Destin. Metrorail walk Pct.))

Bus Access Fare **Single** bus fare zone to **Single** Metrorail bus fare zone =

Bus Fare(bi1/mi1) – 0.5 Rail-Bus Discount

Bus Access Fare **Single** bus fare zone to **Double** Metrorail bus fare zone =

Min[Bus Fare(bi1/mi1) , Bus Fare(bi1/mi2)] – 0.5 Rail-Bus Discount

Bus Access Fare **Double** bus fare zone to **Single** Metrorail bus fare zone =

[Bus Fare(bi1/mi1) + Bus Fare(bi2/mi1)]/2.0 – 0.5 Rail-Bus Discount

Bus Access Fare **Double** bus fare zone to **Double** Metrorail bus fare zone =

[Min[Bus Fare(bi1/mi1) , Bus Fare(bi1/mi2)] + Min[Bus Fare(bi2/mi1) , Bus Fare(bi2/mi2)]]/2.0 – 0.5 Rail-Bus Discount

Bus egress fares are calculated in the same way that bus access fares are calculated. A fare discount is applied to the fare calculation before it is written out to the binary output.

18 Demographic Submodels

Demographic submodels are applied within the *Trip_Generation.bat* batch file using the *Demo_Models.s* Cube Voyager script (see page A-6 of Appendix A). This script applies the three demographic submodels that are run prior to trip generation: household size, household income, and vehicle availability (see Chapter 3 of the calibration report for more details). The inputs to the model are zonal land use data (zone.dbf), data about area types (areaType_File.dbf), and information about the accessibility to jobs via transit. The zone.dbf file contains zonal households, population, jurisdiction code, and income index, as well as the household size and household income submodels (in the form of lookup tables). The households in each TAZ are then allocated to a household size group (1, 2, 3, or 4+) and an income group (<50K, 50K-100K, 100K-150K, or 150+K).

Next, the *Demo_Models.s* reads in the number of jobs accessible by AM Metrorail and Bus/Metrorail service within 45 minutes for each TAZ (see Table 50). This information along with household size, household income, area type, and the DC dummy variable are used to allocate households to the four vehicle ownership categories (0, 1, 2, or 3+).

Then, a file is produced, for each of the four income levels, which contains the number of households by household size and vehicle availability. These files are later used in trip generation. Lastly, the script accumulates the households by area type and prints out the following summaries located in the <ITER>_Demo_Models.txt:

- Regional Households by Size and Income Summary
- Jurisdictional Households by Size
- Jurisdictional Households by Income
- Regional Households by Vehicles Available and Size Summary
- Regional Households by Vehicles Available and Income Summary
- Jurisdictional Households by Vehicles Available
- Estimated Households by Size Level by Area Type
- Estimated Households by Income Level by Area Type
- Estimated Households by Vehicle Availability Level by Area Type

Process inputs and outputs are shown in Table 54 and Table 55.

Table 54 Inputs to the Demographic Models

Zonal Land Use File	Inputs\zone.dbf	DBF
Zonal Area Type File	AreaType_File.dbf	DBF
Transit Accessibility File (Metrorail only and Bus & Metrorail service)	<ITER>_AM_WK_MR_JOBACC.dbf <ITER>_AM_DR_MR_JOBACC.dbf <ITER>_AM_WK_BM_JOBACC.dbf <ITER>_AM_DR_BM_JOBACC.dbf	DBF

Note: <ITER> =PP, i1…i4

Table 55 Outputs of the Demographic Models

Zonal HHs of Income Level 1, Stratified by Size and Vehicle Avail.	HHI1_SV.txt	Text
Zonal HHs of Income Level 2, Stratified by Size and Vehicle Avail.	HHI2_SV.txt	Text
Zonal HHs of Income Level 3, Stratified by Size and Vehicle Avail.	HHI3_SV.txt	Text
Zonal HHs of Income Level 4, Stratified by Size and Vehicle Avail.	HHI4_SV.txt	Text
Interim Output: Zonal Households stratified by Income Level, household Size, and vehicle available (64 cross-classes)	<iter> _Demo_Models_HHbyISV.dbf	DBF

19 Trip Generation

19.1 Control/Support File(s):

Trip_Generation.s, Trip_Generation_Summary.s, Truck_Com_Trip_Generation.s

19.2 Application Details:

Trip generation is executed within the Trip_Generation.bat batch file using three Cube Voyager scripts: *Trip_Generation.s*, *Trip_Generation_Summary.s*, and *Truck_Com_Trip_Generation.s* (as shown on page A-6 of Appendix A). The inputs to the Trip_Generation.bat batch file are shown in Table 56.

Table 56 Inputs to trip generation

Zonal land use file	zone.dbf	DBF
Zonal Area Type File	AreaType_File.dbf	DBF
Zonal HHs stratified by income level, HH size, & vehs available	<iter>_Demo_Models_HHbyISV.dbf	DBF
Zonal GIS variable file	GIS_variables.dbf	DBF
Trip production rates	weighted_trip_rates.dbf	DBF
External Production and Attraction File	Ext_PsAs.dbf	DBF
Non-motorized trip production share model coefficients	NMPrates.dbf	DBF
Non-motorized trips Attraction share model coefficients	NMArates.dbf	DBF
Trip attraction rates	AttrRates.dbf	DBF
HB income shares	HBINCRAT.dbf	DBF
Consolidated zonal land use file	TripGen_LUFile.dbf	DBF
Truck and commercial vehicles trip rates	support\truck_com_trip_rates.dbf	DBF
Zonal access verification file	Skimtot<ITER>.txt	Text
	JurCore.dbf	DBF

The *Trip_Generation.s* script calculates zonal trip productions and attractions. The *Trip_Generation_Summary.s* summarizes the demographic information and the trip ends by jurisdiction. *The Truck_Com_Trip_Generation.s* produces trip ends for commercial vehicles and trucks.

The *Trip_Generation.s* script is very long (almost 1,500 lines). Figure 64 presents an outline or pseudo code of the steps in the trip generation script. The script has three phases, as indicated in the figure. There are a few points to note: **First**, the program is applied to compute zonal initial trip productions and (unscaled) zonal trip attractions. Attraction scaling is performed later, in the "*Prepare_Internal_Ends.s*" script. **Second**, the program makes sparing use of two sets of adjustments: jurisdiction level adjustments (end of phase 1) and area-type level adjustments (phases 1 and 2). The model does not make use of any "special generators" (other than the truck trip generation phase, where special generator TAZs are identified) and the model does not make use of zone-level adjustments, which are used in some models and are usually referred to production-modification factors ("P-mods") and attraction-modification factors ("A-mods").[105] These multiplicative adjustment factors included in

[105] See, for example, William W. Mann, "TRIMS - Four Steps: One Execution," *ITE Journal* 52, no. 12 (December 1982): 16, http://www.ite.org/membersonly/itejournal/pdf/JLA82A13.pdf.

the Version 2.3 and Version 2.4 series of models are used to refine the trip productions and trip attractions that are normally calculated with land activity inputs and modeled trip rates. P-mods or A-mods may be applied either on a zonal basis or on an areawide basis at the discretion of the analyst. There are two principal reasons to use these types of adjustments:

- To more accurately account for the trip generation effects of special land activity conditions that are not adequately captured by the land activity or by the modeled trip rate. These types of conditions are typically known as special generators; or
- To refine the model calibration at higher geographic levels of aggregation such as at a district or a jurisdiction level of analysis. As trip generation is applied on a zone-by-zone basis, comparisons of estimated and observed results at higher levels of aggregation usually exhibit marginal disagreements. P-mods and A-mods may serve as adjustment tools for refining trip generation at more aggregate levels of analysis. While this adjustment is normally small in magnitude, it can substantially improve the downstream (trip distribution and mode choice) model performance.

Modification factors used for the purpose of refining the model calibration typically range between 0.90 and 1.10 (i.e., +/- 10%). In contrast, adjustments made for the purpose of reflecting special generators may be much larger in magnitude, yielding a result that is in line with observed traffic generation for a specific location. Admittedly, these types of external adjustments are sometimes viewed as ways to bias the model output or a way to undermine the logic of the model. It is important to include reasoned justifications for the use of these types of adjustments.

Phase 1: Read in input data and trip rates and establish parameters

1. *Read input files into arrays. The inputs include zonal land activity, external Ps/As, zonal area types, zonal HHs stratified by Inc./Size/ VA., zonal GIS variables, trip production rates, trip attraction rates, and income attraction shares by HB purpose area type*
2. *Establish output files:*
   a. *Report file (%_iter_%_Trip_Generation.txt')*
   b. *Computed Zonal trip productions ('%_iter_%_Trip_Gen_Productions_Comp.dbf')*
   c. *Computed Zonal trip Attractions ('%_iter_%_Trip_Gen_Attractions_Comp.dbf')*
3. *Establish Area-Type trip end (motorized, non-motorized) factors by purpose and area type*
4. *Establish External trip parameters (Share of ext. NHB travel that is NHW and NHO, auto occupancies of external autos, by purpose)*
5. *Establish Jurisdictional trip end factors by purpose*

Phase 2: Compute Initial Trip Productions and Attractions

1. *Loop through each **internal** zone*
   a. *Apply trip production rates to stratified HHs by income, size, vehav. To arrive at total Ps*
   b. *Computed non-motorized production shares by purpose and area type*
   c. *Apply non-motorized shares and adjustment parameters to total Ps to arrive at final motorized & non-motorized Ps*
   d. *Summarize and write out internal computed trip Ps stratified by income*
   e. *Apply trip attraction rates to land activity*
   f. *Computed non-motorized attraction shares by purpose and area type*
   g. *Apply non-motorized shares and adjustment parameters to total As to arrive at final motorized & non-motorized As*
   h. *Disaggregate total final attractions to income strata, by purpose and area type*

   *End **internal** zone loop*

2. *Loop through each internal zone: Summarize and write out internal computed attractions by income*
3. *Loop through each **external** zone*
   a. *Read external auto driver trip Ps and As*
   b. *Convert external vehicle Ps and As to auto person trips based on car occ. parameters*
   c. *Disaggregate total external NHB auto persons among NHW and NHO based on parameters*
   d. *Write out external Ps and As*

   *End **external** zone loop*

Phase 3: Print out regional totals of computed trip productions/attractions

Figure 64 Outline/pseudo code for *trip_generation.s*

Trip_generation.s begins, in phase 1, by reading the zonal land use (Zone.dbf); the area type file (AreaType_File.dbf); external trip productions and attractions (EXT_PsAs.dbf, described in Table 57); zonal households stratified by income, size, and vehicles available (<iter>_Demo_Models_HHbyISV.dbf);

zonal walkability factors (GIS_variables.dbf); trip production rates (weighted_trip_rates.dbf); non-motorized production model coefficients (NMPrates.dbf); non-motorized attraction model coefficients (NMArates.dbf); trip attraction model coefficients (AttrRates.dbf); and income shares for home-based trips (HBINCRAT.dbf).

The zonal GIS variable file (GIS_variables.dbf) contains a number of built-environment variables that describe the walkability of an area, such as the number of 3-legged intersections per TAZ, the number of cul-de-sacs per TAZ, the number of street blocks per TAZ, and the number of Census blocks per TAZ. Although the GIS file contains a number of variables, the trip generation process uses only one: **the number of street blocks per TAZ ("BLOCKS")**.[106] Since these built-environment variables are intended to deal with issues of walkability, it is best to use a detailed street network when calculating these metrics (as opposed to simply using the highway network itself, which is quite coarse). In our case, we used NAVTEQ's NAVSTREETS Street Data[107] (for which COG pays a license fee) and the work was performed in 2010 by COG/TPB staff.[108] Note that NAVTEQ is now known as HERE. A block is defined as a 2-dimensional area (polygon) that is completely enclosed by a series of NAVTEQ street segments. Prior to forming blocks, the following segments were removed from the NAVTEQ street network:

- Street segments with no name (ST_NAME=blank), since these are not actually street segments;
- "Major highways" (NAVTEQ functional class [FUNC_CLASS] equal to 1 or 2).[109]
- Ramps (RAMP = Y)

Figure 65 shows an example of the seven blocks that are contained within TAZ 283 (Union Station), as defined by NAVTEQ street segments (omitting major highways and ramps, as discussed above).

[106] It has been found that areas with a higher density of street blocks are more walkable.
[107] NAVTEQ, "NAVTEQ's NAVSTREETS Street Data, Reference Manual v3.2," Proprietary and Confidential (Chicago, Illinois: NAVTEQ, April 1, 2009).
[108] Mary Martchouk to Mark S. Moran, "Developing GIS Walkability Measures," Memorandum, June 2, 2010, 6–7.
[109] NAVTEQ, "NAVTEQ's NAVSTREETS Street Data, Reference Manual v3.2", p. 4-5.

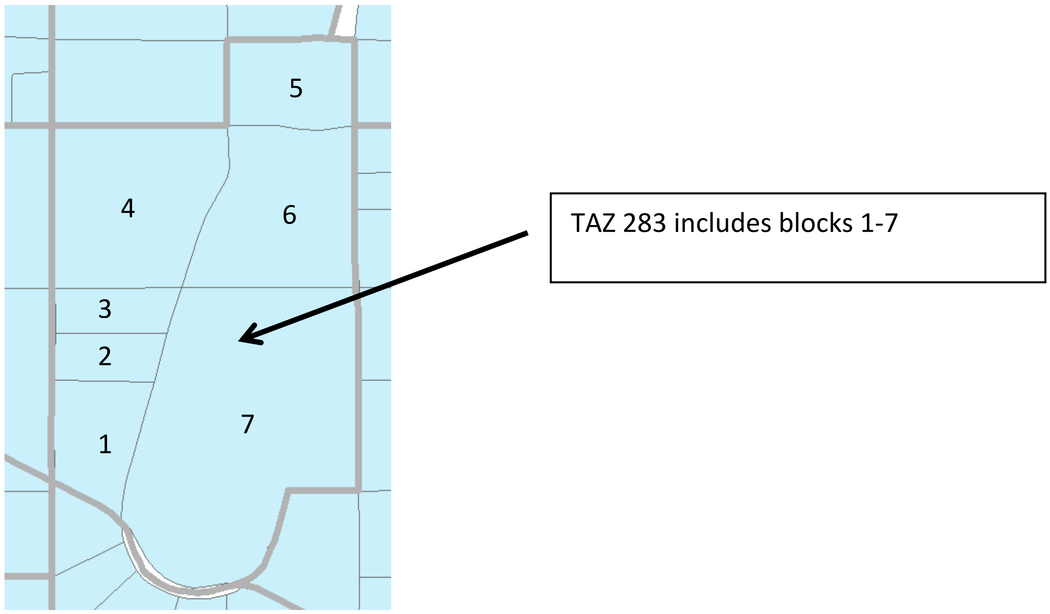

Figure 65 Example of seven NAVTEQ street blocks within TAZ 283 (Union Station)

In the trip generation script (*Trip_Generation.s*), the number of blocks per TAZ is then converted to a density measure, specifically the floating 0.5-mile block density for each TAZ (BLOCKS05, lines 180-215 of Trip_Generation.s). In the travel model, it is assumed that the block density has an effect on non-motorized trip productions and attractions **only for area types 1 and 2** (See, for example, Tables 27-29 of the calibration report for non-motorized productions and Tables 30-32 for non-motorized attractions, where the floating 0.5-mile block density is called BLKDEN05).[110]

It is assumed that the model user will rarely change the value of BLOCKS (or its derivative, BLKDEN05) when running the model (i.e., the modeler will freeze the base-year levels of block density). This is analogous to the way that household income distributions are generally frozen in the model. The exception to this rule is if the modeler believes that the street network in an area will become denser or sparser, then the modeler can make appropriate manual adjustments to the zonal BLOCK variable.

The trip generation process also reads external trip ends from a file (Ext_PsAs.dbf) that is developed exogenously. The data items are shown in Table 57. The *Trip_Generation.s* script writes out an intermediate dBase file containing land activity, one-mile "floating" land use density, one-half mile "floating" block density, and jurisdictional and area type codes. The file is a consolidation of input data from various zone files and derived variables.[111] The specific data elements are shown on Table 58. Note that, in the file Ext_PsAs.dbf (Table 57), the last two variables are medium truck external-internal (X-I) trip ends (MTK_XI) and heavy truck external-internal (X-I) trip ends (HTK_XI), but there are no

[110] Milone et al., "Calibration Report for the TPB Travel Forecasting Model, Version 2.3," 4–17 to 4–20.
[111] Floating densities are calculated using the centroids of the TAZs and street blocks, with a point buffer around the centroid with the given radius (0.5 mile or 1.0 mile).

corresponding variables for the internal-external movements (e.g., MTK_IX and HTK_IX). This is because it is assumed that the two movements (XI and IX) are the same.

Table 57 External Production and Attraction File (Ext_PsAs.dbf)

Variable	Description
TAZ	External station no. (3676-3722)
FACILITY	Facility route no./name
AAWT_CTL	Average annual weekday traffic count (observed or forecasted)
CNTFTR	(unused)
AUTO_XI	Auto driver external-internal (X-I) trip ends
AUTO_IX	Auto driver internal-external (I-X) trip ends
AUTO_XX	Auto driver through (X-X) trip ends
CV_XX	Commercial vehicle through (X-X) trip ends
HBW_XI	HBW external-internal (X-I) trip ends
HBS_XI	HBS external-internal (X-I) trip ends
HBO_XI	HBO external-internal (X-I) trip ends
NHB_XI	NHB external-internal (X-I) trip ends
CV_XI	Commercial vehicle external-internal (X-I) trip ends
HBW_IX	HBW internal-external (I-X) trip ends
HBS_IX	HBS internal-external (I-X) trip ends
HBO_IX	HBO internal-external (I-X) trip ends
NHB_IX	NHB internal-external (I-X) trip ends
CV_IX	Commercial vehicle internal-external (I-X) trip ends
TRCK_XX	Truck through (X-X) tip ends (medium and heavy truck)
TRCK_XI	Truck external-internal (X-I) trip ends (medium and heavy truck)
TRCK_IX	Truck internal-external (I-X) trip ends (medium and heavy truck)
MTK_XI	Medium truck external-internal (X-I) trip ends
HTK_XI	Heavy truck external-internal (X-I) trip ends

Source: Milone, R. (2011, July 1). Version 2.3 Exogenous Trip Files. Memorandum.

The one-mile floating density is then calculated for population and employment and a half-mile floating density is calculated for street blocks. These are saved in an intermediate file named TripGen_LUFile.dbf (Table 58). Then, the script calculates zonal trip productions based on demographic data and applies the non-motorized production model to the results. Motorized internal trips productions are then obtained by subtracting the estimated non-motorized trips. The output production file data items are shown on Table 59.

Table 58 Consolidated Zonal Land Use File

File Name	Variable Name	Description
TripGen_LUFile.dbf	TAZ	TAZ Number (1-3,722)
	HH	Number of house holds
	TOTPOP	Total Population
	TOTEMP	Total employment
	RETEMP	Retail employment
	NRETEMP	Non-retail employment
	OFFEMP	Office employment
	OTHEMP	Other employment
	INDEMP	Industrial employment
	HHPOP	House hold population
	GQPOP	Group quarter population
	LANDAREA	Land area (sq. mi.)
	POP_10	Number of population within one "floating" mile
	EMP_10	Number of employment within one "floating" mile
	AREA_10	Zonal Area within one "floating" mile
	POPDEN10	Population density within one "floating" mile
	EMPDEN10	Employment density within one "floating" mile
	ADISTTOX	Distance to the nearest external station
	BLOCKS05	Blocks within 0.5 mile "floating" blocks
	AREA05	Area within 0.5 mile "floating" blocks
	BLOCKDEN05	Block density within 0.5 mile "floating" blocks
	JURCODE	Jurisdiction code (0-23)
	ATYPE	Area Type (1-6)

Table 59 Computed zonal trip productions file (<iter>_Trip_Gen_Productions_Comp.dbf)

Variable Name	Description
TAZ	TAZ Number (1-3,722)
HBW_MTR_PS	Home-Based-Work motorized person trip productions
HBW_NMT_PS	Home-Based-Work non-motorized person trip productions
HBW_ALL_PS	Home-Based-Work motorized and non-motorized person trip productions
HBWMTRP_I1	Home-Based-Work Motorized person trip productions, Income level 1
HBWMTRP_I2	Home-Based-Work Motorized person trip productions, Income level 2
HBWMTRP_I3	Home-Based-Work Motorized person trip productions, Income level 3
HBWMTRP_I4	Home-Based-Work Motorized person trip productions, Income level 4
HBS_MTR_PS	Home-Based-Shop motorized person trip productions
HBS_NMT_PS	Home-Based-Shop non-motorized person trip productions
HBS_ALL_PS	Home-Based-Shop motorized and non-motorized person trip productions
HBSMTRP_I1	Home-Based-Shop Motorized person trip productions, Income level 1
HBSMTRP_I2	Home-Based-Shop Motorized person trip productions, Income level 2
HBSMTRP_I3	Home-Based-Shop Motorized person trip productions, Income level 3
HBSMTRP_I4	Home-Based-Shop Motorized person trip productions, Income level 4
HBO_MTR_PS	Home-Based-Other motorized person trip productions
HBO_NMT_PS	Home-Based-Other non-motorized person trip productions

HBO_ALL_PS	Home-Based-Other motorized and non-motorized person trip productions
HBOMTRP_I1	Home-Based-Other Motorized person trip productions, Income level 1
HBOMTRP_I2	Home-Based-Other Motorized person trip productions, Income level 2
HBOMTRP_I3	Home-Based-Other Motorized person trip productions, Income level 3
HBOMTRP_I4	Home-Based-Other Motorized person trip productions, Income level 4
NHW_MTR_PS	Non-Home-Based Work-Related motorized person trip productions
NHW_NMT_PS	Non-Home-Based Work-Related non-motorized person trip productions
NHW_ALL_PS	Non-Home-Based Work-Related motorized & non-motorized person trip productions
NHO_MTR_PS	Non-Home-Based Non-Work-Related motorized person trip productions
NHO_NMT_PS	Non-Home-Based Non-Work-Related non-motorized person trip productions
NHO_ALL_PS	Non-Home-Based Non-Work-Related motorized & non-motorized person trip productions

Next, the zonal trip attractions are calculated by applying the attraction trip models to the land use file. Non-motorized trip attractions are then determined and subtracted from the total trip attractions. Similar to productions, attractions are multiplied by an adjustment factor (Appendix A of the Calibration Report) and disaggregated by income level. The computed trip attractions are then written out to <ITER>_Trip_Gen_Attractions_Comp.dbf file. The final trip attractions are saved in the <ITER>_Trip_Gen_Attractions_Final.dbf described in Table 60.

Table 60 Computed zone trip attractions file (<iter>_Trip_Gen_Attractions_Comp.dbf)

Variable Name	Description
TAZ	TAZ Number (1-3,722)
HBW_MTR_AS	Home-Based-Work motorized person trip Attractions
HBW_NMT_AS	Home-Based-Work non-motorized person trip Attractions
HBW_ALL_AS	Home-Based-Work motorized and non-motorized person trip Attractions
HBWMTRA_I1	Home-Based-Work motorized person trip Attractions, Income level 1
HBWMTRA_I2	Home-Based-Work motorized person trip Attractions, Income level 2
HBWMTRA_I3	Home-Based-Work motorized person trip Attractions, Income level 3
HBWMTRA_I4	Home-Based-Work motorized person trip Attractions, Income level 4
HBS_MTR_AS	Home-Based-Shop motorized person trip Attractions
HBS_NMT_AS	Home-Based-Shop non-motorized person trip Attractions
HBS_ALL_AS	Home-Based-Shop motorized and non-motorized person trip Attractions
HBSMTRA_I1	Home-Based-Shop motorized person trip Attractions, Income level 1
HBSMTRA_I2	Home-Based-Shop motorized person trip Attractions, Income level 2
HBSMTRA_I3	Home-Based-Shop motorized person trip Attractions, Income level 3
HBSMTRA_I4	Home-Based-Shop motorized person trip Attractions, Income level 4
HBO_MTR_AS	Home-Based-Other motorized person trip Attractions
HBO_NMT_AS	Home-Based-Other non-motorized person trip Attractions
HBO_ALL_AS	Home-Based-Other motorized and non-motorized person trip Attractions

HBOMTRA_I1	Home-Based-Other motorized person trip Attractions, Income level 1
HBOMTRA_I2	Home-Based-Other motorized person trip Attractions, Income level 2
HBOMTRA_I3	Home-Based-Other motorized person trip Attractions, Income level 3
HBOMTRA_I4	Home-Based-Other motorized person trip Attractions, Income level 4
NHW_MTR_AS	Non-Home-Based Work-Related motorized person trip Attractions
NHW_NMT_AS	Non-Home-Based Work-Related non-motorized person trip Attractions
NHW_ALL_AS	Non-Home-Based Work-Related motorized & non-motorized person trip Attractions
NHO_MTR_AS	Non-Home-Based Non-Work-Related motorized person trip Attractions
NHO_NMT_AS	Non-Home-Based Non-Work-Related non-motorized person trip Attractions
NHO_ALL_AS	Non-Home-Based Non-Work-Related motorized & non-motorized person trip Attractions

The *Trip_Generation_Summary.s* creates a summary text file, <ITER>_Trip_Generation_Summary.txt, which includes the following tables:

- Land Activity by Jurisdiction
- Land Activity by Area Type
- Motorized Trip Productions by Purpose and Jurisdiction
- Motorized Trip Productions per Household by Purpose and Jurisdiction
- Motorized Trip Productions by Purpose and Area Type
- Non-Motorized Trip Productions by Purpose and Jurisdiction
- Non-Motorized Trip Productions by Purpose and Area Type
- Home-Based Motorized Trip Productions by Purpose, Income, and Jurisdiction
- Home-Based Motorized Trip Productions by Purpose, Income, and Area Type
- Motorized Trip Attractions by Purpose and Jurisdiction
- Motorized Trip Attractions per Job by Purpose and Jurisdiction
- Motorized Trip Attractions by Purpose and Area Type
- Non-Motorized Trip Attractions by Purpose and Jurisdiction
- Non-Motorized Trip Attractions by Purpose and Area Type
- Home-Based Motorized Trip Attractions by Purpose, Income, and Jurisdiction
- Home-Based Motorized Trip Attractions by Purpose, Income, and Area Type

The *Truck_Com_Trip_Generation.s* script reads in the zonal land use file (Zone.dbf), the area type file (AreaType_File.dbf), external trip productions and attractions (EXT_PsAs.dbf), demographic model outputs (%_iter_%_Demo_Models_HHbyISV.dbf), truck and commercial trip model coefficients (truck_com_trip_rates.dbf), and the zonal access verification file (Skimtot<ITER>.txt). For the list of inputs, see Table 56. The script then uses the truck and commercial trip model coefficients and the land use data to calculate medium and heavy truck and commercial vehicle zonal trips. After an adjustment factor is applied, these are written out to a ComVeh_Truck_Ends_<ITER>.dbf file described in Table 61.

Table 61 Truck and commercial vehicles trip ends (<iter>_ComVeh_Truck_Ends.dbf)

Variable Name	Description
TAZ	TAZ number (1-3722)
COMM_VEH	Commercial vehicle trip ends
MED_TRUCK	Medium truck trip ends
HVY_TRUCK	Heavy truck trip ends
ICOMM_VEH	Commercial vehicle trip ends (internal only)
IMED_TRUCK	Medium truck trip ends (internal only)
IHVY_TRUCK	Heavy truck trip ends (internal only)

The script also generates a summary text file- <ITER>_Truck_Com_Trip_Generation.txt, which includes the following tables:

- Regional Total Truck and Commercial Trip-Ends
- Truck and Commercial Vehicle Internal Trip Totals by Area Type
- Truck and Commercial Vehicle Internal Trip Totals by Jurisdiction

The trip generation process is currently applied to produce computed trip productions and computed (un-scaled) attractions by trip purpose. The computed productions and attractions are provided explicitly as motorized and non-motorized. The Home-Based motorized Ps and As are further stratified by income level. In prior trip generation versions, an Internal to External production share model was employed to extract the external travel component of total trip productions (of I-X trips). The extraction was necessary because external trip ends are prepared exogenously based on projected traffic counts. The potential problem with an I-X extraction model is that there is no guarantee that the model would yield I-X productions already developed exogenously at the external station level. It was ultimately decided that the approach for treating external trips in the generation and distribution process, and the approach for trip attraction scaling would be modified to ensure that I-X trips would be better preserved.

The modified process now involves the following Trip Generation and Trip distribution steps:

1. *Trip_Generation.s*: Computed trip productions and computed trip attractions are developed by purpose and mode (motorized and non-motorized). Trip attraction scaling is not undertaken.
2. *Prepare_Ext_Auto_Ends.s, Prepare_Ext_ComTruck_Ends.s*: External trip-ends (Ps and As) are prepared.
3. *Trip_Distribution_External.s*: External trip-ends are distributed, resulting in external trip tables, by purpose. Please note that the *Prepare_Ext_Auto_Ends.s* and *Trip_Distribution_External.s* scripts have been further updated in the Ver. 2.4 Model based on the 2014 cellular origin-destination (O-D) data.
4. *Prepare_Internal_Ends.s*: Final internal trip-ends are computed as follows:
    - External trip ends (I-X) trips and (X-I) trips-ends are summarized by purpose from the external trip matrices developed in Step 3

- The zonal I-X trip ends are subtracted from the motorized trip productions computed in Step 1. This results in final motorized productions. Non-motorized productions are unaffected.
- Scaling factors for internal trip attractions are computed by purpose. The factor is[112]

  IntAttrScaleFtr = ("Final" Intl P's + Extl. P's – Extl. A's) / (Intl. "Computed" A's)

  The above factor is applied to both motorized and non-motorized trip attractions

5. *Trip_Distribution_Internal.s*: The final internal P's and balanced A's are run through trip distribution. The resulting internal trips are combined with the external trips developed in step three.

While this process is slightly more complicated than the prior approach it better ensures that external trips developed exogenously are preserved through the trip distribution stage.

[112] This equation was developed by Bill Mann in the early 1990s.

20 Trip Distribution

20.1 Overview

The trip distribution process (shown on page A-7 of Appendix A) is invoked by the *Trip_Distribution.bat* file. The input and output files are listed in Table 62 and Table 63. As stated in the calibration report, the gravity model is doubly constrained for all five trip purposes.

The trip distribution process entails five Cube Voyager steps that involve two separate trip distribution procedures: one to distribute external auto person trips by purpose, and another to distribute internal motorized person trips by purpose. As explained in the trip generation chapter, this dual distribution procedure enables external trips (I-X) trips to be more precisely preserved at the station level compared to the prior trip generation/distribution approach.

Table 62 Inputs to trip distribution

Item	Filename	Format
Computed zonal motorized trip productions	<iter>_Trip_Gen_Productions_Comp.dbf	dBase
Computed zonal motorized trip attractions (un-scaled)	<iter>_Trip_Gen_Attractions_Comp.dbf	dBase
Computed zonal commercial, truck trip ends (Ps, As)	<iter>_ComVeh_Truck_Ends.dbf	dBase
AM highway skims	<PreIter>_AM_SOV.SKM	Binary
OP highway skims	<PreIter>_OP_SOV.SKM	Binary
AM Walk Access Metrorail-only total travel time	<iter>_AM_WK_MR.ttt	Binary
AM Drive Access Metrorail-only total travel time	<iter>_AM_DR_MR.ttt	Binary
OP Walk Access Metrorail-only total travel time	<iter>_OP_WK_MR.ttt	Binary
OP Drive Access Metrorail-only total travel time	<iter>_OP_DR_MR.ttt	Binary
Toll-time equiv. file (by Income/purpose)	Equiv_Toll_Min_by_Inc.s	Text
K-Factor matrices	HBW_K.mat, HBS_k.mat, … ,NHO_k.mat	binary
Friction factors	Ver23_F_Factors.dbf	dBase

Note: <ITER> =PP, i1, …, i4

Table 63 Outputs of trip distribution

Item	Filename	Format
HBW Motorized Psn. Trips (internal & external)	<iter>_HBW.PTT	Binary
HBS Motorized Psn. Trips (internal & external)	<iter>_HBS.PTT	Binary
HBO Motorized Psn. Trips (internal & external)	<iter>_HBO.PTT	Binary
NHW Motorized Psn. Trips (internal & external)	<iter>_NHW.PTT	Binary
NHO Motorized Psn. Trips (internal & external)	<iter>_NHO.PTT	Binary
Commercial Vehicle Trips (internal & external)	<iter>_Commer.PTT	Binary

Medium Truck Trips (internal & external)	<iter>_MTruck.PTT	Binary
Heavy Truck Trips (internal & external)	<iter>_HTruck.PTT	Binary
HBW Motorized Psn. Trips (internal only)	<iter>_HBW_NL.PTT	Binary
HBS Motorized Psn. Trips (internal only)	<iter>_HBS_NL.PTT	Binary
HBO Motorized Psn. Trips (internal only)	<iter>_HBO_NL.PTT	Binary
NHW Motorized Psn. Trips (internal only)	<iter>_NHW_NL.PTT	Binary
NHO Motorized Psn. Trips (internal only)	<iter>_NHO_NL.PTT	Binary

20.2 Application Details

The Trip Distribution process is executed with the batch file named, *Trip_Distribution.bat*. Five Cube Voyager scripts are used to carry out the process.

The first two scripts, *Prepare_Ext_Auto_Ends.s* and *Prepare_Ext_ComTruck_Ends.s,* read the computed zonal Productions and Attraction resulting trip generation and prepares trip ends that are suitable for applying trip distributing for external Ps and As only.

The *Trip_Distribution_External.s* script executes the distribution of external trip-ends, resulting in external trip tables, by purpose. The script also calculates zonal impedances that are used in both the distribution of external and internal trips.

The trip distribution process uses different LOS impedances measures, depending on trip purpose. Work (HBW) trips are distributed using AM peak travel impedances while midday (MD) impedances are used for all remaining purposes.

The script first prepares zonal highway terminal times, which are based on the zonal area type. The terminal times, which represent the time needed to park and un-park a vehicle, range from 1 minute in the least developed areas to 5 minutes for highly developed areas. The terminal times are then added to the over-the-network highway travel time skims. Next, composite impedance tables are developed combining transit time and highway times, based on the formula shown in Equation 2:

Equation 2 Composite time

$$CT_i = \frac{1}{\frac{1}{HT + TollT_i} + \frac{P_i}{TT}}$$

where

CT_i = Composite time for income level i
HT = Congested highway time (minutes), including terminal time
$TollT_i$ = Time equivalent (minutes)of tolls associated with the minimum-time path for income i
P_i = Regional transit share of income i for the trip purpose
TT = Metrorail-related transit time (min.), including in-vehicle and out-of-veh. time components

The basis of the $TollT_i$ term calculation is specified in Table 64. The table indicates the average time valuation, in minutes, per year-2007 dollar, that is assigned to a toll value by income level and trip type. The table indicates, for example, that a $1.00 toll equates to 8.7 minutes of travel time for a traveler in income level 1. More generally, the table indicates that travelers commuting to work are less sensitive to tolls than non-work-bound travelers because the time valuation of commuters is relatively high. The table also reflects the intuitive generalization that lower income travelers are more sensitive to tolls than the higher income travelers.

Table 64 Time Valuation (Minutes/2007$) by Purpose and Income Level

HH Income Quartile Range (1)	Assumed Mid-Point of HH Inc. Range	Hourly Rate per Worker (2)	2007 Time Valuation (Minutes per Dollar)	
			Work Trips (75% VOT)	Non-work (50% VOT)
$ 0 - $ 50,000	$25,000	$9.23	8.7	13.0
$ 50,000 - $ 100,000	$75,000	$27.70	2.9	4.3
$100,000 - $150,000	$125,000	$46.17	1.7	2.6
$150,000 +	$175,000	$64.64	1.2	1.9

Notes:
(1) Income groups based on 2007 ACS-based quartiles
(2) Hourly rate based on 1,920 annual hours/worker * 1.41 workers/HH = 2,707 hrs/HH
(3) Median 2007 annual HH income for the TPB modeled area is $84,280

Prepare_Internal_Ends.s reads the external trip tables created above and summarizes the trip-ends from those trip tables. It also reads the internal trip-ends from the trip generation process. The script subtracts I-X trips from the total computed trip productions (by purpose), to arrive at "final" internal trip productions. An internal trip attraction trip scaling factor is next computed. The factor is computed by purpose as:

IntAttrScaleFtr = ("Final" Intl Ps + Extl. Ps – Extl. As)/ Intl. "Computed" As

The internal Ps and As in the above equation include both motorized and non-motorized trips. A summary of the initial and final/scaled trip-ends is provided in a small text file named <iter>_Prepare_Internal_Ends.txt.

Trip_Distribution_Internal.s: The final internal Ps and scaled As are run through trip distribution. The resulting internal trips are combined with the external trips developed above. The trip distribution process produces complete (internal and external) trip tables by purpose and produces internal-to-internal (I-I) trip tables which will be inputs to the mode choice model later in the model stream. A complete set of jurisdictional trip tables by purpose is reported in a text file named <iter>_Trip_Distribution_Internal.tab.

21 Mode Choice

21.1 Travel modes represented in the mode choice model

As shown in Figure 66, the mode choice model in the Version 2.4 Travel Model was designed to have 15 choices, made up of the following modes:

- Three auto modes: Drive alone, shared ride 2 person, and shared ride 3+ person.
- Three transit access modes:
    - Drive to transit and park in a park-and-ride (PNR) lot;
    - Drive to transit and drop off passenger(s) at the kiss and ride (KNR) lot or station; and
    - Walk to transit.
- Four transit modes: Commuter rail, all bus, all Metrorail, and combined bus/Metrorail.

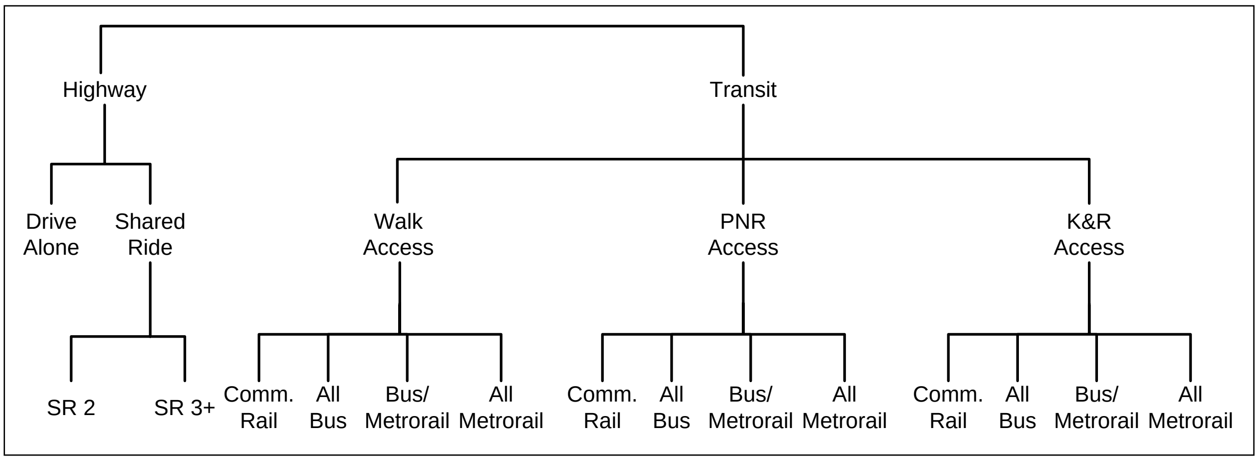

Figure 66 Designed nesting structure of the nested-logit mode choice model in the Version 2.4 Model

* In model implementation, PNR and KNR access modes for commuter rail are combined into one choice, resulting in 14 choices, not 15.

Ref: "I:\ateam\nest_log\NestedChoice_Struct4.vsd"

Two important distinctions should be made. First, as per the design of AECOM, for the commuter rail mode, the model was implemented such that PNR and KNR commuter rail are combined as a single choice (in mode choice) or a single path (in path building), since, for commuter rail, the PNR- and KNR-access links are identical. Thus, instead of 12 access-mode/transit-mode choices, the model is implemented using 11 access-mode/transit-mode choices. Consequently, as implemented in the model, the mode choice model has 14 choices, not 15. This is difficult to portray in Figure 66, but is noted in a footnote on the figure. This combining of modes is also apparent in Table 69 ("Outputs from the AEMS mode choice application program").

Second, regarding the three auto modes: As discussed in the calibration report, the definition of high-occupancy vehicle (HOV) trips has changed, compared to the definition that was used in the Version 2.2 Travel Model. Previously, HOV trips coming out of the mode choice model referred to *only those that* *use HOV facilities for a substantial portion of their trip*. Similarly, in previous models, the definition of low-occupancy vehicle (LOV) included both drive-alone and carpools (provided the carpools did not use a preferential HOV facility). By contrast, in the Version 2.3 and 2.4 NLMC model, the term LOV refers to only the drive-alone trips. Similarly, HOV refers to all shared-ride 2 (2-person carpools) and shared-ride 3 (3+ person carpools), irrespective of whether they use an HOV facility or not.

21.1.1 Treatment of LRT, BRT, and streetcar

Note that the nesting structure of the TPB Version 2.4 NLMC model does not include branches for specialized transit modes, such as light-rail transit (LRT), bus rapid transit (BRT), and streetcar. From this, one might conclude that the mode choice model is not designed to deal with these special transit modes. In fact, the model is designed to deal with these special transit modes. This section of the report discusses how these modes are treated in both the mode choice model and the transit path skimming process that feeds the mode choice model. This is the scheme that was developed by AECOM in 2004-2005 and has been retained by TPB staff. One of the underlying assumptions is that "premium" transit modes (e.g., Metrorail, commuter rail, LRT, BRT, and streetcar) will typically travel faster than buses, since they have one or more of these characteristics:

- A dedicated right-of-way, at least for part, if not all, of the route
- Traffic signal priority
- Superior acceleration/deceleration (compared to buses)

21.1.1.1 Network representation: LRT, BRT, and streetcar

In terms of network representation, LRT is typically coded as "mode 5." BRT and streetcar are coded as "mode 10," referred to in some parts of the model as the "new" mode. The thought is that LRT will travel mainly on its own grade-separated right-of-way (ROW), where it does not have to interact with road traffic. By contrast, it is assumed that streetcar will travel mostly in mixed traffic, i.e., it will share an at-grade right-of-way with road traffic. It is believed that AECOM chose to include BRT with streetcar, since although BRT will often include some grade-separated rights-of-way for the trunk-line portion of the route, the beginning and ending of the BRT route are likely to be in mixed traffic, making it more similar to the streetcar.

In cases where a travel demand modeler is coding a new transit line representing a "premium" transit mode,[113] the modeler must add "transit-only" links to the transit network to represent the new service, since the line requires a dedicated ROW which is not part of the highway network. In the past, one would have added these transit-only links to the rail link file (rail_link.bse). However, with the advent of TPB staff using an Esri geodatabase to manage the highway and transit networks, the rail_link.bse file no longer exists. For a modeler working at COG, one should add transit-only links directly into the highway/transit network geodatabase. For a modeler working external to COG (who will not have access

[113] Such as Metrorail (Mode 3), commuter rail (Mode 4), LRT (Mode 5), and BRT/streetcar (Mode 10).

to the COGTools ArcGIS add-in for managing the geodatabase), one should modify the text *.tb files that are output from the *create_support_files.s* Cube Voyager script.

The "station file" (station.dbf) contains information about transit stations in the modeled area. More formally, the station file contains information about Metrorail stations, commuter rail stations, light rail stations, bus rapid transit stations/stops, streetcar stations/stops, express-bus bus stops, and park-and-ride (PNR) lots that serve these stations/stops. One must add Mode 5 and Mode 10 station nodes to the station file using a mode code of "L" for LRT/Mode 5 and "N" for New/BRT/streetcar/Mode 10. Mode 5 and 10 stations do not require a station centroid number,[114] though recent network documentation has designated the node number range of 7000-7999 (light rail/BRT PNR centroids), even though this range is not currently in use in the geodatabase.[115] Cube Voyager cannot combine headways for routes unless they are part of the same mode code, so, in cases where Mode 10 routes share a street segment with local bus (Mode 1), these two routes will not be represented with a combined headway.

21.1.1.2 Transit path building and skimming, mode choice, and transit assignment: LRT, BRT, and streetcar

In transit path building and skimming, mode choice, and transit assignment, the following two rules apply:[116]

- LRT: Mode 5 is treated like Metrorail (Mode 3)
- BRT: Mode 10 is treated like local bus (Modes 1, 6, & 8)

21.1.1.3 Fares: LRT, BRT, and streetcar

Fares for Mode 5 and Mode 10 are computed like those for local bus (Modes 1, 6, & 8).

21.1.1.4 Inclusion of LRT, BRT, and streetcar trips in trip tables

Following the mode choice step, the output trip table files (*.MTT) each contain 14 tables, as shown in Table 69. Any table that lists "MR" (Metrorail) actually includes both Metrorail and LRT, since Mode 5 [LRT] is treated like Metrorail (Mode 3) in transit path building/skimming, mode choice and transit assignment. Similarly, any table that lists "BU" (Bus) actually includes both bus and BRT/streetcar. The only way to get the actual breakout of the estimated level of LRT or BRT/streetcar travel is to look at the transit assignment results (keeping in mind that, although we assign all transit trips, we validated only Metrorail trips, and, at the current time, these are validated only to station groups, not to individual stations). So, after transit assignment, one is able to see how many trips/boardings/alightings occurred

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[114] Jain to Milone and Moran, "MWCOG Network Coding Guide for Nested Logit Model (First Draft: September 20, 2007; Updated February 2008 and October 2010)," October 2010, 6.
[115] Meseret Seifu, Ronald Milone, and Mark Moran, "Highway and Transit Networks for the Version 2.3.66 Travel Model, Based on the 2016 CLRP and FY 2017-2022 TIP," Final Report (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, March 17, 2017), 17, https://www.mwcog.org/transportation/data-and-tools/modeling/model-documentation/.
[116] Jain to Milone and Moran, "MWCOG Network Coding Guide for Nested Logit Model (First Draft: September 20, 2007; Updated February 2008 and October 2010)," October 2010, 10.

on a given LRT line, but, since we do not validate results at the LRT line level, model users are recommended to use caution when using these numbers.

21.1.2 Other issues relating to travel modes

Table 65 list the ten transit modes that are handled by the Version 2.4 mode choice model and lists the mode code used in the station file (station.dbf), which is an input to the *parker.s* script that is part of the *transit_skim_all_modes.bat* batch file (see Section 16, Transit Skim File Development). Note that the consolidated station file does not include bus stops, except for bus stops that have their own PNR lot (generally express bus service). Transit routes are represented in Cube Voyager's TRNBUILD module using the LINE command, which is usually placed in a *.LIN file or, using COG/TPB convention, in a MODE*.TB file (a "mode" file).

Table 65 Transit sub-modes represented in the Version 2.4 Model

Mode #	Transit sub-mode	Mode code in station file
1	Local Metrobus	(not represented in the sta. file)
2	Express Metrobus	B
3	Metrorail	M
4	Commuter rail	C
5	Light rail transit (LRT)	L
6	Other local bus in the WMATA service area	(not represented in the sta. file)
7	Other express bus in the WMATA service area	B
8	Other local bus beyond the WMATA service area	(not represented in the sta. file)
9	Other express bus beyond the WMATA service area	B
10	Bus rapid transit (BRT) and streetcar	N (for "New" mode)

In addition, there are five non-transit modes that are used to access transit and make transfers to, from, and between transit services. These are detailed in Table 66.

Table 66 Transit Access and Transfer Links

Mode #	Link Type
11	Drive access, for both PNR and KNR (from the zone centroid to a transit stop node)
12	Walk transfer link (between transit services or to/from transit station)
13	Sidewalk link
14	Unused
15	Walk transfer link between PNR lot and transit station
16	Walk access (from the zone centroid to a transit stop node)

All the modes described in Table 65 and Table 66 can be used in the path-building process (see 16). If no prohibitions are imposed, path building assumes that transfers between all modes are possible. For example, a person could theoretically access Metrorail by driving (mode 11) to the station, use Metrorail (mode 3), and egress Metrorail by driving (mode 11) as well. When trips are in production-attraction format, as is the case for transit path-building and mode choice, a person cannot egress from a station and take a car. To prevent the foregoing behavior in the model, some limitations with regard to transfers need to be imposed. These are described in Table 67. The mode interchanges where transfers are prohibited are denoted by "Y".

Table 67 Transfer Prohibitions (No Transfer or NOX)

From	To Mode															
Mode	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	n	n	n	n	n	n	n	Y	Y	n	Y	n	n	n	Y	n
2	n	n	n	n	n	n	n	Y	Y	n	Y	n	n	n	Y	n
3	n	n	n	n	n	n	n	Y	Y	n	Y	n	n	n	Y	n
4	n	n	n	n	n	n	n	Y	Y	n	Y	n	n	n	Y	n
5	n	n	n	n	n	n	n	Y	Y	n	Y	n	n	n	Y	n
6	n	n	n	n	n	n	n	Y	Y	n	Y	n	n	n	Y	n
7	n	n	n	n	n	n	n	Y	Y	n	Y	n	n	n	Y	n
8	n	n	n	n	n	n	n	n	n	n	Y	n	n	n	Y	n
9	n	n	n	n	n	n	n	n	n	n	Y	n	n	n	Y	n
10	n	n	n	n	n	n	n	Y	Y	n	Y	n	n	n	Y	n
11	n	n	n	n	n	n	n	n	n	n	Y	Y	n	Y	n	n
12	n	n	n	n	n	n	n	n	n	n	Y	Y	n	n	Y	n
13	n	n	n	n	n	n	n	n	n	n	Y	n	n	n	Y	n
14	n	n	n	n	n	n	n	n	n	n	Y	n	n	n	Y	n
15	n	n	n	n	n	n	n	n	n	n	Y	Y	Y	Y	Y	Y
16	n	n	n	n	n	n	n	n	n	n	Y	n	n	n	Y	Y

21.2 Elimination of Metrorail constraint to and through the regional core

As of Ver 2.3.75, the Metrorail constraint to and through the regional core has been removed due to the stable long-term funding of $500 million a year for Metro to support WMATA's plans to implement all 8-car trains during peak periods in the Visualize 2045 Plan.[117] For the sake of documentation, below is a more detailed description of the constraint and its modeling-related aspects. This description came from previous model documentation.[118]

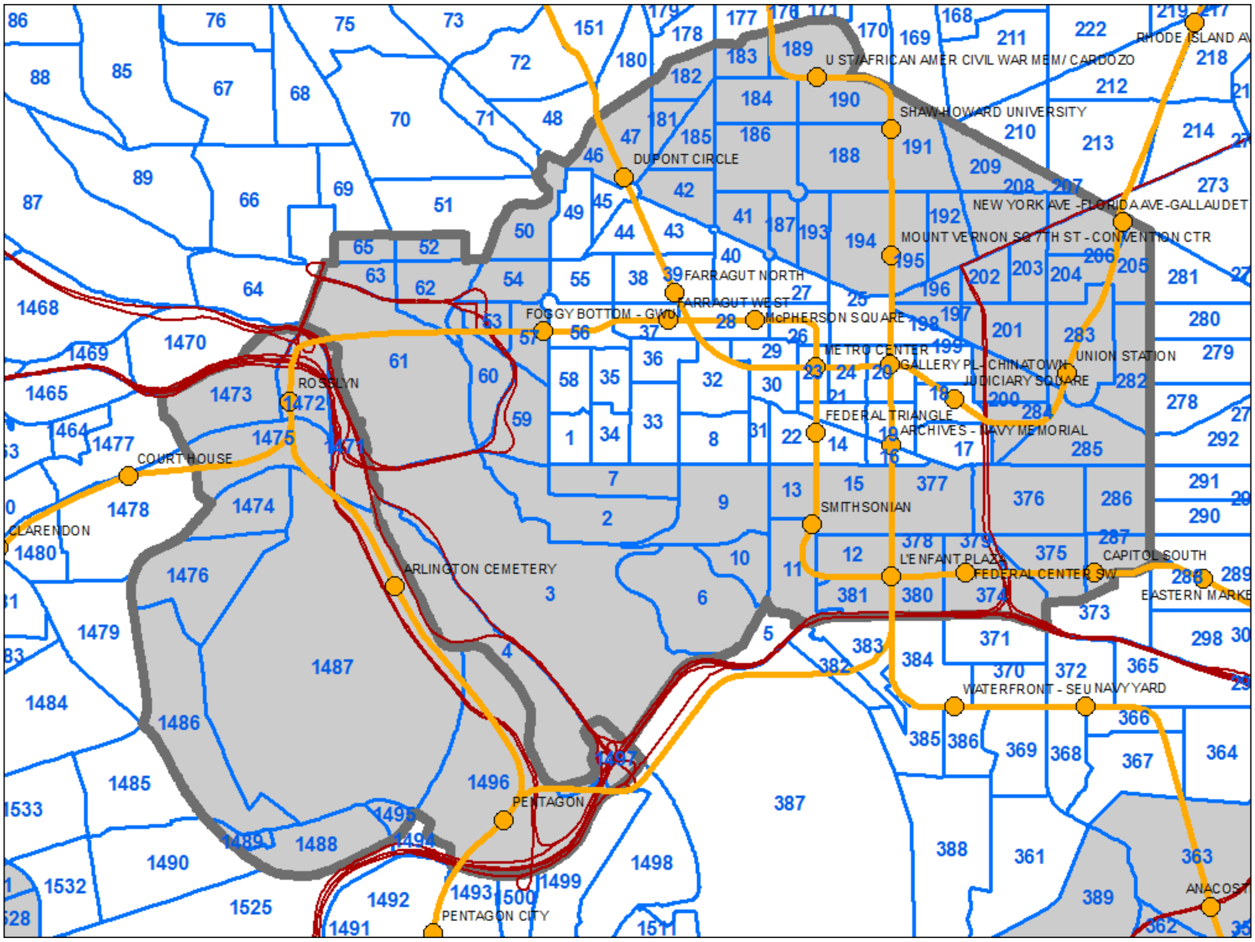
The Metrorail constraint through the regional core (sometimes referred to using the less precise term "transit constraint through the regional core") is a technical adjustment to the trip tables coming out of the mode choice process designed to reflect a WMATA policy assumption that, during peak periods, the Metrorail system may have insufficient capacity to handle all the demand traveling to and through the

[117] Jane Posey, "Amendments to the Visualize 2045 Air Quality Conformity Scope of Work," Memorandum, May 16, 2018.
[118] Moran, Milone, and Seifu, "User's Guide for the COG/ TPB Travel Demand Forecasting Model, Version 2.3.70. Volume 1 of 2: Main Report and Appendix A (Flowcharts)."

regional core. Typically, it is assumed that the Metrorail system will be able to handle all of the peak-period demand to and through the regional core in the near term, but, since demand is growing through time, the system might not be able to handle all the peak-period demand at some future time, depending on the amount of growth in demand and the number of rail cars available in a given year. The assumed year at which the Metrorail system will be at its peak capacity during the peak periods to and through the regional core is known as the "binding year." For years beyond the binding year, it is assumed that any growth in peak-period Metrorail demand to and through the regional core will be forced to switch to other travel modes (specifically, auto person trips). The Metrorail constraint was initiated by WMATA in 2000 to address funding shortfalls restricting the expansion of the rail fleet.[119] WMATA policy sets the binding year, which is currently set at 2020. This means that, for any forecast year past 2020, the Metrorail constraint is applied, i.e., forecasted peak-period Metrorail trips to and through the regional core are shifted to other travel modes (specifically, auto person trips). The regional core is defined as the set of Metrorail stations in the central employment area, i.e., the portion of the system bounded by Dupont Circle, U Street, New York Avenue (NOMA), Capital South, L'Enfant Plaza, Pentagon, Arlington Cemetery, and Rosslyn stations. This area is also sometimes referred to by technical audiences as "Ring 0" and "Ring 1." In Figure 67, Ring 0 is shown as the white area shaped like a trapezoid in the center of downtown Washington, D.C. Ring 1 is shown as the gray area surrounding Ring 0. The two areas together comprise the regional core. Note that non-Metrorail-related transit trips and off-peak Metrorail trips are not affected by the Metrorail constraint process.

[119] Ronald Milone, "TPB Version 2.3 Travel Model on the 3,722-TAZ area system: Status report" (presented at the September 23, 2011 meeting of the Travel Forecasting Subcommittee of the Technical Committee of the National Capital Region Transportation Planning Board, held at the Metropolitan Washington Council of Governments, Washington, D.C., September 23, 2011).

Figure 67 Ring 0 (white trapezoid) and Ring 1 (gray polygon), which form the "core" area used in the Metrorail constraint through the regional core



Ref: I:\ateam\gis\taz\taz_2191_3722.mxd

The Metrorail constraint is applied in the following way (assuming that 2020 is the binding year). Model runs representing the binding year and years prior to the binding year are conducted in the normal fashion, i.e., using the ***mode_choice.bat*** batch file (see page A-13 of Appendix A). Model runs representing any year following the binding year, e.g., 2030, are conducted using the ***mode_choice_tc_v23.bat*** batch file (see page A-13 of Appendix A), as follows:

- Peak 2020 Metrorail trips to and through the core are estimated using a time-of-day model.
- Peak 2030 Metrorail trips to and through the core are estimated using a time-of-day model.
- Peak 2030 Metrorail trips to and through the core are adjusted (downward) to match 2020 ridership levels.
- The "excess" 2030 Metrorail trips that cannot be accommodated are converted to auto person trips
- The constraint process occurs for each speed feedback iteration ("i1" through "i4).

Thus, the mode choice model is executed normally with the *mode_choice.bat* batch file, which invokes the following:

- Mode choice model application program (AEMS.EXE);
- Jurisdictional summary script (*MC_NL_Summary.s*);

By contrast, the mode choice model and Metrorail constraint process are executed using the *mode_choice_tc_v23.bat* batch file, which invokes the following:

- Mode choice model application program (AEMS.EXE);
- Jurisdictional summary script (*MC_NL_Summary.s*);
- Constraint adjustment script (*MC_Constraint_V23.s*);

21.3 Control/Support Files

The nested-logit mode choice (NLMC) model is applied using a Fortran program called AEMS.[120] AEMS.EXE is the compiled version of the source code AEMS.FOR. In order to run, AEMS.EXE needs to have several DLL files. The model is run one for each of the five trip purposes, as shown on page A-13 of the flowchart in Appendix A. Each run of the mode choice model requires a “control file,” so there are five in total: HBW_NL_MC.CTL, HBS_NL_MC.CTL, HBS_NL_MC.CTL, NHW_NL_MC.CTL, and NHO_NL_MC.CTL. After the five mode choice models run, there is a Cube Voyager script, *MC_NL_Summary.s*, which is used to create jurisdiction-to-jurisdiction tabulations of the trip tables output from the mode choice model. The inputs to the AEMS mode choice application program are shown in Table 68. The outputs are shown in Table 69.

Table 68 Inputs to the AEMS mode choice application program

Daily person trips, stratified by income group (1, 2, 3, 4), in production/attraction format (INFILE 1)	hbw_income.ptt, hbs_income.ptt, hbo_income.ptt, nhw_income.ptt, nho_income.ptt	Binary
Highway skims, nine tables – SOV, HOV2, HOV3+ for time, distance, and tolls on non-variably-priced facilities (INFILE 2)	hwyam.skm, hwyop.skm	Binary
Commuter rail transit skims (INFILE 3)	trnam_cr.skm, trnop_cr.skm	Binary
All bus transit skims (INFILE 4)	trnam_ab.skm, trnop_ab.skm	Binary
Metrorail transit skims (INFILE 5)	trnam_mr.skm, trnop_mr.skm	Binary
Bus/Metrorail transit skims (INFILE 6)	trnam_bm.skm, trnop_bm.skm	Binary
Zonal data (INFILE 8)	zonev2.a2f	Text

[120] “AECOM Consult Mode Choice Computation Programs, AEMS, Users Guide,” Draft report (Fairfax, Virginia: AECOM Consult, Inc., April 5, 2005).

Table 69 Outputs from the AEMS mode choice application program

Daily person trips, stratified by travel mode (14 tables): 1. DR ALONE 2. SR2 3. SR3+ 4. WK-CR 5. WK-BUS 6. WK-BU/MR 7. WK-MR 8. PNR-CR & KNR-CR 9. PNR-BUS 10. KNR-BUS 11. PNR-BU/MR 12. KNR-BU/MR 13. PNR-MR 14. KNR-MR	hbw_nl_mc.mtt, hbs_nl_mc.mtt, hbs_nl_mc.mtt, nhw_nl_mc.mtt, nho_nl_mc.mtt	Binary

21.4 Market segmentation

Most mode choice models used in large urban areas in the U.S. have historically been estimated at a disaggregate level but are applied at an aggregate level. Specifically, these models are typically estimated at the person-trip level but applied at the zone-to-zone interchange level. Furthermore, in application mode, within each zone-to-zone interchange, many models subdivide the travel market into homogeneous groups, known as market segments. The nested-logit mode choice model (NLMC) that is used in the Version 2.4 Travel Model uses three types of market segmentation:

- Household income
- Geography
- Access to transit

Note that there has been a recent trend away from disaggregate estimation, due, in part to guidance from the FTA.[121]

21.4.1 Market segmentation by household income

The income segmentation is the same that is used for the first two steps of the travel model (i.e., trip generation and trip distribution), namely households are segmented by the four household income quartiles, which are shown in Table 70.[122]

Table 70 Household income quartiles computed from the ACS

Quartile	Income range (2007 dollars)
First	Less than $50,000
Second	$50,000 to $99,999
Third	$100,000 to $149,999
Fourth	$150,000 or more

21.4.2 Market segmentation by geography

When AECOM Consult, Inc. first developed a mode choice model for the Washington, D.C. metropolitan area in 2004-2005, it divided the modeled area into seven superdistricts:[123]

1. DC core
2. VA core
3. DC urban

[121] See, for example, Federal Transit Administration, "Discussion Piece #16: Calibration and Validation of Travel Models for New Starts Forecasting" (Workshop on Travel Forecasting for New Starts Proposals, Minneapolis, Minnesota, 2006), http://www.fta.dot.gov/planning/newstarts/planning_environment_5402.html.
[122] Hamid Humeida to Files, "Analysis of Data from the American Community Survey (ACS): Households by Household Income, Household Size, and Vehicle Availability," Memorandum, March 19, 2010.
[123] Bill Woodford, "Development of Revised Transit Components of Washington Regional Demand Forecasting Model" (Transit Modeling Meeting, held at the Metropolitan Washington Council of Governments, Washington, D.C., December 1, 2004), 30.

4. MD urban
5. VA urban
6. MD suburban
7. VA suburban

AECOM's mode choice model was applied as a post process to the COG/TPB travel model (the Version 2.1 Travel Model). COG/TPB staff used the AECOM post-process mode choice model as a starting point for its work on the Version 2.3 Travel Model in work done from 2008 to 2011. TPB staff integrated the mode choice model into the modeling chain (i.e., moved from a post process for the regional model to its normal position in the speed feedback loop, following trip distribution), and re-calibrated the model. **When COG/TPB staff retained and re-calibrated the NLMC model, it retained the same geographic market segmentation that had been developed by AECOM**.

These seven superdistricts are shown in Figure 68 and in Table 71. Table 71 shows the equivalency between the seven NLMC superdistricts and the new 3,722-TAZ area system.

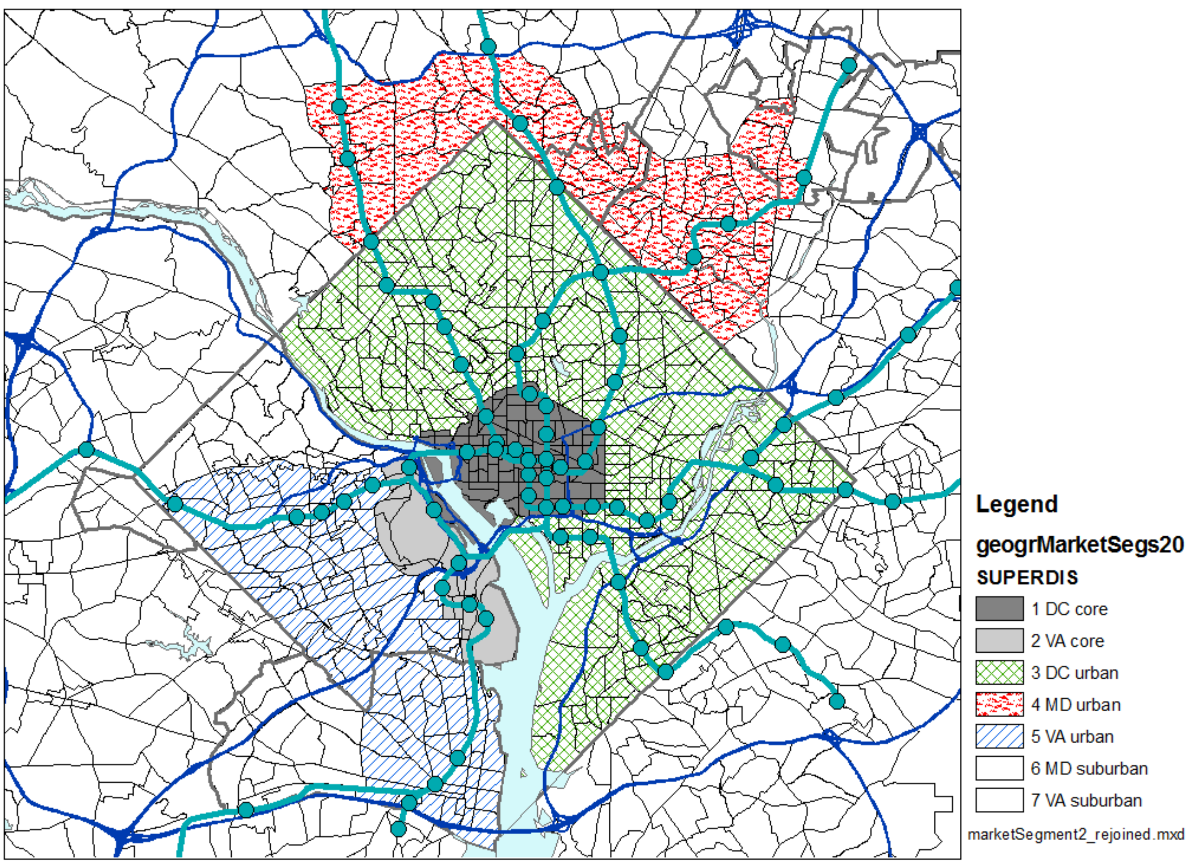


Figure 68 Seven superdistricts used in the Versions 2.3 and 2.4 nested-logit mode choice model

Ref: "I:\ateam\nest_log\marketsegment2_rejoined.tif"

Table 71 Equivalency between nested-logit mode choice superdistricts and TPB TAZ 3,722

No.	Name	TAZs (TPB TAZ 3,722)
1	DC core	1-4,6-47,49-63,65,181-287,374-381
2	VA core	1471-1476,1486-1489,1493,1495-1504,1507,1508,1510,1511
3	DC urban	5,48,51,64,66-180,210-281,288-373,382-393
4	MD urban	603,606,612-628,630-640,662-664,669,670,913,916,917,939-957,959,961-982,985,
4	MD urban	986
5	VA urban	1405-1422,1427-1435,1448,1452,1454-1464,1477-1485,1490-1492,1494,1505,1506,
5	VA urban	1509,1512-1545,1569-1609
6	MD suburban	394-602,604,605,607-611,629,641-661,665-668,671-912,914,915,918-938,958,960,
6	MD suburban	983,984,987-1404,2820-3102,3104-3409
7	VA suburban	1423-1426,1436-1447,1449-1451,1453,1465-1470,1546-1568,1610-2554,2556-2628,
7	VA suburban	2630-2819,3410-3477,3479-3481,3483-3494,3496-3675

Ref: "I:\ateam\nest_log\equiv_tpbTaz3722_nlmc_superdistr.txt" and "I:\ateam\nest_log\Market_segment_NewTAZs_sorted.xlsx"

The TAZs in Table 71 are referred to as "TPB TAZ" to distinguish them from "COG TAZ." In 2008 and 2009, the COG GIS staff developed a new system of transportation analysis zones (TAZs), which had more zones, but did not increase the size of the modeled area. In other words, the new zones were, on average, smaller than the previous zone system, which is useful for better modeling of transit trips. The old zone system had 2,191 TAZs and the new system has 3,722 TAZs. After the COG GIS staff was finished with their work, the COG model development group reviewed the new zone system and found a few cases where the zone boundaries needed adjustment.[124] The final result was that there were now two sets of zones for the 3,722-TAZ area system:

- COG TAZs: For land activity forecasts (COGTAZ3722_TPBMOD)
- TPB TAZs: For transportation modeling (TPBTAZ3722_TPBMOD)[125]

Although seven market areas could lead to 49 (= 7 x 7) geographic interchanges, AECOM Consult, Inc. grouped them into the 20 paired production/attraction areas shown in Table 72 and Table 73. Another way to view the 20 geographic market segments is shown in Table 74.

[124] Meseret Seifu, "Review of New Zone System: 3722 Transportation Analysis Zones (TAZ)" (January 22, 2010 meeting of the COG/TPB Travel Forecasting Subcommittee, held at the Metropolitan Washington Council of Governments, Washington, D.C., January 22, 2010), 4, http://www.mwcog.org/uploads/committee-documents/Zl5aV1dd20100122152445.pdf.

[125] Seifu, 23.

Table 72 Production and attraction market segments used in the TPB Versions 2.3 and 2.4 NLMC model

Production Areas	Attraction Areas
1. DC Core / Urban	1. DC Core
2. MD Urban	2. VA Core
3. VA Core / Urban	3. Urban
4. MD Suburban	4. Suburban
5. VA Suburban	

Ref: "I:\ateam\nest_log\marketSeg.xls"

Table 73 20 geographic market segments used in the TPB nested-logit mode choice model

Market Seg No.	Prod Superdis	Attr Superdis	Production Area	Attraction Area
1	1,3	1	DC	DC core
2	1,3	2	DC	VA core
3	1,3	3,4,5	DC	Urban DC, MD, VA
4	1,3	6,7	DC	Suburban MD, VA
5	4	1	MD urban	DC core
6	4	2	MD urban	VA core
7	4	3,4,5	MD urban	Urban DC, MD, VA
8	4	6,7	MD urban	Suburban MD, VA
9	2,5	1	VA core/urban	DC core
10	2,5	2	VA core/urban	VA core
11	2,5	3,4,5	VA core/urban	Urban DC, MD, VA
12	2,5	6,7	VA core/urban	Suburban MD, VA
13	6	1	MD suburban	DC core
14	6	2	MD suburban	VA core
15	6	3,4,5	MD suburban	Urban DC, MD, VA
16	6	6,7	MD suburban	Suburban MD, VA
17	7	1	VA suburban	DC core
18	7	2	VA suburban	VA core
19	7	3,4,5	VA suburban	Urban DC, MD, VA
20	7	6,7	VA suburban	Suburban MD, VA

Ref: "I:\ateam\nest_log\marketSeg.xls"

Table 74 Equivalency between seven super-districts and the 20 geographic market segments

		1 DC core	2 VA core	3 DC urban	4 MD urban	5 VA urban	6 MD suburban	7 VA suburban
1	DC core	1	2	3	3	3	4	4
3	DC urban	1	2	3	3	3	4	4
4	MD urban	5	6	7	7	7	8	8
2	VA core	9	10	11	11	11	12	12
5	VA urban	9	10	11	11	11	12	12
6	MD suburban	13	14	15	15	15	16	16
7	VA suburban	17	18	19	19	19	20	20

Ref: "I:\ateam\nest_log\superDistr_marketSeg.xlsx"

21.4.3 Market segmentation by access to transit

The section of the report contains two subsections. The first includes a general discussion about how transit-access markets are developed in relatively simple mode choice models. It gives the example of the three transit access markets that are often used by the Federal Transit Administration (FTA): "can walk," "must drive," and "no transit."[126] The second subsection describes the more specific case of the seven transit-access markets used in the mode choice model of the Version 2.4 Travel Model. In both the general discussion and the more specific case, zonal percent-walk-to-transit (PWT) values are used to develop the transit access markets. In the latter case, the mode choice model application program is AEMS.EXE, developed by AECOM.

21.4.3.1 General discussion

The purpose of a mode choice model is to predict the number and or share of trips that will be made by each major travel mode represented in a model. Transit, in one form or another, is usually one of the travel modes represented in most mode choice models. In order to use transit, one must be able to access it, either via non-motorized modes, such as walking and biking, or motorized modes, such as driving an automobile. Many mode choice models segment transit trips by walk access and drive access. A typical zonal metric for how easily one may walk to transit is the "percent walk to transit" (PWT) value, which is defined as the percent of a zone's area that is within walking distance to transit service. So, for example, a PWT value of 20% means that 20% of the zone's area lies within walking distance to transit service. If walking distance has been defined to be one mile, then this means that 20% of the zone lies within one mile of transit service. The walking distance threshold is set by the modelers in each urban area and should reflect the typical distance that people are likely to walk to reach transit. Typical values range from 0.5 miles to 1 mile. Some travel models, such as the TPB Version 2.4 Travel Model, make use of two walk-to-transit threshold distances, e.g., a short-walk distance (e.g., 0.5 miles) and a long-walk

[126] See, for example, Federal Transit Administration, "Discussion Piece #11: Illustrative Mode-Choice and Summit Calculations for Travel by One Market Segment between a Pair of Zones for Base and Build Alternatives" (Workshop on Travel Forecasting for New Starts Proposals, Minneapolis, Minnesota, 2006), http://www.fta.dot.gov/planning/newstarts/planning_environment_5402.html.

distance (e.g., 1 mile). The TPB travel model is discussed in the next section of the report. For this section of the report, it is assumed that there is only one walk-to-transit threshold distance (e.g., 1 mile).

A typical method for calculating the percent walk to transit for each zone in the modeled area is the following:

1. Determine a threshold distance for walking to transit (or two threshold distances may be used).
2. Determine point locations where transit service can be accessed (i.e., transit stop nodes and transit stations). In other words, create a geographic data set that includes all the points representing transit stop nodes and transit stations.
3. Determine transit walksheds, which are polygons composed of circular areas around transit stop nodes. In other words, create a geographic data set that represents point buffers (i.e., circles of radius X = the threshold walking distance) around each transit stop node and transit station.
4. Given that there is already a polygon layer of TAZ boundaries, perform a polygon-on-polygon overlay (TAZ boundaries and walkshed boundaries) to create a new geographic data set that can be used to calculate the percent walk to transit value for each zone.
5. Calculate the percent walk to transit values for each zone.[127]

For many years, the Federal Transit Administration (FTA) has used a simple transit-access market segmentation system that has three segments known as "can walk," "must drive," and "no transit." These segments are defined at the zone-to-zone interchange level (the level used by most mode choice application programs) and can be determined using the percent-walk-to-transit (PWT) values in the production and attraction zones of the interchange. Before defining these three transit access markets, one must make a few assumptions:

1. Trips are in production/attraction format, not origin/destination format:
    a. A trip **production** is defined as the **home**-end of a home-based trip, or the **origin** of a non-home-based trip.
    b. A trip **attraction** is defined as the **non-home**-end of a home-based trip, or the **destination** of a non-home-based trip.
2. Travelers "access" transit at the production end of the trip and "egress from" transit at the attraction end of the trip.
3. At the production end of the trip, one may access the transit system by either walking or driving. Bike access is considered part of "walking."
4. At the attraction end of the trip, the only egress option is walking, since it is assumed that travelers do not have an automobile available at the non-home end of the trip.
5. The zonal PWT value functions as a probability value. Thus, if the PWT is 20%, this can be interpreted as meaning that, for trips that start (are produced in) or end (are attracted to) this

[127] See, for example, Yew Yuan, "Transit Walkshed Generator: A GIS Application to Generate Transit Walksheds, Technical Report," Draft (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, November 15, 2012).

zone, there is a 20% chance of that the trips will access or egress from the transit system via walking.

The "can walk" market is defined as the set of trips, within a given zone-to-zone interchange, where one can walk to transit at the production end of the trip (One can also walk from transit at the attraction end of the trip, but this is not a distinguishing feature, since "must drive" trips also walk from transit at the attraction end of the trip). Even though a trip may be included in the "can walk" segment, it is understood that drive access to transit is also a possibility for this market. In probability theory, if two events, A and B, are independent, the probability of the intersection of A and B equals the product of the probabilities of A and B, i.e.,

$$P(AB) = P(A) * P(B)$$

Since the PWT is considered a probability or likelihood of walking, and since the PWT for two given zones are considered to be independent, then, for a given zone-to-zone interchange, the probability of being in the "can walk" market -- P("can walk") or P(CW) -- is simply the product of the PWT of the production zone and the PWT of the attraction zone:

$$P(\text{"}can\ walk\text{"}\ for\ interchange\ ij) = PWT(i) * PWT(j)$$

The "must drive" market includes trips that must access the transit market via driving since the trip begins outside of the transit walk-access threshold distance. The "no transit" market includes trips for which transit is not an option, since, at the attraction end of the trip, there is no transit available within walking distance. So, for a given interchange, the probability of being in the "must drive" market -- P("must drive") or P(MD) -- is simply the product of the non-walkable share of the production zone and the PWT of the attraction zone:

$$P(\text{"}must\ drive\text{"}\ for\ interchange\ ij) = \big(1 - PWT(i)\big) * PWT(j)$$

Similarly, for a given interchange, the probability of being in the "no transit" market -- P("no transit") or P(NT) -- is simply the non-walkable share of the attraction zone:

$$P(\text{"}no\ transit\text{"}\ for\ interchange\ ij) = \big(1 - PWT(j)\big)$$

So, whereas the P(CW) and P(MD) are a function of the PWT in both the production and attraction zones, the P(NT) is a function of only the PWT in the attraction zone.   For a given interchange

$$P(CW) + P(MD) + \ P(NT) = 100\%$$

Table 75 presents 11 examples, or cases, of how various production and attraction PWT values are combined to get the probabilities of being in the "can walk," "must drive" and "no transit" zone-to-zone interchange market segments. For example, in the case #1, both the production zone and the attraction zone have percent-walk-to-transit (PWT) values of 0%, which results in the all the trips in the interchange being in the "no transit" market segment. By contrast, in case #2, PWT(i) = 0% and PWT(j) = 50%, which results in a 50%/50% split of trips in that interchange into the "must drive" and "no transit" markets. When, in case #3, PWT(i) = 0% and PWT(j) = 100%, this results in all trips being allocated to the "must drive" market.

In any of these cases, the number of trips in each of the three markets is equal to the total number of person trips in the zone-to-zone interchange times each of the three probabilities. **After trips have been assigned to the three markets, then the mode choice model is applied**, as described FTA's Discussion Piece #11 (Discussion_11_Summit_Calcs.doc) and shown in its associated spreadsheet (Discussion_11_Summit_Example_Calcs.xls).[128]

Table 75 Eleven examples showing how zonal percent-walk-to-transit values translate into probabilities of being in three transit-access markets: can walk, must drive, and no transit

	Zonal Attributes		**Zone-to-Zone Interchange Attributes**			
	Percent Walk to Transit Prod. Zone	**Percent Walk to Transit Attr. Zone**	**Proba-bility "Can Walk"**	**Proba-bility "Must Drive"**	**Proba-bility "No Transit"**	**Total Proba-bility**
	PWT(i)	PWT(j)	P(CW,ij)	P(MD,ij)	P(NT,ij)	
Case	A	B	A*B	(1-A)*B	(1-B)	
1	0%	0%	0.0%	0.0%	100.0%	100.0%
2	0%	50%	0.0%	50.0%	50.0%	100.0%
3	0%	100%	0.0%	100.0%	0.0%	100.0%
4	50%	0%	0.0%	0.0%	100.0%	100.0%
5	50%	50%	25.0%	25.0%	50.0%	100.0%
6	50%	100%	50.0%	50.0%	0.0%	100.0%
7	100%	0%	0.0%	0.0%	100.0%	100.0%
8	100%	50%	50.0%	0.0%	50.0%	100.0%
9	100%	100%	100.0%	0.0%	0.0%	100.0%
10	75%	50%	37.5%	12.5%	50.0%	100.0%
11	100%	75%	75.0%	0.0%	25.0%	100.0%

Ref: "percent_walk_transit_can_walk.xlsx"

Table 76, Table 77, and Table 78 provide a more complete picture of how P(CW), P(MD), and P(NT) each vary with the production and attraction PWT values. For example, Table 76 shows the probability of being in the "can walk" market segment for a zone-to-zone interchange as a function of the production and attraction percent-walk-to-transit values. The probability of "can walk" is zero if either the

[128] Federal Transit Administration, "Discussion Piece #11: Illustrative Mode-Choice and Summit Calculations for Travel by One Market Segment between a Pair of Zones for Base and Build Alternatives."

production PWT or the attraction PWT equal zero. By contrast, the probability of "can walk" is 100% only if the production PWT and the attraction PWT equal 100%.

Table 76 Probability of being in the "can walk" market segment for a zone-to-zone interchange, based on the production and attraction percent-walk-to-transit values

		PWT(i)										
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
PWT(j)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	10%	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
	20%	0%	2%	4%	6%	8%	10%	12%	14%	16%	18%	20%
	30%	0%	3%	6%	9%	12%	15%	18%	21%	24%	27%	30%
	40%	0%	4%	8%	12%	16%	20%	24%	28%	32%	36%	40%
	50%	0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
	60%	0%	6%	12%	18%	24%	30%	36%	42%	48%	54%	60%
	70%	0%	7%	14%	21%	28%	35%	42%	49%	56%	63%	70%
	80%	0%	8%	16%	24%	32%	40%	48%	56%	64%	72%	80%
	90%	0%	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%
	100%	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

Ref: "percent_walk_transit_can_walk.xlsx"

Table 77 shows the probability of being in the "must drive" market segment for a zone-to-zone interchange as a function of the production and attraction percent-walk-to-transit values. The probability of "must drive" is zero if either the production PWT equals 100% or the attraction PWT equal zero. By contrast, the probability of "must drive" is 100% only if the production PWT equals zero and the attraction PWT equals 100%.

Table 77 Probability of being in the "must drive" market segment for a zone-to-zone interchange, based on the production and attraction percent-walk-to-transit values

		PWT(i)										
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
PWT(j)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	10%	10%	9%	8%	7%	6%	5%	4%	3%	2%	1%	0%
	20%	20%	18%	16%	14%	12%	10%	8%	6%	4%	2%	0%
	30%	30%	27%	24%	21%	18%	15%	12%	9%	6%	3%	0%
	40%	40%	36%	32%	28%	24%	20%	16%	12%	8%	4%	0%
	50%	50%	45%	40%	35%	30%	25%	20%	15%	10%	5%	0%
	60%	60%	54%	48%	42%	36%	30%	24%	18%	12%	6%	0%
	70%	70%	63%	56%	49%	42%	35%	28%	21%	14%	7%	0%
	80%	80%	72%	64%	56%	48%	40%	32%	24%	16%	8%	0%
	90%	90%	81%	72%	63%	54%	45%	36%	27%	18%	9%	0%
	100%	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%

Ref: "percent_walk_transit_can_walk.xlsx"

Table 78 shows the probability of being in the "no transit" market segment for a zone-to-zone interchange as a function of solely on the attraction percent-walk-to-transit values. The probability of "no transit" is zero only if the attraction PWT equals 100%. By contrast, the probability of "no transit" is 100% only if attraction PWT equals zero.

Table 78 Probability of being in the "no transit" market segment for a zone-to-zone interchange, based solely on the attraction percent-walk-to-transit values

		PWT(i)										
		0%	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
PWT(j)	**0%**	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	10%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
	20%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
	30%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
	40%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%
	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
	60%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%
	70%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%
	80%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
	90%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Ref: "percent_walk_transit_can_walk.xlsx"

21.4.3.2 Version 2.4 Travel Model and AEMS

Regarding the percent-walk-to-transit (PWT) values used by the mode choice model of the TPB Version 2.4 Travel Model, two distance thresholds are used:

- Short walk to transit: ≤ 0.5 mile
- Long walk to transit: > 0.5 mile and ≤ 1 mile

Furthermore, the mode choice model differentiates between peak period transit service and off-peak period transit service. When calculating average headways and run times for transit routes running during the peak and off-peak periods, the historical practice, which is continued to this day, has been to use a subset of the period to represent service during the entire period. Specifically, the one-hour time period from 7:00 AM to 7:59 AM is used to represent peak-period conditions, and the five-hour time period from 10:00 AM to 2:59 PM is used to represent off-peak-period conditions.[129] It is also assumed that home-based-work (HBW) trips occur in the peak periods, and thus make use of the peak-period transit skims and peak-period PWT values. Similarly, it is assumed that the other trip purposes (HBO, HBS, NHW, and NHO) occur in the off-peak periods, and thus make uses of the off-peak transit skims and off-peak PWT values.

[129] Seifu, Milone, and Moran, "Highway and Transit Networks for the Version 2.3.66 Travel Model, Based on the 2016 CLRP and FY 2017-2022 TIP," 8.

The mode choice model in the TPB Version 2.4 Travel Model is a 15-choice, nested-logit mode choice (NLMC) model that includes

- Three auto modes (drive alone [DA], shared ride 2-person [SR2], and shared ride 3+person [SR3]);
- Four transit modes (commuter rail [CR], all bus [AB], all Metrorail [MR], and combined bus/Metrorail [BM]); and
- Three modes of access to transit (park and ride [PNR], kiss and ride [KNR], and walk [WK])

These 10 modes are combined in nests, in such a way that there are 15 choices in the mode choice model, as shown in Figure 66 (p. 183). The NLMC model is applied using the AECOM mode choice application program (AEMS).

Although light-rail transit (LRT), bus rapid transit (BRT), and streetcar are not explicit transit modes in the mode choice model, the model has, nonetheless, been designed to deal with these three special transit modes. Mode 5 is reserved for modeling LRT. Mode 10 is reserved for modeling BRT and streetcar. It is assumed that Mode 5 (LRT) will travel mostly on its own, dedicated right of way. By contrast, it is assumed that Mode 10 (BRT and streetcar) will travel mostly in mixed traffic on a shared right of way. Full details of how these three transit modes are modeled can be found in either the calibration report[130] or in section 21.1.1 of this report, but one of the key assumptions is the following:

- For transit path building/skimming, mode choice, and transit assignment
    - Mode 5 (LRT) is treated like Mode 3 (Metrorail)
    - Mode 10 (BRT or streetcar) is treated like Mode 1 (local bus)

When AECOM first developed the nested-logit mode choice model that TPB staff later adopted and recalibrated, AECOM used six percent-walk-to-transit values:[131]

- Percent of the zone within a short walk to Metrorail (Mode 3): PSWMET
- Percent of the zone within a long walk to Metrorail (Mode 3): PLWMET
- Percent of the zone within a short walk to any transit in the AM peak period: PSWALLAM
- Percent of the zone within a long walk to any transit in the AM peak period: PLWALLAM
- Percent of the zone within a short walk to any transit in the off-peak period: PSWALLOP
- Percent of the zone within a long walk to any transit in the off-peak period: PLWALLOP

However, in 2012, thanks to work done by Dusan Vuksan and Feng Xie, it was discovered that **the first two PWT values should include both Metrorail and LRT, not simply Metrorail**. This oversight had not been noticed before, since 1) LRT was not part of the base-year (year-2007) calibration networks, and 2) when LRT was modeled in close-in areas that already had significant transit service, the omission of LRT PWT values from the Metrorail/LRT group was hard to detect. However, in the work conducted by

[130] Milone et al., "Calibration Report for the TPB Travel Forecasting Model, Version 2.3," 6–3 to 6–5.
[131] AECOM Consult, Inc., "Post MWCOG – AECOM Transit Component of Washington Regional Demand Forecasting Model: User's Guide" (AECOM Consult, Inc., March 2005), 11.

Dusan and Feng, the LRT service was in suburban areas without significant surrounding transit service, and it became apparent that the model was underestimating LRT ridership. The net effect is that the first two zonal PWT values now include both Metrorail and LRT together:

- Percent of the zone within a short walk to Metrorail (Mode 3) **or LRT (Mode 5)**: PSWMET
- Percent of the zone within a long walk to Metrorail (Mode 3) **or LRT (Mode 5)**: PLWMET
- Percent of the zone within a short walk to any transit in the AM peak period: PSWALLAM
- Percent of the zone within a long walk to any transit in the AM peak period: PLWALLAM
- Percent of the zone within a short walk to any transit in the off-peak period: PSWALLOP
- Percent of the zone within a long walk to any transit in the off-peak period: PLWALLOP

"Any transit" includes all transit, including Metrorail and LRT service.

As of the Ver. 2.3.57 model (and continued in subsequent models, including the Ver. 2.4 Model), these new definitions have been incorporated in the automated ArcPy transit walkshed process.

There are two other assumptions governing the use of the six PWT values that need to be kept in mind. The first is definitional and the second relates to differentiating between peak-period and off-peak-period transit service. Regarding the definitional difference, when AECOM first developed the percent walk values, it defined them based on zonal areas:

$$Percent = \frac{walkshed\ area}{total\ zonal\ land\ area}$$

As an example, if a zone has half of its land area in the short-walk-to-Metrorail area and half of its land area in the long-walk-to-Metrorail area, one might expect that PSWMET = 50% and the PLWMET = 50%. However, the real PWT values for this scenario would be PSWMET = 50% and the PLWMET = 100%, since the short-walk area is always contained within the long-walk area. Consequently, if one wants the <u>net</u> area that is in the long walk area, one must subtract the two areas:

$$\text{Net Percent Long Walk} = (\text{Percent long walk}) - (\text{Percent short walk})$$

Evidence of this will be seen in later calculations discussed in this report.

The second assumption about PWT values relates to the coverage of transit service in the peak period versus in the off-peak period. It is assumed that transit service is accessed at the transit stop nodes (e.g., bus stops) and transit stations. In the case of Metrorail, there are no examples of stations that operate in the peak period, but do not operate in the off-peak period. Instead, all stations operate in all periods, even though the frequency of service changes (peak versus off-peak), and there are some <u>segments</u> that exist in the off-peak but not in the peak (e.g., in 2006, WMATA began running the Yellow Line from Gallery Place to Fort Totten, but only in the off-peak). However, since the transit walkshed buffers are drawn around points, and not segments, this does not affect Metrorail, meaning that the percent-walk-to-transit values need not be calculated separately for peak and off-peak Metrorail. Furthermore, now that we are including LRT with Metrorail for determining walksheds and calculating PWT values, it is also assumed that there is no difference between LRT stations operating in the peak periods and those in the off-peak.

Finally, transit access markets are determined within the mode choice application program (AEMS) by combining information from the six PWT values already discussed. AEMS is a compiled Fortran program, which requires a control file (*.CTL) for each mode choice model. The Version 2.4 Travel Model uses five mode choice models (one per trip purpose), and so it requires five control files (e.g., HBW_NL_MC.CTL, HBS_NL_MC.CTL, HBO_NL_MC.CTL, etc.). Percent-walk-to-transit values are stored in a zonal data file (ZONEV2.A2F) that is read into AEMS.

The remainder of this section of the report draws heavily from a 2012 memo from AECOM staff to COG/TPB staff.[132]

In each of the AEMS control files, the six PWT values are referenced using the following 4-character pattern:

<production or attraction indicator (1 char)><file number (1 char)><table number (2 char)>

The production or attraction zone status is indicated using the letter "i" (production") or "j" (attraction). In the current AEMS control files, the file number for the zonal data file is "8." Using current modeling conventions, the table numbers for the percent-walk-to-transit values go from 7 to 12 (and this information is noted in comment records in the AEMS control files). Thus, the following 3-digit codes refer to the six PWT values:

- 807: Percent of the zone within a short walk to Metrorail (Mode 3) or LRT (Mode 5): PSWMET
- 808: Percent of the zone within a long walk to Metrorail (Mode 3) or LRT (Mode 5): PLWMET
- 809: Percent of the zone within a short walk to any transit in the AM peak period: PSWALLAM
- 810: Percent of the zone within a long walk to any transit in the AM peak period: PLWALLAM
- 811: Percent of the zone within a short walk to any transit in the off-peak period: PSWALLOP
- 812: Percent of the zone within a long walk to any transit in the off-peak period: PLWALLOP

For example, if the control file refers to "i807", this means the percent of the zone within a short walk to Metrorail or LRT for production zone "i".

The aforementioned six percent-walk-to-transit values define the percentage of the zonal area that is within walking distance to transit, but they do not indicate the share of productions or attractions are assumed to walk. For example, not all transit trips that begin in a long-walk area will end up walking to transit (some will drive access). Consequently, the next step in the process is to calculate six values representing the likely walk-access markets. To do this, two assumptions are made:

[132] David Roden to Mark S. Moran, "Memorandum for Task Order 7 (FY13 Task 1) of COG Contract 12-006, Interpreting AEMS Market Shares," Memorandum, September 24, 2012.

1. 100% of the transit trips beginning or ending in the short-walk area will access transit via walking;
2. Only 25% of the transit trips beginning or ending in the long-walk area will access transit via walking (i.e., 75% are assumed to use drive access).

The six assumed walk markets are the following:

`PCMI`	Percent of trips assumed to access Metrorail/LRT via walking at the production zone
`PCMJ`	Percent of trips assumed to access Metrorail/LRT via walking at the attraction zone
`PCTIAM`	Percent of trips assumed to access all transit via walking at the production zone, AM peak per.
`PCTJAM`	Percent of trips assumed to access all transit via walking at the attraction zone, AM peak per.
`PCTIOP`	Percent of trips assumed to access all transit via walking at the production zone, off-peak per.
`PCTJOP`	Percent of trips assumed to access all transit via walking at the attraction zone, off-peak per.

Percent-walk-to-transit values are calculated using point buffers around transit stop nodes (i.e., stations, bus stops, etc.). As is the case with the original percent-walk-to-transit values, it is assumed that Metrorail and LRT service, in terms of stations in service, does not vary by time of day. By contrast, it is assumed that time-of-day variations in other transit modes, such as bus or commuter rail, will mean that the set of AM stop nodes will be different from the off-peak stop nodes. For this reason, there are two sets of percent-walk-to-transit values for all transit (one for AM and one for off peak), but only one for Metrorail and LRT.

For each of the five mode choice models (HBW, HBS, HBO, NHW, NHO), only four of these values are used at once (HBW gets AM and the other purposes get off-peak):

- PCMI: Percent of trips assumed to access Metrorail/LRT via walking at the production zone
- PCMJ: Percent of trips assumed to egress from Metrorail/LRT via walking at the attraction zone
- PCTI: Percent of trips assumed to access all transit via walking at the production zone
- PCTJ: Percent of trips assumed to egress from all transit via walking at the attraction zone

In all four cases, the following is assumed:

Percent of trips in the interchange assumed to be in one of the four categories =

(100% of the trips in the short-walk area) + (25% of the trips in the long-walk area)

In terms of equations in the mode choice control files, one finds:

- PCMI: Percent of trips assumed to access Metrorail/LRT via walking at the production zone
  - = (i807 + 0.25 * (i808 – i807)) / 100
- PCMJ: Percent of trips assumed to egress from Metrorail/LRT via walking at the attraction zone
  - = (j807 + 0.25 * (j808 – j807)) / 100
- PCTI: Percent of trips assumed to access "all transit" via walking at the production zone
  = (i809 + 0.25 * (i810 – i809)) / 100 for AM (used for HBW purpose)
  - = (i811 + 0.25 * (i812 – i811)) / 100 for off-peak (used for non-work purposes)

- PCTJ: Percent of trips assumed to egress from "all transit" via walking at the attraction zone
  - = (j809 + 0.25 * (j810 – j809)) / 100 for AM (used for HBW purpose)
  - = (j811 + 0.25 * (j812 – j811)) / 100 for off-peak (used for non-work purposes)

A distinction is drawn between Metrorail/LRT and "other transit" (i.e., transit that is neither Metrorail nor LRT). In the "can walk" market, there are four sub-markets, as shown in Table 79. Similarly, in the "must drive" market, there are two sub-markets, as shown in Table 80. Lastly, there is the "no access to transit" market, which is not part of either table.

Table 79 Four "can walk" sub-markets

Sub-mkt	Transit Service Available		Description
	Production TAZ	Attraction TAZ	
WM	MR/LRT	MR/LRT	Share that can use MR/LRT at both ends of the trip
W1	Other transit	MR/LRT	Share that can use "other transit" at production end and MR/LRT at attraction end of the trip
W2	Other transit	Other transit	Share that can use "other transit" at both ends of the trip
W3	MR/LRT	Other transit	Share that can use MR/LRT at production end and "other transit" at attraction end of the trip

Table 80 Two "must drive" sub-markets

Sub-mkt	Transit Service Available		Description
	Production TAZ	Attraction TAZ	
M1	Any transit	MR/LRT	Share that must drive to any transit at the production end and can use MR/LRT at the attraction end of the trip
M2	Any transit	Other transit	Share that must drive to any transit at the production end and can use "other transit" at the attraction end of the trip

AEMS makes use of WALK SEG commands to allow the model users to specify subzone segmentation such as "can walk," "must drive," and "no transit,"[133] so **the six sub-markets above, along with the "no transit" segment, are represented with <u>seven</u> WALK SEG (WS) variables in the AEMS control files**, and these six variables are calculated as follows from the previously-defined walk percentages:

"Can walk" market

- WSWM – Share of the "walk segment" that can use Metrorail/LRT at both ends of the trip
  = PCMI * PCMJ
- WSW1 – Share of the "walk segment" that can use "other transit" at production end and MR/LRT at attraction end of the trip
  = (PCTI – PCMI) * PCMJ

---

[133] "AECOM Consult Mode Choice Computation Programs, AEMS, Users Guide," 29–31.

- WSW2 – Share of the "walk segment" that cannot walk to Metrorail/LRT at either end of the trip (i.e., can use "other transit" at both ends of the trip)
  = (PCTI – PCMI) * (PCTJ – PCMJ)
- WSW3 – Share of the "walk segment" that can use MR/LRT at production end and "other transit" at attraction end of the trip
  = PCMI * (PCTJ – PCMJ)

"Must drive" market

- WSM1 – Share of the "walk segment" that must drive (to any transit) at the production, but can walk to Metrorail/LRT at the attraction
  = (1 – PCTI) * PCMJ
- WSM2 – Share of the "walk segment" that must drive (to any transit) at the production, but cannot walk to Metrorail/LRT at the attraction (i.e., must use "other transit" at the attraction)
  = (1 – PCTI) * (PCTJ – PCMJ)

"No transit" market

- WSNT – Share of the "walk segment" with no access to transit at the attraction end (thus, no access to transit for this zone-to-zone interchange)
  = (1 – WSWM – WSW1 – WSW2 – WSW3 – WSM1 – WSM2)

As was the case before with just three transit-access markets, the sum of the seven transit-access shares must equal 100% for any given interchange.

$$WSWM + WSW1 + WSW2 + WSW3 + WSM1 + WSM2 + WSNT = 100\%$$

Application of seven transit market segments to travel modes in the mode choice model

Given the aforementioned definitions of the transit-access market segments, the mode choice model must be applied to estimate the mode shares for each zone-to-zone interchange. In this case, the seven transit-access markets are applied in AEMS to the travel modes represented in the Ver. 2.4 nested-logit mode choice model as shown in Table 81.

Table 81 Application of the seven transit-access segments to travel modes represented in the Ver. 2.4 mode choice model

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			SOV	**SR2**	**SR3+**	**WK-CR**	**WK-BUS**	**WK-BU/MR**	**WK-MR**	**PNR-CR**	**KNR-CR**	**PNR-BUS**	**KNR-BUS**	**PNR-BU/MR**	**KNR-BU/MR**	**PNR-MR**	**KNR-MR**
1	WM	Can walk MR/LRT	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2	W1	Can walk 1	x	x	x	x	x	x		x	x	x	x	x	x	x	x
3	W2	Can walk 2	x	x	x	x	x	x		x	x	x	x	x	x		
4	W3	Can walk 3	x	x	x	x	x	x		x	x	x	x	x	x		
5	M1	Must drive 1	x	x	x					x	x	x	x	x	x	x	x
6	M2	Must drive 2	x	x	x					x	x	x	x	x	x		
7	NT	No transit	x	x	x												

Ref: "percent_walk_transit_can_walk.xlsx"

Where

- SOV = Drive Alone / single occupancy vehicle
- SR2 = Shared Ride with 2 persons
- SR3+ = Shared Ride with 3 or more persons
- WK-CR = walk to commuter rail
- WK-BUS = walk to bus
- WK-BU/MR = walk to/from bus and Metrorail/Light Rail
- WK-MR = walk to/from Metrorail/Light Rail only
- PNR-CR = park-n-ride to commuter rail
- KNR-CR = kiss-n-ride to commuter rail
- PNR-BUS = park-n-ride to bus
- KNR-BUS = kiss-n-ride to bus
- PNR-BU/MR = park-n-ride to bus and Metrorail/Light Rail
- KNR-BU/MR = kiss-n-ride to bus and Metrorail/Light Rail
- PNR-MR = park-n-ride to Metrorail/Light Rail

KNR-MR = kiss-n-ride to Metrorail/Light Rail

21.5 Transit access coding

In addition to the expanded set of transit submodes in the mode choice model, the Version 2.4 Model includes new transit access coding enhancements which cover five areas:

1. The station file;
2. Sidewalk links and zonal walk links;
3. Zonal auto-access links;
4. Station transfer links; and
5. Zonal percent-walk-to-transit calculations.

21.5.1 Station file

The station file is a dBase file (station.dbf) that contains information about Metrorail stations, commuter rail stations, light rail stations, bus rapid transit stations/stops, streetcar stations/stops, express-bus bus stops, and park-and-ride lots that serve these stations/stops. Each station file is associated with one scenario, with the most typical scenarios being the "modeled year" (e.g., 2017, 2020, 2040). This file contains information such as:

- The mode code, a single-letter code indicating Metrorail (M), commuter rail (C), etc.
- A flag indicating whether the station is active in the given year/scenario (Y/N)
- A flag indicating whether the station PNR lot is active (Y/N)
- Station name

Six new columns/variables were added to the station file that were not present in earlier versions of the regional travel model (e.g., Ver. 2.2 and before). Only the first four of these six variables are currently used:

1. Access distance code (NCT)

2. Parking capacity
3. Peak-period parking cost
4. Off-peak-period parking cost
5. Peak-period shadow price (not used)
6. Off-peak-period shadow price (not used)

The full list of variables in the station file is described in Table 40 on page 148, with the new variables in bold font.

The "access distance code," known as NCT in the autoacc5.s script, is a newly added variable in the station file that controls the number, extent, and directionality of PNR/KNR access links generated for each parking lot (in the case of PNR) or each station (in the case of KNR). Table 41 describes the meaning of each of the six access distance codes.

The access distance code, along with the transit mode, determines the maximum link distance for the drive-access-to-transit links generated by autoacc5.s for the TPB nested-logit mode choice model. The maximum link distances for PNR are shown in Table 83. Although not shown in the table, the maximum allowed link distance for KNR links is 3 miles. It is also important to note that the KNR links are generated to Metrorail stations, light rail stations, streetcar stops, and bus stops with parking lots, but not commuter rail stations.

Table 82 shows the mode codes that are used in the station file. "Station centroids" are used to build minimum-impedance paths to all Metrorail and commuter rail stations. In the table below, even though modes 5 and 10 are shown as having a range of numbers designated for station centroids, only Metrorail and commuter rail require station centroids.

Table 82 Mode codes used in the consolidated station file/database (station.dbf)

Mode	Mode Code	Station Centroid Range	Station Node Range
Metrorail (Mode 3)	M	5000-5999	8000-8999
Commuter rail (Mode 4)	C	6000-6999	9000-9999
Light rail transit (Mode 5), Bus rapid transit/streetcar (Mode 10)	L, N	7000-7999*	10000-10999
Bus (Modes 1, 2, 6-9)	B	Not used	Not used

Notes: * Station PNR centroids (a.k.a. dummy station centroids) are not required for Mode 5 (LRT) or Mode 10 (BRT/streetcar).[134] For the sake of consistency, the current COG coding practice is to refrain from using station PNR centroids for LRT, BRT, and streetcar. In other words, in the station file, the STAC variable is coded with a value of zero.

21.5.2 Sidewalk links and zonal walk links

In the Version 2.2 Travel Model and earlier models, there was a walk network (sidewalk network), used for transferring from one transit line to another, in downtown DC and downtown Silver Spring, Maryland. In the Version 2.3 and Version 2.4 Travel Models, there is a sidewalk network in almost the

[134] Jain to Milone and Moran, "MWCOG Network Coding Guide for Nested Logit Model (First Draft: September 20, 2007; Updated February 2008 and October 2010)," October 2010, 6 and 10.

entire modeled area. The regional sidewalk network is generated automatically using a script *walkacc.s* (see p. A-5 of the flowchart in Appendix A). *walkacc.s* creates a sidewalk network by converting all suitable highway links into sidewalk links (Mode 13). Examples of highway links that are not converted into sidewalk links include freeways, parkways, and ramps (Facility Type = 1, 5, or 6). In order to limit the size of the sidewalk network to links that are likely used for walking, *walkacc.s* eliminates sidewalk links from zones where the "percent walk to transit" is zero. There is also a way to supply the program with a list of sidewalk links to be manually added or subtracted to the automated list of sidewalk links. For example, one can manually add a sidewalk link for Memorial Bridge, and one can manually remove sidewalk links that should not exist due to a physical barrier. See Jain's 2010 memo for more details.[135]

walkacc.s also generates zonal walk-access-to-transit links (Mode 16 links). It automatically sweeps each TAZ, generating walk-access links from the zone centroid to all highway network nodes within a maximum walk distance (See Equation 3).

Equation 3 Maximum walk distance formula, used for generating walk-access-to-transit links

$$(\text{maximum walk distance}) = \sqrt{(\text{zonal area})} * 0.75$$

So, for a small, downtown zone with an area of 0.1 square miles, the program would calculate a maximum walk distance of 0.237 miles and connect all highway network stop nodes that lie within that distance from the zone centroid. There is an absolute maximum of 1.0 mile, which would be obtained for zones with a size of 1.78 square miles or greater. The actual calculated (straight-line) distance and computed walk time are stored on each link. No walk-access links are generated for zones with a zero percent walk to transit. Figure 69 shows zonal walk access links and sidewalk links in downtown Washington, D.C., near Farragut Square (TAZ 37, which is in the center of the figure). The thickest gray lines are the TAZ boundaries, which are not part of the actual highway or transit network, but are shown for reference. The lines emanating from each TAZ centroid (dark-blue, when the figure is viewed in color) are the zonal walk access links (Mode 16). The rectilinear (green) lines over many, but not all roads, are the sidewalk links (Mode 13). Mode 13 and 16 links can be shown in Cube Base by adding the four files "support link" files associated with walk-access to transit

- supl??wkam.asc for AM: suplABWKAM.asc, suplBMWKAM.asc, suplCRWKAM.asc, suplMRWKAM.asc
- supl??wkop.asc for off peak: suplABWKOP.asc, suplBMWKOP.asc, suplCRWKOP.asc, suplMRWKOP.asc

If prompted to give a coordinate file for 8,000-series nodes (Metrorail), use the following "support node" file: supnmrwkam.dbf. If prompted to give a coordinate file for 9,000-series nodes (commuter rail), use the following "support node" file: supncrwkam.dbf.

135 Manish Jain to Ronald Milone and Mark Moran, "MWCOG network coding guide for Nested Logit Model (First draft: September 20, 2007; Updated February 2008 and Oct. 2010)," Memorandum, October 2010, 7.

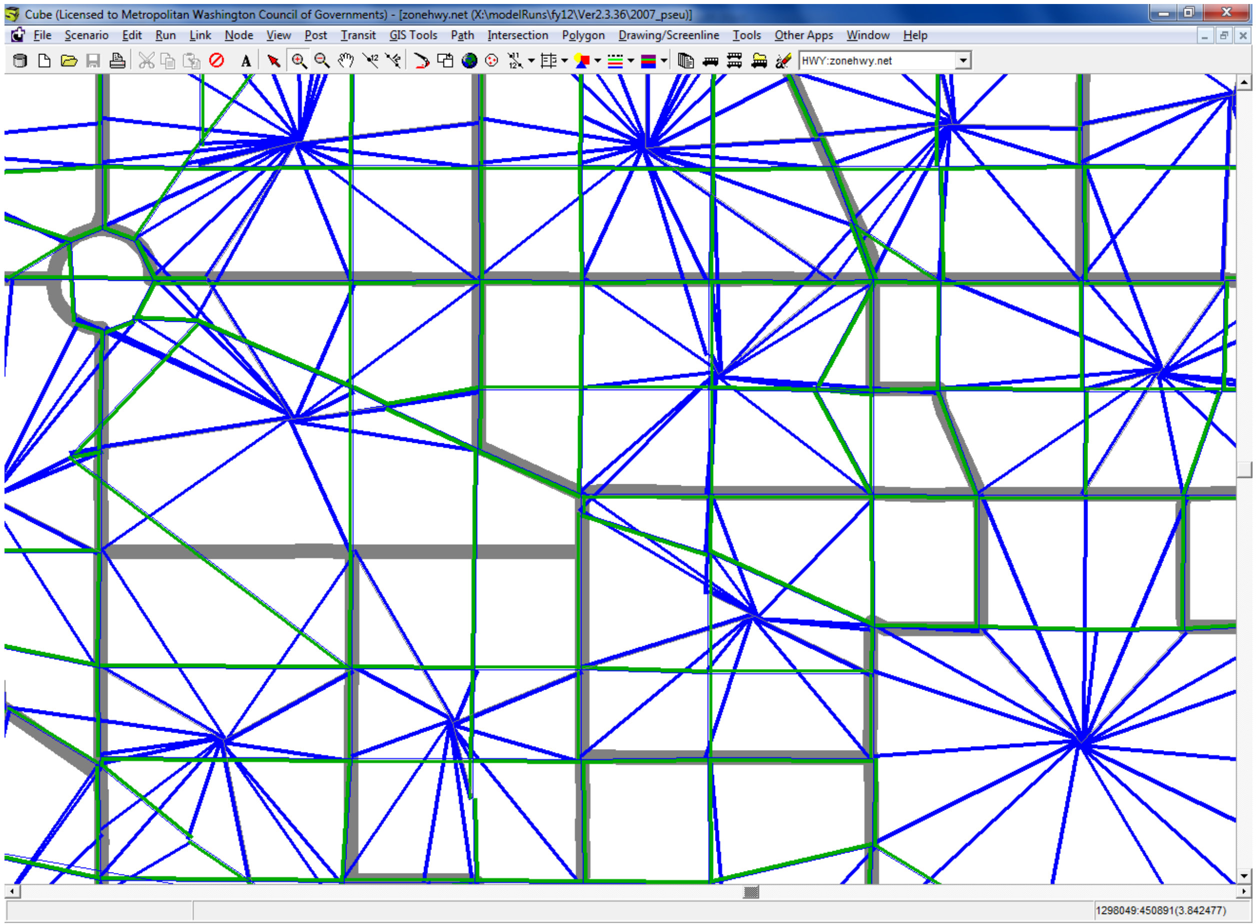


Figure 69 Zonal walk access links and sidewalk links in downtown DC near Farragut Square (Ver. 2.4 NL MC model)

Ref: "X:\modelRuns\fy12\Ver2.3.36\2007_pseu\zonehwy.net"

21.5.3 Zonal auto-access links

The Cube Voyager script *Autoacc5.s*, originally created by AECOM Consult as a Fortran program and later transferred to Voyager script by TPB staff, is used to generate auto-access-to-transit links. Zonal auto access links are generated by transit mode (Metrorail, commuter rail, light rail, BRT, streetcar, and bus) for both the peak ("AM") and off-peak ("mid-day") time periods. Auto access links (Mode 11) are a function of multiple criteria:

- Orientation toward downtown (defined as TAZ 8, which corresponds to The Ellipse, just south of The White House)
- A backtracking penalty and a prohibition of crossing the Potomac River (except for trips from Loudoun County to MARC commuter rail);

- A maximum link distance (Table 83), which is a function of station type (e.g., terminal vs. non-terminal) and transit mode[136];
- Manually specified overrides; and
- Distances based on the highway skims from the highway network that includes dummy centroids representing Metrorail and commuter rail stations.

Table 83 Maximum link distances for drive-access-to-transit links: Ver. 2.4 NL MC model

Mode	Access Dist. Code	Maximum Connect. Length (miles)
Metrorail station PNR	1	15
Metrorail station PNR	2	5
Metrorail station PNR	3	3
Metrorail station PNR	0	3
Commuter rail station PNR	1	15
Commuter rail station PNR	2	10
Commuter rail station PNR	0	5
Bus PNR	1	5
Bus PNR	0	3
BRT/Street car PNR	1	5
BRT/Street car PNR	0	3
LRT PNR	1	5
LRT PNR	0	3

Ref: I:\ateam\meetings_conf\transitModelingGroup\2007-11-07\maxDistForAutoAccConnect.xls

Figure 70 shows kiss-and-ride (KNR) auto-access-to-transit links for the AM period associated with Metrorail stations in Northern Virginia.

[136] The maximum auto-access link distances in the Ver. 2.3/Ver. 2.4 Models are defined in the \Inputs\StaAcc.dbf file. In theory, a model user could alter maximum link distances by modifying this input file. It should be noted that, however, a significant change to this file may necessitate the re-calibration / re-validation of the transit models.

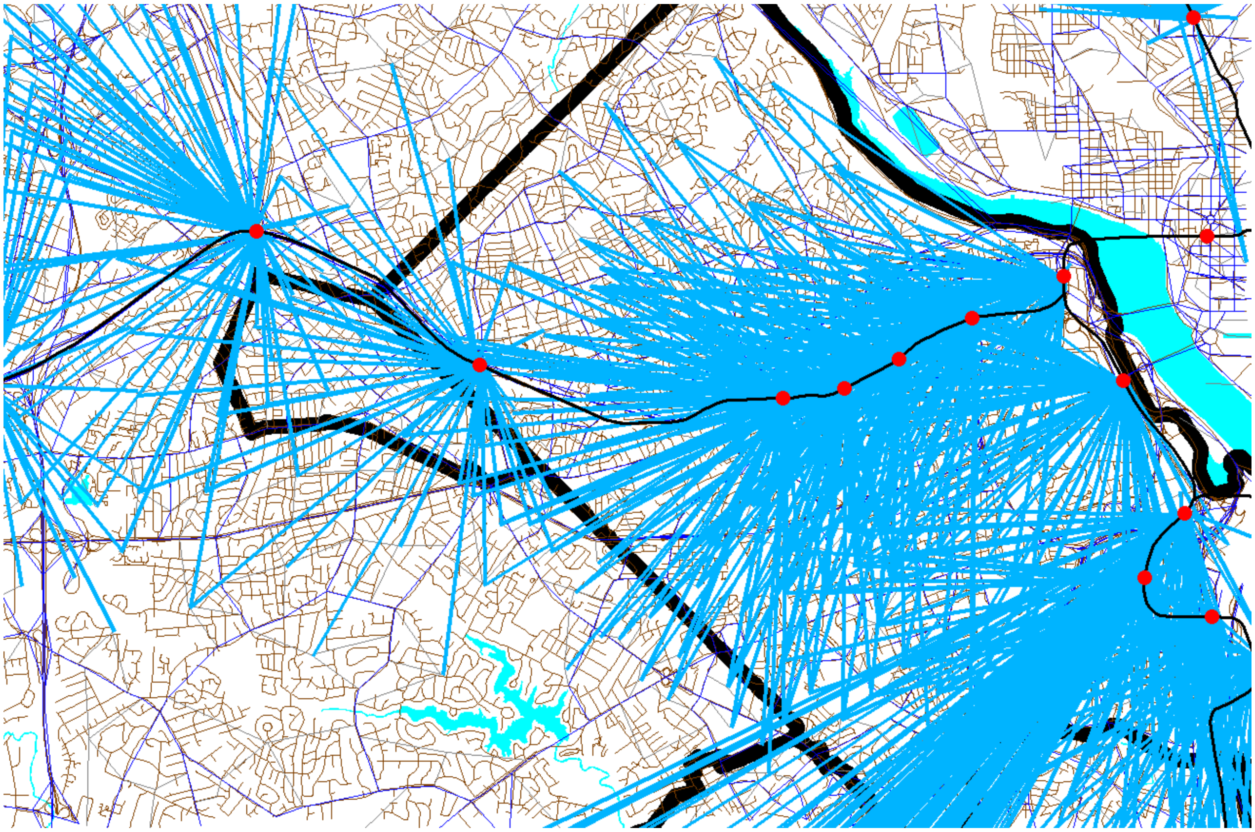


Figure 70 Kiss-and-ride (KNR) auto access links to Metrorail stations in Northern Virginia

Ref: "X:\modelRuns\fy12\Ver2.3.36\2007_pseu\zonehwy.net"

Figure 71 shows park-and-ride (PNR) auto-access-to-transit links for the AM period associated with Metrorail stations in Northern Virginia. Notice that the Orange Line stations from Clarendon to Rosslyn do not have PNR-access links, since they do not have PNR lots. By contrast, these stations do have KNR-access links, since these stations can have KNR access. The Pentagon Metrorail station is another example of a station where the model does not allow travelers to have PNR access, but they may have KRN access. Notice that the KNR-access links and PNR-access links are not shaped like a circular "starburst," but are somewhat flattened, due to the backtracking penalty. This was done to mimic the behavior of travelers who tend not to want to backtrack when driving to park at or be dropped off at a Metrorail or commuter rail station.

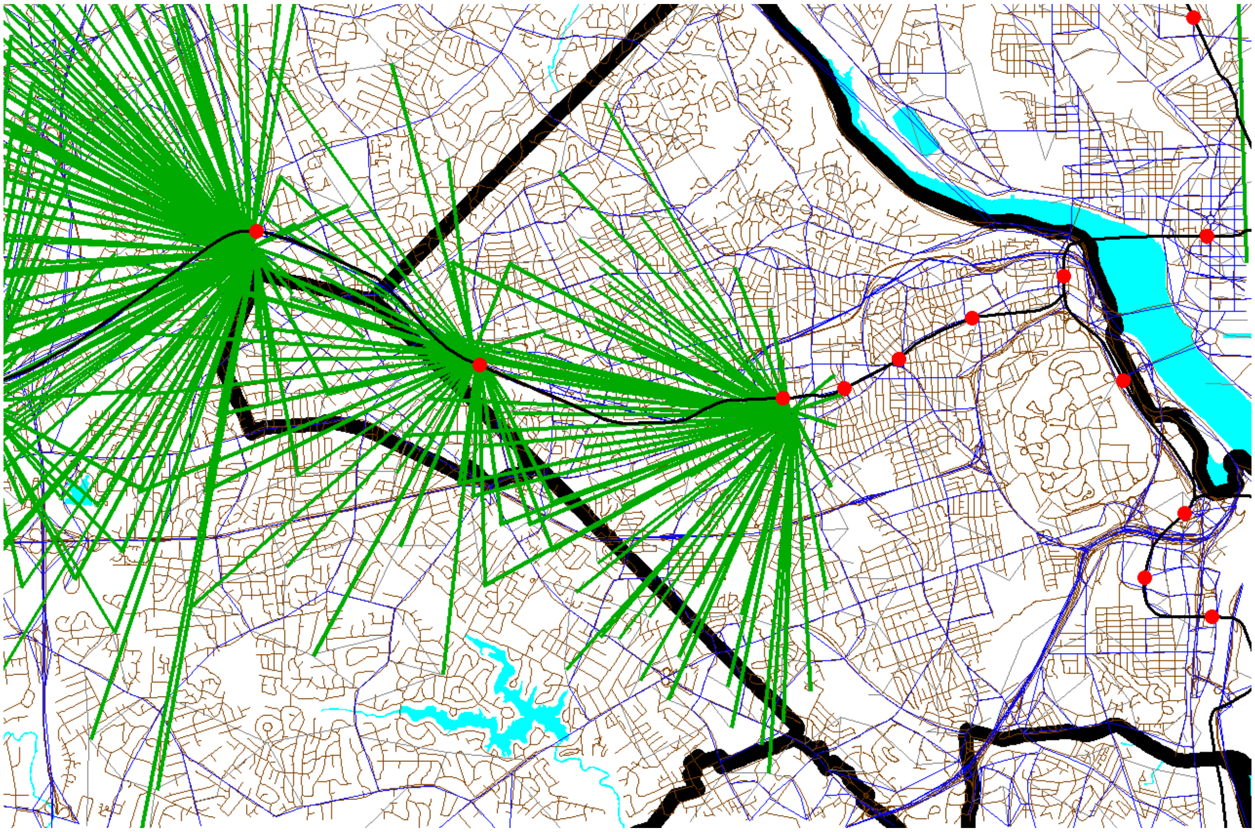


Figure 71 Park-and-ride (PNR) auto access links to Metrorail stations in Northern Virginia

Ref: "X:\modelRuns\fy12\Ver2.3.36\2007_pseu\zonehwy.net"

21.5.4 Station transfer links

Station transfer links are walk links connecting:

Stations and sidewalks (Mode 12)
Stations and bus service (Mode 12)
Stations and PNR lots (Mode 15)

These links are generated automatically from data in the station file. **For PNR-station transfer links, the walk time is a function of parking capacity and parking cost, since it is reasoned that bigger parking lots and more expensive parking lots make them more burdensome to use.**[137]

The station file also includes shadow parking price variables (STAPKSHAD & STAOPSHAD, see Table 40) which are not currently used. However, the PNR capacity and parking costs are coded into the station file and are used by *Parker.s* to create PNR-to-station links read into TRNBUILD. The PNR-to-station time/impedance is computed as:[138]

[137] Jain to Milone and Moran, 6.
[138] Personal communication from Ron Milone, 9/25/13.

Equation 4 PNR-to-station time/impedance

$$(PNR\ time) = walk + SHAD + (MinPerDollar * park)$$

where

$$(PNR\ time) = \text{PNR} - \text{to} - \text{station link time/impedance}$$
$$walk = (1\ to\ 5\ min)\text{Base time, which is a function of the number of PNR spaces}$$
$$SHAD = \text{Shadow cost (min.)}$$
$$MinPerDollar = \text{Equivalent minutes per dollar. Currently set to 6 (each dollar paid = 6 min.)}$$
$$Park = Parking\ cost\ at\ station\ divided\ by\ two$$

The Mode 15 links are generated by the script parker.s (see page A-5 of the flowchart in Appendix A). The following files contain the mode 15 links:

```
busampnr.tb
busoppnr.tb
comampnr.tb
comoppnr.tb
lrtampnr.tb
lrtoppnr.tb
metampnr.tb
metoppnr.tb
newampnr.tb
newoppnr.tb
```

The mode 12 links are developed manually using the COGTools geodatabase. These links can be found in the following files (see page A-5 of the flowchart in Appendix A):

```
Com_Bus.tb
LRT_bus.tb
Met_Bus.tb
NEW_bus.tb
```

21.5.5 Zonal percent walk to transit calculations

The zonal percent walk is the percent of a zone's area that lies within walking distance to transit service (i.e., a transit stop node, such as a bus stop or rail station). A short walk is defined as one that is less than or equal to 0.5 miles and a long walk is defined as one that is less than or equal to one mile. The following walk designations are used:

Short walk to Metrorail (<= 0.5 miles);
Long walk to Metrorail (>0.5 and <= 1.0 miles);
Short walk to AM transit;
Long walk to AM transit;
Short walk to off-peak transit;
Long walk to off-peak transit.

These walk-to-transit areas are sometimes called transit walksheds. Under contract with COG, AECOM has developed a new, automated/integrated Python/ArcPy walkshed process that is describe in Chapter 11 ("Building transit walksheds and calculating zonal walk percentages") on p. 123.

21.6 Transit path-building procedures

Given the segmentation in the model, 24 separate transit paths can be enumerated between each production zone and attraction zone:

Three modes of access to transit

1. Walk
2. Park and ride (PNR driver)
3. Ride to transit/KNR (drop-off/pick-up, or ride with a PNR driver)

Four transit modes/combinations

4. Commuter rail (alone and in combination with bus and/or Metrorail)
5. Bus-Metrorail (bus and Metrorail used in combination)
6. All bus (buses only)
7. All Metrorail (Metrorail only)

Two time-of-day periods

8. Peak (represented by transit service in the AM peak hour)
9. Off-peak (represented by transit service in the five-hour midday period)

However, at present, PNR and KNR to commuter rail are combined as a single path, since, for commuter rail, the PNR- and KNR-access links are identical. Consequently, the number of transit paths built between each production/attraction zone pair is 22. Table 84 summarizes the paths and available transit sub modes in each path. Again, in this figure, "drive to commuter rail" and "KNR to commuter rail" are combined into one category.

Run times for transit routes are controlled by the RUNTIME keyword (TRNBUILD).[139] As stated previously, path weights are consistent with the weights used in the mode choice model:

- Drive access time: Equal to 1.5 times the in-vehicle time
- Walk access time: Equal to 2.0 times the in-vehicle time
- Other out-of-vehicle time: Equal to 2.5 times the in-vehicle time

Headway combination between two or more transit routes is allowed to occur provided 1) the routes share the same transit mode code and 2) the difference between the run time and the minimum run time is less than a designated number of minutes (5 minutes for AM and 10 minutes for off peak). A maximum path time is set at 360 weighted minutes. There is no weighting of in-vehicle time by transit

[139] In Ver. 2.3.57a and earlier, bus IVT skims were adjusted to reflect the general level of road congestion using the factor table Lbus_TimFTRS.asc. In Ver. 2.3.66 and later models, this adjustment is now done directly to the mode 1, 6, and 8 local bus line files (*.TB) using the script Adjust_Runtime.s.

sub-modes (i.e., all transit modes have an IVT weight of 1.0). The maximum initial wait time for all ten transit modes is set at 60 perceived minutes. The minimum transfer wait time is 4.0 minutes for bus (Modes 1, 2, 6, 7, 8), 0 minutes for Metrorail (Mode 3), 4.0 minutes for commuter rail (Mode 4), 0 minutes for LRT (Mode 5), 10.0 minutes for express bus (Mode 9), and 4.0 minutes for Mode 10 (streetcar and/or BRT).

Table 84 Path-specific parameters used in transit path building

		Transit Submodes			
Path	**Path Parameter**	**Comm Rail**	**Express Bus**	**Local Bus**	**Metrorail**
Walk-to-Commuter Rail	Modes Available	X		X	X
	Weight	1.0		1.0	1.0
	Path Testing	must appear		can appear	can appear
Walk-to-Bus/Metrorail	Modes Available		X	X	X
	Weight		1.0	1.0	1.0
	Path Testing		either must appear		must appear
Walk-to-Bus	Modes Available		X	X	
	Weight		1.0	1.0	
	Path Testing		either must appear		
Walk-to-Metrorail	Modes Available				X
	Weight				1.0
	Path Testing				must appear
Drive-to-Commuter Rail	Modes Available	X		X	X
	Weight	1.0		1.0	1.0
	Auto access links to	CRsta. w/ parking		no	no
	Path Testing	must appear		can appear	can appear
K&R-to-Commuter Rail	Modes Available	X		X	X
	Weight	1.0		1.0	1.0
	Auto access links to	CRsta. w/ parking		no	no
	Path Testing	must appear		can appear	can appear
Drive-to-Bus/Metrorail	Modes Available		X	X	X
	Weight		1.0	1.0	1.0
	Auto access links to		all Bus park-ride lots		MRsta. w/ parking
	Path Testing		either must appear		must appear
K&R-to-Bus/Metrorail	Modes Available		X	X	X
	Weight		1.0	1.0	1.0
	Auto access links to		all Bus park-ride lots		all MRsta.
	Path Testing		either must appear		must appear
Drive-to-Bus	Modes Available		X	X	
	Weight		1.0	1.0	
	Auto access links to		all Bus park-ride lots		MRsta. w/ parking
	Path Testing		either must appear		
K&R-to-Bus	Modes Available		X	X	
	Weight		1.0	1.0	
	Auto access links to		all Bus park-ride lots		all MRsta.
	Path Testing		either must appear		
Drive-to-Metrorail	Modes Available				X
	Weight				1.0
	Auto access links				MRsta. w/ parking
	Path Testing				must appear
K&R-to-Metrorail	Modes Available				X
	Weight				1.0
	Auto access links				all MRsta.
	Path Testing				must appear

Source: AECOM Consult, Inc.[140]

21.7 Treatment of parking costs and terminal times for non-transit-related trips

Parking costs can be associated with either a transit trip (in the case of a drive-access transit trip) or a non-transit trip (an auto person trip, where no transit is involved). For drive-access transit trips, the cost of parking is stored in the station file. For park-and-ride (PNR)-to-station transfer links, the walk time is a function of parking capacity and parking cost,[141] but parking cost is not used as part of the transit path-building. For driving trips not involving transit, a parking cost model is used, where parking cost is a function of employment density. The next section of the report concerns parking costs that are not associated with a transit trip.

21.7.1 Non-transit-related parking costs

In applying the Version 2.4 Model, prior to the execution of the mode choice model, a Voyager script (*prefarv23.s*) is used to generate zonal files containing zonal parking costs and highway terminal times (the time to park and "un-park" a vehicle). The files are, in turn, read into the mode choice model upon execution. The Version 2.4 Model includes a new parking cost model estimated based on the 2007/2008 HTS.[142] HBW trip purpose utilizes the daily parking rate, while all other purposes use the hourly parking rate. Thus, two separate parking cost models were estimated, one for daily rates and one of hourly rates. For the daily rates model, the observed data indicated that it is rare for a traveler to incur parking costs in area types 4 and above, thus the model was estimated only for area types 1-3. A daily parking cost was estimated to be:

Equation 5 Daily non-transit-related parking cost for area types 1-3

$$\text{Non-transit-related parking cost} = 2.1724 * \ln(\text{floating employment density}) - 15.533$$

The resulting non-transit-related parking costs are also shown in Figure 72.

[140] AECOM Consult, Inc., *Post MWCOG – AECOM Transit Component of Washington Regional Demand Forecasting Model: User's Guide* (AECOM Consult, Inc., March 2005).
[141] Jain to Milone and Moran, "MWCOG Network Coding Guide for Nested Logit Model (First Draft: September 20, 2007; Updated February 2008 and October 2010)," October 2010, 6.
[142] Mary Martchouk to Mark S. Moran, "Developing a Parking Cost Model for Automobile Modes in the Version 2.3 Travel Model," Memorandum, June 14, 2010.

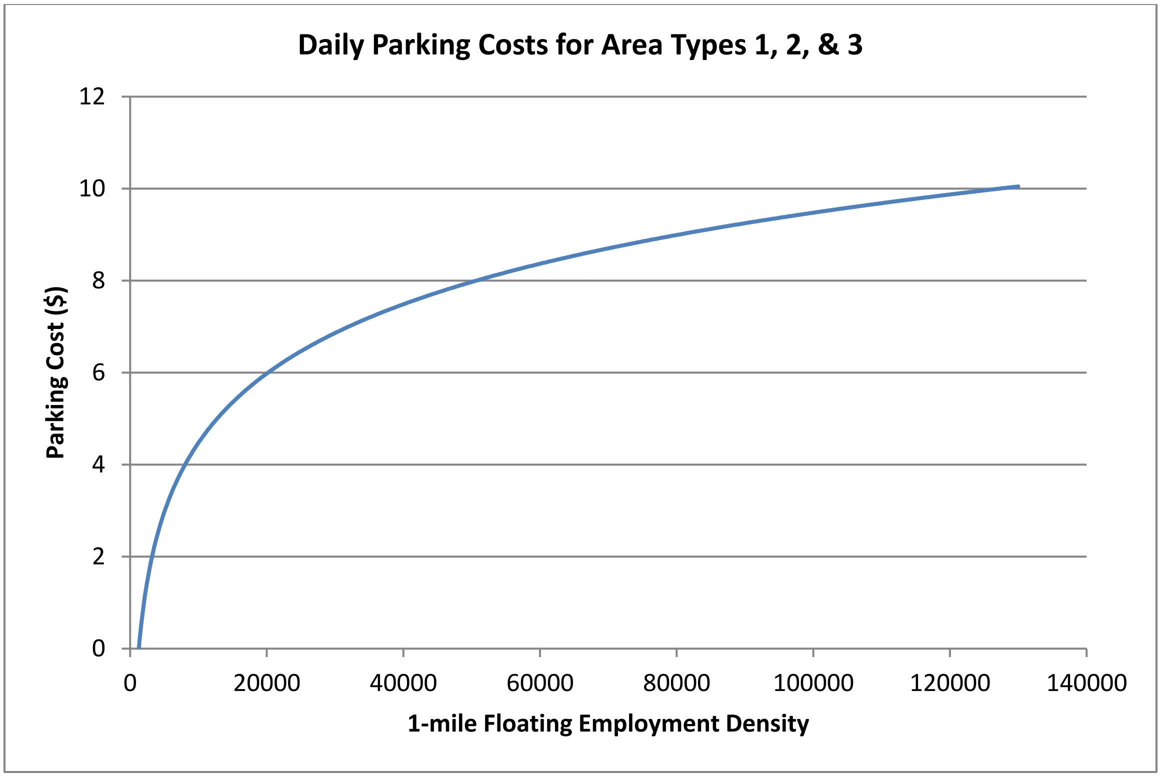


Figure 72 Non-transit-related, daily parking cost model used in the Version 2.4 Model

Ref: I:\ateam\docum\FY11\Ver2.3\modelDoc_v3\02_userGuide\parking_scatterplots.xlsx

For hourly rates, there was insufficient data to estimate a reliable model. Thus, a decision was made to assign a flat rate based on the prevalent metered rates for each area type. For area type 1, the most prevalent metered rate of parking was $2.00 and thus that value was selected. For area type 2, the average hourly parking cost was assumed to be $1.00. For area type 3, the value of $0.25 per hour was selected. For area types 4 and higher, no parking cost was anticipated.

21.7.2 Non-transit-related highway terminal time assumptions

Non-transit-related highway terminal time is typically associated with the average time spent parking or "un-parking" an automobile. The current mode choice model application program considers highway terminal time only at the attraction end. Highway time is calculated as a function of employment density, as shown in Table 85.

Table 85 Non-transit-related highway terminal time as a function of employment density

Employment density range (Emp/Sq. Mi.)	Highway terminal time (minutes)
0 - 4,617	1
4,618 - 6,631	2
6,632 - 11,562	4
11,563 - 32,985	6
32,986 +	8

21.8 Auto Operating Costs

The auto operating cost in the mode choice model relate to out-of-pocket expenditures directly associated with the requirements of an automobile trip, including fuel, oil, maintenance, tire wear, etc. (auto ownership costs including insurance, registration fees are not included). The mode choice model expresses operating costs as a per-mile rate (year-2007 cents) that is specified as a parameter in the nested-logit mode choice model control files. We are currently using 10 cents per mile and this rate is not varied over time (i.e., the auto operating cost for 2016 and 2030 are both assumed to be 10 cents per mile, in year-2007 cents).

22 Time-of-Day Processing

22.1 Overview

The time of day process (page A-9 of the flowchart in Appendix A) is applied to convert daily vehicle trips to time-of-day vehicle trips for the four modeled time periods, prior to being assigned to the network. The process is applied with the *Time-of-Day.s* and *Misc_Time-of-Day.s* scripts. The *Prepare_Trip_Tables_for_Assignment.s* script is used to combine the various trips by time period into combined trip tables for the traffic assignment process. The input and output files are listed in Table 86 and Table 87.

Table 86 Inputs to time-of-day process

Daily Auto Driver Trips, by Occupancy Levels	HBW<ITER>.ADR, HBS<ITER>.ADR, HBO<ITER>.ADR, NHW<ITER>.ADR, NHO<ITER>.ADR	Binary
Daily Miscellaneous and Truck Trips (From the \Inputs subdirectory)	VISI.ADR, TAXI.ADR, SCHL.ADR, AIRPAX.ADR, XXCVT.VTT, XXAUT.VTT,	Binary
Truck and commercial vehicle trip tables	MTK<ITER>.PTT, HTK<ITER>.PTT, COM<ITER>.PTT	Binary
Adjustment or 'delta' trip tables used for commercial and truck models	CVDelta_3722.trp TKDelta_3722.trp	Binary
Time of Day Percent File by Purpose, Mode, and Direction	todcomp_2008HTS.dbf	DBF

Note: <ITER> =PP, i1…i4

Table 87 Outputs of time-of-day process

Trip Tables by Time Period	AM<ITER>.ADR, MD<ITER>.ADR, PM<ITER>.ADR, NT<ITER>.ADR,	Binary
Miscellaneous Time-of-Day Files	MISCAM<ITER>.TT, MISCMD<ITER>.TT, MISCPM<ITER>.TT, MISCNT<ITER>.TT	Binary
Total Vehicle Trips by Six Markets T1 – SOVs T2 – 2 occ. vehicles T3 – 3+ occ. vehicles T4 – Commercial vehicles T5 – Medium + Heavy Trucks Combined T6 – Airport passenger auto-driver trips/vehs.	<ITER>AM.VTT, <ITER>MD.VTT, <ITER>PM.VTT, <ITER>NT.VTT	Binary

23 Traffic Assignment

23.1 Overview

As mentioned in section 2.3 ("Modeling steps and the speed feedback loop"), the Version 2.4 Travel Model uses a user-equilibrium (UE) traffic assignment, which is the generally accepted method for static traffic assignments. The user equilibrium condition was defined by Wardrop in 1952.[143] According to Wardrop's first principle, in the case where all trip makers perceive costs the same way (i.e., no stochastic effects):

> *Under equilibrium conditions, traffic arranges itself in congested networks such that all used routes between an O-D pair have equal and minimum costs, while all unused routes have greater or equal costs.*[144]

Furthermore, the assignment process is a multi-class UE assignment, meaning that separate user classes can be assigned at the same time. The Version 2.4 Model includes six user classes:

1. Single-occupant vehicle (SOV)
2. High-occupant vehicle with two persons (HOV2)
3. High-occupant vehicle with three+ persons (HOV3+)
4. Medium and heavy trucks
5. Commercial vehicles
6. Airport passengers traveling to/from the three commercial airports

In Version 2.2, there were only five user classes, since the commercial vehicles category was grouped with medium/heavy truck. The primary reason for distinguishing truck markets is to allow for the option of using passenger car equivalents (PCEs) in the traffic assignment process. The use of PCEs has not yet been implemented, but they will be considered in future developmental work.

Additionally, the Version 2.4 Model includes four time-of-day periods for traffic assignment:

- AM peak period (3 hours: 6:00 AM to 9:00 AM)
- Midday period (6 hours: 9:00 AM to 3:00 PM)
- PM peak period (4 hours: 3:00 PM to 7:00 PM)
- Night/early morning period (11 hours: 7:00 PM to 6:00 AM)

Most MPOs use a UE traffic assignment that relies on an optimization algorithm known as the Frank-Wolfe (FW) algorithm.[145] The FW algorithm is essentially a series of all-or-nothing traffic assignments where flows are combined using weights from an optimization process whose goal is to minimize an

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[143] John Glen Wardrop, "Some Theoretical Aspects of Road Traffic Research," *Proceedings of the Institution of Civil Engineers* 1, no. 3 (January 1952): 325–62, https://doi.org/10.1680/ipeds.1952.11259.
[144] Juan de Dios Ortúzar and Luis G. Willumsen, *Modelling Transport*, 2nd ed. (John Wiley & Sons, 1994), 304.
[145] Frank and Wolfe, "An Algorithm for Quadratic Programming."

objective function. The process stops when a stopping criterion is met. Previously, the Version 2.2 Travel Model used the following UE stopping criterion: When the relative gap ≤ 10^{-3} OR the number of UE iterations ≥ 300. The relative gap threshold was always intended to be the primary stopping criterion, with the number of UE iterations functioning as a backup criterion. Now, however, we have moved to what we call a "progressive" relative gap stopping criterion. The idea is that, in the early SFB iterations, the UE closure criterion will be relatively loose, but, in the later SFB iterations, the UE closure criterion will tighten, as shown in Table 9.

Table 88 User equilibrium closure criterion (relative gap) varies by speed feedback iteration

Speed feedback iteration	Primary closure criterion for UE traffic assignment	Secondary closure criteria for UE traffic assignment
Pump prime	Relative gap ≤ 10^{-2} (i.e., 0.01)	Number of UE iterations ≥ 1000
1	Relative gap ≤ 10^{-2} (i.e., 0.01)	Number of UE iterations ≥ 1000
2	Relative gap ≤ 10^{-2} (i.e., 0.01)	Number of UE iterations ≥ 1000
3	Relative gap ≤ 10^{-3} (i.e., 0.001)	Number of UE iterations ≥ 1000
4	Relative gap ≤ 10^{-4} (i.e., 0.0001)	Number of UE iterations ≥ 1000

By using the higher value for UE iterations (1000 vs. 300), we were able to ensure that this secondary criterion is unlikely to be used as the stopping criterion. Based on a series of sensitivity tests,[146] we found that the new progressive relative gap scheme results in a relatively converged traffic assignment, without the extremely lengthy model run times that would be needed if one were to use a high threshold (e.g., 10^{-4} relative gap) for each of the five SFB iterations. The Version 2.4 Travel Model uses a slight variation of the FW algorithm, called the *bi-conjugate* Frank-Wolfe algorithm, which converges marginally faster than the classic FW algorithm.

23.2 Two-step assignment

23.2.1 Prior to 2008: 5 user classes

The Version 2.2 traffic assignment process prior to the fall of 2008 consisted of three separate assignment executions for each speed feedback (SFB) loop: AM peak period, PM peak period, and the off-peak period (see Table 89). To respect the various highway path options and prohibitions in the Washington region, five separate markets or "user classes" (trip tables) were loaded during each assignment execution:

1. Single-occupant vehicles, including commercial vehicles (SOV),
2. 2-occupant vehicles (HOV2),
3. 3+occupant vehicles (HOV3+),
4. Trucks (medium and heavy), and

[146] Moran and Milone, "Status Report on the Version 2.3 Travel Model: Updates to the Model and Year-2010 Validation," 7–11.

5. Airport passenger vehicles.

Table 89 Traffic assignment in the Version 2.2 Travel Model prior to fall 2008: Three multiclass assignments

For each SFB loop	Assignment period	Trip markets assigned
Assignment 1	AM peak	1. SOV 2. HOV2 3. HOV3+ 4. Trucks 5. Airport passengers
Assignment 2	PM peak	1. SOV 2. HOV2 3. HOV3+ 4. Trucks 5. Airport passengers
Assignment 3	Off-peak	1. SOV 2. HOV2 3. HOV3+ 4. Trucks 5. Airport passengers

In the fall of 2008, as part of air quality conformity work, the traffic assignment process was modified to improve the assignment of HOV/HOT traffic on the Capital Beltway in Virginia and the I-395 Shirley Highway.[147] In the revised process, shown in Table 90, the AM traffic assignment was split into two parts: non-HOV 3+ (i.e., SOV, HOV2, trucks, and airport passengers) and HOV 3+. Similarly, the PM traffic assignment was also split into two parts: non-HOV 3+ and HOV3+. This new traffic assignment process is sometimes referred to as the "two-step assignment," since it splits the AM and PM assignment each into two parts.[148]

[147] Ronald Milone and Mark S. Moran, "TPB Models Development Status Report" (November 21, 2008 meeting of the Travel Forecasting Subcommittee of the Technical Committee of the National Capital Region Transportation Planning Board, held at the Metropolitan Washington Council of Governments, Washington, D.C., November 21, 2008).

[148] Jinchul Park to Files, "Two Step Traffic Assignment for HOT Lane Modeling in 2008 CLRP," Memorandum, December 2, 2008.

Table 90 Traffic assignment in the Version 2.2 Travel Model prior to fall 2008: Five multiclass assignments

For each SFB loop	Assignment period	Trip markets assigned
Assignment 1	AM peak (non-HOV3+)	1. SOV 2. HOV2 3. Trucks 4. Airport passengers
Assignment 2	AM peak (HOV3+)	1. HOV3+
Assignment 3	PM peak (non-HOV3+)	1. SOV 2. HOV2 3. Trucks 4. Airport passengers
Assignment 4	PM peak (HOV3+)	1. HOV3+
Assignment 5	Off-peak	1. SOV 2. HOV2 3. HOV3+ 4. Trucks 5. Airport passengers

The result was five (not three) traffic assignments, with either four, one, or five user classes, depending on which assignment was being conducted. The fifth traffic assignment, representing the off-peak period, included all five trip markets (it was only the two peak-period assignments where the non-HOV 3+ and HOV 3+ were split out).

In the first step of the two-step assignment (assignments #1 and #3), non-HOV 3+ traffic (i.e., SOV, HOV 2, truck, and airport passenger trips) is assigned to all facilities (HOV and general purpose). In the second step, HOV 3+ traffic is assigned to HOT lanes and other facilities on the partially loaded network. The pre-assignment of non-HOV 3+ traffic results in congested link speeds for the general-purpose lanes. This means that HOV 3+ traffic has a greater incentive to use HOV facilities, which results in improved HOV 3+ loadings on priority-use and general-use facilities.

23.2.2 After 2008: 6 user classes

Recent versions of the regional travel demand model (e.g., from Version 2.3.52 to Version 2.4) continue to use the same two-step assignment, but there are now six assignments (not five) in each speed feedback loop, since the off-peak period has been split into midday and nighttime. Also, commercial vehicles are split out from trucks, as shown in Table 91. Note that four of the six traffic assignments are multi-class, but two of the assignments contain only one user class (HOV3+ vehicles in the AM peak and HOV3+ vehicles in the PM peak).

Table 91 Traffic assignment in the Version 2.3.52 and later travel model: Six traffic assignments per speed feedback loop

For each SFB loop	Assignment period	Trip markets assigned
Assignment 1	AM peak (non-HOV3+)	1. SOV 2. HOV2 3. Trucks 4. Commercial vehicles 5. Airport passengers
Assignment 2	AM peak (HOV3+)	1. HOV3+
Assignment 3	PM peak (non-HOV3+)	1. SOV 2. HOV2 3. Trucks 4. Commercial vehicles 5. Airport passengers
Assignment 4	PM peak (HOV3+)	1. HOV3+
Assignment 5	Off-peak, midday	1. SOV 2. HOV2 3. HOV3+ 4. Trucks 5. Commercial vehicles 6. Airport passengers
Assignment 6	Off-peak, nighttime	1. SOV 2. HOV2 3. HOV3+ 4. Trucks 5. Commercial vehicles 6. Airport passengers

23.3 Application details

The traffic assignment process is shown on page A-10 of the flowchart in Appendix A. The *Highway_Assignment_Parallel.bat* batch file calls the *Highway_Assignment_Parallel.s* script. As described in Chapter 8 ("Use of parallel processing to reduce model run times"), the highway assignment process has been "parallelized" by using Cube Cluster (both IDP and MDP), which is Cube's implementation of distributed processing. See section 8.2.1 for terminology related to distributed processing, and see section 8.2.4 for details about how Cube Cluster has been implanted in the Version 2.3.52 model (and later versions, such as 2.4), including the traffic assignment step.

23.3.1 Generalized cost

The highway assignment process uses a generalized cost or impedance, which is function of both travel time and cost. Cost is converted to travel time based on the vehicle class and time of day, as described in Table 92. These minutes/per-dollar factors are used for both variably-priced facilities, such as the I-495 HOT lanes in Virginia, and for fixed-price facilities, such as the Governor Nice Bridge.

Table 92 Time Valuation by Vehicle Type and Time Period (minutes/dollar, in year-2007 prices)

	Equivalent Minutes per Dollar			
Mode	AM Peak	Midday	PM Peak	Night
SOV	2.5	3.0	3.0	3.0
HOV 2-occupant auto	1.5	4.0	2.0	4.0
HOV 3+occupant auto	1.0	4.0	1.0	4.0
Light duty commercial vehicle	2.0	2.0	2.0	2.0
Truck	2.0	2.0	2.0	2.0
Auto serving airport passenger	2.0	2.0	2.0	2.0

(Time_Valuation_V2.3.xls)

23.3.2 Inputs and outputs

The inputs and outputs of the *Highway_Assignment_Parallel.s* script are shown in Table 93 and Table 97, respectively.

Table 93 Inputs to traffic assignment process

Volume delay parameters and free-flow speed assumptions	support\hwy_assign_Conical_VDF.s support\hwy_assign_capSpeedLookup.s	Script block
Total vehicle trips by 4 time-of-day periods and 6 user classes	<ITER>_AM.VTT, <ITER>_MD.VTT, <ITER>_PM.VTT, <ITER>_NT.VTT	Binary
Toll minutes equivalence file	support\toll_minutes.txt	Text
AM Toll Factors by Vehicle Type	Inputs\AM_Tfac.dbf	DBF
Midday Toll Factors by Vehicle Type	Inputs\MD_Tfac.dbf	DBF
PM Toll Factors by Vehicle Type	Inputs\PM_Tfac.dbf	DBF
Night Toll Factors by Vehicle Type	Inputs\NT_Tfac.dbf	DBF
Network files	ZONEHWY.NET, <ITER>_HWY.NET	Binary

Note: <ITER> =PP, i1…i4

Table 94 is a lookup table showing highway link capacities in free-flow conditions (vehicles per hour per lane). Table 95 is a lookup table showing the updated highway link speeds in free-flow conditions (mph).

Table 94 Lookup table: Highway link capacities in free-flow conditions (vehicles per hour per lane)

		Area Type					
		1	**2**	**3**	**4**	**5**	**6**
0	**Centroid Connectors**	3150	3150	3150	3150	3150	3150
1	**Freeways**	1900	1900	2000	2000	2000	2000
2	**Major Arterials**	600	800	960	960	1100	1100
3	**Minor Arterials**	500	600	700	840	900	900
4	**Collectors**	500	500	600	800	800	800
5	**Expressways**	1100	1200	1200	1400	1600	1600
6	**Ramps**	1000	1000	1000	1000	2000	2000

Ref: "I:\ateam\docum\fy19\tpb_tdfm_gen2\ver2.3\travel_model_user_guide\ver2.3.75_highway_link_lookupTables_capacity_speed.xlsx"

Table 95 Lookup table: Highway link speeds in free-flow conditions (mph)

		Area Type					
		1	2	3	4	5	6
0	Centroid Connectors	17	17	23	29	35	40
1	Freeways	63	63	69	69	75	75
2	Major Arterials	40	40	52	52	58	58
3	Minor Arterials	40	40	46	46	46	52
4	Collectors	35	35	35	40	40	40
5	Expressways	52	52	58	58	58	63
6	Ramps	23	23	35	35	40	58

Ref: "I:\ateam\docum\fy21\Verson24Development\travel_model_user_guide\ver2.4_highway_link_lookupTables_capacity_speed.xlsx"

23.3.3 Multi-class assignment

As noted earlier, TPB travel forecasting model Ver. 2.3.52 (and later, including Ver. 2.4) perform six traffic assignments per speed feedback iteration (see Table 91). Four of these are multi-class assignments and two of them are single-class assignments. For the multi-user class assignments, two have five user classes (i.e., AM peak non-HOV3+ and PM peak non-HOV3+) and two have six user classes (i.e., midday and nighttime). The Cube Voyager PATHLOAD command is used to perform a traffic assignment, i.e., to load trips to a minimum-impedance path. For each of the traffic assignments, the number of PATHLOAD statements corresponds to the number of user classes (five or six, depending on the assignment). To perform a multi-user class assignment in Cube Voyager, a script must follow two steps:

1. First, in the LINKREAD phase, assign one or more links to a user group. To do this, one primarily uses the ADDTOGROUP (or ADDTOGRP) command, which sets group codes for a link.[149] Generally, one also makes use of link codes that indicate which vehicles are allowed or limited, such as our link LIMIT codes, whose values are shown in Table 96.
2. Second, when performing the traffic assignment with the PATHLOAD statement, one can then specify which groups are to be excluded from the traffic assignment.

Table 96 Link limit code, traffic assignment add group, and its meaning

Link Limit Code	Link Add Group	Definition
1	1	All vehicles accepted
2	2	Only HOV2 (or greater) vehicles accepted
3	3	Only HOV3 (or greater) vehicles accepted

[149] ADDTOGROUP is a subkey word of SETGROUP, although the key word SETGROUP does not need to appear in the script.

Link Limit Code	Link Add Group	Definition
4	4	Medium and heavy trucks are not accepted, but all other traffic is accepted
5	5	Airport passenger vehicle trips
6-8	6	(Unused)
9	7	No vehicles are accepted

So, for example, links that should be restricted to HOV2+ traffic can be added to group 2:

```
PHASE=LINKREAD
       IF (LI.@PRD@LIMIT==2) ADDTOGROUP=2
```

Then, when performing the traffic assignment with the PATHLOAD statement for HOV2+ trips, one can use the EXCLUDEGROUP command like this:

```
PATHLOAD PATH=LW.HV2@PRD@IMP,  EXCLUDEGROUP=3,5,6,7,    VOL[2]=MI.1.2   ;  HOV 2
```

This means that HOV2 trips are excluded from using links that have been added to link groups 3 (HOV3+), 5 (airport passenger vehicles), 6 (unused), and 7 (unused).

23.3.4 Volume-delay functions

The Version 2.4 family of models use conical volume-delay functions (VDFs). More information about these VDFs can be found on pp. 8-13 to 8-17 of the calibration report dated 1/20/12.[150]

23.3.5 Convergence of user equilibrium traffic assignment

When the traffic assignment process is run, the script creates a series of user equilibrium convergence report files, as shown in Table 97. Each file contains the relative gap by user equilibrium iteration. By using these files with a spreadsheet, one can make plots of the rate of convergence of the traffic assignment.

[150] Milone et al., "Calibration Report for the TPB Travel Forecasting Model, Version 2.3."

Table 97 Outputs of traffic assignment process

Loaded-link files by time period	<ITER>_am_load_link.asc, <ITER>_md_load_link.asc, <ITER>_pm_load_link.asc, <ITER>_nt_load_link.asc,	Text
Loaded Highway Network	<ITER>_ Assign_output.net	Binary
UE convergence report files	<iter>_ue_iteration_report_AM_nonHov.txt <iter>_ue_iteration_report_AM_hov.txt <iter>_ue_iteration_report_PM_nonHov.txt <iter>_ue_iteration_report_PM_hov.txt <iter>_ue_iteration_report_MD.txt <iter>_ue_iteration_report_NT.txt	Text

Note: <ITER> =PP, i1…i4

23.3.6 Loaded link highway network

Table 98 provides further details regarding the attributes of the final loaded highway network.

Table 98 Variables included in the final iteration, loaded highway network (i4_Assign_output.net)

Variable Name	Description
A	A-Node
B	B-Node
DISTANCE	Link Distance in miles (x.xx)
SPDC	(Not used)
CAPC	(Not used)
JUR	Jurisdiction Code (0-23) *0/DC, 1/MTG, 2/PG, 3/ALR/, 4/ALX,5, FFX, 6/LDN, 7/ PW, 8/(unused), 9/FRD, 10/HOW, 11/AA, 12/CHS, 13/(unused), 14/CAR, 15/CAL, 16/STM, 17/KG, 18/FBG, 19/STF, 20/SPTS, 21/FAU, 22/CLK, 23/JEF*
SCREEN	Screenline Code (1-38)
FTYPE	Link Facility Type Code (0-6)
	0/Centroids, 1/Freeways, 2/Major Art., 3/Minor Art, 4/Collector, 5/Expressway, 6/Ramp
TOLL	Toll Value in current year dollars
TOLLGRP	Toll Group Code (1-9999)
<Period> LANE	<Period> No. of Lanes
<Period>LIMIT	<Period> Limit Code (0-9)
EDGEID	Geometry network link identifier
LINKID	Logical network link identifier
NETWORKYEA	Planning year of network link
SHAPE_LENG	Geometry length of network link (in feet)
PROJECTID	Project identifier
TAZ	Nearest TAZ centroid to midpoint of link (1-3,722)
ATYPE	Area Type (1-6)
SPDCLASS	Speed Class

CAPCLASS	Capacity Class
DEFLATIONFTR	Factor for deflating current year tolls to constant year tolls
<Period>TOLL	<Period> Toll Value in current year dollars - all tolled facilities
<Period>TOLL_VP	<Period> Toll Value in current year dollars - Variably priced tolled facilities only
<Period> HTIME	<Period> Highway Time - based on initial highway lookup speeds
I4<Period>SOV	Iteration 4 <Period> assigned SOV Volume
I4<Period>HV2	Iteration 4 <Period> assigned HOV2 Volume
I4<Period>HV3	Iteration 4 <Period> assigned HOV3 Volume
I4<Period>CV	Iteration 4 <Period> assigned Commercial Vehicle Volume
I4<Period>TRK	Iteration 4 <Period> assigned Truck Volume
I4<Period>APX	Iteration 4 <Period> assigned Airport Passenger Volume
I4<Period> VOL	Iteration 4 <Period> assigned Volume
I4<Period>VMT*	Iteration 4 <Period> Vehicle Miles Travelled (VMT)
I4<Period>FFSPD	Iteration 4 <Period> free flow speed (mph)
<Period>HRLKCAP	<Period> hourly link capacity
<Period>HRLNCAP	<Period> hourly lane capacity
I4<Period>VC	Iteration 4 <Period> Volume Capacity ratio
I4<Period>VDF	Iteration 4 <Period> Volume Delay function
I4<Period>SPD	Iteration 4 <Period> Speed (mph)
I424VOL	Iteration 4 Daily (24 hour) Volume

KEY <Period>= AM	AM Peak Period (6:00-9:00 AM)
MD	Mid-Day (9:00 AM - 3:00 PM)
PM	PM Peak Period (3:00 - 7:00 PM)
NT	All remaining hours

* The link VMT does not account for centroid connector links (Ftype=0). Centroid connectors represent minor, local roadways that are not coded in the planning networks. This essentially means that our travel demand model simulates only average weekday “non-local roadway” VMT, or “network” VMT as we sometimes refer to it (i.e., Total Roadway VMT= Local Roadway VMT + Non-Local Roadway VMT, and the model only simulates the Non-Local Roadway VMT component). Please note that “local” in this case refers to the roadway type and not the trip origin or destination.

23.3.7 Averaging of link volumes

Since the travel model includes speed feedback, in order to ensure that highway volumes and hence speeds are stabilizing with each successive speed feedback iteration, it is necessary to apply a link-level “method of successive averaging” (MSA) process. The MSA averaging is performed on the basis of total (non-segmented) link volumes and is performed individually for each time period. This process is performed after each successive highway assignment process using the *Average_Link_Speeds.bat* file that includes the *Average_Link_Speeds.s* script. This script uses the current iteration and previous iteration loaded networks to develop a network with volume averaging named <ITER>_HWY.net.

23.3.8 Treatment of airport passenger auto driver trips on HOV and HOT lane facilities

Text for this section of the report come from or are derived from a recent memo on this subject.[151]

The terms "airport passenger trips" or "air passenger trips" refer to a motor vehicle carrying air passengers to or from one of the three commercial airports in the region: Reagan National (DCA), Dulles International (IAD), and Baltimore-Washington International (BWI). The focus is on highway assignment, not mode choice or transit assignment.

23.3.8.1 Real world conditions

Regarding the use of HOV- and HOT-lane facilities by motor vehicles carrying passengers to the region's three commercial airports (DCA, IAD, and BW), several real-world issues that make it challenging to reflect the corresponding occupancy restrictions in the travel model. There are many different HOV and HOT facilities with different restrictions on their use, as shown in Table 99.

Table 99 HOV and HOT-lane facilities in the Washington, D.C. area

Type of Facility	Use Restrictions	Examples
HOV2+	Vehicles must have two or more occupants (certain exemptions apply, including an airport-related exemption)	I-270, I-66, US 50 (MD)
HOV3+	Vehicles must have three or more occupants.	I-395, I-95 (VA)
HOT2+	Vehicles with two or more occupants can use the facility for free. Vehicles with one occupant may pay to use the facility. Users of the facility must have either an "E-Zpass" OR "E-ZPass Flex" tag/RFID transponder in vehicle. Users who want to gain free access to the facility due to meeting the occupancy requirement must have an "E-ZPass Flex" transponder.	I-66 Inside the Beltway starting in 2017
HOT3+	Vehicles with three or more occupants can use the facility for free. Vehicles with one or two occupants may pay to use the facility. Users of the facility must have either an "E-Zpass" OR "E-ZPass Flex" tag/RFID transponder in vehicle. Users who want to gain free access to the facility due to meeting the occupancy requirement must have an "E-ZPass Flex" transponder.	I-495 (VA), I-395 starting in 2019

Prior to 2017, when the I-66 inside the Beltway HOT lanes opened, there was an exception to the HOV occupancy restrictions regarding auto trips to/from one of the three commercial airports in the region: Motorists traveling to and from Dulles International Airport to board a flight or to pick someone up at

[151] Dusan Vuksan, Dzung Ngo, and Mark S. Moran, "Air Passenger Trips on HOV/HOT Lanes in the TPB Version 2.3 Travel Model: Discussion of Current Treatment and Recommendations for Modifications," Memorandum, April 24, 2017.

the airport were permitted to use I-66 inside the Beltway (I-495) for free during HOV hours. This exception ended when the I-66 Inside the Beltway lanes converted from HOV to HOT in December 2017.

23.3.8.2 Treatment in the Ver. 2.4 Model

Before discussing how the model handles air passenger travel on HOV and HOT-lane facilities, this section of the report discusses the general way in which air passenger trips are handled in the travel demand model. Although air passenger travel on the road network is handled by the travel model, it is considered an exogenous input to the model. Other exogenous inputs to the travel model include taxi trips, visitor/tourist trips, school trips, through trips, and external trips. As noted in a recent memo:[152]

> *The airport passenger auto driver trip tables are prepared based on base- and future-year trip tables that are developed as part of COG's Continuous Air System Planning (CASP) activities. The trip tables indicate local originations to the region's three major airports with commercial air service:*
>
> - *Ronald Reagan Washington National Airport (DCA)*
> - *Washington Dulles International Airport (IAD)*
> - *Baltimore/Washington International Thurgood Marshall Airport (BWI)*
>
> *The trip tables are stratified by mode and purpose (Home-Based and Non-Home-Base). The trip tables are developed by year and are prepared at the Airport Analysis Zone (AAZ) level of geography (p. 17).*

Airport passenger trips are stored in a binary trip-table file called airpax.adr. The current air passenger auto driver trip tables were developed using the COG 2011 Regional Air Passenger Survey. The 2013 and 2015 surveys were not used because they were conducted during a full and partial shutdown of the federal government. Although the most recent Airport Passenger Survey was conducted in 2017 without any issue, the reason that this survey was not used to develop the air passenger auto driver trip tables is explained in the previously mentioned memo as follow:

> *Compared to the 2011 APS, the 2017 APS forecasts significant drops of auto driver travel (about 35%) and high increases in auto passenger travel. The changes are partly due to the shifts of trips from some other modes, including personal car and taxi, to Uber and Lyft, which did not exist in the 2011 APS. We acknowledge the importance of using the latest data available, but, in this case, we have decided to use the ground access trips from 2011 APS for processing airport passenger auto driver trip tables because:*
>
> > *1. In 2017 APS, Uber/Lyft trips were processed as auto passenger trips and the distinction of Uber/Lyft from other auto passenger trip modes requires the revision of SAS scripts used for processing the raw data. Unfortunately, the current budget does not allow this update.*

---

[152] Ray Ngo to DTP Technical Staff and Mark Moran, "Exogenous Demand Inputs to the TPB Travel Demand Model: Update for Round 9.1a Cooperative Forecasts," Memorandum, September 25, 2019.

2. The total ground access trips to the three airports has a minor change between the two surveys. For example, the total trip forecast in the 2017 APS decreases 1% compared to the forecast in 2011 APS.

In terms of the treatment of air passenger trips on HOV and HOT-lane facilities, the Ver. 2.3.70 model (and earlier) allowed airport trips to use any HOV facility regardless of the vehicle occupancy. For the HOV2+ lanes on I-66 Inside the Beltway, **this makes sense**, given the current policy for I-66 mentioned earlier. For other HOV facilities in the region, however, the model's representation does not reflect the real transportation system. For these other HOV facilities, vehicles carrying air passengers should be allowed to use the other HOV facilities only if the vehicles meet the occupancy requirements for the facility.

Table 100 shows how airport passenger trips are treated with respect to HOV facilities in the real world, the Ver. 2.3.66 model (and later, including the Ver. 2.4 Model). The three areas highlighted in yellow show where there was a mismatch between the real world and the Ver. 2.3.66 model.

Table 100 Use of HOV and HOT-lane facilities by autos serving airport passengers: Real world, Ver. 2.3.66 Model (and later, including Ver. 2.4 Model)

Auto Serving Airport Passenger (no. of occupants)	Case	HOV Facility			HOT-Lane Facility		
		2+	2+ I-66 Inside Beltway	3+	2+	2+ I-66 Inside Beltway	3+
1 occupant	**Real World**	**No**	**Yes, VDOT exemption (1)**	**No**	**Yes (pay toll)***	**Yes (pay toll)* (2)**	**Yes (pay toll)***
	V. 2.3.66 Model	Yes	Yes	Yes	Yes (pay toll)	Yes (pay toll)	Yes (pay toll)
	V. 2.3.75 Model	Yes	Yes	No	Yes (pay toll)	Yes (pay toll)	Yes (pay toll)
2 occupants	**Real World**	**Yes**	**Yes**	**No**	**Yes (free)****	**Yes (free)****	**Yes (pay toll)***
	V. 2.3.66 Model	Yes	Yes	Yes	Yes (pay toll)	Yes (pay toll)	Yes (pay toll)
	V. 2.3.75 Model	Yes	Yes	No	Yes (pay toll)	Yes (pay toll)	Yes (pay toll)
3+ occupants	**Real World**	**Yes**	**Yes**	**Yes**	**Yes (free)****	**Yes (free)****	**Yes (free)****
	V. 2.3.66 Model	Yes	Yes	Yes	Yes (pay toll)	Yes (pay toll)	Yes (pay toll)
	V. 2.3.75 Model	Yes	Yes	No	Yes (pay toll)	Yes (pay toll)	Yes (pay toll)

(1): Per VDOT: "Motorists traveling to and from Dulles International Airport to go to the airport to board a flight or to pick someone up at the airport are permitted to use I-66 inside the Beltway (I-495) during HOV hours. Motorists traveling to or from Dulles International Airport are not exempt from HOV restrictions on I-66 outside the Beltway (I-495). You are not permitted to use I-66 inside the beltway during HOV hours if you are going to the airport to eat, get coffee, get gas or any other reason other than boarding a plane or picking someone up at the airport." (Source: "High Occupancy Vehicle (HOV) Lanes - Rules and FAQs." *Virginia Department of Transportation*, February 1, 2017. http://www.virginiadot.org/travel/hov-rulesfaq.asp).

(2): Exemption for travelers to/from Dulles Airport will end when the I-66 Inside the Beltway HOT lanes open (Source: Thomson, Robert. "As Virginia Sets up I-66 HOT Lanes, Drivers Again Ask: What about Me?" *The Washington Post*. August 16, 2016. https://www.washingtonpost.com/news/dr-gridlock/wp/2016/08/11/as-virginia-sets-up-i-66-hot-lanes-drivers-again-ask-what-about-me/)

* Must have an "E-Zpass" OR "E-ZPass Flex" tag/RFID transponder in vehicle.

** Must have an "E-ZPass Flex" tag/RFID transponder in vehicle.

The only change made to the travel model (as of Ver. 2.3.75) regarding modeling airport trips was to prohibit airport trips from using HOV3+ facilities, since observed car occupancy for these types of trips is approximately 1.6 persons per vehicle, which is calculated from the Average Weekday Air Passenger Ground Access trip data documented in the 2013 Washington – Baltimore Regional Air Passenger Survey. These three areas are highlighted in green in Table 100.

24 Transit Assignment, Including Summary Process (LineSum)

24.1 Transit assignment process

Transit assignment is a new feature of the Version 2.3 and Version 2.4 Travel Models that was not part of the Version 2.2 Travel Model. Transit assignment is where transit trips are loaded on to the transit network. Although highway and transit assignment have some similarities, it is useful to point out some of the differences between these two assignment procedures. First, whereas highway assignment is done with trip tables in origin/destination (O/D) format, transit assignment is done with trip tables in production/attraction (P/A) format. Second, whereas highway assignment is capacity constrained, transit assignment is not. Lastly, whereas highway assignment is done in each of the five speed feedback loops (i.e., pump prime, i1, i2, i3, and i4), transit assignment is conducted only at the conclusion of the i4 speed feedback loop (See Figure 42 and Figure 43).

Procedures for transit assignment are shown on pages A-15 through A-17 in the flowchart in Appendix A. The transit assignment is run using the *Transit_Assignment_Parallel.bat* and *Transit_Assignment_LineHaul_Parallel.bat* batch files, the first of which is called from the "run model steps" batch file. Prior to transit assignment, the five mode choice trip tables (HBW, HBS, HBO, NHW, and NHO) are combined into two trip tables (AM = HBW; and OP = HBS + HBO + NHW + NHO), using the *Combine_Tables_For_TrAssign_Parallel.s* script. After the transit assignment has been run, the transit assignment output files are summarized using the LineSum program. This is also called from the *Transit_Assignment_Parallel.bat* batch file via the *TranSum.bat* batch file. The transit assignment process is run in the standard scenario/output folder (e.g., 2016), but the transit assignment summary files are stored in a sub-folder called "transum." The inputs to the *Transit_Assignment_Parallel.bat* batch file are shown in Table 101 and the outputs are shown in Table 102.

Table 101 Inputs to transit assignment process

Trip tables segmented by mode (coming from the mode choice model)	i4_HBW_NL_MC.MTT i4_HBS_NL_MC.MTT i4_HBO_NL_MC.MTT i4_NHW_NL_MC.MTT i4_NHO_NL_MC.MTT	Binary
Highway network	Zonehwy.net	Binary
AM peak transit lines	Inputs\MODE1AM…MODE10AM.TB	Text
Off peak transit lines	Inputs\MODE1OP…MODE10OP.TB	Text
Transit network files	met_node.tb, met_bus.tb, met_link.tb, com_node.tb, com_bus.tb, com_link.tb, lrt_node.tb, lrt_bus.tb, lrt_link.tb new_node.tb, new_bus.tb, new_link.tb met_pnrn.tb, com_pnrn.tb, bus_pnrn.tb, lrt_pnrn.tb, new_pnrn.tb met_[AM|OP] _pnr.tb, com_ [AM|OP] _pnr.tb, bus_ [AM|OP] _pnr.tb, lrt_ [AM|OP] _pnr.tb, new_ [AM|OP] _pnr.tb met_[AM|OP] _pnr.asc, com_ [AM|OP] _pnr.asc, bus_ [AM|OP] _pnr.asc, lrt_ [AM|OP] _pnr.asc, new_ [AM|OP] _pnr.asc met_[AM|OP] _knr.asc, bus_ [AM|OP] _knr.asc, lrt_ [AM|OP] _knr.asc, new_ [AM|OP] _knr.asc met_bus.tb, com_bus.tb, lrt_bus.tb, new_bus.tb	Text
Transit network walk links	walkacc.asc, sidewalk.asc	Text

Note: <ITER> =PP, i1…i4

Table 102 Outputs of transit assignment process

Combined transit trip file	<ITER>_<Prd>MS.TRP	Binary
Transit assignment node file	<ITER>_*<AA><??><Prd>*node.dbf	DBF
Transit assignment Link file	<ITER>_*<AA><??><Prd>*link.dbf	DBF
Support links	Supl_<??>_*<AA>*_*<Prd>*.asc	Text

Note: <ITER> =PP, i1…i4, <AA>= WK, DR, KR ??= CR, MR, AB, BM, Prd=AM, OP

The transit assignment is done for two time-of-day periods: the peak period and the off-peak period. The peak period is represented by the three-hour AM peak period. The off-peak period is represented by the five-hour midday period. Thus, when calculating peak-period travel times on transit ("skims") the AM peak period is used to represent the level of service in both the AM and PM peak period. Similarly, when calculating the average headway and average run time for each transit route, these calculations are done for the peak period (represented by the AM peak) and the off-peak period (represented by the midday period). It is assumed that the majority of HBW trips will occur in the peak periods and that the majority of non-work trips will occur in the off-peak periods. Consequently, prior to the actual transit assignment, the five trip tables coming out of mode choice are combined into two tables: one for the peak period and one for the off-peak period. The peak-period trip table ("AM") contains only one trip table (HBW). By contrast, the off-peak period trip table ("OP") contains the trip tables from the other four trip purposes (HBS, HBO, NHW, NHO) as shown in Table 103.

Table 103 Mapping/concatenation of trip tables by trip purposes into peak and off-peak period trip tables prior to transit assignment

Before combining trip tables	After combining trip tables
i4_HBW_NL_MC.MTT	i4_AMMS.TRP
i4_HBS_NL_MC.MTT i4_HBO_NL_MC.MTT i4_NHW_NL_MC.MTT i4_NHO_NL_MC.MTT	i4_OPMS.TRP

This is mapping/concatenation of trip tables done with the Cube Voyager script *Combine_Tables_For_TrAssign.s* script. There are 11 tables on the *.TRP files, not 12, since, for commuter rail, KNR and PNR are combined:

WK_CR, WK_BUS, WK_BUS_MR, WK_MR,

PNR_KNR_CR, PNR_BUS, KNR_BUS, PNR_BUS_MR, KNR_BUS_MR, PNR_MR, KNR_MR

There are four transit assignment scripts, one for each transit submode (commuter rail, Metrorail, all bus, and bus/Metrorail):

```
transit_assignment_CR.s
transit_assignment_MR.s
transit_assignment_AB.s
transit_assignment_BM.s
```

24.1.1 Inputs to the transit assignment

As can be seen on page A-15 of Appendix A, the specific list of inputs for transit assignment varies for each of the four transit submodes.

24.1.2 Outputs of the transit assignment

The output of the four transit assignment scripts are a series of transit link files and transit node files in dBase (DBF) format. These files are generated in Cube Voyager's TRNBUILD module using the LINKO and NODEO keywords. The transit node files (NODEO) simply contain the node number and its X and Y coordinates, as shown in Figure 73.

	A	B	C
1	N	X	Y
2	1	1298543	446898
3	2	1298807	445281
4	3	1297889	443318
5	4	1296811	441898
6	5	1303089	442174
7	6	1301409	443113
8	7	1299596	445914
9	8	1301916	446878
10	9	1302004	445336
11	10	1302622	443982
12	11	1303826	443797
13	12	1305207	444137
14	13	1303781	445659
15	14	1304865	446730

Figure 73 Excerpt from one of the transit node DBF files output from transit assignment (i4_WKMRAMnode.dbf)

Ref: "X:\modelRuns\fy12\Ver2.3.36\2007_pseu\i4_WKMRAMnode.dbf"

Transit link files (LINKO) files include the following attributes:[153]

- A: A-node of link
- B: B-node of link
- TIME: A-B time (hundredths of minutes)
- MODE: Mode of link (1-255)
- COLOR: User designated drawing color
- STOP_A: 1 = A is a stop node
- STOP_B: 1 = B is a stop node
- DIST: A-B distance (hundredths of miles)
- NAME: Name of line on this link
- FREQ: Service frequency (min)
- PLOT: Always = 0

The following additional attributes are included due to transit assignment:

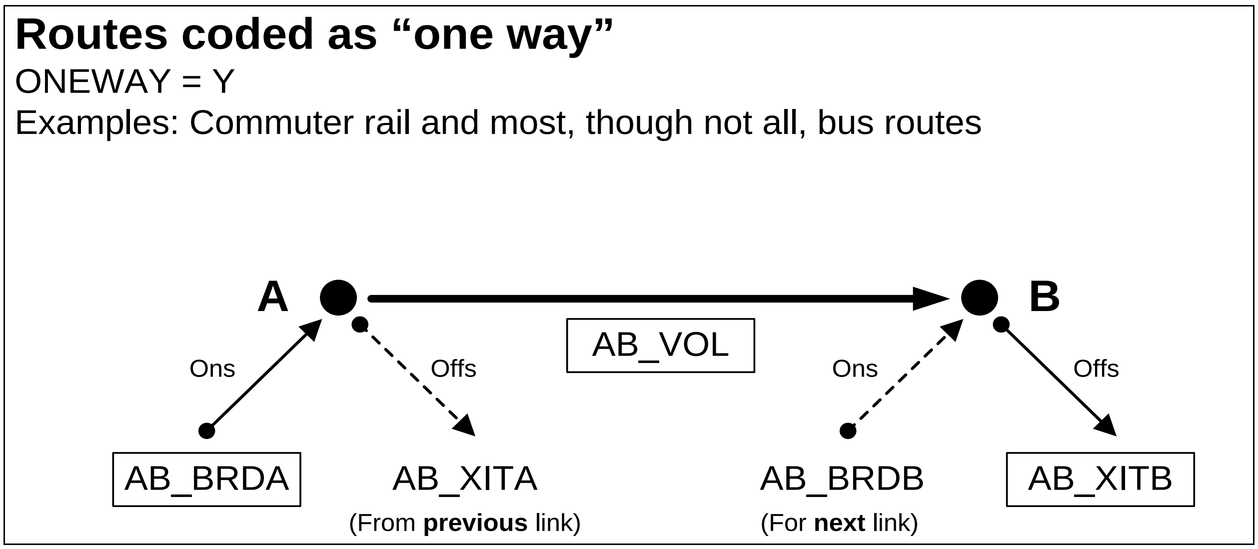
- SEQ: Link sequence in the line
- OWNER: Line owner (first ten characters)
- AB_VOL: Volume
- AB_BRDA: Number of trip boardings at A
- AB_XITA: Number of exits at A

[153] Citilabs, Inc., "Cube Voyager Reference Guide, Version 6.0.2" (Citilabs, Inc., July 26, 2012), 958.

- AB_BRDB: Number of boardings at B
- AB_XITB: Number of exits at B
- (last 5 variables are also repeated for B-A direction)

Figure 74 and Figure 75 show the naming conventions used for transit volumes from a TRNBUILD-based transit assignment. Both figures show the associated volumes ("ons," "throughs," and "offs") for a hypothetical transit link AB. Figure 74 is for the case of a one-way transit route, and Figure 75 is for the case of a two-way transit route. These figures can also be useful when interpreting reports from the LineSum transit assignment summary program (covered in the next section of the report).

Figure 74 Transit volumes from transit assignment using TRNBUILD: One-way route



Ref: transit_volumes_ab_ba_trnbuild_v2.vsd

Note: For a description of AB_VOL, AB_BRDA, AB_XITA, etc., see page 1020, Cube Voyager Reference Guide, Version 6.4.1 Citilabs, Inc., September 30, 2015.

The simplest case is the one-way route (Figure 74). In this case, the three important values for the link AB are:

- AB_VOL: Transit person trips on link AB ("throughs")
- AB_BRDA: Transit person boardings ("ons") at the "from" node (node A in the figure)
- AB_XITB: Transit person alightings ("offs") from the "to" node (node B in the figure)

All three of these variables are shown in rectangular boxes in Figure 74. The other two values shown in Figure 74 (AB_XITA and AB_BRDB) are associated with the **link prior to link AB** (AB_XITA) and the **link after link AB** (AB_BRDB).

For routes coded as two-way (Figure 75), the situation is similar, but a bit more complex. When traveling in the A-to-B direction, the three important variables for transit volumes are the same as before:

- AB_VOL: Transit person trips on link AB ("throughs")
- AB_BRDA: Transit person boardings ("ons") at the "from" node (node A in the figure)

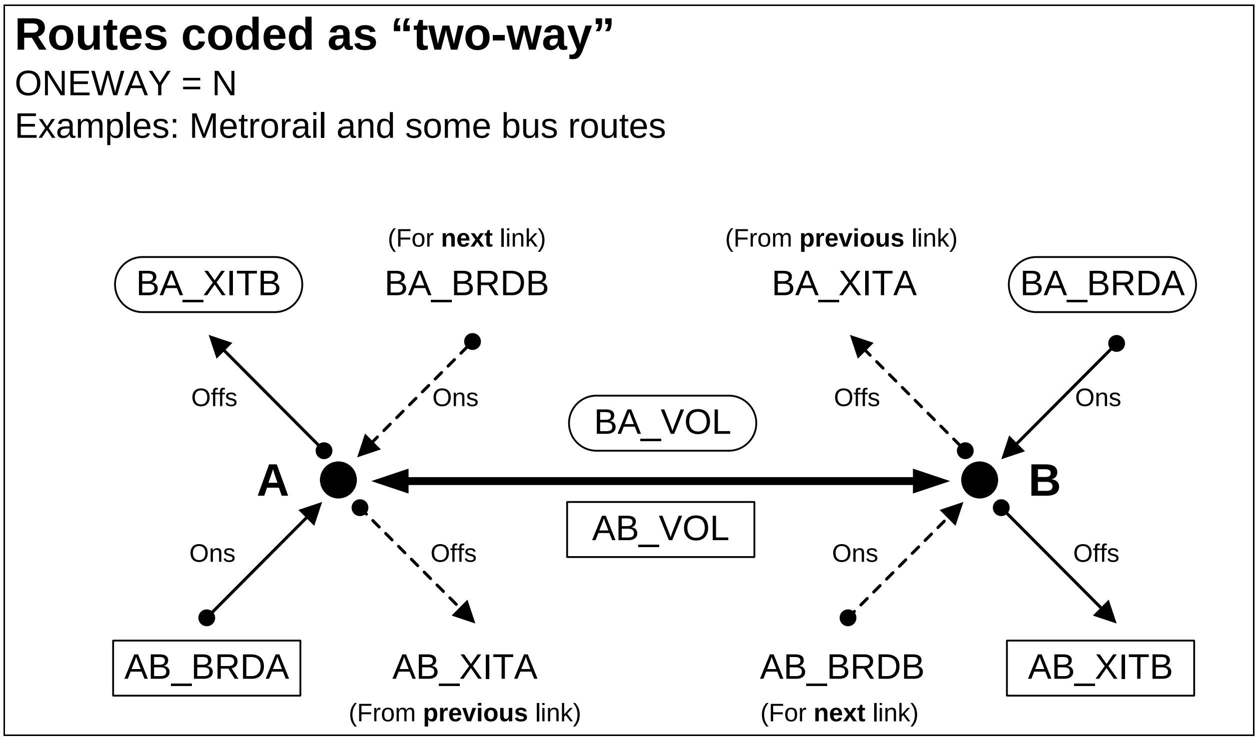
- AB_XITB: Transit person alightings ("offs") from the "to" node (node B in the figure)

However, when travelling in the B-to-A direction, the three relevant variables are:

- BA_VOL: Transit person trips on link AB in the B-to-A direction ("throughs")
- BA_BRDA: Transit person boardings ("ons") in the B-to-A direction at the "from" node (node B in the figure)[154]
- BA_XITB: Transit person alightings ("offs") in the B-to-A direction from the "to" node (node A in the figure)

These are indicated in Figure 75 with rectangular boxes that have rounded corners.

Figure 75 Transit volumes from transit assignment using TRNBUILD: Two-way route



Ref: transit_volumes_ab_ba_trnbuild_v2.vsd

Note: For a description of AB_VOL, AB_BRDA, AB_XITA, etc., see page 1020, Cube Voyager Reference Guide, Version 6.4.1 Citilabs, Inc., September 30, 2015.

Keep in mind that, since transit path-building and assignment are conducted in production/attraction (P/A) format, **all of the values on these tables are also in P/A format**. Conducting transit assignment in production/attraction format is state of the practice for transit assignments and has the benefit of

[154] Typically, the convention is that the "from" node is the A node and the "to" node is the B node. However, in Figure 76, for movement in the B-to-A direction, the "from" node is labeled B and the "to" node is labeled A, since those were the labels used for movement in the A-to-B direction.

showing the peak orientation of the transit line. **To estimate the boardings at a given station in origin/destination format, you need to add the “ons” and “offs” together and divide by two**.[155]

Some examples of the LINKO attribute values can be found in Figure 76 through Figure 78. For example, Figure 76 shows a portion of the AM walk-access to Metrorail LINKO file (i4_WKMRAMlink.dbf) that has mode-16 links (walk access to transit). Similarly, Figure 77 shows a portion of the AM walk-access to Metrorail LINKO file (i4_WKMRAMlink.dbf) that has mode-3 links (Metrorail line segments). Lastly, Figure 78 shows a portion of the AM walk-access to Metrorail LINKO file (i4_WKMRAMlink.dbf) that has mode-12 links (walk transfer links).

[155] AECOM, “LineSum (Version 5.0.17)” (Arlington, Virginia: AECOM, June 13, 2012), 14.

	A	B	TIME	MODE	FREQ	PLOT	COLOR	STOP_A	STOP_B	DIST	NAME	SEQ	OWNER	AB_VOL	AB_BRDA	AB_XITA	AB_BRDB	AB_XITB	BA_VOL	BA_BRDA	BA_XITA	BA_BRDB	BA_XITB
2	1	20263	280	16	0.00	0	6	0	0	14	*16	0		0	0	0	0	0	0	0	0	0	0
3	1	20266	200	16	0.00	0	6	0	0	10	*16	0		0	0	0	0	0	0	0	0	0	0
4	1	20269	180	16	0.00	0	6	0	0	9	*16	0		0	0	0	0	0	1344	0	0	0	0
5	1	20341	300	16	0.00	0	6	0	0	15	*16	0		0	0	0	0	0	0	0	0	0	0
6	1	20344	240	16	0.00	0	6	0	0	12	*16	0		0	0	0	0	0	0	0	0	0	0
7	1	20346	300	16	0.00	0	6	0	0	15	*16	0		0	0	0	0	0	0	0	0	0	0
8	1	20442	60	16	0.00	0	6	0	0	3	*16	0		0	0	0	0	0	0	0	0	0	0

Figure 76 Excerpt from one of the transit link DBF files output from transit assignment (i4_WKMRAMlink.dbf) showing mode-16 links

Ref: "X:\modelRuns\fy12\Ver2.3.36\2007_pseu\i4_WKMRAMlink.dbf"

	A	B	TIME	MODE	FREQ	PLOT	COLOR	STOP_A	STOP_B	DIST	NAME	SEQ	OWNER	AB_VOL	AB_BRDA	AB_XITA	AB_BRDB	AB_XITB	BA_VOL	BA_BRDA	BA_XITA	BA_BRDB	BA_XITB
2	8001	8002	406	3	6.00	0	0	1	1	261	WMREDA	1	WMATA;SHAD	601	601	0	813	28	138	0	138	9	568
3	8002	8001	406	3	6.00	0	0	1	1	261	WMREDA-	26	WMATA;SHAD	138	9	568	0	138	601	813	28	601	0
4	8002	8003	329	3	6.00	0	0	1	1	213	WMREDA	2	WMATA;SHAD	1385	813	28	970	93	697	9	568	54	994
5	8003	8002	329	3	6.00	0	0	1	1	213	WMREDA-	25	WMATA;SHAD	697	54	994	9	568	1385	970	93	813	28
6	8003	8004	308	3	6.00	0	0	1	1	109	WMREDA	3	WMATA;SHAD	2263	970	93	593	89	1637	54	994	54	940
7	8004	8003	308	3	6.00	0	0	1	1	109	WMREDA-	24	WMATA;SHAD	1637	54	940	54	994	2263	593	89	970	93
8	8004	8005	203	3	6.00	0	0	1	1	135	WMREDA	4	WMATA;SHAD	2767	593	89	814	8	2523	54	940	143	47
9	8005	8004	203	3	6.00	0	0	1	1	135	WMREDA-	23	WMATA;SHAD	2523	143	47	54	940	2767	814	8	593	89
10	8005	8006	305	3	6.00	0	0	1	1	219	WMREDA	5	WMATA;SHAD	3573	814	8	344	213	2427	143	47	50	825
11	8005	8006	306	3	6.00	0	0	1	1	219	WMREDB	1	WMATA;GROS	801	801	0	337	63	44	0	44	1	697
12	8006	8005	305	3	6.00	0	0	1	1	219	WMREDA-	22	WMATA;SHAD	2427	50	825	143	47	3573	344	213	814	8
13	8006	8005	306	3	6.00	0	0	1	1	219	WMREDB-	19	WMATA;GROS	44	1	697	0	44	801	337	63	801	0
14	8006	8007	201	3	6.00	0	0	1	1	102	WMREDA	6	WMATA;SHAD	3704	344	213	1362	383	3202	50	825	266	1886
15	8006	8007	201	3	6.00	0	0	1	1	102	WMREDB	2	WMATA;GROS	1074	337	63	1329	117	740	1	697	62	1656
16	8007	8006	201	3	6.00	0	0	1	1	102	WMREDA-	21	WMATA;SHAD	3202	266	1886	50	825	3704	1362	383	344	213
17	8007	8006	201	3	6.00	0	0	1	1	102	WMREDB-	18	WMATA;GROS	740	62	1656	1	697	1074	1329	117	337	63
18	8007	8008	308	3	6.00	0	0	1	1	170	WMREDA	7	WMATA;SHAD	4683	1362	383	1739	169	4822	266	1886	401	845
19	8007	8008	309	3	6.00	0	0	1	1	170	WMREDB	3	WMATA;GROS	2286	1329	117	1706	97	2334	62	1656	254	771
20	8008	8007	308	3	6.00	0	0	1	1	170	WMREDA-	20	WMATA;SHAD	4822	401	845	266	1886	4683	1739	169	1362	383
21	8008	8007	309	3	6.00	0	0	1	1	170	WMREDB-	17	WMATA;GROS	2334	254	771	62	1656	2286	1706	97	1329	117

Figure 77 Excerpt from one of the transit link DBF files output from transit assignment (i4_WKMRAMlink.dbf) showing mode-3 links

Ref: "X:\modelRuns\fy12\Ver2.3.36\2007_pseu\i4_WKMRAMlink.dbf"

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	A	B	TIME	MODE	FREQ	PLOT	COLOR	STOP_A	STOP_B	DIST	NAME	SEQ	OWNER	AB_VOL	AB_BRDA	AB_XITA	AB_BRDB	AB_XITB	BA_VOL	BA_BRDA	BA_XITA	BA_BRDB	BA_XITB
256	8001	22395	20	12	0.00	0	2	0	0	1	*12	0	WMATA;SHAD	138	0	0	0	0	601	0	0	0	0
257	8002	9005	20	12	0.00	0	2	0	0	1	*12	0	WMATA;SHAD	0	0	0	0	0	0	0	0	0	0
258	8002	22351	20	12	0.00	0	2	0	0	1	*12	0	WMATA;SHAD	160	0	0	0	0	236	0	0	0	0
259	8002	22370	20	12	0.00	0	2	0	0	1	*12	0	WMATA;SHAD	436	0	0	0	0	586	0	0	0	0
260	8003	22344	20	12	0.00	0	2	0	0	1	*12	0	WMATA;SHAD	542	0	0	0	0	776	0	0	0	0
261	8003	22672	20	12	0.00	0	2	0	0	1	*12	0	WMATA;SHAD	545	0	0	0	0	248	0	0	0	0
262	8004	22332	20	12	0.00	0	2	0	0	1	*12	0	WMATA;SHAD	830	0	0	0	0	613	0	0	0	0
263	8004	22670	20	12	0.00	0	2	0	0	1	*12	0	WMATA;SHAD	199	0	0	0	0	34	0	0	0	0
264	8005	22327	20	12	0.00	0	2	0	0	1	*12	0	WMATA;GROS	99	0	0	0	0	1757	0	0	0	0

Figure 78 Excerpt from one of the transit link DBF files output from transit assignment (i4_WKMRAMlink.dbf) showing mode-12 links

Ref: "X:\modelRuns\fy12\Ver2.3.36\2007_pseu\i4_WKMRAMlink.dbf"

24.2 Transit assignment summary process

The purpose of the transit assignment *summary* process is to summarize the output from the transit assignment process. The process is run with the *transum.bat* batch file, which, like the *Transit_Assignment_Parallel.bat* batch file, is called from the "run model steps" batch file (see page A-16 of Appendix A). Whereas the transit assignment process is run in the scenario/output folder (e.g., 2019), the transit assignment summary process is run in the **transum** folder (e.g., 2019**transum**), which is a subfolder of the scenario/output folder. In the past, such as the Version 2.3.36 model, there were two transit assignment summary programs (LineVol and LineSum). LineVol was used to merge transit assignment output files into peak and off-peak files. Now, there is only one of these (LineSum, ver. 6.0.2),[156] since LineSum performs all the functionality needed, including the merging of output files.

An excerpt from the *transum.bat* batch file is shown in Figure 79 and the complete batch file can be found in Appendix B. When the model run is begun, the "transum" folder must exist under the scenario folder (e.g., 2019 \transum), **but the folder is completely empty**. The control files needed to run LineSum are stored in the "controls" folder. Although the station names file (station_names.dbf) used to be stored in the "controls" folder, this file is now generated by *Set_Factors.s* and is stored in the "inputs" folder (this change occurred in the Ver. 2.3.57a and subsequent models). The station names file includes Metrorail stations, commuter rail station, and other "named" nodes, such as the following:

Metrorail		Commuter rail		Other named nodes	
8001	Shady Grove	9001	Union Station	45558	Bristol
8002	Rockville	9002	Silver Spring	44132	Broken Land Pkwy
8003	Twinbrook	9003	Kensington	22539	Burtonsville Crossi
8004	White Flint	9004	Garrett Park	26130	Capital Plaza
8005	Grosvenor	9005	Rockville	20811	Carter Barron
8006	Medical Center	9006	Washington Grove	49556	Charlotte Hall
8007	Bethesda	9007	Gaithersburg	27208	Clinton

Once the transit assignment summary process is finished, the folder will include both a copy of the control files that were used and the report files generated by LineSum.

The following control files, associated with LineSum, are stored in the "controls" folder and are called by the *transum.bat* batch file:

```
LineSum_Volume.ctl
lineSum_MR_access.ctl
lineSum_MR_line.ctl
```

These files are described below, and the model user can always develop more control files to generate more reports.

[156] AECOM, *LineSum*, version 6.0.2 (Arlington, Virginia: AECOM, 2014).

At the beginning of the transum.bat batch file (line 8 in Figure 79), the change directory command is used to change the working directory to the "transum" folder. In line 11, a local copy of the LineSum control files is made in the transum folder. In line 14, we create a peak-period and off-peak period file containing the transit assignment. In line 18 of Figure 79, we generate a Metrorail station access report. This station access report does not include transfers from one Metrorail line to another, just the number of boardings at each station. Lastly, in line 22, we create line summaries for the Metrorail system.

Figure 79 An excerpt of *tranSum.bat* transit summary batch file

```
1  :: TranSum.bat
2  :: To be run from the root directory (e.g., E:\modelRuns\fy13\Ver2.3.46)
3  
4  
5  REM Change to the Transum folder, under the scenario-specific folder
6  REM Output report files will be stored in the Transum folder
7  REM The Transum folder starts out empty, since station_names.dbf is stored in Controls
8  CD %1\Transum
9  
10 REM Copy the lineSum control files from the Controls folder to the Transum folder
11 copy ..\..\Controls\LineSum_*.ctl
12 
13 REM Consolidate peak and off-peak volumes from transit assignment
14 ..\..\software\LineSum.exe  LineSum_Volume.ctl
15 if %ERRORLEVEL% == 1 goto error
16 
17 REM Metrorail station access (does not include transfers)
18 ..\..\software\LineSum.exe  lineSum_MR_access.ctl
19 if %ERRORLEVEL% == 1 goto error
20 
21 REM Metrorail line summaries
22 ..\..\software\LineSum.exe  lineSum_MR_line.ctl
23 if %ERRORLEVEL% == 1 goto error
24 
25 (etc.)
```

Ref: M:\fy17\CGV2_3_66_Conformity2016CLRP_Xmittal\TranSum.bat

24.2.1 Consolidating transit assignment output and displaying results

As shown on page A-16 of Appendix A, the LineSum_Volume.ctl (Figure 80) control file is used to consolidate the transit assignment volume DBF files into two summary volume files, one for the peak period (PK_VOL.DBF, equal to the HBW transit volumes) and one for the off-peak period (OP_VOL.DBF, equal to the sum of the HBS, HBO, NHW, and NHO transit volume files).

Figure 80 Consolidating peak and off-peak transit assignment volumes (LineSum_Volume.ctl)

```
TITLE                           Merge the Transit Volumes

DEFAULT_FILE_FORMAT             DBASE

PEAK_RIDERSHIP_FILE_1           ..\i4_DRABAMlink.dbf                //DRIVE ACCESS
PEAK_RIDERSHIP_FILE_2           ..\i4_DRBMAMlink.dbf
PEAK_RIDERSHIP_FILE_3           ..\i4_DRCRAMlink.dbf
PEAK_RIDERSHIP_FILE_4           ..\i4_DRMRAMlink.dbf
PEAK_RIDERSHIP_FILE_5           ..\i4_KRABAMlink.dbf                //KISS AND RIDE ACCESS
PEAK_RIDERSHIP_FILE_6           ..\i4_KRBMAMlink.dbf
PEAK_RIDERSHIP_FILE_7           ..\i4_KRMRAMlink.dbf
PEAK_RIDERSHIP_FILE_8           ..\i4_WKABAMlink.dbf                //WALK ACCESS
PEAK_RIDERSHIP_FILE_9           ..\i4_WKBMAMlink.dbf
PEAK_RIDERSHIP_FILE_10          ..\i4_WKCRAMlink.dbf
PEAK_RIDERSHIP_FILE_11          ..\i4_WKMRAMlink.dbf

OFFPEAK_RIDERSHIP_FILE_1        ..\i4_DRABOPlink.dbf                //DRIVE ACCESS
OFFPEAK_RIDERSHIP_FILE_2        ..\i4_DRBMOPlink.dbf
OFFPEAK_RIDERSHIP_FILE_3        ..\i4_DRCROPlink.dbf
OFFPEAK_RIDERSHIP_FILE_4        ..\i4_DRMROPlink.dbf
OFFPEAK_RIDERSHIP_FILE_5        ..\i4_KRABOPlink.dbf                //KISS AND RIDE ACCESS
OFFPEAK_RIDERSHIP_FILE_6        ..\i4_KRBMOPlink.dbf
OFFPEAK_RIDERSHIP_FILE_7        ..\i4_KRMROPlink.dbf
OFFPEAK_RIDERSHIP_FILE_8        ..\i4_WKABOPlink.dbf                //WALK ACCESS
OFFPEAK_RIDERSHIP_FILE_9        ..\i4_WKBMOPlink.dbf
OFFPEAK_RIDERSHIP_FILE_10       ..\i4_WKCROPlink.dbf
OFFPEAK_RIDERSHIP_FILE_11       ..\i4_WKMROPlink.dbf

NEW_PEAK_RIDERSHIP_FILE         PK_VOL.dbf
NEW_PEAK_RIDERSHIP_FORMAT       DBASE
NEW_OFFPEAK_RIDERSHIP_FILE      OP_VOL.dbf
NEW_OFFPEAK_RIDERSHIP_FORMAT    DBASE
```

The output from the LineSum_Volume.ctl process is pk_vol.dbf and op_vol.dbf. Either of these transit loaded-link files can be brought into Cube Base as the transit layer, as is shown in Figure 81 through Figure 85.

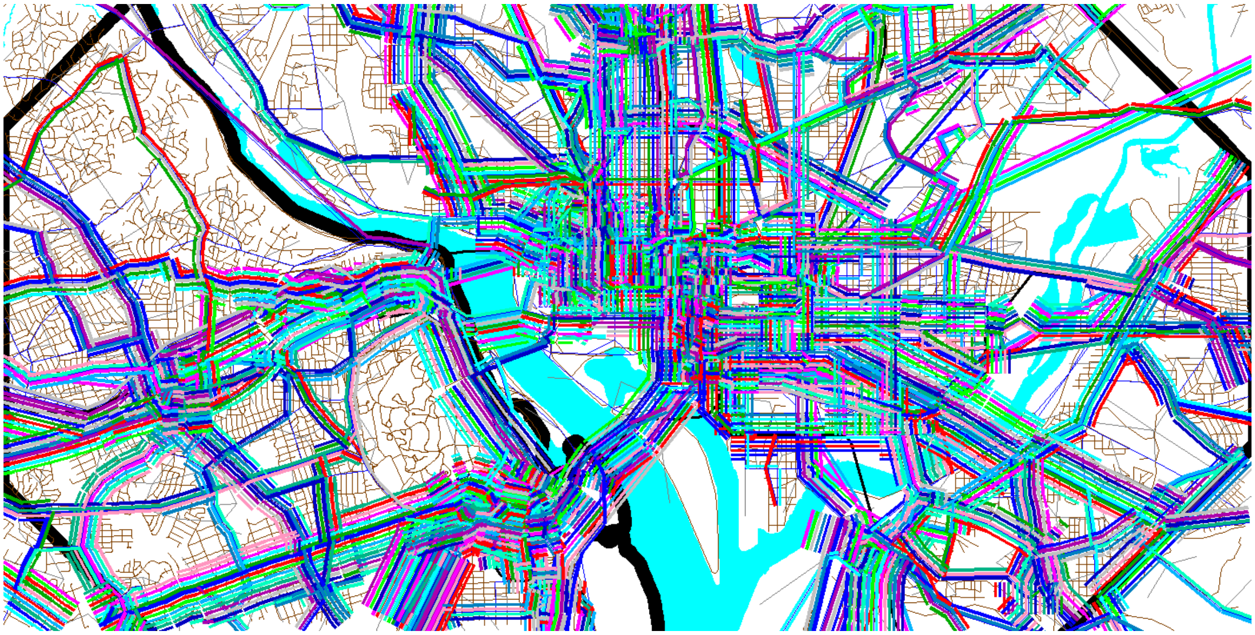


Figure 81 Using the pk_vol.dbf file in Cube Base as the transit layer: All transit routes turned on, but non-transit links (modes 11-16) turned off

Ref: "X:\modelRuns\fy12\Ver2.3.36\2007_pseu\zonehwy.net"

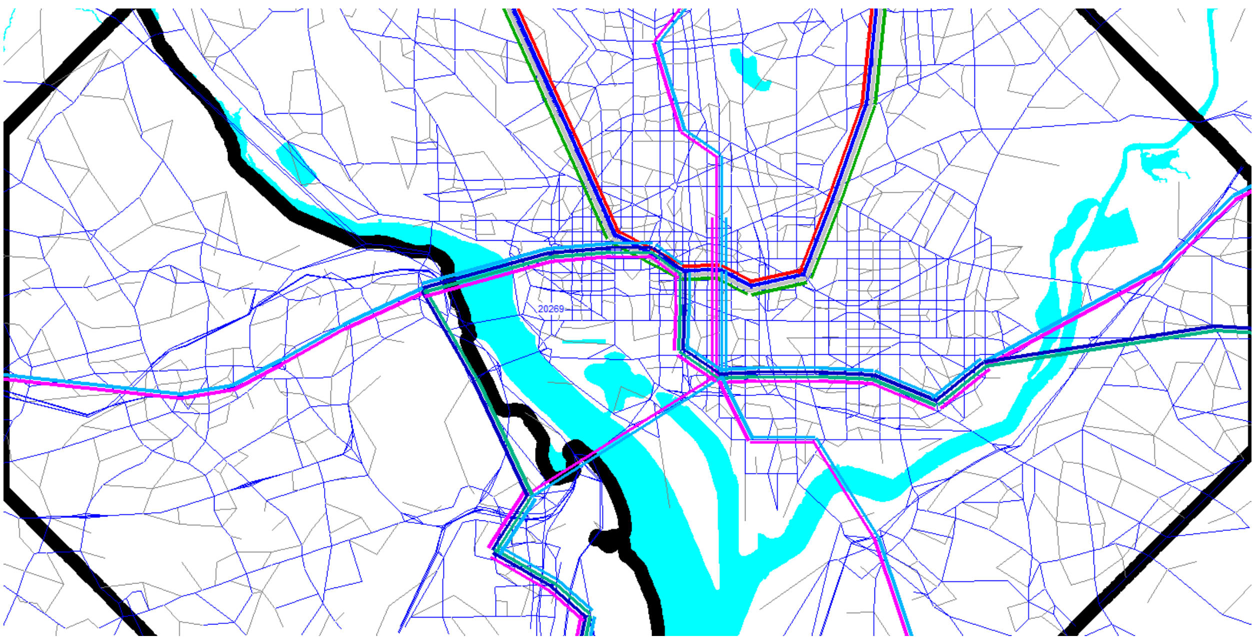


Figure 82 Using the pk_vol.dbf file in Cube Base as the transit layer: Only mode-3 (Metrorail) links turned on

Ref: "X:\modelRuns\fy12\Ver2.3.36\2007_pseu\zonehwy.net"

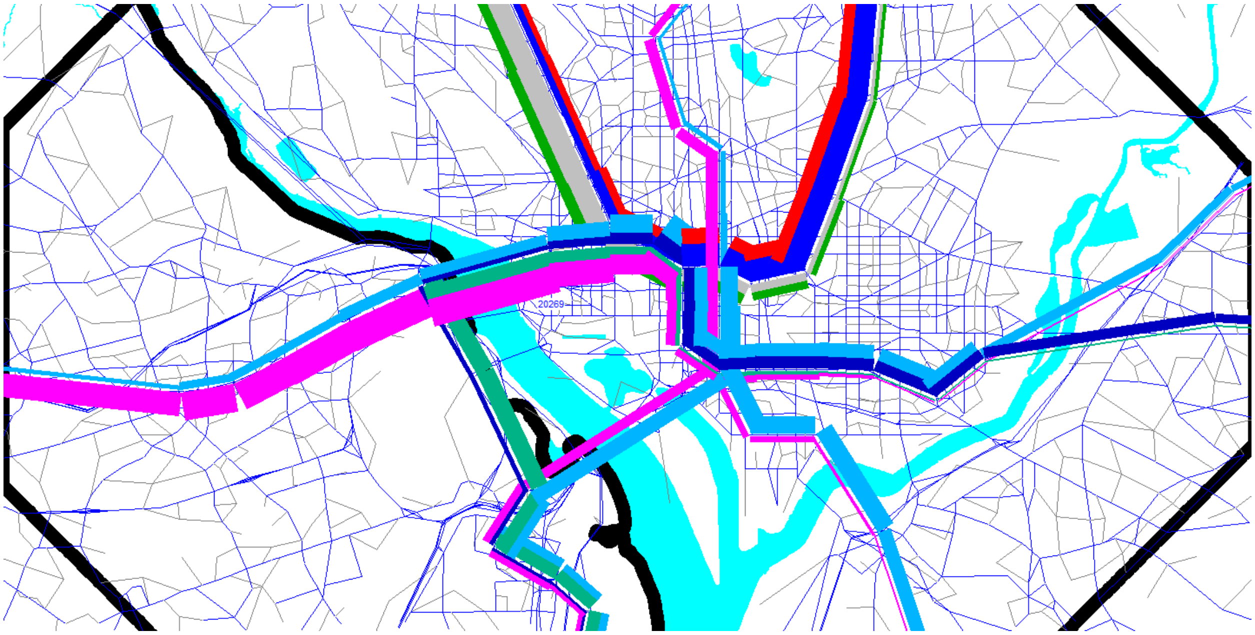


Figure 83 Using the pk_vol.dbf file in Cube Base as the transit layer: Only mode-3 (Metrorail) links turned on; using multi-bandwidth to represent transit loads (ab_vol): Arlington and DC

Ref: "X:\modelRuns\fy12\Ver2.3.36\2007_pseu\zonehwy.net"

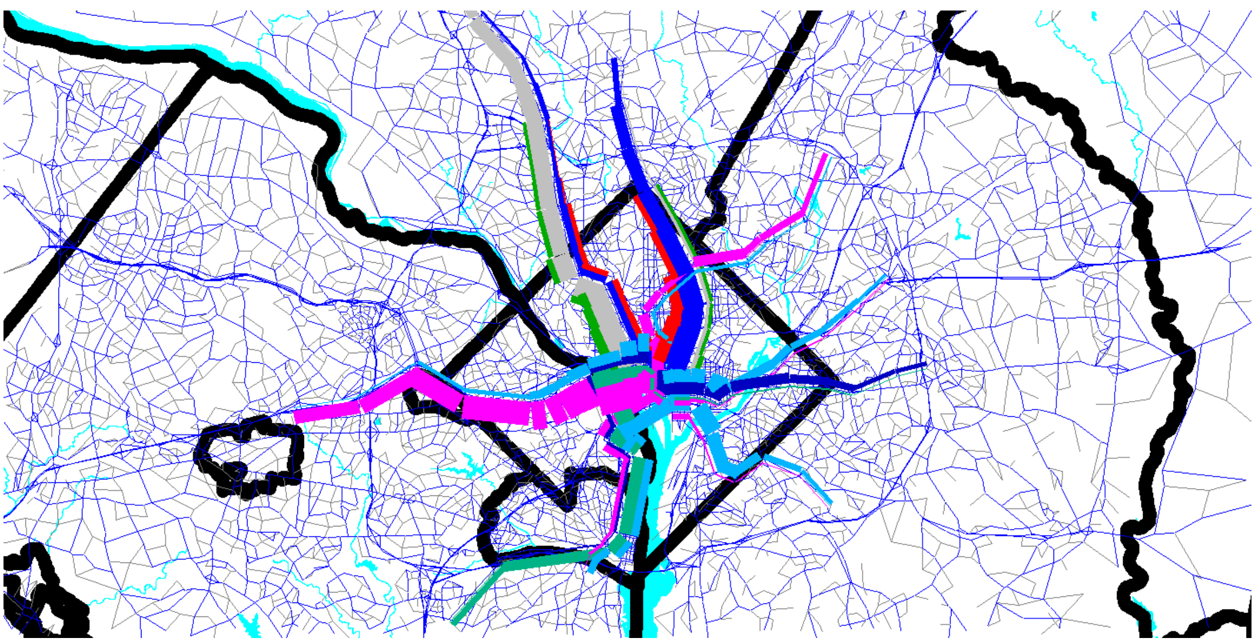


Figure 84 Using the pk_vol.dbf file in Cube Base as the transit layer: Only mode-3 (Metrorail) links turned on; using multi-bandwidth to represent transit loads (ab_vol): Metrorail system

Ref: "X:\modelRuns\fy12\Ver2.3.36\2007_pseu\zonehwy.net"

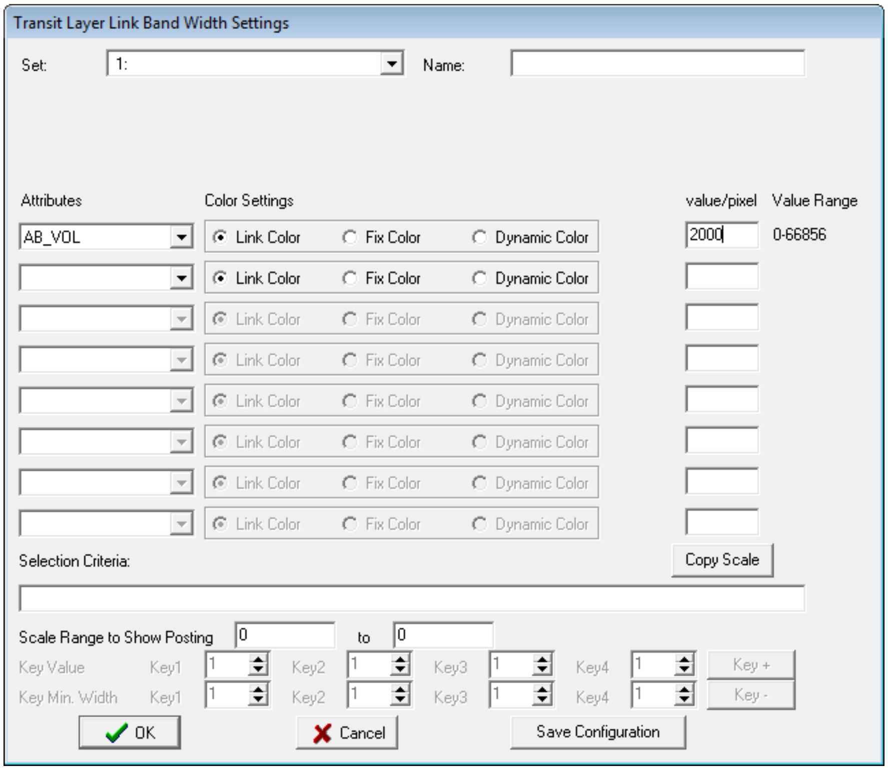


Figure 85 Using the multi-bandwidth option in Cube Base to show transit volumes on the Metrorail system.

24.2.2 Generating transit assignment summaries using LineSum

The LineSum C++ program summarizes transit line volume data stored in a TRNBUILD loaded link DBF file. It can be used to create the following summaries:

- Boarding/alighting information
- Station access information
- Link-based summaries (i.e., between stations).
- Transit route/line summaries

An example of a control file used to generate an access report showing riders who arrive at and depart from Metrorail stations (via transit access links) can be seen in Figure 86. The station_names.dbf file is now stored in the "inputs" folder (not the "controls") folder.

Figure 86 Generating a Metrorail station access report (lineSum_MR_access.ctl)

```
## Access reports focus on riders who arrive or depart using transit access links
## i.e., the summary does not include transfers
TITLE                              Metrorail Station Access Summmary
DEFAULT_FILE_FORMAT                DBASE

PEAK_RIDERSHIP_FILE_1                                  PK_VOL.DBF
PEAK_RIDERSHIP_FORMAT_1                                DBASE
OFFPEAK_RIDERSHIP_FILE_1                               OP_VOL.DBF
OFFPEAK_RIDERSHIP_FORMAT_1                             DBASE

STOP_NAME_FILE                     ..\inputs\station_names.dbf
STOP_NAME_FORMAT                   DBASE

ACCESS_REPORT_TITLE_1                                            All
ACCESS_REPORT_STOPS_1                                            8001..8100, 8119..8140, 8145..8148, 8150..8154,
8160..8166, 8169..8182
##ACCESS_REPORT_MODES_1                                          11,12,14,15,16
ACCESS_REPORT_MODES_1                                            ALL
##ACCESS_REPORT_DETAILS_1        MODE
NEW_ACCESS_REPORT_FILE_1                 MR_access.txt
NEW_ACCESS_REPORT_FORMAT_1               TAB_DELIMITED
```

Similarly, an example of a control file used to generate a Metrorail line summary can be seen in Figure 87. Once again, the station_names.dbf file is now stored in the "inputs" folder (not the "controls") folder.

Figure 87 Generating a Metrorail line summary (lineSum_MR_line.ctl)

```
## Line reports summarize boardings, alightings, and ridership for one or more line
TITLE                              Metrorail Line Summmary
DEFAULT_FILE_FORMAT                DBASE

PEAK_RIDERSHIP_FILE_1                                  PK_VOL.DBF
PEAK_RIDERSHIP_FORMAT_1                                DBASE
OFFPEAK_RIDERSHIP_FILE_1                               OP_VOL.DBF
OFFPEAK_RIDERSHIP_FORMAT_1                             DBASE

STOP_NAME_FILE                     ..\inputs\station_names.dbf
STOP_NAME_FORMAT                   DBASE

LINE_REPORT_TITLE_1                                                All
LINE_REPORT_LINES_1            All
LINE_REPORT_MODES_1            3
```

```
NEW_TOTAL_RIDERSHIP_FILE_1    MR_line.txt
NEW_TOTAL_RIDERSHIP_FORMAT_1  TAB_DELIMITED
```

An example of the report generated by the lineSum_MR_**access**.ctl control file can be found in Figure 88. Similarly, an example of the report generated by the lineSum_MR_**line**.ctl control file can be found Figure 89.

More information about using LineSum can be found in its documentation:

- AECOM. (2013). LineSum, Quick Reference, Version 5.0.17. Arlington, Virginia: AECOM.
- AECOM. (2014). LineSum (Version 6.0.2). Arlington, Virginia: AECOM.

Figure 88 An excerpt from the report file generated by lineSum_MR_access.ctl

```
********************************************
|                                          |
|         LineSum - Version 6.0.2          |
|  Copyright 2014 by TRANSIMS Open-Source  |
|         Tue Sep 11 04:41:33 2018         |
|                                          |
********************************************

Control File = lineSum_MR_access.ctl
Report File  = lineSum_MR_access.prn (Create)

Metrorail Station Access Summmary

Default File Format = DBASE

LineSum Control Keys:

Peak Ridership File #1 = PK_VOL.DBF

Offpeak Ridership File #1 = OP_VOL.DBF


Stop Name File = ..\..\controls\station_names.dbf

Access Report Title = All
Access Report Stops = 8001..8100, 8119..8140, 8145..8148, 8150..8154, 8160..8166, 8169..8182
Access Report Modes = ALL
New Access Report File #1 = MR_access.txt
New Access Report Format #1 = TAB_DELIMITED


Number of Stop Names = 446  Metrorail Station Access Summmary
Tue Sep 11 04:41:34 2018  LineSum  page 2


Title: All
Modes: All

        ---- Peak ----  -- Offpeak ---  ---- Daily ---
Stop    Arrive  Depart  Arrive  Depart  Arrive  Depart

8001     34719    2676    2252     705   36971    3381  Shady Grove
8002     12771    2899    1209     865   13980    3764  Rockville
8003      5500    4230     947    1400    6447    5630  Twinbrook
8004      6462    7816    1273    2706    7735   10522  White Flint
8005      9806     301    2003     587   11809     888  Grosvenor
8006      4902    7237    1085    1584    5987    8821  Medical Center
```

```
8007     15291   19297    4879    6070   20170   25367  Bethesda
8008     10843    6735    3402    2916   14245    9651  Friendship Heights
8009     10247    5849    2938    1708   13185    7557  Tenleytown
8010      5501    3360    1946    1368    7447    4728  Van Ness-UDC
8011      4685     889    1539     760    6224    1649  Cleveland Park
8012      8082    2629    2660    1537   10742    4166  Woodley Park-Zoo
8013     10939   30437    1946    6301   12885   36738  Dupont Circle
8014      3399   35046    1389    3722    4788   38768  Farragut North
8015       691   31251     295    4081     986   35332  Metro Center
8016       490   20397     707    3286    1197   23683  Gallery Place
8017       251   14986     212    1310     463   16296  Judiciary Square
8018     29588   39035    5116    6321   34704   45356  Union Station
```

Figure 89 The report file generated by lineSum_MR_line.ctl

```
********************************************
|                                          |
|         LineSum - Version 6.0.2          |
|  Copyright 2012 by TRANSIMS Open-Source  |
|         Tue Sep 11 04:41:34 2018         |
|                                          |
********************************************

Control File = lineSum_MR_line.ctl
Report File  = lineSum_MR_line.prn (Create)

Metrorail Line Summmary

Default File Format = DBASE

LineSum Control Keys:

Peak Ridership File #1 = PK_VOL.DBF

Offpeak Ridership File #1 = OP_VOL.DBF


Stop Name File = ..\..\controls\station_names.dbf

Line Report Title = All
Line Report Lines = All
Line Report Modes = 3


Number of Stop Names = 267       Metrorail Line Summmary
Tue Sep 11 04:41:35 2018         LineSum  page 2


Title: All
Lines: All
Modes: 3
```

			A->B Direction (Read Down)									B->A Direction (Read Up)									Total		
	Dist	Time	Peak			Off-Peak			Daily			Peak			Off-Peak			Daily			Daily		
Stop	(miles)	(min)	On	Off	Ride	On	Off	Ride	On	Off	Ride	On	Off	Ride	On	Off	Ride	On	Off	Ride	On	Off	Ride
Franconia-	3.49	6.29	12346	0	12346	1380	0	1380	13726	0	13726	0	2446	2446	0	602	602	0	3048	3048	13726	3048	16774
Van Dorn S	3.86	5.08	8410	174	20584	1997	59	3318	10407	233	23902	466	831	2810	76	704	1231	542	1535	4041	10949	1768	27943
King Stree	0.68	2.07	4386	1666	48952	1075	847	7331	5461	2513	56283	549	2619	11717	267	1248	5521	816	3867	17238	6277	6380	73521
Braddock R	1.21	1.98	5789	1541	53201	1657	1113	7872	7446	2654	61073	707	2841	13853	658	2133	6996	1365	4974	20849	8811	7628	81922
Potomac Ya	1.82	2.98	10851	2311	61738	3073	1448	9498	13924	3759	71236	1306	3903	16445	2000	1930	6928	3306	5833	23373	17230	9592	94609
National A	0.49	2.65	0	1198	60540	371	173	9695	371	1371	70235	0	2675	19124	73	686	7540	73	3361	26664	444	4732	96899
Crystal Ci	0.76	2.07	5140	5462	60219	3087	1532	11249	8227	6994	71468	949	17358	35532	1047	5514	12007	1996	22872	47539	10223	29866	119007
Pentagon C	0.61	1.01	8973	5450	63740	2039	825	12463	11012	6275	76203	2029	5116	38617	1118	2343	13230	3147	7459	51847	14159	13734	128050
Pentagon	1.24	2.99	2336	5842	18109	2063	1785	8540	4399	7627	26649	2693	2568	11286	1634	1278	5934	4327	3846	17220	8726	11473	43869
Arlington	0.99	2.14	105	0	18213	75	0	8615	180	0	26828	36	0	11249	25	0	5910	61	0	17159	241	0	43987
Rosslyn	1.35	3.19	5710	13813	88316	1830	6291	14363	7540	20104	102679	11195	14723	47980	5065	4051	13410	16260	18774	61390	23800	38878	164069
Foggy Bott	0.57	2.14	2148	11054	79410	1394	2638	13119	3542	13692	92529	814	29872	77039	841	5620	18193	1655	35492	95232	5197	49184	187761
Farragut W	0.38	0.99	1229	13797	66840	466	1567	12014	1695	15364	78854	834	24187	100391	354	2825	20660	1188	27012	121051	2883	42376	199905

McPherson	0.46	1.11	4155	11702	59294	1362	2010	11367	5517	13712	70661	2426	36361	134327	964	4082	23773	3390	40443	158100	8907	54155	228761
Metro Cent	0.29	0.94	18835	36658	41472	3476	5778	9065	22311	42436	50537	66870	22588	90043	10239	5363	18896	77109	27951	108939	99420	70387	159476
Federal Tr	0.41	2.15	0	6810	34665	30	805	8289	30	7615	42954	70	1264	91236	104	284	19078	174	1548	110314	204	9163	153268
Smithsonia	0.59	2.34	389	8833	26224	191	1748	6731	580	10581	32955	1206	2399	92434	577	759	19261	1783	3158	111695	2363	13739	144650
L'Enfant P	0.33	1.99	12507	12401	26326	3579	3179	7132	16086	15580	33458	46959	21081	66557	7352	6982	18895	54311	28063	85452	70397	43643	118910
Federal Ce	0.57	1.96	53	9530	16851	173	1854	5453	226	11384	22304	990	1976	67546	984	722	18632	1974	2698	86178	2200	14082	108482
Capitol So	0.50	1.99	70	8924	8000	248	1551	4149	318	10475	12149	811	3214	69946	903	985	18713	1714	4199	88659	2032	14674	100808
Eastern Ma	0.63	2.02	160	2580	5578	368	928	3587	528	3508	9165	3809	2248	68386	1950	539	17301	5759	2787	85687	6287	6295	94852
Potomac Av	0.66	0.99	413	1101	4892	268	815	3041	681	1916	7933	9501	434	59320	3706	406	14006	13207	840	73326	13888	2756	81259
Stadium Ar	2.69	3.17	687	515	2528	299	779	1410	986	1294	3938	5186	921	32604	1710	415	8440	6896	1336	41044	7882	2630	44982
Benning Ro	1.42	2.90	266	746	2045	201	608	1004	467	1354	3049	5890	376	27091	2586	362	6215	8476	738	33306	8943	2092	36355
Capitol He	0.97	2.95	119	477	1687	62	429	639	181	906	2326	5397	97	21790	2818	95	3491	8215	192	25281	8396	1098	27607
Addison Ro	1.77	3.13	155	327	1515	44	121	560	199	448	2075	8360	54	13485	1234	28	2282	9594	82	15767	9793	530	17842
Morgan Blv	1.23	2.78	141	466	1189	40	142	459	181	608	1648	3707	45	9823	637	34	1678	4344	79	11501	4525	687	13149
Largo Town				1189			459			1648		9823			1678			11501			11501	1648	
Greenbelt	2.44	2.88	15152	0	15152	1417	0	1417	16569	0	16569	0	1155	1155	0	225	225	0	1380	1380	16569	1380	17949
College Pa	1.94	3.02	5085	694	19543	1384	171	2630	6469	865	22173	210	3534	4476	54	1119	1289	264	4653	5765	6733	5518	27938
PG Plaza	1.24	3.14	5513	687	24364	1339	222	3749	6852	909	28113	481	2172	6163	178	487	1598	659	2659	7761	7511	3568	35874
West Hyatt	1.99	2.92	4343	140	28567	1998	245	5502	6341	385	34069	582	359	5943	251	302	1649	833	661	7592	7174	1046	41661
Fort Totte	1.62	2.89	6778	17364	17977	2895	3176	5221	9673	20540	23198	3378	3340	5902	920	1685	2413	4298	5025	8315	13971	25565	31513
Georgia Av	0.86	3.11	8768	3350	23396	2616	1117	6720	11384	4467	30116	2434	3916	7384	998	1168	2582	3432	5084	9966	14816	9551	40082
Columbia H	0.95	2.02	11346	1047	33692	2676	622	8772	14022	1669	42464	1029	2223	8580	495	1191	3280	1524	3414	11860	15546	5083	54324
U-Street-C	0.51	2.05	5194	2931	35959	2242	979	10038	7436	3910	45997	492	6235	14323	341	2402	5340	833	8637	19663	8269	12547	65660
Shaw-Howar	0.56	1.13	3186	685	38460	1462	380	11121	4648	1065	49581	734	2174	15764	333	1064	6070	1067	3238	21834	5715	4303	71415
Mt Vernon	0.49	1.66	2096	2600	37958	1203	1082	11242	3299	3682	49200	158	11171	26774	211	2561	8418	369	13732	35192	3668	17414	84392
Gallery Pl	0.36	1.92	37196	19641	55514	5690	5039	11892	42886	24680	67406	13001	45140	58913	2840	7040	12619	15841	52180	71532	58727	76860	138938
Archives	0.58	1.97	2411	3268	54655	156	656	11391	2567	3924	66046	4679	10749	64983	44	1454	14028	4723	12203	79011	7290	16127	145057
L'Enfant P	0.79	1.91	14484	21213	30763	2656	3917	6073	17140	25130	36836	10228	39128	66117	3302	11376	19284	13530	50504	85401	30670	75634	122237
Waterfront	0.59	1.80	816	5192	26386	657	911	5817	1473	6103	32203	4152	1394	63360	1867	1059	18477	6019	2453	81837	7492	8556	114040
Navy Yard	1.20	2.06	438	19198	7629	662	3025	3454	1100	22223	11083	6662	4978	61677	3773	1514	16217	10435	6492	77894	11535	28715	88977
Anacostia	1.38	2.98	369	5063	2934	470	1793	2128	839	6856	5062	14738	1087	48028	6810	466	9872	21548	1553	57900	22387	8409	62962
Congress H	0.97	1.78	85	1203	1815	113	642	1598	198	1845	3413	4877	372	43524	2138	195	7930	7015	567	51454	7213	2412	54867
Southern A	1.24	2.76	214	302	1725	112	484	1224	326	786	2949	14918	67	28674	3795	130	4266	18713	197	32940	19039	983	35889
Naylor Roa	1.48	2.34	184	619	1291	74	638	661	258	1257	1952	8961	119	19831	1317	67	3015	10278	186	22846	10536	1443	24798
Suitland	1.64	2.66	35	929	396	12	482	191	47	1411	587	4426	89	15495	1189	19	1844	5615	108	17339	5662	1519	17926
Branch Ave				396			191			587		15495			1844			17339			17339	587	
Vienna	2.39	3.69	21333	0	21333	1868	0	1868	23201	0	23201	0	1330	1330	0	596	596	0	1926	1926	23201	1926	25127
Dunn Lorin	2.49	3.99	6374	190	27519	1218	63	3023	7592	253	30542	113	1542	2757	57	762	1302	170	2304	4059	7762	2557	34601
West Falls	2.09	2.93	3279	54	30744	633	27	3629	3912	81	34373	122	342	2977	48	307	1562	170	649	4539	4082	730	38912
East Falls	2.51	3.96	12817	3272	81908	2585	835	10985	15402	4107	92893	632	1582	22154	434	1213	9219	1066	2795	31373	16468	6902	124266

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			A->B Direction (Read Down)									B->A Direction (Read Up)									Total		
	Dist	Time	Peak			Off-Peak			Daily			Peak			Off-Peak			Daily			Daily		
Stop	(miles)	(min)	On	Off	Ride	On	Off	Ride	On	Off	Ride	On	Off	Ride	On	Off	Ride	On	Off	Ride	On	Off	Ride
Ballston	0.49	1.67	14638	6083	90465	4959	1756	14188	19597	7839	104653	2657	11870	31363	1544	4254	11933	4201	16124	43296	23798	23963	147949
Virginia S	0.49	2.01	3318	2807	90974	1323	1085	14426	4641	3892	105400	1066	4023	34322	558	1613	12993	1624	5636	47315	6265	9528	152715
Clarendon	0.67	2.52	5780	2744	94010	1787	1484	14727	7567	4228	108737	1673	4925	37567	1361	1905	13536	3034	6830	51103	10601	11058	159840
Court Hous	0.91	1.69	6302	3940	96369	2540	1633	15636	8842	5573	112005	1553	7596	43613	1369	2516	14680	2922	10112	58293	11764	15685	170298
Rosslyn				18164			5429			23593		10410			6171			16581			16581	23593	
Stadium Ar	2.19	3.99	799	0	3333	231	0	1380	1030	0	4713	0	668	23120	0	282	4556	0	950	27676	1030	950	32389
Minnesota	0.91	1.95	360	1094	2603	208	347	1240	568	1441	3843	5891	425	17653	1753	173	2976	7644	598	20629	8212	2039	24472
Deanwood	1.15	1.90	271	247	2626	95	247	1087	366	494	3713	3372	67	14348	1104	71	1942	4476	138	16290	4842	632	20003
Cheverly	1.89	2.99	106	421	2312	19	108	1000	125	529	3312	1597	94	12848	332	16	1627	1929	110	14475	2054	639	17787
Landover	1.36	2.69	240	278	2276	30	195	836	270	473	3112	4593	101	8353	433	20	1214	5026	121	9567	5296	594	12679
New Carrol				2276			836			3112		8353			1214			9567			9567	3112	
Shady Grov	2.61	4.06	34720	0	34720	2262	0	2262	36982	0	36982	0	2677	2677	0	705	705	0	3382	3382	36982	3382	40364
Rockville	2.13	3.29	12479	673	46524	1106	159	3207	13585	832	49731	290	2227	4615	101	704	1306	391	2931	5921	13976	3763	55652
Twinbrook	1.09	3.08	4880	1291	50114	699	353	3555	5579	1644	53669	618	2941	6936	250	1047	2102	868	3988	9038	6447	5632	62707
White Flin	1.35	2.03	5580	2334	53359	842	647	3750	6422	2981	57109	884	5480	11535	433	2060	3728	1317	7540	15263	7739	10521	72372
Grosvenor	2.19	3.05	9180	76	62465	1824	108	5467	11004	184	67932	629	226	11131	182	478	4024	811	704	15155	11815	888	83087
Medical Ce	1.02	2.01	4610	2098	64972	835	398	5905	5445	2496	70877	290	5136	15978	246	1183	4962	536	6319	20940	5981	8815	91817
Bethesda	1.70	3.08	11451	6438	69987	3479	2155	7227	14930	8593	77214	3841	12859	24995	1405	3914	7471	5246	16773	32466	20176	25366	109680
Friendship	0.91	2.41	8133	2004	76118	1801	1157	7870	9934	3161	83988	2712	4731	27016	1605	1754	7623	4317	6485	34639	14251	9646	118627
Tenleytown	1.09	2.03	7407	1674	81849	1782	441	9213	9189	2115	91062	2834	4174	28355	1157	1267	7735	3991	5441	36090	13180	7556	127152
Van Ness-U	0.55	1.82	4602	972	85482	1311	354	10169	5913	1326	95651	906	2388	29840	638	1015	8112	1544	3403	37952	7457	4729	133603
Cleveland	0.80	2.33	3547	213	88814	1083	191	11061	4630	404	99875	1136	676	29376	463	569	8219	1599	1245	37595	6229	1649	137470
Woodley Pa	1.15	1.99	6949	679	95085	2053	407	12706	9002	1086	107791	1132	1947	30197	611	1125	8735	1743	3072	38932	10745	4158	146723
Dupont Cir	0.56	2.28	9505	11510	93080	1494	2224	11977	10999	13734	105057	1435	18923	47687	454	4078	12359	1889	23001	60046	12888	36735	165103
Farragut N	0.79	2.22	1728	18506	76303	841	1307	11509	2569	19813	87812	1670	16539	62557	548	2414	14227	2218	18953	76784	4787	38766	164596
Metro Cent	0.33	1.18	30702	33439	73564	6140	4777	12873	36842	38216	86437	13349	67635	116842	3055	10775	21946	16404	78410	138788	53246	116626	225225
Gallery Pl	0.33	0.92	26852	30441	69977	4602	4202	13274	31454	34643	83251	27957	29690	118577	5986	5415	21372	33943	35105	139949	65397	69748	223200
Judiciary	0.67	2.14	47	11446	58581	57	890	12438	104	12336	71019	204	3543	121917	155	416	21635	359	3959	143552	463	16295	214571
Union Stat	0.73	1.06	4865	24861	38582	1681	3704	10419	6546	28565	49001	24726	14175	111367	3434	2621	20821	28160	16796	132188	34706	45361	181189
New York A	0.96	1.86	685	24610	14655	797	6236	4979	1482	30846	19634	7632	11225	114955	4908	2917	18829	12540	14142	133784	14022	44988	153418
Rhode Isla	0.93	2.23	1569	3640	12582	1234	1672	4542	2803	5312	17124	15376	1857	101437	6658	772	12943	22034	2629	114380	24837	7941	131504
Brookland-	1.30	2.98	459	2036	11004	535	932	4150	994	2968	15154	3115	1448	99768	1496	594	12042	4611	2042	111810	5605	5010	126964
Fort Totte	1.89	3.10	3703	3725	10978	1643	1742	4049	5346	5467	15027	27293	5054	77530	5761	1158	7437	33054	6212	84967	38400	11679	99994
Takoma	1.47	3.22	757	2363	9373	445	888	3607	1202	3251	12980	6122	829	72237	1753	342	6025	7875	1171	78262	9077	4422	91242
Silver Spr	1.75	3.25	658	7872	2161	425	2720	1309	1083	10592	3470	41358	2970	33850	4840	757	1941	46198	3727	35791	47281	14319	39261
Forest Gle	1.58	4.07	63	897	1327	26	457	874	89	1354	2201	5556	163	28456	472	48	1519	6028	211	29975	6117	1565	32176
Wheaton	1.75	3.31	25	1077	273	20	721	174	45	1798	447	14672	116	13902	547	49	1018	15219	165	14920	15264	1963	15367
Glenmont				273			174			447		13902			1018			14920			14920	447	
Route 772/	2.08	3.53	13861	0	13861	515	0	515	14376	0	14376	0	397	397	0	94	94	0	491	491	14376	491	14867
VA 606/Wes	3.15	4.22	1055	124	14792	76	13	578	1131	137	15370	133	234	501	9	30	115	142	264	616	1273	401	15986
Dulles Air	1.83	2.88	0	52	14741	112	10	681	112	62	15422	0	250	749	7	87	194	7	337	943	119	399	16365
Innovation	1.84	4.18	5170	216	19695	843	38	1486	6013	254	21181	152	863	1458	30	535	699	182	1398	2157	6195	1652	23338
Herndon	1.15	1.85	8285	1092	26886	1507	247	2745	9792	1339	29631	315	2808	3950	151	1345	1895	466	4153	5845	10258	5492	35476
Reston Tow	1.27	3.76	2568	2091	27365	1213	906	3051	3781	2997	30416	725	3340	6568	686	1572	2781	1411	4912	9349	5192	7909	39765
Wiehle/Res	5.83	7.70	7272	888	33750	1186	718	3521	8458	1606	37271	1238	1586	6915	1007	832	2608	2245	2418	9523	10703	4024	46794
Spring HIl	0.46	1.03	3854	1231	36375	2077	523	5074	5931	1754	41449	528	4300	10687	504	2676	4779	1032	6976	15466	6963	8730	56915
Greensboro	0.69	1.56	3802	1544	38632	1274	434	5913	5076	1978	44545	798	4174	14061	399	2040	6421	1197	6214	20482	6273	8192	65027
Tysons Cor	1.19	2.79	3238	3237	38632	1801	1343	6373	5039	4580	45005	1361	7001	19703	1310	2679	7791	2671	9680	27494	7710	14260	72499
McLean Tys	3.90	6.10	6484	2512	42602	1967	2029	6310	8451	4541	48912	2132	6084	23654	2176	2515	8130	4308	8599	31784	12759	13140	80696
East Falls				984			706			1690		5429			1250			6679			6679	1690	

```
           L'Enfant P    2.35   5.15  18655     0  35818   5988     0  10048  24643     0  45866      0 39343  67109      0  2883   5702      0 42226  72811  24643 42226 118677
           Pentagon                          8612               3110               11722         24983                1501                26484               26484 11722
           King Stree    0.64   1.89   1624     0   8459    573     0   3882   2197     0  12341      0  2425  28076      0   557   4341      0  2982  32417   2197  2982  44758
           Eisenhower    0.55   1.08    119  6339   2238    124  2682   1323    243  9021   3561   4196  1355  25234   1363   783   3761   5559  2138  28995   5802 11159  32556
           Huntington                        2238               1323                3561         25234                3761                28995               28995  3561

           Total       130.90 261.70       575826             136451             712277             633113             162008             795121            1507398

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                                    ---------------- A->B Direction (Read Down) --------------  --------------- B->A Direction (Read Up) -----------------  -------Total------
                         Dist   Time  -------Peak-------  -----Off-Peak-----  -------Daily------  -------Peak-------  -----Off-Peak-----  -------Daily------  -------Daily------
           Stop        (miles) (min)     On   Off   Ride     On   Off   Ride     On   Off   Ride     On   Off   Ride     On   Off   Ride     On   Off   Ride     On   Off   Ride


           Max           5.83   7.70  37196 36658  96369   6140  6291  15636  42886 42436 112005  66870 67635 134327  10239 11376  23773  77109 78410 158100  99420116626 228761

           Passenger Miles              3932608             612906            4545514            3305303             732957            4038260            8583774
           Passenger Hours               141005              23187             164192             129617              28892             158509             322701
           Average Trip Length (miles)      6.8                4.5               11.3                5.2                4.5                9.7               21.1
           Average Trip Length (minutes)   14.7               10.2               24.9               12.3               10.7               23.0               47.9

           Tue Sep 11 04:41:35 2018 -- Process Complete with 9 Warnings (0:00:01)
```

Appendix A. Flowcharts

Ref: Ver2.4_flowchart.vsd

Flowchart numbers associated with flowchart steps

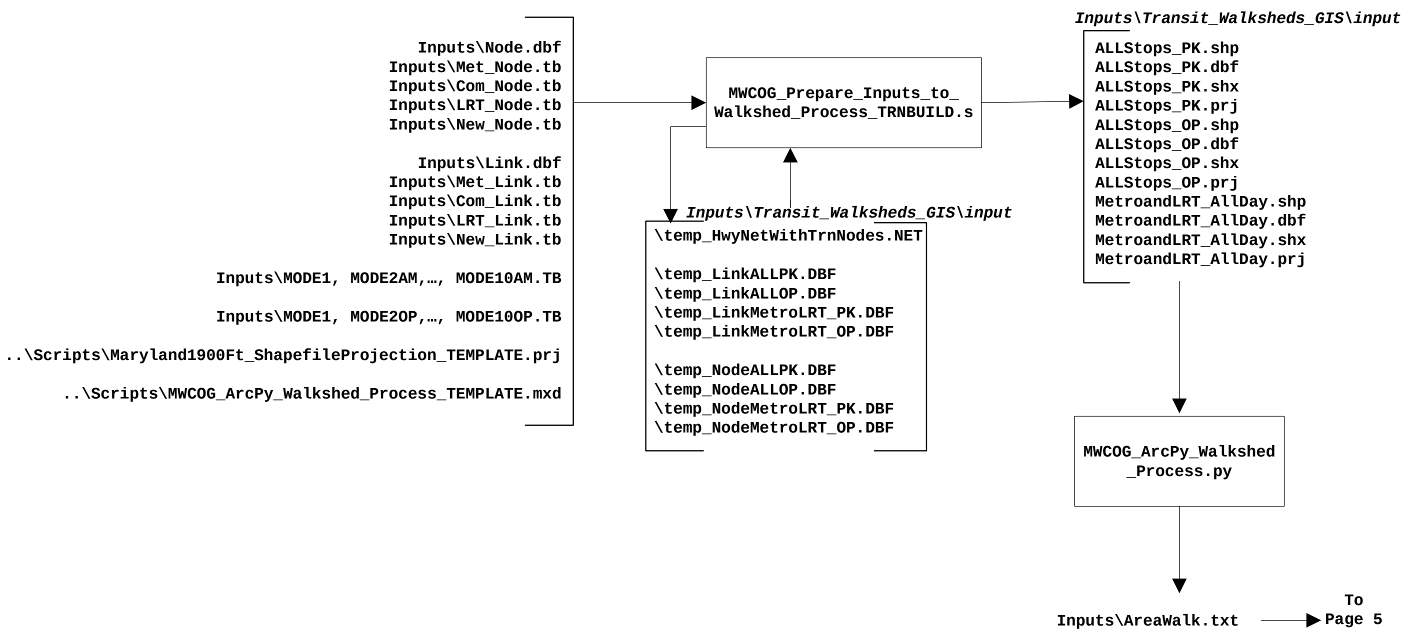
This appendix contains a flowchart showing the flow of data through the TPB regional travel demand forecasting model (Ver. 2.4). The flowcharts are arranged on the basis of the 19 batch files used in the model application. Many of the batch files are reused during the application of the model. The table below describes the sequence of each batch file used by speed-feedback iteration. The flowcharts are numbered as indicated in the table below.

<table>
<tr><th rowspan="2">Batch File</th><th colspan="5">Initial (Pump Prime) Iteration ↓ / Standard Iterations →</th></tr>
<tr><th>PP</th><th>1</th><th>2</th><th>3</th><th>4</th></tr>
<tr><td></td><td colspan="5"></td></tr>
<tr><td>ArcPy_Walkshed_Process.bat</td><td>1</td><td colspan="4"></td></tr>
<tr><td>Set_CPI.bat</td><td>2</td><td colspan="4"></td></tr>
<tr><td>PP_Highway_Build.bat</td><td>3</td><td colspan="4"></td></tr>
<tr><td>PP_Highway_Skims.bat</td><td>4</td><td colspan="4"></td></tr>
<tr><td>Transit_Skim_All_Modes_Parallel.bat
Transit_Skim_LineHaul_Parallel.bat</td><td colspan="5">5</td></tr>
<tr><td>Trip_Generation.bat</td><td colspan="5">6</td></tr>
<tr><td>Trip_Distribution.bat</td><td colspan="5">7</td></tr>
<tr><td>PP_Auto_Drivers.bat</td><td>8</td><td colspan="4"></td></tr>
<tr><td>Time-of-Day.bat</td><td colspan="5">9</td></tr>
<tr><td>Highway_Assignment_Parallel.bat</td><td colspan="5">10</td></tr>
<tr><td>Average_Link_Speeds.bat</td><td colspan="2"></td><td colspan="3">11</td></tr>
<tr><td>Highway_Skims.bat</td><td colspan="5">12</td></tr>
<tr><td>Transit_Fare.bat</td><td></td><td colspan="4">13</td></tr>
<tr><td>Mode_Choice_Parallel.bat</td><td></td><td colspan="4">14</td></tr>
<tr><td>Auto_Driver.bat</td><td></td><td colspan="4">15</td></tr>
<tr><td>Transit_Assignment_Parallel.bat
Transit_Assignment_LineHaul_Parallel.bat</td><td colspan="4"></td><td>16</td></tr>
<tr><td>Transum.bat</td><td colspan="4"></td><td>17-18</td></tr>
</table>

Ref: Appendix_A_UB_flowchart_table_v2.4.xlsx

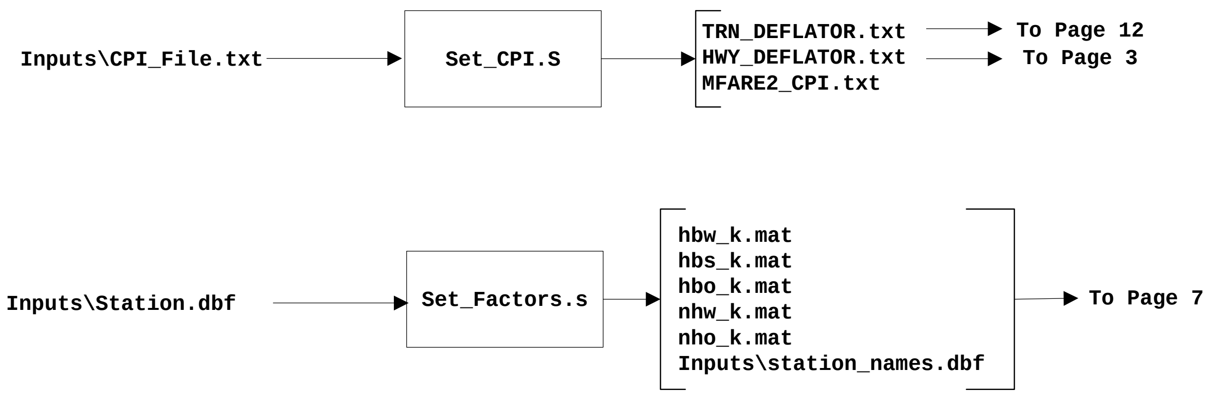
TITLE:	**Flowchart for the TPB trip-based, regional travel demand forecasting model, Ver. 2.4**
COMPANY: **COG/TPB**	Authors RJM, MS, MSM, RN
DATE: 3/15/2021	PG: 1 OF 17
FILENAME: Ver2.4_flowchart.vsd	

ArcPy_Walkshed_Process.bat



Report Files Generated by ArcPy_Walkshed_Process.bat:
AreaWalk_REPORT.prn

Set_CPI.bat:
Develop CPI and K-factors



Report Files Generated by Set_CPI.bat:
Set_CPI.rpt
Set_Factors.rpt

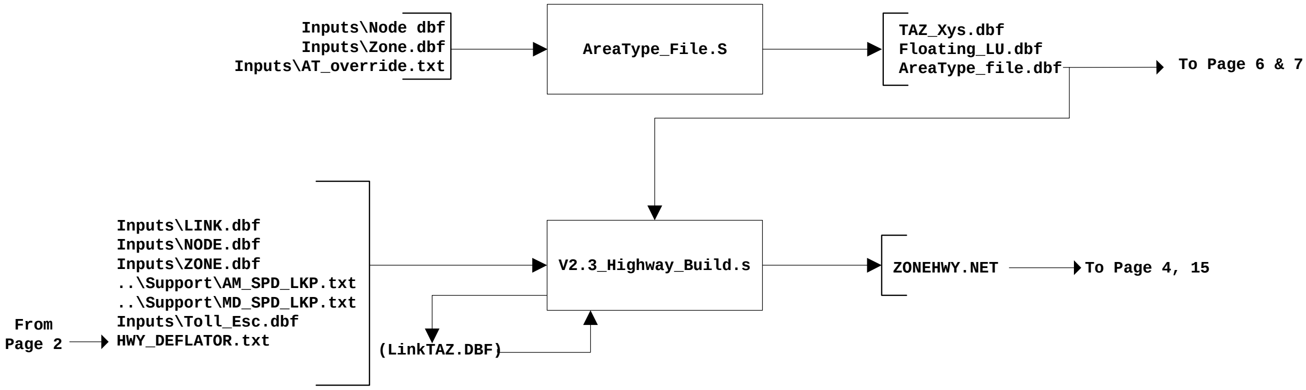
TITLE: Flowchart for the TPB trip-based, regional travel demand forecasting model, Ver. 2.4

COMPANY: COG/TPB Authors RJM, MS, MSM, RN

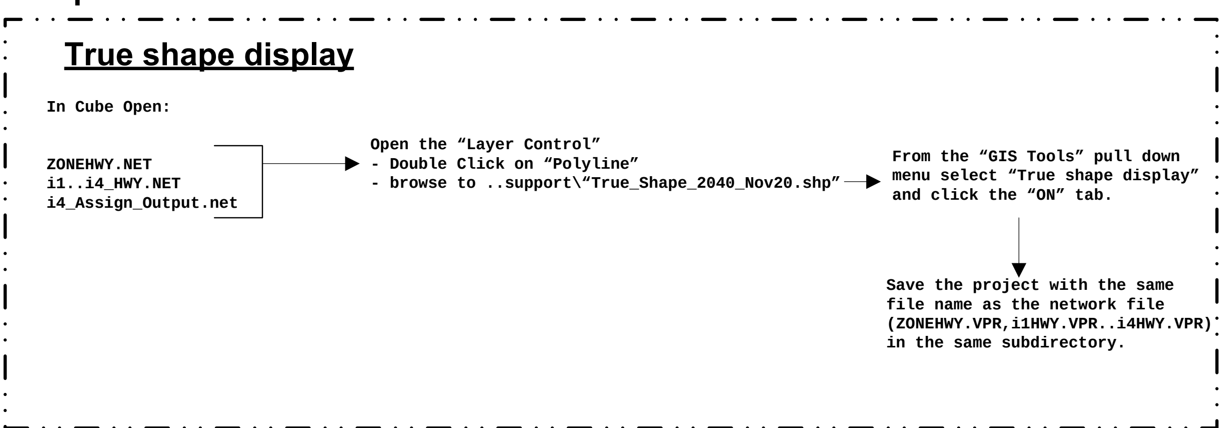
DATE: 3/15/2021 PG: 3 OF 17

FILENAME: Ver2.4_flowchart.vsd

PP_Highway_Build.bat



Optional

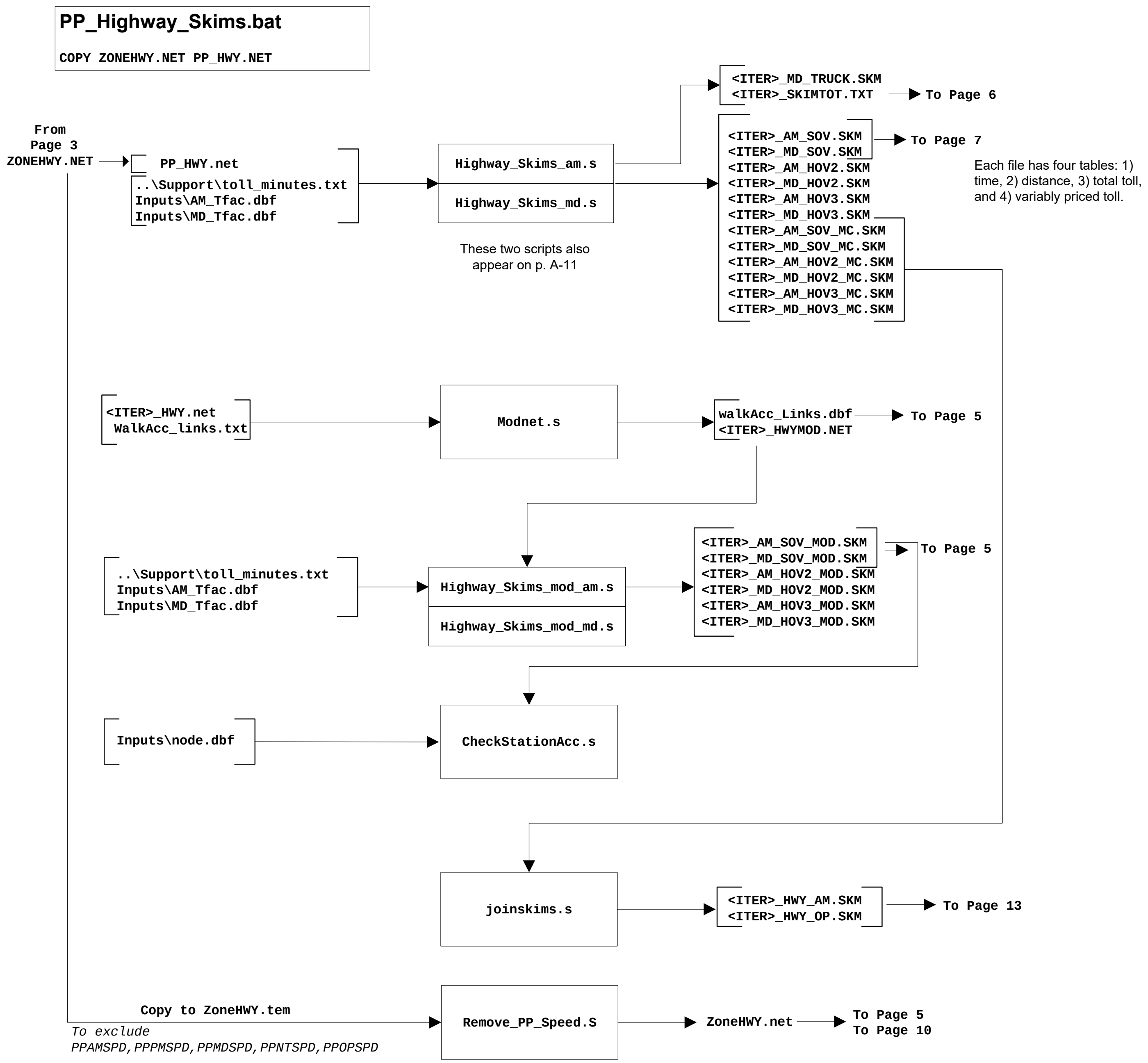


Report Files Generated by PP_Highway_Build.bat:
AreaType_File.rpt
V2.3_highway_build.rpt

TITLE:	**Flowchart for the TPB trip-based, regional travel demand forecasting model, Ver. 2.4**
COMPANY: **COG/TPB**	Authors RJM, MS, MSM, RN
DATE: 3/15/2021	PG: 4 OF 17
FILENAME: Ver2.4_flowchart.vsd	

PP_Highway_Skims.bat

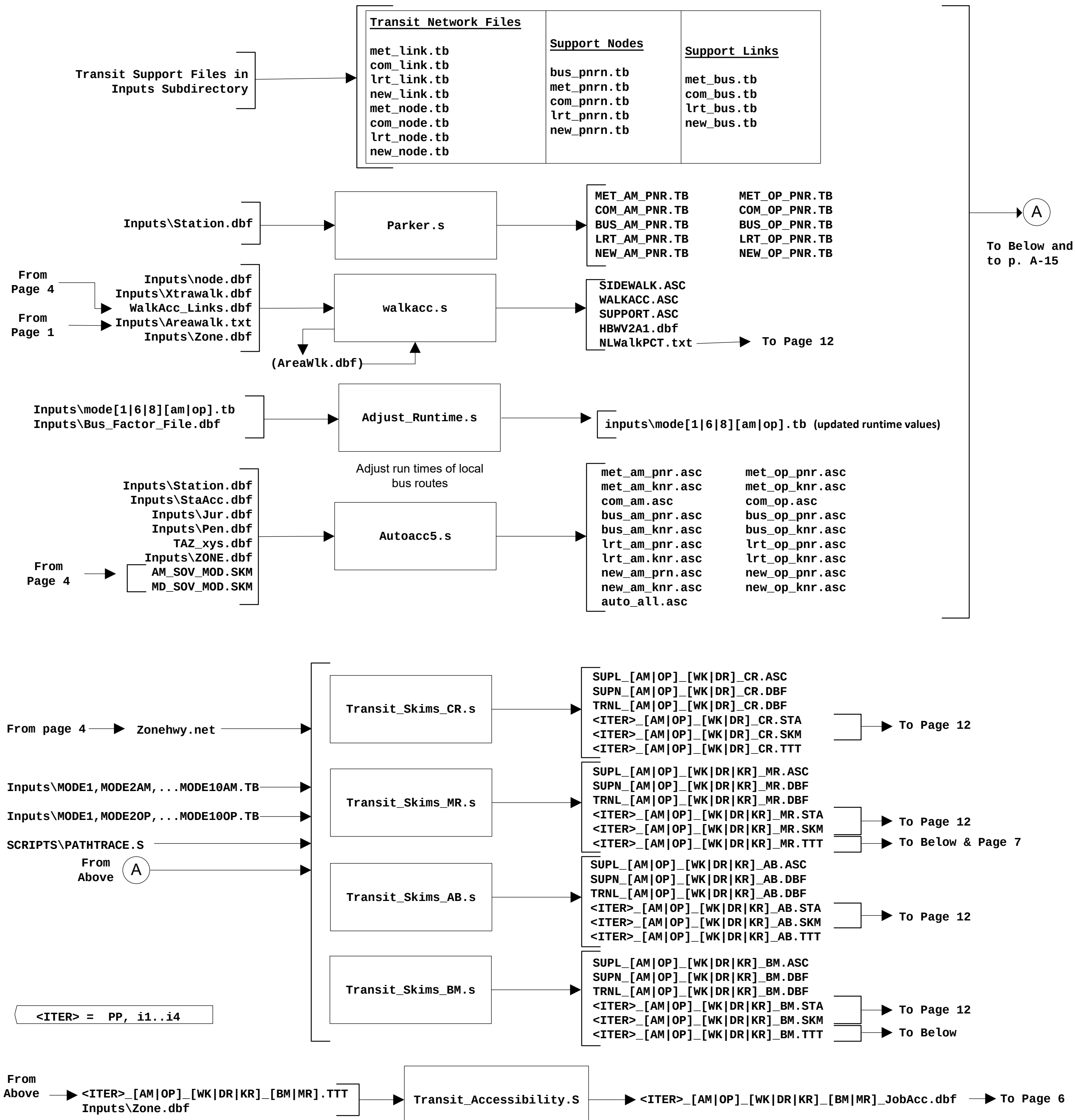
(See also page A-11 for highway skimming process used in speed feedback iterations 1-4)



Report Files Generated by PP_Highway_Skims.bat:

pp_Highway_skims.rpt
pp_Joinskims.rpt
pp_Modnet.rpt
pp_Highway_skims_mod.rpt
CheckStationAccess.rpt
pp_RemovePPSpeed.rpt

Transit_Skim_All_Modes_Parallel.bat
Transit_Skim_LineHaul_Parallel.bat



Report Files Generated by TRANSIT_Skim_All_Modes.bat:
Walkacc.rpt
Parker.rpt
Autoacc4.rpt
Transit_Skims_CR.rpt, Transit_Skims_MR.rpt, Transit_Skims_AB.rpt, Transit_Skims_BM.rpt
Transit Accessibility.rpt

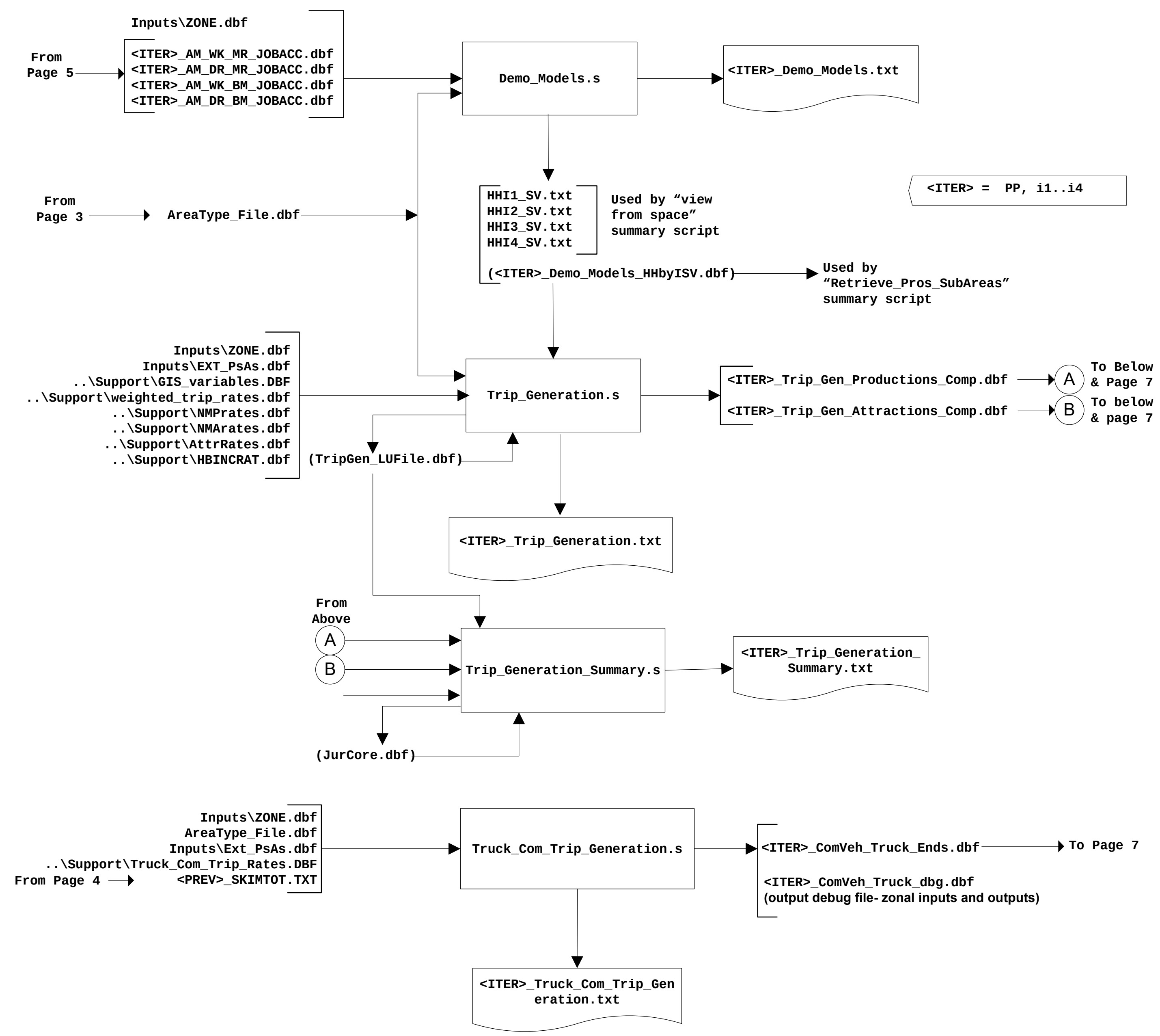
TITLE: Flowchart for the TPB trip-based, regional travel demand forecasting model, Ver. 2.4

COMPANY: COG/TPB Authors RJM, MS, MSM, RN

DATE: 3/15/2021

FILENAME: Ver2.4_flowchart.vsd

Trip_Generation.bat



Report Files Generated by Trip_Generation.bat:

<ITER>_Demo_Models.rpt
<ITER>_Trip_Generation.rpt
<ITER>_Trip_Generation_Summary.rpt
<ITER>_Truck_Com_Trip_Generation.rpt

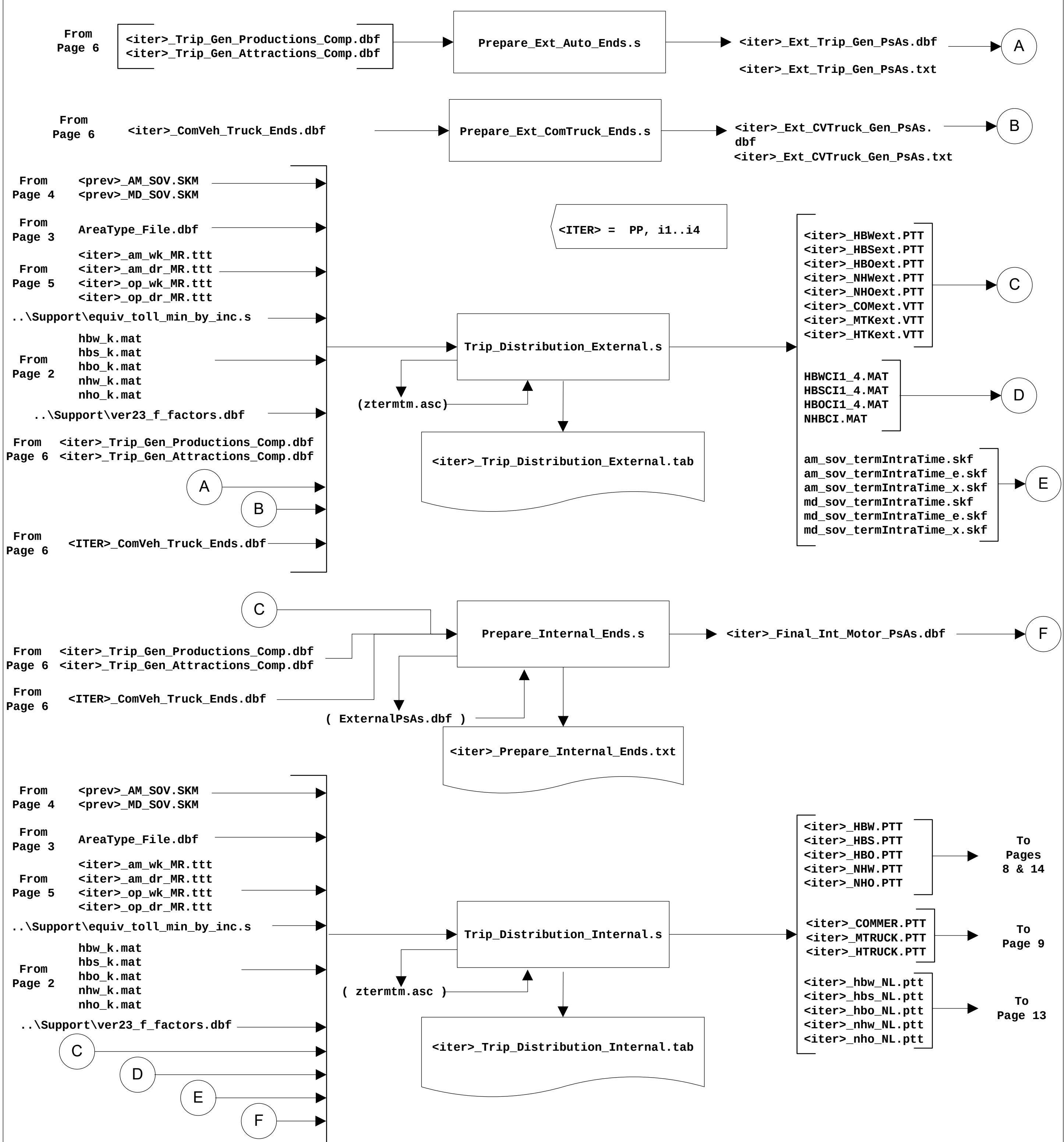
TITLE: Flowchart for the TPB trip-based, regional travel demand forecasting model, Ver. 2.4

COMPANY: COG/TPB Authors RJM, MS, MSM, RN

DATE: 3/15/2021 PG: 7 OF 17

FILENAME: Ver2.4_flowchart.vsd

Trip_Distribution.bat



Report Files Generated by Trip_Distribution.bat:
Trip_Distribution.rpt

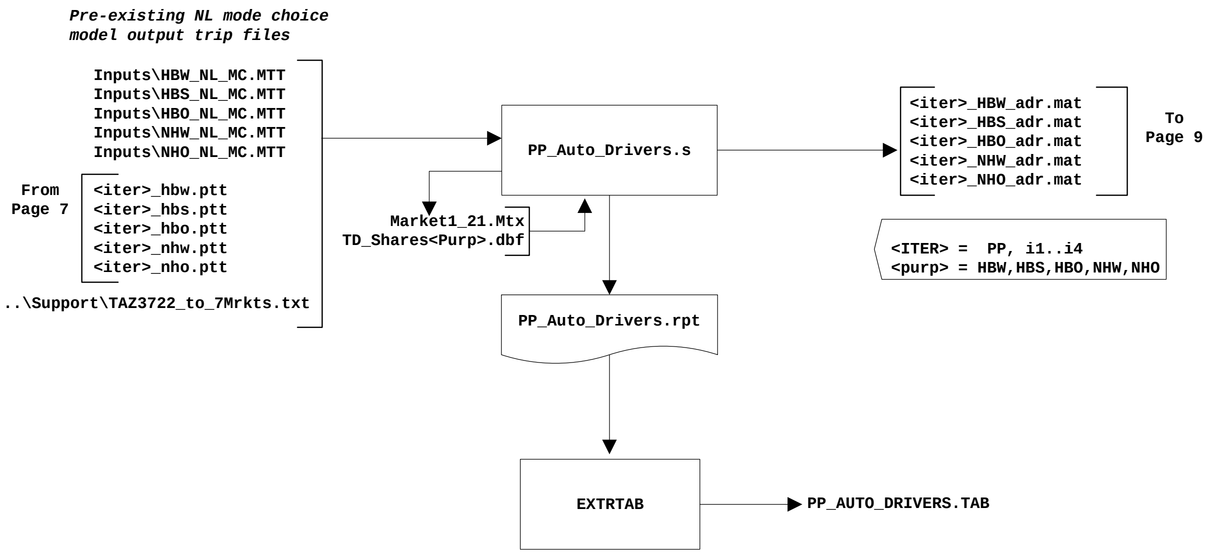
TITLE: Flowchart for the TPB trip-based, regional travel demand forecasting model, Ver. 2.4

COMPANY: COG/TPB Authors RJM, MS, MSM, RN

DATE: 3/15/2021

FILENAME: Ver2.4_flowchart.vsd

PP_Auto_Drivers.bat



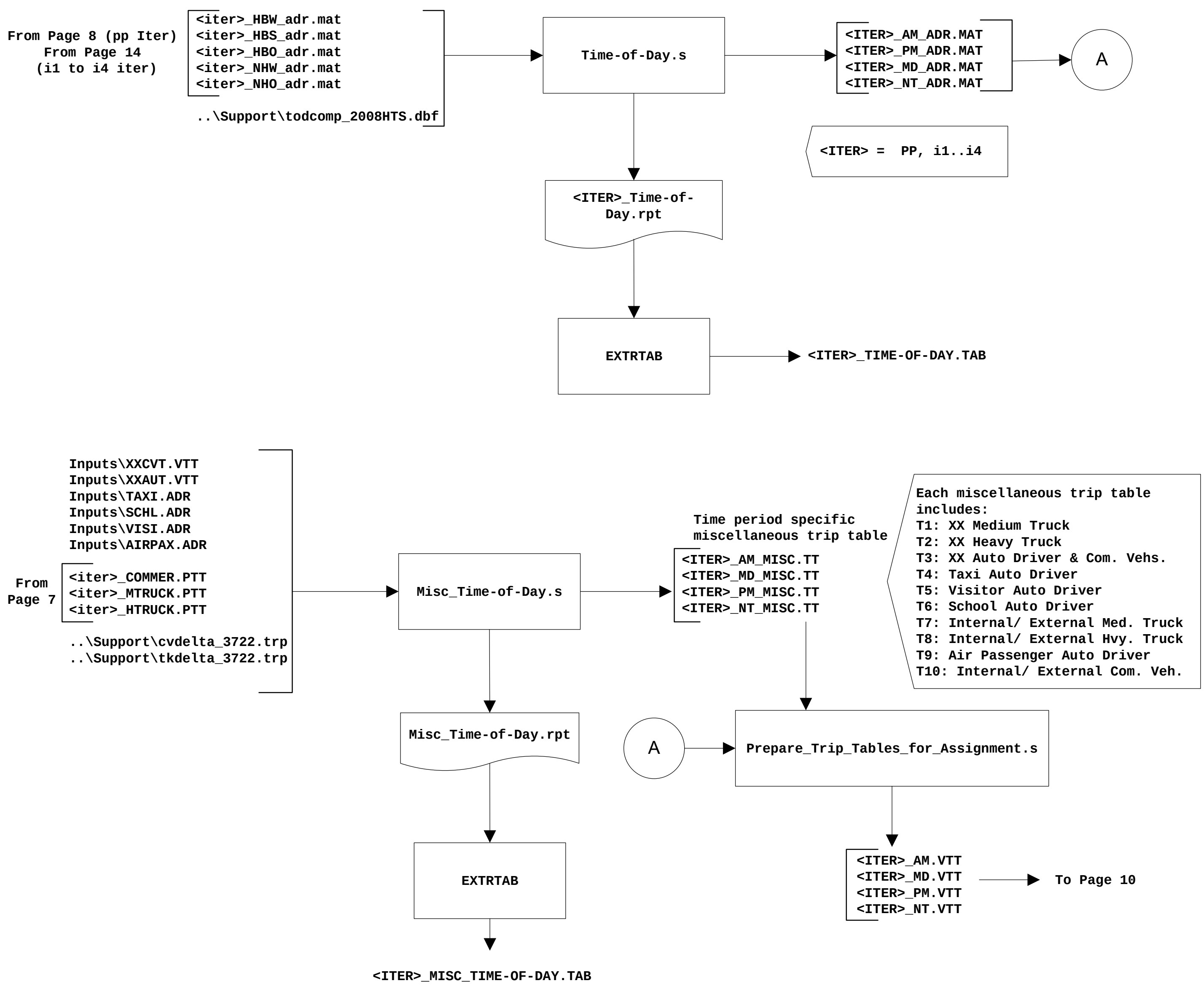
TITLE: **Flowchart for the TPB trip-based, regional travel demand forecasting model, Ver. 2.4**

COMPANY: **COG/TPB** Authors RJM, MS, MSM, RN

DATE: 3/15/2021 PG: 9 OF 17

FILENAME: Ver2.4_flowchart.vsd

Time-of-Day.bat



Report Files Generated by Time-of-Day.bat:

<ITER>_Time-of-Day.rpt

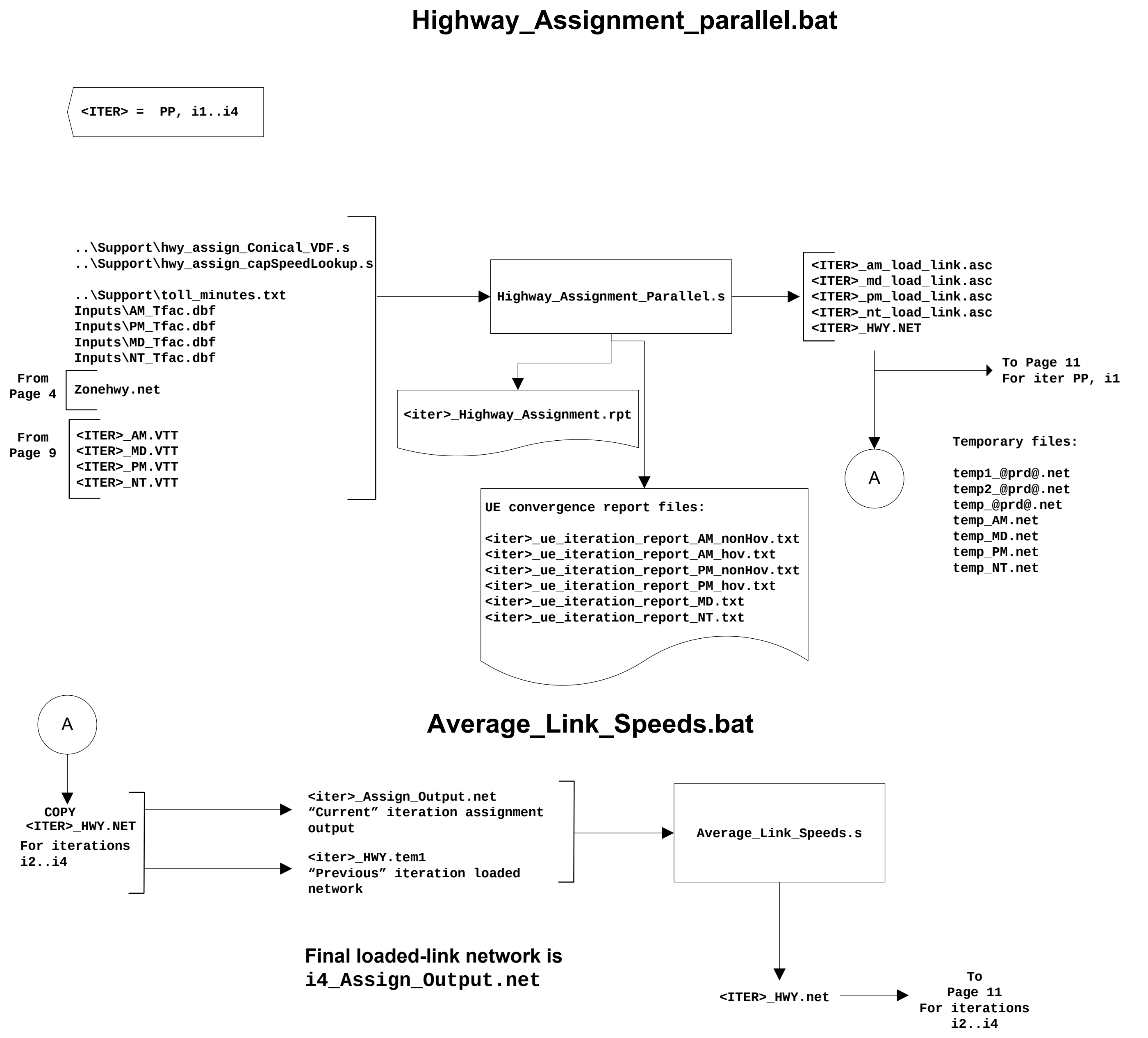
<ITER>_Misc_Time-of-Day.rpt

TITLE: Flowchart for the TPB trip-based, regional travel demand forecasting model, Ver. 2.4

COMPANY: COG/TPB Authors RJM, MS, MSM, RN

DATE: 3/15/2021 PG: 10 OF 17

FILENAME: Ver2.4_flowchart.vsd



Report Files Generated by Highway_Assignment.bat:

<ITER>_Highway_assignment.rpt
Average_Link_Speeds.rpt

TITLE: Flowchart for the TPB trip-based, regional travel demand forecasting model, Ver. 2.4

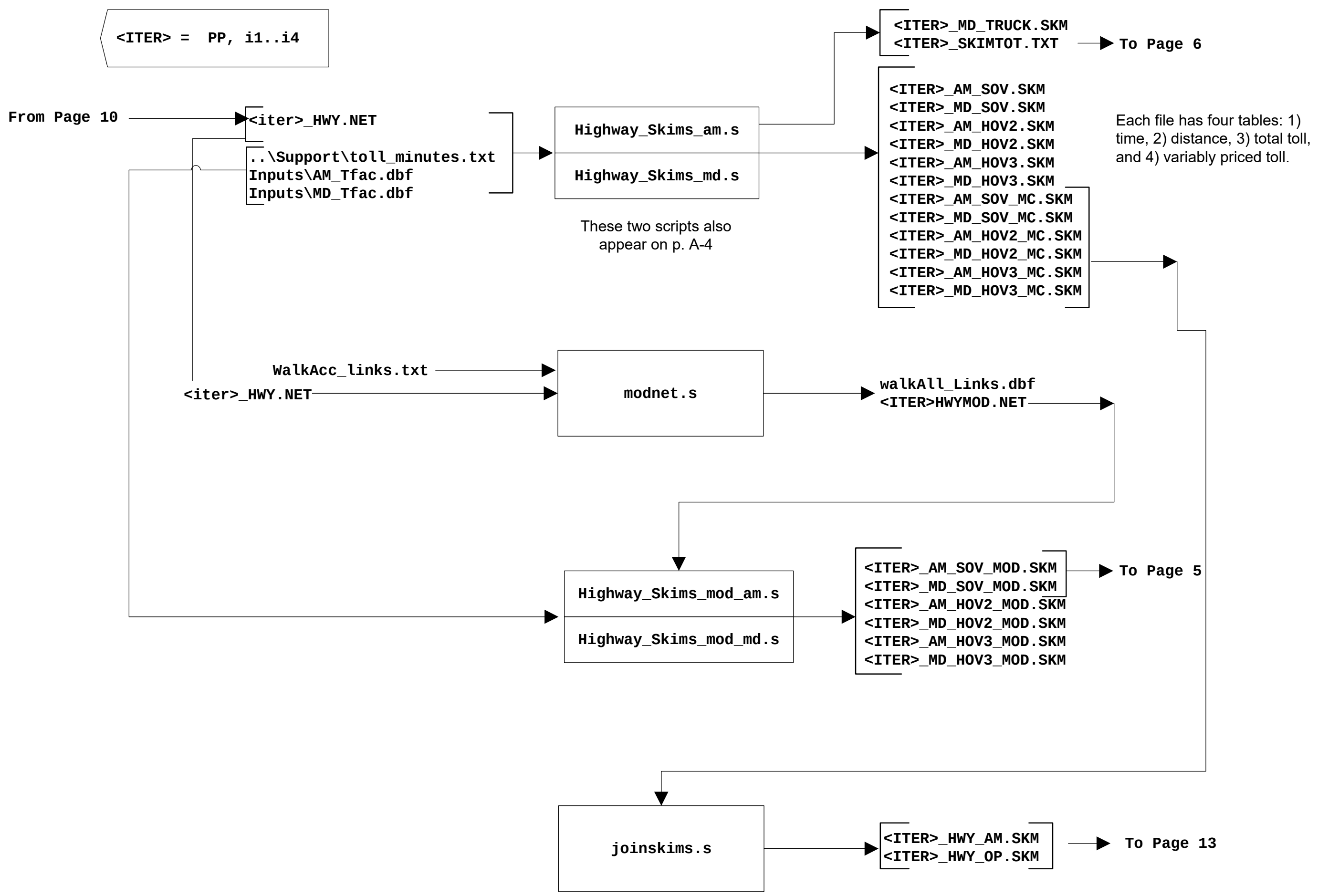
COMPANY: COG/TPB Authors RJM, MS, MSM, RN

DATE: 3/15/2021

FILENAME: Ver2.4_flowchart.vsd

Highway_Skims.bat

(See also page A-4 for highway skimming process used in the “pump prime” speed feedback iteration)



Report Files Generated by Highway_Skims.bat:

<ITER>_Highway_skims.rpt
<ITER>_Joinskims.rpt
<ITER>_Modnet.rpt
<ITER>_Highway_skims_mod.rpt

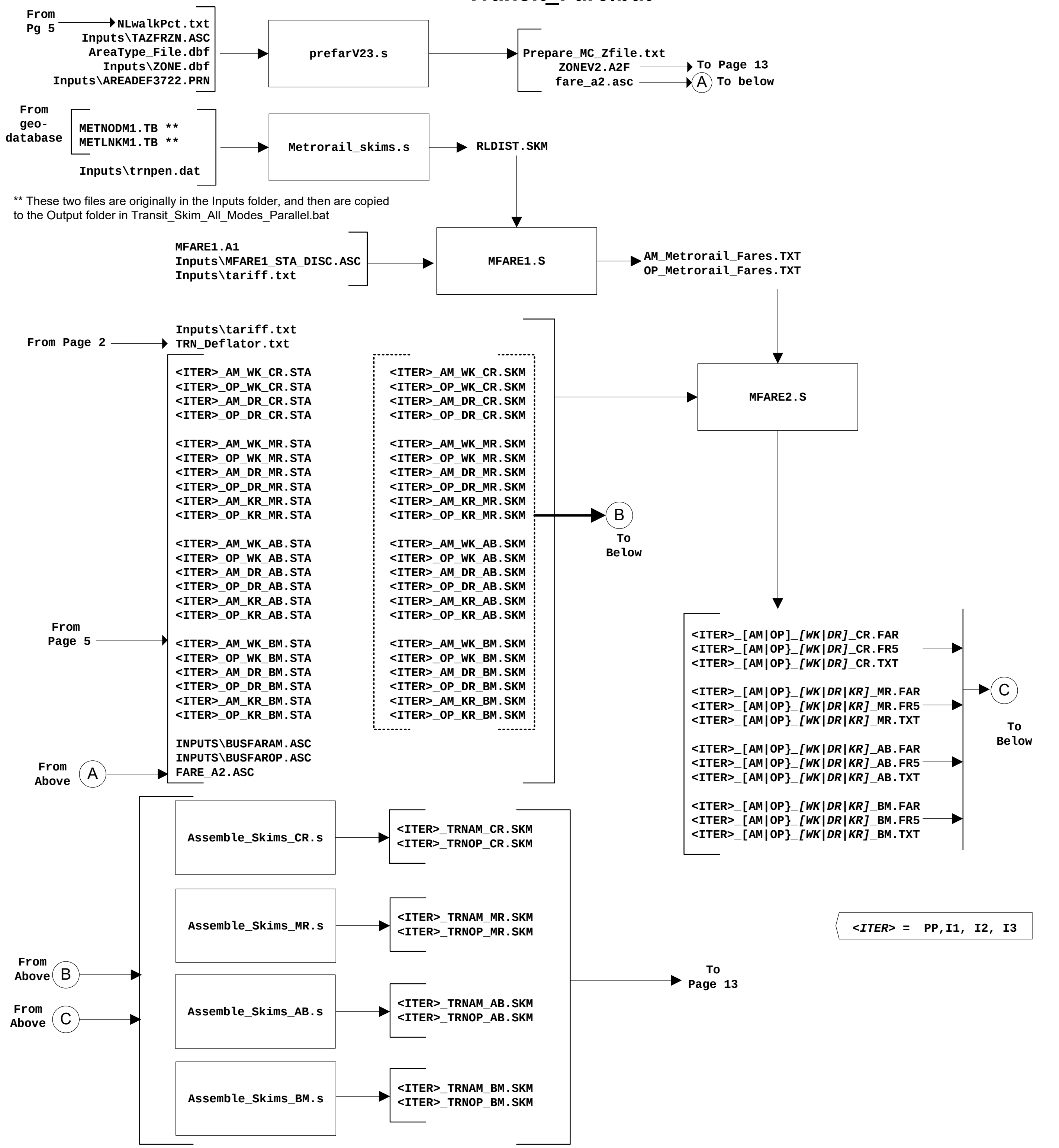
TITLE: Flowchart for the TPB trip-based, regional travel demand forecasting model, Ver. 2.4

COMPANY: COG/TPB Authors RJM, MS, MSM, RN

DATE: 3/15/2021

FILENAME: Ver2.4_flowchart.vsd

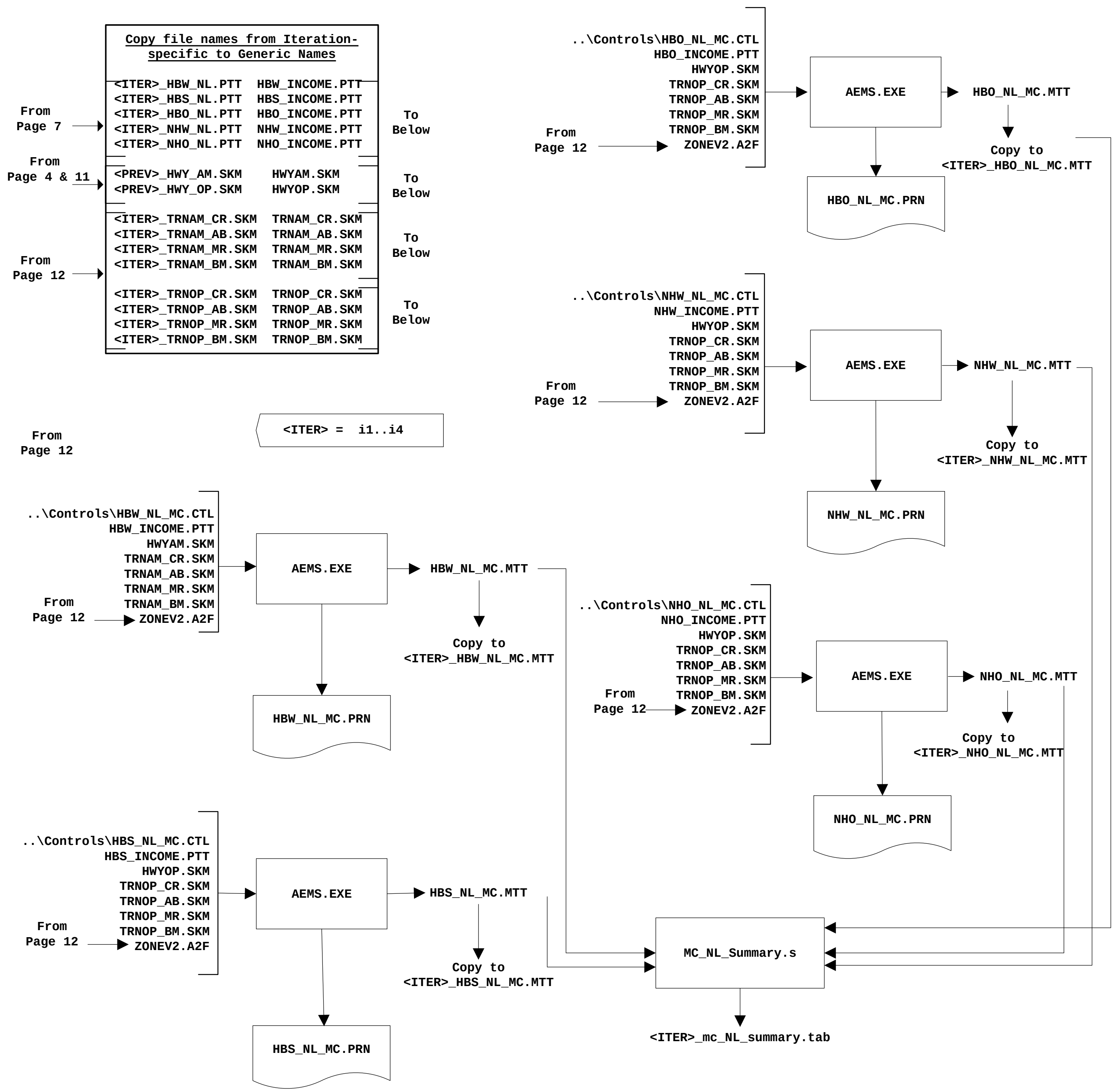
Transit_Fare.bat



Report Files Generated by Transit_Fare.bat: Prepare_MC_ZFile.rpt
<ITER>_prefarV23.rpt
<ITER>_Metrorail_Skims.rpt
<ITER>_Mfare1.rpt
<ITER>_Mfare2.rpt
<ITER>_Assemble_Skims_CR.rpt, Assemble_Skims_MR.rpt, Assemble_Skims_AB.rpt, Assemble_Skims_BM.rpt

TITLE:	Flowchart for the TPB trip-based, regional travel demand forecasting model, Ver. 2.4
COMPANY: COG/TPB	Authors RJM, MS, MSM, RN
DATE: 3/15/2021	PG: 13 OF 17
FILENAME: Ver2.4_flowchart.vsd	

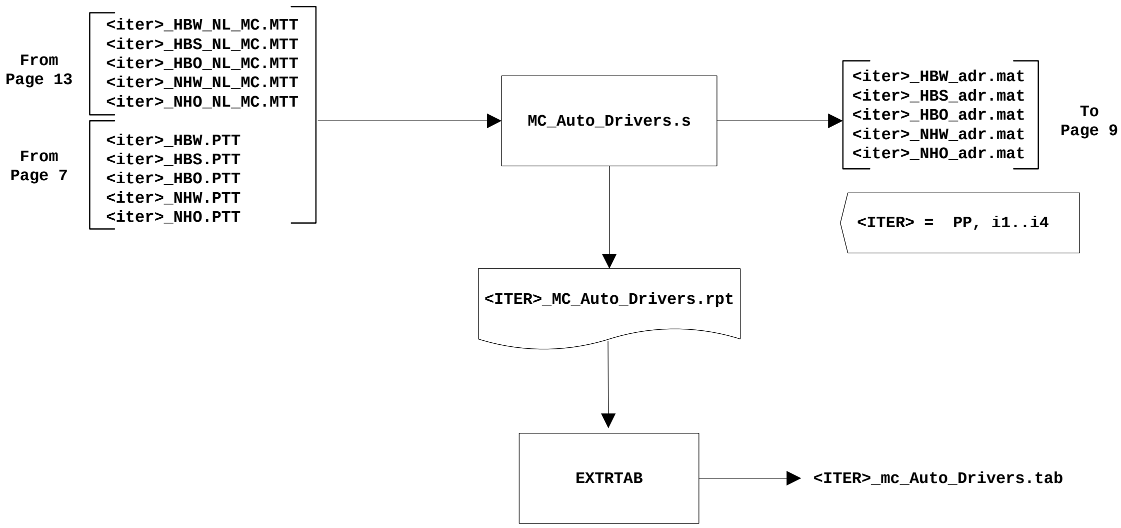
Mode_Choice_parallel.bat



Report Files Generated by Mode_Choice.bat:
<ITER>_MC_NL_Summary.rpt

TITLE:	**Flowchart for the TPB trip-based, regional travel demand forecasting model, Ver. 2.4**
COMPANY: **COG/TPB**	Authors RJM, MS, MSM, RN
DATE: 3/15/2021	PG: 14 OF 17
FILENAME: Ver2.4_flowchart.vsd	

Auto_Driver.bat



Report Files Generated by Auto_driver.bat:
<ITER>_MC_Auto_Drivers.rpt

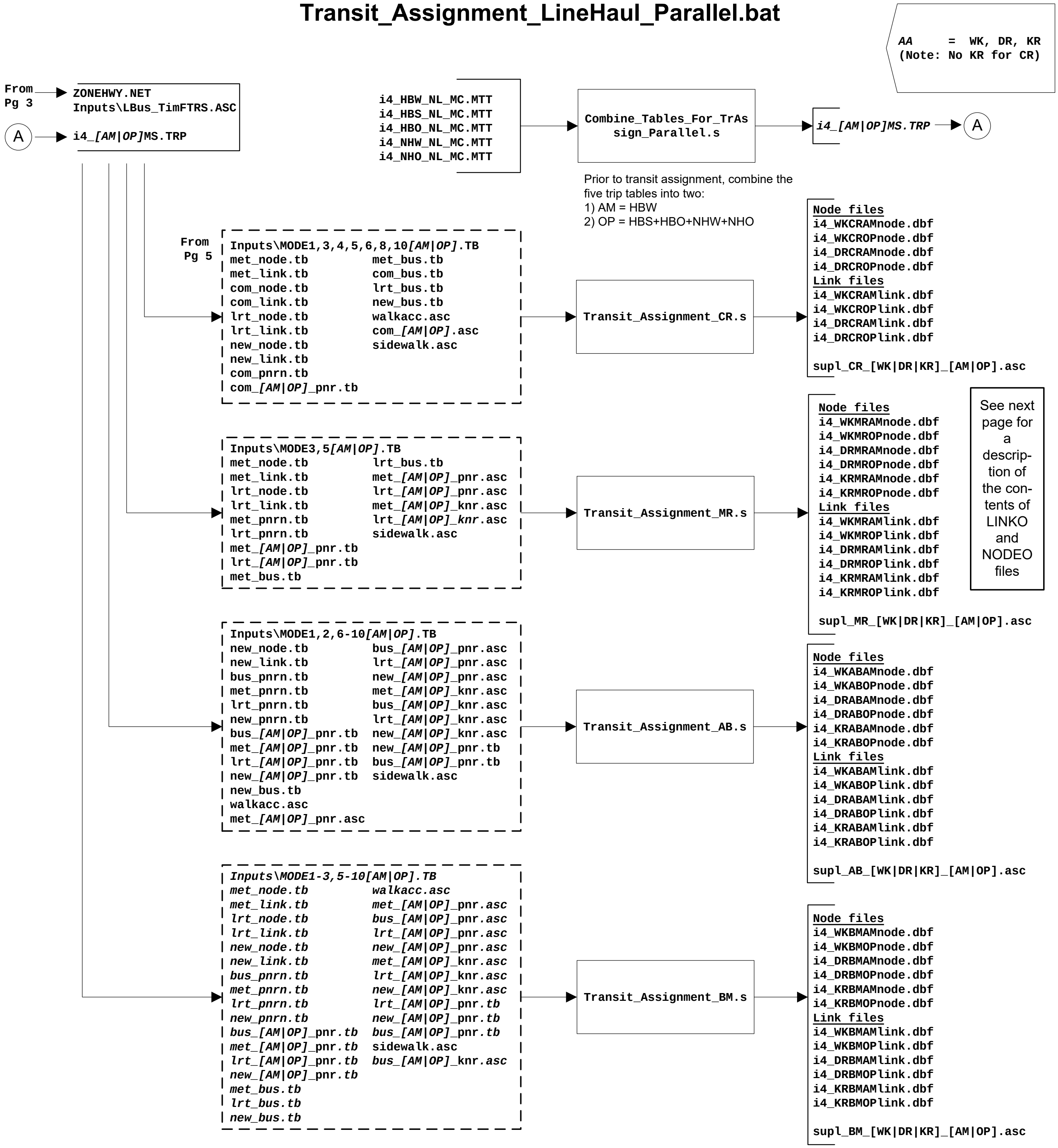
TITLE: **Flowchart for the TPB trip-based, regional travel demand forecasting model, Ver. 2.4**

COMPANY: **COG/TPB** Authors RJM, MS, MSM, RN

DATE: 3/15/2021

FILENAME: Ver2.4_flowchart.vsd

Transit_Assignment_Parallel.bat
Transit_Assignment_LineHaul_Parallel.bat

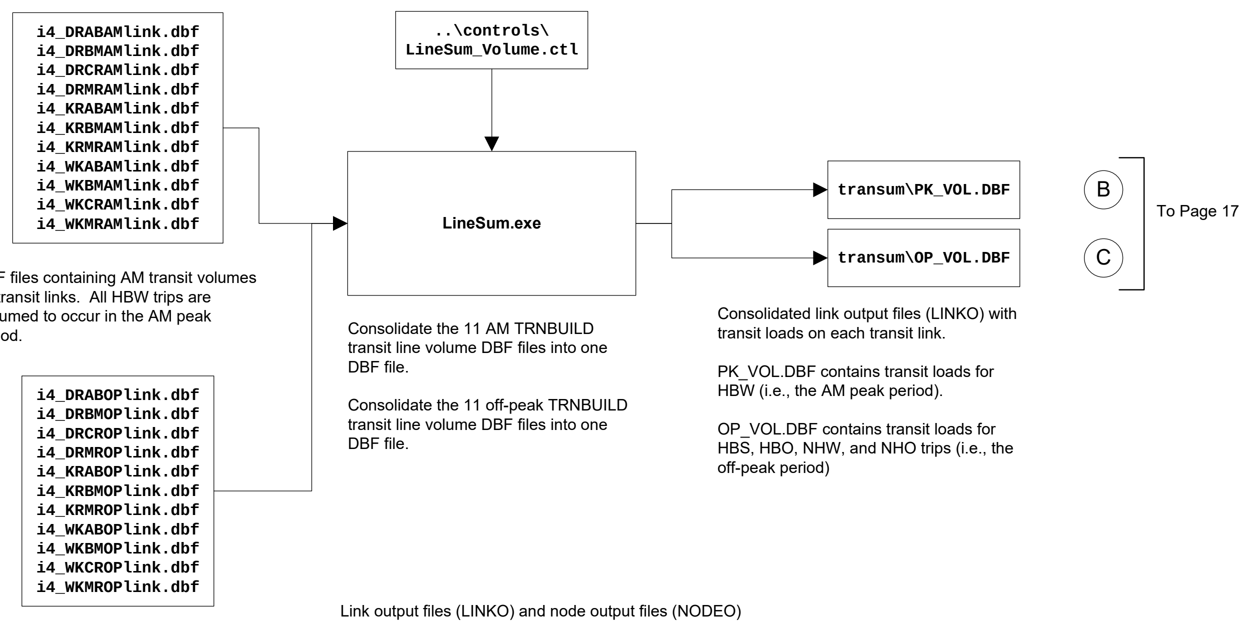


Report Files Generated by Transit_Assignment.bat:

Combine_Tables_For_TrAssign_Parallel.rpt

Transit_Assignment_CR.rpt, Transit_Assignment_MR.rpt, Transit_Assignment_AB.rpt, Transit_Assignment_BM.rpt

Transum.bat (page 1 of 2)



DBF files containing AM transit volumes on transit links. All HBW trips are assumed to occur in the AM peak period.

Consolidate the 11 AM TRNBUILD transit line volume DBF files into one DBF file.

Consolidate the 11 off-peak TRNBUILD transit line volume DBF files into one DBF file.

Consolidated link output files (LINKO) with transit loads on each transit link.

PK_VOL.DBF contains transit loads for HBW (i.e., the AM peak period).

OP_VOL.DBF contains transit loads for HBS, HBO, NHW, and NHO trips (i.e., the off-peak period)

DBF files containing midday ("off peak") transit volumes on transit links. It is assumed that all HBS, HBO, NHW, and NHO trips occur in the off-peak period.

Link output files (LINKO) and node output files (NODEO) are produced in the transit assignment.

NODEO files include the X,Y coordinates.

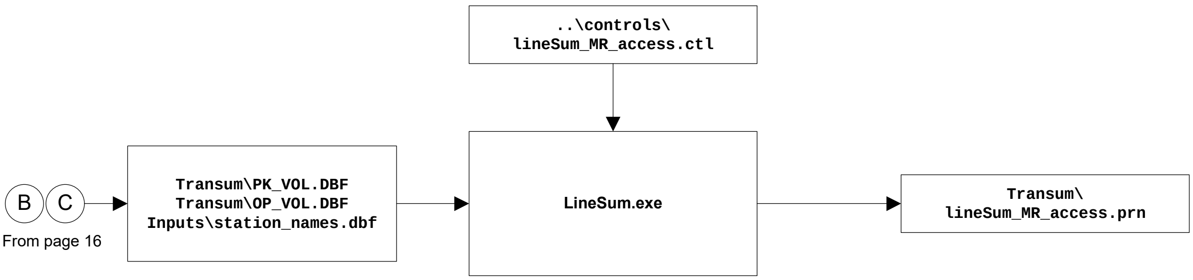
LINKO files include:

A — A-node of link
B — B-node of link
TIME — A-B time (hundredths of minutes)
MODE — Mode of link (1-255)
COLOR — User designated drawing color
STOP_A — 1 = A is a stop node
STOP_B — 1 = B is a stop node
DIST — A-B distance
NAME — Name of line on this link
FREQ — Service frequency (min)
PLOT — Always = 0

The following are included due to transit assignment
SEQ — Link sequence in the line
OWNER — Line owner (1st ten characters)
AB_VOL — Volume
AB_BRDA — Number of trip boardings a A
AB_XITA — Number of exits at A
AB_BRDB — Number of boardings at B
AB_XITB — Number of exits at B
(last 5 variables are also repeated for B-A direction)

See p. 1020 of Citilabs, Inc., "Cube Voyager Reference Guide, Version 6.4.1." September 30, 2015.

Transum.bat (page 2 of 2)



station_names.dbf is an equivalency between node/station number and the node name/station name. It is created from station.dbf using set_factors.s (p. 2).

LINESUM summarizes transit line volume data stored in a TRNBUILD loaded link DBF file. It can be used to create the following summaries:

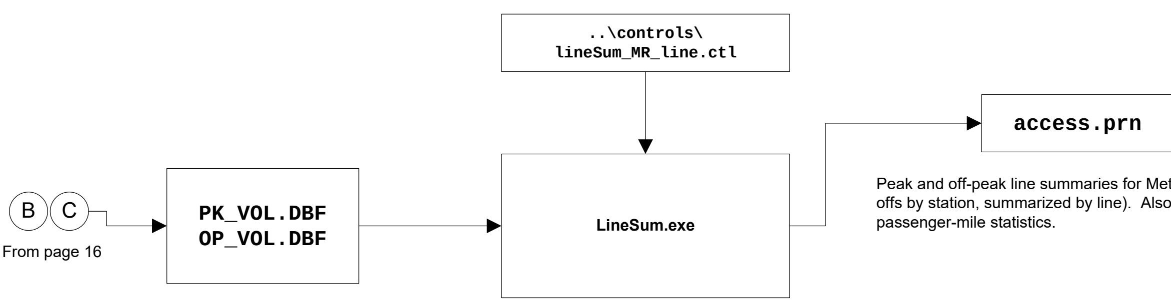
* Boarding/alighting information
* Station access information
* Link-based summaries (i.e., between stations).
* Transit route/line summaries

In this case, we are using the "ACCESS" keyword, so the program summarizes the number of riders accessing a station.

Transit assignment is in P/A format.

Number of passengers accessing one or more stations, i.e., number of passengers boarding and alighting each station. This can be disaggregated by access mode, but, in this case, it is not.

	---- Peak ----		-- Offpeak ---		---- Daily ---		
Stop	Arrive	Depart	Arrive	Depart	Arrive	Depart	
8001	23143	1508	1610	621	24753	2129	Shady Grove
8002	10395	2022	1026	718	11421	2740	Rockville
8003	3934	2983	770	1394	4704	4377	Twinbrook
8004	2931	2976	615	1413	3546	4389	White Flint
8005	8117	197	1979	716	10096	913	Grosvenor
8006	4491	7324	955	1805	5446	9129	Medical Center
8007	11213	12786	3916	5519	15129	18305	Bethesda
8008	9492	5630	3230	3340	12722	8970	Friendship Heights
8009	7904	3640	2780	1856	10684	5496	Tenleytown
8010	4845	2721	2041	1610	6886	4331	Van Ness-UDC



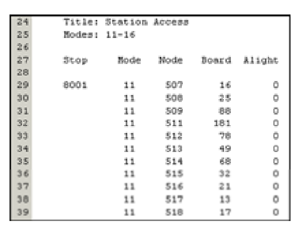
Peak and off-peak line summaries for Metrorail (ons and offs by station, summarized by line). Also includes passenger-mile statistics.

Files representing loaded transit links from the AM peak and off-peak (midday) transit networks

LINESUM summarizes transit line volume data stored in a TRNBUILD loaded link DBF file. It can be used to create the following summaries:

* Boarding/alighting information
* Station access information
* Link-based summaries (i.e., between stations).
* Transit route/line summaries

In this case, we are using the "LINE" keyword, so the program produces boarding and alighting information.



```
Title: Station Access
Modes: 11-16

Stop      Node    Node    Board  Alight

8001        11     507       16       0
            11     508       25       0
            11     509       88       0
            11     511      181       0
            11     512       78       0
            11     513       49       0
            11     514       68       0
            11     515       32       0
            11     516       21       0
            11     517       13       0
            11     518       17       0
```