

# REVIEW OF TRANSIT MODELING WITH RESPECT TO FTA GUIDANCE

## ***Task Order 15.3, Draft Report***

*prepared for*

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

*prepared by*

**Cambridge Systematics, Inc.**

**June 30, 2015**



*report*

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## 1.0 Introduction

Regional travel demand models are often used to develop ridership forecasts in support of project development and application for federal funding through the Federal Transit Administration (FTA) Capital Investment Grant (CIG) Program, which includes New Starts, Small Starts, and Core Capacity programs for rail fixed-guideway transit systems.<sup>1</sup> The National Capital Region Transportation Board (TPB) is the Metropolitan Planning Organization (MPO) for the Washington, D.C. metropolitan area and is one of several policy boards that meets at the Metropolitan Washington Council of Governments (COG). While COG does not directly conduct CIG studies, the consultants who do conduct these studies typically make use of the regional COG/TPB travel demand model. The current version of this model is the Version 2.3 model.<sup>2</sup> Recently, however, COG/TPB staff have noticed that some consultants and project sponsors who are conducting New Starts/CIG studies have chosen to forego using the current COG/TPB model (Version 2.3) as the basis for subsequent New Start/CIG post-processing work, choosing, instead, to use an older version of the TPB model (e.g., Version 2.2) as the basis for subsequent New Start/CIG post-processing work. This approach may be appealing to project sponsors as some of the post-processing models based on the Version 2.2 model have been used previously in New Starts/CIG studies and have been already reviewed by the FTA. Similarly, significant resources were spent to create some of these post-processing tools, and making a similar investment to transition the tools to the Version 2.3 model may be viewed as cost prohibitive. Consequently, COG/TPB staff tasked Cambridge Systematics (CS) to investigate transit modeling in the following areas:<sup>3</sup>

- Review documentation and memos for the latest version of the TPB model (Version 2.3.57);
- Review the latest FTA guidance on ridership forecasting for New Starts and Small Starts;
- Review the use and applicability of Simplified Trips-on-Project Software (STOPS) model; and
- Propose options and recommendations for addressing FTA guidance.

It needs to be kept in mind that there are some cases where FTA guidance (such as using fixed trip tables) is in conflict with air quality conformity guidance that MPOs must follow (e.g., using speed feedback). Nonetheless, COG/TPB staff thought that it would be possible to make the

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<sup>1</sup> "New Starts/Small Starts - Capital Investment Program Frequently Asked Questions," *Federal Transit Administration*, 2014, [http://www.fta.dot.gov/12304\\_15522.html](http://www.fta.dot.gov/12304_15522.html).

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

<sup>3</sup> "Proposal for Task Order 15.3: Review of Transit Modeling with Respect to FTA Guidance" (Cambridge Systematics, Inc., September 17, 2014)

current travel demand forecasting model more FTA compliant than it currently is, which could bring benefits to both the COG/TPB staff and the consultants conducting CIG studies.

This task report documents the review, findings, and recommendations in the above four areas in the sections that follow.

## 2.0 FTA Guidance on Ridership Forecasting for New Starts and Small Starts

FTA has provided guidance on what it considers as the five key aspects of travel forecasts for project evaluation under the New Starts, Small Starts, and (by extension) Core Capacity, programs:<sup>4</sup>

1. The properties of the forecasting methods;
2. The adequacy of current ridership data to support useful tests of the methods;
3. The successful testing of the methods to demonstrate their grasp of current ridership;
4. The reasonableness of inputs (demographics, service changes) used in the forecasts; and
5. The plausibility of the forecasts for the proposed project.

FTA also lists three approaches to prepare ridership forecasts:

- Region-wide travel models;
- Incremental data-driven methods; and
- STOPS.

If STOPS is used to prepare the ridership forecasts, FTA considers only the last two of the five aspects listed above. If region-wide travel models or incremental data-driven methods are used, FTA will consider all five aspects listed above when reviewing the forecasts.

FTA's expectations can be summarized as follows:<sup>5</sup>

- Coherent narrative of the model parameters, inputs, and outputs;
- Regular and early communication regarding model parameters and forecasts to ensure that the agency/sponsor is proceeding in the proper direction;

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<sup>4</sup> FTA. "Travel Forecasts" <<http://www.fta.dot.gov/grants/15681.html>>, January 6, 2015.

<sup>5</sup> Cambridge Systematics, Inc., et al. "Travel Demand Forecasting: Parameters and Techniques." NCHRP Report 716. 2012. Transportation Research Board of the National Academies. p. A-7.



- Reasonable model forecasts in light of the expected land use growth, service characteristics, and other project-related attributes; and
- Proper documentation and uncertainty analysis.

The 2014 FTA rules regarding NEPA, effective February 2014, have no effect on transit modeling for New Starts or Small Starts.<sup>6</sup> The “Major Capital Investment Projects” rules established in April 2013 are still in effect.<sup>7</sup> More recently, FTA issued Proposed Interim Policy Guidance for its Capital Investment Grant Program, which provides, among other information, descriptions of the proposed evaluation and rating process for core capacity improvement projects including the measures and breakpoints for all of the criteria, and ways in which New Starts, Small Starts, and Core Capacity projects can qualify for automatic ratings on various evaluation criteria otherwise known as “warrants.”<sup>8</sup>

## 2.1 Properties of Forecasting Methods

FTA has fairly broad requirements for the properties of forecasting methods, recognizing that the forecasting method needs to reflect the unique nature of the study area and be responsive to local planning processes. The forecasting methods can range from a simple data-driven method developed in a spreadsheet, to a conventional four-step travel demand model, or even an activity-based model. These methods, however, must have several desired properties, including:<sup>9</sup>

- Be consistent with good practice;
- Grasp the current transit situation;
- Be mindful of new behaviors;
- Adequately support the case for the project; and
- Quantify FTA evaluation measures (and respect conventions).

FTA has promoted good modeling practices through a series of workshops over the years. The topics cover a wide spectrum of model areas, including data for model testing especially transit on-board surveys, testing of travel models, representation of non-included transit attributes,

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<sup>6</sup> “Environmental Impact and Related Procedures” Title 49 Code of Federal Regulations, Part 622. 2014 ed.

<sup>7</sup> “Major Capital Investment Projects” Title 49 Code of Federal Regulations, Part 611. 2013 ed.

<sup>8</sup> Federal Transit Administration, “Proposed Interim Policy Guidance, Federal Transit Administration, Capital Investment Grant Program,” April 2015, <http://www.fta.dot.gov/12304.html>, Accessed May 6, 2015.

<sup>9</sup> FTA, Travel Forecasting for New Starts Proposals – March 2009, Slide 32, Day2\_Sessions\_01\_03.ppt [http://www.fta.dot.gov/12304\\_9547.html](http://www.fta.dot.gov/12304_9547.html), Accessed May 6, 2015.

and analysis of uncertainties in ridership forecasts. Over the years, FTA has identified a number of modeling practices that are inconsistent with good modeling practice, which are discussed in later sections of this report.

FTA emphasizes that it is essential for the forecasting method/model to explain the existing travel markets and travel patterns. To achieve this, FTA requires testing the chosen model/forecasting method against current data that are collected to characterize current transit conditions. It is a good practice to identify key markets such as major travel patterns, types of travelers (commuters, students, shoppers, others), drive access such as park-and-ride (formal/informal) and kiss-and-ride, and special generators/events. Typically, on-board rider surveys are collected to provide the current transit market conditions, and FTA has issued specific requirements and guidance on surveys as described below. One key consideration in collecting new transit surveys is to evaluate any new travel patterns and new travel behavior that may have emerged since the last transit survey.

In addition to local data, new transit modes and behavior for a study area can be better understood through references to experience with similar modes and behavior elsewhere.<sup>10</sup> FTA recommends checking ridership forecasts against ridership outcomes in similar settings. Modest credits for guideway effects other than cost and travel time savings are allowed within utility expressions for mode choice, but these must be carefully explained and justified in terms of the specific unincorporated benefits that are being offered.

## 2.2 Adequacy of Current Transit Surveys and Data

FTA requires testing of models against current data and determines the adequacy of data on a case-by-case basis. A key consideration is whether current data capture the current transit travel patterns. Data should address both supply side observations, such as highway speeds, parking costs, transit itineraries, speeds, and fares, and demand side observations, such as overall travel patterns, transit counts, and transit rider travel patterns.

FTA guidance on good practice regarding survey data include:<sup>11</sup>

- A data collection plan that identifies key markets and fits survey instruments to the purpose and setting for key markets;
- A sampling plan design that incorporates transit markets that are determined not only by the socioeconomic attributes, but also by the geographic attributes and that considers alternative approaches for key markets, such as stratified random sampling and sampling based on a linked trip table;

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<sup>10</sup> FTA, Travel Forecasting for New Starts Proposals – March 2009, Slide 25, Day2\_Sessions\_01\_03.ppt [http://www.fta.dot.gov/12304\\_9547.html](http://www.fta.dot.gov/12304_9547.html), Accessed May 6, 2015.

<sup>11</sup> FTA, Travel Forecasting for New Starts Proposals – March 2009, Day2\_Sessions\_04\_05.ppt [http://www.fta.dot.gov/12304\\_9547.html](http://www.fta.dot.gov/12304_9547.html), Accessed May 6, 2015.

- A sample expansion plan that:
  - Accounts for transit riders not sampled;
  - Recognizes non-response biases such as by trip purposes, income, education, language, age, and time of day;
  - Detects and corrects non-response biases through multi-dimensional sample expansion and ancillary data such as on and off passenger counts, counts of access and egress modes, and on-to-off passenger counts (i.e., surveyed trip table);
- A questionnaire design that relates to the visual and interpretational aspects of the survey so that the surveys are simple in terms of layout, readability, and wording;
- Collection of key data items, including origin and destination variables (location, purpose, transit access mode, park-and-ride lot location), transit path (full set of origin-to-destination transit lines used, boarding and alighting stop for surveyed vehicle), and basic rider characteristics;
- A pilot test of the survey instruments and all survey mechanics, with non-respondent interviews;
- Fielding of the survey with experienced and motivated crews and conducting daily quality control checks; and
- A geocoding process with manual checking of usual paths and other quality control procedures.

## 2.3 Problematic Characteristics of Transit Forecasting Methods

Over the years, FTA has identified a number of “problematic characteristics of transit forecasting methods,” including the following:<sup>12 13</sup>

- Unusual coefficients;
- Bizarre alternative-specific constants;
- Non-logit decision rules;

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<sup>12</sup> Cambridge Systematics, Inc., et al. “Travel Demand Forecasting: Parameters and Techniques.” NCHRP Report 716. 2012. Transportation Research Board of the National Academies. p. A-7.

<sup>13</sup> Federal Transit Administration, “12 - Early Quality-of-Service Analysis of the Alternatives,” Slide 37. presented at the Workshop on Travel Forecasting for New Starts Proposals, Minneapolis, Minnesota, 2006, slide 36. Jim Ryan, “Travel Forecasting for New Starts: The FTA Perspective” (presented at the Florida Model Task Force Transit Committee, Transit Workshop, Tampa, Florida, April 7, 2004), 52.

- Problems in choice-set formation;
- Transit path-builder inconsistencies with mode choice models;
- Inaccuracy of bus running times; and
- Instability of highway assignment results.

Many of the above relate to specification of the mode choice model used. Common practice in major metropolitan areas is to use a logit model formulation for mode choice. The logit model operates under the premise of consumer utility theory, that the probability of a choice in the modeled choice set is related to the consumer utility of that choice. For mode choice models, utility is typically expressed in terms of negative utility (disutility), i.e., longer travel times or higher costs result in larger disutilities. Thus, coefficients on travel time and cost typically are negative in value.

FTA requires **compelling evidence** if the HBW in-vehicle travel time (IVTT) or HBW out-of-vehicle travel time (OVTT) utility expression coefficients in the mode choice model (*Civtt* and *Covtt*, respectively) are outside a certain range:

- $-0.03 < Civtt < -0.02$ ; <sup>14</sup>
- $2.0 < (Covtt/Civtt) < 3.0$ . <sup>15</sup>

FTA also requires **compelling evidence** if mode-specific *Civtt* are used instead of “generic” *Civtt* for all modes. For example, if mode-specific *Civtt* are used, FTA requires **compelling evidence** if the relative magnitude of mode-specific *Civtt* does not follow appropriate relationships:

- *Civtt* for transit less negative than *Civtt* for automobile.
- *Civtt* for commuter rail less negative than *Civtt* for other transit.<sup>16</sup>

These relationships are intuitive, given the utility that can be gained with time spent in commuter rail versus transit versus automobile. It is not specifically defined as to what constitutes compelling evidence, but simply stating that the “unusual” coefficients were estimated from the observed data is not satisfactory to FTA.

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<sup>14</sup> Federal Transit Administration, “12 - Early Quality-of-Service Analysis of the Alternatives,” Slide 37. presented at the Workshop on Travel Forecasting for New Starts Proposals, Minneapolis, Minnesota, 2006, slide 37.

<sup>15</sup> Ibid., slide 38.

<sup>16</sup> Jim Ryan, “Travel Forecasting for New Starts: The FTA Perspective” (presented at the Florida Model Task Force Transit Committee, Transit Workshop, Tampa, Florida, April 7, 2004), 54.

FTA identified a wide variation of model coefficients such as  $-0.045 < Civtt < -0.007$ ,  $0.25 < (Covtt/Civtt) < 16.0$ ,<sup>17</sup> and expressed concern that the range observed in these coefficients may not reflect real travel behavior differences, but instead may be due to estimation errors or distortion.

FTA guidance highlights the importance of maintaining consistency between the transit path builder and the mode choice model, specifically the consistency between weights used in transit path building and mode choice utility functions for transit choices. In other words, the path-building process must weigh the various travel time and cost components in a manner that is consistent with the relative values of the mode choice model coefficients. This consistency would help minimize the situations where better transit paths look worse in mode choice; and build alternatives lose some trips and benefits.

Network representation and speeds in a regional model affect the magnitude and pattern of predicted trip making and eventually ridership forecasting. FTA “recommends a careful analysis of highway and transit travel times between carefully selected origins and destinations to understand the quality of the model networks.”<sup>18</sup> FTA requires that level-of-service estimates for transit and highway must replicate current conditions reasonably well. FTA further requires that the forecast should be based on defensible differences in travel times when comparing conditions today versus future conditions or when comparing conditions across alternatives. In essence, FTA is interested in being able to reasonably capture travel time savings due to the proposed project.

## 3.0 TPB Travel Demand Model

The TPB Travel Demand Model has been updated and refined over the years, and its history of recent updates, model structure, model application process, individual model components, and validation results are documented in the Calibration report<sup>19</sup> and User’s Guide.<sup>20</sup> In the subsections that follow, we review the model through the lens of the FTA guidance.

### 3.1 Mode Choice Model Structure

The mode choice model of the TPB Version 2.3.57 Travel Demand Model is a nested logit model. The nesting structure of the model is shown in Figure 3.1. The nesting structure starts

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<sup>17</sup> Ibid., 55.

<sup>18</sup> Cambridge Systematics, Inc., et al. “Travel Demand Forecasting: Parameters and Techniques.” NCHRP Report 716. 2012. Transportation Research Board of the National Academies. p. A-6.

<sup>19</sup> National Capital Region Transportation Planning Board/Metropolitan Washington Council of Governments. Calibration Report for the TPB Travel Forecasting Model, Version 2.3, on the 3,722-Zone Area System Report. Final Report. January 20, 2012.

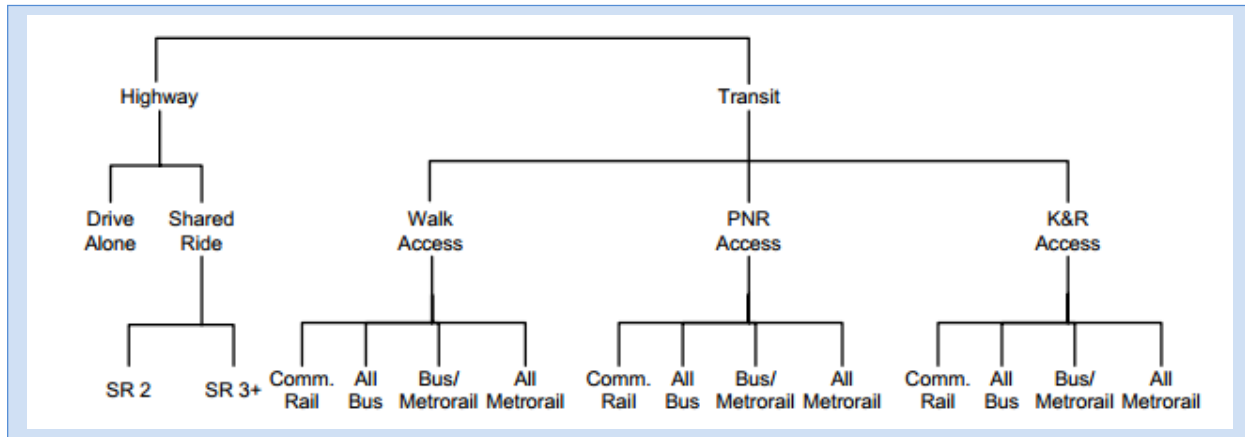
<sup>20</sup> National Capital Region Transportation Planning Board/Metropolitan Washington Council of Governments. User’s Guide for the MWCOG/NCRTPB Travel Demand Forecasting Model, Version 2.3, Build 57. October 17, 2014.

with two motorized modes (auto and transit), which are further branched out based on three types of auto occupancies (drive alone, shared ride 2 person, and shared ride 3+ person) and four transit submodes (commuter rail, all bus, all Metrorail, and combined bus/Metrorail). The four transit submodes are stratified by three modes of access to transit – park and ride (PNR), kiss and ride (KNR), and walk.

The person trip inputs to the TPB mode choice modeling process are distinguished by purpose, without further stratification by time period. However, the level-of-service inputs are distinguished by AM peak and midday periods. The AM LOS inputs are currently used for the HBW purpose while midday LOS inputs are used for non-HBW purposes.

Cambridge Systematics recommends revising the process such that person trip inputs are stratified by purpose and by time period. The model structure should also be reviewed to confirm its analytical usefulness and theoretical soundness (e.g., consistency with the independence of irrelevant alternatives principal, as discussed in Section 5.1.1 on p. 20).

Figure 3.1 Nesting Structure of the Nested-Logit Mode Choice Model



### 3.2 Market Segmentation

The TPB Version 2.3 Travel Demand Model uses several types of market segmentation:

- Household income (in four income quartiles: <\$50,000, \$50,000 - \$99,999, \$100,000 - \$149,999, \$150,000+);
- Trip purposes (HBW, HBS, HBO, NHBW, and NHBO);
- Geographies (in 20 district-to-district interchanges, based on seven superdistricts: DC core, VA core, DC urban, MD urban, VA urban, MD suburban, VA suburban);
- Transit access mode (walk, park-and-ride, kiss-and-ride); and
- Primary transit mode (all-bus, all-Metrorail, bus plus Metrorail, and commuter rail).

The existing geographic segmentation, with 20 district-to-district interchanges, based on seven superdistricts (DC core, VA core, DC urban, MD urban, VA urban, MD suburban, VA suburban), was developed by AECOM in 2004.<sup>21</sup> COG/TPB staff adopted the AECOM mode choice model, including the geographic market segmentation, when it began developing the Version 2.3 travel model in 2008. Note that, in subsequent modeling work, AECOM moved away from using the 20 geographic market segments, replacing this market segmentation with a pedestrian environment factor (PEF).<sup>22</sup> The original geographic segmentation developed by AECOM was intended to capture geographic variations in behavior. However, this practice is inconsistent with FTA guidance, which discourages the use of geographically-based constants in the mode choice model, except for very special cases, such as a downtown district. From the policy evaluation and planning application perspective, it is more useful to include variables that explicitly represent urban design, land use density, or other mode choice indicators. In the previous versions of the TPB model (e.g., Version 2.2 and Version 2.1D#50), land use index variables were included in the mode choice model.<sup>23</sup>

Cambridge Systematics recommends exploring reformulating the TPB mode choice model to eliminate the use of the geographic market segments. Specifically, explicit variables that represent urban design and land use diversity and density can be in the mode choice models so that geographic variations can be captured. Introducing these variables may have the added benefit of allowing sensitivity testing of different policy approaches.

### 3.3 Mode Choice Coefficients

As discussed in Section 2.3, FTA recommends that mode choice models be specified using main-level coefficient values and applying the same coefficient value to all modes. The current mode choice component of the TPB model is consistent with this guidance in that it does not allow mode-specific attribute coefficients.

FTA recommends that the weights used in the transit path building process be consistent with the weights used in the mode choice model, and this is true of the TPB model.

Table 3.1 identifies time and cost coefficients in the Version 2.3 nested-logit mode choice model. These are further discussed in the subsections below.

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<sup>21</sup> Bill Woodford, "Development of Revised Transit Components of Washington Regional Demand Forecasting Model" (presented at the Transit Modeling Meeting, held at the Metropolitan Washington Council of Governments, Washington, D.C., December 1, 2004), 30.

<sup>22</sup> See, for example, AECOM Consult, Inc., "VRE Haymarket Extension Model Update," Technical Memorandum, (November 2008).

<sup>23</sup> See, for example, p. 19-8 of 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).

Table 3.1 Mode Choice Coefficients<sup>24</sup>

Trip Purpose (5)						
Variable	Name	HBW	HBS	HBO	NHBW	NHBO
In-vehicle time	ivt	-0.02128	-0.02168	-0.02322	-0.02860	-0.02860
Auto access time	aat	-0.03192	-0.03252	-0.03483	-0.04290	-0.04290
Walk access time	ovtwa	-0.04256	-0.04336	-0.04644	-0.05720	-0.05720
Other out-of-vehicle time*	ovtot	-0.05320	-0.05420	-0.05805	-0.07150	-0.07150
Cost - Income group 1	costinc1	-0.00185	-0.00202	-0.00202	-0.00994	-0.00994
Cost - Income group 2	costinc2	-0.00093	-0.00101	-0.00101	-0.00994	-0.00994
Cost - Income group 3	costinc3	-0.00062	-0.00067	-0.00067	-0.00994	-0.00994
Cost - Income group 4	costinc4	-0.00046	-0.00051	-0.00051	-0.00994	-0.00994

\* Includes boarding penalty

### 3.3.1 Coefficients on In-Vehicle Travel Time

The coefficients on in-vehicle travel time (*Civtt*) that are currently used were statistically estimated as part of the sequential, multinomial-logit mode choice model in the earlier versions of the TPB travel demand model, Version 2.1 and Version 2.2.

FTA guidance with respect to *Civtt* was introduced in Section 2.3 of this report. For the TPB model, the *Civtt* values are the same across all of the various transit submodes as recommended.<sup>25</sup> The *Civtt* for HBW, NHBW, and NHBO trips are within the recommended range.

Additional FTA guidance suggests that the *Civtt* for HBO trips should be 0.1 to 0.5 times the *Civtt* for HBW trips.<sup>26</sup> In the TPB Version 2.3 model, the *Civtt* values for HBS and HBO are slightly higher than the *Civtt* for HBW. Cambridge Systematics recommends that TPB review these coefficients during future refinement of the mode choice model.

<sup>24</sup> "Calibration Report for the TPB Travel Forecasting Model, Version 2.3, on the 3,722-Zone Area System Report." Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, January 20, 2012.

<sup>25</sup> FTA has accepted discounts on in-vehicle time to account for attributes of rail travel time in some applications (e.g., commuter rail).

<sup>26</sup> Federal Transit Administration, "12 - Early Quality-of-Service Analysis of the Alternatives," Slide 37. presented at the Workshop on Travel Forecasting for New Starts Proposals, Minneapolis, Minnesota, 2006.



### 3.3.2 Coefficient of Out-of-Vehicle Time (*Covtt*)

Section 2.3 discussed the FTA recommendations for relationships between *Covtt* and *Civtt*. In the TPB Version 2.3 model, following the practice developed by AECOM in the mid-2000s, the *Covtt* were set as multiples of the *Civtt*, as follows:

- 1.5 for auto access time;
- 2.0 for walk access time; and
- 2.5 for other out-of-vehicle time.

The ratio of *Covtt* to *Civtt* for auto access time falls outside of the recommended range.

## 3.4 Implicit Value of Time

FTA has recommended that the implied value of time (VOT), calculated as *Civtt* divided by the coefficient of cost (*Ccost*), should be within the following range of average annual wage rate (dollars per person per hour):

$$\frac{\text{AverageWage}}{4} < \frac{\text{Civtt}}{\text{Ccost}} < \frac{\text{AverageWage}}{3}$$

This range avoids having large cost-related differences be observed in the utilities of different modal alternatives.

TPB Version 2.3.57 has cost coefficients segmented by household income categories, with the cost coefficient for the lowest income category taking a statistically estimated value from a previous version of the regional travel model. The remaining three cost coefficients for the three home-based trip purposes were set as factors of the cost coefficient for income group 1, as follows:

- ½ for income group 2;
- 1/3 for income group 3; and
- ¼ for income group 4.

The values of time were calculated using the coefficient values in Table 3.1 and show a wide range from \$1.73 to \$27.76 per hour, with HBW and HBO having the highest values, and NHBW and NHBO the lowest values. The values of time for HBW and HBO trips were 42 percent to 75 percent of the hourly rates of the mid-points of the household income groups, while the values of time for NHBW and NHBO trips were 3 percent to 19 percent of the hourly rates of the mid-points of the household income groups.

These implied values of time appear to be higher than recommended for home-based trips and lower than recommend for those non-home-based trips, when viewed against the FTA recommended ranges. Cambridge Systematics recommends revisiting the cost coefficient values when the mode choice model is refined.

### 3.5 Alternative-Specific Constants

The TPB Version 2.3.57 mode choice model has alternative-specific constants specified by trip purposes (5 trip purposes), by modes (15 choices), and by geographic market segments (20 markets). For each trip purpose, there are 280 constants. However, use of geography-based constants is not consistent with FTA recommendations.

As noted previously, mode choice utilities and coefficients are expressed in terms of utility, thus positive values indicate that a choice apparently has additional positive utility versus what the utility calculated based on time and cost alone would imply. Mode choice model constants are typically set with reference to single occupancy automobile driving serving as a base mode (i.e., having a constant of zero).

The transit constants, as documented on page 6-23 to 6-25 in the *Calibration Report for the TPB Travel Forecasting Model, Version 2.3, on the 3,722-Zone Area System Report*, have a wide range of values, which are translated to the following ranges of equivalent in-vehicle travel minutes:

- HBW: -188.5 to +330.4 minutes;
- HBS: -2,348.3 to +293.5 minutes;
- HBO: -1,278.3 to +269.3 minutes;
- NHBW: - 212.0 to +311.0 minutes; and
- NHBO: - 876.9 to +673.4 minutes.

For HBW trips, most constants are positive for walk access to transit. Walk access to Metro has the highest positive constants. Therefore, these highly positive values indicate a need to express in the model a strong preference for walk access to transit, especially walk access to Metro for all geographic markets and walk access to bus/Metrorail and commuter rail for markets associated with DC Core/Urban and its combination with VA Core and Urban. Drive access to transit has mostly negative constants, except for DC Core related markets, meaning that without them, the model would tend to overestimate the use of this choice.

For HBS, HBO, and NHB trips, transit constants are mostly negative, but the MD Urban-VA Core market has positive constants with the walk access to transit being the highest. Constants for drive access to transit are more negative than those for walk access to transit. Highly negative transit constants indicate a strong preference for not using drive access to transit

Version 2.3.57 also uses income constants for walk access to transit by low and high income groups. Positive constants were used for low income group (group 1) to favor walk access to transit, while negative constants were used for high income group (group 4).

In general, large constant values can be of potential concern. Larger constants can imply that other variables included in the utility expression do not adequately address the dimensions of the choice being modeled for the given market segment. A model with smaller constant values is often viewed as superior to a model with larger constant values. Cambridge Systematics would recommend observing the effect on constant values of incorporating additional explanatory variables in future work to refine the mode choice models.

### 3.6 Unmeasured Attributes

A major factor that seems to impact the demand for transit services is the preference for the trip maker to use a premium transit mode. In the consumer utility framework underlying the mode choice model, this preference is addressed through expression of unmeasured attributes in the alternative-specific constants. For existing transit modes, these constants are usually calibrated using local transit survey data. For new transit modes, such as streetcar or bus-rapid transit (BRT), the survey would not specifically distinguish them and the resulting calibration would not specially consider them.

FTA has issued guidance regarding appropriate levels of constants to consider to represent potential unmeasured attributes of fixed-guideway modes. Three categories of attributes are recognized for credits, including guideway-like characteristics, span of good service, and passenger amenities. Two types of adjustments can be made for unmeasured attributes of fixed guideway in the areas where a new fixed guideway would be introduced. First, FTA assigns a credit in terms of equivalent minutes of travel time savings to increase the attractiveness of the new guideway for guideway trips. Second, a discount on the weight applied to in-vehicle travel time on the guideway is determined to increase the attractiveness of guideway travel. FTA assigns specific values for these two types of credits, based on the specific characteristics of a project in each of the three categories of unmeasured attributes. The maximum values are 15 minutes of time savings for each rider and a 20 percent discount on the travel time weight.<sup>27</sup> These credits vary by transit submodes: heavy rail tends to have the highest credits, earning nearly the full total credit and a substantial discount on the travel-time coefficient, while an arterial BRT operating in mixed traffic would have a low credit because it would not carry significant guideway benefits.

The Washington metropolitan region has Metrorail and commuter rail defined, but it did not have new modes such as light rail transit (LRT), BRT, or streetcar for the model base year of 2007 or the 2007-2008 household travel and transit-on-board surveys. Metroway, the Washington region's first BRT line, opened in late August 2014. Streetcar remains planned for operation in the District of Columbia.

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<sup>27</sup> Federal Transit Administration, Travel Forecasting for New Starts Proposals – September 2007, a two-day workshop September 19 & 20, 2007, at the Adam's Mark Hotel in St. Louis, Missouri, slide 2-86.

In Version 2.3.57, LRT (Mode 5) is treated like Metrorail (Mode 3) in transit path building and skimming, mode choice, and transit assignment. This means that the calibrated constants that reflect strong preferences for Metrorail for certain market segmentations, as described earlier, will be used for LRT as well. In other words, the LRT would assume the unmeasured guideway effects which are the same as Metrorail. This assumption would result in an overestimation of unmeasured guideway effects for a LRT project, based on the FTA's guidance that provides a LRT project a smaller total credit than a heavy rail like Metrorail.

On the other hand, BRT and streetcar (Mode 10), are treated like local Metrobus (Mode 1) in transit path building and skimming, mode choice, and transit assignment in the Version 2.3.57 model. Therefore, there is no unmeasured guideway effect reflected for BRT and streetcar (coded travel times are used, so if a BRT offers a travel time advantage it is still reflected).

Cambridge Systematics has noted in its model estimation work that relatively few distinctions between specific transit modes appear to directly relate to transit mode choice, but that selecting specific transit routes (i.e., transit route choice) appears to be more involved. Additional local data may be available from transit operators with which to further explore the associated local differences in travel behavior, if any, between different transit submodes.

### 3.7 Calibration and Validation

FTA recognizes the limitations of mode choice model estimation and, in particular, discusses that relatively more resources should be dedicated to model calibration and validation as compared with model estimation.<sup>28</sup>

Version 2.3 focuses its calibration and validation at the following levels:

- Region level:
  - the modeled area,
  - the TPB planning area,
  - the metropolitan statistical area (MSA), or
  - one of the air quality non-attainment areas, which can vary by pollutant;
- Jurisdiction level;
- Jurisdiction-to-jurisdiction level;
- For highway assignments: Regional screenlines; and

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<sup>28</sup> Federal Transit Administration, "Discussion-piece #16, Calibration and Validation of Travel Models for New Starts Forecasting" (presented at the Workshop on Travel Forecasting for New Starts Proposals, Minneapolis, Minnesota, 2006), [http://www.fta.dot.gov/planning/newstarts/planning\\_environment\\_5402.html](http://www.fta.dot.gov/planning/newstarts/planning_environment_5402.html).

- For transit assignments: Metrorail station groups.

For New Start applications, FTA requires more rigorous calibration and validation than a general calibration and validation of a regional travel demand model. FTA emphasizes the model's ability to replicate the existing markets for travel, especially transit markets. Estimated travel patterns are often compared with the observed data at the district level, which is more fine-grained than the jurisdictional level. Transit ridership and their patterns in the study corridor need to receive special attention. FTA recommends a calibration and validation approach that includes the following:<sup>29</sup>

- Adjustments to match all available data in useful detail;
- Scrutiny of coefficients, constants, key assumptions;
- Back-cast, if possible; and
- Model description with user's guide and applicability of the model.

To the extent that COG/TPB wishes to utilize the regional model for transit project forecasting, it may be necessary to engage in the FTA recommended calibration and validation approach for the applicable study corridor and/or travel markets.

## 3.8 Other Observations

This section incorporates observations regarding the TPB transit model not incorporated elsewhere in this report.

### 3.8.1 Fare Representation

The current model uses simplifications in fare representation among different transit providers and submodes, but this can lead to differences in forecast versus observed levels of transit demand, particularly at finer levels of detail. Cambridge Systematics recommends that TPB consider incorporating explicit representation of transit fares by transit providers and/or submodes to enhance the validation and to allow testing the effects of transit fare policy on transit ridership in the future.

### 3.8.2 Drive Access to Transit Trips

Trips for drive access to transit are not currently assigned to the highway network. This can lead to some variations from observed patterns in the vicinity of transit park-and-ride stations and thus require special post-processing for subarea studies in these situations.

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<sup>29</sup> FTA, Travel Forecasting for New Starts Proposals – March 2009, Day2\_Sessions\_01\_03.ppt, [http://www.fta.dot.gov/12304\\_9547.html](http://www.fta.dot.gov/12304_9547.html), slide 34, Accessed May 6, 2015.

However, complications with assigning these trips include: 1) to fully address this would create added complexity within the feedback loops of the model; and 2) drive access to park-and-ride trips are not subject to parking lot capacity constraints in the model, meaning that their impact on travel patterns could end up distorting the other traffic.

Options to address these trips within the highway assignment, include making it an optional selection for the user (much as the Metrorail core capacity constraint can be “turned off”), incorporating a capacity constraint park-and-ride shadow price to arrive at appropriate volumes (although this can create future year distortions), and/or assigning prior to other trips to ensure drive-to-transit trip patterns are reasonable.

Cambridge Systematics recommends including a mechanism to permit drive to transit trips to be assigned to the highway network, but also encourages exploration of the most appropriate method to achieve this improvement.

### *3.8.3 Bus Transit Trip Validation*

The present TPB model calibration and validation focuses on overall transit ridership and addressing rail transit modes with more detail. Bus transit ridership makes up a substantial number of daily transit trips and new data streams have become available to explore model calibration and validation. While line-level matching of bus transit ridership is likely an elusive goal, line group validation can be possible, and further consideration should be given to expanding the ways in which bus ridership is incorporated as part of the transit validation.

## 4.0 Use of STOPS

The “Major Capital Investment Projects” rules established in April 2013 revised the measures for FTA to use in evaluating and rating proposed major transit projects. To implement the rules, FTA has developed a simplified method to quantify the revised measures, which include the predicted number of trips that would use the project, project trips that would be made by transit dependents, and the predicted change in automobile vehicle-miles of travel (VMT). STOPS was developed to “predict detailed transit travel patterns for the No-build and Build scenarios, quantify the trips-on-project measure for all travelers and for transit dependents, and compute the change in automobile VMT based on the change in overall transit ridership between the two scenarios.”<sup>30</sup>

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<sup>30</sup> “An Overview of STOPS” (FTA, September 5, 2013) <http://www.fta.dot.gov/grants/15682.html>. RSG. User Guide, STOPS, Simplified Trips-on-Project Software, Version 1.50. Washington, D.C.: Federal Transit Administration, April 29, 2015. [http://www.fta.dot.gov/grants/15682\\_15620.html](http://www.fta.dot.gov/grants/15682_15620.html).

## 4.1 Capability and Limitations

STOPS can generate the trips-on-project measure for all travelers and for transit dependents and the change in automobile VMT, which are required as part of a project sponsor's application for the FTA's New Starts and Small Starts programs. Characteristics include:

- STOPS can be used for ridership forecasts for fixed guideways, but it cannot be used for evaluation of local buses and for highway studies or air quality analysis;
- STOPS estimates transit demand that is not constrained by transit system capacity, and thus cannot be used to study transit system capacity relief projects;
- STOPS considers routine weekday trips by residents, including home-based work, home-based non-work, and non-home-based trip purposes, but it does not consider special travel markets such as college students, air passengers or visitor travel;
- STOPS uses worker-flows from the CTPP to represent work trip patterns and uses the predicted locations of home-based transit attractions to estimate non-home-based trips;
- STOPS predicts future transit demand by using population and employment forecasts to adjust the 2000 CTPP travel patterns, which does not incorporate the effects of accessibility changes on travel patterns due to changes in the transportation system supply; and
- STOPS uses the zone-to-zone roadway travel times and distances from the regional travel model to adjust the zone-to-zone bus runtime, and it does not incorporate bus runtime changes due to revised bus routings, street improvements, and other localized changes.

The current version of STOPS, Version 1.5, uses the 2000 CTPP as the underlying data for trip patterns. This is often raised as a concern, especially when a project is proposed in an area with a lot of growth since 2000 and/or a lot of forecasted growth in the future. This concern can be mitigated through the use of special features in STOPS to address zones with growth.

STOPS includes a visibility factor which can be used as a way to account for some of the unmeasured attributes of transit discussed in Section 3. A BRT that operates mostly like a regular local bus would receive a relatively low visibility factor as compared with a BRT that operates on exclusive right-of-way with other features like a typical rail service.

## 4.2 Model Structure

STOPS has a simplified conventional trip-based model structure, with the following components:

- Travel patterns and trip tables estimated from the CTPP worker flow tabulations;
- A mode-choice model to predict zone-to-zone transit travel based on zone-to-zone travel characteristics of the transit and roadway networks; and

- A transit assignment to assign transit trips to fixed guideways in the transit network.

Motorized travel is stratified into home-based work, home-based non-work, and non-home-based trip purposes. The worker-flow tabulations from the CTPP are factored to represent home-based work-trip patterns and home-based non-work-trip patterns. The non-home-based travel market is approximated based on the use of an approach derived from the National Cooperative Highway Research Program Report 716, *Travel Demand Forecasting: Parameters and Techniques*. These travel patterns and trip tables are scaled based on population and employment forecasts for a future horizon year.

STOPS represents the transit system service levels using the General Transit Feed Specification (GTFS) and incorporates highway congestion using zone-to-zone roadway times and distances obtained from the regional travel demand model.

STOPS is nationally calibrated and validated and can be locally calibrated and validated using local data. The national calibration and validation used current ridership on over two dozen fixed-guideway systems in more than a dozen metropolitan areas in the United States (though none from the Washington, D.C. area). Rider-survey datasets from six metropolitan areas with fixed-guideways were used for calibration, while station-specific counts of trips in nine other metropolitan areas with fixed-guideway systems were used for validation. Local calibration and validation with STOPS can take into account total weekday boardings on the area's transit system, local CTPP HBW attraction district-level transit shares, and local fixed-guideway station counts.

### 4.3 Data Requirements

STOPS requires the following three types of data:

- 2000 CTPP data and census geography, which are available for download in the FTA STOP website;
- GTFS data for the local transit system under study, which can be obtained from the local transit provider(s) that is available publicly on the web or directly from each agency; and
- Data from the regional travel model: (1) zone-specific population and employment estimates for the year 2000, the current year and, if applicable, for one or more future years; and (2) zone-to-zone roadway travel times and distances, again for the current and, if applicable, future years.

### 4.4 Application Cases

STOPS is primarily used in the following two ways:

- As a useful alternative when locally maintained methods – either the regional model or an incremental model – are unavailable or not sufficiently tailored to the task; and



- In a quality-control role – providing a second ridership forecast for comparison to a forecast prepared with locally maintained methods.

STOPS produces all of the reporting needed by project sponsors to review ridership forecasts in detail and to support grant applications to the FTA New and Small Starts program. When using STOPS, the FTA review of forecasts can be focused on the inputs, assumptions, and forecasts produced rather than on the modeling tool being used. Once STOPS is configured and calibrated to address the subject project corridor forecasting, multiple alternative build scenarios may be readily tested.

STOPS is relatively straightforward to run and has been tested in several dozen applications. It does require substantial care in proper setup and assembly of inputs. STOPS is recommended to be used to generate ridership forecasts for the build options under consideration. Furthermore, CS recommends focusing on performing analysis for “current” conditions first and address required horizon year forecasting (if any) using a smaller set of refined alternatives.

## 5.0 Options and Recommendations

### 5.1 Suggestions from WMATA

The Washington Metropolitan Area Transit Authority (WMATA) wrote a letter to TPB dated October 30, 2014.<sup>31</sup> In this letter, WMATA calls for discussion on enhancing the TPB model’s treatment of transit and non-motorized modes. The letter outlined three primary suggestions for TPB. TPB responded to these suggestions in a response letter dated December 3, 2014.<sup>32</sup> On February 11, 2015, a follow-up meeting was held between WMATA and TPB staff regarding transit-related improvements to the TPB regional travel demand model. In addition to discussions of the WMATA recommendations and the TPB responses, the meeting attendees also discussed potential items for inclusion in the upcoming strategic plan for the TPB travel demand forecasting model.<sup>33</sup> The following is a summary of the WMATA recommendations, the TPB staff responses, and our discussion of the issues and options.

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<sup>31</sup> Shyam Kannan to Patrick Wojahn, Letter, (October 30, 2014), “Item 5 - Letters Sent and Received,” pp. 29-30, from the Nov. 19, 2014 meeting of the NCRTPB, <http://www.mwcog.org/uploads/committee-documents/a11XXI9X20141113131836.pdf>.

<sup>32</sup> Ronald Milone to Shyam Kannan, Letter, (December 3, 2014), “Item 5 - Letters Sent and Received,” from the Dec. 17, 2014 meeting of the NCRTPB, <http://www.mwcog.org/uploads/committee-documents/bF1XXF1c20141211093433.pdf>.

<sup>33</sup> Mark S. Moran to Ronald Milone and Wendy Jia, Memorandum, (March 2, 2015), “Meeting summary and points of agreement from the February 11, 2015 meeting between WMATA and COG/TPB staff regarding transit-related improvements to the COG/TPB regional travel demand model.”

### 5.1.1 Light Rail and BRT Modes in Mode Choice Model

WMATA recommended improved distinctions among the transit submodes of Metrorail, BRT, light rail, and streetcar in the model. TPB acknowledged that LRT is grouped to the “Metrorail” category and BRT to the regular bus category in the mode choice model sets. However, distinct BRT and LRT link volumes are created as a standard output.

TPB staff agreed that explicitly distinguishing LRT and BRT in the choice set would be desirable to isolate the respective unmeasured attributes of each, but there exist obstacles for implementation. A major hurdle in incorporating more detail in the mode choice model is the lack of locally observed travel data for BRT, streetcar, and light rail. Another is the limitation in the ability to model the attractiveness of these other modes in the mode choice model, as some attractiveness attributes such as reliability and comfort are not modeled in a conventional mode choice model. There is a further concern that to the extent the modes are in fact not distinct, including them may violate the theoretical underpinnings of the model formulation (i.e., the independence of irrelevant alternatives axiom of decision theory<sup>34</sup>).

TPB suggested that “A review of how other metropolitan areas are addressing light rail and BRT modes within the mode choice process in their regional travel demand models is a worthy endeavor.”

CS did a scan of modeling practice on treating LRT and BRT in the regional model of large MPOs. While most regional mode choice models do not have a distinct treatment of LRT and/or BRT, a few regional models do have such a treatment. For example, in the recently updated San Antonio - Bexar County MPO Travel Demand Model, street car, BRT and LRT are included in the nesting structure.<sup>35</sup> These modes did not exist in 2010, while the BRT opened in 2012, streetcar is expected to open in 2017 and LRT is in the long range plan. Coefficients and constants were asserted based on the FTA guidelines.

One of the problematic characteristics of transit forecasting methods that FTA identified previously was “bizarre alternative-specific constants”, which resulted from the calibration of each choice and market segment against the observed data. The more complex the nesting mode choice structure, the more targets are needed for model calibration. When the nesting structure gets more complex, it becomes not only more difficult to get accurate targets for calibration but also more and more a challenge to assume that person trip tables for each

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<sup>34</sup> Consumer utility theory, which underpins the logit mode choice model, holds that each choice should be distinct and selected with equal probability within a given choice set if given equal utility of the choices within the choice set. When indistinct choices are incorporated in the choice set (e.g., instead of “bus” have “red bus” and “blue bus” as separate choices, with no utility distinction between them), the probability of choosing either of the two highly-related choices (different colors of buses) is improperly increased (in this example, the probability of choosing a bus, all things being equal, is increased by there being two bus choices).

<sup>35</sup> Cambridge Systematics, Inc. VIA Travel Model Improvements: San Antonio - Bexar County MPO Travel Demand Model. prepared for VIA Metropolitan Authority. October 31, 2014.

choice in each market can be generated accurately. FTA emphasizes distinctions of transit service quality attributes rather than transit submode technology.

Nesting mode choice structure is one of the issues discussed in the recent Peer Review of the Baltimore Metropolitan Council (BMC) Activity-Based Travel Model, sponsored by the FHWA Travel Model Improvement Program (TMIP).<sup>36</sup> The panel recommended to keep the mode choice model structure shallow, namely, using “shallow” sets of modal alternatives in the mode choice model. Several advantages of the shallow structure include a reduction of skims needed for mode choice model estimation and application, a reduced complexity and difficulty for estimating the mode choice models, and obviating the need for rules to assign multimodal transit trips to a particular modal alternative. This shallow structure is conducive to modeling “mixed mode” trips, where more than one transit submode is involved and it is hard to classify them in the conventional complex nesting model structure. A disadvantage is that differences in the perceived experience on the level of services, e.g., the different degrees of “premium” modes, are not directly considered in mode choice utility functions. As a result, explicit validation of transit assignment by transit submode becomes more difficult. One way to address this is by effectively discounting in-vehicle time for different “premium” modes.

Cambridge Systematics recommends exploring the approach to mode choice modeling further as part of anticipated activities incorporated in the forthcoming TPB model development strategic plan.

### *5.1.2 Linking Bus Speed with Highway Speed*

The second suggestion from WMATA was to tie bus speeds to highway speeds to better reflect how congestion affects this relationship.

TPB staff states that the existing model uses a global factoring approach to degrade the bus speed in the future, so as to reflect increasing congestion. TPB staff is concerned about moving to a link-based approach to linking bus speeds with congested highway network. TPB staff notes that “the ability to reflect bus priority measures will be a challenge in a regional travel demand model, given the aggregate scale of the network used in the model” and that, in general, “this type of analysis is better conducted in a project-planning context.”<sup>37</sup>

TPB did agree that a review of other metropolitan areas’ methods would be useful.

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<sup>36</sup> FHWA. Baltimore Metropolitan Council (BMC) Activity-Based Travel Model Peer Review Report. April 24, 2014, pp. 18, 26.

<sup>37</sup> Ronald Milone to Shyam Kannan, Letter, (December 3, 2014), 2, “Item 5 - Letters Sent and Received,” from the Dec. 17, 2014 meeting of the NCRTPB, <http://www.mwcog.org/uploads/committee-documents/bF1XXF1c20141211093433.pdf>.

Linking transit travel time/speed to highway travel time/speed in one way or another is state of the practice in regional models of large MPOs.<sup>38</sup> CS identified three approaches to establishing the relationships between high-travel time and mixed flow transit travel time: bus speed curves, a regression model, and highway time/speed with bus delay, depending on how various elements of transit time are explicitly or implicitly represented, including:

- Auto travel speed/time on roadway network;
- Acceleration/deceleration of transit vehicles;
- Dwell time at stops/stations; and
- Recovery time at the end of each trip.

CS recommends that TPB consider establishing an explicit relationship between bus speed and highway speed, along with bus delay. While highway travel time reflects traffic congestion on the highway system, bus delay captures all sorts of delays caused by the bus operations, including dwell time, acceleration and deceleration, and recovery time. Bus delay can be formulated as a delay factor multiplied by the number of stops (alternatively, link length). The delay factor can be empirically estimated using actual or scheduled bus run times and best estimates for auto travel time on the highway system. The relationship can be established by transit submodes, peak and off-peak periods, area types, and facility types.

### *5.1.3 Enhance the Non-Motorized Modes in the Model*

Lastly, WMATA suggested that the TPB's geographically focused household survey be integrated into the model and non-motorized modes be added to the mode choice model. This suggestion was interpreted by TPB as two points: the first being that the survey data be used to enhance the model, and the second being that non-motorized modes be incorporated as primary modes to the mode choice model.

TPB states that the geographically focused household data has been used to enhance the trip generation component of the travel demand model. TPB also agrees that more can be done with these data, particularly when combined with the 2012 Metrorail Passenger Survey data.

Adding biking and walking trips as a primary mode to the mode choice model may be challenged by the lack of granularity in the TAZ system and network. Recent or upcoming improvements to the detail of the TAZ system may make this suggestion more viable.

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<sup>38</sup> Cambridge Systematics, Inc., Fiscal Year 2010 Task Reports, Final Report (Washington, D.C.: National Capital Region Transportation Planning Board, November 16, 2010). 4-12 to 4-20.

Nationally, progress has been made on modeling nonmotorized travel in regional models, but challenges remain, especially in trip-based modeling frameworks.<sup>39</sup> More than two thirds of the 28 large MPOs with trip-based models incorporate non-motorized travel in some fashion in the regional travel demand model, and of those with non-motorized modeling, more than half treat non-motorized travel as part of a mode choice model. However, considerable challenges remain, including:

- Adequacy of travel surveys for nonmotorized modeling (stratification by geography, socioeconomic strata, and mode choice);
- Adequacy of non-motorized infrastructure databases;
- Mode choice model estimation, validation data for non-motorized travel;
- Model sensitivity and responses to urban design changes;
- Representation of non-motorized travel markets; and
- Evaluation of specific non-motorized facility investments.

One major limitation of a zone-based modeling framework is the size of the TAZs, which not only affect the accurate measurement of variables used to estimate trip ends but also zone-to-zone impedance variables. Recent enhancements of the MWCOG/TPB TAZ structure, especially in the region's activity centers, mitigate some of the limitations.

## 5.2 Findings and Recommendations

As also discussed in Section 3.0, CS reviewed the transit modeling elements of the TPB model (Version 2.3.57) in the context of the latest FTA guidance on ridership forecasting for New Starts and Small Starts. CS also reviewed the desired functionality and needs from the TPB stakeholders, especially the Washington Metropolitan Area Transit Authority (WMATA). Our findings and recommendations can be summarized as follows:

- The latest TPB model (Version 2.3.57) represents significant progress made in the TPB transit modeling capability over the past ten years. Recent major enhancements include a nested structure with transit submodes, access modes, and household income segmentations, better convergence for highway assignments, refined TAZ structure, and automated/integrated GIS functionality to support transit modeling;
- During the development of TPB Version 2.3 travel model, it appears that FTA guidance was considered, to some extent, in the mode choice and path building processes, including ensuring proper relationship between coefficients of in-vehicle time and coefficients of out-

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<sup>39</sup> Feng Liu, John E. (Jay) Evans, and Thomas Rossi, "Recent Practices in Regional Modeling of Non-Motorized Travel," *Transportation Research Record 2303*, Washington, D.C., 2012.

of-vehicle time and consistency between weights used in path building and coefficient values in mode choice. Further refinements could be pursued in light of this review to address findings with respect to our review/comparison with the latest guidance. More broadly stated, mode choice coefficients and constants such as cost coefficients and alternative specific constants need to be updated to be in the reasonable ranges recommended by the FTA, unless compelling evidence can be provided otherwise;

- TPB Version 2.3.57 model uses survey data from the MWCOG/TPB 2007-2008 Household Travel Survey, as well as bus and Metrorail on-board transit surveys. The transit on-board surveys were conducted in the context of a New Starts project application. Ongoing efforts to update survey databases and incorporate additional transit data into the resources available for model enhancement should be continued;
- The existing geographic segmentation, with 20 district-to-district interchanges, based on seven superdistricts (DC core, VA core, DC urban, MD urban, VA urban, MD suburban, VA suburban), was intended to capture geographic variations, but should be eliminated and replaced with explicit variables that represent urban design and land use diversity and density;
- The current transit peak/off-peak segmentation can be refined to include peak and off-peak segmentation by all trip purposes, not limited to home-based work trips;
- Extending the current treatment of non-motorized trips to the mode choice model will allow the explicit trade-offs among non-motorized, auto, and transit modes;
- Explicit representation of transit fares by transit providers and/or submodes will allow testing the effects of transit fare policy on transit ridership;
- An explicit relationship between bus speed and highway speed, along with bus delay, is recommended to represent the bus speed and time;
- Trips for drive access to transit should be assigned to the highway network; and
- Further consideration should be given to including bus ridership as part of the transit validation, at least at the regional level. For example, estimated bus boardings may be compared with observed bus boardings by major line groups and/or transit providers.