National Capital Region Transportation Planning Board
Metropolitan Washington Council of Governments

TPB staff review of six years of consultant recommendations from the ongoing consultant-assisted project for models development

Final Report

July 19, 2012

Acknowledgements

We would like to acknowledge the following staff of COG's Department of Transportation Planning (DTP) for their review of earlier drafts of this report: Ron Kirby, Bob Griffiths, and Meseret Seifu.

We would also like to acknowledge the review by the Travel Forecasting Subcommittee, which provides oversight of activities related to development of the regional travel demand forecasting model for the Metropolitan Washington region.

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Table of contents

1 INTRODUCTION 1

1.1 Background 1

1.2 Report Organization 3

2 MODELING TOPICS 7

2.1 Input data 7
2.1.1 Data collection and surveys 7
2.1.2 Inputs to the travel model 7
2.1.3 External and through travel 8
2.1.4 Socio-economic models 12
2.1.5 Fuel prices in travel models 12
2.1.6 Effects of an aging population on travel 13

2.2 Improvements to the trip-based model 14
2.2.1 Trip generation 14
2.2.2 Trip distribution and destination choice 15
2.2.3 Mode choice 17
2.2.4 Modeling transit 19
2.2.5 Time-of-day/peak spreading 25
2.2.6 Traffic assignment 28
2.2.7 Speed feedback in the travel model 35
2.2.8 Modeling HOT/managed lanes 37
2.2.9 Special generators, including modeling airport access trips 40
2.2.10 Modeling non-motorized (walk and bike) trips 44
2.2.11 Model sensitivity to land use policies such as smart growth 45
2.2.12 Sensitivity testing of the regional travel model 48
2.2.13 Screenlines/cutlines 49
2.2.14 Value of time 50
2.2.15 Trip purposes 50

2.3 Software issues and reducing run times 51
2.3.1 Reducing model run times 51
2.3.2 Review of travel demand forecasting software packages 53
2.3.3 Review of TPB's travel modeling scripts 55

2.4 Activity-based models (ABMs) 56
2.4.1 Summary of consultant findings and recommendations 56
2.4.2 Discussion and TPB staff response 59

3 CONCLUSION AND NEXT STEPS 63

4 REFERENCES 69

List of figures

Figure 1 Potential COG/TPB super-region for modeling external trips 9

List of tables

Table 1 Matrix of consultant recommendations by topic area and consultant/year 4
Table 2 Status of consultant recommendations received over the first six years of the scanning project 66
Table 3 Recommendation topics by status 67

Abbreviations

BMI	Bellomo-McGee, Inc.
CS	Cambridge Systematics, Inc.
COG	Metropolitan Washington Council of Governments
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
MWCOG	Metropolitan Washington Council of Governments
NCRTPB	National Capital Region Transportation Planning Board
PB	Parsons Brinckerhoff
TPB	National Capital Region Transportation Planning Board
TRB	Transportation Research Board
VHB	Vanasse Hangen Brustlin, Inc.

1 Introduction

Since FY 2006, the staff of the National Capital Region Transportation Planning Board (TPB) has maintained a consultant-assisted project to evaluate the travel forecasting practices used in the Metropolitan Washington region. The objectives of the project are to ensure that the TPB's modeling methods are in line with the practices of other MPOs and to provide guidance and advice in the area of travel demand modeling. These objectives are well aligned with the skill sets of many consultants in the Metropolitan Washington region, who are familiar with the travel demand forecasting practices used both locally and across the U.S. This project has frequently included focused research (or "scans") on the modeling practices and methods used by other MPOs across the U.S. Consequently, the project is often referred to as the "scan of best modeling practice" project.

Consultant findings and recommendations from this "scanning" project, now in its seventh year, have been instrumental in guiding the TPB models development program. In some cases, we have implemented the consultant recommendations; in other cases, we have not. Both cases are noted in the report. However, up to now, TPB staff has not issued a formal report documenting the TPB staff response to these consultant recommendations. This report represents the TPB staff response to consultant recommendations received in the first six years of this project. This report will be used to update the TPB models development work plan, in terms of short-term and long-term objectives.

1.1 Background

The project contract was designed to operate on a fiscal-year basis and to be renewable for up to two additional fiscal years. This arrangement would allow the consultant to hold the contract for up to three years in total, at which time re-bidding of the contract would occur. Vanasse Hangen Brustlin, Inc. (VHB) was awarded the contract for the three-year period between FY 2006 and FY 2008. The contract was next awarded to Cambridge Systematics, Inc. (CS) for the period between FY 2009 and FY 2011. The current contract (FY 2012), entitled "Assistance with development and application of the TPB travel demand model," was awarded to AECOM Consult, Inc. (Metropolitan Washington Council of Governments, 2011).

Seven reports have thus far been released by the first two consultants since FY 2006:

- Vanasse Hangen Brustlin, Inc. (VHB):
  - Results of FY 2006 Travel Forecasting Research (2006)
  - Results of FY 2007 Travel Forecasting Research (2007)
  - Expanded Evaluation of Peak Spreading (2008a)
  - Estimating the Impact of Exurban Commuters on Travel Demand (2008b)
- Cambridge Systematics, Inc. (CS):
  - Fiscal Year 2009 Task Reports, Final Report (2009)
  - Fiscal Year 2010 Task Reports, Final Report (2010)
  - Fiscal Year 2011 Task Reports, Final Report (2011)

Copies of the seven consultant reports listed above can be found on this web page (www.mwcog.org/transportation/activities/models/review.asp).

The reports have addressed research into a wide range of technical areas associated with travel modeling, addressing subjects of immediate interest to the TPB's models development staff. The reports have provided TPB staff with an improved view of what "best" practices are, and how TPB's modeling forecasting methods practices compare with those of other comparable planning agencies. The research has also resulted in numerous findings and recommendations on improving travel forecasting methods currently used by TPB staff. This report presents a concise listing of the recommendations that have been compiled from the above documents and includes TPB staff's responses.

It is generally considered best practice for metropolitan planning organizations (MPOs) to seek independent evaluation of their travel demand modeling procedures on a regular, on-going basis. The two most common forms of evaluation are either "peer review" or "consultant review." A peer review is typically conducted mostly or entirely with volunteers from agencies that are peers of the MPO seeking the review, such as the staff of other MPOs. One of the best known examples of the peer review approach is the Travel Model Improvement Program (TMIP) Peer Review Program.[1] Alternatively, the consultant review approach is conducted by non-MPO practitioners who are conversant with travel modeling practice, including consultants and/or members of the academic community.

In 2002, the TPB sought an independent assessment and review of its travel demand forecasting process, both current and planned. It chose to hire the Transportation Research Board (TRB) to conduct the review. In December of 2002, COG signed a contract with the National Academy of Sciences, which oversees the National Research Council (NRC), the parent organization for TRB,[2] to perform the model review. The NRC created a committee – Committee for Review of Travel Demand Modeling by the Metropolitan Washington Council of Governments – and appointed the members of the committee, which included representatives from academia, consulting, and practice. The TRB review committee could be seen as a "third way," since it is neither purely a peer review, nor a consultant review. The committee review culminated in two letter reports to the TPB (Transportation Research Board's Committee for Review of Travel Demand Modeling by the Metropolitan Washington Council of Governments, 2003, 2004). The letters listed several observations relating to the TPB's modeling practice. The committee found most of the TPB's methods were consistent with acceptable practice, but some observations questioned specific features of the travel model and mobile emissions post processor. All of the committee's observations were considered by TPB staff and several changes to the travel model were subsequently implemented in response (see, for example, National Capital Region Transportation Planning Board, 2003). At the time of the TRB review, it was expected that two other

[1] http://tmip.fhwa.dot.gov/resources/peer_review

[2] TRB is one of six major divisions of the National Research Council (NRC). NRC functions under the auspices of the National Academy of Sciences (NAS), the National Academy of Engineering (NAE), and the Institute of Medicine (IOM).

MPOs would also undergo a similar TRB review, but no other MPO chose to follow in the footsteps of the TPB.

To maintain continuity in the oversight of the TPB's modeling practice, TPB staff established a consultant-assisted project to serve this function in 2006. The project was designed to provide an on-going review of the TPB's travel demand forecasting process and to perform a scan of the best modeling practice in the U.S. on a task-order basis. This on-going project has provided staff with considerable feedback on modeling concerns and has also relieved staff of conducting research at the expense of other work program activities.

1.2 Report Organization

This report is divided into three main chapters: 1) Introduction; 2) Modeling topics; and 3) Conclusions and next steps. The "modeling topics" chapter is divided into four main sections: 1) Input data; 2) Improvements to the trip-based model; 3) Software issues and reducing run times; and 4) Activity-based models. Within each of these sections, over 20 modeling topics are presented, such as trip generation or mode choice. Within each modeling topic, there are two subsections:

1. **Summary of the consultant findings and recommendations** for the given topic area. The emphasis is on the recommendations. Findings are presented mainly to give context to the recommendations. We have striven to include all the consultant recommendations (there are over one hundred), but only a subset of findings (about 50), which were deemed necessary to provide context.
2. **Discussion and TPB staff response** to the consultant recommendations.

Since many recommendations can pertain to more than one topic area, cross references are included to refer the reader to report sections where relevant recommendations are discussed. In a few sections, such as "data collection and surveys," and "socio-economic models," the reader will find only cross references to the appropriate topic area.

When discussing the current TPB modeling procedures, it should be noted that the currently adopted regional travel model is the Version 2.3 Travel Model, adopted November 16, 2011. However, the Version 2.2 Travel Model (adopted March 2008) is also described in some sections, since 1) it formed the foundation for developing the Version 2.3 Travel Model, 2) it was the adopted travel model when many of these recommendations were made, and 3) many local modeling practitioners are more familiar with Version 2.2 than Version 2.3, due to the fact that Version 2.2 has been in use for many years.

In some cases, a topic is covered in only one of the seven reports. In other cases, a topic is covered in multiple consultant reports. Table 1 shows a matrix of consultant recommendations by topic area and consultant/year.

Table 1 Matrix of consultant recommendations by topic area and consultant/year

		VHB	VHB	VHB	CS	CS	CS
Section & Modeling Topic		**FY 2006**	**FY 2007**	**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
Input data							
	Data collection and surveys				x		
	Inputs to the travel model				x		
	External and through travel	x		x			
	Socio-economic models				x		
	Fuel prices in travel models				x		
	Effects of an aging population on travel	x	x				
Improvements to the trip-based model							
	Trip generation				x		
	Trip distribution and destination choice				x		
	Mode choice				x	x	
	Modeling transit		x			x	x
	Time-of-day/peak spreading		x	x	x	x	
	Traffic assignment	x	x		x	x	
	Speed feedback in the travel model		x		x	x	
	Modeling HOT/managed lanes	x			x	x	x
	Special generators, including modeling airport access trips	x	x		x	x	
	Modeling non-motorized (walk and bike) trips				x		
	Model sensitivity to land use policies such as smart growth				x		
	Sensitivity testing of the regional travel model	x					
	Screenlines/cutlines		x				
	Value of time				x		
	Trip purposes					x	
Software issues and reducing run times							
	Reducing model run times				x		
	Review of travel demand forecasting software packages						x
	Review of TPB's travel modeling scripts						x
Activity-based models (ABMs)		x			x		

Ref: matrix_scanning_topics_after6years_v5.xlsx

An "x" in the table indicates that the given consultant report contained **one or more** recommendations or findings on that topic. Since an "x" can represent one or multiple recommendations, one cannot simply count the x's to determine the total number of recommendations. Keeping this caveat in mind, the FY 2009 CS report had recommendations in the most topic areas, and the topic areas that were covered the most often – four times each – were the following:

- Time-of-day/peak spreading
- Traffic assignment
- Modeling HOT/managed lanes
- Special generators, including modeling airport access trips

Note that the coverage of topics is a function of the areas for which the TPB staff requested reviews. In this report, consultant recommendations and findings are numbered sequentially, each with its own index.

Note about citations: This report uses American Psychological Association (APA) style for citations, which is an author-date citation style. So a citation of "(Smith, 2011b)" indicates a work written by Smith in the year 2011 and can be found in the references section at the end of this report by searching for "Smith" and "2011b" (the "b" indicates this is the second citation to a work written by Smith in 2011). In some cases, for brevity, the citation may use an abbreviation (such as VHB) even though the reference at the end of the report spells out the full name (e.g., Vanasse Hangen Brustlin, Inc.). A list of abbreviations can be found at the beginning of this report. Page numbers for quotations are typically indicated in the citation parentheses in one of two ways, as is illustrated in the following two examples:

- One researcher found that "factors were not commonly used" (Smith, 2011b, p. 65).
- Smith (2011b) found that "factors were not commonly used" (p. 65).

2 Modeling topics

As was stated earlier, the "modeling topics" chapter is divided into four main sections: 1) Input data; 2) Improvements to the trip-based model; 3) Software issues and reducing run times; and 4) Activity-based models. Within each of these sections, over 20 modeling topics are presented.

2.1 Input data

2.1.1 Data collection and surveys

See Recommendation 32, from CS (2009), in the section "time-of-day/peak spreading" for a recommendation about collecting enhanced time-of-day traffic counts. See also Recommendation 58 on the subject of before-and-after studies for the effect of HOT lanes on HOV traffic. See also Section 2.2.9 ("Special generators, including modeling airport access trips").

While models development work has been supported with a recent household travel survey during 2007 and 2008 (11,400 household samples), the TPB has recently asked TPB staff to proceed with collecting additional household travel data in seven geographically focused sub-areas of the region (about 2,400 household samples). This focused data collection effort will be used to study travel behavior in transit-oriented neighborhoods or will be used to study "before and after" conditions for areas where development is in transition. These data, though not explicitly recommended in the consultant reports, will be useful in better understanding non-motorized travel (see section 2.2.10) and the study of land development policy (see section 2.2.11).

2.1.2 Inputs to the travel model

2.1.2.1 Summary of consultant findings and recommendations

Recommendation 1

On the subject of the new, 3,700-TAZ system that was being developed at COG, CS (2009) had the following recommendation, "In addition to expanding the TAZ system as it currently is being developed, TPB also should incorporate the designated Regional Activity Centers and Clusters (RACC) into the TAZ system to ensure that the boundaries coincide with each other" (p. 4-8).

2.1.2.2 Discussion and TPB staff response

TPB staff is in agreement with the recommendation and has followed through with the recommendation. The 3,722-TAZ system which now supports the Version 2.3 Travel Model (adopted in November 2011) was intentionally designed around the RACC concept in order to better integrate land use and transportation planning decisions. The new TAZ system has also improved the regional model's sensitivity to non-motorized travel markets, and the representation of transit-oriented developments.

The RACC concept has been in formulation in the Washington, D.C. region over the past decade. In 1998, the TPB adopted its "vision" for the Metropolitan Washington region. One of the objectives of this vision plan was to adopt "a composite general land use and transportation map of the region that identifies the key elements needed for regional transportation planning -- regional activity centers, principal transportation corridors and facilities, and designated green space" (as cited in Metropolitan Washington Council of Governments, 2007, p. 1). The Planning Directors Technical Advisory Committee (PDTAZ) completed its first map of regional activity centers in 1999 and, in 2002, the COG Board of Directors and the TPB approved the final Regional Activity Centers and Clusters (RACCs) maps based on the Round 6.1 Cooperative Forecasts (2007, p. 1). In the mid 2000s, TPB staff began preparing for an increase in the number of TAZs, while maintaining the existing modeled area, which would result in smaller average zone size, which should facilitate modeling transit and non-motorized trips. Between 2007 and 2009, TPB staff developed a new TAZ system, which ended up with 3,722 TAZs, including external stations.

2.1.3 External and through travel

2.1.3.1 Summary of consultant findings and recommendations

In the area of external trip forecasts, VHB (2006) had two findings and two recommendation, which are listed below.

Recommendation 2

VHB (2006) recommended the following:

> *In addition to looking at the absolute number of forecast external trips, the purpose and direction of trips should also be considered. As exurban development grows, the proportion of external productions is likely to grow while the proportion of external attractions is likely to decrease. The relationship between external-external (E-E) and external-internal (E-I) trips may also change. TPB should investigate the regional impact of these potential changes. (p. 10)*

Finding 1

To obtain information about how agencies forecasted external travel, VHB (2006) conducted a literature review and surveyed 14 MPOs, nine of which responded. VHB found that "the results of the survey closely mirror[ed] the results of the literature review: MPOs either essentially follow the same process as TPB, or obtain external trips from a statewide model's internal trips" (p. 24). VHB describes the TPB process as follows, "Collecting base data at external stations through a combination of traditional link traffic counts and license plate or mailout / mailback surveys, and forecasting future trips by using a straight-line extrapolation or a simple growth-factor" (p. 25). VHB (2006) also found the following:

> *MPOs that do not use a statewide model to forecast external trips are not doing anything significantly different than TPB's current process. However, in both high-growth regions and complex moderate-growth areas like the National Capital Region, the issue of forecasting external trips is growing in importance as jobs and household[s] continue to locate farther away from traditional urban core areas and contribute to an increased share of external trips in overall regional travel. (p. 27)*

Finding 2

VHB (2006) found the following:

> *Clearly, the use of internal trips from a statewide travel demand model as external trips for the TPB model is not a feasible approach at this time. Maryland lacks a statewide model, and*

> *although Virginia does have a statewide model, the Virginia Department of Transportation (VDOT) has encountered problems with its application. (p. 27)*

Recommendation 3

VHB (2006) recommended the following:

> *A possible approach is to combine elements of both of the above procedures. First, TPB could create a model 'super-region' at the super-district or county level extending as far as 150 miles from Washington, D.C. based on data available from the 2000 Census Transportation Planning Package (CTPP) and anticipated changes to the areas that regularly interact with the TPB area* [See Figure 1, reproduced from VHB 2006]. *The number of external stations in the model network could be increased to match each station with a super-regional county or super-district. In Virginia and Pennsylvania, it may be worth considering adopting the statewide model network for those areas outside the current TPB modeled area for compatibility. Following the collection of external station base counts through traditional counts and surveys, the data could be supplemented by the superregional jurisdictions and MPOs, similar to the coordination TPB already does with BMC and FAMPO, just over a larger area. For future year external trip forecasts, rather than extrapolating or using a growth-factor, TPB could use the updated population / household and employment forecasts for the super-regional jurisdictions and convert the growth to productions and attractions and ultimately external (E-E, E-I, and I-E) trips. (p. 27-28)*

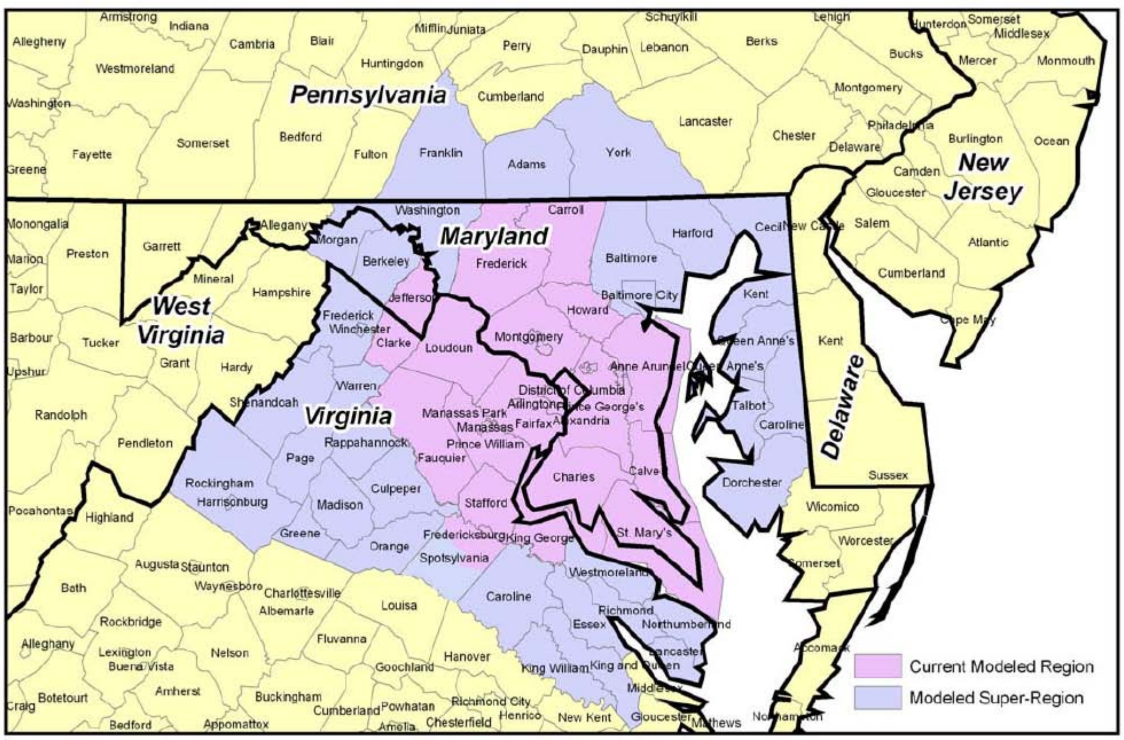

Figure 1 Potential COG/TPB super-region for modeling external trips

Source: VHB, 2006, Figure 3-1, p. 29

> *Special attention will need to be paid to coordination with existing small MPOs in or near the super-region who may have existing modeling programs, such as the Hagerstown, Cumberland,*

> *and Winchester MPOs. These agencies will benefit from the use of the TPB model to produce external trip matrices for their areas. Those areas that may have a designated MPO following the 2010 census, such as the Gettysburg, PA area, should also be considered. Finally, the superregion could encompass most or all of the State of Maryland, thus creating a de facto Maryland statewide model. In addition to improving TPB's forecasting process, this model could be useful to the Baltimore Metropolitan Council (BMC), Hagerstown Eastern Panhandle MPO and other areas throughout the state. In view of the benefits accrued to areas in Maryland outside the Capital Region, this effort may be undertaken jointly with BMC and the Maryland DOT. It could also be expanded to create statewide modeling capabilities in Maryland. In view of the benefits to Maryland, TPB may wish to seek additional funding from BMC and the Maryland Department of Transportation (MDOT) to support development of this process for forecasting external trips. (p. 28)*

Finding 3

VHB (2008b) used the year-2000 Census Transportation Planning Package (CTPP) data to analyze external travel in the Metropolitan Washington region. After its initial review of year-2000 CTPP data, VHB (2008b) found that the "TPB region experiences a significant level of external-internal (E-I) travel from workers who live outside the region, including many 'extreme commuters' who live more than 100 miles away from the Capitol" (p. 1).

Finding 4

VHB (2008b) found that the rate of growth in external ("E-I") travel was going down over time. For example, the compound annual growth rate (CAGR) from 1970 to 1980 was 8%; from 1980 to 1990 was 6%; and from 1990 to 2000 was 2% (p. 9).

Finding 5

VHB (2008b) stated:

> *VHB attempted to develop methods for forecasting external trips by type of jurisdiction (central, inner and outer suburbs, etc.) by creating regression equations to test the relationship between external trips and the difference between employment and workers by jurisdiction. The test results show a very strong relationship between these variables for the Central Jurisdictions and a less strong relationship for the outermost areas in the modeled region and for all areas with a negative difference between employment and workers. (p. 21)*

Recommendation 4

VHB (2008b) mentioned two areas for potential testing in the future. First, VHB states that "it does seem likely that a continued increase in gas prices will eventually temper the growth in E-I trips, but much is dependent on the impact across different economic strata, something which should be addressed by further testing." (p. 23). Second, VHB states that "one other potential area for further analysis would be backcasting using some of the predictive equations, the historical BEA data, and the actual boundaries of the TPB modeled region for 1970, 1980, and 1990 to see how well E-I travel was forecast in the past under previous models, as well as the effect of expanding the model boundary" (p. 23).

2.1.3.2 Discussion and TPB staff response

Conceptually, TPB staff is in agreement with Recommendation 2 and Recommendation 3, which would result in a model that addresses changes in the directionality and the distributions of trip purposes of external travel over the forecasting horizon. These types of external trip patterns are currently fixed to those observed in the most recent auto external survey. A review and analysis of the directionality of external trips using CTPP data for a super-region is attainable in the short term. However, such an analysis will have limitations. For example, CTPP data addresses only the commuting portion of external travel. Further, there may be some question as to whether an extremely long (>60 miles) home-to-work trip that is reported in the CTPP is a regular weekday occurrence.

The suggestion that TPB could use the updated population/household and employment forecasts for the super-regional jurisdictions as a basis for external growth is an interesting concept, but it is an idea that is ultimately based on judgment: How will household and employment growth, inside and outside of the modeled area, impact the pattern of in-commuting and out-commuting? That is a question with no clear answer.

Staff is not receptive to Recommendation 4, which requires backcasting of external trips from long ago. Historical external productions and attractions developed for varying TAZ systems no longer exist and so a time series comparison of external trips to BEA data is not feasible.

TPB staff recognizes that external and through trips are important components of the overall travel forecasts in the Washington region. In fact, resources invested into the development of external and through trip forecasts have steadily increased in recent years. Staff has been especially focused on: 1) using the most up-to-date traffic counts at external stations as a basis for extrapolating external and through trip markets, and 2) ensuring that the growth rates assumed for external traffic are reasonable and consistent with projected land activity growth for the modeled region (see, for example, Milone, 2012b). Staff also acknowledges that overall production and attraction balance over time is another important forecasting consideration, particularly with respect to the work purpose.

In the Version 2.3 Travel Model, external productions and attractions are entered as an exogenous input, by purpose, into the trip generation process. The travel model represents external travel for auto person trips, commercial vehicle trips and truck trips. The model does not currently include external *transit* person trips, i.e., transit person trips that either start or end external to the modeled area (see the section on "modeling transit"). The omission of external (XI/IX) transit trips confounds any comparative analysis involving commuting traffic (e.g., the CTPP) and the travel model. TPB staff is currently conducting work on addressing external transit in the Version 2.3 model. (External transit trips constitute about 5% of Metrorail travel).

The existing approach for developing future-year external and through files involves essentially factoring observed external and through trip patterns through time, based on assumed growth rates, which vary by station group (Milone, 2011a, pp. 2–3). The travel patterns are station-specific and include: 1) the proportion of external and through trips, 2) the directional orientation of external productions and attractions, the share of external trips by trip purpose, and the composition of vehicle types (private auto, commercial auto, medium truck and heavy truck). In staff's view, there is currently no basis by which to alter the observed probabilities over time.

TPB staff continues to strive for on-going data collection as a means of understanding external trip patterns, purposes, and vehicle composition. The most recent external travel surveys were conducted in the mid 1990s:

- 1994 COG/TPB Auto External Survey
- 1996 COG/TPB Truck External Survey

The cost of conducting external surveys using conventional techniques is growing over time, and is clearly an impediment to periodic data collection efforts. Staff acknowledges that improved (smarter) data collection techniques may enable data collection of this type to occur more frequently.

Modeling external *transit* travel is discussed in the section entitled "modeling transit." Regarding Finding 2, from VHB (2006), TPB staff notes that the state of Maryland is currently developing a statewide model (See, for example, National Center for Smart Growth Research and Education, University of Maryland & Parsons Brinckerhoff, 2011), though this did not exist when VHB did its review in 2006.

Regarding VHB's work in 2008, VHB (2008b) used the year-2000 CTPP data to analyze external travel in the Metropolitan Washington region. In its analysis, it excluded trips destined to Howard and Anne Arundel counties in Maryland (p. 4). It is not clear to TPB staff why this step (post-processing step 1) was taken.

2.1.4 Socio-economic models

See Recommendation 74 in the section entitled "Model sensitivity to land use policies such as smart growth."

2.1.5 Fuel prices in travel models

2.1.5.1 Summary of consultant findings and recommendations

Finding 6

On the subject of forecasting fuel prices as an input to the travel model, although there have been rapid changes in fuel prices recently (for example, fuel prices in 2009 had more than doubled since 2003), CS (2009) found that "observing short-term adjustments provides useful insights, but for travel forecasting purposes, long-term effects are more important" (p. 1-1). CS also found that "fixed costs like vehicle ownership cost and insurance are generally not considered as part of the automobile operating cost" (p. 1-1), which is consistent with the practice that has been used in the TPB travel model. CS also states that fuel costs are generally represented in only the mode choice step, so the effect of fuel prices on trip generation and destination choice is not captured in most four-step travel models (p. 1-2).

Finding 7

CS (2009) noted that the behavioral response to changes in fuel prices has not been consistent. The two biggest increases in real prices of gasoline, since 1919, were in 1970s and the mid to late 2000s (see

Figure 1, p. 1-3 of CS 2009, or the U.S. Energy Information Administration's Real Prices Viewer (2012)), but, CS noted that "even with a doubling of real fuel prices since 2003, fuel price increases over this period have not seemed to induce the behavioral adjustments observed during the 1970s" (p. 1-2).

Recommendation 5

On the subject of forecasting fuel prices, CS (2009) stated that "historical fuel prices do not reveal any predictable trend. Most underlying factors affecting fuel prices are impossible to predict" (p. 1-12). Consequently, when forecasting fuel prices, CS recommended freezing fuel prices at their current level: "Current fuel price is widely considered as the best estimate of future year fuel prices and using current fuel prices is the most widely accepted practice. Most of the other forecasting methods are considered too speculative to be reliable" (p. 1-12).

Recommendation 6

Given the uncertainties in forecasting fuel prices, CS (2009) recommended using sensitivity testing: "Given the constraints, employing a multi-scenario analysis to predict a spectrum of possible future scenarios while using reasonably robust model structures and relying on professional judgment is probably the best way forward" (p. 1-15).

2.1.5.2 Discussion and TPB staff response

On the subject of forecasting fuel prices, CS (2009) recommended freezing fuel prices at their current level (Recommendation 5). This is effectively the practice followed by TPB staff, since we freeze the auto operating costs in the mode choice model at 10 cents per mile for all analysis years (See, for example, Milone, Humeida, Martchouk, Moran, & Seifu, 2012a, p. 11-21).

Given the uncertainties in forecasting fuel prices, CS (2009) recommended using sensitivity testing (Recommendation 6). TPB staff concurs with this recommendation. As indicated in the TPB staff response to Recommendation 81, TPB has done extensive sensitivity testing and plans to continue this practice in the future.

2.1.6 Effects of an aging population on travel

2.1.6.1 Summary of consultant findings and recommendations

Recommendation 7

VHB (2006) recommended that TPB staff consider changes in travel behavior due to the aging population, in particular, changes in travel by the baby boomer generation as it moves into retirement (p. 9). VHB (2007) reiterated this recommendation in its 2007 report, saying that the TPB "needs to consider now what will happen to trip making characteristics as the baby boomer generation moves into retirement" (p. 11).

2.1.6.2 Discussion and TPB staff response

VHB (2006) recommended that TPB staff consider changes in travel behavior due to the aging population (Recommendation 7). TPB staff has not yet acted on this recommendation using an explicit model. Staff believes this issue must be handled in close coordination with the COG Cooperative Forecasting process.

2.2 Improvements to the trip-based model

2.2.1 Trip generation

2.2.1.1 Summary of consultant findings and recommendations

See, also, Section 2.2.9, "Special generators, including modeling airport access trips."

On the subject of near-term improvements/fine tuning the trip generation model, CS (2009) had three recommendations:

Recommendation 8

"Review and summarize findings of the 2008 household trip generation and attraction rates at the subregional level" (p. 2-19).

Recommendation 9

"Consider enhancing the application of year 2000 PUMS data by incorporating more detailed zonal data found in the 2000 CTPP" (p. 2-19).

Recommendation 10

"Determine the reasonableness of the current trip generation rates relative to procedures used by similar size MPOs, and estimate new generation rates from the 2008 household survey by TAZ or district" (p. 2-19).

2.2.1.2 Discussion and TPB staff response

The current TPB procedure for the calibration and application of the trip generation model is described in Chapter 4 of the Version 2.3 Travel Model calibration report (Milone, Humeida, Martchouk, Moran, & Seifu, 2012b).

Staff supports Recommendation 8 and has already presented such an analysis of trip rates by regional activity centers to the Travel Forecasting Subcommittee (Milone, 2010a). Perhaps, in the future, these summaries could be made part of the calibration report. Further work along this line is planned in the near-future. For example, TPB has recently embarked on a new Household Travel Survey (HTS) that targets geographically focused subareas of the Washington, D.C. region. The first phase of data collection has been completed during the spring of 2011, and a spring 2012 data collection effort is underway now. These new data will also enable staff to analyze travel behavior (including trip rates) at a much higher level of resolution than would be available with a regional sample. This type of analysis is important in the view of TPB staff. While the existing trip generation rates from the regional 2007/08 HTS have been developed on the basis of 64 cross classes (stratified by income, household size, and vehicle availability), there is still a sizeable degree of variation in household trip rates within each class. A comparative analysis of regional trip rates with rates developed with more highly sampled subareas will be useful in better understanding the variation observed in the regional trip rates.

Staff does not view Recommendation 9 (enhancing the 2000 PUMS data set) as a useful activity at this time given that the data is over ten years old and it is not clear that this exercise will prove useful.

Staff is in agreement with Recommendation 10 (assessing the TPB's trip rates against those of comparable metropolitan areas). All travel modeling practitioners strive to develop modeling parameters that are reasonable and generally consistent with those developed in metropolitan areas of similar size and system composition. TPB has obtained a documented recent survey of recent trip generation rates (Hartgen & San Jose, 2009) as a basis of comparison against rates developed for the Version 2.3 Travel Model, though no formal document was prepared on this comparison. This type of comparative analysis may be viewed as another validation check of the travel model.

2.2.2 Trip distribution and destination choice

2.2.2.1 Summary of consultant findings and recommendations

On the subject of near-term improvements to the trip distribution model, CS (2009) had the following recommendations:

Recommendation 11

"The highway network speeds should be validated to observed speeds as they serve as a key input to trip distribution" (p. 2-19).

Recommendation 12

"Review the intradistrict versus interdistrict trip movements against the household and Census datasets. Test the option of using two sets of friction factor curves, one for short trips and another for long trips" (p. 2-19).

Recommendation 13

"Validate county-level average trip lengths and times for all trip types to the 2008 household survey and the 2000 work trip data from the Census" (p. 2-19).

Recommendation 14

"Validate screenlines by time period to evaluate the trip distribution and assignment validation. Adjust networks along with trip generation and distribution parameters to improve screenline validation" (p. 2-19).

Recommendation 15

On the subject of destination choice models, which perform the same generation function as trip distribution models, CS (2009) had the following finding/recommendation, "Though there is little doubt that destination choice models are superior to gravity models, the value of migration may be limited if an activity-based model is planned within a few years because re-estimation would be necessary" (p. 2-20).

See also Recommendation 78, found in section 2.2.11 ("Model sensitivity to land use policies such as smart growth").

2.2.2.2 Discussion and TPB staff response

The current TPB procedure for applying trip distribution is described in Chapter 5 of the Version 2.3 Travel Model calibration report (Milone et al., 2012b).

CS (2009) recommended that “highway network speeds should be validated to observed speeds” (Recommendation 11). Staff does not agree that the speeds resulting from a static traffic assignment process should be rigorously validated against observed speed, but staff maintains that link speeds should be checked to ensure that they: 1) fall within a reasonable range of observed speed values (the upper range in particular) and 2) are appropriate and consistent with the simulated time period. Traffic assigned link speeds will not validate well against real-world speeds because the assignment process does not explicitly represent intersection/signal delay and queue formation (this issue is discussed in Miller, Fitch, Dougald, Kreissler, & Hill, 2005). The static traffic assignment also allows for the condition in which a link, time-period volume may exceed the assumed time-period capacity. This condition, though physically unrealistic for an assignment focusing on a peak hour, is allowable in the traffic assignment process as an indicator that peaking occurs over multiple hours. Staff maintains that a more meaningful speed validation should be undertaken using “post processed” link speeds that are used in the mobile emissions process. The post processor is used essentially to convert the link volumes from the traffic assignment process into hourly speeds and volumes, using refined speed-flow relationships and implementing peak volume spreading in cases where hourly volumes exceeds hourly capacities. Staff has used hourly data from INRIX as a basis for comparison against simulated hourly volumes in the emissions post processor with success. Results of this analysis were presented to the Travel Forecasting Subcommittee (Milone, 2011b), but have not been formally documented.

Recommendation 12 (reviewing the trip distribution model at the district level, and possibly bifurcating friction factors among short trip and long trip markets) is a suggestion that staff can consider, but staff will require more detailed procedural guidance on this recommendation. One of the technical problems staff encountered during the Version 2.3 model trip distribution validation was a pervasive underestimation of intra-jurisdictional trips, particularly for the non-work purposes (where trip lengths are relatively short). Many of these problems were treated with K-factors used to “encourage” trips to remain within the origin jurisdiction. This recommendation may lead to a reduction in use of K-factors.

Staff agrees with Recommendation 13 (validating county-based trip lengths) and will follow through with this suggestion. TPB staff agrees with Recommendation 14 (“validate screenlines by time period”), but the biggest obstacle to this activity is a dearth of time-of-day traffic counts (there are currently hourly counts for about 850 locations in the entire 2007 network). TPB staff is working on ways to increase the sample, but these are essentially ways to *estimate* observed values (e.g. factoring locally collected period counts up to daily estimates, or factoring historical daily counts up to current-year counts, etc.). Staff has discussed with the state DOT’s the idea of establishing a metropolitan sample traffic counting program as part of the HPMS process, but this idea has not yet been realized.

In Recommendation 15, CS states that destination choice models are superior to gravity models, but recommends waiting on developing a destination choice model if TPB staff is planning to move to an activity-based model (ABM) in the next few years. TPB staff will consider this recommendation. The decision on whether (and how) to implement an activity based model has not yet been made.

2.2.3 Mode choice

2.2.3.1 Summary of consultant findings and recommendations

On the subject of near-term improvements to the mode choice model, CS (2009) had two recommendations:

Recommendation 16

The mode choice model should be updated such that it will meet the FTA guidelines for New Starts analyses (p. 2-19). Although CS did not cite specific documents from the FTA, a number of these documents can be found on the FTA website (See, for example, Federal Transit Administration, 2006a, 2006b, 2006d). As CS notes, although these guidelines are focused mainly on improving mode choice modeling, they also apply to developing the highway and transit networks and to path building.

Recommendation 17

"The new 2008 household survey data should be used to update and re-calibrate the mode choice model parameters" (p. 2-19).

Finding 8

According to CS (2010), the three major techniques for developing mode choice models are statistical estimation, assertion of coefficient values, and a hybrid approach (p. 4-21 to 4-22). CS (2010) reviewed mode choice models from a sample of the largest MPOs in the U.S. and found the following:

> *Many MPOs have asserted coefficients or have used a hybrid approach of combining statistically estimated coefficients with asserted coefficients based on rules of thumb. Out of the 25 regional models reviewed, approximately half of the mode choice models were estimated, and the remaining half took either the assertion approach or the hybrid approach. (p. 4-23)*

Finding 9

According to CS (2010):

> *FTA recognizes the limitations of mode choice model estimations and in particular, believes that too many resources were spent on model estimation and too little resources on model calibration and validation. Therefore, FTA recommends that resources be better spent in careful mode choice model calibration and validation, with asserted coefficients for time and costs. (p. 4-25)*

Recommendation 18

On the subject of which of the three approaches (estimation, assertion, or a hybrid) to take for developing a mode choice model, CS (2010) recommended "a hybrid approach be taken to develop a new mode choice model for the next model update" (p. 4-26). In other words, CS recommended that a model be statistically estimated first, but, if or when "unreasonable results emerge from the estimation," then the FTA-approved values and relationships between coefficients should be "asserted" (p. 4-23). CS finished by noting:

> *This approach will ensure compliance of the resulting mode choice model with FTA requirements, and at the same time, allow the flexibility of incorporating additional variables that are of*

> *interest to the TPB. These additional variables may be important in explaining travel behaviors in the Washington metropolitan area, and also be important to analysis of some policies. (p. 4-23)*

2.2.3.2 Discussion and TPB staff response

The current TPB procedure for applying mode choice is described in Chapter 6 of the Version 2.3 Travel Model calibration report (Milone et al., 2012b). The Version 2.3 Travel Model uses a nested-logit (NL) mode choice model with 15 choices. This model was first developed by AECOM Consult, for corridor studies, and was applied as a post process to the four-step travel model (AECOM Consult, Inc., 2005). TPB staff adopted this model and moved it into the speed feedback loop, necessitating its recalibration. When AECOM first developed the model for its corridor study work, it used what CS refers to as the "hybrid approach," i.e., some coefficients were statistically estimated, others were asserted (including the nesting *coefficients*), and the alternative-specific constants (the nesting *constants*) were calibrated using an automated calibration routine, implemented in a Fortran program called CALIBMS (AECOM Consult, Inc., 2006). TPB staff has continued to use this same calibration technique.

Staff agrees with Recommendation 16 ("mode choice model should be updated such that it will meet the FTA guidelines for New Starts analyses"). The model now used in the Version 2.3 Travel Model has been built as a direct result of New Starts work conducted by AECOM Consult. The AECOM mode choice model was initially applied as a post processor step, after the regional model was executed. TPB staff subsequently inserted the nested logit model into the Version 2.3 Travel Model, as a replacement to the sequential multinomial mode choice model used in the previous Version 2.2 model.

Staff initially agreed with Recommendation 17 ("The new 2008 household survey data should be used to update and re-calibrate the mode choice model parameters") and set out to do just that with the calibration of the model choice model used in the Version 2.3 Travel Model. However, staff ultimately re-calibrated the mode choice model using on-board transit surveys, instead of the 2007/2008 COG Household Travel Survey because the sample was more robust – a necessity given the exhaustive transit choice set considered. The calibration process is described in the calibration report (Milone et al., 2012b, pp. 6–17 to 6–30). The HTS would have provided about 5,000 unweighted transit person trips, versus about 50,000 unweighted transit person trips from the on-board transit surveys. The on-board transit surveys used are listed in the calibration report (Milone et al., 2012b, pp. 6–18 to 6–19) and are also listed here:

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

Regarding Recommendation 18 (i.e., CS recommending a hybrid approach for developing a new mode choice model for the next model update), TPB staff did use the hybrid approach (i.e., some coefficients were statistically estimated and others were asserted based on rules of thumb), with the model being calibrated by adjusting the nesting constants, using an automated routine, implemented as a Fortran program named CALIBMS). However, the coefficients that were statistically estimated —in this case, in-vehicle travel time (IVTT) and the cost coefficient for income group 1—were estimated using Alogit for previous modeling work (Milone et al., 2012b, p. 6-14), but this estimation work was not well documented. Consequently, it may make sense for future mode choice model work, to re-estimate some of the model coefficients using statistical estimation software.

2.2.4 Modeling transit

This section includes consultant recommendations regarding modeling transit, including issues related to changing transit path building software. The Version 2.3 Travel Model currently uses the TRNBUILD transit path building module, which started in TP+, but is now also a part of Cube Voyager. However, Citilabs is not planning to make any major updates to TRNBUILD and is encouraging its users to migrate to Cube Voyager Public Transport (PT). TRNBUILD is a single-path transit path builder. By contrast, PT is a multi-user-class, multi-path transit path builder, though it can be forced to operate in a single-path manner, if the user so desires. TPB staff asked CS to consider the implications of making such a conversion.

2.2.4.1 Summary of consultant findings and recommendations

Recommendation 19

Although the TPB staff does not regularly work on FTA New Starts studies, the regional travel demand model is used by consultants who do. Consequently, VHB (2007) had several suggestions for changes to the regional travel demand model to make it more compliant with the Summit software developed by FTA to determine changes in user benefits associated with new transit service operating on fixed-guideway transit systems:

- For each study or project, maintain consistency between transportation networks, with special attention focused on transit access links (e.g., walk access and drive access) (p. 22).
- Fixed trip table: The same trip table should be used in both the baseline and “build” alternative. The final trip table used should reflect the “build” alternative (p. 22).
- Land use must be held constant (p. 22).
- “The in-vehicle time coefficients for all modes must be the same in path building. There cannot be different coefficients for highway modes and rail modes.” (p. 22)
- “The access-sheds for rail and bus must be the same. Rail cannot have a longer walk access than bus – unless, as stated above, the engineer or planner responsible for the model has data to support it” (p. 22).

Recommendation 20

Many consultants who used the TPB Version 2.2 Travel Model for FTA New Starts work applied a post-process mode choice model after the four-step travel model. This was done, first, to ensure that a fixed trip table was used, and second, to make use of a more sophisticated mode choice model (The mode choice model in the Version 2.2 Travel Model was a 5-choice sequential, multinomial-logit model. By contrast, the post-process mode choice model was a 15-choice nested-logit mode choice model). This practice led to an inconsistency between the two mode-choice models used in these analyses.

Regarding this inconsistency, VHB (2007) stated that "the correct action for TPB is to incorporate a better mode choice model in the four-step process" (p. 24).

Recommendation 21

As a long-term model improvement, CS (2009) suggested that "model improvement might include calibrating the model set to work with transit travel time coding that is directly based on the underlying highway link travel times," citing the San Diego regional travel model as one that makes use of a bus-speed model (p. 5-4). Similarly, CS (2010) found that "while the current TPB bus travel time approach was designed to represent increasing congestion in the Washington region, it does not provide a direct linkage between bus travel speeds and the level of roadway congestion" (p. 4-20). Consequently, CS recommended that "TPB consider establishing an explicit relationship between bus speed and highway speed, along with bus delay" (p. 4-20).

Recommendation 22

On the subject of transit fare representation in the travel model, CS (2010) reviewed the state of the practice on fare representation at a sample of the largest MPOs in the U.S. Based on this review, CS found that "an explicit representation of transit fares by provider and mode appears to be a preferred method for use in the regional travel demand model" (p. 4-2) and CS recommended that TPB staff should consider making this change as one of its short-term model enhancements (pp. 4-2, 4-9). As noted by CS (2010), this method is able "to accurately represent the complex transit fare structures in the region" and "offers an easy way to test the effects of fare policies on transit usage and ridership, particularly for different providers and/or modes" (p. 4-9).

Finding 10

TPB staff had recently conducted a test to determine the feasibility of incorporating the transit fare subsidy that many transit riders in the Washington, D.C. area receive as part of the SmartBenefits program (Milone, Humeida, Moran, & Seifu, 2009, pp. 2–24 to 2–29). Nonetheless, CS (2010) found that, based on its scan of regional travel demand models, "no large MPO has consideration of transit fare subsidies built into [its] travel demand model, though a few incorporate fare-free zones" (p. 4-10).

Recommendation 23

CS (2010) mentioned some of the shortcomings with the TPB staff methodology for representing fare subsidies, such as the fact that is was applied to only Metrorail trips and not other transit modes (p. 4-10). Nonetheless, citing the prevalence of the fare subsidies, CS (2010) stated, "consideration of other methods of incorporating the fare subsidy which could be applied to all transit modes is encouraged" (p. 4-11). CS described three possible approaches for doing this, including a more explicit representation of parking subsidies, on pages 4-11 to 4-12.

Finding 11

Relating to Recommendation 21, on the subject of representing bus speeds in the travel model, CS (2010) found the following:

> *The review of regional travel demand models used by large MPOs shows that it is a state of the practice technique to estimate the travel time of transit modes operating in mixed traffic as a*

> *function of congested highway time. All the MPO models reviewed make the linkage between transit travel time and highway travel time in one way or another. It also is a state of the practice technique to directly code transit travel time or speed for transit modes operating on exclusive right-of-way transit lines. (p. 4-12)*

Finding 12

CS (2011) found that "there are no national standards for transit validation or validation in general, but there is guidance available" (p. 1-5).

Recommendation 24

Given the lack of standards, CS (2011) suggested that TPB may want to consider using the Florida Department of Transportation (FDOT) standards for validating transit model results (pp. 1-5 to 1-6).

Finding 13

Based on its experience working on transit planning studies in the region, CS (2011) found that "screenline volumes serve as a very good measure for evaluating and demonstrating the validity of the transit assignment" (p. 1-9), starting with the Potomac River and the Capital Beltway (p. 1-10). However, CS (2011) cautioned that "it is important to convert the production and attraction trips in the transit assignment to origin and destination trip flows" so that they are consistent with the data found in cordon counts. Based on the assessment done by CS with the Version 2.3.9 Travel Model, CS found that the transit assignment across the Potomac River was reasonable (p. 1-10).

Recommendation 25

CS (2011) stated that "one area of focus on improving the transit assignment might be to improve the drive access coding" (p. 1-11). CS added that "one potential improvement might be to explore the features available in Citilabs PT product for coding transit drive access" (p. 1-12).

Finding 14

CS added that it found that "drive access coding tended to favor stations further in towards the core areas" (p. 1-11). A possible reason for this finding can be found in the TPB response to Recommendation 25 (on page 24) and is also explained in the CS (2011) report in a footnote (p. 1-12).

Recommendation 26

CS (2011) stated that it has found the cordon count data collected by COG to be very useful for transit validation work (p. 1-14). CS also made the following recommendation:

> *A recommendation might be to evaluate the potential and feasibility for conducting counts on three cordons in the future. The three cordons could be the central employment core, the Capital Beltway, and some combination of highway facilities to form a virtual outer beltway such as the Fairfax County Parkway in Virginia and the Intercounty Connector and U.S. Route 301 in Maryland. (p. 1-14)*

CS (2011) noted that the "cordon counts in the Washington, D.C. region provide a good source of data to balance with the operator-supplied boarding data" (p. 1-21) and recommended that TPB continue or restart this type of data collection (p. 1-21).

Recommendation 27

On the issue of improving transit assignment, CS (2011) made the following recommendations:

> *Obtain additional boarding or other validation data for Metrorail, commuter rail, and all bus services;*
>
> *Evaluate the ability to include drive access trips in the highway assignment and feedback the travel impedance to the supplemental access link files; and*
>
> *Evaluate the potential path building advantages for different travel demand forecasting software tools, including Citilabs PT. (p. 1-21)*

Finding 15

According to a survey of large MPOs that CS conducted as part of an earlier task (Task 12), CS (2011) "was able to identify three large MPOs (Houston- Galveston Area Council, San Juan, and Northeast Ohio Areawide Coordinating Agency) that have switched to PT and one model in the Miami region that uses PT for network building purposes only" (p. 3-7).

Finding 16

CS (2011) listed a number of the benefits of switching to PT, such as the following (p. 3-9):

- *Enumeration of multiple paths;*
- *Ability to save enumerated paths;*
- *Definition of multiple user classes;*
- *Advanced transit network building capabilities;*
- *Ability to trace transit paths on screen;*
- *Advanced method for calculating wait time;*
- *More transit skimming options;*
- *Advanced algorithms for transit route selection;*
- *Incorporation of crowd modeling;*
- *Better representation of complex fare systems;*
- *Ability to create circular and linear transit routes;*
- *More rigorous and flexible analysis and reporting tools;*
- *Acceptance by FTA; and*
- *Ability to function as a mode choice model.*

An example of the new analysis and reporting tools is stop-to-stop transit reporting (STOP2STOPO), which can be used similarly to the select-link functionality available in highway assignment (p. 3-15). Another example is the line loading summary (see, for example, Citilabs, Inc., 2011, pp. 797–798; or Schmitt & Kumar, 2008, pp. 396–400), which might be able to replace some or all of the functionality or purpose-written software such as the current transit summary software used by TPB staff and written in Fortran by AECOM: LineVol and LineSum.

Finding 17

CS (2011) indicated that "it is possible to migrate from TRNBUILD to PT in steps" (p. 3-17).

Recommendation 28

CS (2011) recommended that TPB make the transition to PT and found that "a step-by-step migration to PT seems to be the most reasonable path" (p. 3-18).

2.2.4.2 Discussion and TPB staff response

VHB (2007) had several suggestions for changes to the regional travel demand model to make it more compliant with the Summit software developed by FTA to determine changes in user benefits associated with new transit service operating on fixed-guideway transit systems (Recommendation 19). TPB staff generally concurs with the suggestions in this recommendation, with the following notes: Some of these suggestions do not apply to TPB's normal way of using the travel model (e.g., using fixed trip tables and holding land use constant). The first suggestion is a goal for all TPB modeling work: maintaining consistency between transportation networks. The last two suggestions conform to TPB's current modeling practice:

- "The in-vehicle time coefficients for all modes must be the same in path building. There cannot be different coefficients for highway modes and rail modes." (VHB, 2007, p. 22)
- "The access-sheds for rail and bus must be the same. Rail cannot have a longer walk access than bus – unless, as stated above, the engineer or planner responsible for the model has data to support it." (VHB, 2007, p. 22)

When the Version 2.2 Travel Model was the adopted regional travel model, many consultants, when conducting FTA New Starts work, would apply a post-process mode choice model after the four-step travel model. This practice led to an inconsistency between the two mode-choice models used in these analyses, since the one in the speed feedback loop had only five choices and the one applied as a post process had 15 choices. VHB (2007) recommended that TPB staff correct this inconsistency by incorporating the more complex (15-choice) mode choice model within the speed feedback loop (Recommendation 20). TPB staff concurred with this recommendation and acted upon it. The Version 2.3 Travel Model now features a 15-choice, nested-logit mode choice model as part of the four-step model (i.e., not simply applied as a post process). Of course, since the 15-choice, nested-logit mode choice model is now in the speed feedback loop, this will violate the FTA's rule of using a fixed trip table for New Start analyses. So, consultants will still need to run a final application of the nested-logit mode choice model that is outside the speed feedback loop, but, now, this model will be consistent with the mode choice model that is within the speed feedback loop.

CS suggested in two different reports (2009, 2010) that TPB staff should consider using a bus-speed model to connect transit travel times to the underlying highway link travel times (Recommendation 21). Beyond the simple bus-speed degradation factors used in the Version 2.3 Travel Model, TPB staff has not yet acted upon this recommendation, but recent advances in GIS-aided transit network development, such as GTFS data for local transit routes, should allow for detailed bus speed relationships to be studied in the near future.

On the subject of transit fare representation in the travel model, CS (2010) recommended that TPB staff should consider representing transit fares by provider and mode, which appeared to be the state of the practice, based on a sample of the largest MPOs in the U.S. (Recommendation 22). At this time, TPB staff has not yet acted upon this recommendation.

On the subject of representing fare subsides, such as the SmartBenefits program, in the travel model, CS (2010) noted some of the weakness with the approach that had been tried by TPB staff. Nonetheless, CS (2010) stated, “consideration of other methods of incorporating the fare subsidy which could be applied to all transit modes is encouraged”(Recommendation 23). At this point, however, TPB staff has not made any further attempt to include fare subsidies in the travel model.

Given the lack of national standards for transit validation, CS (2011) suggested that TPB may want to consider using the Florida Department of Transportation (FDOT) standards for validating transit model results (Recommendation 24). TPB staff has not yet used these standards.

CS (2011) stated that “one area of focus on improving the transit assignment might be to improve the drive access coding,” adding that “one potential improvement might be to explore the features available in Citilabs PT product for coding transit drive access” (Recommendation 25). Regarding the first point, TPB staff points out that for its transit assignment validation work, CS (2011) used the Version 2.3.9 Travel Model. One of the bugs discovered in this release (and fixed in Version 2.3.16) was that the model was not building paths between TAZs and PNR lots. When the auto-access-to-transit program (AutoAcc4.s) found a case where no path was built, it created auto-access links with a default value for the distance of 0.5 miles. Thus, auto access links that should have had a coded, over-the-road distance of anywhere from zero to 15 miles, all had distances of 0.5 miles. The effect of this would have been to overestimate auto-access to transit. After this bug was fixed in the travel model, the mode choice model was re-calibrated (Version 2.3.17). Regarding the second point, TPB staff is working with its current consultant, AECOM, to switch from TRNBUILD to PT.

CS (2011) noted that COG’s cordon count data is very useful for transit validation work and recommended that COG continue with three cordon counts: 1) the central employment core, 2) the Beltway, and 3) an area representing an “outer beltway” (Recommendation 26). TPB staff agrees that the Metro Employment Core Cordon Counts have been useful for transit and HOV validation work and plans to conduct the next Core Cordon Count in spring 2013. The time and effort to conduct these cordon counts is substantial. The 2009 Cordon Count could not be fully completed within the time and budget available. Also, these counts are currently only single-day counts. TPB staff is examining ways of reducing costs and improving the timeliness of these counts. Two options that are being considered are 1) Focusing these counts on just the major commuter routes and conducting multi-day counts, and 2) applying sampling methods to the counting procedures to obtain vehicle occupancies. Also, enhanced use of new technology, especially for counting transit passengers at various screenlines is also being pursued.

On the issue of improving transit assignment, CS (2011) made the following recommendations (summarized in this report as Recommendation 27):

> *Obtain additional boarding or other validation data for Metrorail, commuter rail, and all bus services;*

> *Evaluate the ability to include drive access trips in the highway assignment and feedback the travel impedance to the supplemental access link files; and*
>
> *Evaluate the potential path building advantages for different travel demand forecasting software tools, including Citilabs PT. (p. 1-21)*

TPB staff agrees with the first part of the recommendation and will plan to work with the staffs of WMATA and the other transit providers to obtain the best boarding data it can. Some of this data is currently being added, by TPB staff, to COG Regional Transportation Data Clearinghouse (RTDC). Regarding the second part of the recommendation (including drive access trips), TPB staff appreciates this recommendation, but we have not yet acted upon it, since it is not considered a high priority item. Regarding the third part of the recommendation, TPB is working on this issue with its current task-order consultant, AECOM, as part of project spanning FY 2012 and FY 2013 to upgrade from the TRNBUILD transit path builder to the PT transit path builder.

CS (2011) recommended that TPB make the transition from TRNBUILD to PT and found that "a step-by-step migration to PT seems to be the most reasonable path" (Recommendation 28). As stated earlier, TPB staff is currently working with its task-order consultant to make this transition.

2.2.5 Time-of-day/peak spreading

2.2.5.1 Summary of consultant findings and recommendations

Recommendation 29

On the subject of developing a peak spreading model, VHB (2007) suggested that TPB staff could consider feeding back congested network conditions to pre-assignment and adjusting the time-of-day factors until all volume-to-capacity (V/C) ratios were below an accepted threshold (p. 76).

Recommendation 30

VHB (2007) also recommended "that the regional model approach identified in Task 5 [Research Techniques for Peak Spreading Analysis] be tested initially as this would require much less effort and results could be presented several months after project initiation" (p. 11). This approach, detailed on page 76 and developed by VHB, was a time-of-day model that involves using a series of trip tables representing peak periods of differing durations (e.g., 2-hour, 3-hour, 4-hour). VHB indicated that the benefit of this time-of-day model was that "the time-of-day factors [would be] based on actual count data which includes behavior not revealed in household and transit surveys, and the time-of-day factor is effectively disaggregated to the interchange level which would capture the variances in peaking patterns in a region the size of TPB" (p. 78).

Finding 18

In 2008, TPB staff had asked the consultant to analyze peak spreading conditions in the Metropolitan Washington region. VHB (2008a) found that it could not conduct peak spreading analyses in Virginia, since the Virginia Department of Transportation (VDOT) did not release hourly count data (it released only daily traffic counts). By contrast, VHB was able to obtain hourly traffic count data from the Maryland State Highway Administration (MD SHA), so VHB obtained this data for the following counties in Maryland: Montgomery, Prince George's, Frederick, Howard, and Anne Arundel (p. 2). VHB's analysis showed (2008a) that "the major freeway radial corridors in the Maryland areas of the TPB region behave[d] in a similar manner in terms of peaking, peak spreading, and directional flows; however, the Beltway behave[d] differently" (p. 2).

Recommendation 31

VHB (2008a) indicated that once hourly traffic count data becomes available for other sites (i.e., those not addressed in the VHB report), "regression tests should also be performed on major arterial radial corridors to further test their behavior against nearby, parallel freeway facilities" (p. 2). VHB added that "further analysis is needed to determine if the geographic extent of peak spreading is truly regional, is confined to a handful of major facilities, or symptomatic of specific regional travel markets" (p. 2).

Finding 19

On the subject of time-of-day models, CS (2009) found that "one of the key issues of primary importance to improving existing travel models for pricing studies is the lack of temporal detail and behavioral choice for time-of-day models" (p. 2-20). CS added that its recommended approach for improving four-step travel models used for pricing studies is focused on "estimating and applying time-of-day choice models in existing four-step models" (p. 2-20).

Recommendation 32

CS (2009) stated:

> *Cambridge Systematics recognizes that there are traffic count data limitations in the TPB modeled region that may make immediate development and validation of time-of-day choice models difficult, but addressing these limitations should be among the near-term regional data improvement priorities of its member governments. Enhanced time-of-day count data could support not only the advanced modeling but also inform many other types of analyses and provide much richer data for validation. Prioritization of the development of a time-of-day choice model for the existing four-step model depends somewhat on the anticipated timing for development of an activity-based model framework because the time-of-day choice model would need to be replaced as part of the migration to an activity-based model framework and the resources required for its development might then have been better expended in other areas. In addition, there are fewer success stories of implementation of time-of-day choice models within the four-step model framework as compared with success stories of destination choice model implementation within such a framework. (p. 2-23)*

Recommendation 33

In terms of long-term enhancements to the TPB modeling process, CS (2009) recommended that TPB staff consider developing a time-of-day choice model (p. 4-13).

Finding 20

Building on its recommendation from its previous report (2009, mentioned above), in its 2010 report, CS (2010) described the benefits of using a time-of-day choice model, including that fact that it will help address peak spreading and better forecast changes in time of day splits in the future (pp. 3-2 to 3-4).

Recommendation 34

On the subject of time-of-day periods, CS (2010) recommended the following:

> *As part of the development of a time of day choice model for TPB, it is recommended that the daily trip tables be divided into at least four or preferably five large time periods. This would involve breaking the off-peak period into midday and night periods; an evening time period could be included as well. (p. 3-5)*

Recommendation 35

In the case that the TPB does develop a time-of-day choice model, CS (2010) warned that TPB staff and other users of the model should not use the outputs of the regional time-of-day model for small area analysis because these would likely be inaccurate at the level of individual facilities (p. 3-7).

2.2.5.2 Discussion and TPB staff response

A time-of-day model is used to represent the spread of trips across different times of the day. Time-of-day models are usually applied between trip distribution and traffic assignment. The two primary ways to implement time-of-day models are fixed factors (often from a household travel survey) and choice models. Fixed factors are the more common method and the method used by TPB. Choice models have the benefit that they can represent peak spreading, which is either the shifting of trips from one part of the peak period to another part of the peak period, or shifting out of the peak period entirely. The Version 2.2 Travel Model used three time-of-day periods for traffic assignment with the following breakpoints:

- AM peak period, 6:00 AM to 9:00 AM: 3 hours
- PM peak period, 4:00 PM to 7:00 PM: 3 hours
- Off-peak period, all remaining hours: 18 hours

The Version 2.3 Travel Model uses four time-of-day periods for traffic assignment:

- AM peak period, 6:00 AM to 9:00 AM: 3 hours
- Midday, 9:00 AM to 3:00 PM: 6 hours
- PM peak period, 3:00 PM to 7:00 PM: 4 hours
- Nighttime/early morning, 7:00 PM to 6:00 AM: 11 hours

The decision to make this change also accounted for the operating times of various HOV facilities in the region (Moran, 2010). More details about the Version 2.3 time-of-day model can be found in Chapter 7 of the calibration report (Milone et al., 2012b).

TPB staff is not in agreement with Recommendation 29 (adjusting the time of day model based on V/C ratio levels) for several reasons. An excessive level of congestion may elicit several responses: A change of mode, a change of path, and/or a change of departure time. A mechanical process for shifting travel by only time of day would presumably need to be part of the feedback process, and would likely require a recalibration of the model. It is not clear to staff what V/C levels would be appropriate thresholds for modifying the time-of-day factors, in particular for forecast year simulations. Ultimately, a behavioral method, rather than a mechanical, would be preferred. However modeling a behavioral response is a complicated matter.

Regarding Recommendation 30 (testing a regional model that involves using a series of trip tables representing peak periods of differing durations), this recommendation has not yet been acted on by TPB staff, though, in 2010, TPB staff did calculate time-of-day factors from reported trip start/stop times (trips "in-motion") from the 1994 and 2007/2008 household travel surveys (Milone, 2010b).

Regarding Recommendation 31 on performing regression tests and conducting further analysis, this recommendation has not yet been acted on by TPB staff. This type of analysis is not achievable in the short term given the limited sample of hourly counts that is available.

In Recommendation 32, CS (2009) recommended that TPB, and its member governments, should be working to get better time-of-day traffic count data. TPB staff agrees with this sentiment and continues to work with state and local agencies on this matter. Also, as part of Recommendation 32, CS recommended that one consider foregoing the development of a time-of-day model for use with the trip-based travel model, if one is planning to implement an ABM in the near future. Since TPB staff does not have immediate plans for developing an ABM, this would increase the benefit of developing a time-of-day choice model, which was the subject of Recommendation 33 and Finding 20. TPB staff has not yet acted on Recommendation 33.

In Recommendation 34, CS (2010) recommended that TPB staff divide its trip tables into "at least four or preferably five large time periods," including breaking the off-peak period into midday and night periods. TPB staff has followed this recommendation. As noted above, TPB staff increased the number of time-of-day periods from three (in Version 2.2) to four.

Recommendation 35 does not currently apply, since the TPB has not yet developed a time-of-day choice model.

2.2.6 Traffic assignment

This section of the report discusses traffic assignment. Its main focus is on the macroscopic-level, static traffic assignment that is used by the Version 2.3 Travel Model and most regional travel models in the U.S. Nonetheless, the section also covers mesoscopic-level and microscopic-level traffic assignment techniques, such as dynamic traffic assignment (DTA) and traffic microsimulation. In general, for a macroscopic, static traffic assignment, it is assumed that the traffic flow exists in a steady-state along the entire path between two zones for the entire time period of the assignment (e.g., the peak period). By contrast, a mesoscopic assignment model generally tracks the flow of platoons of vehicles and the demand varies within the assignment period. Lastly, a microscopic traffic assignment model tracks individual vehicles. It should be noted that the demarcation line between mesoscopic and microscopic traffic assignment models is a fluid one, since some assignment techniques involve elements of both mesoscopic and microscopic assignment.

2.2.6.1 Summary of consultant findings and recommendations

Recommendation 36

According to VHB (2006), when the TPB staff evaluates traffic microsimulation software, it should not limit its search to only Citilabs products, such as Cube Dynasim. Products from other vendors, such as VISSIM and Paramics, should also be investigated. Also, it is recommended that TPB staff "evaluate what kind of a model and what kind of applications of a simulation model will best meet its needs" (p. 9).

Finding 21

VHB (2006) found that "For almost all agencies, highway traffic is assigned using an equilibrium method… Few agencies were able to report the number of iterations required to achieve closure in equilibrium assignment or the closure tolerance used. Many reported that they used the default values of their software packages. Few agencies had examined equilibrium assignments to see if the results were stable and none of those sampled reported problems such as those noted in studies conducted for FTA" (p. 35).

Finding 22

Citing work done by Allen and Schmitt (2005), Goldfarb and Spielberg (2005), and the FTA (2006c), VHB (2006) reported that, "It has been shown that in a highly congested network hundreds of iterations are required until a true state of equilibrium is reached" (p. 36).

Recommendation 37

According to VHB (2006), TPB staff should consider incremental assignment instead of user equilibrium, if more stable assignment results are desirable. TPB staff should choose between the stability provided by the incremental assignment and the improved accuracy of the user equilibrium assignment (p. 47).

Recommendation 38

According to VHB (2006):

> *While new methods of reaching convergence with equilibrium algorithms are being developed for macro-level assignments, the move to more meso-level and micro-level traffic assignments is the future. This is true even within the framework of the region travel demand forecast model. TPB should allocate time and resources to examining these evolving methods and how they can be applied. (p. 47)*

Recommendation 39

According to VHB (2007), "The simulation and/or DTA software selected and implemented by TPB should reflect existing staff and consultant capabilities as well as provide new and/or better solutions to the most pressing modeling questions that TPB faces" (p. 38).

Finding 23

According to VHB (2007):

> *Peak spreading and managed lanes are two areas where the existing regional model has limitations, and DTA would theoretically provide better answers because of its ability to explicitly*

> *model time as well as capture impacts of traffic control and queuing, which all relate to peak spreading. Likewise, Express Toll Lanes (ETL) require the ability to model congestion over time, which would require a DTA model to do this type of analysis at the regional level or a traffic simulation model with DTA capability to evaluate these types of strategies at the corridor level. (p. 38)*

Finding 24

When VHB (2007) discussed the pros and cons of using traffic microsimulation versus mesoscopic DTA, they noted that "the more appropriate tool for regional planning purposes, particularly in the context of HOT/Managed Lanes analysis and regional ITS planning would be a mesoscopic DTA model which would explicitly model peak period demand over time and illustrate the queuing affects associated with HOT lanes and other roadway elements" (p. 38).

Finding 25

VHB (2007) states that, "given that COG/TPB staff uses Cube for regional planning efforts, Cube Avenue would be the most practical mesoscopic DTA model to use for HOT/Managed lanes analysis" (p. 38).

Recommendation 40

VHB (2007) stated that "TPB may want to pursue a pilot study where DTA is used as the fourth step of the modeling process and conduct a screenline and corridor level validation to determine if the DTA assignment is indeed an improvement over the existing static equilibrium process. If the results are positive based on this test study, then it is recommended that TPB test DTA in the context of ETL and HOT lanes as well as peak spreading" (p. 38).

Recommendation 41

According to VHB (2007), TPB staff should also test and implement new advanced traffic assignment algorithms as they become available in Cube (p. 66). In 2007, VHB believed that the upcoming release of Cube (version 5.0) would include origin-based assignment (p. 57).

Recommendation 42

According to VHB (2007), "Given TPB's commitment to the Citilabs modeling platform, the next logical step is to pursue whatever run-time and convergence gains can be achieved under the TP+/Cube environment. In order to accomplish this, TPB must convert the v2.2 model to a form that can be used under Cube Cluster" (p. 65). According to VHB (2007), TPB staff should modify the production-use travel demand forecasting model so that it makes use of Cube Cluster (p. 66).

Recommendation 43

VHB (2007) also suggested TPB investigate the possibility of implementing Dynamic Traffic Assignment (DTA) (p. 78).

Recommendation 44

On the subject of updating the traffic assignment models, CS (2009) stated that the traffic assignment models "should be recalibrated to match the latest traffic count data along screenlines, major corridors, and against the HPMS-based VMT estimates" (p. 2-25).

Recommendation 45

CS (2009) also stated, "In order to analyze new policies such as travel demand management strategies and variable pricing, trip purpose and income group stratifications are more desirable to be incorporated into the multiclass assignment procedures" (p. 2-25).

Recommendation 46

On the issue of volume-delay functions, CS (2009) also stated, "It is recommended that different parameters be estimated and explored for different facility types. Other functions such as conical and Akcelik functions should be also evaluated to see if they improve the assignment model" (p. 2-25).

Recommendation 47

In traffic assignment, the Version 2.2 Travel Model makes use of user equilibrium, or Wardrop's equilibrium, which consists of a series of all-or-nothing assignments that are run until a sufficiently converged solution is obtained. A typical convergence threshold metric is the gap or the relative gap. However, instead of using the gap or relative gap, the Version 2.2 traffic assignment process was set to simply run a fixed number of user equilibrium iterations (in this case, 60), at which point it was assumed that the traffic assignment solution was sufficiently converged. CS (2009) recommended that TPB staff move away from using a fixed number of UE iterations and toward using a standard convergence metric, such as the relative gap (p. 5-7). This is also re-stated later in the report (p. 5-12).

Recommendation 48

CS (2009) recommended that TPB staff introduce more time periods, so that congestion on some links can be reduced and trip tables could be made smaller for each assignment (p. 5-9).

Recommendation 49

CS (2009) recommended that TPB staff consider investing in enhanced computing power (p. 5-12). This includes possibly using distributed processing, e.g., Cube Cluster (p. 5-9).

Recommendation 50

CS (2009) recommended that TPB staff follow the developments in path-based and origin-based transit assignment algorithms (p. 5-12).

Finding 26

On the subject of using newer traffic assignment algorithms, such as path-based or origin-based approaches, although some have argued that one cannot perform select-link analyses using the newer methods, CS (2010) notes that "the methods implemented by both Caliper and INRO maintain full route flow capabilities, including select link, select zone, and subarea analysis" (p. 1-2).

Recommendation 51

In the past, CS (2009) had mentioned testing a hybrid assignment approach:

> *Such an approach might employ an equilibrium assignment with strong convergence criteria at both the beginning and end of the feedback loop process, but in the middle iterations employ a different assignment method (such as an incremental assignment informed by the initial equilibrium assignment) or a lesser convergence criteria for equilibrium assignment. (p. 5-11)*

In its 2010 report, however, CS stated

> *At the request of TPB, further discussion of the hybrid assignment approach is provided in Section 4. This approach has not to our knowledge been implemented at other MPOs or planning agencies, but is based on the practice of using incremental assignment at the Baltimore Metropolitan Council (BMC). CS does not recommend further exploration of the approach for TPB due in part to the recent performance advances in equilibrium assignment approaches. (p. 1-2)*

CS (2010) re-iterated this point later in its 2010 report:

> *This approach was originally postulated as a stop-gap method to be considered as a means for reducing the model run time. However, the theoretical issues with incremental assignment coupled with the recently enhanced ability to reduce the run time of equilibrium assignment methods with a high level of convergence through hardware, software, and algorithm advances suggests that no further consideration should be given to the hybrid assignment approach. Better options exist for achieving the goal of shortening the model run time and improving the accuracy of the assignment. (p. 1-20)*

Finding 27

On the subject of queuing delay functions (QDFs), which TPB staff used in the Version 2.2 Travel Model, but no longer uses in the Version 2.3 Travel Model, CS (2010) noted that the QDF may not be the most accurate way to capture the desired network constraints (p. 3-19).

Recommendation 52

Continuing on the subject of QDFs, CS (2010) concluded by suggesting that TPB staff may want to consider re-calibrating its conical function or switching to an Akçelik form or use both, based on facility type (p. 3-19).

2.2.6.2 Discussion and TPB staff response

VHB (2006) recommended that, when TPB staff evaluates traffic microsimulation software, it should not limit its search to only Citilabs products, such as Cube Dynasim (Recommendation 36). This recommendation was not followed by TPB staff in the past, perhaps because it came after staff had already purchased Cube Dynasim (in 2005) and decided that it was too difficult for a regional planning agency to be conducting traffic microsimulation studies (based on work done in 2006 and 2007). However, if TPB staff chooses to re-test traffic microsimulation, or DTA, in the future, TPB staff will have the opportunity to follow this recommendation.

VHB (2006) recommended that TPB staff consider the use of incremental traffic assignment (instead of user equilibrium traffic assignment), if more stable assignment results were desirable (Recommendation 37). In a similar vein, CS (2009) made a related recommendation (Recommendation 51) that TPB staff consider a hybrid assignment technique that could involve applying an incremental assignment. However, in its report the next year, CS (2010) indicated that TPB staff should no longer consider testing this hybrid assignment approach. TPB staff concurs with the idea that we should not be going back to using or testing incremental assignment.

VHB (2006) recommended that TPB staff allocate time and resources to examining new traffic assignment techniques that operate at the mesoscopic or microscopic level (Recommendation 38). At the current time, TPB staff does not think that traffic microsimulation has a role in regional travel demand forecasting work. However, staff does believe that mesoscopic traffic assignment techniques, such as DTA, are advancing to the stage where they may be practical at the regional level in the near future (See, for example, Hicks, 2008, which describes work done in the Atlanta region).

According to VHB (2007), "The simulation and/or DTA software selected and implemented by TPB should reflect existing staff and consultant capabilities as well as provide new and/or better solutions to the most pressing modeling questions that TPB faces" (Recommendation 39). VHB (2007) also stated that "TPB may want to pursue a pilot study where DTA is used as the fourth step of the modeling process and conduct a screenline and corridor level validation to determine if the DTA assignment is indeed an improvement over the existing static equilibrium process"(Recommendation 40). Other than the informal testing that TPB staff conducted in 2006/2007 using Cube DTA (now Cube Avenue), TPB staff has not acted on this recommendation. On the subject of validating DTA models, Donnelly, Erhardt, Moeckel, and Davidson noted that "The paucity of traffic counts in most urban areas, and especially at 15-, 30-, or 60-min intervals, is a significant barrier to definitive assessment of these models" (Donnelly, Erhardt, Moeckel, & Davidson, 2010, p. 17).

VHB (2007) recommended that TPB staff begin testing some of the new traffic assignment algorithms that were being introduced in Cube Voyager (Recommendation 41). TPB staff has followed this recommendation. TPB staff tested the new link-based algorithms (conjugate Frank-Wolfe and bi-conjugate Frank-Wolfe) and the new path-based algorithm (gradient projection algorithm). Unfortunately, the gradient projection algorithm was much slower than the existing Frank-Wolfe algorithm, so staff discontinued testing it. TPB staff, did, however, end up using the new bi-conjugate Frank-Wolfe as part of the production-use Version 2.3 Travel Model.

VHB (2007) recommended that TPB staff begin using Cube Cluster to shorten model run times (Recommendation 42). TPB staff has followed this recommendation. The Version 2.3 Travel Model uses Cube Cluster in a number of steps (Milone et al., 2012a, pp. 1–10 to 1–11) and has worked with a consultant to consider "parallelizing" other model steps to further shorten model run times.

Regarding Recommendation 43 ("suggested TPB investigate the possibility of implementing Dynamic Traffic Assignment"), in late 2005, TPB staff purchased Citilabs' software products for DTA ("Cube DTA," now called Cube Avenue) and traffic microsimulation ("Cube Dynasim"). In May and June of 2006, DTP staff received some training in these two software packages (Milone, Humeida, Moran, & Seifu, 2007, p. 5-1). In 2006 and 2007, DPT staff worked with the software, but found two major obstacles to its continued use. First, the software had a number of bugs, which Citilabs was quick to fix, but which ultimately slowed down progress with testing the software. Second, it became apparent that DTA and traffic microsimulation software needed too much data to be of practical use for the regional studies normally conducted by TPB staff. Later, since staff was no longer using the software, TPB staff abandoned interest in Cube Avenue and Cube Dynasim.

CS (2009) recommended that the traffic assignment models "should be recalibrated to match the latest traffic count data along screenlines, major corridors, and against the HPMS-based VMT estimates" (Recommendation 44). Staff agrees with this recommendation. Staff consulted HPMS VMT figures and traffic counts to assess traffic assignment performance in the Version 2.3 Travel Model (for the base year 2007). This analysis included county-level VMT checks, screenline crossing checks, and checks of traffic counts by time period (Milone et al., 2012b, chap. 9). The analysis was hindered somewhat by an incomplete traffic count sample on the regional screenlines and a minimal count sample by time period. Staff is currently working to address these challenges.

CS (2009) also stated that it would be desirable to include trip purpose and income group stratifications in the multiclass traffic assignment procedures (Recommendation 45). Although the current Version 2.3 Travel Model does include multi-class assignment with six user classes, TPB staff has not yet brought trip purpose and/or income-group stratification into the highway assignment for the following reasons. First, such a change would dramatically increase model run times and the size of model outputs. Current model run times are about 30 hours per alternative and the current size of model outputs is over 20 GB per alternative. Second, the Cube Voyager software has a limit on the number of user classes (called "volume sets" in the software documentation) that can be used. The current limit is 20. We are already using six user classes (Milone et al., 2012b, p. 8-7). If the first three of these (SOV, HOV2, and HOV3+) were to be segmented by trip purpose (5), that would result in 18 user classes (3 x 5 + 3). If one were to segment by both trip purpose (5) and household income (4), the number of user classes would go beyond the maximum number allowable (and the model would likely take several days to run).

On the subject of volume-delay functions, CS (2009) recommended that TPB staff test "different parameters…for different facility types" and try "other functions such as conical and Akcelik functions" to see if they "improve the assignment model" (Recommendation 46). TPB staff performed a number of tests with different VDFs in the fall of 2010, including the Akçelik function (Milone & Moran, 2010). However, none of these tests resulted in finding a better set of VDFs than the existing conical VDFs, so the original conical-function VDFs were retained for the Version 2.3 Travel Model.

CS (2009) recommended that TPB staff move away from using a fixed number of user equilibrium iterations in traffic assignment (60 in the Ver. 2.2 model) and move toward using a standard convergence metric, such as the relative gap (Recommendation 47). TPB staff agrees with this recommendation and updated the travel model to comply with this recommendation. As of build 9 of the Version 2.3 Travel Model (Feb. 2011), the highway assignment script was modified to have the following convergence threshold: a relative gap of 10^{-3} or 200 user equilibrium iterations (whichever condition occurs first). The UE threshold of 200 iterations is used as a stop-gap measure to make sure that the model does not run for too long. For build 18 of the Version 2.3 Travel Model the threshold condition was updated to the following: a relative gap of 10^{-3} or <u>300</u> user equilibrium iterations (whichever condition occurs first). For project planning studies, when the relative gap threshold is lowered to 10^{-4} or 10^{-5}, the UE iteration threshold should also be relaxed. The maximum value allowed by the software is 999 iterations.

CS (2009) recommended that TPB staff introduce more time periods (Recommendation 48). As noted in the response to Recommendation 34, TPB staff has followed this recommendation: TPB staff increased the number of time-of-day periods from three (in Version 2.2) to four. CS (2009) also recommended that TPB staff invest in more computing power and begin using distributed processing (Recommendation 49). TPB staff concurred with this recommendation. It bought two new travel model servers in 2011: one for the models development team and one for the models application team in COG's Dept. of Transportation Planning (DTP). As stated earlier, the Version 2.3 Travel Model now includes Cube Cluster.

CS (2009) recommended that TPB staff follow the developments in path-based and origin-based transit assignment algorithms (Recommendation 50). TPB staff concurs with this recommendation. Staff has followed developments by designating this as a research topic for the consultant-assisted scanning project and by attending recent conferences that included sessions on these topics, such as:

- Transportation Research Board 91st Annual Meeting, January 22-26, 2012, Washington, D.C.
- 13th TRB National Transportation Planning Applications Conference, May 8-12, 2011,Reno, Nevada
- Transportation Research Board 90th Annual Meeting, January 23-27, 2011, Washington, D.C.
- 3rd Conference on Innovations in Travel Modeling, May 10-12, 2010, Tempe, Arizona
- 12th TRB National Transportation Planning Applications Conference, May 17-21, 2009, Houston, Texas
- Transportation Research Board 88th Annual Meeting, January 11-15, 2009

On the subject of queuing delay functions (QDFs), which TPB staff used in the Version 2.2 Travel Model, but no longer uses in the Version 2.3 Travel Model, CS (2010) suggested that TPB staff may want to consider re-calibrating its conical function or switching to an Akçelik form or use both, based on facility type (Recommendation 52). TPB staff did, in fact, test out Akcelick VDFs in 2010, but found that they did not improve model performance, either in terms of convergence or matching observed speeds (though this work was not documented).

2.2.7 Speed feedback in the travel model

2.2.7.1 Summary of consultant findings and recommendations

See also Section 2.2.3 ("Mode choice"), Section 2.2.4 ("Modeling transit"), and Recommendation 88.

Finding 28

TPB staff had requested that the consultant review the use of feedback loops in the travel model coupled with nested-logit mode choice models. VHB (2007) stated that the use of a nested logit mode choice model was state of the practice (pp. 113, 114), indicating that "nearly 75% of large MPOs (peers to TPB) use a nested logit mode choice model for home-based work trips and nearly 60% use nested logit for other trip purposes" (p. 114). Similarly, VHB also stated that the use of a speed feedback loop was also state of the practice (p. 114), indicating that "over 80% of large MPOs feedback highway and transit travel times to trip distribution and mode choice." What was less clear was the percentage of large MPOs that use both speed feedback and nested-logit mode choice models. VHB (2007) also discussed the differing requirements in this area. For example, speed feedback is required by law for performing the air quality conformity analysis (p. 121), but FTA New Starts work requires fixed trip tables, i.e., the removal of speed feedback loops (p. 121).

Recommendation 53

On the subject of how many speed feedback loops or iterations to use in model application, VHB (2007) stated that "further research may be needed to determine an optimal number of feedback iterations to be used with the TPB model" (p. 122).

Recommendation 54

CS (2009) recommended that TPB "apply the method of successive averaging (MSA) procedure for speed feedback but still assign a final trip table to the highway network" (p. 5-12).

Recommendation 55

CS (2009) recommended that TPB "determine a criterion for the number of feedback loops," adding that "it is accepted as a state-of-the-practice technique for this procedure to use a heuristic approach" (p. 5-12).

Recommendation 56

Although the relative gap measure is becoming a standard measure of traffic assignment convergence, CS (2010) found that there is no such standard measure of convergence for the speed feedback loop (p. 1-20). CS mentioned two possible metrics that could be used. The first is used by the Denver Regional Council of Governments (DRCOG), the only agency that CS could find that is using a convergence measure for the speed feedback loop. This metric is "achieving one percent or less of links with a greater than 10 percent change in link volume" (p. 1-20). The second possible candidate metric would be the one mentioned in a presentation made by Slavin (2007), the "skim matrix root mean square error" (slide 11).

2.2.7.2 Discussion and TPB staff response

On the subject of how many speed feedback loops or iterations to use in model application, VHB (2007) suggested that TPB staff may want to conduct further research "to determine an optimal number of feedback iterations" (Recommendation 53). This recommendation was made at a time when the Version 2.2 Travel Model was the production travel model.

Both the Version 2.2 and 2.3 travel models include speed feedback loops. The AM and off-peak SOV restrained times resulting from the traffic assignment step are fed back into trip generation (via transit accessibility), trip distribution, and mode choice. In the Version 2.2 Travel Model, the four-step process was executed a total of seven times. The first of these traffic assignments is known as the "pump prime" assignment, since it primes the pump, or gets the process started. The pump prime assignment uses "starting" link speeds (based on a lookup table) and exogenous mode choice percentages (i.e., the mode choice model is not run). In Version 2.2, each traffic assignment used a user equilibrium (UE) approach with a fixed number of UE iterations (60). By contrast, in the Version 2.3 Travel Model, the four-step process is executed a total of five times (one pump-prime and four standard executions), and the traffic assignment closure rule is now a relative gap of 10^{-3} or 300 UE iterations, whichever comes first (typically the relative gap threshold). This increase in the number of UE iterations and decrease in the number of speed feedback iterations was based on testing done by TPB staff, but is not formally documented.

Both the Version 2.2 and 2.3 travel models use a link-level method of successive averaging (MSA) process, that is applied after each highway assignment to ensure that highway volumes (and hence speeds) will stabilize in the speed feedback process. The MSA averaging is performed on the basis of total (non-segmented) link volumes, and is performed individually for each time period.

CS (2009) recommended that TPB apply the method of successive averaging (MSA) procedure for speed feedback, "but still assign a final trip table to the highway network" (Recommendation 54). TPB staff has adopted this recommendation and the Version 2.3 Travel model now does a final assignment of the trip table that is not volume averaged.

CS (2009) recommended that TPB "determine a criterion for the number of feedback loops," adding that "it is accepted as a state-of-the-practice technique for this procedure to use a heuristic approach" (Recommendation 55). Although the relative gap measure is becoming a standard measure of traffic assignment convergence, CS (2010) found that there is no such standard measure of convergence for the speed feedback loop, though CS presented two possible metrics that could be used (Recommendation 56). TPB staff has not yet acted on these two recommendations. Staff maintains that a starting point is to conduct a more thorough assessment of convergence of the Version 2.3 model (as it is currently being executed today). The assessment would include a base year and forecast year scenario. The assessment would focus on convergence of both skim matrices and link level volumes.

2.2.8 Modeling HOT/managed lanes

See also Section 2.2.6 ("Traffic assignment").

2.2.8.1 Summary of consultant findings and recommendations

Finding 29

According to VHB (2006), "Most of the available research recommends moving toward tour-based models as the best way to model managed lanes; however, that is not a viable option for TPB at this time" (p. 19).

Finding 30

"For trip-based models, representation of toll trips as discrete choices in a NL mode choice model structure appears to be the best option, but the research is not conclusive. The primary obstacle to including managed lane tolls in mode choice is the lack of observed data to use for calibration and validation" (p. 19).

Finding 31

"TPB is currently employing an approach similar to Atlanta in modeling managed lanes," i.e., a post processor to optimize tolls, "and VHB feels this is the best strategy for TPB at this time" (p. 19).

Recommendation 57

VHB (2006) recommended that TPB "consider following Salt Lake City's method of using the AM peak period for developing toll forecasts, and consider Seattle's approach of further subdividing the peak period to increase the variability of dynamic tolling in the model" (p. 19).

Recommendation 58

On the subject of conducting a before-and-after study on the effect of HOT lanes on HOV traffic, CS (2009) recommended the following:

> *The next step in building an evaluation framework would be to begin the process of identifying a set of evaluation goals, and within each evaluation goal, a set of hypotheses to be tested. Measures of effectiveness required to test for the hypotheses then could be identified leading to a list of data elements required for the evaluation. A high priority should be placed on identifying data elements requiring advanced automated data collection capabilities to allow any regional limitations in this area to be addressed sooner rather than later. Data collection then should proceed across the required dimensions to permit the evaluation of the hypotheses at the midpoint and conclusion of the HOT network expansion. (pp. 3-10 to 3-11)*

Recommendation 59

VDOT's stated policy on new HOT lanes has been that the paying HOT-lane vehicles should not degrade the operations of the existing HOV traffic on the facility. To model this policy, TPB staff developed a modeling technique, in the Version 2.2 Travel Model, known as the "HOV3+ skims substitution" technique (Milone, Humeida, Moran, & Seifu, 2008, p. 1-10). This technique requires two runs of the travel model: a base run and a final run. For this reason, the technique is also referred to as the "multi-run assignment" process to deal with HOT-lane modeling.[3] Regarding the HOV3+ skims substitution technique, for the "base run," all Virginia HOT lanes are re-coded as HOV3+ lanes, which has the effect of simulating the unimpeded flow of HOV traffic on the HOT lanes. The resulting HOV3+ skims, corresponding to each speed-feedback iteration, are preserved for later use. The travel model is then executed in a second, "final" run in which all the Virginia HOT lanes are allowed to function as true HOT lanes (not the HOV3+ lanes used in the base run). See the Version 2.2 Travel Model documentation for details (Milone et al., 2008, p. 1-11).

CS (2010) has proposed "combining the two runs into a one-run process to save model run time and to provide more consistency in mode choice modeling" (p. 3-20). On the consistency issue, CS argued that, under the current multi-run assignment procedure, since HOV skims are obtained on a network that does not allow non-HOV vehicles to use HOT facilities, this has both an intended and unintended consequence. The intended consequence is that it ensures free-flow traffic conditions on the HOT lanes, in conformance with VDOT's operational policy. The unintended consequence is that the "accuracy of the HOV time skims on the non-highway links (especially arterials that load onto the highways) [is] likely affected by the fact that fewer vehicles will be using the tolled highway paths," (p. 3-20) which results in

[3] Note that this is different from another technique, known as the "two-step assignment," that is designed to improve the assignment of HOV/HOT traffic on the Capital Beltway in Virginia and I-395/Shirley Highway (For more details, see Milone & Moran, 2008, pp. 6–9; or Park, 2008).

"different time skims for non-freeway links being used in the final assignment for the HOV and HOT modes" (p. 3-20).

CS recommended eliminating the multi-run assignment and replacing it with just one application of the travel model. In order to do this, CS stated that "the tolls must be adjusted to achieve free flow traffic conditions that are consistent with the regional operational policy" (p. 3-20). CS further recommended that "the toll rate continue to be set based on link capacity rather than speed, as is done in the Version 2.2 model," noting that link speeds are typically not well represented in travel models (p. 3-20).

CS (2010) performed an actual test of its proposal, using the Version 2.2 Travel Model (Ver. 2.2.11 dated spring 2009). CS found that the revised procedure, which eliminated the multi-run assignment, had "the desired benefit of accurately measuring HOV travel times without negatively affecting the results of the assignment procedure" (p. 3-21). CS documented the model performance in its report.

Finding 32
In a similar vein to FY 2010, in FY 2011, CS was tasked to review the current methodology used by the TPB staff to model tolls in the Metropolitan Washington region. CS (2011) stated that there are two primary ways to model tolls in travel demand models. The first is to include toll choice in the mode choice step, e.g., "drive-alone with toll" and "drive-alone without toll." The second way is to "leave the decision of whether or not to pay a toll as part of the route choice decision in traffic assignment" (pp. 3-20 to 3-21). It is this second approach used by TPB staff in both the Version 2.2 and 2.3 travel models. CS found that "the state of the practice for modeling toll facility demand generally appears to address toll choice as part of the highway assignment step" (p. 3-21).

Finding 33
CS (2011) found that "the PSRC model uses different values of time in the mode choice model than in the traffic assignment model for automobile trips" (p. 3-21).

Recommendation 60
On the subject of value of time calculations and how far to carry household-income stratification in the model, CS (2011) found the following:

> *The value of time used in the highway assignment step of the TPB model is not stratified by income and is instead an average regional value. This is perhaps the best option in the situation where income groups are not carried past the mode choice step. As toll facilities profligate across the region, there may be real benefits to carrying these income stratifications forward and maintaining the more accurate values of time in highway assignment. The route assignments made with more accurate values of time are likely to produce more accurate results. (p. 3-23)*

Recommendation 61
In a similar vein to the previous recommendation, CS (2011) stated:

> *Another potential area for investigation would be the implementation of an embedded route choice model immediately prior to the highway assignment step like the one implemented for the Central Texas Turnpike System. Implementing this type of toll choice analysis assumes that*

> *tolling does not affect the results of a mode choice decision. This process allows for market segmentation by trip purpose, vehicle type, and potentially by income group. (p. 3-23).*

2.2.8.2 Discussion and TPB staff response

VHB (2006) recommended that TPB "consider following Salt Lake City's method of using the AM peak period for developing toll forecasts, and consider Seattle's approach of further subdividing the peak period to increase the variability of dynamic tolling in the model" (Recommendation 57). The planned variable pricing operations and policies in the Washington D.C. region are quite unique and will vary throughout the day. Staff does not agree that developing toll forecasts using an AM peak condition will be sufficient. Staff does not agree that subdividing the peak periods to reflect the variability of dynamic tolling will result in an improved regional traffic assignment.

On the subject of conducting a before-and-after study on the effect of HOT lanes on HOV traffic, CS (2009) recommended a series of steps that need to be followed, including identifying a set of evaluation goals (Recommendation 58). TPB staff has not yet acted upon this recommendation and has not yet prepared any before-and-after data collection plans related to the proposed HOT lanes in Northern Virginia.

On the subject of the "HOV3+ skims substitution" technique, also known as the "multi-run assignment" process to deal with HOT-lane modeling, CS (2010) proposed "combining the two runs into a one-run process to save model run time and to provide more consistency in mode choice modeling," i.e., eliminating the multi-run assignment and replacing it with just one application of the travel model (Recommendation 59). Despite the fact that CS tested its proposal and found that it did not negatively affect the results of traffic assignment, TPB staff remains unconvinced of the merits of this recommendation. Consequently, the Version 2.3 Travel Model still employs the "HOV3+ skims substitution" technique to model HOT lanes. TPB staff acknowledges, that, time permitting, it may be wise to review this approach in the future.

On the subject of value of time calculations and how far to carry household-income stratification in the model, CS (2011) suggested that, as "toll facilities profligate across the region, there may be real benefits to carrying these income stratifications forward and maintaining the more accurate values of time in highway assignment" (Recommendation 60). This is similar to Recommendation 45, so the TPB staff response is similar: There are limits to what the travel demand forecasting software will allow, but TPB staff will keep this recommendation in mind, especially as hardware and software improvements make this recommendation more practical.

In a similar vein, CS (2011) also suggested that TPB staff may want to consider implementation of an embedded route choice model immediately prior to the highway assignment step (Recommendation 61). TPB staff has not taken any action on this recommendation.

2.2.9 Special generators, including modeling airport access trips

As stated by CS (2010), "The TPB model currently handles the three commercial airports as special generators, but not universities, group quarters, regional shopping centers, or military bases. TPB staff is considering whether the TPB model should enhance and/or explicitly include special generators in the upcoming Version 2.3 model update." (p. 2-13). Exogenous trip files used in the Version 2.3 Travel Model represent special travel markets that need to be accounted for in the regional forecast, but which are not well represented in household travel surveys. Such markets include external trip-ends, through trips, airport passenger trips, and "miscellaneous" (or taxi, school, and visitor/ tourist) trips. Airport auto driver forecasts are formulated as exogenous inputs to the regional travel model. The process involves the use of a Fratar-technique in which forecasted airport trip tables are developed using observed travel patterns that are adjusted over time in accordance with adopted household and job growth forecasts (Milone et al., 2009, p. 3-1).

2.2.9.1 Summary of consultant findings and recommendations

Recommendation 62

The three commercial airports in the region have undergone improvement and expansion projects in recent years, and some of this work is still ongoing, such as at Dulles International Airport. VHB (2006) recommended that TPB staff consider how the trip generation characteristics of the three commercial airports have changed over time (p. 10). TPB staff should also review the documented airport trip generation rates that can be found in the FHWA publication *Intermodal Ground Access to Airports: A Planning Guide* (Bellomo-McGee, Inc., 1996; referenced in Vanasse Hangen Brustlin, Inc., 2006, p. 10). VHB (2007) reiterated this same recommendation in its year-2007 report (p. 11).

Finding 34

CS (2009) did not explicitly recommend developing an airport model, stating simply, "If TPB decides to develop an airport model to model these trips, then this section briefly describes the data needs, model estimation, validation, and implementation of such a model within the TPB travel model system" (p. 2-25). CS discusses the benefits of developing a four-step airport model, such as the ability to project the future distribution of air passengers and employees by airport for the three commercial airports (pp. 2-25 to 2-27).

Finding 35

CS (2009) did not specifically recommend that COG/TPB develop a special events model, but, nonetheless, it discussed some of the issues involved in creating one (pp. 2-27 to 2-28).

Recommendation 63

CS (2009) stated that "visitor travel is usually not explicitly modeled in regional travel models, which instead are entirely based on local household survey data and transit on-board surveys," (p. 2-28), but then noted that visitor models have been estimated in other large urban areas that receive lots of visitor trips, e.g., San Francisco and Las Vegas (p. 2-28). CS added that it may be worthwhile for COG/TPB to consider developing a visitor model (p. 2-28).

Recommendation 64

CS (2010) recommended that TPB staff consider the following "short-term enhancement" relating to special travel markets: "Develop an airport trip submodel set incorporating the current best practice, taking full advantage of the ongoing air passenger travel survey data. This airport model would include ground access mode choice models with a nested logit structure for at least four market segments (resident business trips, resident non-business trips, nonresident business trips, and non-resident non-business trips)" (p. 2-18).

Recommendation 65

CS (2010) recommended that TPB staff consider the following "short-term enhancement" relating to special travel markets: "Plan a visitor travel survey and a special events survey in support of model development for a visitor model and a special events model. At the same time, an evaluation of the exogenously generated visitor/tourist auto driver trips data can be made to see if the data fully account for trips made by visitors within the region. Interim enhancements can be made using some simple assumptions and adjustments." (p. 2-18).

Recommendation 66

CS (2010) recommended that TPB staff consider the following "short-term enhancement" relating to special travel markets: "Model HBU trips as an independent trip purpose as recommended in Section 2.2. Other college-related trips from college dormitories and other group quarters trips should be estimated using simplified assumptions or using trip rates from other similar regions, and checked against the ITE trip rates." (p. 2-18).

Recommendation 67

CS (2010) recommended that TPB staff consider the following "short-term enhancement" relating to special travel markets: "It is not recommended to treat shopping centers as special generators" (p. 2-18).

Recommendation 68

CS (2010) recommended that TPB staff consider the following "short-term enhancement" relating to special travel markets: "Explore use of ITE trip generation rates for treatment of group quarters trip generation" (p. 2-18).

2.2.9.2 Discussion and TPB staff response

VHB (2006) recommended that TPB staff consider how the trip generation characteristics of the three commercial airports have changed over time and suggested that TPB staff should also review the documented airport trip generation rates that can be found in the FHWA publication *Intermodal Ground Access to Airports: A Planning Guide* (Recommendation 62). TPB staff has not taken action on this specific recommendation, in part because staff has not been able to find a copy of this report, but staff has recently sought consultant help to develop a better way to model transit trips associated with access to the region's three commercial airports.

CS (2009) stated that "visitor travel is usually not explicitly modeled in regional travel models," but then added that it may be worthwhile for COG/TPB to consider developing a visitor model, given the large number of visitors and tourist to the Metropolitan Washington region (Recommendation 63). Visitor/tourist trips are added to the travel model as one of a number of exogenous trip tables. Unfortunately, the survey data underlying the visitor/tourist trip tables is dated. Nonetheless, TPB staff recognizes that, given the importance of visitor/tourist travel in this region, TPB will plan to revisit the treatment of this special travel market in the near future.

Under the heading of "short-term" enhancements, CS (2010) made the following recommendations (TPB staff response follows each recommendation):

Recommendation 64: Develop an airport trip submodel set incorporating the current best practice, taking full advantage of the ongoing air passenger travel survey data. This airport model would include ground access mode choice models with a nested logit structure for at least four market segments (resident business trips, resident non-business trips, nonresident business trips, and non-resident non-business trips).

TPB staff response: We agree with this recommendation and hope to make it part of our long-term models development plan. Over the long term, TPB staff hopes to be able to develop both an airport choice model and an airport ground access model. However, this effort has been stymied by limited resources and data.

Recommendation 65: Plan a visitor travel survey and a special events survey in support of model development for a visitor model and a special events model. At the same time, an evaluation of the exogenously generated visitor/tourist auto driver trips data can be made to see if the data fully account for trips made by visitors within the region. Interim enhancements can be made using some simple assumptions and adjustments.

TPB staff response: We agree with this recommendation and hope to make it part of our long-term models development plan. We have already started on some interim enhancements, with AECOM and its subcontractor Stump/Hausman.

Recommendation 66: Model HBU trips as an independent trip purpose as recommended in Section 2.2. Other college-related trips from college dormitories and other group quarters trips should be estimated using simplified assumptions or using trip rates from other similar regions, and checked against the ITE trip rates.

TPB staff response: TPB staff understands that "school" or "university" trip purposes are common in model sets developed in large metropolitan areas. A Home-Based-University purpose was tested about 15 years ago but was ultimately abandoned as the number of samples in the 1994 Household Travel Survey was very small. TPB staff agrees that the treatment of this market needs to be improved as a long-term goal (if not as an explicit modeled purpose, perhaps as a family of special generators).

Recommendation 67: It is not recommended to treat shopping centers as special generators.

TPB staff response: We concur.

Recommendation 68: Explore use of ITE trip generation rates for treatment of group quarters trip generation.

TPB staff response: Staff was interested in the use of special generators in the context of military bases. Staff agrees that travel associated with military bases should be better addressed as a long-term goal.

2.2.10 Modeling non-motorized (walk and bike) trips

2.2.10.1 Summary of consultant findings and recommendations

See also section 2.2.11 ("Model sensitivity to land use policies such as smart growth").

Recommendation 69

CS (2009) notes that the current TPB travel model, Version 2.2, addresses non-motorized travel only for home-based work (HBW) trips (in trip generation) and suggests that TPB staff could extend the same non-motorized travel estimation to the other trip purposes (p. 4-10).

Recommendation 70

In the Version 2.2 model, there was a non-motorized trip extraction model, for HBW trips only, that used area type to determine the share of total person trips that were non-motorized person trips (Milone et al., 2008, p. 4-8). In addition to mentioning that TPB staff could extend the estimation of non-motorized travel to other trip purposes, CS also suggested that TPB staff could consider introducing other segmentations (in addition to area type) such as density, accessibility, and/or an RACC indicator (p. 4-10).

Recommendation 71

According to CS (2009), another approach for enhancing the modeling of non-motorized travel is to implement a pre-trip distribution model that predicts the binary choice between motorized and non-motorized modes of travel based on socioeconomic characteristics, local land use attributes, and transportation conditions (p. 4-11).

Recommendation 72

CS (2009) concluded by stating, "In the longer term, consideration should be given to extending the treatment of nonmotorized travel through the trip distribution and mode choice model steps" (p. 4-11).

2.2.10.2 Discussion and TPB staff response

CS (2009) notes that the current TPB travel model, Version 2.2, addresses non-motorized travel only for home-based work (HBW) trips (in trip generation) and suggests that TPB staff could extend the same non-motorized travel estimation to the other trip purposes (Recommendation 69). TPB staff agreed with this recommendation and implemented it. The Version 2.3 Travel Model models non-motorized trip generation for all five resident trip purposes: HBW, HBS, HBO, NHW, and NHO.

In addition to mentioning that TPB staff could extend the estimation of non-motorized travel to other trip purposes, CS (2009) also suggested that TPB staff could consider introducing other segmentations (in addition to area type) such as density, accessibility, and/or an RACC indicator (Recommendation 70). The new non-motorized models in the Version 2.3 Travel Model include variables such as population density, employment density, and street block density (Milone et al., 2012b, pp. 4–16 to 4–20).

According to CS (2009), another approach for enhancing the modeling of non-motorized travel is to implement a pre-trip distribution model that predicts the binary choice between motorized and non-motorized modes of travel based on socioeconomic characteristics, local land use attributes, and transportation conditions (Recommendation 71). Again, TPB staff has not yet acted upon this recommendation.

CS (2009) concluded by stating, "In the longer term, consideration should be given to extending the treatment of nonmotorized travel through the trip distribution and mode choice model steps" (Recommendation 72). TPB staff is guardedly optimistic about extending the treatment of non-motorized trips through trip distribution and mode choice. In the Version 2.2 Travel Model, it was difficult to get the level-of-service matrices/skims needed to bring walking and biking into trip distribution, since the walk network (sidewalk network) existed only in downtown DC and downtown Silver Spring, Maryland. In the Version 2.3 Travel Model, by contrast, there is a sidewalk network in almost the entire modeled area, so it should be possible to develop non-motorized zone-to-zone skims. The regional sidewalk network is generated automatically using a script (walkacc.s), which creates a sidewalk network by converting all suitable highway links into sidewalk (mode 13) links (See Milone et al., 2012a, p. 11-9 for more details). This could be part of TPB's long-term models development plan.

2.2.11 Model sensitivity to land use policies such as smart growth

2.2.11.1 Summary of consultant findings and recommendations

Recommendation 73

In Chapter 4 of its 2009 report, CS (2009) made several recommendations of near-term improvements which it thought could be incorporated into the new Version 2.3 Travel Model. The objective of these recommendations was to enhance the model sensitivity to land use policies such as smart growth strategies, transit-oriented development, and non-motorized travel initiatives (p. 4-8). COG had recently developed a series of Regional Activity Centers and Clusters, or RACCs (See, for example, Griffiths, 2009; or Metropolitan Washington Council of Governments, 2007). CS noted that, "although a RACC Indicator shows promise based on these preliminary household travel survey findings, it should be noted that it is always preferable to use a fully objective measure in the model rather than simply a designation" (p. 4-9). Instead of simply using an RACC indicator, CS went on to recommend that "effort be made to determine if alternative, fully objective measures of pedestrian and transit supportive land use could be used to achieve similar differentiation of household composition and travel behavior" (p. 4-9).

Recommendation 74

CS (2009) recommended that "explorations for improving the representation of land use policies and nonmotorized travel in the trip generation step begin with [the] demographic submodels," (p. 4-9) since this would reduce the need to make changes to the trip generation models themselves.

Recommendation 75

On the subject of the TPB's vehicle availability model, CS (2009) made the following suggestions, "Possible improvements to the vehicle availability model include: 1) adding a RACC indicator, and/or 2) introducing a density variable. Other land use related variables could also be considered, such as housing type, to the extent data are available for both base and forecast year usage" (p. 4-10).

Recommendation 76

On the subject of short-term improvements to the trip generation model, CS (2009) suggested the following:

> *…introducing further market segments in the classification using either one or a combination of the following indicators: RACC indicator, density, area type, and accessibility. As with the demographic submodel improvement, extensive testing should be conducted to determine the best specification. (p. 4-10)*

See also section 2.2.10 ("Modeling non-motorized (walk and bike) trips").

Recommendation 77

As for long-term enhancements that TPB staff might want to consider to improve the model's sensitivity to land use policies such as smart growth, transit-oriented development, and non-motorized travel incentives, CS (2009) suggested the following:

> *It might be feasible to introduce special purpose models in RACC areas for pedestrian modeling in the manner provided as an example from the Central Artery/Tunnel project. That is, to develop nonmotorized trip generation, trip distribution, and trip assignment models for special purpose evaluations. (p. 4-11)*

Recommendation 78

Continuing in the area of long-term enhancements, CS (2009) stated that "the desirability of developing a destination choice model to replace the gravity-based trip distribution model remains a high-priority longer term recommendation" (p. 4-12). CS added that "a destination choice model provides a platform to introduce land use variables, therefore enhancing the sensitivity of the TPB model to land use changes" (p. 4-12).

Recommendation 79

CS (2009) recommended the following:

> *To the extent not already available, it is recommended that attention be given to developing and/or enhancing the land use database (for both existing and forecasted land use). In addition to the summary land use measures used in the current modeling, an enhanced database should include additional variables that would facilitate the calculation of density using the various methods described in Section 2.0 (e.g., net density) and permit the exploration of additional land use related variables in model estimation (e.g., housing type). (p. 4-13)*

Recommendation 80

CS (2009) recommended a "possible long-term goal for TPB is to pursue adoption of a formal land use model," noting that it "could further contribute to the program by providing a scientific formula and detailed criteria for designation of new or existing growth centers" (p. 4-13).

2.2.11.2 Discussion and TPB staff response

In Chapter 4 of its 2009 report, CS (2009) made several recommendations of near-term improvements which it thought could be incorporated into the new Version 2.3 Travel Model. The objective of these recommendations was to enhance the model sensitivity to land use policies such as smart growth strategies, transit-oriented development, and non-motorized travel initiatives. CS noted that, instead of simply using an RACC indicator, TPB staff should determine if it can develop one or more fully objective measures of pedestrian trip making and/or transit supportive land use (Recommendation 73). TPB staff concurs with this recommendation. In FY 2012, it reviewed work done by AECOM for both a VRE study in 2008 (AECOM Consult, Inc., 2008) and for WMATA in 2011 and 2012 to include a pedestrian environment factor (PEF) in its nested-logit mode choice, which might have the added benefit of reducing the mode choice model's dependence on statically defined geographic superdistricts. TPB staff concluded that the work on the PEF was not yet ready for inclusion into the TPB model. TPB staff plans to re-assess inclusion of a PEF once the WMATA work is done and documented, likely spring or summer of 2012.

CS (2009) recommended that explorations for improving the representation of land use policies and non-motorized travel in the trip generation step begin with the demographic sub-models (Recommendation 74). Continuing in this vein, on the subject of the TPB's vehicle availability model, CS (2009) made a number of suggestions about possible new variables to include in the model (Recommendation 75). At this point, TPB staff has not yet acted upon either of these recommendations. CS (2009) also made suggestions about enhancing the trip generation model, such as adding further market segmentation or adding one or more new indicator variables (Recommendation 76). TPB staff has not acted upon this recommendation.

Continuing on the subject of enhancing the model's sensitivity to land use policies such as smart growth, transit-oriented development, and non-motorized travel incentives, but shifting from short-term enhancements to long-term enhancements, CS (2009) suggested that it "might be feasible to introduce special purpose models in RACC areas for pedestrian modeling in the manner provided as an example from the Central Artery/Tunnel project" (Recommendation 77). Given the current constraints on resources, TPB staff does not currently have plans to develop these special-purpose, pedestrian models.

Continuing in the area of long-term enhancements, CS (2009) stated that "the desirability of developing a destination choice model to replace the gravity-based trip distribution model remains a high-priority longer term recommendation" (Recommendation 78). CS (2009) had also noted that "the value of migration [to a destination choice model] may be limited if an activity-based model is planned within a few years because re-estimation would be necessary"(Recommendation 15). TPB staff needs to determine whether to proceed with developing a destination choice model or to move to an activity-based model. Given recent funding cuts, it does not appear that development of an activity-based model is imminent.

CS (2009) recommended that TPB develop and/or enhance the regional land use database, for both existing and forecasted land use (Recommendation 79). TPB staff is currently working with the members of the Cooperative Forecasting and Data Subcommittee and State Employment and Labor Administration agencies to the enhance the quality of regional employment data by detailed North American Industry Classification System (NAICS) categories and small-area geographies. COG and TPB staff, within specified confidentiality restrictions required by State Employment and Labor Administration agencies, will have access to high quality ES-202 (Covered Employment and Wages

Program) employment data by establishment address. COG and TPB staff will use this information, to the extent permitted by the confidentiality restrictions, to improve existing TAZ-level employment estimates by type. Also, on the residential side, TPB staff has begun to assemble local real estate assessment files and will work with the COG's Community Planning and Services staff and the members of the Cooperative Forecasting Subcommittee to enhance the quality of regional housing unit and household estimates by small area geographies.

CS (2009) recommended a "possible long-term goal for TPB is to pursue adoption of a formal land use model"(Recommendation 80). At one time, MWCOG did use a land use model. According to Ewing and Bartholomew, MWCOG "long ago attempted to use the EMPIRIC land use model with disappointing results" (2009, p. 347). Ewing and Bartholomew concluded by saying, "The experience soured the MWCOG on formal models, and the agency has no current plan to develop an integrated land use and transportation model." Although there are theoretical advantages to developing and using a land use model, it is very difficult given past experiences at COG, current political forces, and the added resources that would need to be devoted to developing and maintaining a land use model. Further, COG's joint regional/local Cooperative Forecasting process continues to provide very good estimates of current land activity and forecasts of future growth by small-area transportation analysis zones. Comparison of previous Cooperative Forecasts made 20+years ago with current household and employment estimates have been found to be accurate within a few percent.

2.2.12 Sensitivity testing of the regional travel model

See also Recommendation 6, which discusses sensitivity testing.

2.2.12.1 Summary of consultant findings and recommendations

Recommendation 81

VHB (2006) recommended that TPB staff consider dynamic validation, also known as sensitivity testing, including changing a parameter such as employment or housing in selected zones or removing one major link at a time from several locations to determine how the model results have changed (p. 9).

2.2.12.2 Discussion and TPB staff response

TPB staff concurs with the VHB recommendation. TPB staff has conducted a number of sensitivity tests on both the Version 2.2 and 2.3 travel models since 2006, including the following:

- Version 2.2 Travel Model
    - (Milone, 2007)
    - (Milone & Seifu, 2007)
    - (Milone et al., 2007)
- Version 2.3 Travel Model
    - (Moran, 2008a)
    - (Moran, 2008b)
    - (Milone et al., 2009)
    - (Vuksan & Xie, 2011)
    - (Milone & Moran, 2011)

- (Martchouk, 2011)
- (Milone, 2012a)

2.2.13 Screenlines/cutlines

In addition to being discussed in this section, screenlines are also discussed in Section 2.2.2 (Trip distribution and destination choice), Section 2.2.4 (Modeling transit), and Section 2.2.6 (Traffic assignment).

2.2.13.1 Summary of consultant findings and recommendations

Screenlines and cutlines are imaginary lines that intersect a series of roads or transit facilities and are used to aggregate observed and estimated flows of vehicles or persons (so called "screenline crossings"). Screenlines and cutlines are most commonly associated with travel on the highway network, but they may also be used for aggregating trips made by other travel modes, such as transit. VHB (2007) uses the terms screenlines and cutlines to apply to both (private motor) vehicle travel and transit travel. Cutlines are usually shorter in length than screenlines, but the practice at many agencies, including TPB is to use the term "screenlines" to refer to all such imaginary lines.

Recommendation 82

VHB (2007) recommended that TPB staff consider moving and/or adding screenlines to the modeled area (p. 92). VHB recommended adding 23-24 new screenlines (p. 102) to the existing 35 screenlines currently used by TPB (which are numbered 1 to 38). This should ideally be done for the next validation of the travel model (p. 107).

Recommendation 83

VHB (2007) recommended that TPB staff use the VDOT traffic engineering traffic count database and eventually the freeway data archives for Northern Virginia to obtain robust observed data sets (p. 107).

Recommendation 84

Although the TPB has employed cordon lines around the certain parts of the region, such as the Metro Core cordon and the Beltway cordon, there are other parts of the region that do not have such designation, but may benefit from them, according to VHB (2007). Examples include designating cordon lines around Tysons Corner, Bethesda, and possibly others (p. 108).

2.2.13.2 Discussion and TPB staff response

VHB (2007) recommended moving and/or adding about 23 screenlines to the modeled area, ideally before the next validation of the travel model (Recommendation 82). TPB staff has not taken the time to consider each of these new or moved screenlines, but it would make sense to do so soon, especially before the year-2010 validation of the Version 2.3 Travel Model. Additionally, as TPB staff has become more conversant with the new transit assignment capabilities of the Version 2.3 Travel Model, it has become apparent to staff that some of these screenline should be used for transit network validation as well as highway network validation. TPB staff did, however, perform work to adjust the locations of the existing screenlines so that they would be more accurate and would be easier to use with the TPB highway networks (Snead et al., 2010, sec. 4.7).

VHB (2007) recommended that TPB staff use the VDOT traffic engineering traffic count database and eventually the freeway data archives for Northern Virginia (Recommendation 83). Staff has begun formulating a time-series database of HPMS traffic counts at the highway network link level. Staff is working toward a more robust traffic count database containing both stated and locally collected traffic counts. Staff is currently trying to formulate how to deal with certain issues, including metadata and *hourly* counts (as opposed to daily counts).

VHB (2007) encouraged the use of a new set of cordon lines around key activity centers, such as Tysons Corner and Bethesda (Recommendation 84). TPB staff generally agrees with the sentiment behind this recommendation, but has not had the time to develop any of these new cordon lines.

2.2.14 Value of time

2.2.14.1 Summary of consultant findings and recommendations

Finding 36
CS (2009) states:

In a fully disaggregate travel demand forecasting system, values of time (or distributions of values of travel time) can be used based on the traveler, the trip, the vehicle type, and the goods being carried and could remain consistent throughout the forecasting process, eliminating the application-related issues surrounding the values of time. For aggregate trip-based models, such as the TPB travel model, incorporating values of time for individual travelers, trips, and vehicles is impossible, but it is possible to identify specific categories of travelers, trips, and vehicles and apply values of time for these categories. This can be an effective means of distributing values of time within the forecasting system, but to make it fully effective requires using consistent market segmentation throughout the model chain (i.e., to assess values of time by income group, one must represent income group within each model component, including trip assignment). (p. 2-24)

2.2.14.2 Discussion and TPB staff response
In Finding 36, CS (2009) makes the case for the advantage of including the household income group stratification, which is used in trip generation, trip distribution, and mode choice, all the way through traffic assignment. Although TPB staff agrees with the motivation behind such a change, implementing this could prove to be challenging, as mentioned in the staff response for Recommendation 45.

2.2.15 Trip purposes

2.2.15.1 Summary of consultant findings and recommendations

Recommendation 85
CS (2010) recommended the following "short-term" enhancements to the regional travel model: "Split non-home-based (NHB) into NHB work related and NHB other trip purposes and model them at least through trip distribution" (p. 2-12).

Recommendation 86

CS (2010) recommended the following "short-term" enhancements to the regional travel model: "Establish a home-based university (HBU) trip category and model in trip generation and distribution, assuming data are available to support it" (p. 2-12).

Recommendation 87

CS (2010) recommended the following "short-term" enhancements to the regional travel model: "Establish a home-based school (HBSch) trip category for trip generation and distribution, assuming data are available to support it" (p. 2-12).

2.2.15.2 Discussion and TPB staff response

CS (2010) recommended that TPB staff split the non-home-based (NHB) trip purpose into NHB work related and NHB other trip purposes and model them at least through trip distribution (Recommendation 85). TPB staff agreed with this recommendation and acted upon it. In 2010, TPB staff decided to split the NHB trip purpose used in the Version 2.3 Travel Model into two categories: Non-Home-Base Work (NHW) and Non-Home Base Other (NHO), as staff recognized that the modal preferences and temporal characteristics between the two sub-groups vary substantially. CS (2010) recommended that TPB staff establish a home-based university (HBU) trip category and model it in trip generation and distribution, assuming data are available to support it (Recommendation 86). CS (2010) also recommended that staff establish a home-based school (HBSch) trip category for trip generation and distribution, assuming data are available to support it (Recommendation 87). TPB staff has decided not to establish the HBU or HBSch trip purpose at this point in time, due to resource constraints. TPB staff is willing to consider adding HBU or HBSch trip purposes in future model updates.

2.3 Software issues and reducing run times

2.3.1 Reducing model run times

2.3.1.1 Summary of consultant findings and recommendations

Recommendation 88

In the Version 2.2 Travel Model, bus speeds were not dynamically linked with link speeds from the highway network. Instead, the model used a system of "local bus time degradation factors" (LBUS_TIMFTRS.ASC) (Milone et al., 2008, pp. 10–7, 14–1, and 14–3). The Version 2.2 model did, however, feature, as one of its feedback loops, the "peak-period transit accessibility to jobs," which is an input to the demographic sub-models (See, for example, Cambridge Systematics, Inc., 2009, p. 5-2; or Milone et al., 2008, p. 1-8). The foregoing description also applies to the Version 2.3 Travel Model. However, as CS (2009) pointed out, "only the drive access component of the transit time between zonal pairs is dynamically affected by the recycled highway speeds" (p. 5-3). CS concluded that one would not expect much change in the transit accessibility skims as a result of the updated highway speeds used in the speed feedback process. Consequently, as a short-term strategy, CS (2009) suggested that TPB staff could change "the feedback loop to return to the trip distribution step rather than to the demographic submodel step" and that this would likely have "little-to-no impact" on the model results, but would lead to a shortened run time for the model set (p. 5-4). CS did, however, state that this strategy should be used in only the short term.

Recommendation 89

CS (2009) stated:

> *Adjusting the skimming for the HOV and HOT facilities may provide an additional area of focus for reducing the model run time. The current Version 2.2 model framework requires two model runs to be performed for each feedback iteration to address HOV policy. The base model run captures the travel time for unimpeded flow of HOV traffic on HOT lanes consistent with the stated operational policy. The "conformity run" substitutes the HOV skims thus obtained for the HOV skims that would otherwise be obtained by simply skimming the networks with HOT lanes in operation. Streamlining this process has the potential to greatly decrease the run time of the model set.*
>
> *An alternative methodology would be to skim the HOT facilities once for both HOT and HOV paths, with the tolls adjusted to achieve flow conditions consistent with the stated operational policy. For the HOV paths, the tolls would not be included in the path cost calculations. This change would provide HOV skims that would more accurately reflect traffic conditions on the arterial approaches to the HOT facilities, which could impact the HOV users' path choice. It could also serve to provide consistent link travel times for HOV and HOT paths. (p. 5-4)*

CS went on to recommend testing the impacts of making such a change, before adopting it (p. 5-5).

Recommendation 90

CS (2009) discussed the pros and cons of removing the transit capacity constraint on Metrorail service running to and through the regional core (p. 5-5). The transit constraint process adds to run time since one must perform two runs of the travel model, one to establish the Metrorail core volumes in the constraining year and one to establish the Metrorail core volumes in the out year.

2.3.1.2 Discussion and TPB staff response

Reducing the turn-around time required to execute the Version 2.3 Travel Model has been identified by staff as a top-priority. The computation times have been very high due to the newly expanded TAZ system and the numerous travel time skims used to support the nested-logit mode choice model. Most of the recent work in this area has been to: 1) exploit the capabilities of distributed processing (the use of multiple computer CPUs) and 2) consider streamlining the model code as much as possible.

CS (2009) suggested that, as a short-term step, TPB staff could change "the feedback loop to return to the trip distribution step rather than to the demographic submodel step" (Recommendation 88). CS thought that this would have little impact on the model results, but would lead to a shortened run time for the model set (p. 5-4). TPB staff has not yet acted on this recommendation, but agrees that the concept could be tested to see how results would be impacted.

CS (2009) recommended eliminating the "HOV3+ skims substitution" technique (i.e., the multi-run assignment) and replacing it with just one application of the travel model (Recommendation 89). This subject was already addressed in Recommendation 59.

CS (2009) discussed the pros and cons of removing the transit capacity constraint on Metrorail service running to and through the regional core, which adds to run time since one must perform two runs of the travel model (Recommendation 90). TPB staff has not taken any action on this recommendation, so the Version 2.3 Travel Model still uses the process to constrain Metrorail transit through the regional core to a constraint year (currently 2020).

2.3.2 Review of travel demand forecasting software packages

2.3.2.1 Summary of consultant findings and recommendations

Ideally, TPB staff should perform a periodic review of travel demand forecasting software to make sure that TPB staff is using the package that best meets its modeling needs. Realistically, software reviews take time, and, if the result of the review is a recommendation to change software packages, the changeover can be disruptive and require many resources. One key question is how frequently to perform these reviews so as to strike a balance between ensuring we are using the best software and minimizing the disruption caused by these reviews and possible software migrations. Though there is no easy answer to that question, some have argued that about every ten years or so is appropriate. The last time that TPB staff performed such a review was in 2000/2001. This review resulted in a migration of software packages -- from MINUTP to TP+ (See, for example, Milone & Zilliacus, 2000; Milone, 2001), but no migration of vendors, since both packages are made by the same vendor. Given that it has been over ten years since the last review, TPB staff asked CS to help assemble some review criteria that one might use for such a review, in the case that TPB staff decides to go forward with such a review in the near future.

Finding 37

CS (2011) stated that “to avoid the perception of favoritism towards any particular software package, a comprehensive list of criteria should be developed before the evaluation process begins” adding that such a list would ensure “that all potential issues can be addressed during the evaluation in a fair and objective manner” (p. 2-1).

Finding 38

CS (2011) stated:

> *It is difficult to know in which areas the next set of important advancements in travel demand forecasting will develop; however it is certain that the TPB model must be able to keep pace with these advancements. There is no way to know for certain which packages will make these advances first, best, and easiest. One good indicator is the amount of cutting edge research currently conducted by the staff of a given software manufacturer, which can in part be gauged by participation in professional conferences and publication in technical journals. (p. 2-3)*

Finding 39

CS (2011) stated:

> *In an environment of limited resources, TPB will certainly be looking for a cost-effective solution. Cost also is one of the more easily quantifiable criteria. However, the importance of cost alone should not be overstated; the evaluation process should consider the costs of each potential*

> *software package without allowing it to overshadow or outweigh the other criteria. Cost effectiveness should be the ultimate goal, not simply low costs. (p. 2-4)*

Finding 40

CS (2011) noted that "any software package selected by TPB should have a high degree of freedom to implement customized methods in any part of the model chain, in addition to customized reports and analyses on the model results," (p. 2-4) such as via scripting. However, CS also warned that "a platform where scripting is the only method for conducting analyses or customizing the model may limit what model users are able to accomplish" (p. 2-4).

Recommendation 91

CS (2011) stated:

> *If the current TPB model is pushing the limits of a software package's capabilities, then the ability to improve the model in the future may be limited. TPB should search for a powerful software package so that the processing capacity of the modeling software is never the limiting element of the travel demand forecasting process. (p. 2-5)*

Finding 41

CS (2011) stressed the importance of customer support, noting that "poor support can result in substantial time and productivity losses as TPB staff try to solve problems and resolve issues with the software on their own" (p. 2-8). CS also stressed the need to talk to current and former users of the software packages, not just the vendors:

> *The quality of customer support is somewhat difficult to gauge without personal experience, and no ready source of customer reviews exists in the small market of travel demand forecasting software. However, because customer satisfaction is one of the best clues to the level of support to be expected by a software vendor, interviews with current and former customers of each of the alternatives may be warranted to gain an understanding of this dimension. (p. 2-8)*

Similarly, CS (2011) added that "discussions with users of a software package can be very enlightening and often provide the type of unique insights that evaluators may find most useful and that may be unavailable from any other potential sources" (p. 2-14).

Finding 42

CS (2011) stated that "TPB will need to develop a complete list of functionalities for an idealized software package in order for this criterion [technical functionality] to be evaluated in an objective manner" (pp. 2-9 to 2-10).

Finding 43

CS (2011) stated that "the major issues at the start of the transfer process are likely to be related to staff productivity as they learn the new system" (p. 2-10).

Finding 44

CS (2011) discussed the two most commonly used methods of rating the various software packages: average scoring and weighted average scoring (p. 2-14).

Finding 45

Citing a table from the October 12, 2001 issue of The Urban Transportation Monitor (UTM), CS (2011) stated that "the average length of use of a software package by MPOs in 2001 [was] approximately six years" (p. 2-17). CS (2011) provided advice for how to conduct such a review, such as lists of criteria and questions in Chapter 2 of its report (pp. 2-1 to 2-24). In a related area, CS cited a 2004 survey, also by UTM, that included 81 MPOs, which showed that Citilabs and Caliper were the two most commonly used packages, each accounting for about 28% of the market (2011, p. 2-17).

Finding 46

CS (2011) found that, although TPB is not the biggest MPO in the U.S., it had one of the largest TAZ systems in the U.S., with only four MPOs having more TAZs: NCTCOG, SANDAG, Miami, and SCAG (but not NYMTC) (p. 2-20).

2.3.2.2 Discussion and TPB staff response

In the chapter entitled, "Consideration of Available Commercial Software Travel Demand Forecasting Software Packages," CS (2011) provided many findings, but only one recommendation (Recommendation 91). For this report, we have listed only some of the many findings in the CS report. Regarding Recommendation 91 (searching for a powerful software package), TPB staff plans to follow this recommendation when it next performs a review of modeling packages. Similarly, based on the finding that the average length of use of a software package by an MPO in 2001 was about six years (Finding 45), this provides an indicator that TPB staff should consider doing a software review in the next few years.

2.3.3 Review of TPB's travel modeling scripts

2.3.3.1 Summary of consultant findings and recommendations

Finding 47

After reviewing the scripts that make up the Version 2.3.9 Travel Model, with an emphasis on the highway assignment script, CS (2011) found that the modeling process was "handled in a very solid manner" (p. 3-2). Although CS did identify some errors in the scripts, these errors had been "found and corrected by TPB staff" in "later builds of the model" (p. 3-2). CS concluded the section of the report by stating, "Overall, the review of the Version 2.3 model scripts resulted in an affirmation of the strength of TPB's model" (p. 3-4).

Finding 48

On the subject of the benefits of switching from using a series of batch files to apply the TPB travel model to using Cube's Application Manager and Scenario Manager, CS (2011) found that "the TPB batch file system is very advanced and provides a good structure for the model," adding, "while switching to Scenario/Application Manager is an option that can be considered, at this point it is more a matter of user preference and is certainly not a requirement for the continued advancement and development of the model" (p. 3-2).

As of 2011, however, based on discussions with Citilabs staff, TPB staff believes that it may be necessary to switch to Scenario/Application Manager if one wants to use the new Cube Cloud Services (CCS). At this time, however, TPB staff is not convinced that the benefits of switching to CCS outweigh the risks.

Recommendation 92

The CS (2011) review of the highway assignment script found several ways to improve efficiency and modestly reduce run times:

> *First, in the highway assignment step when calculating congested speeds, CS recommends storing the volumes as working variables instead of referring back to the network to read from the link inputs. (p. 3-2)*
>
> *The script review also pointed out that calculating the initial link impedance in the LINKREAD phase is unnecessary, as it has been previously calculated elsewhere in the script. … This will save some computation time, but not a significant amount. (p. 3-3)*

Recommendation 93

CS (2011) stated, "In addition, the link impedance calculation in the ILOOP phase may be able to be completed more efficiently in the ADJUST phase and without specifying a LINKLOOP. This has not been tested, and is likely to provide only small time savings" (p. 3-4).

2.3.3.2 Discussion and TPB staff response

Regarding Recommendation 92, TPB staff implemented this change in the highway assignment as part of build 25 of the Version 2.3 Travel Model, i.e., 2.3.25. TPB staff has not yet tested or implemented Recommendation 93.

2.4 Activity-based models (ABMs)

The majority of MPOs in the U.S. that perform travel demand modeling activities use an aggregate, trip-based travel demand model (TBM), also known as a four-step model (FSM). Over the last decade, several MPOs, especially the larger MPOs, have begun developing, or even implementing, a new paradigm known as the activity-based travel model (ABM). A review of the differences between a typical TBM and a typical ABM can be found in NCHRP Synthesis 406 (Donnelly et al., 2010, pp. 11–14).

2.4.1 Summary of consultant findings and recommendations

Please see Finding 29, in the section about "managed lanes" for discussion about VHB's (2006) ideas on using tour-based models for analyses of managed lanes.

Finding 49

VHB (2006) felt that TPB's move to an ABM would require significant resources:

> *Moving to an activity-based model would likely require a significant increase in available funding to support additional staff and training to introduce new skill-sets (programming and model techniques) into the TPB knowledge base, provide consultant support, and would introduce another level of scrutiny to TPB's activities, since the model would be radically changed. (p. 62)*

Recommendation 94

VHB (2006) stated, “Now is not the right time for TPB to begin full-scale adoption of an activity-based model – the technique is not yet widely accepted, and there are still numerous issues to be resolved before activity-based modeling is ‘ready for prime time’ in the Washington region” (p. 63).

Recommendation 95

On the issue of difficulty getting data to support an ABM, VHB (2006) stated, “A very extensive validation effort is planned for the DRCOG activity-based model, and this[,] along with the recent validation for the SACOG activity based model[,] should be reviewed by TPB to see both what data are used and what actions are considered for adjusting to data availability problems” (p. 60).

Recommendation 96

According to VHB (2006), “The best activity that can be undertaken to keep pace with advanced model development is to ensure that current data collection efforts include data that will allow transition to a tour or activity-based framework” (p. 63).

Recommendation 97

According to VHB (2006), TPB staff should consider beginning an incremental approach of moving towards an activity-based model. Three possible first steps mentioned by VHB:

- Convert trips from the latest household travel survey into tours, which could then be used to create a tour generation model (p. 63).
- Develop a more detailed assignment procedure, similar to those used by NYMTC and MORPC (p. 63).
- Develop a population synthesizer, as is being done by ARC in Atlanta (p. 63).

Recommendation 98

According to VHB (2006), “TPB may wish to consider formalizing a closer relationship with area universities to begin research into the development and application of an activity-based model for the Washington region” (p. 64).

Recommendation 99

According to VHB (2006), “Another option is for TPB to participate in (and if necessary lead) a joint program with other MPOs that will keep abreast of the current status of activity-based models. This joint project could document the success or failure of activity-based model development and application efforts by the early adopters of activity-based models” (p. 64).

Recommendation 100

CS (2009) indicated that TPB staff need to decide whether to devote resources to improving the current trip-based travel model or to developing an activity-based travel model, adding that, at a minimum, “an early step should be the development of a work program for movement to an activity-based model framework” (p. 2-29).

Finding 50

On the subject of developing an activity-based model, CS (2009) stated that "decisions regarding implementation should depend on planning analysis needs of the Washington D.C. area region and will also depend on resource constraints for model development and application" (pp. 2-29 to 2-30).

Finding 51

CS (2009) stated that "TPB will easily be able to use their recently completed home interview survey for their activity-based model, since it includes detailed activity and travel information for each individual in selected households" (p. 2-30).

Recommendation 101

In the event that TPB chose to develop an ABM, CS (2009) stated:

> *The SFCTA model uses five aggregate time periods for time-of-day choice; the more recent models use hour- or half-hour-long periods. TPB should consider using half-hour or hour-long periods, as shorter time periods allow for more options and flexibility when analyzing sensitivity to policy scenarios. (pp. 2-31 to 2-32)*

Recommendation 102

CS (2009) stated:

> *TPB has the option to either develop the system all at once, or implement a phased approach. A phased approach would take longer and would cost more, but may be a good option if sufficient funding is only available over time or if short-term products help get political support. Otherwise, it is suggested that TPB not use a phased approach. There is no documentation on whether interim products are useful, and the additional cost and time of implementing a phased approach make it generally undesirable compared to developing the system all at once. (p. 2-32)*

Recommendation 103

CS (2009) stated:

> *It is advised that TPB plan for implementation to take two to four years and cost $750,000 to $1,250,000 for consultant involvement. This would be in the range of $250,000 to $450,000 per year not including in-house staff costs and data collection. This is above the current $150,000 per year in total costs that TPB currently has budgeted. (pp. 2-32 to 2-33)*

Recommendation 104

CS (2009) stated that "activity-based models are able to address the increasingly complex policy questions that are of concern for MPOs and state DOTs today that traditional four-step models cannot address" (p. 2-33). CS concluded by stating, "It is advised that TPB put significant time and resources toward moving to an activity-based model" (p. 2-33).

Recommendation 105

CS (2009) recommended the following:

> *Decide on Near-Term Enhancements to Four-Step Model – It is advised that time and resources be invested toward developing an activity-based model, and, therefore, recommended (ideally)*

> *that further near-term enhancements to the four-step model not be undertaken beyond those already underway. However, if development of an activity-based model will not occur within the next few years, TPB should enhance their four-step model by updating every model component using the new 2008 household survey data, considering estimating destination and time-of-day choice models, and developing special generator models. (p. 2-34)*

Recommendation 106

CS (2009) recommended the following, "Assess and Create Timeline and Budget for Moving Toward Activity-Based Model – While TPB has a preliminary budget of $150,000 per year for activity-based model development, expansion of this funding should be explored to enable more rapid implementation of an activity-based model" (p. 2-34).

Recommendation 107

On the subject of moving to an ABM, CS (2009) recommended the following:

> *Based on Timeline, Budget, and Policy Needs, Decide on Broad Model Components and Model Development Process … especially with regard to the level of intrahousehold interactions, time-of-day choice placement, and whether to implement a standard trip assignment or incorporate some form of disaggregate traffic assignment (e.g., dynamic traffic assignment or microsimulation). (p. 2-34)*

Recommendation 108

On the subject of moving to an ABM, CS (2009) recommended the following:

> *Focus on Updating Inputs to System (i.e., Network TOD, Validation Data) that can be Done In-House in the Near Term – There are a number of in-house tasks TPB can undertake to prepare for the activity-based model development. Examples include creating network skims with greater temporal resolution and collecting detailed observed data that can be used for validation purposes. (p. 2-34)*

2.4.2 Discussion and TPB staff response

As noted in the beginning of this section, over the last decade, several MPOs, especially the larger MPOs, have begun developing, or even implementing, ABMs. In most cases, the ABM usually replaces the internal-to-internal trip portion of the TBM, but does not replace the entire TBM. For example, external travel models and commercial vehicle travel models from the TBM are usually retained.[4] Also, although some would argue that an ABM is better prepared to use dynamic traffic assignment, up to now, most MPOs that have developed ABMs have continued to use static traffic assignment processes, perhaps due to issues with model run time. Several large MPOs, such as TPB, are still in the process of assessing whether the benefits of switching to an ABM outweigh the costs. TPB was one of eleven MPOs that used a pooled funding mechanism to fund a study by the Association of Metropolitan Planning Organizations (AMPO) of ABMs. Phase 1 of the study has resulted in a report (Vanasse Hangen Brustlin, Inc., Resource Systems Group, Inc., Shapiro Transportation Consulting, LLC, & Urban Analytics, 2011). A

[4] One notable exception: The City of Calgary, in Alberta, Canada, developed an ABM for commercial vehicles (City of Calgary, 2006).

second phase of the study, supported by the Federal Highway Administration (FHWA), is currently underway and a report is expected in summer 2012. The AMPO study is discussed later in this section.

In 2006, VHB (2006) advised TPB staff not to begin full-scale adoption of an activity-based model, since, according to VHB, the technique was "not yet widely accepted" and there were still "numerous issues to be resolved"(Recommendation 94). VHB felt that, in order "to see both what data are used and what actions are considered for adjusting to data availability problems" with ABMs, TPB staff should review the validation effort planned for the DRCOG ABM and the SACOG ABM (Recommendation 95). Although not following this recommendation to the letter, TPB staff has followed the spirit of this recommendation by participating in the AMPO advanced modeling study, whose Task 1 report examined both the DRCOG and SACOG ABMs, among others (Vanasse Hangen Brustlin, Inc. et al., 2011).

Despite VHB's recommendation not to move to an ABM at this time, VHB (2006) nonetheless recommended that TPB staff "ensure that current data collection efforts include data that will allow transition to a tour or activity-based framework" (Recommendation 96). TPB staff concurs with this recommendation and has followed this advice. For example, the 2007/2008 COG Household Travel Survey was designed to feed either a trip-based model or an activity-based model.

Despite its admonition against making a "full-scale adoption" of ABMs, VHB (2006) did, however, indicate that TPB staff should *consider* beginning an incremental approach of moving towards an activity-based model, identifying three possible first steps (Recommendation 97):

- Convert trips from the latest household travel survey into tours, which could then be used to create a tour generation model.
    - **TPB staff response**: We have not yet acted on this recommendation.
- Develop a more detailed assignment procedure, similar to those used by NYMTC and MORPC.
    - **TPB staff response**: We do not fully understand this statement. Based on a recent TPB staff investigation, it appears that NYMTC is using 4 time-of-day periods and MORPC is using 24.
- Develop a population synthesizer, as is being done by ARC in Atlanta.
    - **TPB staff response**: We have not yet acted on this recommendation, although we recognize one of the benefits of developing a population synthesizer is that it could be used to "feed" either an existing trip-based travel model or an activity-based travel model. So, we are open to this idea, provided resources can be identified to fund the effort.

VHB (2006) recommended that "TPB may wish to consider formalizing a closer relationship with area universities to begin research into the development and application of an activity-based model for the Washington region" (Recommendation 98). We have tried to do this by encouraging local universities to participate in meetings of the Travel Forecasting Subcommittee. In the fall of 2008, TPB staff met with a professor at the University of Maryland and later added him to the TFS e-mail distribution list. In 2012, TPB staff has done some data requests for the University of Maryland and a graduate student from this school came to a TFS meeting to make contacts about transit-oriented development research.

Lastly, VHB (2006) indicated that TPB could participate in, and lead, if necessary, "a joint program with other MPOs that will keep abreast of the current status of activity-based models" (Recommendation 99). This is exactly what Ron Kirby did when he collaborated with AMPO to form the steering group for the AMPO Advanced Model Study, which released the final version of its Phase 1 report in July 2011 (Vanasse Hangen Brustlin, Inc. et al., 2011). This pooled research group consisted of 11 MPOs and the AMPO staff. A second phase of the research, funded primarily by FHWA, is currently underway.

In contrast to VHB, which was more guarded, CS was more sanguine about the benefits of TPB moving toward an ABM. For example, CS (2009) stated that "activity-based models are able to address the increasingly complex policy questions that are of concern for MPOs and state DOTs today that traditional four-step models cannot address." CS (2009) advised TPB to "put significant time and resources toward moving to an activity-based model" (also Recommendation 104). TPB staff would argue that the first statement ("activity-based models are able to address … that traditional four-step models cannot address") is an assertion that has yet to be proven. One of the goals of the AMPO pooled-research study of advanced models was to prove or disprove such statements. A synthesis done in 2010 found the following, "it is not clear that activity-based models are any better at replicating base-year traffic counts or transit volumes than traditional models. *The true advantage is that they are sensitive to a broader range of policies and can answer more complicated questions.*" (Donnelly et al., 2010, p. 33).

CS (2009) indicated that TPB staff need to decide whether to devote resources to improving the current trip-based travel model or to developing an activity-based travel model, adding that, at a minimum, "an early step should be the development of a work program for movement to an activity-based model framework"(Recommendation 100). TPB staff concurs that it needs to develop a long-term work program for planned improvements to the regional travel model and that such a work program should possibly include an activity-based model.

CS (2009) stated that TPB has the option of developing an ABM either all at once (sometimes called the "big bang" approach) or as a phased approach. CS recommended that TPB not use the phased approach, but conceded that it "may be a good option if sufficient funding is only available over time or if short-term products help get political support" (Recommendation 102). TPB staff notes that it does not currently have the funding to pursue a "big bang" approach, and may not even have the funding to pursue an incremental approach at this time. Staff is awaiting a reauthorization of the multi-year surface transportation act, which funds many MPO activities. The current act, SAFETEA-LU, expired in 2009. Instead of developing a new, multi-year act, SAFETEA-LU has been extended nine times, which means funding levels are not increasing over time. A recent synthesis also favored the idea of using an incremental approach to developing an ABM (Donnelly et al., 2010, p. 55).

In terms of budgeting for developing an ABM, CS (2009) advised TPB plan for implementation to take two to four years and cost $750,000 to $1,250,000 for consultant involvement, which would be about $250,000 to $450,000 per year, not including in-house staff costs and data collection (Recommendation 103). Unfortunately, TPB does not have the resources to follow this recommendation. At one time, TPB had developed a fund of about $250k for the purpose of getting into the development of an ABM, when staff had concluded that the time was right. Unfortunately, due to a funding rescission from the state of Maryland, this fund was "zeroed out" to make up for the loss in funding. Perhaps, in the future, if a new surface transportation act is developed, these funds can be restored.

CS (2009) recommended that TPB staff suspend making further updates to the trip-based model (other than those that are already underway), so that staff could devote time to developing an ABM (Recommendation 105). TPB staff notes that this is not currently a likely outcome. CS adds that, "if development of an activity-based model will not occur within the next few years, TPB should enhance their four-step model by updating every model component using the new 2008 household survey data, considering estimating destination and time-of-day choice models, and developing special generator models (again, Recommendation 105). TPB staff concurs with this latter recommendation and will attempt to include these enhancements into its long-term plan for models development. CS (2009) also recommended that TPB staff assess and create a timeline and budget for moving to an ABM (Recommendation 100 and also Recommendation 106). Again, TPB staff concurs with this recommendation.

Continuing on the subject of moving to an ABM, CS (2009) recommended that TPB staff focus on updating inputs to the modeling system, such as network time-of-day data and validation data, that will be useful for activity-based model development. Examples include creating network skims with greater temporal resolution and collecting detailed observed data that can be used for validation purposes (Recommendation 108). TPB staff has not yet acted upon this recommendation.

CS (2009) made two recommendations that are only applicable once we have decided to move forward with an ABM, so they do not require a response from TPB staff at this time:

- Recommendation 101: The SFCTA model uses five aggregate time periods for time-of-day choice; the more recent models use hour- or half-hour-long periods. TPB should consider using half-hour or hour-long periods, as shorter time periods allow for more options and flexibility when analyzing sensitivity to policy scenarios. (pp. 2-31 to 2-32)
- Recommendation 107: Based on Timeline, Budget, and Policy Needs, Decide on Broad Model Components and Model Development Process … especially with regard to the level of intrahousehold interactions, time-of-day choice placement, and whether to implement a standard trip assignment or incorporate some form of disaggregate traffic assignment (e.g., dynamic traffic assignment or microsimulation). (p. 2-34)

3 Conclusion and next steps

TPB has maintained a consultant-assisted project since FY 2006 to evaluate the travel demand forecasting practices used by the TPB in the Metropolitan Washington region. This project has frequently included focused research (or "scans") on the modeling practices and methods used by other MPOs across the U.S. Consequently, the project is often referred to as the "scan of best modeling practice." Now in its seventh year, the scanning project has resulted in seven consultant reports over the first six years of the project, from two consulting firms:

- Vanasse Hangen Brustlin, Inc. (VHB):
    - Results of FY 2006 Travel Forecasting Research (2006)
    - Results of FY 2007 Travel Forecasting Research (2007)
    - Expanded Evaluation of Peak Spreading (2008a)
    - Estimating the Impact of Exurban Commuters on Travel Demand (2008b)
- Cambridge Systematics, Inc. (CS):
    - Fiscal Year 2009 Task Reports, Final Report (2009)
    - Fiscal Year 2010 Task Reports, Final Report (2010)
    - Fiscal Year 2011 Task Reports, Final Report (2011)

The findings and recommendations from these consultant reports have been instrumental in guiding the TPB models development program. As discussed later, in some cases, we have implemented the consultant recommendations; in other cases, we have not. However, up to now, TPB staff had not issued a formal report documenting the TPB staff response to these consultant recommendations. This report represents the TPB staff response to consultant recommendations received in the first six years of this project. This report will be used to update the TPB models development work plan.

Table 2 on page 66 categorizes the over 100 recommendations into nine categories such as:

- TPB staff agrees with recommendation: Recommendation implemented
- TPB staff agrees with recommendation: Recommendation partially implemented
- TPB staff agrees with recommendation: Planned for short-term update
- TPB staff agrees with recommendation: Planned for long-term update

For example, TPB staff has already fully or partially implemented about 31 (= 19 + 12) of the consultant recommendations, which is about 30% of the 104 recommendations.[5] Similarly, TPB staff agrees with another 16 of the recommendations (about 15%) and is suggesting they should form part of a short-term or long-term models development plan. There are 23 recommendations (about 22%) that the TPB staff agrees with, in principal, but feels more investigation/review is needed before committing to their development. A similar number of recommendations (25, or about 24%) are categorized as being "not

[5] Four of the recommendations (#35, 51, 101, and 107) were deemed "not applicable," so they have been removed from the total used to calculate percentages. For example, CS (2009) made a recommendation (Recommendation 51) to test a hybrid assignment approach that could involve using an incremental assignment, but, in its 2010 report, CS indicated that TPB staff should no longer consider testing this hybrid assignment.

acted on yet," which indicates that TPB staff is either uncertain of the merits of the recommendation or has concerns that need to be addressed before making a determination. There were only seven recommendations (about 7%) that the TPB staff indicated that they did not agree with, and are, hence, unlikely to implement.

One of the key observations noted during the assessment of consultant recommendations was that more attention and resources must be devoted to the collection of hourly traffic volumes. It is recognized that more time-of-day data is critical for supporting many of the recommendations that have not yet been addressed. In fact, an increased sample of hourly volume data would benefit the validation of TPB's existing Version 2.3 Travel Model.

Table 3 on page 67 cross categorizes recommendations by modeling topic and recommendation/implementation status, using the same nine status categories as Table 2. The numbers in the table correspond to the recommendation numbers in the report. So, for example, looking at the row labeled "trip generation," we can see that there were three recommendations (#8, 9, and 10) falling in three different status designations:

- #8: TPB staff agrees with recommendation, and it has been implemented;
- #10: TPB staff agrees with recommendation, and it has been partially implemented;
- #9: TPB staff does not agree with the recommendation.

In some cases, a recommendation occurs twice in Table 3. For example, Recommendation 32 is on the subject of "Time-of-day/peak spreading," but it is also related to (cross referenced with) "Data collection and surveys." The recommendation number appears in parentheses when it is the cross-referenced instance of the number.

Using Table 3, one can see topical trends in the recommendations. For example, in the area of traffic assignment, one can see that TPB staff has implemented or partially implemented nine recommendations, but there are also three that staff agrees with, but require more review before proceeding. And there are three recommendations on which that TPB staff has not yet made a determination ("not yet acted upon"). According to Table 3, the category of "special generators" has the largest number (five) of recommendations that are planned for long-term models development. The last observation is about ABMs. Although there is a trend at many larger MPOs of moving toward adoption of ABMs, TPB staff continues to be uncertain that the benefits of such a move outweigh the costs. Nonetheless, the TPB staff would benefit from making a long-term (ca. five-year) plan for models development, and ABMs are likely to play some part on such a plan. Since starting to work with an ABM will likely require consultant assistance, funding is a major determinant on when such a move might be feasible. Unfortunately, the prognosis for enhanced funding for new initiatives, such as developing an ABM, has not been good. For example, the latest surface transportation legislation, SAFETEA-LU,[6] is now on its ninth short-term extension, and prospects for a new multi-year authorization of the law do not look good at the present time.

[6] Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users

Nonetheless, staff is now in a position to move accepted recommendations into a multi-year work program. Staff would also like to make determinations on some of the recommendations that currently fall in the “more review needed” and “not yet acted on” categories. Staff intends to work with the Travel Forecasting Subcommittee in formalizing the work program.

TPB staff plans to continue the existing consultant-assisted project to make sure that a review of the TPB’s travel modeling process, and recommendations for refinement, is ongoing. One of the lessons learned from this current exercise is that TPB staff should not wait another six years before writing the next such report. Consequently, moving forward, staff intends to provide responses to consultant recommendations on an annual or biannual basis.

Table 2 Status of consultant recommendations received over the first six years of the scanning project

	Status category	**Recommendation number**	**Total number of rec's**
1	TPB staff agrees w/ recommendation: Recommendation implemented	1, 5, 6, 8, 20, 34, 41, 47, 48, 49, 50, 54, 67, 69, 85, 92, 94, 96, 99,	19
2	TPB staff agrees w/ recommendation: Recommendation partially implemented	10, 16, 17, 18, 19, 42, 44, 46, 52, 70, 81, 98	12
3	TPB staff agrees w/ recommendation: Planned for short-term update	13, 25, 28, 83	4
4	TPB staff agrees w/ recommendation: Planned for long-term update	14, 32, 63, 64, 65, 66, 68, 72, 79, 84, 100, 106	12
5	TPB staff agrees w/ recommendation: More review needed	2, 3, 12, 15, 26, 38, 43, 45, 53, 59, 60, 73, 78, 80, 82, 86, 87, 89, 91, 95, 104, 102, 103	23
6	TPB staff has not yet acted on this recommendation	7, 21, 22, 23, 24, 30, 31, 33, 36, 39, 40, 55, 56, 58, 61, 62, 71, 74, 75, 76, 88, 90, 93, 97, 108	25
7	TPB staff does not agree w/ recommendation	4, 9, 29, 37, 57, 77, 105	7
8	TPB staff agrees with some of the recommendation, but not all	11, 27	2
9	Recommendation does not currently apply	35, 51, 101, 107	4
		Total	**108**
		Total excluding rec's that do not apply	**104**

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Table 3 Recommendation topics by status

Section & Modeling Topic	Status								
	TPB staff agrees with the recommendation								
	Recomm. implemented	Recomm. partially iImplement	Planned for short-term	Planned for long-term	More review needed	Not yet acted upon	Does not agree w/ recomm.	Partial agreement	Recomm. does not apply
	1	2	3	4	5	6	7	8	9
Input data									
Data collection and surveys				(32)		(58)			
Inputs to the travel model	1								
External and through travel					2, 3		4		
Socio-economic models						(74)			
Fuel prices in travel models	5, 6								
Effects of an aging population on travel						7			
Improvements to the trip-based model									
Trip generation	8	10					9		
Trip distribution and destination choice			13	14	12, 15			11	
Mode choice		16, 17, 18							
Modeling transit	20	19	25,28		26	21,22,23,24		27	
Time-of-day/peak spreading	34			32		30,31,33	29		35
Traffic assignment	41,47,48,49,50	42,44,46,52			38,43,45	36,39,40	37		51
Speed feedback in the travel model	54				53	55,56			
Modeling HOT/managed lanes					59,60	58,61	57		
Special generators, including modeling airport access trips	67			63,64,65,66,68		62			
Modeling non-motorized (walk and bike) trips	69	70		72		71			
Model sensitivity to land use policies such as smart growth				79	73,78,80	74,75,76	77		
Sensitivity testing of the regional travel model		81							
Screenlines/cutlines			83	84	82				
Value of time									
Trip purposes	85				86,87				
Software issues and reducing run times									
Reducing model run times					89	88,09			
Review of travel demand forecasting software packages					91				
Review of TPB’s travel modeling scripts	92					93			
Activity-based models (ABMs)	94,96,99	98		100,106	95,102,103,104	97,108	105		101,107

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4 References

AECOM Consult, Inc. (2005). *Post MWCOG – AECOM Transit Component of Washington Regional Demand Forecasting Model: User's Guide*. AECOM Consult, Inc.

AECOM Consult, Inc. (2006). *CALIBMS: Nested Mode Split Model Constant Calibrator for AEMS (AECOM Consult Mode Choice Computation Programs), Users Guide* (Draft report). AECOM Consult, Inc.

AECOM Consult, Inc. (2008, November). VRE Haymarket Extension Model Update. Technical Memorandum.

Allen, W. G., Jr., & Schmitt, D. (2005). *Using Your Model Effectively*. Presented at the 10th Transportation Research Board National Transportation Planning Applications Conference, held April 24-28, 2005, Portland, Oregon. Retrieved from http://www.williamgallen.com/UsingModelEffectively2005.pdf

Bellomo-McGee, Inc. (1996). *Intermodal Ground Access to Airports: A Planning Guide* (No. DOT-T-97-15). Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration and Federal Aviation Administration. Retrieved from http://ntl.bts.gov/DOCS/AGAPP.html

Cambridge Systematics, Inc. (2009). *Fiscal Year 2009 Task Reports* (Final Report). Washington, D.C.: National Capital Region Transportation Planning Board. Retrieved from http://www.mwcog.org/transportation/activities/models/review.asp

Cambridge Systematics, Inc. (2010). *Fiscal Year 2010 Task Reports* (Final Report). Washington, D.C.: National Capital Region Transportation Planning Board. Retrieved from http://www.mwcog.org/transportation/activities/models/review.asp

Cambridge Systematics, Inc. (2011). *Fiscal Year 2011 Task Reports* (Final Report) (p. 78). Washington, D.C.: National Capital Region Transportation Planning Board. Retrieved from http://www.mwcog.org/transportation/activities/models/review.asp

Citilabs, Inc. (2011). *Cube Voyager Reference Guide, Version 5.1.3*. Citilabs, Inc.

City of Calgary. (2006). *City of Calgary 2001 Regional Transportation Model, Volume II: Commercial Vehicle Model Description* (p. 48). Calgary, Alberta, Canada: Forecasting Division, Transportation Planning, Transportation Department, City of Calgary. Retrieved from http://www.calgary.ca/DocGallery/BU/trans_planning/forecasting/calgary_commercial_vehicle_model_description_report.pdf

Donnelly, R., Erhardt, G. D., Moeckel, R., & Davidson, W. A. (2010). *NCHRP Synthesis 406: Advanced Practices in Travel Forecasting*. National Cooperative Highway Research Program, A Synthesis of Highway Practice. Washington, D.C.: Transportation Research Board of the National Academies. Retrieved from http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_406.pdf

Ewing, R., & Bartholomew, K. (2009). Comparing Land Use Forecasting Methods: Expert Panel Versus Spatial Interaction Model. *Journal of the American Planning Association*, *75*(3).

Federal Transit Administration. (2006a). Calibration and Validation of Travel Models for New Starts Forecasting, Discussion Piece #16. Presented at the Workshop on Travel Forecasting for New Starts Proposals, Minneapolis, Minnesota. Retrieved from http://www.fta.dot.gov/planning/newstarts/planning_environment_5402.html

Federal Transit Administration. (2006b). Ridership and User Benefits from Variable Trip Tables, Discussion Piece #4. Presented at the Workshop on Travel Forecasting for New Starts Proposals, Minneapolis, Minnesota. Retrieved from http://www.fta.dot.gov/planning/newstarts/planning_environment_5402.html

Federal Transit Administration. (2006c). Evaluation of Highway Capacity Congestion Relief Benefits, Discussion Piece #3. Presented at the Workshop on Travel Forecasting for New Starts Proposals, Minneapolis, Minnesota. Retrieved from http://www.fta.dot.gov/planning/newstarts/planning_environment_5402.html

Federal Transit Administration. (2006d, June). *Travel Forecasting for New Starts*. Presented at the Travel Forecasting for New Starts Proposals Workshop, Minneapolis, Minnesota. Retrieved from http://www.fta.dot.gov/documents/Presentation_1.pdf

Goldfarb, D., & Spielberg, F. (2005). Does the Emperor Have Clothes? A Comparative Evaluation of Assignment Techniques. Presented at the 10th Transportation Research Board National Transportation Planning Applications Conference, held April 24-28, 2005, Portland, Oregon: Unpublished. Retrieved from http://www.vhb.com/SiteObjects/published//4FCC5B454FF7253000FE9B66206DA365/4FCC5B4502945C6B01072E2CB53C412A/file/TDFM%20assignment%20tech%20evaluation.pdf

Griffiths, R. E. (2009, May 20). *2007/2008 TPB Household Travel Survey: Major Findings for Regional Activity Centers/Clusters*. Presented at the National Capital Region Transportation Planning Board, Washington, D.C.

Hartgen, D. T., & San Jose, E. (2009). *Costs and Trip Rates of Recent Household Travel Surveys*. Charlotte, North Carolina: The Hartgen Group. Retrieved from http://www.hartgengroup.net/Projects/National/USA/household_travel_summary/2009-11-11_Final_Report_Revised.pdf

Hicks, J. E. (2008). Dynamic Traffic Assignment Model Breakdown. *Conference Proceedings 42, Innovations in Travel Demand Modeling, Summary of a Conference* (Vol. 2, Papers, pp. 101–108). Presented at the Innovations in Travel Demand Modeling, May 21-23, 2006, Austin, Texas: Transportation Research Board of the National Academies.

Martchouk, M. (2011, October 11). Cube Cluster Testing. Memorandum.

Metropolitan Washington Council of Governments. (2007). *Metropolitan Washington Regional Activity Centers and Clusters* (No. 20078299). Washington, D.C.: Metropolitan Washington Council of Governments (COG).

Metropolitan Washington Council of Governments. (2011, August 18). Contract no. 12-006, a contract between the Metropolitan Washington Council of Governments and AECOM Technical Services, Inc. for assistance with the development and application of the National Capital Region Transportation Planning Board travel demand model.

Miller, J., Fitch, G., Dougald, L., Kreissler, S., & Hill, D. (2005). Surprises from a Field Validation of Speed Estimation Techniques for Air Quality Conformity Analysis. *Transportation Research Record: Journal of the Transportation Research Board*, (1941), 72–80. doi:10.3141/1941-09

Milone, R. (2001, January 11). COG/TPB Transportation Planning Software Migration. Memorandum.

Milone, R. (2007, March 23). *Version 2.2 Travel Demand Model Sensitivity Analysis*. Presented at the March 23, 2007 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.

Milone, R. (2010a, January 22). *2007/08 Household Travel Survey, Preliminary Trip Generation Analysis for the Region and at Activity Centers*. Presented at the January 22, 2010 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.

Milone, R. (2010b, September 17). *Development of New Time-of-Day Model using the 2007/08 HTS*. Presented at the September 17, 2010 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.

Milone, R. (2011a, July 1). Version 2.3 Exogenous Trip Files. Memorandum.

Milone, R. (2011b, September 23). *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.

Milone, R. (2012a, March 23). *Version 2.3 Travel Model: Status report and use in project planning studies*. Presented at the March 23, 2012 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.

Milone, R. (2012b, March 27). Round 8.1-Based Exogenous Travel Files. Memorandum.

Milone, R., Humeida, H., Martchouk, M., Moran, M., & Seifu, M. (2012a). *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. Retrieved from http://www.mwcog.org/transportation/activities/models/documentation.asp

Milone, R., Humeida, H., Martchouk, M., Moran, M., & Seifu, M. (2012b). *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. Retrieved from http://www.mwcog.org/transportation/activities/models/documentation.asp

Milone, R., Humeida, H., Moran, M. S., & Seifu, M. (2007). *FY-2007 Development Program for TPB Travel Forecasting Models* (Draft). Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board (COG/TPB).

Milone, R., Humeida, H., Moran, M. S., & Seifu, M. (2009). *FY-2009 Development Program for TPB Travel Forecasting Models* (Draft report). Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board.

Milone, R., Humeida, H., Moran, M., & Seifu, M. (2008). *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. Retrieved from http://www.mwcog.org/transportation/activities/models/documentation.asp

Milone, R., & Moran, M. S. (2008, November 21). *TPB Models Development Status Report*. Presented at 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.

Milone, R., & Moran, M. S. (2010, November 19). *Version 2.3 Travel Model on the 3,722-TAZ area system: Traffic assignment of observed trips*. Presented at the November 19, 2010 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.

Milone, R., & Moran, M. S. (2011, July 22). *TPB Version 2.3 travel model on the 3,722-TAZ area system: Status report and sensitivity tests*. Presented at the July 22, 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.

Milone, R., & Seifu, M. (2007, May 18). *Version 2.2 Travel Model Sensitivity Analysis*. Presented at the May 18, 2007 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.

Milone, R., & Zilliacus, C. P. (2000, November 7). Software Migration Review. Memorandum.

Moran, M. S. (2008a, June 3). Sensitivity tests of the Version 2.3 travel model: Changes in fares. Memorandum.

Moran, M. S. (2008b, November 16). Sensitivity analyses of the Version 2.3 travel model: Fare elasticities. Memorandum.

Moran, M. S. (2010, October 21). Choosing the breakpoints for and duration of time-of-day periods used in the Version 2.3 travel model. Memorandum.

National Capital Region Transportation Planning Board. (2003). *Descriptions of Proposed Work Elements for the TPB Models Development Program to a) Address Concerns Raised by the TRB Committee's First Letter Report b) Advance the State of Modeling Practice in the Metropolitan Washington Region*. Washington, D.C.: National Capital Region Transportation Planning Board.

National Center for Smart Growth Research and Education, University of Maryland, & Parsons Brinckerhoff. (2011). *Maryland Statewide Transportation Model (MSTM), Training Manual*. Baltimore, Maryland: Maryland State Highway Administration.

Park, J. (2008, December 2). Two Step Traffic Assignment for HOT Lane Modeling in 2008 CLRP. Memorandum.

Schmitt, D., & Kumar, A. (2008, September 15). *Using Cube for Transit Project Planning and New Starts*. Training Class presented at the Metropolitan Washington Council of Governments, Washington, D.C.

Slavin, H. (2007). *Achieving planning model convergence*. Presented at the 11th National Transportation Planning Applications Conference, May 6-10, 2007, Daytona Beach, Florida. Retrieved from http://trb-appcon.org/2007conf/program.html

Snead, R., Milone, R., Hamlin, M. S., Davis, J., Seifu, M., & Martchouk, M. (2010). *FY-2010 Network Documentation: Highway and Transit Network Development* (Draft). Washington, D.C.: National Capital Region Transportation Planning Board.

Transportation Research Board's Committee for Review of Travel Demand Modeling by the Metropolitan Washington Council of Governments. (2003, September 8). First letter report. Retrieved from http://www.mwcog.org/transportation/activities/models/review.asp

Transportation Research Board's Committee for Review of Travel Demand Modeling by the Metropolitan Washington Council of Governments. (2004, May 10). Second letter report. Retrieved from http://www.mwcog.org/transportation/activities/models/review.asp

U.S. Energy Information Administration. (2012). Short-Term Energy Outlook - U.S. Energy Information Administration (EIA), Real Prices Viewer. Retrieved February 28, 2012, from http://www.eia.gov/forecasts/steo/realprices/

Vanasse Hangen Brustlin, Inc. (2006). *Results of FY 2006 Travel Forecasting Research*. Washington, D.C.: National Capital Region Transportation Planning Board, Metropolitan Washington Council of Governments. Retrieved from http://www.mwcog.org/transportation/activities/models/review.asp

Vanasse Hangen Brustlin, Inc. (2007). *Results of FY 2007 Travel Forecasting Research*. Washington, D.C.: National Capital Region Transportation Planning Board, Metropolitan Washington Council of Governments. Retrieved from http://www.mwcog.org/transportation/activities/models/review.asp

Vanasse Hangen Brustlin, Inc. (2008a). *Expanded Evaluation of Peak Spreading*. Washington, D.C.: National Capital Region Transportation Planning Board, Metropolitan Washington Council of Governments. Retrieved from http://www.mwcog.org/transportation/activities/models/review.asp

Vanasse Hangen Brustlin, Inc. (2008b). *Estimating the Impact of Exurban Commuters on Travel Demand*. Washington, D.C.: National Capital Region Transportation Planning Board, Metropolitan Washington Council of Governments. Retrieved from http://www.mwcog.org/transportation/activities/models/review.asp

Vanasse Hangen Brustlin, Inc., Resource Systems Group, Inc., Shapiro Transportation Consulting, LLC, & Urban Analytics. (2011). *Advanced Travel Modeling Study* (Final Report). Association of Metropolitan Planning Organizations. Retrieved from http://www.ampo.org/assets/1307_ampotravelmodelingstudyfi.pdf

Vuksan, D., & Xie, F. (2011, June 20). Traffic Assignment Convergence - Results of the Version 2.3 Sensitivity Analyses, Draft. Memorandum.