Exhibit B

Metropolitan Washington Council of Governments (COG)
National Capital Region Transportation Planning Board (TPB)

Product Requirements Document for the TPB Travel Demand Forecasting Model, Generation 3, the Next-Generation Model

To be submitted with the Request for Information (RFI) for consultant services

May 25, 2018

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National Capital Region
Transportation Planning Board

Product Requirements Document for the TPB Travel Demand Forecasting Model, Generation 3, the Next-Generation Model

May 25, 2018

About the TPB

The National Capital Region Transportation Planning Board (TPB) is the federally designated metropolitan planning organization (MPO) for metropolitan Washington. It is responsible for developing and carrying out a continuing, cooperative, and comprehensive transportation planning process in the metropolitan area. Members of the TPB include representatives of the transportation agencies of the states of Maryland and Virginia and the District of Columbia, 23 local governments, the Washington Metropolitan Area Transit Authority, the Maryland and Virginia General Assemblies, and nonvoting members from the Metropolitan Washington Airports Authority and federal agencies. The TPB is staffed by the Department of Transportation Planning at the Metropolitan Washington Council of Governments (COG).

About COG

The Metropolitan Washington Council of Governments (COG) is an independent, nonprofit association that brings area leaders together to address major regional issues in the District of Columbia, suburban Maryland, and Northern Virginia. COG's membership is comprised of 300 elected officials from 23 local governments, the Maryland and Virginia state legislatures, and U.S. Congress.

Credits

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1 Introduction

The National Capital Region Transportation Planning Board (NCRTPB or simply TPB) is the federally designated Metropolitan Planning Organization (MPO) for the Washington, D.C. metropolitan area. The TPB is also one of several policy boards that operate at the Metropolitan Washington Council of Governments (MWCOG or simply COG). COG is the administrative agent for the TPB, and the TPB is staffed by COG's Department of Transportation Planning (DTP). The TPB staff, with some consultant assistance, develops, maintains, applies, and improves the TPB's family of regional travel demand forecasting models, which are used for regional, long-range transportation planning in the metropolitan Washington region. These regional travel demand models are developed under the guidance of the Travel Forecasting Subcommittee (TFS), a subcommittee of TPB's Technical Committee.

At any given time, the TPB staff is maintaining at least two models:

- The adopted, production-use travel model and
- One or more developmental travel models, which may become production-use model(s) in the future.

The production-use model is the one that is used in planning studies conducted by COG/TPB and is made available to outside parties.[1] The developmental models are those that are currently under development by TPB staff, and, in some cases, consultants under contract with COG. The developmental models are generally not made available to outside parties, since these models are not yet considered finished products. The adopted, production-use, regional travel model is used by TPB staff for many planning activities, including the following:

- Development of the TPB's regional long-range transportation plan (LRTP), currently known as "Visualize 2045."
- Evaluation of the performance of the LRTP.
- Air quality conformity analysis and determination of the LRTP and its associated Transportation Improvement Program (TIP).
- Scenario studies, i.e., changes in forecasted land use and/or transportation networks.
- Transportation project planning studies.

Many project planning studies are conducted by consultants, but TPB staff also perform some of these, typically under the TPB's Technical Assistance programs, set up for the District, Maryland, Virginia, and the Washington Metropolitan Area Transit Authority (WMATA or Metro).

2 Purpose

The purpose of this document is to serve as a product requirements document (PRD) for the TPB Travel Demand Forecasting Model, Generation 3 (TPB TDFM Gen3), also currently known as the TPB Next-Generation (NextGen) travel model. This document presents the functionality that is sought by

[1] The procedures for requesting the model can be found on the "Data Requests" webpage (https://www.mwcog.org/transportation/data-and-tools/modeling/data-requests/).

TPB staff in the Gen3 model. This document will be part of the request for information (RFI) that is issued to seek consultant assistance. The RFI is to be followed by a request for proposals (RFP).

It is expected that the Gen3 model will use one of the following model forms:

- Trip-based
- Tour-based
- Activity-based
- Hybrid of these

The current TPB travel model is a trip-based model (see Section 3, "Background"). Trip-based models have been widely used since the 1970s. They are the most common type of regional travel demand model. However, academics and others have pointed to shortcomings with these models.[2] Over the last 10-15 years, many large urban areas are moving toward activity-based models (ABMs), which have some theoretical advantages over trip-based models, but also added complexity and cost.[3] Tour-based models chain daily trips into one or more tours. All ABMs are tour-based models, but not all tour-based models are ABMs. Purely tour-based models are not as common as ABMs, but there are some examples in the U.S.[4] Lastly, another model form that is gaining some traction is the hybrid model, which includes elements of both aggregate, trip-based models and disaggregate ABMs.[5]

2.1 RFI process

The RFI process has two goals. First, to solicit input from interested vendors/consultants about their proposed solution to our modeling needs, as described in this PRD. **Second, to help COG/TPB staff decide on the preferred direction for model upgrades that will be specified in the upcoming RFP.** COG, working as the administrative agent for the TPB, will issue the RFI. When the RFI and PRD are ready, they will be posted on COG's Contracts and Purchasing website (https://www.mwcog.org/purchasing-and-bids/cog-bids-and-rfps/). After that, the RFI and PRD will be posted on the Mid-Atlantic Purchasing Team (MAPT) website (www.midatlanticpurchasing.net). Vendors interested in following RFIs/RFPs should go to the MAPT website and register on the vendor registration system (VRS) and sign up for automatic notifications about new postings. In response to the RFI, vendors may choose to submit to COG a

[2] Transportation Research Board, Committee for Determination of the State of the Practice in Metropolitan Area Travel Forecasting, "Special Report 288, Metropolitan Travel Forecasting: Current Practice and Future Direction" (Washington, D.C.: Transportation Research Board of the National Academies, 2007), http://onlinepubs.trb.org/onlinepubs/sr/sr288.pdf.

[3] See, for example, Joe Castiglione, Mark Bradley, and John Gliebe, "Activity-Based Travel Demand Models: A Primer," SHRP 2 Capacity Project C46 (Washington, D.C.: Transportation Research Board of the National Academies, 2015), http://www.trb.org/main/blurbs/170963.aspx.

[4] See, for example, Parsons Brinckerhoff Quade & Douglas, Inc., "New York Best Practice Model (NYBPM)," General Final Report, Transportation Models and Data Initiative (New York, New York: New York Metropolitan Transportation Council, January 30, 2005), http://www.nymtc.org/project/bpm/model/bpm_finalrpt.pdf; William G. Allen Jr., "Simplified Tour-Based Model," July 26, 2017.

[5] See, for example, Vincent Bernardin, "The Spectrum of Model Designs," March 28, 2018; Gaurav Vyas et al., "Stepping Closer to ABM: Hybrid 4-Step Models," Pre-Print Paper Submitted for Presentation at the 97th Annual Meeting of the Transportation Research Board, January 2018, and/or Publication in the Transportation Research Record (Transportation Research Board 97th Annual Meeting, January 7-11, 2018, Washington, D.C., 2017), Paper #18-05303.

“vendor response,” which is essentially a proposed plan for the TPB Gen3 travel demand forecasting model (TDFM). The vendor response to this RFI will consist of two items:

1. A concise report that explains and justifies the vendor’s proposed approach for the TPB’s Gen3 travel demand forecasting model.
2. A completed model checklist that describes the vendor’s proposed approach for the TPB’s Gen3 travel demand forecasting model. A blank copy of the model checklist will be provided along with the PRD.

More details about these two items can be found in section 7 of this report (“Deliverables”). In general, however, the checklist will provide a short summary of the proposed plan and the report will allow the vendor the opportunity to further describe and support the responses in the checklist, and to present additional information that the vendor feels is relevant.

The RFI is meant to be an information-gathering period, where TPB staff may follow up with one or more vendors about proposed modeling solution(s). As mentioned later in this report, the RFI is <u>not</u> being used for pre-qualification in the RFP, i.e., vendors are not required to respond to the RFI in order to respond to the upcoming RFP. However, it is believed that vendors who participate in the RFI will be in a more informed position to provide a compelling proposal in the RFP stage. The RFI process is described in more detail later in this report.

2.2 RFP process

After the RFI process is completed, TPB staff plans to choose a selected modeling approach (e.g., trip-based, tour-based, activity-based, or hybrid), and then issue an RFP for consultant assistance to develop a model, based on the chosen approach. The RFP will include a scope of work (SOW). **The goal of the RFP process is to select one or more vendors/consultants to develop the Gen3 travel demand model**. More discussion about the RFI and RFP processes can be found in section 4.1 (“Overview and timeline for the RFI and RFP”).

2.3 Categorization of functional and usability requirements in the PRD

In the PRD, each requirement or specification (“spec”) is rated by TPB staff as follows:

- Mandatory or non-mandatory: Mandatory requirements must be met to have a satisfactory model. For non-mandatory items, consultants may propose which requirements should be part of an updated travel model.
- Priority: For non-mandatory requirements, TPB staff has generally rated each requirement as having one of three priority levels: High, medium, and low. Given limits on time and resources, consultants may need to propose an updated model that includes only a subset of the non-mandatory requirements. The three priority levels will help consultants choose which requirements/updates to include in their proposal for the Gen3 model. The priority values indicated in the RFI process could shift somewhat in the RFP process, depending on consultant input in the RFI.

3 Background

3.1 COG's Department of Transportation Planning (DTP)

As noted earlier, COG's Department of Transportation Planning (DTP) provides the staff to the National Capital Transportation Planning Board (TPB). COG has about 120 staff, and DTP staff (TPB staff) comprises about half the COG staff and about two-thirds of the COG budget. Like all MPOs, the TPB develops a Unified Planning Work Program (UPWP). The most recent UPWP can be found on the COG website (https://www.mwcog.org/transportation/plans/upwp/).

DTP is divided into five programmatic teams. One of these deals with travel demand forecasting: the Travel Forecasting and Emissions Analysis Team, headed by Ron Milone. This team has 16 employees, including its program director. Fourteen of these employees work in the following two groups:

- Model Development Group, headed by Mark Moran (6 staff)
- Model Application Group, headed by Dusan Vuksan (8 staff)

The mission of the Model Development Group is to develop, maintain, and improve the TPB's regional travel demand forecasting model. This is often done with some consultant support, though no consultant is currently under contract. The mission of the Model Application Group is to apply the TPB's regional travel demand model, for example to conduct the air quality conformity analysis of the LRTP and TIP, and to conduct project planning studies.

3.2 Model development by TPB staff and consultants

TPB staff has a long history of developing regional travel demand models for use in the long-range transportation planning activities in the metropolitan Washington region, spanning back to the 1970s, when TPB staff used federally developed travel demand forecasting software, known as the Urban Transportation Planning System (UTPS). UTPS was designed to run on a mainframe computer and was developed by the federal government.[6] In the late 1970s and the 1980s, TPB staff developed and used a travel forecasting software package known as TRIMS,[7] which was compatible with UTPS and ran on a mainframe computer. At about the same time, in the 1980s, the federal government decided to stop developing and supporting travel demand forecasting software. Instead, the federal government encouraged private vendors to develop travel demand forecasting software for personal computers.

The first TPB travel demand model for a personal computer was developed by TPB staff in the early 1990s and was implemented in MINUTP.[8] Following that initial model, TPB staff developed a series of travel demand forecasting models that ran on personal computers (and later computer servers). One of the first of these was developed in 1994 by TPB staff.[9] Although it did not have a specific name when it

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[6] UTPS was developed by the U.S. Urban Mass Transit Administration (UMTA) -- now known as the Federal Transit Administration (FTA) -- and the Federal Highway Administration (FHWA).

[7] William W. Mann, "TRIMS - Four Steps: One Execution," *ITE Journal* 52, no. 12 (December 1982): 13–18, http://www.ite.org/membersonly/itejournal/pdf/JLA82A13.pdf.

[8] "Application of COG/TPB Travel Modeling Procedures within the MINUTP Microcomputer Environment," Project Report (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, October 1990).

[9] Ronald Milone, "FY-94 Development Program for MWCOG Travel Forecasting Models, Volume A: Current Applications," Draft (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, June 30, 1994).

was developed, this model later became known as the "Version 1" model (see the first row of Table 1). This model was developed from about 1989 to 1994, and was used in production from about 1994 to 2001. The model was estimated using the 1987-1988 COG Home Interview Survey and other related data sets.

Following the "Version 1" model came a series of models in the "Version 2" model family. We are now also referring to this family as "Generation 2" or Gen2. First, there was the Version 2.0 model, which continued to use MINUTP software. Next, the Version 2.1 model was developed. For this model, TPB staff migrated the model application software, from MINUTP to TP+.[10] This was followed by the Ver. 2.2 model and the Ver. 2.3 model. Each of these is listed in Table 1.

3.2.1 Current TPB travel model

The current adopted, production-use travel demand forecasting model is called the TPB Travel Demand Forecasting Model, Generation 2, Version 2.3.70 (TPB TDFM Gen2, Ver. 2.3.70). This is shown in bold in Table 1. The Ver. 2.3 model was calibrated to year-2007 conditions [11] and was validated to year-2010 conditions.[12] The Ver. 2.3 model has a user's guide that is updated on a regular basis, and the latest guide was developed in November 2017.[13] The modeled area for the Ver. 2.3 travel model is shown in Figure 1. The modeled area includes 6,800 square miles, and covers the District of Columbia, suburban Maryland, Northern Virginia, and one county in West Virginia (see Figure 1).

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[10] Ronald Milone, "Version 2.1/TP+ Travel Model Calibration Report" (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, November 15, 2002).

[11] Ronald Milone et al., "Calibration Report for the TPB Travel Forecasting Model, Version 2.3, on the 3,722-Zone Area System," Final Report (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, January 20, 2012), https://www.mwcog.org/transportation/data-and-tools/modeling/model-documentation/.

[12] Ronald Milone to Files, "2010 Validation of the Version 2.3 Travel Demand Model," Memorandum, June 30, 2013.

[13] Ronald Milone, Mark Moran, and Meseret Seifu, "User's Guide for the COG/TPB Travel Demand Forecasting Model, Version 2.3.70: Volume 1 of 2: Main Report and Appendix A (Flowcharts)" (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, November 28, 2017), https://www.mwcog.org/transportation/data-and-tools/modeling/model-documentation/.

Table 1 Naming conventions for the TPB travel demand forecasting model (TDFM): Past, current, and future

Model Type	Name	Unit of Analysis	Ver. #	Build #	Approx. Time Period Develop-ment	Approx. Time Period Production Use	Strategic Plan	Estima-tion Data (1)
Production (past)	TPB TDFM, Generation 1	Trip	1.0	N/A	1989-1994	1994-2001	N/A	1987
Production (past)	TPB TDFM, Generation 2 (Gen2)	Trip	2.0	N/A	2000-2001	2001-2002	N/A	1994
Production (past)	TPB TDFM, Generation 2	Trip	2.1	N/A	2002	2002-2008	N/A	1994
Production (past)	TPB TDFM, Generation 2	Trip	2.2	N/A	2008	2008-2011	N/A	2007
Production (current)	**TPB TDFM, Generation 2**	**Trip**	**2.3**	**70**	**2008-2011**	**2011-2019**	**N/A**	**2007**
Developmental (current)	TPB TDFM, Generation 2	Trip	2.5	N/A	2017-2019	2019-2021	Phase 1	2007
Developmental (future)	TPB TDFM, Generation 3 (Gen3)	TBD (2)	3.0	N/A	2019-2021	2021-2023	Phase 2	2007
Developmental (future)	TPB TDFM, Generation 4 (Gen4)	TBD (2)	4.0	N/A	2022-2023	2023-2026	Phase 3	2017

(1) Estimation data:

1987 => 1987-1988 COG Home Interview Survey and other associated data sets.

1994 => 1994 COG Household Travel Survey and other associated data sets.

2007 => 2007/2008 COG Household Travel Survey and other associated data sets, such as transit on-board surveys.

2017 => 2017/2018 COG Regional Travel Survey and other associated data sets, such as transit on-board surveys. Expected to be ready for model estimation in 2019 or 2020.

(2) TBD: To be determined: Unit of analysis could be trip, tour, activity, or a hybrid combination of these.

Figure 1 Modeled area for the TPB Ver. 2.3 travel model

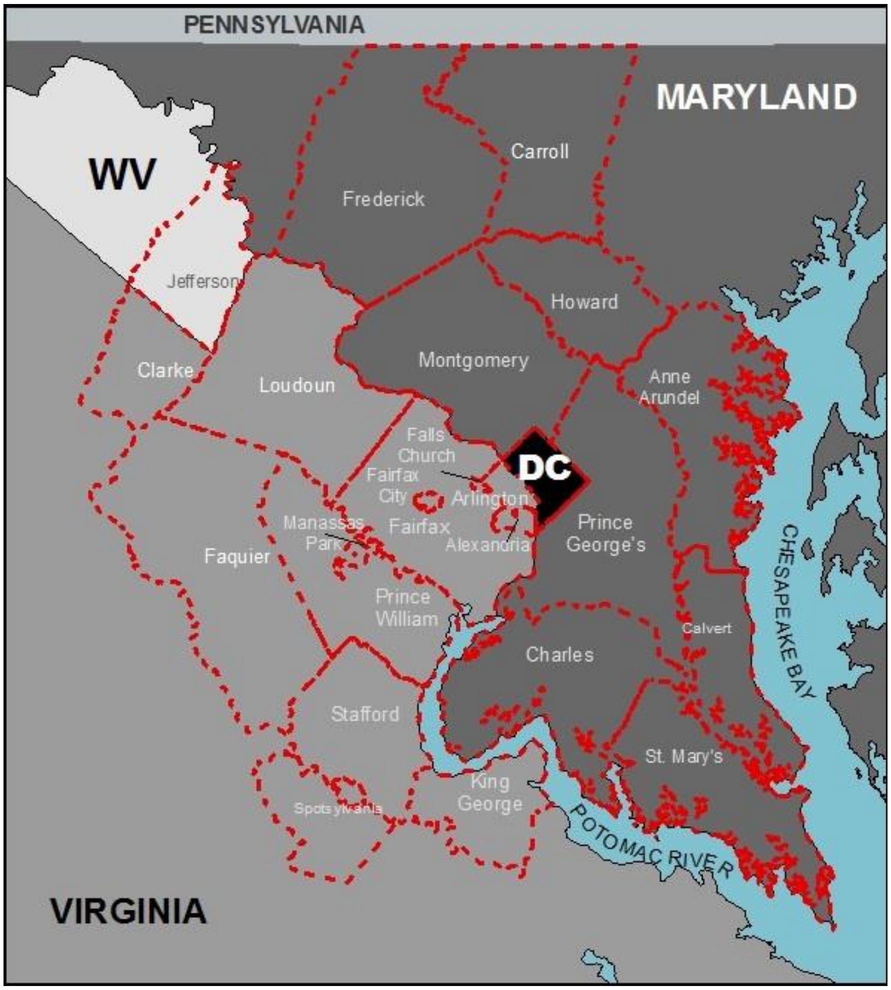

Image credit: Jessica Mirr, COG/TPB staff
"I:\ateam\team_mem\...\2016_vaTech\TPB_Plan_EastCoast-Model_crop.jpg"

3.2.2 Future TPB travel models

Generation 2 of models does not end with the current production-use model. Gen2 continues with a developmental, but still aggregate, trip-based model, known as Ver. 2.5. The last two rows in Table 1 represent two final generations of TPB travel models: Gen3 and Gen4. Thus, Table 1 shows four generations of travel models:

- Gen1: Version 1.0
- Gen2: Versions 2.0 to 2.X (currently Ver. 2.3.70 for production and 2.5 for development)
- Gen3
- Gen4

The focus of this document is on the TPB Gen3 model.

3.2.3 Consultant assistance

Since 2005 (FY 2006), COG/TPB staff has maintained a consultant-assisted project to apply and improve the TPB regional travel demand model. The project has been carried out using a series of one-year, task-order-based consultant contracts. Each of these contracts was renewable, for up to two years, allowing any one consultant to hold the contract for three years, at which point COG must offer a new solicitation if it wants to continue with the project. This contract has been held by the following firms:

- Vanasse Hangen Brustlin, Inc. (VHB), from FY 2006 to 2008
- Cambridge Systematics, Inc. (CS) and Gallop Corporation, from FY 2009 to 2011
- AECOM and Stump/Hausman Partnership, from FY 2012 to 2014
- Cambridge Systematics, Inc. (CS) and Gallop Corporation, from FY 2015 to 2017

In 2012, TPB staff reviewed all the consultant recommendations that had been produced over the first six years of the contracting period, and summarized the findings in report.[14] The most recent consultant to hold the on-call contract developed the following reports, including a **strategic plan for model development**, which is the focus of the following section of this report:

- Cambridge Systematics, Inc. *Review of Consultant Recommendations from FY 2012-2014 of the COG/TPB Travel Demand Modeling Consultant-Assistance Project, Task Order 15.1*. Final Report. Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, October 15, 2015.
- ———. ***Identifying Potential Opportunities for Model Improvement, Task Order 15.2, Report 1 of 3***. Final Report. Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, October 15, 2015.
- ———. ***Status of Activity-Based Models and Dynamic Traffic Assignment at Peer MPOs, Task Order 15.2, Report 2 of 3***. Final Report. Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, October 15, 2015.
- ———. ***Strategic Plan for Model Development, Task Order 15.2, Report 3 of 3***. Final Report. Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, October 15, 2015.
- ———. *Review of Transit Modeling with Respect to FTA Guidance, Task Order 15.3*. Final Report. Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, October 15, 2015.
- Gallop Corporation. *Task Order 15.4, Modeling with Public Transport*. Final Report, October 15, 2015.
- Cambridge Systematics, Inc., and Gallop Corporation. *FY 16 Task Orders*. Final Report. Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, November 2016.

[14] Mark S. Moran, Mary Martchouk, and Ronald Milone, "TPB Staff Review of Six Years of Consultant Recommendations from the Ongoing Consultant-Assisted Project for Models Development," Final Report (Washington, D.C.: National Capital Region Transportation Planning Board, Metropolitan Washington Council of Governments, July 19, 2012), https://www.mwcog.org/events/2012/?F_committee=199.

- ———. *FY 17 Task Orders*. Final Report. Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, June 2017.

3.3 Strategic plan for improving the TPB travel demand model

3.3.1 Original plan

The on-call consultant for FY 2015-2017 was Cambridge Systematics, Inc. (CS). In 2015, in response to one of its assigned task orders, CS developed a strategic plan for improving the TPB travel demand model. There were three major inputs to the strategic plan:

- Review of TPB policy reports, such as TPB Vision document, the Regional Transportation Priorities Plan (RTPP), and the Regional Activity Centers;
- Survey of Washington-D.C.-area modeling stakeholders;[15]
- Survey of peer MPOs regarding modeling practices (see Table 2);[16]

The strategic plan consists of three volumes, which were also listed above:

1. Identifying Potential Opportunities for Model Improvement;[17]
2. Status of Activity-Based Models and Dynamic Traffic Assignment at Peer MPOs;[18]
3. Strategic Plan for Model Development;[19]

The first two volumes provide background information and the third volume is the actual plan.

In 2010, Los Angeles was the largest MPO in the U.S., with a population of 18 million people (Table 2). New York City was the second largest, with 12 million people. Washington, D.C. was #9, with 5 million. And, Saint Louis, Missouri was the smallest of the top 20, with a population of 2.5 million people.

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[15] MWCOG/Cambridge Systematics survey to solicit stakeholder input from users of the COG/TPB regional travel demand model, conducted February 13 to March 3, 2015, interview by Metropolitan Washington Council of Governments/National Capital Region Transportation Planning Board and Cambridge Systematics, Inc., Web-based survey, February 2015.

[16] MWCOG/Cambridge Systematics survey of peer MPOs to assess the state of modeling practice, conducted March 6-25, 2015, interview by Metropolitan Washington Council of Governments/National Capital Region Transportation Planning Board and Cambridge Systematics, Inc., Web-based survey, March 2015.

[17] Cambridge Systematics, Inc., “Identifying Potential Opportunities for Model Improvement, Task Order 15.2, Report 1 of 3,” Final Report (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, October 15, 2015).

[18] Cambridge Systematics, Inc., “Status of Activity-Based Models and Dynamic Traffic Assignment at Peer MPOs, Task Order 15.2, Report 2 of 3,” Final Report (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, October 15, 2015).

[19] Cambridge Systematics, Inc., “Strategic Plan for Model Development, Task Order 15.2, Report 3 of 3,” Final Report (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, October 15, 2015).

Table 2 MPOs considered to be peers of the TPB*

Metropolitan Planning Organization	2010 Population
1. Southern California Association of Governments (SCAG)	18,051,203
2. New York Metropolitan Transportation Council (NYMTC)	12,367,508
3. The Chicago Metropolitan Agency for Planning (CMAP)	8,454,538
4. Metropolitan Transportation Commission (MTC)	7,150,828
5. North Jersey Transportation Planning Authority (NJTPA)	6,579,801
6. North Central Texas COG (NCTCOG)	6,417,630
7. Houston-Galveston Area Council (H-GAC)	5,892,002
8. Delaware Valley Regional Planning Commission (DVRPC)	5,626,318
9. National Capital Region Transportation Planning Board (TPB)	**5,068,737**
10. Atlanta Regional Commission (ARC)	4,818,052
11. Southeast Michigan COG (SEMCOG)	4,703,593
12. Maricopa Association of Governments (MAG)	4,055,281
13. Puget Sound Regional Council (PSRC)	3,690,866
14. Boston Region MPO	3,159,512
15. San Diego Association of Governments (SANDAG)	3,095,271
16. Metropolitan Council	2,906,684
17. Denver Regional COG (DRCOG)	2,827,082
18. Baltimore Regional Transportation Board (BRTB)	2,684,661
19. Southwestern Pennsylvania Commission (SPC)	2,574,953
20. East-West Gateway Council of Government (EWGCOG)	2,571,327
21. Sacramento Area COG (SACOG)	2,274,557
22. Portland Area Comprehensive Transportation System (METRO)	1,499,844
23. Mid-Ohio Regional Planning Commission (MORPC)	1,436,334

*20 largest MPOs (based on 2010 population in the MPO planning area) plus three smaller MPOs known for innovation in travel demand modeling

Key findings: One of the findings from the survey of peer MPOs was that 70% of our peer group were using or developing an ABM.[20] TPB was in the 30% of peer MPOs that were not. Another finding was that regional DTA is not being pursued to the same extent as ABMs: Only two of the 23 peer MPOs (9%) were using regional DTA in production, though seven of the 23 (30%) reported that they are developing regional DTA capabilities.[21]

[20] Cambridge Systematics, Inc., "Status of Activity-Based Models and Dynamic Traffic Assignment at Peer MPOs, Task Order 15.2, Report 2 of 3," 10.
[21] Cambridge Systematics, Inc., 25.

In the DC area, regional DTA is being used for project prioritization by both VDOT[22] and NVTA.[23] NVTA would like to see DTA added to the TPB travel model. TPB staff is interested adding DTA to the regional model, but the question is when is the right time to pursue it, given the increased resources that would be needed to develop and maintain DTA-capable networks (e.g., traffic signal timing and phasing) and the increased model run time that would result from using DTA at the regional level.

The strategic plan recommended three phases of development over a seven-year period (FY 16-22), as shown in Table 3. See later in this document for an updated version of this table.

Table 3 Strategic plan for the TPB regional travel demand model: Original plan

Phase	Description	Duration (Years)	Fiscal Years
1	Updates to the existing trip-based model	2	2016-2017
2	Development of an ABM with **existing** data, e.g., 2007/2008 Household Travel Survey	3	2018-2020
3	Development of an ABM with **new** data, e.g., 2017/2018 Regional Travel Survey	2	2021-2022

A short-term plan was developed to execute the first phase of the plan.[24] By the end of FY 2017, the consultant, CS, had developed a revised, proposed, trip-based model, known as the Ver. 2.5 model. Although this is a developmental model, this is still considered a Generation 2 model, since it is an aggregate, trip-based model calibrated with existing data (e.g., the 2007/2008 Household Travel Survey). Nonetheless, this model was validated to year-2014 conditions. This proposed model has enhancements in four areas:

1. Updated transit network/path-building software: From TRNBUILD to Public Transport (PT)
2. Improved non-motorized model: Used to split total productions and attractions into motorized and non-motorized trips (walk and bike).
3. Simplified mode choice model: Transit choice set reduced from 11 to 3 modes.
4. Highway & transit assignment enhancements
    a. Highway assignment: Uses value-of-time stratification (3 levels). CS has written a paper on this topic that should be presented at the TRB Annual Meeting in January 2018.
    b. Transit assignment: Includes transit sub-mode choice (e.g., bus, light rail, commuter rail), which used to be represented in the mode choice model.

[22] See, for example, David Roden, "VDOT's Project Prioritization Process in Northern Virginia Using TRANSIMS and the COG/TPB Travel Model" (July 22, 2016 meeting of the COG/TPB Travel Forecasting Subcommittee, held at the Metropolitan Washington Council of Governments, Washington, D.C., July 22, 2016).
[23] AECOM, "Model Validation," Technical Memorandum, Draft, NVTA's TransAction, Transportation Action Plan for Northern Virginia (Northern Virginia Transportation Authority (NVTA), October 3, 2016), http://www.vdot.virginia.gov/projects/northernvirginia/evaluating_significant_projects.asp.
[24] John (Jay) Evans to Mark Moran, "Short-Term Trip-Based Model Strategy Implementation Plan," Memorandum, November 11, 2015.

CS developed and delivered the Ver. 2.5 model at the end of the contract (June 30, 2017).[25] During FY 18, TPB staff has been conducting model testing and sensitivity to ensure that the models performance is satisfactory and to explore application options to reduce the model run time.

3.3.2 Updates to the plan

TPB staff has recently decided to make several adjustments to the strategic plan for improving the TPB travel model. First, the schedule has been modified. Phase 1 (updates to the existing trip-based model) is now planned to last for three years, not two. Although the planned duration for Phases 2 and 3 remains the same (three years for Phase 2 and two years for Phase 3), given the longer duration for Phase 1, the schedules for Phases 2 and 3 have been shifted back by a year. Similarly, the duration for the entire strategic plan is now eight years, not seven.

Second, we have changed our assumption about the model form that would be used for Phases 2 and 3. Previously, the strategic plan had assumed that the model form would be an activity-based model (ABM). Although TPB staff is still open to using an ABM for Phases 2 and 3, at this point, **staff prefers that the model form be decided based on the modeling need and requirements listed in the product requirements document** (PRD, this report). So, the current assumption for Phases 2 and 3 of the strategic plan is that the model structure will be either trip-based, tour-based, activity-based, or some hybrid of these. The broad structure of the revised plan is shown in Table 4.

Table 4 Strategic plan for the TPB regional travel demand model: Revised plan

Phase	Description	Duration (Years)	Fiscal Years
1	Updates to the existing trip-based (Gen2) model	3	2016-2018
2	Development of Gen3 model with **existing** data, e.g., 2007/2008 Household Travel Survey	3	2019-2021
3	Development of Gen4 model with **new** data, e.g., 2017/2018 Regional Travel Survey	2	2022-2023

3.4 Context

The development of the Gen3 travel demand model should be guided by the transportation system in the Washington, D.C. metropolitan area (both current and future), the modeling environment, and the policy questions of interest to the TPB and other stakeholders in the metropolitan area. Each of these three topics is discussed below.

3.4.1 Transportation system in the Washington, D.C. metropolitan area

The Washington, D.C. metropolitan area has a population of about 6 million people and is the sixth largest Metropolitan Statistical Area (MSA) in the United States. The TPB is the 9th largest MPO in the U.S., based on 2010 population. The region is host to many travel modes, both passenger and freight, spanning surface transportation, aviation, and maritime transportation.

[25] Cambridge Systematics, Inc. and Gallop Corporation, "FY 17 Task Orders," Final Report (Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, June 2017).

In the Washington, D.C. area, as is true in many urban areas in the U.S., a large share of travel is made by private-transportation, motor vehicles, such as cars (automobiles), light-duty trucks, sports utility vehicles (SUVs), and motorcycles.

The highway system includes high-occupancy vehicle (HOV) lanes, high-occupancy/toll (HOT) lanes, and toll roads, both fixed price (e.g., Dulles Toll Road) and variably-priced -- where the toll is not dependent on the vehicle occupancy (e.g., the Intercounty Connector, or ICC). Carpooling is an important travel mode and slugging (where carpools are formed informally at one or more designated locations) is also widely used in the I-95/I-395 corridor in Virginia.

In terms of public transportation, the DC area has the 4th largest transit system in the U.S. For a long period, the DC area had the second largest heavy rail system, though, it may now be in third place after Chicago.[26] The transit system includes commuter rail, Metrorail, light rail, streetcar, bus rapid transit (BRT), express bus, and local bus. Inter-city passenger rail (Amtrak) and bus service are also important travel modes within and through our region. In some parts of the region, shuttle bus service, often associated with universities or federal government sites, can also be extensive.

Although taxis and taxicabs are a small share of resident passenger travel (about 0.3% of travel, according to our 2007-2008 Household Travel Survey), they account for a much larger share of traffic in markets with lots of non-resident travel (e.g., downtown, travel to/from airports). Similarly, the usage of transportation network companies (TNCs) has been growing quickly, following the start of Uber (in 2009), Lyft (in 2012), and other similar services. In one recent study in California, TNCs were found to account for as much as 20% of intra-San-Francisco vehicle miles of travel (VMT).[27] Short-term car rental, including those that forego centralized rental offices, are also becoming more popular, particularly in denser parts of the region (car2go started service in DC in 2012).

In terms of non-motorized transportation (walking and biking), the DC area has a respectable mode split of biking and walking trips (at the regional level, about 1% of commute mode share for bikes and 3% for walk,[28] though these percentages can be much more for certain areas of the region). Furthermore, these modes are important access modes for transit. The region also includes several bikeshare systems, including those that make use of docking stations (e.g., Capital Bikeshare) and dockless systems (e.g., Mobike, Spin, and LimeBike). Capital Bikeshare is subsidized by the local governments, but the other bikeshare systems are not.

The metropolitan Washington region has three commercial airports – Ronald Reagan Washington National Airport (DCA), Washington Dulles International Airport (IAD), and Baltimore/Washington International Thurgood Marshall Airport (BWI) – and many general aviation airports. Washington, D.C. is not a port city, like Baltimore or New York City, but it does have navigable rivers (the Potomac and the

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[26] DW Rowlands, "Metrorail Is No Longer the Second-Busiest Rapid Transit System in the Country," Greater Greater Washington, February 8, 2018, https://ggwash.org/view/66466/metrorail-is-no-longer-the-second-busiest-rapid-transit-system-in-the-country.
[27] "TNCs Today: A Profile of San Francisco Transportation Network Company Activity," Final Report (San Francisco County Transportation Authority, June 2017), 2, http://www.sfcta.org/tncstoday.
[28] Robert E. Griffiths, "Regional Travel Trends" (April 20, 2016 meeting of the National Capital Region Transportation Planning Board, held at the Metropolitan Washington Council of Governments, Washington, D.C., April 20, 2016), 15.

Anacostia), which include some existing water taxi service, and which have been considered for additional service.[29]

In terms of future, but not yet existing, travel modes, it is expected that connected and autonomous vehicles (CAVs) will begin to enter the vehicle fleet here and in the rest of the U.S. in the next few years. CAVs could be privately owned by households, or could be operated as fleets owned by private companies, which could include the idea of Mobility as a Service (MaaS). Maryland is considering options for high-speed rail (magnetic levitation or maglev) between Washington, D.C. and Baltimore,[30] and private firms have considered developing a high-speed tunnel transportation system between the two cities (i.e., Loop or Hyperloop). Lastly, some have noted that TNCs may get into the business of offering air taxis, especially using newer, still developing technologies, such as electric vertical take-off and landing (eVTOL) aircraft that build upon knowledge gained from the rise in unmanned aerial vehicles (UAVs), also known as unmanned aircraft systems (UAS), or drones.[31]

3.4.2 Modeling environment

As noted earlier, the current adopted, production-use TPB regional travel demand forecasting model is an aggregate trip-based travel demand model, known as the Ver. 2.3.70 model. The model was calibrated and validated with local data. As noted earlier, the current model (Version 2.3) is documented in a calibration report,[32] validation memo,[33] and a user's guide.[34] The modeled area is relatively large – it covers DC and sections of three states (Virginia, Maryland, and one county in West Virginia). In all, the modeled area includes 22 counties/jurisdictions and about 6,800 square miles. The TPB modeled area overlaps with that of the Baltimore Metropolitan Council (BMC)/Baltimore Regional Transportation Board (BRTB), and vice a versa. In the past, some have argued the technical merits of a combined, two-city (Washington, D.C. and Baltimore) travel model, but, for various reasons, more institutional than technical, that has never occurred.

The next generation travel demand model could be a trip-based model, a tour-based model, an activity-based model (ABM), or a hybrid of these, as noted in a recent presentation to the TFS.[35] A tour-based model could either be an *aggregate* tour-based model (just as our trip-based model is aggregate) or a

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[29] Luz Lazo, "At Ferry Summit, a Vision Emerges for a Commuter System along the Potomac River," *The Washington Post*, September 21, 2017, sec. Transportation, https://www.washingtonpost.com/local/trafficandcommuting/at-ferry-summit-a-vision-emerges-for-a-commuter-system-along-the-potomac-river/2017/09/21/ee3717d4-9d5d-11e7-9c8d-cf053ff30921_story.html.

[30] Luz Lazo, "Officials Have Settled on 2 Possible Routes for the High-Speed Maglev, but Project Is Still Years Away," The Washington Post, February 11, 2018, https://www.washingtonpost.com/local/trafficandcommuting/officials-have-settled-on-2-possible-routes-for-the-high-speed-maglev-but-project-is-still-years-away/2018/02/11/d50238d2-0cf9-11e8-8b0d-891602206fb7_story.html?utm_term=.b4ca5becbcd1.

[31] Biz Carson, "Uber Wants To Bring Its Flying Taxis to Traffic-Congested Los Angeles Ahead Of The Olympics," Forbes, November 8, 2017, https://www.forbes.com/sites/bizcarson/2017/11/08/uber-wants-to-bring-its-flying-taxis-to-traffic-congested-los-angeles-ahead-of-the-olympics/.

[32] Milone et al., "Calibration Report for the TPB Travel Forecasting Model, Version 2.3."

[33] Milone to Files, "2010 Validation of the Version 2.3 Travel Demand Model."

[34] Milone, Moran, and Seifu, "User's Guide for the COG/TPB Travel Demand Forecasting Model, Version 2.3.70: Volume 1 of 2: Main Report and Appendix A (Flowcharts)."

[35] Mark S. Moran, "Next-Generation Travel Demand Forecasting Model for the TPB: Current Plans for Development (Phase 2 of the Strategic Plan)" (January 19, 2018 meeting of the COG/TPB Travel Forecasting Subcommittee, held at the Metropolitan Washington Council of Governments, Washington, D.C., January 19, 2018).

disaggregate tour-based model, which is more like an ABM. The Gen3 travel model will need to address all the travel modes that are currently active in the DC region, and should also address many of the emerging travel modes, described earlier. The Gen3 model development effort will also need to review and consider updates to what are known as exogenous travel markets in the model. These exogenous inputs are associated with travelers who reside outside of the study area (non-residents) or who live in the region (residents), but are not well represented in a typical household travel survey.[36]

Any consultant wishing to work with COG/TPB staff on TPB's next generation model should be cognizant of other modeling efforts in the region and beyond, such as the following:

- Baltimore Metropolitan Council's (BMC's) ABM, known as InSITE
- Maryland and Virginia's statewide modeling efforts
- Maryland's innovative modeling work, e.g., MITAMS
- Modeling work at the University of Maryland[37]
- DTA modeling work for VDOT and NVTA[38]
- Model review conducted by Montgomery County Planning Department[39]
- ActivitySim
- Zephyr Foundation
- Use of big data for model estimation, calibration, and validation[40]

3.4.3 Uses of the TPB travel model and policies that the Gen3 model would ideally address

Like all MPOs, the TPB must develop a Unified Planning Work Program (UPWP), which is updated on an annual basis and lists all the planning activities that the MPO staff will undertake for a given year. The TPB travel demand forecasting model (TDFM) is used for several of the tasks specified in the UPWP, including the following:

- Development of an LRTP, which must extend at least 20 years into the future. The 2018 version of the TPB's LRTP is called Visualize 2045. The MPO must also designate a subset of the LRTP that is financially constrained to reasonably expected future revenues. In the past, TPB called

[36] Ronald Milone to DTP Technical Staff, "Round 9.0-Based Exogenous Demand Inputs to the Travel Model," Memorandum, May 25, 2016.
[37] University of Maryland, Lei Zhang, and Gang-Len Chang, "Developing Mesoscopic Models for the Before and After Study of the Inter-County Connector: Phase One" (Baltimore, Maryland: Maryland State Highway Administration, March 2013), http://ntl.bts.gov/lib/47000/47200/47250/MD-13-SP109B4P_ICC-Before-After-Study_Report.pdf.
[38] AECOM, "Evaluation and Rating of Significant Projects in Northern Virginia," Technical Report (Virginia Department of Transportation, April 29, 2015), http://www.vdot.virginia.gov/projects/northernvirginia/evaluating_significant_projects.asp.
[39] Fehr & Peers, "Transportation Models Review Tabular Summary (Attachment D of Subdivision Staging Policy – Briefing on Transportation Modeling Tools and Metrics)" (Silver Spring, Maryland: Montgomery County Planning Department, Maryland-National Capital Park and Planning Commission, January 28, 2016), http://www.montgomeryplanningboard.org/agenda/2016/agenda20160128.html.
[40] See, for example, Josephine D. Kressner et al., "Using Passive Data to Build an Agile Tour-Based Model: A Case Study in Asheville," in *Travel Forecasting Resource* (6th TRB Conference on Innovations in Travel Modeling, May 1-4, 2016, Denver, Colorado: Transportation Research Board, 2016), http://tfresource.org/6th_ITM_Conference,_Denver,_Colorado_(2016).

this the constrained, long-range plan (CLRP). But, the new nomenclature is the constrained element of the LRTP (Visualize 2045).

- Assessment of the performance of the LRTP, both in general terms of interest to the MPO and in more specific terms dictated by performance-based planning and programming (PBPP).
- Air Quality Conformity Determination, since the metropolitan Washington area is a non-attainment area for one or more air pollutants.
- Regional scenario studies, where changes are made to one or more of the following: transportation networks, land use, or policy assumptions.
- Transportation-related corridor studies and project planning studies. Although these types of studies are often conducted by state and local governments (and their consultants), the TPB staff does perform these types of studies under technical assistance projects that are conducted by TPB staff for the three "states" (DC, Maryland, and Virginia) and WMATA.
- Analyses of the impacts of transportation projects and policies on environmental justice (EJ)/social equity, although much of this analysis is currently done outside of the regional travel model.

When it comes to developing a travel demand forecasting model for an urban area, one should not rely on the assumption that one size fits all. In other words, the planning needs and issues in one city may differ from those of another city. Consequently, below is a list of some of the policies that are important in the metropolitan Washington region, and, hence, should ideally be addressed in the Gen3 model. Some of these were identified by TPB staff, others by modeling stakeholders.[41] Many of these are discussed in more detail later in this report.

Polices/modeling issues important to the metropolitan Washington region:

- Modeling of transit and transit sub-modes (e.g., bus versus light rail)
    - Mode choice and path-building: The trend has been to move some of this modeling of transit sub-modes out of mode choice and into path building
    - Transit assignment
        - All-or-nothing versus capacity restrained
        - Production/attraction format versus origin/destination format
        - Transit crowding. Even though there have been some declines in transit ridership in recent years, transit crowding/capacity, on both rail and some bus lines, remains an issue. For example, the model must represent the fact that there is a limit to the number of Metrorail trains that can travel to/through the regional core in peak periods.
- Modeling highway travel (private-use cars and trucks)
    - Highway assignment: Very long run times to reach acceptable levels of convergence
    - Modeling HOV lanes, HOT lanes, and other managed-lane facilities
- Modeling non-motorized modes (walk and bike)

[41] See, for example Cambridge Systematics, Inc., "Identifying Potential Opportunities for Model Improvement, Task Order 15.2, Report 1 of 3," especially pages 17-21.

- Assessing the effect of land development patterns and job/housing balance on transportation system performance
- Estimating the impacts of infill development on mode share/choice, particularly with regards to walk and bike modes
- Modeling the effect of the employer-based transit subsidies that some workers, especially federal, currently receive
- Telework, which has risen substantially over the past decade
- Increasing use of transportation network companies (TNCs) and other shared-mobility modes, including their effect on competing modes of travel
- Visitor/tourist travel: The Washington region receives many visitors, due, in part, to its role as the nation's capital.[42]
- Modeling peak spreading; Addressing the duration of the peak period, as opposed to focusing simply on the peak-hour condition
- Modeling the impact of travel time reliability (typically difficult to do with regional travel demand models)
- Representing/conveying the level of uncertainty in model inputs and outputs
- Impact of connected/autonomous vehicles (CAVs) in the coming years
- Modeling the impact of travel behavior of subsets of population, such as for the purposes of environmental justice (EJ)/social equity
- Freight planning. Although the Washington, D.C. area is not considered a major freight city, freight and commercial vehicles are still an important segment of the travel market.
- Greenhouse gas analysis (identified by modeling stakeholders)
- Effect of Internet on travel (identified by modeling stakeholders)
- Traffic microsimulation (identified by modeling stakeholders)

Additionally, modeling stakeholders noted several areas that they would like to see improved in the model:

- Improved ease of adapting the regional model for sub-regional travel analyses
- Improved ease of use
- Shorter model run times

3.4.4 Observed data for estimation, calibration, and validation of travel models

A memo from 2014 documents the large number of observed data sets that have been used to estimate, calibrate, and/or validate current and past travel demand models used by TPB staff.[43] The next section

[42] At least one DC-area modeling stakeholder has expressed an interest that the TPB regional travel model be able to represent intercity rail, commuter rail, intercity bus, and ground access travel to the region's three commercial airports. Travel associated with the region's three commercial airports is discussed on pp. 33 and 34 of this report. Additionally, TPB staff categorizes intercity rail and intercity bus as "external transit," which is discussed in section 6.1.4.4. Although external transit is often omitted from regional travel demand models, TPB staff is open to consultant suggestions about whether incorporation of these travel markets is feasible.

[43] Hamid Humeida to Mark Moran and Milone Ronald, "List of Surveys Used in Models Development at COG," Memorandum, October 9, 2014.

of this report lists some of the most important existing and upcoming data for model calibration and validation.

COG/TPB staff conducts a household travel survey about every ten years. These surveys, along with transit on-board surveys, are very important sources of data for model estimation, calibration, and validation. TPB staff is currently conducting a household travel survey, known as the COG 2017-2018 Regional Travel Survey (RTS). It is expected that this survey will be cleaned, documented, and factored by 2019 or 2020. Thus, it is not available for developing the Gen3 travel model, but it is expected to be available for the Generation 4 travel model. Prior to that, the most recent survey was the 2007-2008 COG Household Travel Survey.[44] This survey, along with a series of transit on-board surveys, was used for calibrating the Ver. 2.3 travel demand model and will also be used for developing the Gen3 model. The next three sections of this report list possible data sets that may be used for model estimation, calibration, and validation.

3.4.4.1 Existing data used to calibrate the current travel model

- Census Data
    - 2010 Census Data: Population and households
    - American Community Survey (ACS)
        - 1-Year ACS estimates: 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013
        - 3-Year ACS estimates: 2005-2007, 2006-2008, 2007-2009, 2009-2011, 2010-2013
        - 5-Year ACS estimates: 2006-2010
- Household Travel Surveys
    - 2007-2008 COG/TPB Household Travel Survey
- Transit On-Board Surveys
    - 2008 Metrorail Passenger Survey (conducted by WB & A for the Maryland Transit Administration)
    - 2008 Regional Bus Survey
    - 2007-2008 On-Board Survey of Maryland Transit Administration (MTA) Riders, which includes users of MARC train service
    - 2005 Virginia Railway Express (VRE) Passenger Survey
- Washington-Baltimore Regional Air Passenger Surveys: Typically conducted every other year, including 2009, 2011, 2013, 2015, and 2017

3.4.4.2 Other existing data

These data were not used to calibrate the current TPB model, but could have been used for model validation, or could be used to calibrate the Gen3 model (in addition to the data listed above).

[44] National Capital Region Transportation Planning Board, Metropolitan Washington Council of Governments, "2007/2008 TPB Household Travel Survey: Technical Documentation," Draft report (Washington, D.C.: National Capital Region Transportation Planning Board, Metropolitan Washington Council of Governments, August 27, 2010), http://www.mwcog.org/uploads/committee-documents/Zl5YWV5W20100903131244.pdf.

- Household Travel Surveys
    - COG/TPB Geographically Focused Household Travel Surveys (2011 and 2012)
- Transit On-Board Surveys
    - Alexandria Transit (DASH, bus service): 2013 survey and planned 2018 survey[45]
    - DDOT: Annual survey
    - Fairfax Connector (bus service): 2013/2014 survey
    - WMATA Metrobus: 2014 survey and planned 2018 survey
    - WMATA Metrorail: Surveys in 2012 and 2016. No future planned surveys
    - PRTC (commuter bus): Surveys in 2013 and 2017
    - VRE (commuter rail): 2016 survey
- Highway Performance Monitoring System (HPMS) data
- INRIX traffic speed data, available through our participating in the I-95 Corridor Coalition.
- National Performance Management Research Data Set (NPMRDS)
- AirSage origin-destination data, purchased by COG in 2014.[46]
- Taxicab data: DC provides observed taxi cab data (http://opendata.dc.gov/datasets?q=taxi).
- TNC data.[47]
- Streetlight origin-destination data. VDOT has purchased this data.

3.4.4.3 Upcoming data (available in the future)

- Census Data
    - 2020 Census[48]
- Household Travel Surveys
    - 2017-2018 COG/TPB Regional Travel Survey (available in 2019 or 2020)
- Transit On-Board Surveys?

The main upcoming data set is the 2017-2018 COG/TPB Regional Travel Survey (available in 2019 or 2020). It is not known, now, which transit on-board surveys will be conducted in the near future.

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45 Eric Randall, "Work Program Update" (October 25, 2016 meeting of the COG/TPB Regional Public Transportation Subcommittee, held at the Metropolitan Washington Council of Governments, Washington, D.C., October 25, 2016), 4.

46 Ronald Milone, "Preliminary Evaluation of Cellular Origin-Destination Data as a Basis for Forecasting Non-Resident Travel," in *15th TRB National Transportation Planning Applications Conference, May 17-21, 2015 (Website)* (15th TRB National Transportation Planning Applications Conference, May 17-21, 2015, Atlantic City, New Jersey, 2015).

47 Sharon Feigon and Colin Murphy, "Broadening Understanding of the Interplay Between Public Transit, Shared Mobility, and Personal Automobiles," Pre-publication draft of TCRP Research Report 195 (Washington, D.C.: Transportation Research Board of the National Academies, 2018), http://www.trb.org/TCRP/Blurbs/177112.aspx.

48 Following the release of the Census Transportation Planning Products (CTPP) 2012-2016 dataset in early 2019, the Oversight Board to the CTPP Program is announcing it will no longer include Transportation Analysis Zone (TAZ) and Transportation Analysis District (TAD) geographies in future requests for special tabulations of the U.S. Census Bureau's American Community Survey (ACS) data. Future CTPP special tabulation requests will include the standard census block group geography instead (Source: http://ctpp.transportation.org/Pages/Policy-Change-on-Small-Geography.aspx)

4 Overview, timeline, phasing and budget of the contract

4.1 Overview and timeline for the RFI and RFP

An overview of the current proposed timeline is shown in Table 5. This table lists the approximate duration for various steps and the approximate dates, although these are subject to change if delays occur.

Table 5 Current proposed timeline: Overview

Step	Approx. Duration	Approx. Dates
Request for Information (RFI) and PRD	6 months*	Jan. to Jul. 2018
Request for Proposals (RFP) and SOW	2 months**	Jul. to Oct. 2018
Vendor selection	1 month	Oct. to Nov. 2018
Start of contract		Nov. 2018
Investigations (consultant)	4 months	Nov. 2018 to Mar. 2019
Decisions (TPB staff)	3 weeks	Mar. to Apr. 2019
Development and implementation of Gen3 model	16 months	Apr. 2019 to Jul. 2020
Data collection for Gen3 or Gen4 model?	6 to 16 months	Apr. 2019 to Jul. 2020
Testing, sensitivity analyses, and updates	16 months	Jul. 2020 to Sep. 2021
Final decision: Is Gen3 model ready for use?		Sep. to Oct. 2021
End of contract		Oct. 2021

* RFI: It is planned that vendors would have about 1.5 months (30 working days) to submit a response to the RFI

** RFP: It is planned that vendors would have about 1 month (22 working days) to submit a response to the RFP

Ref: "I:\ateam\model_dev\tpb_tdfm_gen3_nextGen\mwcog_nextGen_trav_model_v11.mpp"

4.1.1 RFI process details

The process to develop the Gen3 model will begin with the Request for Information (RFI), which will include the product requirements document (PRD). This is planned to last about 6 months, though the time between the advertisement of the RFI and the due date for vendor responses is planned to be about 1.5 months. It is planned that the TFS would review the PRD, but would not review the responses to the RFI. As noted earlier in this report, the vendor response to this RFI will consist of two items:

1. A concise report that explains and justifies the vendor's proposed approach for the TPB's Gen3 travel demand forecasting model.
2. A completed model checklist that describes the vendor's proposed approach for the TPB's Gen3 travel demand forecasting model. A blank copy of the model checklist will be provided along with the PRD.

More details about these two items can be found in section 7 of this report ("Deliverables").

The RFI process has two goals. First, to solicit input from interested vendors/consultants about their proposed solution to our modeling needs, as described in this PRD. Second, to help COG/TPB staff decide on the preferred direction for model upgrades that will be specified in the upcoming RFP. It is planned that the RFI will help the TPB staff decide what model structure (e.g., trip-based, tour-based, activity-based, hybrid) to use for the request for proposals (RFP) step.

As noted earlier, the RFI is not being used for pre-qualification, which means that vendors are not required to respond to the RFI to respond to the upcoming RFP.

4.1.2 Comparison of the RFI and RFP processes

The RFI step will be followed by the Request for Proposals (RFP) process, whose goal is to select one or more vendors to develop the Gen3 model. The RFP will include a scope of work (SOW) that defines the work that the selected vendor is expected to accomplish. Although the RFP step is planned to last about two months, the time between the advertisement of the RFP and the due date for vendor proposals is planned to be about one month.

It is planned that the RFI process will be somewhat open in nature, and the RFP process will by more closed in nature. Specifically, once one or more vendors respond to the RFI with their proposed modeling approach, TPB staff may choose to follow up with one or more of the vendors to obtain more information or clarification about the vendor responses. Ideally, this follow-up would be conducted in writing (via email), with a copy to the COG Contracts and Purchasing Office (purchasing@mwcog.org). If TPB staff feels a meeting is warranted, TPB staff will consult with the COG Contracts and Purchasing Office before setting up such a meeting. **Note to vendors: Anything that comes from the vendor responses or possible subsequent follow up with the vendors is for information purposes only. Thus, it is the RFP itself that is the determinant on what services are being solicited, not the RFI. Thus, during the RFI process, TPB staff will not reveal any inside information about the contents of the eventual RFP, to maintain a fair and even competition**.

TPB staff would not share the responses to the RFI with other vendors (participating or not), and TPB staff does not plan to share the RFI responses with members of the TFS, even though the TFS is the review body for most activities related to travel demand forecasting.

The RFP process, by contrast, is more closed. During the period where the RFP is open (i.e., during the time, about one month, between the RFP advertisement and the deadline for proposals), **any vendor questions should be submitted to COG's Contracts and Purchasing Office (purchasing@mwcog.org), who will then forward the questions to the COG project manager/subject-matter experts (TPB staff)**. TPB staff will then send the responses to COG's Contracts and Purchasing Office, which will distribute the questions and answers as an addendum to the RFP. This addendum will be placed on the same webpage as the RFP (https://www.mwcog.org/purchasing-and-bids/cog-bids-and-rfps/), so that it is equally available to all the vendors wishing to submit a proposal. Typically, after vendors submit their RFP proposals, there is no more interaction between the vendors and the COG/TPB staff. Vendor proposals are not shared with anyone except the members of a Technical Selection Committee, which is discussed below.

4.1.3 Award of contract/Post RFP

Vendor selection will make use of a technical selection committee (TSC) to score the vendor proposals, based on the evaluation factors listed in the RFP. It is thought that vendor selection will take about one month. Currently, the start of the contact is planned for November 2018, but this could be delayed if there are delays in the prior steps. In most cases, vendor selection is made by the TSC, without any further interaction with the proposers. In some very special cases, however, such as in the event of a close score, the top-scoring vendors may be called in for an interview.

Development of the contract, including sign-offs, can typically take 7-10 days, and may require legal review.

Following the signing of the contract, it is planned that the project will begin with a series of investigations. These investigations, which will last about 4 months, are discussed later in this document. The investigations will result in a series of technical memos from the vendor/contractor/consultant. The TPB staff will then have 3 weeks to review these technical memos and make decisions about which improvements to pursue. It is possible that the investigations would lead to the decision that more data needs to be collected. If that is the case, it is planned that the data would be collected during the three-year contract period, even though some of the data might not be ready for use until the following generation of the travel model (i.e., Generation 4, which is represented as Phase 3 of the strategic plan for model development). Note that if data collection needs are identified by the winning vendor, the data collection is likely to occur under a separate contract, which is focused on travel monitoring.[49]

Currently, it is planned that the consultant will have 16 months to develop the Gen3 travel demand forecasting model. Following this development period, it is planned that there will be a 16-month period where the TPB staff will conduct model testing and sensitivity tests, while the consultant is still under contract. One scenario would include 12 months of testing by TPB staff, followed by 2 months of model updates (in response to TPB staff findings) by the consultant, followed by 2 final months of testing. Alternatively, at the discretion of TPB staff and the selected vendor, the model updates could happen at multiple points during the testing phase, instead of simply at the end of the testing phase. Either way, at the end of this 3-year period, TPB staff would make the final decision about whether the Gen3 model is ready for production use by the TPB. If the vendors replying to the RFI process think that time segmentation is not corrected (i.e., 16 months of development with 16 months of testing and refinement), the vendors should propose an alternative time segmentation. However, it is not intended for the total contract to span more than 3 years, so cutting one period will result in a reduction in another period.

4.2 Phasing

As noted earlier, the focus of this model development contract is on Phase 2 of the strategic plan, which is known as the TPB TDFM Gen3. This model is to be developed and implemented with **existing** data, by which we mean the **2007/2008 Household Travel Survey, any corresponding transit on-board surveys, and any data that is currently available** (data for model calibration is discussed later). The expected phases of the Gen3 model contract are shown below:

1. Investigations: The first part of the 3-year project will be investigations. Each investigation will be documented in a report or memorandum, each of which will be reviewed by TPB staff, and schedule permitting, by the TFS.
2. Decisions: Based on the investigations, decisions will be made about the type of model, the features to be included in the model, and the implementation software.

[49] See, for example, Richard I. Roisman, "Travel Monitoring Program, Contractor Procurement" (January 19, 2018 meeting of the COG/TPB Travel Forecasting Subcommittee, held at the Metropolitan Washington Council of Governments, Washington, D.C., January 19, 2018), 10.

3. Development of TPB TDFM Gen3 model (16 months planned). As noted above, if the investigations point to the need for more data collection to support new model development, some of that data could be collected during this period of the contract. It is understood that some of such data collected might not be ready for use in model development efforts until the next phase of model development: Phase 3 of the strategic plan (TPB TDFM Gen4).
4. Consultant delivers model and model documentation to TPB staff
5. Testing phase (16 months)
6. Close of contract (about 3 years after the start of contract)

4.3 Expected budget

We anticipate a consultant funding level of $300k per year for each of three years. This means that, if one consultant holds the contract for all three years, the total budget would be $900k. It is also possible that added funding sources for special data collection efforts may be identified. Vendor proposals need not include cost estimates for the RFI, but proposals must adhere to the time (3 years) and cost ($900k) constraints.

4.4 Data for model calibration

Data for model calibration was discussed in Section 3.4.4 ("Observed data for estimation, calibration, and validation of travel models") on p. 17.

5 Investigations

It is expected that the development of the TPB TDFM Gen3 model will begin with by a series of investigations. Some of these investigations will be part of the RFI. Then, after the contract has been awarded, more in-depth investigations will be undertaken by the consultant. Both are discussed below, following a discussion of the long-term goal for the travel demand modeling process.

5.1 Long-term goal for the travel demand model

The long-term goal of the TPB staff, and for many modeling staff at large MPOs, is a disaggregate travel demand model (such as an ABM) paired with a disaggregate travel supply model (such as DTA), which is represented as Quadrant 4 in Table 6. The current TPB travel model includes both an aggregate representation of demand (e.g., zone-level, trip-based, four-step model) and an aggregate representation of supply (TAZ-level transportation network with a static traffic assignment), which is represented as Quadrant 1 in Table 6. The question is which path is used to move from Quadrant 1 to Quadrant 4, and what is the speed of the movement. Most of our peer MPOs have chosen to take the following path: Quadrant 1 > Quadrant 3 > Quadrant 4. We do not expect that the Gen3 model will be able to move directly to Quadrant 4, so **the going assumption is that the Gen3 model will move to either Quadrant 3 or Quadrant 2**.

Table 6 Cross classification of travel demand models by demand/supply versus aggregate and disaggregate

		Travel Supply and Trip Assignment	
		Aggregate (e.g., TAZ-level, macroscopic traffic assignment)	**Disaggregate (e.g., TAZ, MAZ, or parcel-level; DTA/mesoscopic/ microscopic assignment)**
Travel Demand	**Aggregate (e.g., zone-level, trip-based, 4-step model)**	Quadrant 1 (current TPB travel model)	Quadrant 2
	Disaggregate (e.g., person and household level, activity-based model)	Quadrant 3	Quadrant 4 (long-term goal)

5.2 Investigations in the RFI

As noted in this report, TPB staff needs a travel model that can analyze the current and future transportation issues of the metropolitan Washington region, but it must also be also tractable (i.e., practical to use). Vendor responses to the RFI should include two parts: 1) a concise report that describes the vendor's proposed approach for the TPB Gen3 travel demand forecasting model; 2) a completed model checklist. The checklist can be found in a separate document. The vendor report should include all the issues/questions raised in the checklist. Although the checklist includes many check boxes, it also includes some space for written comments. These written comments should be relatively brief, since more details can be included in the vendor report. Although the model checklist includes over 25 items, three of these items are listed below and are described in the next section of the report:

1. Type of travel model
2. Land use forecasting
3. Use of dynamic traffic assignment (DTA)

Type of travel model: The consultant should recommend the type of travel model (e.g., trip-based, tour-based, activity-based, or some hybrid of these) that should be pursued to meet both the model requirements and project constraints in the PRD. In the strategic plan developed by CS in 2015, an ABM was recommended.[50] However, based on discussions with staff at MPOs that have implemented or are working to implement an ABM, it is become clear that, despite the theoretical advantages of ABMs, the development and use of an ABM comes with many challenges, e.g., long development times, long model run times, and difficulties for staff when they need to track down the source of counterintuitive results. Consequently, TPB staff is open to a variety of model types, and recognizes that a hybrid approach could be a good compromise. Hybrid models were discussed in a recent TRB presentation and conference paper.[51] However, TPB staff is also open to other model forms, such as a trip-based, tour-based, or activity-based model. Irrespective of the model type chosen by the consultant as their choice of solution to the PRD, it is recommended that consultant make a compelling argument, ideally evidence-based, for

[50] Cambridge Systematics, Inc., "Strategic Plan for Model Development, Task Order 15.2, Report 3 of 3."
[51] Vyas et al., "Stepping Closer to ABM: Hybrid 4-Step Models."

their proposed solution. Evidence-based means citing examples where the proposed solution is being used in practice. So, for example, if a consultant recommends developing a new trip-based model (which implies shorter development times) with lots of new data collection, the consultant should make a compelling case for why that is superior to recommending an activity-based model with no further data collection (e.g., make a clear case for why the added complexity if offset by the benefits, and provide evidence that the proposed model can be used by both TPB staff and the various regional modeling stakeholders, principally state and local governments and consultants). Lastly, the consultant should also make clear any changes to the travel model inputs (also discussed in Section 6.1.5, "Model inputs"). This could include:

- Changes to the zone system, e.g., use of land ownership parcels or micro-analysis zones (MAZs)
- Changes to the transportation networks, e.g., use of more disaggregate networks to aid in non-motorized modeling or representing access to transit.
- Changes to the land activity/land use data, which is currently input to the model at the TAZ level.

Changes to any of the model inputs could require one or more years to implement, so consultants should specify if these updates would be started during the development of the Gen3 model, even though they might not be ready for use until the Gen4 model.

Land use forecasting: COG staff, working with local government staff, develop zone-level (TAZ-level) land activity forecasts for the modeled area shown in Figure 1 using a process known as the Cooperative Forecasts.[52] This process is essentially a modified Delphi approach that combines both top-down regional land activity forecasts from an econometric model with bottom-up zone-level land activity forecast from the local jurisdictions. [53] This contrasts with other MPOs that use formal land use models, instead of a Delphi process. In the 1970s, COG attempted to use the EMPIRIC land use model, but the results were "disappointing."[54] Although it is unlikely that COG would replace its Cooperative Forecasting process with a land use model, one could envision an approach where the Cooperative Forecasting process is informed by a land use model.

Regarding land use models, there seems to be some debate about whether the use of an ABM necessitates the use of a land use model. According to one East Coast MPO, use of an ABM does not necessitate the move to a land use model. However, according to a West Coast MPO, use of an ABM necessitates the use of a land use model. In consultant responses to the RFI, consultants should be explicit about whether they are recommending changes to the current COG/TPB land use forecasting practice. The following questions should be addressed:

- What is the recommended technique or model to use for land use forecasting?

[52] "Cooperative Forecast," Metropolitan Washington Council of Governments, 2018, https://www.mwcog.org/community/planning-areas/cooperative-forecast/.

[53] Greg Goodwin, "Cooperative Forecasting Program: Background and Draft Round 8.2 Estimates (Slides 9 and 10 Corrected on 4/4/13)" (March 22, 2013 meeting of the Travel Forecasting Subcommittee of the Technical Committee of the National Capital Region Transportation Planning Board, held at the Metropolitan Washington Council of Governments, Washington, D.C., March 22, 2013), http://www.mwcog.org/committee/committee/archives.asp?COMMITTEE_ID=43.

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

- What is the recommended aggregation level (e.g., TAZs, MAZs, parcels)?
- Should there be a feedback loop between the land-use model and the travel model? If so, what should be the general structure of this feedback loop?

Use of dynamic traffic assignment (DTA): Consultants recommending moving to a dynamic traffic assignment (DTA) should make the case why it is better to move to a disaggregate supply sooner, rather than later, and why it makes sense to move to a disaggregate supply model before moving to a disaggregate demand model. Most MPOs in our peer group have elected to move to a disaggregate demand model (e.g., ABM) first. The TPB staff recognizes that the ultimate goal is a disaggregate demand model (such as an ABM) paired with a disaggregate supply model (such as DTA), but is unconvinced that, given the current state of these models and computing technology, it makes sense to move to this modeling structure for the Gen3 model.

Final note: In all cases, the goal of the consultant submissions is to make the case for the recommended modeling strategy. The baseline case is always the existing, aggregate, trip-based four-step travel demand model. In cases where consultants propose a new approach, they need to make a convincing case for why the benefits of the new approach outweigh the costs. It is not enough to simply say that model B is better than model A. If model B is more sophisticated or complicated, then it also comes with added costs. The consultant submittals should make the case for why the added benefits of the new model outweigh the added costs.

5.3 RFI: Use of consultant proposals

TPB staff intends to review the consultant proposals received in response to the RFI. As noted earlier, TPB staff does not intend to share the consultant proposals with competing vendors or other outside parties. TPB staff may have follow-up questions and dialog with one or more of the responding vendors. Ideally, this follow-up would be conducted in writing (via email), with a copy to the COG Contracts and Purchasing Office (purchasing@mwcog.org). If TPB staff feels a meeting is warranted, TPB staff will consult with the COG Contracts and Purchasing Office before setting up such a meeting. TPB staff intends to use the information supplied in the RFI responses to set some of the general parameters used in the RFP. Thus, the TPB staff plans to pick the type of model (trip-based, tour-based, activity-based, or hybrid), and other related issues, such as the possible use of a land use model, DTA, or more disaggregate model inputs/supply-side data, to write the SOW for the RFP.

5.4 Investigations in the contract

Once the contract has been awarded, it is planned that one of the first tasks for the consultant will be to conduct a series of investigations. These investigations should occur during the early part of the three-year contract, since later work in the contract is dependent on the outcomes of the investigations. Each of these investigations will be documented in a memo or report, which will then be reviewed by TPB staff and, ideally, the TFS. Although some of the investigation topics are the same as were covered in the RFI process, it is planned that the repeated investigated will be conducted in more depth than was used in the RFI process. Additionally, there will also be one or more new investigations, which were not covered as part of the RFI process.

5.4.1 Base investigations

As a minimum, there are likely to be three base investigations:

1. Type of travel model
2. Land use forecasting
3. Use of dynamic traffic assignment (DTA)

Type of travel model: Suppose, for example, that, in the RFP, the TPB staff chose to solicit proposals for a hybrid model. As part of the initial stages of the contract, the selected vendor would need to specify and finalize several details, such as the type of hybrid model, and which components would be aggregate versus disaggregate, and which components would be trip-based versus tour-based. Thus, this investigation would provide the details about the type of model that would be developed by the selected vendor later in the three-year contract.

Land use forecasting: The consultant should specify the details of the recommended land use forecasting process, particularly if it is different from the current process (e.g., recommending the use of a land use model; recommending an aggregation level that is different from the current TAZ-based system).

Use of dynamic traffic assignment (DTA): Consultants who are recommending moving to DTA, should conduct a more detailed investigation about the pros and cons of moving to DTA, to ensure that a tractable model/process is developed. TPB staff is not expecting that the Gen3 model will make use of DTA, so, if a consultant is recommending that DTA be part of the Gen3 model, then the consultant has to make a strong case for the change.

5.4.2 Other investigations

In addition to the base investigations, there could be other investigations that the selected vendor would conduct in the early phases of the contract to help define work that would be conducted in later phases of the contract. For example, one such investigation could be about recommended software (see below).

Recommended software: What is the best software to use to implement the new model? It is possible/recommended that multiple software packages could be required to support the recommended model? Below is a list of some of the key software packages:

1. Travel demand forecasting software, for path building, traffic assignment, and transit assignment: Citilabs Cube (our current software), Caliper TransCAD, INRO EMME, PTV VISUM, or even a combination of these. Each of these packages has strengths and weaknesses. In theory, our current travel model and a future travel model could be implemented in any of these, but aspects specific to the modeling needs for our region could make one package a better fit than another.
2. Software to develop, edit, and maintain the transportation networks that are a primary input to the travel model. We currently use a combination of ArcGIS, COGTools,[55] and Cube Base. The consultant should provide advice on the recommended spatial database/GIS system for editing and managing transportation networks. Any system should allow storage of multiple network scenarios and more than one user should be able to make edits at once.

[55] Qiang Li and Jim Yin, "COGTOOLS User Guide, Revision 3.0" (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, October 17, 2013).

3. If we pursue specific new models, which software should be used?
    a. ABM: CT-RAMP, DAYSIM, TourCast, ActivitySim
    b. Land use model
    c. DTA software

6 Model requirements

The model requirements section of this report lists the model functionality and capabilities that we would like to have in the TPB TDFM Gen3 travel model. The word “requirements” is used to mean “expected” or “desired” capabilities. The reason for this is that we recognize that it may not be possible to develop a model that meets every requirement in our list, given time and resource limitations. If a functional requirement is a true requirement (as opposed to just desired functionality), **then it will be marked as “mandatory.” Mandatory requirements must be met, or the proposed model will be deemed unacceptable**. Additionally, **each model requirement is given a priority ranking (high, medium, and low)**, which is meant to help consultants develop their recommended set of improvements that will provide the largest benefit.

General expectation: It is expected that the TPB TDFM Gen3 travel model, will be state of the practice, or even state of the art, when compared to the models used by our peer MPOs (see Table 2).

6.1 Functional requirements

6.1.1 Minimum requirement (**mandatory**)

The current adopted, production-use travel demand forecasting model is called the TPB Travel Demand Forecasting Model, Generation 2, Version 2.3.70 (TPB TDFM Gen2, Ver. 2.3.70). The Gen3 model **must have, as a minimum, all the functional capabilities of the current model**. Additionally, the Gen3 model **must have the mandatory requirements listed in this section of the report, along with as many of the non-mandatory requirements as possible**. The documentation for the current model (the user’s guide, calibration report, and validation memo, which were cited earlier) will provide the best information about the functional capabilities of the current model.

6.1.2 Model form (**mandatory**)

As noted earlier in this report, TPB staff is open to many model forms (e.g., trip-based, tour-based, activity-based, or some hybrid of these), provided the model

- Meets the requirements in this document,
- Addresses the modeling issues important to the metropolitan Washington region, and
- Conforms to the constraints described in this document.

Although the two most dominant model forms in the U.S. are aggregate trip-based models and disaggregate activity-based models, TPB staff, nonetheless, encourages responding consultants/vendors to consider the merits of a hybrid model, which could be a good compromise between an aggregate, trip-based model and a disaggregate, activity-based model. Nonetheless, TPB staff is not committed, at this time, to any one model form, so it is up to the responding consultant to make a compelling argument for why the recommended model form is superior to the alternative model forms. “Model form" is considered a mandatory item, since, by definition, every model in a proposal will have a model form.

Note that, although this section is outlined using vernacular from trip-based models (e.g., "trip generation," "trip distribution," "mode choice"), this is not meant to imply that the Gen3 model will be a trip-based model. It is simply a way to structure functional requirements using a framework that is well established in the travel demand forecasting industry.

6.1.3 Travel modes represented

As alluded to in the first requirement (6.1.1, "Minimum requirement (**mandatory**)"), the Gen3 model must be able to represent all travel modes represented in the current model. The list below shows **travel modes included in the current model, as well as some that are not, but could be, in a Gen3 model**. If a mode in the listed below is not included in the current model, it is noted as such:

1. Person travel
    a. Motor vehicle
        i. Private transportation: Low-capacity motor vehicles, such as cars/automobiles, light-duty trucks, sports utility vehicles (SUVs), and motorcycles
            1. Single-occupant vehicles (SOV)
            2. High-occupant vehicles (HOV2, HOV3+)
        ii. Public transportation
            1. Fixed route, fixed schedule
                a. Rail modes
                    i. Heavy rail (HR)
                    ii. Commuter rail (CR)
                    iii. Light rail transit (LRT)
                    iv. Streetcar (SR)
                b. Non-rail modes
                    i. Local bus (MB)
                    ii. Commuter Bus (CB)
                    iii. Bus Rapid Transit (BRT)
                    iv. Shuttle bus service (not included in current model; **low priority**)
                    v. Ferry (No ferry service is included in the current model, though the model has the capability to represent ferry service, coding them in a similar manner to bus routes)
            2. Flexible route, flexible schedule (completely personalized services)
                a. Low-capacity motor vehicles
                    i. Taxi/taxicab/taxi. Included in the current model, but not in a very complete manner. Taxi travel is incorporated in the current model as one of several

"exogenous"/"residual" trip purposes.[56] (**medium priority** to enhance representation in the model)
        ii. Transportation Network Companies (TNC, not included in the current model; **high priority**)
        iii. Short-term car rental/car sharing, like car2go (not included in the current model; **low priority**)
        iv. Paratransit, such as MetroAccess (not included in the current model; **low priority**)
      b. Demand responsive transit (DRT), such as BRIDJ, which no longer exists in the DC area (not included in the current model; **low priority**)
  b. Non-motorized (NM): Both walk and bike are included in the current model, but not as distinct modes, and only in trip generation and access to transit (**high priority** to improve representation of NM modes)
    i. Walk
    ii. Bike
      1. Private use, privately owned
      2. Public use, bikeshare (not included in the current model)
        a. Stored in docks
        b. Dockless
2. Freight
  a. Medium truck
  b. Heavy truck
3. Other commercial vehicles (some of this is freight, some of it is services)

TNCs are one component of a class of travel services known as shared mobility. A recent federal report discusses ways that MPOs are thinking of using to improve the ability of the regional travel demand model to represent shared mobility modes,[57] including:

- Incorporating shared mobility in travel surveys
- Collecting data continuously
- Using off-model approaches to estimate shared mobility impacts

In addition to the travel modes that are handled in the current model, the Gen3 model should also be able to **address some new travel modes** and/or **better address some of the existing travel modes** (i.e.,

[56] Exogenous/residual travel consists of the following: 1) Through vehicle trips, a.k.a. external-to-external (XX) vehicle trips, consisting of auto, commercial vehicle, heavy truck and medium truck; 2) External-to-internal (XI) and internal-to-external (IX) vehicle trip-ends; 3) Miscellaneous vehicle trips, consisting of taxi, visitor/tourist and school vehicle trips; and 4) Airport-passenger, auto-driver trips. Exogenous travel is not included in trip generation, trip distribution, or mode choice. Instead, it is incorporated into the model stream at the time-of-day model, just before traffic assignment.
[57] "Integrating Shared Mobility into Multimodal Transportation Planning: Improving Regional Performance to Meet Public Goals" (Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration, February 2018), 28–30.

in a more robust manner). Travel modes that could either be added to the travel model or represented in a more robust way are listed below (generally, in descending order of importance):

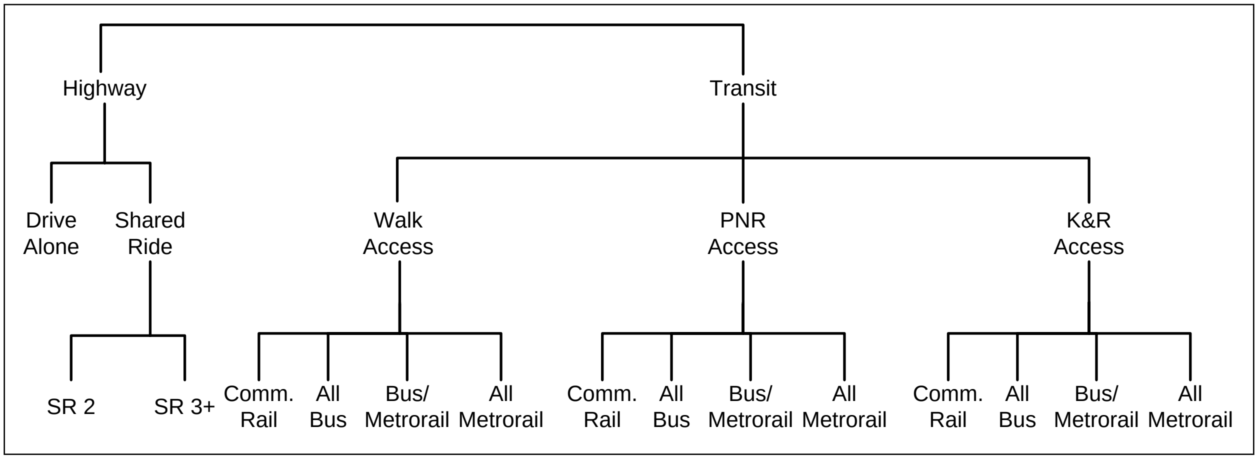
- Non-motorized (NM) trips: The current model represents NM trips in two manners: 1) trip generation; and 2) as an access mode to transit for path building and mode choice. The Gen3 model should expand on this representation (**high priority**). This could be by moving the representation deeper into the model chain, e.g., through to trip distribution and mode choice, or by differentiating between walk and bike travel, or both. There are many MPO travel models that now include these trips all the way through mode choice. Assigning walk/bike trips is still exceedingly rare, but one or two MPOs may be doing this for bike trips (e.g., Portland, OR). Enhanced modeling of NM trips could drive the need for more disaggregate transportation networks (e.g., all streets, Open Street Maps) and more detailed area systems, such as micro-analysis zones (MAZs), which appear to be in use or under development in San Diego, San Francisco, Chicago, and Miami,[58] so consultant responses may want to address the issue of or need for improvements to the supply side of the model (more disaggregate transportation networks and smaller zone sizes).
- Improved ability to distinguish transit sub-modes (**high priority**): Transit can be divided into transit sub-modes such as local bus, express/commuter bus, BRT, streetcar, LRT, rapid transit/heavy rail, and commuter rail. Both the current travel model (Gen. 2/Ver. 2.3) and one of the current developmental models (Gen. 2/Ver. 2.5) can distinguish between transit sub-modes, but they take two different approaches:
    - Ver. 2.3: <u>Complex</u> mode choice model, but <u>simple</u> transit path builder and transit assignment
    - Ver. 2.5: <u>Simple</u> mode choice model, but <u>complex</u> transit path builder and transit assignment

  For example, in the **<u>Ver. 2.3 travel model</u>**, the mode choice model is complex. As shown in Figure 2, the nested-logit (NL) model includes three auto modes (drive alone, shared ride 2 person, and shared ride 3+ person) and four transit modes (commuter rail, all bus, all Metrorail, and combined bus/Metrorail). The four transit modes are stratified by three modes of access to transit: Park and ride (PNR); Kiss and ride (KNR); and Walk.[59] Thus, the mode choice model has 12 transit sub-modes. Although the mode choice model does not explicitly include certain transit sub-modes, such as streetcar, BRT, and LRT, the travel model, including the mode choice model, is, nonetheless, designed to deal with these transit sub-modes.[60] Conversely, the transit path builder and transit assignment in the Ver. 2.3 mode is relatively simple. Since the mode choice model has delineated 12 transit sub-modes, the transit assignment model simply assigns these sub-modes. Transit assignment is conducted for two time-of-day periods: peak and off-peak. It is assumed that all home-based-work (HBW) trips occur in the peak period. All other trip purposes are assigned in the off-peak period. Using a complex mode choice model and a simple

[58] See, for example, Metropolitan Transportation Commission and Parsons Brinckerhoff, Inc., "Travel Model Two: Strategic Supply Design," Technical Paper (Metropolitan Transportation Commission, August 24, 2012), 2.
[59] "User's Guide for the COG/TPB Travel Demand Forecasting Model, Version 2.3.70: Volume 1 of 2: Main Report and Appendix A (Flowcharts)," 169.
[60] 169–70.

transit assignment is a very common practice for regional travel models in the U.S. The mode choice model is implemented in a C++ program called AEMS. The transit path builder and transit assignment are implemented in the TRNBUILD module of Cube Voyager.

Figure 2 Nesting structure of the nested-logit mode choice model in the Version 2.3 travel model



By contrast, in the **Ver. 2.5 travel model**, the mode choice model is relatively simple: The multinomial-logit (MNL) has only six (not 15) choices: 1) Auto, single-occupant vehicle (SOV): 2) Auto, high-occupancy vehicle, 2-person (HOV2); 3) Auto, high-occupancy vehicle, 3-plus-person (HOV3+); 4) Transit, PNR access; 5) Transit, KNR access; and 6) Transit, walk access.[61] So, instead of four explicit transit sub-modes in the mode choice model, there is only one. However, the transit path builder and transit assignment in the Ver. 2.5 mode is relatively complex. The choice of transit sub-mode (local bus, express bus, Metrorail, etc.) has been moved to the path-building and transit assignment steps. Transit assignment in the Ver. 2.5 model is also conducted for two time-of-day periods: peak and off-peak. Using a simple mode choice model and a complex transit assignment is more commonly seen in travel models in Europe, though the practice -- sometimes called "flattened mode choice" or "narrow mode choice" model -- is seeing increasing use in the U.S. The mode choice model is implemented in the MATRIX module of Cube Voyager. The transit path builder and transit assignment are implemented in the Public Transport (PT) module of Cube Voyager.

Rationale: In the case of the Ver. 2.3 and 2.5 travel models, TPB staff chose to move to the flatten mode choice approach for the following reasons:

- By doing this, you are more likely to have consistency within your model between path building and path skimming/mode choice: "Consistency with mode choice parameters—Are transit path-building and assignment parameters consistent with the relationships used in the mode choice model?"[62]

[61] Cambridge Systematics, Inc. and Gallop Corporation, "FY 17 Task Orders," chap. 4.
[62] Cambridge Systematics, Inc. et al., *NCHRP Report 716: Travel Demand Forecasting: Parameters and Techniques*, National Cooperative Highway Research Program (Washington, D.C.: Transportation Research Board of the National Academies, 2012), 78, http://www.trb.org/Main/Blurbs/167055.aspx.

- Other large MPOs seem to be moving in this direction. For example, as noted in a recent report by MTC, the MPO for San Francisco, CA, "Mode choice. As noted in Section 2 Model Design, a modified approach to trip mode choice/transit route choice will be taken. Rather than the traditional creation of mode-weighted paths, the N best paths will be created for each access/egress mode combination – possible access/egress modes include walk, bicycle, and drive. **The route choice model will then determine the best of these paths for selection in the simulation**."[63]
- TCRP Report 166 seems to encourage this trend: "In technical modeling terms, the mode choice model structure was revised to incorporate a path choice sub-nest in the walk and drive access portion of the nested logit (NL) choice model. This process required different path-building parameters for each path choice; these were developed by synthesizing all reasonable path choices (486) and matching them to observed behavior from the on-board transit survey."[64]
- Our past on-call consultant recommended it: "Incorporating PT supported the ability to explore alternative mode choice model structures, including having more of the transit submode choice logic reside within the transit assignment step."[65]

It is expected that the Gen3 mode choice model would likely use the "flattened mode choice" approach, but it is up to each responding vendor to make the case for the approach that they recommend.

- Taxis: Inclusion in a more detailed manner (**medium priority**). Although the Gen3 model is to be developed with "existing" data (e.g., the 2007/2008 COG Household Travel Survey), there could be other existing data sets, that were not used in the original calibration of the model (in 2012), but which are now available (and, hence, are still considered existing data) that could be used. As one example, DC provides observed taxi cab data (http://opendata.dc.gov/datasets?q=taxi).
- Transportation network companies (TNCs, **high priority**). TNCs exist in the DC region currently, but are not included in the model, because they did not exist in the primary model calibration data set (the 2007/2008 COG Household Travel Survey). As noted earlier, TNCs are growing rapidly (one study in San Francisco, cited earlier, suggests that they may account for 20% of VMT in San Francisco). Unfortunately, there is a paucity of data for TNCs, since they are private entities, but a recent TRB draft report did include some TNC data (from an unnamed TNC) for DC and other cities.[66] If any of our peer MPOs are including TNCs in their model, then we would hope that TNCs could be included in our Gen3 model.

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[63] Metropolitan Transportation Commission and Parsons Brinckerhoff, Inc., "Travel Model Two: Strategic Supply Design," 13.
[64] Maren Outwater et al., *TCRP Report 166: Characteristics of Premium Transit Services That Affect Choice of Mode* (Washington, D.C.: Transportation Research Board of the National Academies, 2014), 26, http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_166.pdf.
[65] Cambridge Systematics, Inc. and Gallop Corporation, "FY 17 Task Orders," 1–6.
[66] Feigon and Murphy, "Broadening Understanding of the Interplay Between Public Transit, Shared Mobility, and Personal Automobiles."

- CAVs, privately owned by households, corporately owned fleets of vehicles for use by the general public, or both (**medium priority**). To our knowledge, we do not know of any MPOs that have an explicit capability to model CAVs, though several MPOs have done sensitivity testing in this area (e.g., ARC[67]) and some researchers[68] and consultants have also done sensitivity tests in this area.[69]
- Ground transportation to/from the three commercial airports (ideally in a more explicit manner than is currently done in the current model, **medium priority**). Airport auto driver trips are input to the current model as one of the exogenous travel inputs. All person trips traveling to/from the three commercial airports could be included in the Gen3 model in a more explicit manner. A proposal to include such trips was developed in 2012, but, due to priorities at that time, was never implemented.[70] This issue is discussed more below.
- Short-term car rental/car sharing, such as car2go (**low priority**).

6.1.4 Modeling capabilities that span more than one model step

6.1.4.1 Managed lane facilities

According to a recent FHWA report, managed lanes are defined as “highway facilities or a set of lanes where operational strategies are proactively implemented and managed in response to changing conditions.”[71] The report goes on to cite examples of managed-lane facilities, including high-occupancy vehicle (HOV) lanes, value-priced lanes, high-occupancy toll (HOT) lanes, and exclusive or special-use lanes. TPB’s current production-use travel model (Ver. 2.3.70) can represent and model managed-lane facilities. The Gen3 model must also be able represent and model managed-lane facilities, using state-of-the practice or state-of-the-art techniques. Shortcomings in the current model that could be improved in the Gen3 model:

1. Elimination of the HOV3+ skim replacement (HSR) technique, which guarantees that HOV traffic on HOT lanes will not suffer operationally from the paying HOT-lane traffic, but also necessitates two model runs for every scenario that involves HOT lanes, which is most scenarios, now that HOT lanes have been operating in Virginia since November 2012. The Ver. 2.3.70 model employs

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[67] “Model Development Technical Support,” Request for proposal (RFP) (Atlanta, Georgia: Atlanta Regional Commission, October 2016).

[68] Serbjeet Kohli and Luis G. Willumsen, “Traffic Forecasting and Autonomous Vehicles,” in *Association for European Transport Papers Repository* (44th European Transport Conference, October 5-7, 2016, Barcelona, Spain, 2016), http://www.steerdaviesgleave.com/sites/default/files/elfinder/Traffic-forecasting-and-automated-vehicles-Kohli-Willumsen.pdf.

[69] See, for example, Kevin Johnson and Will Lisska, “Autonomous Vehicle Testing with the COG/TPB Model” (January 27, 2017 meeting of the COG/TPB Travel Forecasting Subcommittee, held at the Metropolitan Washington Council of Governments, Washington, D.C., January 27, 2017).

[70] AECOM and Stump/Hausman Partnership, “FY 2012 Draft Final Report, COG Contract 12-006: Assistance with Development and Application of the National Capital Region Transportation Planning Board Travel Demand Model” (National Capital Region Transportation Planning Board, Metropolitan Washington Council of Governments, July 13, 2012), chap. 8, http://www.mwcog.org/uploads/committee-documents/aV1dWVhb20120720132722.pdf.

[71] FHWA, “Managed Lanes: A Primer” (Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration, 2008), 5, http://www.ops.fhwa.dot.gov/publications/managelanes_primer/managed_lanes_primer.pdf.

the HSR,[72] but the next production model (Ver. 2.3.75 or greater) has been updated to remove this procedure, which results in large savings in model run time. This update is considered to be accomplished, but we are open to other suggested improvements in modeling managed-lane facilities (**medium priority**).

2. Obtaining data for use in a future model update: It has always been a challenge to get observed usage data on HOT lanes, which tend to be operated by private corporations that are unwilling to provide usage data that they consider proprietary (**medium priority**).

6.1.4.2 Exogenous travel markets

The exogenous inputs in the current TPB travel model consist of four major markets: 1) Through vehicle trips, a.k.a. external-to-external (XX) vehicle trips, consisting of auto, commercial vehicle, heavy truck and medium truck; 2) External-to-internal (XI) and internal-to-external (IX) vehicle trip-ends; 3) Miscellaneous vehicle trips, consisting of taxi, visitor/tourist and school vehicle trips; and 4) Airport-passenger, auto-driver trips. Exogenous travel is not included in trip generation, trip distribution, or mode choice. Instead, it is incorporated into the model stream at the time-of-day model, just before traffic assignment. Consultant proposals should consider whether any of these markets can be included in the Gen3 travel model in a more explicit manner (**medium priority**).

6.1.4.3 Travel to the region's three commercial airports

This region is home to three commercial airports. COG/TPB staff have been conducting regional airport system planning for over 30 years, in a process known as the Continuous Airport System Planning (CASP) process, which involves working with the Federal Aviation Administration (FAA). Similarly, COG/TPB staff have been conducting regional air passenger surveys, generally every two years, at the three commercial airports for over 30 years, working in concert with the Metropolitan Washington Airports Authority (MWAA, for DCA and IAD) and the Maryland Aviation Administration (MAA, for BWI).[73]

Here are some topics that may need addressing as part of the Gen3 model. First, transit trips to the region's three commercial airports are not well represented in the model. Could this be improved? Second, we do not currently have an airport choice model, though work has been conducted in this area in the past.[74] Would the Gen3 model benefit from having an explicit airport choice model?

For any work relation the regional airport system, TPB travel modeling staff should coordinate with the TPB Aviation Technical Subcommittee, particularly regarding any potential changes to the air passenger survey, which may not contain all the variables that might be needed to estimate an airport choice model (**medium priority**).

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[72] See, for example, "User's Guide for the COG/TPB Travel Demand Forecasting Model, Version 2.3.70: Volume 1 of 2: Main Report and Appendix A (Flowcharts)," 31–34.

[73] See, for example, Richard I. Roisman and Abdurahman Mohammed, "2011 Washington-Baltimore Regional Air Passenger Survey: General Findings Report" (Washington, D.C.: National Capital Region Transportation Planning Board, Metropolitan Washington Council of Governments, in cooperation with the Federal Aviation Administration, May 2012).

[74] See, for example, Geoffrey D. Gosling, "SCAG Regional Airport Demand Model: Literature Review" (Los Angeles, California: Southern California Association of Governments, June 2003), 7, http://www.scag.ca.gov/modeling/mtf/pdf/literaturereview062403.pdf.

6.1.4.4 Internal-to-external and external-to-internal transit travel

The current model represents internal-to-internal (II) transit travel, but not internal-to-external (IX) or external-to-internal (XI) transit travel. This results in an underestimation of transit trips, particularly to the three commercial airports, but also to Union Station, given the large share of commuter rail trips coming from areas of Maryland that are north of BWI airport and thus external to the region's modeled area. This shortcoming has been identified in the past. A proposed solution was developed in 2012, but 1) it was never implemented, due resource limitations at the time; and 2) it was designed focused on Metrorail trips, not all transit trips, so it did not include commuter rail.[75] It is believed that external transit trips constitute about 5% of Metrorail travel, but this ratio could be much higher in some parts of the region, especially to/from the three commercial airports, or to/from Union Station (**high priority**).

6.1.5 Model inputs

As alluded to earlier, the consultant should provide guidance on whether they recommend any changes to the inputs to the travel model, both the transportation networks (supply side) and the land use inputs, i.e.,

- Changes to the zone system, e.g., use of land ownership parcels or micro-analysis zones (MAZs)
- Changes to the transportation networks, e.g., use of more disaggregate networks to aid in non-motorized modeling or representing access to transit.
- Changes to the land activity/land use data, which is currently input to the model at the TAZ level.

(**high priority**)

6.1.5.1 Zone system

The modeled area for the TPB travel model is shown in Figure 1. It is divided into 3,722 transportation analysis zones (TAZs), comprised of 3,675 internal zones and 47 external stations. The consultant should provide advice on whether the current zone system is sufficient for future model development work, or whether changes need to be made. Although the effort to develop a new zone system can be substantial, possible motivations for such a change include the following:

- Need for smaller zones, such as micro analysis zones (MAZs) or even land parcels, to support a disaggregate demand model.
- The American Association of State Highway and Transportation Officials (AASHTO) has recently announced that, "Following the release of the Census Transportation Planning Products (CTPP) 2012-2016 dataset in early 2019, the Oversight Board to the CTPP Program is announcing it will no longer include Transportation Analysis Zone (TAZ) and Transportation Analysis District (TAD) geographies in future requests for special tabulations of the U.S. Census Bureau's American

[75] AECOM and Stump/Hausman Partnership, "FY 2012 Report," chap. 7.

Community Survey (ACS) data. Future CTPP special tabulation requests will include the standard census block group geography instead."[76]

- In 2007, COG and TPB developed a system of Regional Activity Centers and Clusters.[77] Although the clusters are no longer in use, the Regional Activity Centers are still in widespread use for planning activities.[78] If it is decided to move forward with a new TAZ or MAZ system, these zonal boundaries should be developed with the Regional Activity Centers in mind, so that there is alignment of zonal boundaries, when possible. This issue was also discussed by CS in 2009.[79]

6.1.5.2 Networks

6.1.5.2.1 Highway Networks

See above discussion on model inputs starting on p. 36.

Shape and curvature of network links: Travel demand models make use of transportation networks to build zone-to-zone paths and perform trip assignment. There is no intrinsic need for the network links (road segments) to have shape or curvature, only that the topology be correct. Thus, in many models, links are represented as simply straight-line segments between nodes. However, there can be benefit to networks with links that have accurate geometry. First, it improves the look of the networks, which is especially important for developing reports and presentations. Second, it can lead to more accurate networks, since accuracy of the network can be more easily compared with aerial photography. To add geometry to network links, one generally needs an accurate all-streets network, coupled with processes known as conflation. Once you have a network with geometrically correct links, modelers may still need to select certain software settings to see the detailed geometry (e.g., in Cube Base, turn on "True Shape" Display).

In the mid-1990s, TPB staff developed early versions of transportation networks for the model that were "shape enabled." Around 2009, TPB staff developed a tool to perform network conflation, which resulted in networks with geometrically correct links.[80] When the conflation work was done at COG, not all links were given the true geometry. Specifically, freeway ramps were generally left as straight-line segments. At this point, however, TPB staff and some modeling stakeholders see benefits of giving proper geometry to freeway ramps. Adding curvature to the freeway ramps requires manual work, but TPB staff hopes to implement such work over the next few years. TPB staff are open to solutions for expediting this work (**priority medium**).

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[76] "AASHTO - CTPP - Policy Change on Small Geography," American Association of State Highway and Transportation Officials, February 22, 2018, http://ctpp.transportation.org/Pages/Policy-Change-on-Small-Geography.aspx.

[77] Metropolitan Washington Council of Governments, "Metropolitan Washington Regional Activity Centers and Clusters" (Washington, D.C.: Metropolitan Washington Council of Governments, April 2007), http://www.mwcog.org/uploads/pub-documents/ylhZVw20070828145020.pdf.

[78] "Activity Centers - Data & Tools," Metropolitan Washington Council of Governments, 2018, https://www.mwcog.org/community/planning-areas/land-use-and-activity-centers/activity-centers/.

[79] Cambridge Systematics, Inc., "Fiscal Year 2009 Task Reports," Final Report (Washington, D.C.: National Capital Region Transportation Planning Board, November 20, 2009), 4–8, http://www.mwcog.org/transportation/activities/models/review.asp.

[80] Martha Kile, "Network Conflation" (May 22, 2009 meeting of the COG/TPB Travel Forecasting Subcommittee, held at the Metropolitan Washington Council of Governments, Washington, D.C., May 22, 2009).

6.1.5.2.2 Transit Networks

See above discussion on model inputs starting on p. 36.

6.1.5.2.2.1 Transit fares

The current TPB travel model (Ver. 2.3.) is implemented in Cube Voyager, including TRNBUILD. The current developmental travel model (Ver. 2.5) is also implemented in Cube Voyager, but uses Public Transport (PT). The fare development process for the current model (Ver. 2.3, TRNBUILD) has two main parts and is described in Chapter 17 of the travel model user's guide. First, Metrorail station-to-station fares are calculated (MFARE1.S). These distance-based fares are a function of both the over-the-rail distance and the Euclidean ("as-the-crow-flies") distance between the two stations. Second, TAZ-to-TAZ transit fares are calculated (MFARE2.S). For TAZ-to-TAZ interchanges whose minimum path includes Metrorail for a portion of the path, the transit fare is the sum of the Metrorail station-to-station fare plus the non-Metrorail (principally bus) TAZ-to-TAZ fare. For TAZ-to-TAZ interchanges that do not involve Metrorail, the transit fare is simply non-Metrorail (principally bus) TAZ-to-TAZ fare. The procedure for calculating the non-Metrorail transit fare relies on developing a non-Metrorail fare matrix (called a "bus-fare" matrix, even though it includes non-bus modes such as commuter rail and LRT). Given that 1) we intend to migrate from TRNBUILD to more sophisticated transit path builder (such as Citilabs PT or another vendor solution) in the Gen3 model; and 2) these more sophisticated transit path builders should allow us to use new methods for calculating TAZ-to-TAZ transit fares, as, for instance, was discussed in Chapter 9 of a recent report from AECOM,[81] then we would like to improve the way that transit fares are handled in the Gen3 model (**medium priority**). These improvements could be based on the work that was documented by AECOM.

6.1.5.3 Land use

See above discussion on model inputs.

6.1.5.4 External and through travel

The TPB travel demand forecasting model represents travel that occurs within the modeled area, called internal-to-internal (II) travel. The model also represents trips that cross the external cordon, i.e., internal-to-external (IX) travel, external-to-internal (XI) travel, and through (XX) travel. These last three travel markets are part of the exogenous travel inputs to the model, which are discussed elsewhere in this document. The first two markets (IX and XI) are sometimes collectively referred to as "external travel," even though travel that is strictly external to the modeled area is not really represented in the model.

In the past, consultants have made the following suggestions for mode improvements in this area.[82] Also, TPB staff has recently realized that there are some other problems with the way that external

[81] AECOM and Stump/Hausman Partnership, "Draft FY 2013 Final Report, COG Contract 12-006: Assistance with Development and Application of the National Capital Region Transportation Planning Board Travel Demand Model" (National Capital Region Transportation Planning Board, Metropolitan Washington Council of Governments, July 1, 2013), chap. 9, http://www.mwcog.org/transportation/activities/models/review.asp.
[82] See, for example, Vanasse Hangen Brustlin, Inc., "Results of FY 2006 Travel Forecasting Research" (Washington, D.C.: National Capital Region Transportation Planning Board, Metropolitan Washington Council of Governments, September 22, 2006), 10, 27–28, http://www.mwcog.org/transportation/activities/models/review.asp.

travel has been modeled. Although the issue has been present for several years, staff only recently became aware of the issue, which manifests itself by the fact that these external trip ends seem to be having a much longer trip length than they should. (**high priority**, though this issue is currently being worked on by TPB staff).

6.1.5.5 Treatment of fuel prices

We currently use a fuel price of 10 cents per mile (2007 prices[83]) for both the base year and the out year (i.e., no change in the real price of fuel). This is based on past consultant advice.[84] No items currently identified by TPB staff. We are open to suggested updates that are identified and proposed by consultants. One possible consideration is the fact that, in the future, a sizable share of the fleet could be powered by electricity or other alternative fuels (**medium priority**).

6.1.6 Socio-economic models

No items currently identified by TPB staff. We are open to suggested updates that are identified and proposed by consultants (**low priority**).

6.1.7 Trip generation

Special generators: Some regional travel models make use of special generators, to account for places in the region that generate trips in a way that cannot simply be accounted for by the zone-level land activity data. Examples include universities, regional shopping malls, military installations, and commercial airports. According to the on-call consultant in 2010, "The TPB model currently handles the three commercial airports as special generators, but not universities, group quarters, regional shopping centers, or military bases."[85] The consultant made a series of recommendations (p. 2-18), which should be considered for the Gen3 model (**low priority**).

6.1.8 Trip distribution

The current TPB travel model uses a gravity-model trip distribution process (see Chapter 5 or the calibration report). In 2009, CS had the following recommendation: "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."[86] In 2012, TPB staff noted the following:

> *[TPB staff is open to this suggestion], 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*

[83] All costs and prices are deflated to year-2007 values for consistency, given that the model was calibrated to year-2007 conditions using the 2007/2008 COG Household Travel Survey.
[84] Cambridge Systematics, Inc., "Fiscal Year 2009 Task Reports," 1–12.
[85] Cambridge Systematics, Inc., "Fiscal Year 2010 Task Reports," Final Report (Washington, D.C.: National Capital Region Transportation Planning Board, November 16, 2010), 2–13, http://www.mwcog.org/transportation/activities/models/review.asp.
[86] Cambridge Systematics, Inc., "Fiscal Year 2009 Task Reports," 2–19.

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.

There have also been suggestions that the TPB travel model should shift from a gravity-model trip-distribution model to a destination choice model. In 2009, CS noted "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"[87] (**high priority**).

6.1.9 Mode choice

Historically, most travel models in U.S. cities have featured a relatively complicated mode-choice model and a relatively simple path-building/transit-assignment model. A newer trend has been to use a simpler mode choice model, with more elaborate choices, such as transit sub-mode, made in the path-building/transit-assignment process. This is sometimes called a "flattened mode choice model," though a more apt name might be a "narrower mode choice model." As an example, the Ver. 2.3 mode choice model has 15 modes and 12 transit submodes (i.e., four transit modes by three modes of access). By contrast, the proposed, trip-based successor to the Ver. 2.3 model (the Ver. 2.5 model) incorporates a flattened mode choice model, with the transit sub-mode choice decisions pushed down to the transit path building and transit assignment stages. Although the Ver. 2.5 model is still not a production-use model (it is undergoing testing by COG staff), it is likely that the Gen3 model will also feature a flattened mode choice model, where transit sub-mode choice is made in the transit assignment stage. There is a more detailed discussion of the trade-off between mode choice and transit path building/assignment, including the distinguishing of transit sub-modes on pages 31 to 33 (**high priority**).

Ideally, any future mode choice model should meet Federal Transit Administration (FTA) guidelines for the FTA Capital Investment Grant (CIG) Program, which includes 1) New Starts; 2) Small Starts; and 3) Core Capacity Improvements. In past years, the TPB mode choice model has been identified as having problems with meeting FTA guidelines for New Starts analyses.[88] More recent reviews found fewer problems with the mode choice model, but there still appear to be some issues that should be addressed, e.g., (**medium priority**):

> *During the development of TPB Version 2.3 travel model, it appears that FTA guidance was considered, to some extent, in the mode choice and path building processes, including ensuring proper relationship between coefficients of in-vehicle time and coefficients of out-of-vehicle time and consistency between weights used in path building and coefficient values in mode choice. Further refinements could be pursued in light of this review to address findings with respect to our review/comparison with the latest guidance. More broadly stated, mode choice coefficients and constants such as cost coefficients and alternative specific constants need to be updated to*

[87] Cambridge Systematics, Inc., 2–20.

[88] See, for example, Cambridge Systematics, Inc., 2–19.

be in the reasonable ranges recommended by the FTA, unless compelling evidence can be provided otherwise.[89]

The current mode choice model makes use of seven superdistricts (which are used to create 20 district-to-district geographic market segments) for the purposes of both model calibration and model summary.[90] CS in 2015 recommended that this system of superdistricts be removed (and we concur; **high priority**):

> *The existing geographic segmentation, with 20 district-to-district interchanges, based on seven superdistricts (DC core, VA core, DC urban, MD urban, VA urban, MD suburban, VA suburban), was intended to capture geographic variations, but should be eliminated and replaced with explicit variables that represent urban design and land use diversity and density.*[91]

Nonetheless, the 20 geographic-market-segment-system was not dropped from the Ver. 2.5 model, even though it was developed by CS (this omission was likely due to resource limitations).

If a new mode choice model is estimated/calibrated, our preference would be to first attempt to estimate the coefficients using statistical methods, as opposed to starting with the more common technique these days of setting coefficient values by fiat and simply calibrating the model based on an automated, heuristic calibration method.

6.1.10 Trip assignment

6.1.10.1 Traffic assignment

Must include options for both fast-converging algorithms, such as origin-based assignment and proportional assignment algorithms, which would permit the use of select-link analyses (**high priority**). Regarding the speed of the model run, typically, about half the run time is due to the traffic assignment. The current baseline model (Ver. 2.3.70) makes use of the Citilabs Cube Voyager 6.4.1 (specifically: bi-conjugate Frank-Wolfe traffic assignment algorithm). It should be noted that, although select-link analyses are popular with many analysts, there is a theoretical problem with using them: the lack of guarantee of a unique solution. Specifically, although the user equilibrium solution represents a unique solution in terms of link flows, it does not guarantee a unique solution in terms of path flows.[92] Thus, although there are theoretical reasons why select-link analyses should not be used (e.g., lack of unique solution), they remain popular with some analysts, so it should be expected that that this capability should continue to be a part of the Gen3 TDFM.

In the current model, drive-access-to-transit trips are not part of the highway assignment. Some modeling stakeholders have noted that it would be useful to be able to include drive-access-to-transit trips in the highway assignment. For example, stakeholders would like to be able to obtain from the

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[89] Cambridge Systematics, Inc., "Review of Transit Modeling with Respect to FTA Guidance, Task Order 15.3," Final Report (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, October 15, 2015), 23.
[90] Milone et al., "Calibration Report for the TPB Travel Forecasting Model, Version 2.3," 6–7 to 6–10 and 6–22 to 6–25.
[91] Cambridge Systematics, Inc., "Review of Transit Modeling with Respect to FTA Guidance, Task Order 15.3," 23.
[92] Yosef Sheffi, *Urban Transportation Networks: Equilibrium Analysis With Mathematical Programming Methods* (Englewood Cliffs, New Jersey: Prentice Hall, 1985), http://web.mit.edu/sheffi/www/urbanTransportation.html.

model both park-and-ride (PNR) and kiss-and-ride (KNR) drive-access trips. Stakeholders noted that, if the trip tables from this assignment were made available, the tables could be manipulated to analyze specific locations that are being considered for redevelopment (**medium priority**).

6.1.10.2 Transit assignment

Must be able to perform capacity-constrained assignment. May want to consider moving from production-attraction assignment (the most common approach in the U.S.) to origin-destination assignment (rarer in the U.S., but the dominant approach for highway assignment). May want to consider moving from all-or-nothing assignment (the most common approach for transit assignment in the U.S.) to a capacity-constrained assignment, which makes sense for large metropolitan areas with well-used transit systems (**high priority**).

From 2000 to 2018, the TPB travel model made use of a modeling technique called the "Metrorail constraint through the regional core." This technique, also known as the "transit constraint through the regional core," even though it is specific to Metrorail service, is a technical adjustment to the trip tables coming out of the mode choice process designed to reflect a WMATA policy assumption that, during peak periods, the Metrorail system may have insufficient capacity to serve all the demand traveling to and through the regional core.[93] The Metrorail constraint was initiated by WMATA in 2000 to address funding shortfalls restricting the expansion of the rail fleet. WMATA policy set the binding year, which has most recently been set at 2020. This meant that, for any forecast year past 2020, the Metrorail constraint is applied, i.e., any forecasted peak-period Metrorail trips that exceed the 2020 demand to and through the regional core were shifted to other travel modes (specifically, auto person trips). In 2018, the District of Columbia, Maryland, and Virginia agreed to provide dedicated funding to WMATA ($500 million per year). Due to this historic funding agreement, the Metrorail constraint through the regional core was eliminated as a step in the regional travel demand forecasting model.[94]

6.2 Usability requirements

6.2.1 Model run time

It is expected that the Gen3 model will have a reasonable model run time. The current production-use trip-based model (Ver. 2.3.70) has a run time of about 17 hours. Our current developmental trip-based model (Ver. 2.5) requires about 40 hours to run. For the Gen3 model, the model run time should be no more than 24 hours, assuming a zone-level (TAZ-to-TAZ) analysis, as is the case with the current travel model. If the Gen3 model operates at a more disaggregate level, e.g., micro-analysis zones (MAZs), for one or more modeling steps, the consultant and the TPB staff will agree upon an acceptable model run time. (**mandatory**)

6.2.2 Usage by TPB staff and other local-area modelers (state DOTs, local governments, consultants)

It is expected that the Gen3 TDFM will be able to be run by both TPB staff and other local-area modelers, such as state DOTs, local governments, consultants, which is the case with the current Gen.

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[93] Milone, Moran, and Seifu, "User's Guide for the COG/TPB Travel Demand Forecasting Model, Version 2.3.70: Volume 1 of 2: Main Report and Appendix A (Flowcharts)," 31.
[94] Jane Posey to Transportation Planning Board, "Amendments to the Visualize 2045 Air Quality Conformity Scope of Work," Memorandum, May 16, 2018.

2/trip-based model. Although it is understood that some model forms (such as tour-based, ABM, or hybrid models) may require that model users receive training to be able to run the new model, it is considered mandatory that the Gen3 model be able to be run by current model stakeholders. In other words, any model form that requires consultant assistance to run, will not be considered acceptable. Obviously, some consultant assistance may be necessary in the early stages, but, after an initial introductory/training stage, consultant assistance should no longer be required to run, or, ultimately, to update, the Gen3 model. See, also, the section, below, on Support Requirements. (**mandatory**)

6.2.3 Sub-area analysis

The TPB is a regional entity and focuses on regional transportation planning activities. Nonetheless, consultants, local governments, and, on rare occasions, MPO staff, develop subarea models for project-planning studies and corridor-level studies. Several COG/TPB modeling stakeholders have identified a need to have an easier way to develop subarea models from the regional TPB travel demand model. The TPB travel model is implemented in Citilabs Cube software, which does have methods for creating subnetworks and submodels (e.g., subarea network extraction), but several stakeholders have identified a need to have an easier way to develop subareas and submodels (**priority medium**).

6.3 Technical requirements

6.3.1 Hardware

We currently conduct runs of the regional travel demand forecasting model using four travel model servers, known as tms4, tms5, tms6, and tms7. The computer specifications of these servers can be found in our recent model documentation.[95] It is expected that we will buy a new travel model server (tms8) in 2018 that will have similar, but, hopefully, better, specs to tms7. Although COG has a server room on the second floor of 777 N. Capitol Street, where the travel model servers are kept, we are aware that there is a trend in many agencies of moving some or all servers to the cloud (i.e., the servers are stored in a remote location). So, it is possible, in the future, that we might seek a hardware solution that works with cloud computing.

6.3.2 Current and future software used

We currently use Citilabs Cube software to implement our model. The current production model (Gen. 2/Ver. 2.3) is designed to run within a command window, using a series of Windows batch files and Cube Voyager scripts (and one Fortran program for the mode choice stage). Although TPB staff is comfortable running the model in the command-line mode, TPB staff is open to other ways to implement the model, such as using another execution software environment (e.g., Windows PowerShell, Python, Cube PILOT) or a graphical user interface (GUI), such as Cube Scenario Manager and Cube Application Manager (**medium priority**). Some local modeling stakeholders have expressed an interest in moving from a command-line interface for running the model to a GUI.

[95] Milone, Moran, and Seifu, "User's Guide for the COG/TPB Travel Demand Forecasting Model, Version 2.3.70: Volume 1 of 2: Main Report and Appendix A (Flowcharts)," sec. 3.3.

6.3.3 Version control system and bug-tracking software

We believe that there could be major benefits to using a version control system and a bug-tracking software package to manage the scripts and batch files that make up the model code. We have done some in-house experimentation with Git and GitHub, but we have not implemented a system that can be used by all TPB modeling staff and external users (mainly consultants) who might use or modify the model code. For the RFP/contract phase, we would like consultant assistance to choose the best system for our group and to get it implemented, including training staff or identifying the best written or online training methods (**high priority**).

6.3.4 Software to manage transportation networks used by the travel model

A database is a self-describing collection of data, usually in the form of integrated records. A spatial database is a self-describing collection of spatial data. A relational database is a database consisting of "relations," also known as tables, typically with explicit relationships between tables, such as one-to-one, one-to-many, and many-to-many. A database management system (DBMS) is a set of programs used to define, administer, and process a database. A DBMS is often used to ensure that data tables do not contain duplicates and to enforce referential integrity between data tables. A geographic information system (GIS) is a type of spatial DBMS.

We currently use a series of series spatial databases (Esri personal geodatabases) to store the transportation networks used as inputs to the travel demand forecasting model. Our spatial DBMS is ArcGIS, along with an ArcGIS add-in called COGTools, which was developed for COG by a consultant and now maintained by TPB staff. One question for the consultant would be whether our current system to manage transportation networks is optimal and whether it is up to the task if we make a move to enhance the detail of our networks or our TAZ system (e.g., move to more disaggregate MAZs) (**medium priority**).

6.4 Support requirements

6.4.1 Expectations about TPB staff and consultant support (**mandatory**)

It is expected that there will not be radical changes to the size and expertise of the TPB staff. It is assumed that as staff retire or accept jobs in other agencies, these vacant positions will be refilled with new staff. It is expected that there may need to be training to bring current and new TPB staff up to speed on any new modeling methods. TPB staff can currently develop, maintain, and improve the current trip-based model with only limited consultant assistance. Modeling solutions will be preferred that continue this trend, i.e., that TPB staff can take care of most needs associated with developing, maintaining, and improving the Gen3 travel demand model.

It is assumed that TPB staff will continue to use consultant support to develop, maintain, and improve the Gen3 travel demand model. Table 7 provides the expected division of labor between TPB staff and the consultant. From the table, it should be clear that TPB staff hopes to be involved with all steps of the model development process. This contrasts with some MPO/consultant arrangements where the consultant does all the model development work and the MPO is focused solely on running the model.

Table 7 Division of labor: Expectations about the responsible party for various modeling tasks

Modeling Task	Responsible Party		Notes
	TPB staff	Consultant	
Run the model	x	x	TPB staff should be able to do this without the help of consultants. *
Debug model runs that stop or crash	x	x	Initially, some consultant assistance is OK, but later, staff should be able to do this without consultant assistance
Model development: Speciation and estimation	x	x	Combined effort
Model development: Calibration/validation	x	x	Initially, some consultant assistance is OK, but later, staff should be able to do this without consultant assistance
Maintain the model	x	x	Combined effort
Update/improve the model	x	x	Combined effort

* Nonetheless, one of the consultant deliverables under the contract could be conducting and summarizing a base-year run and a future-year run.

6.5 Interaction requirements

The current, production-use model (Gen. 2/Ver. 2.3) is used with other software such as ArcGIS and COGTools. It is expected that the Gen3 model would also work with these tools, unless replacement tools are proposed/developed. TPB staff also works with SAS and R for data analysis, and some staff are working with Python and SQL.

6.6 Summary

For convenience of vendors responding to the RFI, Figure 3, summarizes the primary investigations, which will be conducted after the award of the contract by the winning vendor, **but should also be addressed in the RFI** via the vendor response report and the completed vendor checklist.

Figure 3 Summary of primary investigations

1. Long-term vision for travel model: Gen3, Gen4, and beyond (see Table 6)
    a. Given the **current model** (an aggregate travel demand model and aggregate travel supply/trip assignment model) and the **long-term model vision** (a disaggregate travel demand model and disaggregate travel supply/trip assignment model), what path should be taken between these two models?
    b. At the end of the three-year, Gen3 model development process, where should we be on the path to the long-term model vision?
    c. How many years should it take to get to the long-term model vision?
2. Type of travel model for Gen3: Trip-based, tour-based, activity-based, or hybrid of these?
3. Land use forecasting: Recommended approach?
4. Use of DTA: When should the TPB model include DTA? What are the steps to get there?
5. New data collection to support Gen3 or Gen4 model development?
6. Role of big data

Similarly, the Gen3 model requirements are summarized in Table 8. Each requirement is categorized as being either mandatory or non-mandatory. The non-mandatory requirements are further categorized by priority level.

Table 8 Summary table: Categorization of functional and usability requirements in the PRD (See Sections 2.3 and 6 of the PRD)

<table>
<tr><th colspan="4">Requirements</th></tr>
<tr><td>Mandatory</td><td colspan="3">Minimum requirement: Gen3 model must have all the functional capabilities of the current travel model (Ver. 2.3.70 or Ver. 2.3.75)
Vendor must specify the recommended model form (e.g., trip-based, tour-based, activity-based, hybrid of these)
Travel modes represented (as a minimum, same as the current model)
Reasonable model run times (current threshold set at 24 hours)
Model useable by all modeling stakeholders (e.g., state DOTs, local governments, consultants)
Expectations about consultant support and staff support of model</td></tr>
<tr><td rowspan="11">Non-Mandatory</td><td colspan="3">Priority</td></tr>
<tr><td>High</td><td>Medium</td><td>Low</td></tr>
<tr><td>Travel modes to be added or enhanced: TNCs; Non-motorized modes.
Ability to distinguish between transit sub-modes</td><td>Travel modes to be added or enhanced: Taxi; CAVs</td><td>Travel modes to be added or enhanced: Shuttle bus; Short-term car rental/car sharing; Paratransit, such as MetroAccess; Demand responsive transit</td></tr>
<tr><td>Improved modeling of external transit (e.g., intercity bus/rail)</td><td>Improved modeling of travel to the region’s three commercial airports</td><td>Advice on socioeconomic models and trip generation</td></tr>
<tr><td>Advice on updating TAZ system & model inputs (land use & networks)</td><td>Improvements in modeling managed-lane facilities, including obtaining better data about HOT-lane usage</td><td>Advice on special generators</td></tr>
<tr><td>Improvements to modeling external and through travel (though this is currently being worked on by TPB staff)</td><td>Improved representation of so-called “exogenous travel” markets</td><td>Adding drive-access-to-transit trips to highway assignment</td></tr>
<tr><td>Improvements in trip distribution</td><td>Improved representation of transit fares</td><td></td></tr>
<tr><td>Improvements in mode choice modeling, incl. elimination of superdistricts</td><td>Advice on treatment of fuel prices.</td><td></td></tr>
<tr><td>Improvements in traffic (highway) assignment</td><td>Meeting FTA guidelines for New Starts projects</td><td></td></tr>
<tr><td>Improvements in transit assignment (capacity constrained; maybe O/D)</td><td>Adding drive-access to transit trips to highway assignment</td><td></td></tr>
<tr><td>Software advice: 1) Version control; 2) Bug tracking.</td><td>Software advice: 1) Application: Command-line vs. GUI; 2) Modeling software: Cube, EMME, PTV, TransCAD; 3) Network management software.</td><td></td></tr>
<tr><td></td><td></td><td>Advice on sub-area extraction</td><td></td></tr>
</table>

7 Deliverables

The goal of the RFI process is to solicit ideas from vendors/consultants about a proposed solution to the Gen3 TDFM that meets the requirements of the PRD. It is expected that vendors/consultants who chose to respond to the RFI will deliver two items to COG:

1. A concise report that explains and justifies the vendor's proposed approach for the TPB's Gen3 travel demand forecasting model.
2. A completed model checklist that describes the vendor's proposed approach for the TPB's Gen3 travel demand forecasting model. A blank copy of the model checklist will be provided along with the PRD.

Below are some notes about the two deliverables.

7.1 Vendor's model checklist regarding proposed modeling solution for Gen3 model

1. Each vendor/consultant should submit a completed model checklist. The model checklist is simply a summary of the proposed modeling approach.
2. All items in the checklist refer to your proposal for the TPB Gen3 model, unless noted otherwise.
3. File format: The checklist is provided in Microsoft Word format to make it easy to complete. Checkboxes can be checked or unchecked. There are also spaces provided for more free-form responses to some questions.
4. The checklist contains mostly checkboxes. For any items marked "please specify," it is assumed that you will specify briefly on this checklist and will provide more detail in your written report. There is no need to include all the detail in your report in the model checklist.

7.2 Vendor's report containing proposed modeling solution for Gen3 model

1. The report should be concise
   a. It should have **no more than 30 pages of content about the vendor's proposed solution/approach**. This does not include the title page or the table of contents.
   b. There can be one page of information about the firm, but there is no need to include information about specific people working at the firm. That information is more suited for vendor proposals to the upcoming RFP, not the RFI.
2. In theory, your report should cover, as a minimum, the items in the checklist. If your report does not include one or more of the items on this checklist, we will assume that you do not think those items are a top priority.
3. The vendor report should make **a compelling (ideally evidence-based) case for why their proposed solution is better than alternate visions for an updated model**.
4. File format: The vendor report should be supplied to COG in both Microsoft Word and PDF format.
5. As a minimum, vendor response reports should cover all the mandatory requirements in the PRD, and some or all the non-mandatory requirements.

As noted earlier, the RFI is not being used for pre-qualification, which means that vendors are not required to respond to the RFI to respond to the upcoming RFP.