Maryland State Highway Administration (SHA) Maryland Statewide Travel Model (MSTM) Peer Review Report

January 2014

TMIP
Better Methods. Better Outcomes.

U.S. Department of Transportation
Federal Highway Administration

FHWA-HEP-14-023

Better Methods. Better Outcomes.

Table of Contents

List of Figures

List of Tables

1.0 Introduction

1.1 Disclaimer

The views expressed in this document do not represent the opinions of the Federal Highway Administration (FHWA) and do not constitute an endorsement, recommendation, or specification by FHWA. The document is based solely on the discussions that took place during the peer review meeting sessions and supporting technical documentation provided by Maryland State Highway Administration (SHA).

1.2 Acknowledgements

FHWA wishes to acknowledge and thank the peer review panel members for volunteering their time to participate in the peer review of the SHA statewide transportation model and for sharing their valuable experience.

The following list includes each peer review panel member and the agency with which they are currently associated:

- Charlene Rohr, RAND Europe;
- Keith Lawton, Keith Lawton Cons.;
- Dan Thomas, North Carolina DOT;
- Thomas Rossi, Cambridge Systematics; and
- Anne Goodchild, University of Washington.

Brief biographies for each of the peer review panel members are presented in Appendix C.

1.3 Report Purpose

This report summarizes the results of a peer review of the SHA's Maryland Statewide Transportation Model (MSTM) with a focus on recommendations for future model enhancements. The peer review was supported by the Travel Model Improvement Program (TMIP), which is sponsored by FHWA. The peer review of a travel model can serve multiple purposes, including identification of model deficiencies, recommendations for model enhancements, and guidance on model applications. Given the increasing complexities of travel demand forecasting practice and the growing demands by decision-makers for information about policy alternatives, it is essential that travel forecasting practitioners have the opportunity to share experiences and insights. The TMIP peer review program provides a forum for this knowledge exchange.

SHA's overall goal for model improvement and motivation for seeking a TMIP peer review was to continuously maintain and apply a model representative of the state of the practice in travel forecasting that equips the agency with the support needed for informed decision making throughout the state. The peer review was conducted in two in-person meetings: one full-day session including presentation of the current model, discussion based on proposed improvements, and panel member discussion and one half-day session consisting of additional panel discussion, a presentation of recommendations by the panelists, and identification of next steps. The results of each of these sessions and recommendations from the panel are presented in this report.

1.4 Report Organization

This report is organized into the following sections:

- *Maryland State Highway Administration Overview* – an introduction to the planning responsibilities of the agency, regional characteristics of the State, and the agency goals for peer review.
- *Development of the Maryland Statewide Transportation Model (MSTM)* – a historical context of travel modeling at SHA, including previous model development efforts and current model improvement efforts.
- *Model Improvement Plan* – a brief summary of the plans to update the statewide model with regard to modeling priorities and necessary considerations.
- *Technical Questions Provided by SHA* – descriptions of highlighted topics for the peer review panel's review.
- *Peer Review Panel Response to Technical Questions* – a detailed synopsis of the panel's analysis and recommendations.
- *Panel Discussion and Recommendations* – a general summary of the peer review panel's recommendations to SHA, including prioritized next steps.

In addition, the report includes six appendices:

- *Appendix A* – List of Peer Review Panel Participants
- *Appendix B* – Peer Review Session Agendas
- *Appendix C* – Peer Review Panelist Biographies
- *Appendix D* – Overview of the Maryland Statewide Transportation Model
- *Appendix E* – SHA Peer Review Application

2.0 Maryland State Highway Administration Overview

This section provides an overview of SHA, including transportation policy and planning issues and demographic characteristics of the state of Maryland to provide context for the peer review discussion.

2.1 Maryland State Highway Administration Responsibilities

The Maryland State Highway Administration is one of the six modal agencies under the Maryland Department of Transportation (MDOT). SHA maintains a majority of the interstates, national highways, and state roads in Maryland, which collectively serve over two thirds of statewide vehicle miles traveled (VMT). Major thoroughfares such as I-95, I-81, and US 301, carry heavy volumes of passenger and freight over long distances.

The Maryland Transportation Authority (MdTA) maintains the eight tolled facilities within the state. Together, these two agencies maintain 17,818 total lane miles.

2.2 Statewide Characteristics

Maryland contains 23 counties and has a population over 5,884,500, according to the 2012 US Census estimate, which ranks Maryland as the nineteenth most populous state and fifth in population density. There are five Metropolitan Planning Organizations in the state, including: the Baltimore Regional Transportation Board, the National Capital Region Transportation Planning Board (the Metropolitan Washington region MPO), the Cumberland Area Metropolitan Planning Organization, Hagerstown Area MPO, the Salisbury MD/DE MPO, and the St. Charles MD MPO.

The state has experienced mild growth over recent decades, with population increases slowly decreasing, but remaining substantial. Between 2000 and 2010, the US Census Bureau reported a population growth of 9.0 percent. Population growth over each decade is provided in Table 1.

Table 1: Maryland State Population Growth

Year	Population[1]	Growth from Previous Year Listed
1980	4,216,975	N/A
1990	4,781,468	13.4%
2000	5,296,486	10.8%
2010	5,773,552	9.0%
2012 (Estimate)	5,884,563	1.9%

It is estimated that Maryland will grow by 1.1 million people and 0.4 million jobs by 2040. According to the 2007-2011 American Community Survey (ACS) Five-Year Estimates Maryland has a civilian labor force of 2,909,794 with a median state household income of $71,122. Table 2 summarizes the commute-to-work mode distribution, as reported by the ACS.

[1] United States Census Bureau. http://www.census.gov/

Table 2: Commute-to-Work Mode Distribution for the State of Maryland

Mode	Percent[2]
Car, Truck, or Van – Drive Alone	73.4%
Car, Truck, or Van – Carpool	9.8%
Public Transportation (Excluding Taxi)	8.9%
Walk	2.5%
Other Means	1.2%
Work at Home	4.2%

The two most prominent transit providers in the state are the Maryland Transit Administration (MTA), which operates Local and Commuter Buses, Light Rail, Metro Subway, Maryland Area Regional Commuter (MARC) Train Service, and a comprehensive paratransit system; and the Washington Metropolitan Area Transit Authority (WMATA), which is comprised of Metrorail, Metrobus, and MetroAccess paratransit services in the Washington region. The Statewide Plan's vision and policy goals include doubling transit ridership and reducing statewide greenhouse gas (GHG) emissions by twenty-five percent by 2020.

While having a small land area, the state of Maryland contains a variety of geographical features and conditions that render the area accessibility via a variety of transportation modes. The Port of Baltimore is the fastest growing port in the United States, while Baltimore-Washington International Airport (BWI) served over 22.6 million people in 2012.

In its statewide long range planning efforts, MDOT and SHA identify the following as key areas of statewide significance moving into the future: land use, transportation, freight, environment, quality of life and the economy. There is a focus on data and performance based planning that evaluates the effect of various investment levels and normalization of outcomes across jurisdictions and corridors.

[2] 2007-2011 American Community Survey 5-Year Estimates. American Fact Finder. http://factfinder2.census.gov

3.0 The Maryland Statewide Transportation Model

This section of the report provides an overview of the Maryland Statewide Transportation Model (MSTM), including a history of the model, a description of the model's components and functionality prior to the peer review, and a list of goals relating to the peer review.

3.1 History of the Maryland Statewide Transportation Model

In the mid-2000s, SHA recognized the need for a comprehensive transportation model that could address statewide issues, such as freight, rural area travel demand, multi-MPO corridors, intercity transit, and long-range planning efforts at the state level. In response to these immediate planning needs, the MSTM was developed in 2008 by the SHA in conjunction with a consultant team consisting of staff from the National Center for Smart Growth (NCSG) at the University of Maryland and Parsons Brinkerhoff. The MSTM was calibrated using 2007 household travel survey data conducted in the Baltimore-Washington metropolitan areas.

The MSTM has been invaluable for transportation planning purposes because it was designed to estimate specific measures of effectiveness consistently throughout the state for the analysis of transportation investments, changes to land use development, and impacts from factors beyond state boundaries, particularly freight. The tool has been used in a variety of studies, including scenario analyses, corridor studies, project forecasting studies, and future transportation system performance analysis to support policy decision making.

The model also supports MPO modeling efforts by providing them with external inputs and connecting MPOs. The model was originally designed under the standard four-step model framework but has since experienced various changes to the modeling structure in response to policy and program study needs. Enhancements after the model's development, from 2010 to 2011, included the estimation of non-motorized travel demand, incorporation of destination choice, refined validation and documentation, and development of staff trainings and workshops.

3.2 Current Maryland Statewide Transportation Model (MSTM)

The current MSTM is a three-level model with the first level being the national-level layer, which spans the entire continental United States, as well as Mexico and Canada captures the interstate and long distance flows. This national level contains much larger zones, entitled regional modeling zones (RMZs), thus resulting in a total of 151 RMZs across Northern America. The second level of the MSTM is a statewide-level model including adjacent areas such as Washington, DC, and Delaware, as well as portions of Virginia, West Virginia, New Jersey, and Pennsylvania. Including these external states, the statewide-level model consists of 1,588 traffic analysis zones (TAZs). The third being an urban-level model with the main purpose of linking the urban travel models where they exist within the statewide model study area for land use and network inputs and comparison purposes only. There are 3,056 urban model zones (UMZs) in the MSTM urban level, which were directly taken from the zones in the Baltimore Metropolitan Council (BMC) and Metropolitan Washington Council of Governments (MWCOG) MPO models.

3.2.1 Data

Collaboration with the state's MPOs has proven critical to the development of the MSTM, in that most local land use, network, and behavioral data are derived from the individual MPO models to create the supply side of the MSTM. Additionally, a household survey was conducted in 2007 in the Baltimore and Washington metropolitan areas, which resulted in 4,500 surveys in

Baltimore and 10,000-12,000 surveys in the DC/Maryland/Virginia area that have subsequently been used for model development and estimation.

Socioeconomic assumptions were derived from BMC and MWCOG estimates while an allocation model was applied to non-metro areas and then refined to address specific projects. SHA explained that Maryland is a home rule states; therefore, socioeconomic forecasting is conducted by local jurisdictions as they exercise land use planning power. The model was tested based on macro-level changes across a range of assumptions. SHA noted that there is still a fair amount of uncertainty in these socioeconomic assumptions after testing; therefore, the agency intends on running the model for various socioeconomic forecast scenarios to assess impacts based on a range of plausible inputs

For areas outside of the Maryland and the surveyed areas, including Virginia, Pennsylvania, and Delaware, the respective state DOTs provided socioeconomic and supply-side data. The majority of the demand-related data was provided by information from MDOT and other state DOTs. Figures 1 and 2 on Page 9 illustrate the TAZs on the state and national levels, respectively.

3.2.2 Networks

The MSTM contains both highway and transit networks that were created through the aggregation of various existing MPO and DOT models. Network details are also included for several counties in Maryland's bordering states.

3.2.3 Person Travel

The MSTM estimates both person and freight travel, including short distance trips in the statewide-level model area and long distance trips with one or both ends in the national-level layer. The model includes time of day split and mode choice for short distance auto trips. The short distance auto trip model is based on the Baltimore Metropolitan Council (BMC) model with revisions including use of densities to calculate non-motorized shares, replacement of the gravity model with a logit-based destination choice model, and addition of a feedback loop from assignment to destination choice to reach equilibrium in destination and travel times.

Trip generation rates were reconciled from the urban models with slight variation between BMC and MWCOG rates, creating variation in trip rates by workers and household size. Trip rates were not developed for different types of employment, for example part time versus full-time, due to limitations in the model development schedule and desire to maintain a simplified model structure. Five income categories for home-based work, home-based shop, and home-based other are applied to determine the relationship between income and distance.

The MSTM applied a nationwide estimate of long distance travel (NELDT) model for capturing interstate person travel. This method uses an air expansion factor to expand the entire long distance sample from the 2002 National Household Travel Survey (NHTS). Long distance trips are split using a discounted approach to obtain daily trips for assignment purposes; 90 percent of business trips are allocated to employment, 50 percent of personal trips go to employment, and the remaining trips are distributed to other households. The model is sensitive to the reallocation of households and employment in future years.

To achieve temporal allocation of person, commercial, and truck vehicle trips, factors are applied to the respective daily trip matrices to derive peak period (AM and PM) and off-peak period (MD and NT) trip matrices for network assignment. The factors for person trips were derived from the 2007 household survey data on a production-to-attraction (PA) basis for home-based travel for application to person trip matrices in PA format. These factors produce directional flow matrices that replicate observed average peaking characteristics. Factors for non-home-based person trips are derived on an origin-destination basis and are applied to the corresponding origin-destination trip matrices. Vehicle trips are then assigned by their appropriate time-of-day period using fixed factors for trip allocation. For short distance trips, allocation occurs at the start of the trip, while long distance trips are scaled to correct the number of trips given the amount of trips occurring across time periods.

The time of day periods in the model include the following:

- AM Peak Period, 6:00 am to 9:00 am
- MD Off-Peak Period, 9:00 am to 3:00 pm
- PM Peak Period, 3:00 pm to 6:00 pm
- NT Off-Peak Period, 6:00 pm to 6:00 am (of next day)

Multi-class highway user equilibrium assignment is conducted with 16 passenger trip purposes and three truck trip tables.

All or nothing transit assignment is conducted for the shortest paths between any origin-destination pair using the mode choice trip tables to produce peak and off-peak transit loads. Transit assignment is accurate on a system wide level but has not been validated on an individual route-level.

The short distance truck model applied the Quick Response Freight Manual (QRFM) to scale trip rates down to reflect truck counts. The long distance truck model, on the other hand, applies Freight Analysis Framework 3 (FAF3) freight flow data by disaggregating the data to the TAZ level and converting tonnage to trucks. Both truck models distinguish single unit and multi-unit trucks. The short distance model reconciles any truck trips less than 50 miles, while the long distance model addresses trips over 50 miles in length.

The short distance truck model generates truck trips using industrial employment, retail employment, office employment, and household data within a gravity model. The QRFM was selected over FAF3 data for short distance trucks because FAF underrepresents short distance travel by a factor of 10. The QRFM methodology was not selected for application in long distance truck travel because it applied a gravity model that does not work well for modeling the distribution of long distance trips.

The long distance truck model uses county employment disaggregated by eleven employment types and applies commodity specific weights derived from input/output coefficients provided by BEA to break down FAF zonal-level flows to county-level flows. Then the same process is used to draw estimates to the TAZ-level, and FAF payload factors are used to convert tonnage to trucks and calculate flows for the truck trip origin-destination matrix. The long distance freight model was tested for national reasonability and also examined at the regional level.

Empty trucks are then added using the empty truck model, which applies an asserted gravity model to distribute empty truck movement. This mode only accounts for one half of empty truck movement according to US Census data, while the other half is calculated by scaling the full truck trip table based on FAF factors.

3.2.4 Validation

Validation was conducted along carefully developed screenlines, taking into account seasonal travel and count errors. Vehicle miles traveled (VMT) by county was assessed using charts and maps to compare the model VMT to HPMS data. This analysis found that urban counties experienced slight underestimation of VMT, while the remainder of the model VMT was somewhat overestimated. Model flows on major corridors and critical bridge crossings were compared with traffic counts to improve model performance. The root mean square errors (RMSEs) were high for low volume facilities, which is fairly typical of statewide models, and at acceptable levels for facilities with traffic volumes above 30,000. Jurisdictional and facility type model outputs from MSTM were compared with MPO model outputs for further validation

3.2.5 Application

The MSTM has an estimated run time of about six and a half hours. The process includes six feedback loops. The MSTM has been applied in a variety of policy analysis studies including system performance analysis, long-range planning efforts, corridor studies, scenario planning, freight movement, intercity transit modeling, highway performance measures studies, MPO modeling efforts, alternative growth forecasts, expansion of the Port of Baltimore, network modifications, and transit service adjustments. The model is currently undergoing improvements to facilitate the implementation of a subarea analysis tool and implement an auto-ownership model.

Appendix D provides further detail regarding the development, functionality, and validation of the MSTM. Figure 1 provides an illustration of the statewide level zones in the MSTM. Figure 2 provides a depiction of the national-level zones in the MSTM.

3.3 Maryland State Highway Administration Goals for Peer Review

SHA's primary aspiration for the TMIP Peer Review was to outline a five year plan for model improvements to further develop the MSTM based on requirements the agency has identified for policy analysis. SHA would like to enhance the model's current capabilities to incorporate policy sensitivity that will address issues such as mode choice, managed lanes, goods movement, and land use. Additionally, the existing base year of 2007 and forecast year of 2030 are planned to be updated to 2010 and 2040, respectively.

SHA acknowledged the notion of potentially redesigning significant portions of the model and noted the desire for feedback from experts in the field prior to such large an endeavor in terms of both resources and budget.

3.4 Previous Peer Reviews

The peer review convened in November of 2013 was the first peer review session conducted for SHA regarding their statewide travel model.

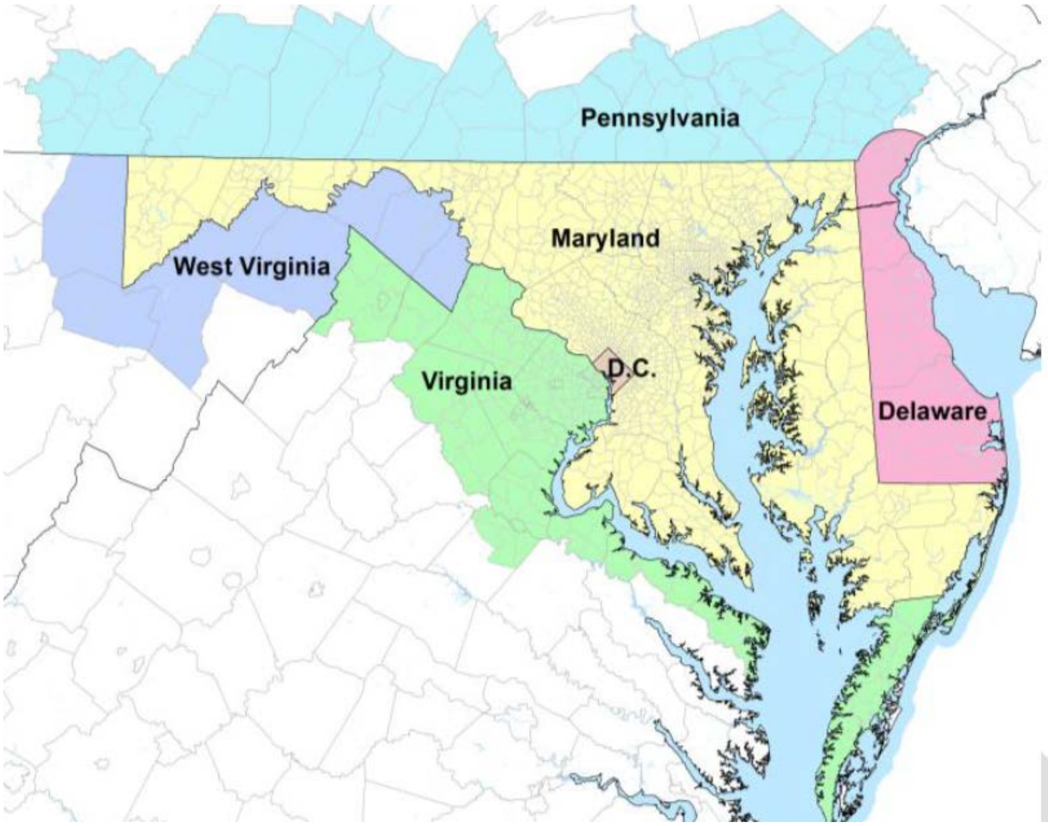


Figure 1: Statewide-Level TAZs in the MSTM

Figure 2: National-Level TAZs in the MSTM

4.0 Model Improvement Plan

SHA is in the process of planning and prioritizing updates for statewide model enhancement. This section summarizes the preliminary stages including identification of agency needs and subsequent model development needs.

4.1 Maryland State Highway Administration Visioning for Model Improvements

SHA described that they have had a system preservation focus over the last several years due to economic situations; however, the state now has additional revenue that can be utilized by SHA. The agency indicated that they would like to apply these funds as efficiently as possible to achieve the highest benefit, drawing an emphasis to decision-making and thus the statewide model as a decision-support tool.

Priorities for implementation are particularly sought by SHA, as well as a path and process for continued improvement of the model over the next five years. Some of the specific improvements that SHA is considering, as defined in their peer review application and model background presentation, include:

- Refine spatial, temporal and functional resolution of zones and network;
- Account for trips that may travel during more than one time-of-day period;
- Bike and Pedestrian modeling;
- Freight mode choice modeling;
- Activity-based travel demand modeling;
- Tour-based auto and truck modeling;
- Land-use model integration;
- Economic model integration;
- Integration with water quality impact models; and
- Analytical dynamic traffic assignments.

SHA explained that they hoped to use the Peer Review session as a way to prioritize these various routes for improvement. The agency also highlighted issues like quantifying travel demand, normalizing outcomes by various area types throughout the state, and planning for low and high funding levels as the major focuses for statewide model development planning. The agency indicated the desire for additional suggestions and enhancement options from the Peer Review expert panel, as well.

4.2 Challenges to the Transportation System

SHA stated that they face a variety of future transportation planning challenges. Based on those challenges, they identified a set of cases that is representative of their needs for further development and refinement of their technical evaluation capabilities. These cases include:

Case 1: Transit Orient Development (MD 355 Corridor, Montgomery County)

Case 2: Amazon Distribution Center (I-95 Corridor, Baltimore City)

Case 3: CSX Intermodal Container Transfer Facility (ICTF) (MD 295 Corridor, Howard County)

Case 4: Arundel Mills (MD 100 and MD 295 Corridors, Anne Arundel County)

Case 5: Multi-Modal Corridor Studies (Various Corridors)

Case 6: Performance-Based Planning and Programming (Systemwide)

Case 7: Improving System Reliability via System of Managed Lanes (Various Corridors)

Case 8: Develop Linkages Between Demand and Operational Modeling (Systemwide)

These cases, along with the model improvement visioning goals, were developed to inform the expert panel of SHA's model improvement focuses and needs.

5.0 Technical Questions Provided by the Maryland State Highway Administration

The first session of the peer review meeting was held on November 11, 2013. At this meeting, SHA and their respective consultant staff provided background information on the MSTM, further articulated their ideas for potential model improvement components from the initial vision described in Section 4.1, and presented on the following areas of interest to lead the initial peer review meeting's discussion via their roadmap for model advancement in Figure 3.

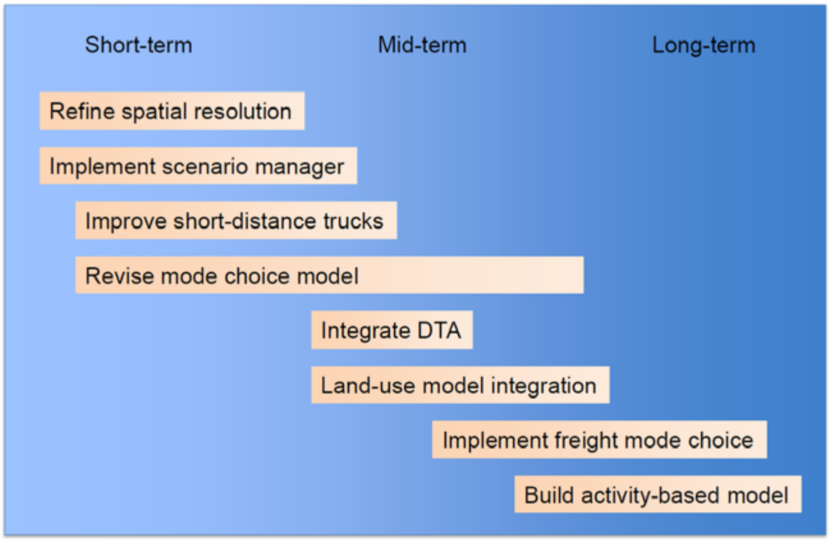


Figure 3: SHA Roadmap for Model Advancement

5.1 General Framework and Processes

SHA requested that the panelists identify additional areas for attention regarding the model's structure, validation, and functionality that would be beneficial to the agency in the development of an enhanced model for their outlined purposes. This section outlines each of SHA's technical topics for discussion, as they were presented in the peer review.

5.2 Raster Cell System

SHA expressed their concern that the current zone system of 1,151 TAZs inside the state was rather coarse while scenario planning efforts require more detailed zonal dimensions. The existing socioeconomic data is weighted very strongly to developed spaces, particularly in developments with higher intensity.

The proposed raster cell zone system that SHA proposed would apply US Geological Survey (USGS) land cover data to disaggregate socioeconomic data by 30m by 30m cells. The initial raster threshold setting was 1,190 people per raster cell, which generated 9,805 raster cells and the smallest size raster was 414m. The objective would be to focus cell detail where population is located. This system would allow for flexible and easy movement between levels of aggregation to be able to help with non-motorized and transit access analysis but also allow up-scaling, so the model could be run at different levels of detail to avoid an exceptionally high runtime.

SHA asked for input from the expert panel on the details of refining the spatial resolution of the model. Adjustment of the zonal structure is a short-term priority for the agency.

5.3 Cube Scenario Manager

SHA would like to implement the use of a Cube scenario manager. In the scenario manager, all scenarios would be created under a parent directory from which they would inherit catalog keys in folders that reflect the scenario names. Each group of processes in the model would be connected through linkages between the input and output files in the scenario manager, while numbers associated with each group would represent the execution order.

Model users would be given the ability to create new catalogs with options to define scenario names and paths, model parameters, and input/output files names. Once a catalog is created, it could be associated with application files by linking the catalog key to specific input files and model parameters. Catalog keys could also be refined by model scenario.

Implementation of this scenario manager interface will promote user-friendliness of the model and potentially expedite model application efforts. SHA would like to implement the use of the scenario manager in the MSTM in the short-term.

5.4 Improving Short Distance Truck Flows

The current MSTM short distance truck model operates using the QRFM model. While this model has been in application in the MSTM since its inception, it has significant limitations. The QRFM methodology is based on information from a survey conducted in Phoenix in 1992, rendering the information over twenty years old. Additionally, the QRFM model does not account for the actual number of shipments, represents only three employment types plus households, and does not account for white-collar workers.

SHA indicated the possibility of revising the short distance truck trip generation process by implementing the QRFM truck model but then running a synthetic matrix estimation (SME) to calculate productions and attractions, which would serve to improve validation. Multiple regression would then be applied to distribute the number of truck trips generated by zone based on employment type, households, area type, density, accessibility, and other zonal data.

5.5 Mode Choice Revisions

The current MSTM model choice model divides auto and transit trips into sub types. Types of auto trips include: auto drive alone, auto shared ride (two persons), and auto shared ride (three or more persons). Types of transit trips include: walk to local bus, walk to express bus, walk to light rail, walk to commuter rail, drive-to local bus, drive-to express bus, drive-to light rail, and drive-to commuter rail, as illustrated in Figure 4. The coefficients have been transferred from the BMC model, and the mode specific constants were derived using the 2007 household survey data merged with onboard surveys rom BMC and MWCOG.

SHA identified the desire for other proposed long-term improvements to the mode choice model of the MSTM that would be dependent on the path selected for restructuring the mode choice nesting process, which include:

- Implementation of an auto-ownership model;
- Representation of government employees;
- Refinement of parking costs;
- Capture of local bus through Google Transit;
- Modeling of non-motorized shares;
- The ability to distinguish residents from visitors; and
- Integration of short- and long distance mode choice.

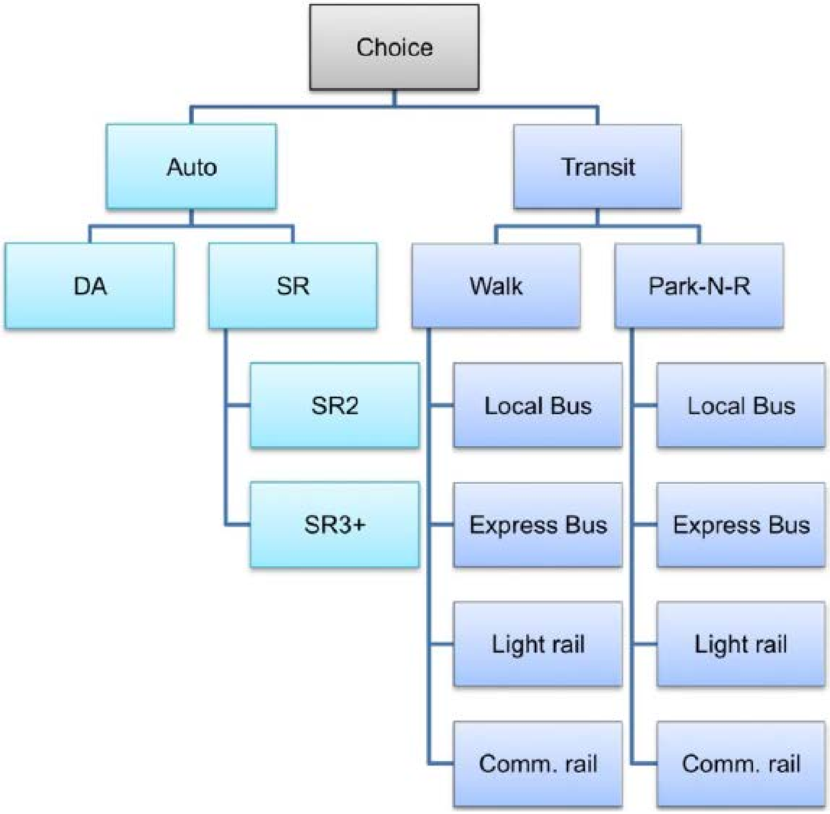
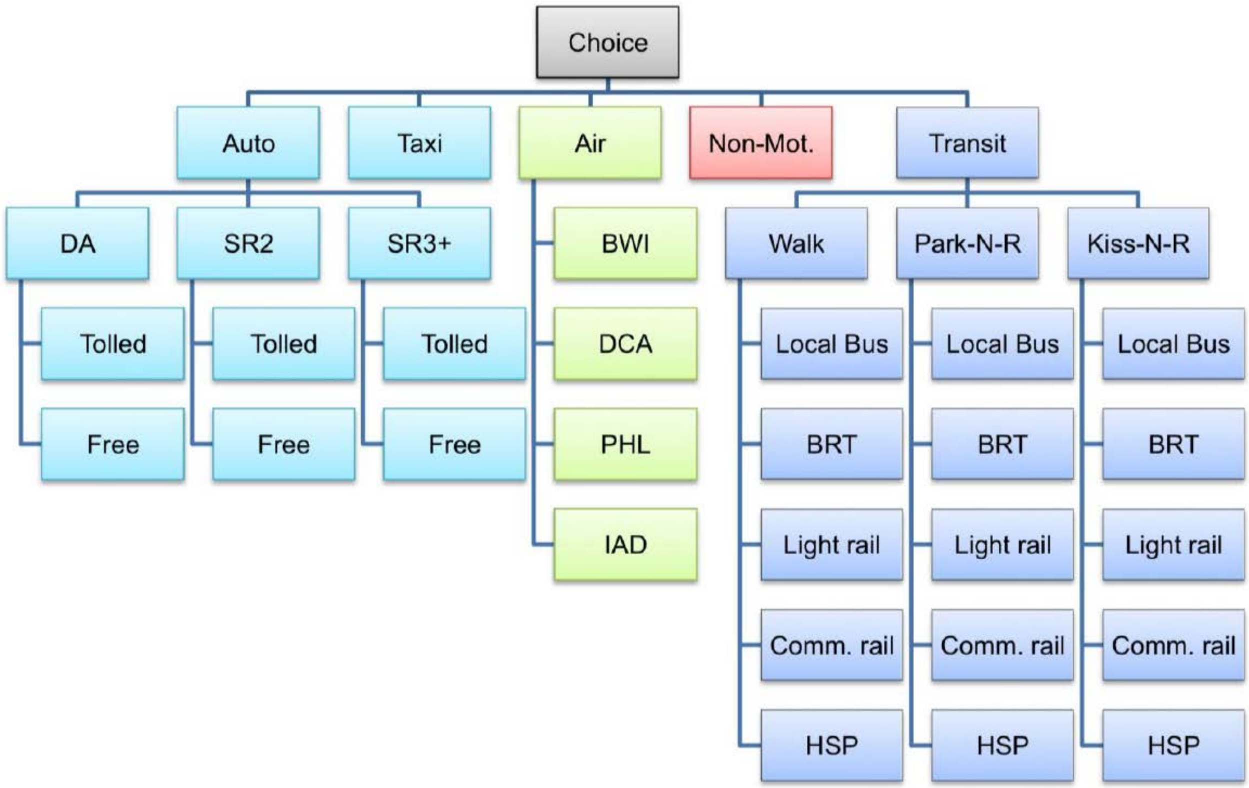


Figure 4: Current MSTM Mode Choice Model

SHA's suggested enhanced approach to allocating modes included further division of auto trips by free or tolled facilities, taxi share, air transportation via four airports (BWI – Baltimore, MD, DCA – Arlington, VA, PHL – Philadelphia, PA, and IAD – Sterling, VA), non-motorized transit, kiss-and-ride transit access, and high speed rail. The addition of these modes in the MSTM are intended to allow for assessment of long distance mode choice, managed lane analysis, system reliability, choice impact, and incident management. With the addition of these adjustments, the structure of the mode choice nesting model would operate as illustrated in Figure 5.

SHA noted that non-motorized share data would need to be interpolated across zones due to a small survey sample size. BMC, for example, utilized a one-mile radius to develop non-motorized share by TAZ, relating non-motorized share to population density rather than survey data.



Pivoting off the various modes in the envisioned mode choice nesting structure outlined in Figure 5, three alternative focuses were proposed for consideration in the restructuring: BRT, managed lanes, or non-motorized travel. Incorporation of these elements into the mode choice nesting structure would require different levels of representation within the model, as summarized the matrix in Figure 6.

	Path 1 Focus on BRT	**Path 2 Focus on Managed Lanes**	**Path 3 Focus on Non-Motorizes Travel**
BRT Representation	Separate nest in mode choice	Represented by existing express bus nest	Represented by existing express bus nest
Managed Lanes Representation	Tolls added to generalized costs in assignment	Separate nest in mode choice	Tolls added to generalized costs in assignment
Non-Motorized Travel	Static share of generated trips	Static share of generated trips	Separate nest in mode choice

Figure 5: Mode Choice Nesting Structure Representation Paths

The matrix in Figure 7 illustrates the requirements for the implementation of additional modules depending on the selected focus in the advanced mode choice nesting structure. SHA will use these requirements in the consideration of paths for restructuring the mode choice model.

	Path 1 Focus on BRT	Path 2 Focus on Managed Lanes	Path 3 Focus on Non-Motorizes Travel
Auto-Ownership Model	Required	Desirable	Desirable
Representation of Government Employees	Desirable	Not Relevant	Not Relevant
P&R Station Parking Capacity	Required	Desirable	Desirable
Include Long-Distance Travelers in Mode Choice	Not Relevant	Desirable	Not Relevant
Increase spatial resolution with raster cells	Required	Desirable	Required
Some parking costs being paid by employer	Desirable	Desirable	Not Relevant
Distinguish residents and visitors	Not Relevant	Desirable	Required
Collect Google Transit Schedules of Local Buses	Desirable	Not Relevant	Not Relevant

Figure 6: Paths of Implementation of Additional Modules

5.6 Reliability and Dynamic Traffic Assignment Integration

SHA identified reliability as a measure for incorporation into the MSTM as a mid-term improvement. The ability to establish values and measures of reliability would be beneficial to the agency in the assessment of project benefits. The agency has received funding from the SHRP 2 program to aid in this effort and has scoped an initial plan for implementation.

Integrating reliability into the model would require a comprehensive review of existing methods of measuring reliability, development of a methodology for implementation in the MSTM based off the identification of best practices in the initial review, and testing of the derived methodology for the MSTM. Testing would entail both comparison against other existing methods of measure reliability and sensitivity tests. Results of tests would be imparted to stakeholders and documented.

At the time of the Peer Review, existing methods of reliability measurement were in the review stage, and a preferred method was in development, which involved link-based reliability measures. Testing stages were scheduled to begin post-Peer Review.

SHA also received funding from FHWA to assess the implementation of analytic dynamic traffic assignment (DTA) in the MSTM. Inclusion of analytic DTA in the MSTM would allow for tracking of individual vehicles, apply a Bureau of Public Roads (BPR) curve to update speeds, and allow for 15-minute time interval updates to facilitate estimation of continuous travel patterns. Additionally, analytic DTA in the model would not require the need for SHA to collect detailed intersection and signal data.

SHA recognized that the addition of analytic DTA in the model would inherently lack intersection detail and provide lower fidelity in comparison to a full microsimulated DTA, but still yield longer model run times that using a static assignment network model. The development of the analytic DTA model for the MSTM was underway at the time of the Peer Review after a review of existing software and subsequent selection of TRANSIMS router as the platform. The model had been developed, run, and entered into validation.

SHA presented this basic information regarding the application of reliability measurements and analytic DTA model to the panelists in anticipation of additional feedback and suggestions for implementation in the MSTM.

5.7 Land Use Model Integration

SHA investigated the addition of land use in the statewide model and found the Simple Integrated Land-Use Orchestrator (SILO) model developed for Minneapolis/St. Paul to be a potential fit for the MSTM. SILO is less complex than either PECAS or UrbanSim, yet it provides more detail than would a sketch planning tool. SILO runs a discrete choice model to generate a microsimulation.

SILO would use household demographics, dwelling units, employment figures, and non-residential floor space values on conjunction with accessibility measures to estimate transportation and environmental impacts. SHA clarified that the model was a household location model, a housing development model, and a household demographics model.

Integration of SILO is anticipated for summer of 2014, at which time initial zoning, transit-oriented development, and pricing scenarios will be tested for performance. If the SILO model produces reasonable results, it may be fully integrated within the MSTM by 2014.

SHA presented basic information regarding the suggested land use model to the panelists in anticipation of additional feedback and suggestions for implementation in the MSTM.

5.8 Freight Mode Choice Options

In addition to addressing person mode choice, SHA identified freight mode choice as a desired capability for the MSTM in the future. SHA indicated that ideally they would like to break down freight by vehicle class (classes 4 through 13) to detail commercial vehicles for highway planning and establish growth by truck type for pavement design and asset management. The agency noted that they could also suffice with more aggregate truck trips if necessary.

SHA acknowledged the difficulty in establishing the best method for adding freight mode choice options given the intricacies of the freight industry, including competing objectives, evolving choice sets, lack of information, and various alternatives for implementation. Factors SHA listed affecting freight mode choice included freight rates, reliability, transit time, over/short/damaged criteria, shipper market characteristics, carrier considerations, and product characteristics. Factors affecting freight logistics costs included: inventory costs (total flow, value density, inventory policy, and interest rates), transport costs (rates, shipment size, transport service, and transport distance), and warehousing costs (handling rates, packaging density, volume-to-weight, and stock rates).

There are four options that SHA identified in order to address these freight factors. These options consist of either adopting a simple modal allocation method using data from FAF3, TranSearch, or another source, incorporating a modal diversion model, applying discrete choice modeling techniques, or another methodology based from expert systems or advice. SHA sought guidance on this topic to help establish the best method of taking freight factors into account to most accurately incorporate freight mode choice and associated factors.

5.9 Activity-Based Modeling

SHA did not provide a direct presentation on activity-based model incorporation into the MSTM, but the agency indicated a desire to gear model improvements toward an activity-based model, as this would be a major long-term goal for inclusion in the model. The agency also alluded to the fact that the BMC MPO has initiated the development of an activity-based model framework for their urban area model.

5.10 Additional Topics

During day one of the Peer Review session, SHA specified that they would like an initial version of the model developed and running by the end of 2014 accompanied by both three-year and five-year model development plans. The agency identified the two issues that they anticipate will be of the utmost importance in future planning years as (1) regional impacts of major development and land policies and (2) multi-modal corridor studies and mega projects. Table 3 provides a summary of the additional policy type priorities that were highlighted by SHA in the first day's session, with several highlighted as particularly high priorities and also an indication of whether the statewide (SW) model or an MPO model was likely to provide the ideal framework for evaluating those policies.

Table 3: SHA Policy Priorities

SW/MPO	Priority	Policy Type
SW		1. Smart growth strategies
SW	High	2. Major commercial nodes and distribution hubs
MPO	High	3. Regional impacts of major developments and land policies
SW	High	4. Multi-modal corridor studies and mega projects
SW		5. Performance measures
SW		6. Network reliability improvements
MPO		7. Network dynamics
SW	High	8. Pricing
MPO	High	9. Major new modes (BRT,…)
SW		10. Growth strategies: increase transit, decrease GHGs

SHA also brought attention to performance measures throughout their initial presentation, recognizing that simply utilizing the cost of congestion via free flow versus congested time was of limited benefit and requested advice on new measures for consideration. SHA highlighted both accessibility and smart growth assessment as primary focuses for new measures. The agency stated that their goal for the next version of the MSTM will be to test policies by applying a consistent framework and provide a tool for transportation analysis in areas without an MPO model, which could entail metrics applicable to the state-level versus metrics applicable to corridor areas.

6.0 Peer Review Panel Response to Technical Questions

When SHA and associated agencies/consultants presented the topics of interest to the peer review panel on day one of the Peer Review, the panel was able to ask questions to gain further detail with respect to each question and provide initial feedback. The panel then convened without SHA staff present to further assess the appropriate responses to each question based on the experiences of each expert panelist. The following section details the responses provided by the panelists as presented to SHA on the second day, November 12, 2013, of the Peer Review.

6.1 General Framework and Processes

General recommendations that were identified by the panelists in the presentation of the model background information related to data acquisition, trip generation, and transit assignment.

The panelists suggested consideration of two areas for additional data collection: a household survey to obtain data for summer versus regular travel and an AMTRAK survey, similar to an airport access survey, to determine the choices of AMTRAK passengers.

With regard to the freight model, the panelists suggested that it may not be necessary to include the port as a unique special generator, as other locations such as automated warehouses, like the Amazon distribution center, may also not be well-represented by employment based truck trip generation. For accuracy at the corridor-level, special locations such as distribution centers will need to be represented with more detail. The panel suggested that the SHA will need to increase their knowledge of the operations of break bulk locations and distribution establishments. Truck counts at key access routes to significant distribution centers can help understand how truck activity does or does not correlate with employment data.

The panel recommended that the reliance of trip generation on income and distance be revisited, as this relationship may simply be a reflection of higher income willingness to travel farther due to less cost sensitivity. The model should attempt to join the estimated destination and mode choice models to capture change in travel time or cost over time, which could provide a more advanced insight in policy sensitivity terms. One example was provided in which the Salem, Oregon MPO was unable to access occupation information for work trips but they were able to segment workers income into three groups and segment employment by ‘retail,’ ‘service,’ and ‘professional’ and establish a connection between worker incomes and different employment types.

One panelist noted that if transit trips are split into peak and non-peak and time-of-day factors are applied, problems could arise where some areas do not have off-peak service. This could cause some trips to not be assigned.

6.2 Raster Cell System

In response to SHA’s interest in refining the spatial resolution of the model, the panelists noted that a statewide model is typically not used to analyze policies that require a high level of spatial detail. Urban area models are the ideal forum for these more detailed analyses, thus removing the need for an intricate zonal system in the MSTM. The panelists did suggest that SHA look further into the issue of difference between zones and networks.

6.3 Cube Scenario Manager

The panelists agreed that the use of an interface would generally improve the model’s usability.

6.4 Improving Short Distance Truck Flows

SHA outlined the shortcomings of the short distance truck model in its current form that applies the QRFM. Rather than attempt to incrementally improve the existing truck model, the panelists recommended that SHA partner with BMC in the consideration of a tour-based urban freight distribution model with representation of the logistics system.

6.5 Mode Choice Revisions

The panelists again noted the distinction between urban models and the statewide model for specific planning purposes. Urban models are intended for studies that require local detail like transit and non-motorized analysis; therefore, the panel recommended against the level of complexity suggested for advancement of the mode choice nesting structure, particularly considering the lack of available data. For example, kiss-and-ride data availability is scarce which renders kiss-and-ride modeling difficult, and air travel inclusion presents a problem due to a lack of data regarding future services pricing. Tolled versus free facility modeling would also be challenging pending data availability. It was suggested that toll facility estimation could be conducted during assignment, which would not limit the model to a binary toll verses non-tolled choice but could account for choosing partially tolled routes.

Instead of moving towards SHA's suggested improvements, the panel suggested that SHA simplify the mode choice structure in the MSTM outside of urban areas. The panelists discussed a tour-based model and considered that it would be feasible and could get the MSTM closer to an activity-based model. This would allow SHA to test features like managed lanes and pricing without having to complicate the mode choice nesting structure.

The panel additionally noted that observations of long distance trips are rare in survey data and attempting to include both short and long distance in the same model is an ambitious undertaking, especially considering the demanding data requirements needed to support the effort. Long distance trips were acknowledged by the panelists as a priority; however, prompting panelists to encourage visitor surveys to understand visitor travel behavior.

One panelist observed that the model could be used for scenario analysis for things like choice impact and incident management. If SHA wanted to build these other factors into the MSTM, they would need to include variability of travel times rather than travel time savings experienced by travelers, which would require a time-of-day model. To accurately capture reliability route choice would require a microsimulation framework.

In response to the three potential paths for implementation of additional modules, the panelists recommended that auto-ownership be required under the, "Focus on non-motorized travel" component of the matrix (Figure 7). Panelists suggested that before considering these three paths for module implementation, SHA should consider the possibility of tour-based and activity-based models that would provide overall improvements to mode choice. These types of models would require population synthesis which would yield more segmentation. This methodology would not drastically increase runtime.

6.6 Reliability and Dynamic Traffic Assignment Integration

The panelists lauded the level of analysis and detail that was used to develop the plan for implementation of the analytic DTA feature in the MSTM. The panelists, however, observed that the length of time to fully implement this significant of a model improvement would require several additional years to move into a production model as DTA is still primarily used in a research context and there is not yet have a high level of confidence for using DTA in a formal planning application setting. The panelists indicated that SHA should continue to support the research to eventually move to application stages.

6.7 Land Use Model Integration

The panelists affirmed conceptual support for the integration of a land use model in the MSTM. The panelists, however, each noted that they did not know enough about the SILO model to evaluate its suitability for the statewide model. The panelists acknowledged the potential for application of the model to facilitate additional performance measures.

6.8 Freight Mode Choice Options

The panelists believed the addition of freight mode choice options into the MSTM to be an advantageous long-term goal. They recommended that SHA first identify the types of policy sensitive questions that they would like the model to be able to answer with regard to freight prior to delving into this development effort. It will be critical for SHA to obtain access to reputable freight data sources to successfully upgrade the freight model. The panelists suggested that SHA partner with adjacent states to develop a model that covers a larger area for freight analysis.

6.9 Activity Based Modeling

The panelists suggested that, to minimize the level of effort and resources that would be required from SHA in this long-term modeling goal, they borrow the information and model features necessary for the development of an activity-based model from the BMC model, which is currently being redeveloped as an activity-based model. Other states like Colorado are building statewide activity-based models from a large MPO activity-based model within the state, in Colorado’s case, it is DRCOG’s model of the Denver region. Additionally, BMC is in the center of the state modeling area, so only portions of east and west Maryland would require other small models. It was also suggested that the agency use a modular approach to achieving an activity-based model rather than one large jump to a new, advanced model structure.

6.10 Additional Topics

The panelists identified six other primary principles and issues to address through the Peer Review session based on the policy priorities that were outlined in SHA’s initial peer review application and their presentation on day one of the Peer Review. These principles and issues included: use of urban models for urban area policy development, emphasis on freight, GHG reductions in relation to modeling, pricing analysis, data collection overlap, and best methods for performance measurement.

6.10.1 Urban Models for Urban Area Policy Development

The panelists recommended that SHA take time to formulate how they envision urban models, including the BMC, MWCOG, and other models, connecting to the MSTM, noting that duplication of the urban model function was a concern. Several possibilities were discussed relating to how the urban models could be linked to the statewide model. MPO models will benefit from the statewide model’s information on external volumes. Internal-internal trips can be directly extracted from urban models while the MSTM would model internal-external, external-internal, and external-external trips.

Additionally, the panelists noted that non-motorized trips may be best represented in the statewide model by using trip tables from urban models as opposed to modeling them directly in the statewide model. The panelists also recommended that SHA consider aggregating urban area zones and leaving the spatial detail required for modeling urban modeling to the MPO models. In areas where urban area models overlap (e.g., the BMC and MWCOG model regions overlap), the panelists recommended that SHA select one model for those areas to consistently use for providing inputs to the statewide model to maintain consistency in this modeling framework.

6.10.2 Emphasis on Freight

The panelists identified freight modeling as a sound place for SHA to invest resources, particularly if they would like to support BMC in developing an urban tour-based framework, as discussed in Section 6.4. The MSTM will need to represent long haul freight movement to move towards a logistics model. In order to represent this goods movement, statewide freight movement will need to be better understood through strategic data acquisition. The panelists recommended collecting data from the ports within the state, obtaining truck counts, requesting information from primary commodity transfer locations, engaging in conversations with freight stakeholders, and a potential roadside survey given the availability of resources. The panel emphasized statewide movements rather than urban distribution systems for the MSTM.

6.10.3 GHG Reductions

Personal vehicle ownership and vehicle type choice were identified by the panelists as critical factors to the modeling of GHG reductions. The panel emphasized the importance that the MSTM include GHG reductions as it is a primary function of the statewide model. Suggestions for improving the estimation of GHG emissions included new data collection efforts, such as a longitudinal survey of vehicle acquisition, vehicle use surveys, and potential linkages to household location choice data. Aggregate data would aid in correctly identifying sizing of the current fleet for validation purposes but additional breakdown would be required for decision-making and assessment of how the vehicle fleet will evolve over time.

Freight fleet information will also be required as understanding how the fleet of freight vehicles will change over time is also critical to the analysis of GHG reduction. This information would not only be useful to the enhancement of the model's ability to measure GHG reduction, but would also aid in improving the mode choice model. The panelists also suggested that not only fleet change but policy decision on land use versus transit investment would effect GHG reductions, and emphasized that GHG reductions would be the results of the combined effects of several policies.

6.10.4 Pricing Analysis

Because most pricing policies can be analyzed in urban models, the panelists suggested that this may not be a necessary element to integrate into the MSTM. The current MSTM will not be able to handle variable pricing, and the truck model in the MSTM is not sensitive enough to pricing for this type of endeavor, so it was recommended that SHA do not prioritize incorporating pricing into the statewide model.

6.10.5 MD/MPO Data Collection Overlap

With regard to data collection efforts, the panelists recommended that SHA collaborate survey efforts and share available data with MPOs as much as possible to avoid overlap and maintain consistency of data sources throughout the state. Cost-sharing these efforts will be beneficial to both the agency and MPOs, saving both time and resources.

6.10.6 Performance Measures

Finally, the panelists commented on the MSTM's ability to address performance measures. SHA's focus in their model development should be to allow demonstration of successful progress towards their agency goals and visions. The panelists began by explaining that the best next steps for the MSTM would be to shift from a congestion-based model to more consequential measures that will best quantify their goals, including reliability and accessibility.

In order to better assess reliability, the panelists recommended moving away from a link-based approach. The panelists noted that smart growth policies, for example, may result in increased congestion and therefore show poorly against congestion performance measures, but formulating accessibility measures will more accurately allow impacts and potential benefits of those policies to be measured. Effects on the economy and land use were suggested by the panelists as alternative ways of assessing transportation impacts. An example was provided in which Portland's model analyzed activity locations within one fourth and one half a mile from households to develop measures of non-motorized accessibility that were not based on arbitrary polygon geographies.

7.0 Panel Discussion and Recommendations

The following section summarizes the panel's comments and recommendations on the topics of interest to SHA, as well as general guidance for the future of the statewide model. This summary follows the panel's final presentation to SHA at the concluding Day Two session of the peer review.

7.1 General Comments and Recommendations

The panelists emphasized the importance of considering the policy objectives that they would like to evaluate and following these objectives to guide model improvements. The panel encouraged SHA to focus on the core capabilities and of the MSTM in supporting evaluation of statewide policy questions, rather than attempting to fixes to address policy questions that might be better handled by other models such as the urban area MPO models.. The panelists recommended testing the model, observing areas it works well in and identifying flaws to rectify as appropriate. The panelists recommended NCHRP 32 as a resource to inform freight and smart growth analysis.

Next, the panelists highly recommended that SHA utilize sensitivity testing to demonstrate how the model responds to changes to use alongside validation. The panel emphasized the importance of detailed validation efforts to establish model functionality. Elasticity tests were suggested to observe the model's response to changes in factors like fuel price.

7.2 Phased Recommendations

The following subsections partition panelist comments by potential timeframe for implementation: short-, mid-, and long-term.

7.2.1 Recommended Shorter-Term Priorities

The panel feels that SHA should focus on the following priorities for near term consideration:

- Review of networks and zones, updates and consistency.
- Implementation of the Scenario Manager.
- Use of urban models for smaller areas studies where applicable rather than application of the statewide model.
- Data acquisition for long distance trips, AMTRAK passengers, freight components, seasonal travel variation, GHG related data measures, and data needed for other improvements.
- Coordination of data efforts with MPOs to avoid overlap and facilitate data cost-sharing.
- Focus on performance measure development in coordination of agency goals.
- Aggregation of urban area zones in areas where consolidation may be beneficial.

7.2.2 Recommended Mid-Term Improvements

Over the next three years, the panel recommended SHA considers the following:

- Partnering with BMC in developing a tour-based freight distribution model.
- Simplify the mode choice structure outside of urban areas.
- Continue with SILO land use model research and potential integration into the MSTM.

7.2.3 Recommended Longer-Term Improvements

The panel also identified potential improvements for SHA to consider over the longer term (beyond the next three years):

- Support research for incorporating analytic DTA and reliability measurement in the model.
- Activity-Based Model development and incremental incorporation into the MSTM, following the development of BMC's activity-based model.
- Freight mode choice development through partnering with adjacent states to develop area-appropriate methodologies.

Appendix A: List of Peer Review Panel Participants

This section contains a list of the peer review participants, including the panel members, local agency staff, and TMIP documentation support staff.

Peer Review Panel Members

Panel Member	Affiliation
Charlene Rohr	RAND Europe
Keith Lawton	Keith Lawton Cons.
Dan Thomas	North Carolina DOT
Thomas Rossi	Cambridge Systematics
Anne Goodchild	University of Washington

Local Agency and Partner Agency Staff

Name	Affiliation
Subrat Mahapatra	DSED-Travel Forecasting and Analysis, OPPE
Lisa Shemer	DSED-Travel Forecasting and Analysis, OPPE
Derek Gunn	DSED-Travel Forecasting and Analysis, OPPE
Greg Slater	Director, OPPE
Morteza Tadayon	Chief, Data Services Engineering Division (DSED), OPPE
Birat Pandey	Baltimore Metropolitan Council
Charles Baber	Baltimore Metropolitan Council

Consultant Staff

Name	Affiliation
Fred Ducca	University of Maryland
Rolf Moeckel	University of Maryland
Rick Donnelly	Parsons Brinkerhoff
Mark Radovic	Gannett Fleming

TMIP Peer Review Support Staff

Name	Affiliation
Colin Smith	TMIP, Resource Systems Group, Inc.

Appendix B: Peer Review Session Agendas

Below are the agendas for the Peer Review meeting sessions.

Day 1 Agenda

Day 1	Topic
8:00 – 8:30 a.m.	Breakfast
8:30 - 8:45 a.m.	Welcome, Introductions, and Peer Process Overview
8:45 - 9:45 a.m.	Background, Future Plans, Q&A (SHA modeling & analysis needs)
9:45 - 11:00 a.m.	Presentations on Current Model – Part 1: • Objectives and history of the MSTM project, three-layer approach, model flowchart • Study area, networks, zone system, socio-economic data and household travel survey • Trip generation (including trip rates, non-mot. Share, comparison to MPO rates) • Trip distribution • Mode choice • Time-of-day and assignment
11:00 - 11:15 a.m.	Break
11:15 - 12:00 p.m.	Presentations on Current Model – Part 2: • Short- and long distance truck model • Long distance person model • Model validation (VMT, counts, screenlines, comparison to other statewide models) • Model result visualizations
12:00 - 1:00 p.m.	Lunch
1:00 - 2:00 p.m.	Participants Discussion and Q&A (Part of this could be closed panel meeting)
2:00 - 2:15 p.m.	Break

2:15 - 3:15 p.m.	Presentations on planned improvements : • Raster cell zone system • Scenario manager • Mode choice model • Short distance freight model • Freight mode choice model • DTA integration and reliability • Land-use model integration
3:15 - 4:00 p.m.	Participants Discussion and Q&A
4:00 – 4:30 p.m.	Panel Discussion (closed)

Day 2 Agenda

Day 2	Topic
8:00 – 8:30 a.m.	Breakfast
8:30 - 10:30 a.m.	Panel Discussion (closed)
10:30 - 10:45 a.m.	Break
10:45 - 11:45 p.m.	Panel Presentation, Participants Discussion and Q&A
11:45 - 12:00 p.m.	Next Steps/ Closing Remarks

Appendix C: Peer Review Panelist Biographies

This section contains a brief bio of each of the peer review panel members.

Charlene Rohr, RAND Europe

Charlene Rohr directs RAND Europe's research in choice modeling and valuation. Her main area areas of interest are estimation of discrete choice models using revealed preference (RP) and stated preference (SP) data sources. She has been involved in developing transport demand forecasting models for in Scandinavia, Europe, Australia, and the UK and has contributed to the design and analysis of stated preference surveys in transport, health, and communication sectors. Rohr received her B.Sc. in civil engineering and her M.Sc. in transportation engineering from the University of Alberta.

Keith Lawton, Keith Lawton Cons.

Keith Lawton is a transport modeling consultant. Past Director of Technical services, Metro Planning Department, Portland, OR. He has been active in model development for over 40 years. He was involved with the application of TRANSIMS in Portland. Keith has led the development of the first tour-based activity model set at an MPO, which was used in a road pricing study at Metro, and been a leader in developing an integrated land-use and transportation model, which has seen project application in Portland. He has also led the move to include the effects of urban design on transport demand, and to embed these model elements in the Portland trip-based models. He has served on a number of modeling peer and expert review committees. He has a BSc. in Civil Engineering from the University of Natal (South Africa), and an M.S. in Civil and Environmental Engineering from Duke University. Keith is a member emeritus and past Chair of the TRB Committee on Travel Demand Forecasting.

Dan Thomas, North Carolina DOT

Dan Thomas has a degree in Civil Engineering from North Carolina State University and has been with the North Carolina Department of Transportation since graduating in 1986. He is a registered Professional Engineer and a Certified Public Manager. During his 27 years as an engineer with NCDOT, Dan has provided long range transportation planning and model development assistance to many areas across North Carolina from small cities and towns to several of North Carolina's largest metropolitan areas. Dan currently leads the Technical Services Unit in the Transportation Planning Branch. This Group is responsible for implementing the *Statewide Multimodal Transportation Plan*, air quality conformity, administration of the statewide traffic count program, model research and development, and development of the North Carolina Statewide Transportation Model.

Thomas Rossi, Cambridge Systematics

Thomas Rossi is a Principal of Cambridge Systematics with 30 years of experience in transportation planning and travel demand forecasting. He has developed and applied trip based and activity based models throughout the U.S. For the past 20 years, Tom has been a consultant to USDOT for model improvement research and development/teaching of training courses. He is the Chairman of TRB Committee on Transportation Demand Forecasting. Tom holds Bachelor's degrees in Civil Engineering and Mathematics and a Master's degree in Transportation from the Massachusetts Institute of Technology.

A-5 *Anne Goodchild, University of Washington*

Anne Goodchild is the Allan and Inger Osberg Endowed Associate Professor in Civil and Environmental Engineering at the University of Washington. Anne Goodchild joined the faculty of the University of Washington as an Assistant Professor in December 2005 after completing her PhD in Civil and Environmental Engineering at UC at Berkeley. Her research interests lie in the analysis of logistic systems, with an emphasis on freight transportation. Recent research has evaluated CO_2 emissions in strategic routing and schedule planning in urban pick-up and delivery systems, policy and technology implementations to improve intermodal interfaces, and the relationship between freight activity and the economy. In addition, a series of recent projects include primary data collection and analysis to build knowledge and algorithms for next generation freight models. Before attending Berkeley she worked in consulting for 5 years in Europe and North America, for PricewaterhouseCoopers LLP and Applied Decision Analysis Inc., modeling business problems such as airline fleet maintenance scheduling. She holds an MS in Civil and Environmental Engineering from the UC at Berkeley, and a BS (with High Honors) in Mathematics from the UC at Davis. She serves as Chair of TRB's Intermodal Freight Transportation committee.

Appendix D: Overview of the Maryland Statewide Transportation Model

The following appendix is information directly extracted from the MSTM model documentation and the SHA Peer Review presentation relating the version of the SHA model at the time of the peer review. Data sources used in the development of the model are also provided.

A1. Introduction

The Maryland State Highway Administration (SHA) has developed a statewide transportation model that (1) will allow consistent and defensible estimates of how different patterns of future development change key measures of transportation performance and (2) can contribute to discussion and other evaluation tools that address how future transportation improvements may affect development patterns.

A2. Zonal Data

The MSTM has three different model levels, regional, statewide, and urban. The following bullets detail the zonal structures for each of these three levels.

- Regional Level: 151 Regional Model Zones (RMZs) in the MSTM Regional model cover the entire US, Canada, and Mexico. These zones are used for the Regional long distance models only. Flows from these model zones are eventually translated into flows assigned to networks and zones at the Statewide Model Zone (SMZ) level.
- Statewide Level: 1,588 Statewide Model Zones (SMZs) in the MSTM Statewide level cover all of Maryland and selected counties in adjacent states. SMZs are the basis for MSTM transportation assignment and input land use assumptions. They nest within counties and are aggregations of MPO TAZs where they exist.
- Urban Level: 3,056 Urban Model Zones (UMZs) in the MSTM urban level are taken directly from the Traffic Analysis Zones (TAZs) in the Baltimore Metropolitan Council (BMC) and Metro Washington Council of Governments (MWCOG) MPO models.

For 2000 SMZ socio-economic data, household data were drawn from Census 2000, which provides consistent data throughout the model area. Consistent employment data was produced for the entire model area at a county level, but more spatially detailed employment, developed later, had to draw on from a variety of sources including MPO TAZ data, Quarterly Census Employment and Wages (QCEW) data for Maryland and TAZ data from statewide modeling efforts in adjacent states. Additional detail regarding socioeconomic data applied in the model is further provided in Section A6.

A3. Networks

The MSTM uses a multi-modal network at the statewide level, including highway and transit networks and associated assumptions on link attributes and model-wide intercity and urban transit service. The networks were compiled from various existing models, including MPO, DOT, and other sources, and standardized. Extensive efforts were made to map the highway network to the SHA CenterLine network to enable sharing of data. The attributes provided in the BMC network were used as the main source. Model networks from MWCOG, DelDOT, and a network prepared by Caliper for a previous regional project were reviewed to identify attributes that matched or nearly matched those provided by the BMC. Table 1 provides a summary of the attributes that have been developed for the MSTM. Table 2 details the model's facility types.

Table 1: Highway Network Attributes

Field	Description
A	A node
B	B node
AMLIMIT	AM peak link usage restriction code
PMLIMIT	PM peak link usage restriction code
OFFLIMIT	Off-peak link usage restriction code
FT	Facility type
DISTANCE	Distance in miles
SPDP	Posted speed limit, mph
CAPCLASS	Maximum daily lane capacity divided by 50 (Service level 'E')
CNTID	Regional count database identification
CNT00	Year 2000 daily count
CNTWKD00	Year 2000 weekday count
HTCNT00	Year 2000 heavy truck count
MTCNT00	Year 2000 medium truck count
COMCNT00	Year 2000 commercial vehicle count (not presently coded)
AMLANE	AM peak number of lanes
PMLANE	PM peak number of lanes
OFFLANE	Off-peak number of lanes
FFSPEED	Free-flow speed, mph
CONGSPD	Initial congested speed, mph
CAPE	Maximum daily lane capacity (Service level 'E')
TOLLCOSTOF	Off-peak toll, cents (year 2000 $)
TOLLCOSTPK	Peak toll, cents (year 2000 $)
FROM_TO_ID	Local network link identifier
MODEL	Local model identifier
PB_DIST	PB calculated distance in feet
RECID	Temporary ID number for links used to stitch networks
FROM_X	From Node X Coordinate
FROM_Y	From Node Y Coordinate
TO_X	To Node X Coordinate
TO_Y	To Node Y Coordinate
SWFT	Statewide Model facility type
DIR	One-way directional code
RMZ_NAME	RMZ name
JUR_NAME	Jurisdiction Name
JUR_FIPS	Jurisdiction FIPS Code
SMZRMZ	SMZ or RMZ number
RT_ID	Route ID number
RT_NAME	Route Name
ACRES	Acres
PBAREATYPE	PB defined area type
AREATYPE	Local network defined area type
FT_ORIG	Original FT

Table 2: Highway Facility Types

Code	Description
1	Interstate
2	Freeway
3	Expressway
4	Major Arterial
5	Minor Arterial
6	Collector
7	Not Used
8	Medium Speed Ramps
9	High Speed Ramps
10	Local Roads
11	Centroid connector
13	Drive Access Link (Hwy - PNR)
15	Rail Links
19	Drive Access Links to IntercityBus
20	Drive Access links to IntercityRail
21	PNR - Hwy walk link
22	Not Used
23	PNR - rail walk link
24	Rail - Rail walk link, Hwy – Hwy walk link
26	Amtrak

The MSTM network includes both MPO and intercity transit systems throughout Maryland and in selected counties of adjacent states. As the transit focus of alternative scenarios will be on intercity transit facilities, ways to simplify local bus services in the transit networks were explored to expedite network coding. This includes the following transit systems and their system miles (two-way distance).

The transit line descriptions follow the standard CUBE coding convention. The time periods are the same as the highway network assignment. Coded headways reflect the headway that is generally implied by the published timetable and are coded to the nearest whole minute. The MSTM contains Baltimore and Metro Washington urban transit networks. These networks are taken directly from the BMC and MWCOG MPO model network files. There are two separate files, one for the peak and one for the off-peak periods. Intercity transit includes Greyhound Bus and Amtrak Rail Lines in the model area, which covers six states. It may be noted that some of the routes described in the Urban Transit section also serve multiple MPOs within the State.

A4. Model Components

The following section provides descriptions of the various modules and parameters applied in the statewide model.

Trip Generation

Person trip generation follows the same basic approach as the BMC model and encompasses the same trip purposes. The trip production component was updated to use household characteristics and trip rates derived from 2007-2008 HTS data and more recent Census data.

The trip attraction component is based on linear regression equations derived from the same household survey data.

The MSTM person trip generation model uses trip production and attraction rates by household size (SIZ) by income (INC) and household workers (WRK) by income (INC). The trip generation model produces trip productions by trip purpose for each SMZ based on joint distributions of households and trip production rates cross-classified by household category. The following trip purposes were identified:

- HBW = Home Based Work;
- HBS = Home Based Shop;
- HBO = Home Based Other;
- HBSCH = Home Based School;
- NHBW = Non Home Based Work; and
- NHBO = Non Home Based Other.

Trip productions for work-related purposes are based on trip rates cross-classified by income and number of workers. The work related trips rates are slightly adjusted (reduced) to reflect the trips attracted to cities outside the MSTM region such as Philadelphia. Trip productions for non-work related purposes are based on trip rates cross-classified by income and number of persons. Differences from the BMC approach are related to the income classification of households and the way motorized shares are derived and trip rates represent only trips within 50 miles. The long distance trips greater than 50 miles are modeled with the long distance travel model. Trip generation rates by household category and region are taken directly from the 2007-2008 HTS survey data. Rates are adjusted to the MSTM income categories.

Trip attractions by SMZ are calculated based on regression-type equations applied to SMZ socioeconomic variables for the non-home end of trips. The attraction rates were derived from the combined HTS survey data. The rates were calculated for the entire survey area, not distinguishing urban, suburban, and rural regions.

Table 3 summarizes the trip generation attributes by purpose, income, and reference.

Table 3: Trip Generation Attributes

Purpose	Income	Reference
HBWORK	BY 5 income groups	Households by Workers
HBSHOP	BY 5 income groups	Households by Size
HBOTHER	BY 5 income groups	
HBSCHOOL	All	
NHBOTHER	All	
NHBWORK	All	Households by Workers

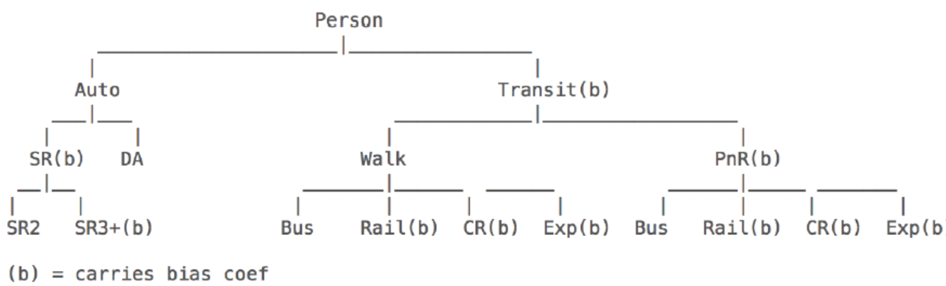
Trip Distribution

The destination choice model predicts the probability of choosing any given zone as the trip attraction end. The model was estimated in a multinomial logit form using the ALOGIT software. These models are preceded by the trip production models, which forecast the number of productions by zone for different trip markets, chiefly identified by purpose and household income level. The destination choice models include mode choice logsums, distance terms, zonal employment, household characteristics, and region geographic characteristics. The destination choice formulation is used for all purposes except for Home Based School (HBSCH), which uses a gravity formulation.

Mode Choice

Person trip mode choice is an adaptation of the most recent BMC nested logit mode choice model in Figure 1 below. Rail includes light rail transit and the DC Metro and the commuter rail (CR) includes AMTRAK services as well as MARC commuter rail. All local bus services are included under the Bus and express bus and commuter bus services are included in the ExpBus modes. Auto includes drive alone (DA), two-person shared ride (SR2), and three-or-more shared ride (SR3+).

Figure 1: Mode Choice Nested Logit Mode Choice Model



Mode choice is based on generalized utility functions for auto and transit travel. Separate utilities were developed to represent peak and off-peak conditions. Home-based work trips and non-home based work trips are based on peak period travel characteristics while other purposes are based on off-peak characteristics. Auto utilities for each auto mode include driving time and cost, terminal time and parking costs at the attraction end, and tolls. Transit utilities for each transit mode include walk and drive-access times, initial wait time, in-vehicle time, and transfer time.

Table 4 summarizes the mode choice coefficients in the MSTM. Table 5 summarizes the nesting coefficients in the mode choice model.

Table 4: Mode Choice Coefficients

Attribute	HBW, NHBW	HBO, HBS, SCH	OBO
In Vehicle Time	-0.025	-0.008	-0.02
Terminal Time	-0.05	-0.02	-0.05
Auto Operating Cost	-0.0042	-0.0018	-0.0044
Auto Parking Cost and Tolls	-0.0084	-0.0036	-0.0088
Walk Time	-0.05	-0.02	-0.05
Initial Wait Time (under 7.5 minutes)	-0.05	-0.02	-0.05
Initial Wait Time (over 7.5 minutes)	-0.025	-0.01	-0.025
Transfer Time	-0.05	-0.02	-0.05
Number of Transfers	-0.125	-0.06	-0.15
Transit Fare	-0.0042	-0.0018	-0.0044
Drive Access Time	-0.05	-0.02	-0.05

Table 5: Nesting Coefficients

Nest	Value
Walk Transit Route (Bus, Rail, MARC)	0.30
Drive Transit Route (Bus, Rail, MARC)	0.30
Transit Access (Walk vs. Drive)	0.65
Shared Ride Occupancy (2 vs. 3+)	0.30
Auto Mode (Drive Alone vs. Shared Ride)	0.65

It should be noted that the MSTM generates motorized trips only. Walk and bike trips are estimated by trip generation but are not included in trip tables for subsequent modules. A certain share of trips is dropped before trip productions and attractions are fed into the destination choice model. Then, the 2007 HTS is used to estimate the non-motorized share by zone. A multiple regression is used to analyze the impact of various measures of densities and accessibilities on non-motorized shares at the zonal level.

Long Distance Model

A long-distance model called Nationwide Estimate of Long-Distance Travel (NELDT) has been implemented in the MSTM to cover long-distance travel. The model was presented at the Transportation Research Forum, and exchange with international researchers helped to further advance the model design. This new person long-distance model covers all trips traveling a one-way distance of 50 miles or more. In other words, this model handles External-External, External-Internal, Internal-External, and Internal-Internal long-distance trips.

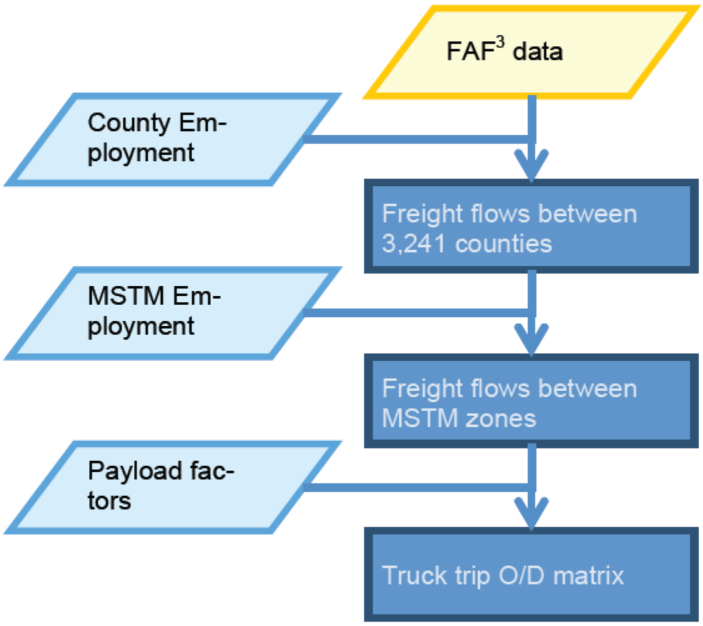
Freight Model

The statewide level truck trip model is an adaption of the BMC and MWCOG truck and commercial vehicles models. Two truck types, Medium Truck and Heavy Truck, and commercial vehicles are distinguished. Trip generation is based on employment by category and total households. BMC truck generation rates are comparable to rates applied in other regions. Trips ends are calculated for the statewide level model area.

The national level freight model utilizes FAF3 data. The resolution of the FAF3 data with 123 zones within the U.S. is too coarse to analyze freight flows in Maryland. Hence, a method has been developed to disaggregate freight flows from FAF zones to counties and further to MSTM zones. An overview of the truck model design is shown in Figure 2.

First, the FAF3 data are disaggregated to counties across the entire U.S. using employment by eleven employment types in each county. Within the MSTM region, detailed employment categories are used to further disaggregate to SMZ. Finally, commodity flows in tons are converted into truck trips using average payload factors. Output of this module is a truck trip table between all MSTM zones for two truck types, single unit trucks and multi-unit trucks.

Figure 2: Truck Model Flow Chart



Trip Assignment

Temporal allocation of the person, commercial, and truck vehicle trips was accomplished by applying factors to the respective daily trip matrices to derive peak (AM and PM) and off-peak (MD and NT) trip matrices for network assignment. The process was taken from the BMC model. Factors for person trips are derived from household survey data on a production-to attraction (PA) basis for home-based travel for application to person trip matrices in PA format.

These factors produce directional flow matrices replicating observed average peaking characteristics. Factors for non-home-based person trips are derived on an OD basis and applied to the corresponding OD trip matrices. Vehicle trips are assigned by time of day period. Separate assignments were done for the AM and PM peak periods and for the rest of the day combined.

Transit trips were assigned on a daily basis with work trip assignment based on peak service characteristics and assignment of all other trips based on off-peak service characteristics. BMC factors for auto person trips and the drive access component of transit drive-access trips are given in Table 6. They sum to 100% by purpose for the P-A and A-P directions individually.

Table 6: Person Trip Time of Day Factors

Purpose	PA_AM	AP_AM	PA_MD	AP_MD	PA_PM	AP_PM	PA_NT	AP_NT
HBW1	55.27%	3.61%	18.96%	27.45%	5.57%	45.00%	20.20%	23.95%
HBW2	60.72%	2.30%	14.26%	20.22%	4.44%	53.03%	20.57%	24.45%
HBW3	63.56%	1.34%	11.57%	19.98%	3.32%	60.17%	21.54%	18.51%
HBW4	68.04%	1.50%	9.45%	18.62%	2.42%	61.94%	20.09%	17.94%
HBW5	71.47%	0.69%	9.10%	15.98%	1.91%	64.32%	17.52%	19.01%
HBS1	18.44%	3.27%	50.53%	43.71%	19.04%	29.45%	11.99%	23.58%
HBS2	17.31%	2.80%	42.50%	38.25%	21.43%	28.27%	18.76%	30.68%
HBS3	16.04%	2.53%	39.67%	37.77%	26.57%	27.63%	17.72%	32.07%
HBS4	15.55%	2.00%	36.14%	33.34%	26.83%	28.48%	21.48%	36.18%
HBS5	17.91%	2.23%	32.72%	33.73%	24.68%	26.43%	24.69%	37.61%
HBO1	38.17%	9.31%	38.69%	39.86%	13.02%	28.33%	10.12%	22.50%
HBO2	32.41%	8.72%	35.66%	32.05%	17.06%	27.42%	14.87%	31.81%
HBO3	31.51%	10.08%	33.74%	31.98%	20.40%	27.24%	14.34%	30.70%
HBO4	31.49%	9.15%	30.86%	27.91%	22.04%	30.56%	15.61%	32.38%
HBO5	31.69%	9.72%	28.98%	27.47%	22.71%	31.08%	16.62%	31.73%
HBSc	89.92%	0.21%	4.11%	62.86%	2.79%	29.16%	3.19%	7.77%
NHBW	4.62%	29.34%	50.44%	58.38%	38.88%	5.89%	6.07%	6.39%
OBO	7.46%	9.08%	57.40%	55.57%	21.16%	22.55%	13.97%	12.80%

Time of Day factors for regional and statewide trucks are shown in Table 7. These are derived from TOD factors reported for the BMC commercial and truck model.

Table 7: Regional and Statewide Truck Time of Day Factors

Assignment Period (P-->A Only)	Com. Veh.	MHDT	HHDT	Regional Trucks	Regional Autos
AM 6:30--9:30	16.982	16.982	16.982	20	Defined Explicitly by the NELDT Model
Midday 9:30a--3:30p	42.845	42.845	42.845	50	
PM 3:30--6:30	15.426	15.426	15.426	20	
Night 6:30p--6:30a	24.747	24.747	24.747	10	
Total	100%	100%	100%	100%	100%

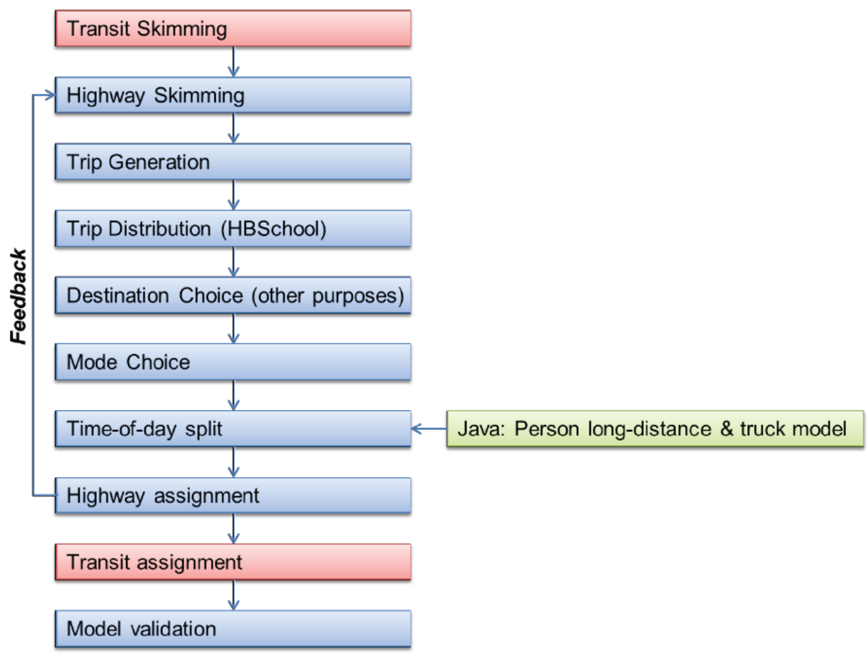
Bridge crossings were a particular challenge to calibrate. On the one hand, bridges are at bottlenecks for many trips, and on the other hand research in travel demand shows that rivers form a mental barrier. To account for this psychological barrier, the destination choice model included a factor that impacted travel from one river zone to another. No further adjustment or factoring has been applied.

Feedback Loop

A crucial input for the model is travel time on the network. Initially, congested travel times were assumed to be based on free-flow speed, link length, area type, and facility. Congested travel times were an exogenous input that did not change with congestion. To overcome this shortcoming, a feedback loop was implemented that uses travel times calculated by the assignment and feeds them back into trip generation. The procedure is visualized in Figure 3. Transit skimming and transit assignment are not included in the feedback loop, as these two processes do not affect highway travel times, nor do transit travel times change with congestion. As these two transit modules are computationally relatively intensive, excluding them from the feedback accelerates a model run.

The initial skim values are calculated using free-flow travel time. All subsequent modules use these skim matrices. After the assignment has been completed, skim matrices are recalculated using the travel times generated in the assignment. To avoid oscillating model results, the new highway skims are not used directly but rather averaged with the previous skim values. By using the average between the previous skim values and the recalculated skim values, changes happen more gradually and the model is able to converge more quickly.

Figure 3: Feedback Loop Design



A5. Validation

Some network coding errors are detected by CUBE, but several definitional errors are not. A number of network validation checks were coded into a tool called the NEtwork VAlidation (NEVA) to ensure that the network is defined correctly. This tool should be run every time the roadway network is modified, covering the following checks:

- Links with differences between coded length and Euclidean distance;
- Asymmetry of two-way link characteristics, such as length, functional classification (link type), area type, number of lanes, or capacity; and
- Dead-end or “dangling” links that do not connect to a downstream link or centroid connector.

After the network passes these tests an assignment is carried out using a demand of one trip for each zone interchange in the trip matrix. The output of the assignment is checked for further problems with network coding:

- Traffic analysis zones that cannot be reached (i.e., have very large interzonal travel times associated with them, or the assignment fails) and
- Links with zero flow after assignment (especially one-way links, which might have directionality coded improperly).

To run the NEVA tool, the Cube network is exported into a shapefile. The tool is started by opening a command prompt, navigating to the location where the NEVA tool is saved, and typing: NEVA <Name of shapefile>. The tool reads the shapefile and the corresponding attribute table and generates plots on the screen showing the links that potentially have problems. In addition, a file called <nevaReport.txt> is written that lists all links that should be checked for consistency. The mode split model has been calibrated to resemble the mode split observed in the survey. As no independent data were available, a true validation of mode split was not possible. Instead, a comparison of survey data and model results shows that the mode split model was calibrated to resemble observed travel behavior.

Given that the statewide model covers a highly heterogeneous study area with parts that have excellent transit service and other parts with almost no transit access, the comparison shows a reasonable picture. For commercial vehicles and trucks, no survey data were available. Instead, data reported in the BMC and MWCOG reports were used to estimate the reasonability of the MSTM model output. Overall, the longer trip lengths may be due to the larger study area of MSTM. The MSTM truck model performs reasonably well. While the midrange from 500 to 5,000 observed truck trips results in a %RMSE of just over 100%, the highest volume range (>=5,000 observed trucks) with 337 truck counts achieves a fairly good %RMSE (by truck modeling standards) of 52%. It is expected that future phases could improve the truck model quite a bit a conducting a local truck survey and by splitting the four employment types currently used in MSTM into a larger number of types (such as ten employment types).

Figure 4 compares the MSTM model results with results from other statewide models for which detailed validation data were available to the authors. Percent Root Mean Square Error (Percent RMSE) of different volume ranges was used as the validation criteria. Overall, the validation of MSTM is within the range of many other statewide models. The plot shows the Maryland model results in blue. There are two models, Ohio and Oregon, for which a lot of count data were available, and therefore, a very detailed analysis was feasible. In general, these two models have performed better than the MSTM model, which is mainly due to two reasons: (1) these two models were developed over more than a decade, and thus had more iterations to evolve than MSTM, which was developed over the course of approximately two years and (2) the geographies of Ohio and Oregon are easier to model than Maryland. Ohio and Oregon have a limited number of metropolitan areas, and density declines rapidly at the border of the study area.

Figure 4: Comparison of MSTM with Other Statewide Models

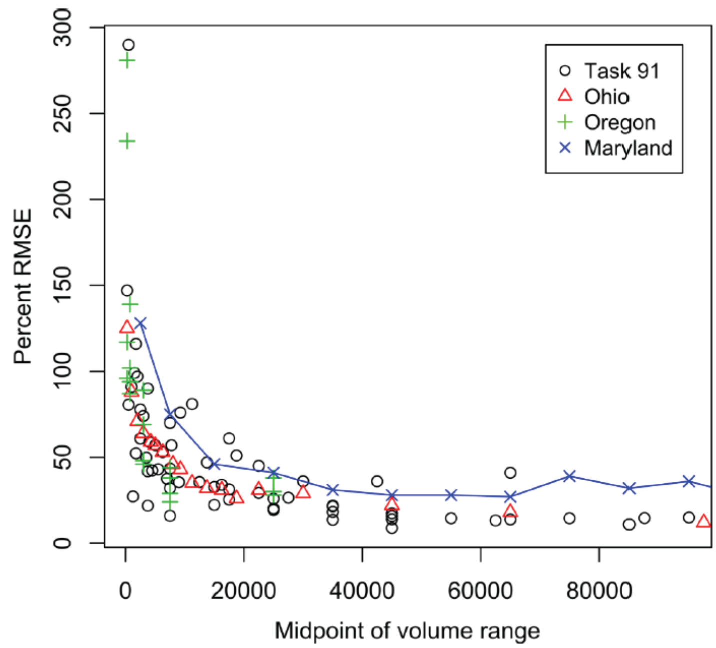


Figure 5 compares the simulated volumes with count data in Maryland. Points were not expected to line up on the diagonal, as count data commonly have a 20% standard deviation from the average volume. Furthermore, the network and zone system of a statewide model are simplified, which reduces the ability to match count data. Nevertheless, the general pattern is represented fairly well. Across all count locations, a Root Mean Square Error (RMSE) of 3,763 is achieved, or a Percent Root Mean Square Error (%RMSE) of 25%. This is reasonable for a statewide model.

Figure 5: Comparison of Counts with Model Volumes, All Vehicles

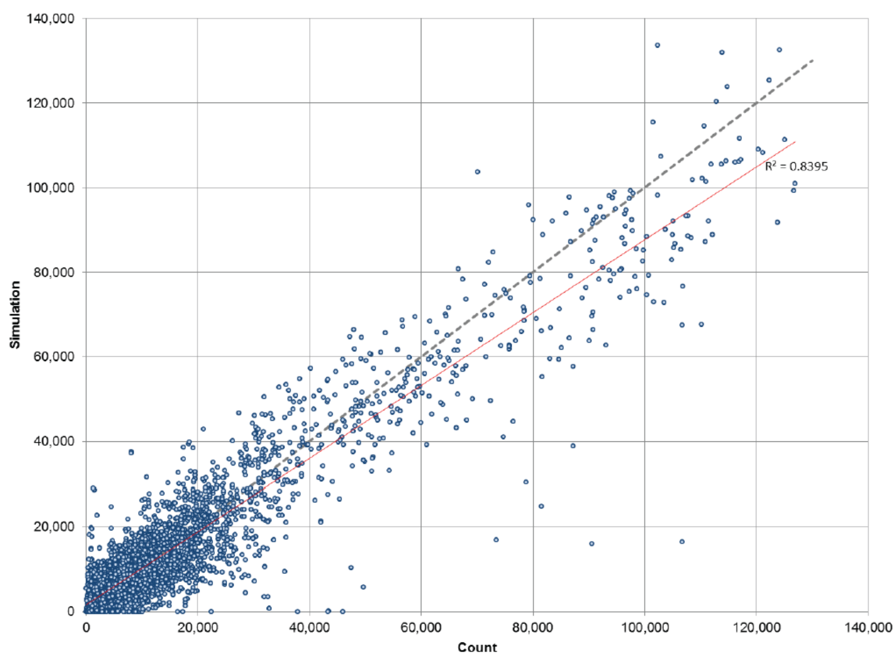


Figure 6 shows the validation across 61 screenlines that have been defined for MSTM. Every dot in this scatter diagram represents one screenline, which is an aggregation of several counts. The color indicates how many links on a given screenline actually have count data. Green dots show screenlines for which at least 75% of all links have count data. Yellow dots are screenlines on which 50% to 75% of its links have count data, and red dots show screenlines with less than 50% of its links filled with counts. The green screenlines are considered to be reliable, while yellow and red screenlines are less informative given the higher uncertainty due to missing counts. Green screenlines show a close resemblance of model volumes and count data, and most of the yellow and red screenlines match count data quite well, too.

Figure 6: Validation by Screenlines

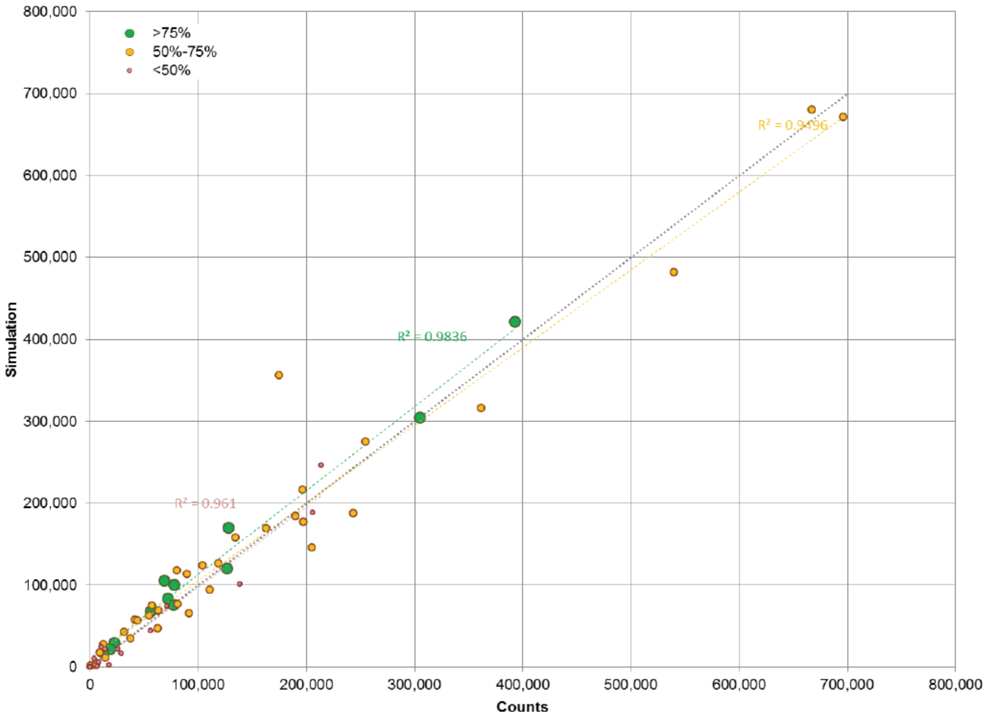


Figure 7 shows that MSTM makes no exception here, truck travel matches count data less well than auto travel. However, in comparison to other truck models, the match is comparatively satisfying. A RMSE of 1,301 or a %RMSE of 77% was achieved. This is significantly better than the RMSE of 2,284 and the %RMSE of 135% that was achieved for trucks at the end of phase III of MSTM.

Figure 7: Comparison of Counts with Model Volumes, Trucks Only

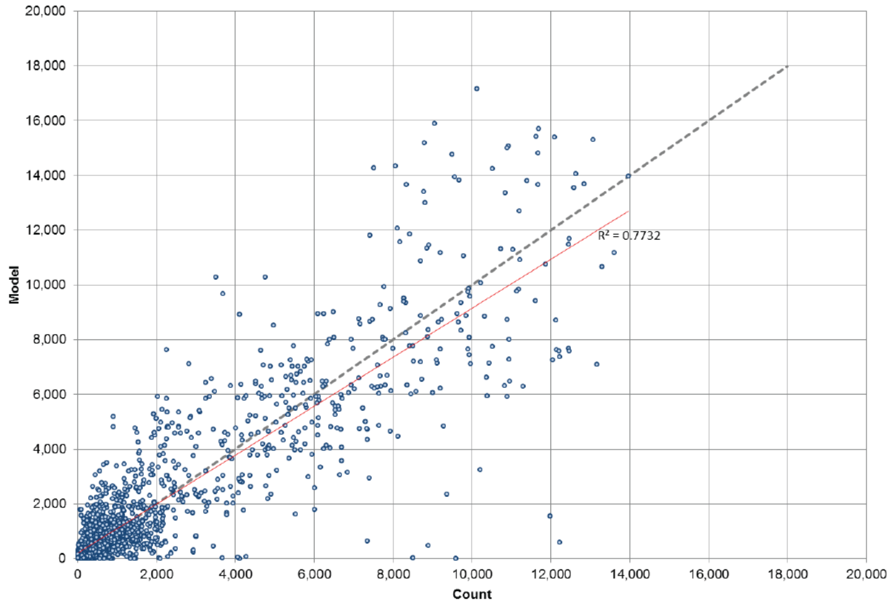
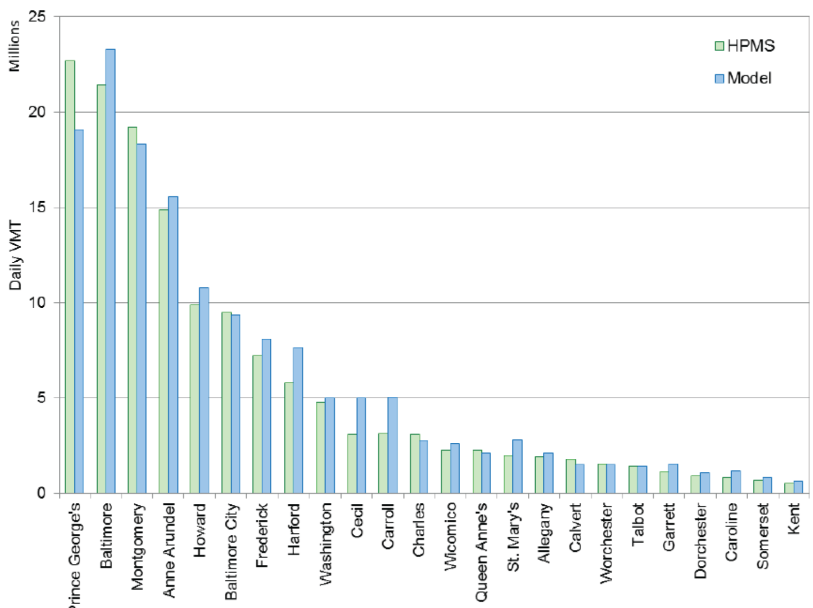


Figure 8 compares estimated VMT with modeled VMT, ordered by estimated VMT. While the overall pattern is replicated, some significant differences can be found for a few counties. Most importantly, Prince George's County is underestimated by about 16%. Part of this deviation is likely a function of the statewide mode choice model that has been implemented to capture mode split in many, very different regions across the state. While MSTM models a transit share of 6.5 percent, the Red Line model has a transit share of 5.1% and the Purple Line model has a transit share of 5.5% for this county. It is possible that MSTM overestimates transit in this county, and therefore, does not send a large enough number of vehicle trips on the network to generate VMT.

Figure 8: Comparison of HPMS and MSTM VMT by County



A6. Model Data Sources

The following section provides brief descriptions of the sources of data used in the model.

Demographic Data

The following is Census 2000 data used at SMZ level for the MSTM Statewide model. Portions of this data are used in the Trip Generation model, to provide a pattern that can disaggregate data to the detail required in that module.

1. Population (SF1)
   A. Population by age group (0-4, 5-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79, 80+)
   B. Population in households
   C. Population in Group Quarters
      I. Institutionalized by type
      II. Non-Institutionalized by type

2. Housing Units (SF1)
   A. Occupied
   B. Vacant

3. Households by income quintile in 1999 dollars) (SF3)
   A. Lower quintile (<$20,000)
   B. Lower-middle quintile ($20,000 to $39,999)
   C. Middle quintile ($40,000 to $59,999)
   D. Upper-middle quintile ($60,000 to $99,999)
   E. Upper quintile ($100,000 or more)

4. Households by number of persons in household (SF3) (1, 2, 3, 4, 5 or more)

5. Households by number of workers in household (CTPP) (0, 1, 2, 3 or more)

6. Average household income (SF3)

7. Median household income (SF3) (optional)

8. Total Workers (CTPP)

2000 Census Transportation Planning Package (CTPP) data was also utilized.

The primary source for socio-economic data in the Baltimore and Washington DC regions are the MPO model base year and forecast data used in the BMC and MWCOG models. Similar data was obtained from the VDOT, PennDOT and DelDOT models. These data were adjusted in the reconciliation process to account for definitional definitions, etc.

- BMC 2000, 2010, and 2030 (7.0) (Release Year: 2010)
- MWCOG 2000, 2010, and 2030 (7.2a) (Release Year: 2010)
- PennDOT 2002 and 2030 (Release Year: 2005)
- VDOT 2000 and 2030 (Release Year: 2005)
- DELDOT 2000 and 2030 (Release Year: 2005)

In addition to preparation of data received from other states and from the BMC and MWCOG it is necessary to develop employment data for the areas of Maryland not covered by BMC or

MWCOG. To do this the QCEW data was used. The QCEW dataset was created by the Maryland Department of Labor, Licensing and Regulation (DLLR) to comply with federal unemployment insurance regulations. The data are collected quarterly and provide monthly summaries of employment by workplace. QCEW data for the year 2000 is not available. The closest QCEW data is for 2003, therefore it was necessary to devise procedures for developing SMZ level employment estimates using a combination of 2003 QCEW data, 2000 MPO TAZ employment data, 2000 county employment and other data and GIS coverages as appropriate. Parsons Brinckerhoff and National Center for Smart Growth (NCSG) staff collaborated on developing the necessary procedures.

The socioeconomic data reconciliation is an important part of establishing the inputs to the MSTM. As the modeling region in MSTM consists of Maryland, and six other neighboring states, the SE data is collected from numerous sources such as MPOs, state DOTs and local agencies. The data sources do not follow the same definition and are not in the same format. The SE data reconciliation integrated all the data sources to provide a unified set of inputs to the MSTM. The methods used for the year 2000, the future year 2030 and the validation year 2007 is summarized in Table 2-3 and described in the following section.

Table 8: Socioeconomic Data Reconciliation Methods

	HH		EMP	
	County Control Totals	**SMZ+Sector Distribution**	**County Control Totals**	**SMZ+Sector Distribution**
2000 Base Year				
BMC	N/A	2000 Census	2000 BEA	2000 BMC (7.0) [1]
MWCOG-MD	N/A	2000 Census	2000 MWCOG (7.2a)	2000 MWCOG (7.2a) sector factors, 2000 CTPP [2]
MWCOG-VA	N/A	2000 Census	2000 MWCOG (7.2a)	2000 MWCOG (7.2a) sector factors, 2000 CTPP
Rest of MD	N/A	2000 Census	2000 BEA	2007 QCEW
Non-MD	N/A	2000 Census	2000 BEA	DL: 2000 DELDOT PA/VA: 2000 PENNDOT/VDOT [3] NJ/WV: 2000 CTPP
2030 Consolidated Forecast				
BMC	N/A	2030 BMC (7.0)	2030 BMC (7.0)	2030 BMC (7.0)
MWCOG-MD	N/A	2030 MWCOG (7.2a)	2030 MWCOG (7.2a)	2000 MWCOG (7.2a) sector factors, 2000 CTPP
MWCOG-VA	N/A	2030 MWCOG (7.2a)	2030 MWCOG (7.2a)	2000 MWCOG (7.2a) sector factors, 2000 CTPP
Rest of MD	2030 TH	2000 Census=TH	2030 TH	2007 QCEW
Non-MD	2030 TH	DL: 2030 DELDOT PA/VA: 2030 PENNDOT/VDOT NJ/WV: 2000 Census	2030 TH	DL: 2030 DELDOT PA/VA: 2030 PENNDOT/VDOT NJ/WV: 2000 CTPP
2007 Validation Year				
BMC	2005-2010 BMC (7.0)	2010 BMC (7.0)	2005-2010 BEA	2005-2010 BMC (7.0)
MWCOG-MD	2005-2010 MWCOG (7.2a)	2010 MWCOG (7.2a)	2005-2010 MWCOG (7.2a)	2030 MWCOG (7.2a)
MWCOG-VA	2005-2010 MWCOG (7.2a)	2010 MWCOG (7.2a)	2005-2010 MWCOG (7.2a)	2030 MWCOG (7.2a)
Rest of MD	2007 Census	2000 Census	2005-2010 BEA	2007 QCEW
Non-MD	2007 Census	2000 Census	2005-2010 BEA	DL: 2000 DELDOT PA/VA: 2000 PENNDOT/VDOT NJ/WV: 2000 CTPP

[1] In the future if there is not much difference between the employment categorization between BMC and ES-202 at SMZ level, ES-202 can be used in the BMC region.

[2] In the future if there is not much difference between the employment categorization between CTPP 2000 and ES-202 at SMZ level, ES-202 can be used in the MWCOG region.

[3] For Industrial and Other category, CTPP 2000 data is used at SMZ level for employment proportions, to avoid definition problems from PennDOT and VDOT data.

TH = Tommy Hammer BEA/Census-based Forecast

County level information is the basic source of input for all employment data. County level employment is then allocated to individual SMZs based on the proportion of employment as determined by MPO estimates, CTPP or QCEW data. For households, 2000 Census allocations were used directly, with future year data taken directly from MPOs or forecast county household allocated to SMZs based on 2000 Census, MPO or State DOT model projections.

Survey Data

The 2007 TPB/BMC Household Travel Survey was utilized extensively throughout the model. The following bullets detail the specifics of this data collection effort:

- Survey conducted between May 2007 and December 2008
- Interviewed 14,365 households
- 108,110 trips were reported

2002 National Household Travel Survey (NHTS) data was utilized for long distance trips.

Highway Network/Transit Network/Traffic Volume Data

Fare and scheduling data was collected for intercity transit including Greyhound Bus and Amtrak Rail line systems for year 2000. The Amtrak data and some Greyhound data were collected using online resources from the transit providers in 2008.

State traffic counts were obtained for traffic volume data needs.

Transit Network data was obtained from the respective urban models (BMC/MWOG) and transit validation data was acquired from transit agency reports.

Freight Data

The third generation of the FAF data, called FAF3, was released in summer 2010 and contains flows between 123 domestic FAF regions and 8 international FAF regions. The MSTM truck model is using the third release of FAF3, also called FAF3.3. The FAF3 database is compiled from information published in:

- Bureau of Transportation's Commodity Flow Survey (CFS);
- Surface Transportation Board's Carload Waybill Sample;
- U.S. Army Corps of Engineers (USACE) waterborne commerce data;
- Bureau of Transportation Statistics' Transborder Surface Freight database; and
- the Air Freight Movements database from BTS.

Each of the 43 commodities employed in the FAF is defined according to the Standard Classification of Transported Goods (SCTG).

Appendix E: MD SHA Peer Review Application

Application for TMIP Peer Review of Maryland Statewide Transportation Model (MSTM)

Contact:

Morteza Tadayon (mtadayon@sha.state.md.us)

Subrat Mahapatra (smahapatra@sha.state.md.us)

Data Services Engineering Division – Travel Forecasting & Analysis

Office of Planning and Preliminary Engineering

MD State Highway Administration

Baltimore, MD

Phone (410) 545-5580 / (410) 545-5649

Background

Since 2006, the Maryland State Highway Administration (SHA) has developed the Maryland Statewide Transportation Model (MSTM) with support from the National Center for Smart Growth (NCSG) at the University of Maryland and Parsons Brinckerhoff, Inc. (PB). MSTM has become a policy decision support tool that is applied extensively for scenario analysis, corridor studies, project forecasts and future transportation performance measurement.

SHA has an ongoing commitment to become a lead agency in advancing the state of practice in statewide modeling that assists in transportation decision-making. Continuous funding and visioning has pushed the model beyond the traditional four-step modeling framework. However, SHA realizes the limitations of the current model implementation to answer all current policy and program level questions, in particular regarding mode choice, managed lane analysis, freight modeling and land use integration. The TMIP Peer Review shall help SHA identifying required steps to lead the MSTM to the next generation of statewide modeling. Leadership at SHA is committed to carry forward the recommendations of the TMIP Peer Review to improve MSTM capabilities for enhanced analysis and transportation decision-making at SHA, its modal agencies including Maryland Department of Transportation and Maryland Department of Planning.

Purpose of TMIP Review

SHA intends to further develop the MSTM, and this TMIP Peer Review shall help defining a road map over the next five years. While SHA has defined the modeling requirements based on current and anticipated requests for policy analysis, SHA is seeking advice to design a model that can address proficiently as many of these requirements as possible. After refining a trip-based model over the past seven years, it might be time to largely overhaul the model design; though SHA requires expert feedback before engaging into substantial model revisions.

After an initial funding of $850,000, SHA has invested approximately $200,000 per year in model development and model applications since 2006, and intends to continue with this level of funding in the future. SHA needs to ensure that this money is spent most effectively on developing model capabilities that best meet the requirements of the agency. While SHA continuously consulted with NCSG, PB and the Civil Engineering Department of the University of Maryland, SHA is seeking input from national experts who have not been involved in this project over the last few years who may provide an independent perspective on future model development.

The Region

The MSTM is designed as a multi-level model that currently works at two geographies. The statewide level covers not only the State of Maryland but also surrounding areas, including Washington, D.C., Delaware, and parts of New Jersey, Pennsylvania, Virginia and West Virginia. The geography has most detail in the urban areas of Baltimore and Washington, D.C., reflecting the centers of activity in this region. The statewide level has 1,588 zones, of which 1,151 zones are located within the state of Maryland.

The national layer contains all of Continental North America, including Canada and Mexico. This national layer accounts for all long distance trips. There are 151 zones at the national level. The geography of this level has more detail in proximity to the statewide model area (smallest geography are counties) and less detail further away.

The Maryland Statewide Transportation Model

The MSTM is a multi-level trip-based model that covers both person and freight travel demand. The figure below shows a high-level flowchart of MSTM, where the box of red dots shows person travel and the box of blue dots shows truck travel. The model works at two geographic layers. Short distance trips are modeled for the statewide model study area, and long distance trips include trips that have one or both trip ends at the national layer.

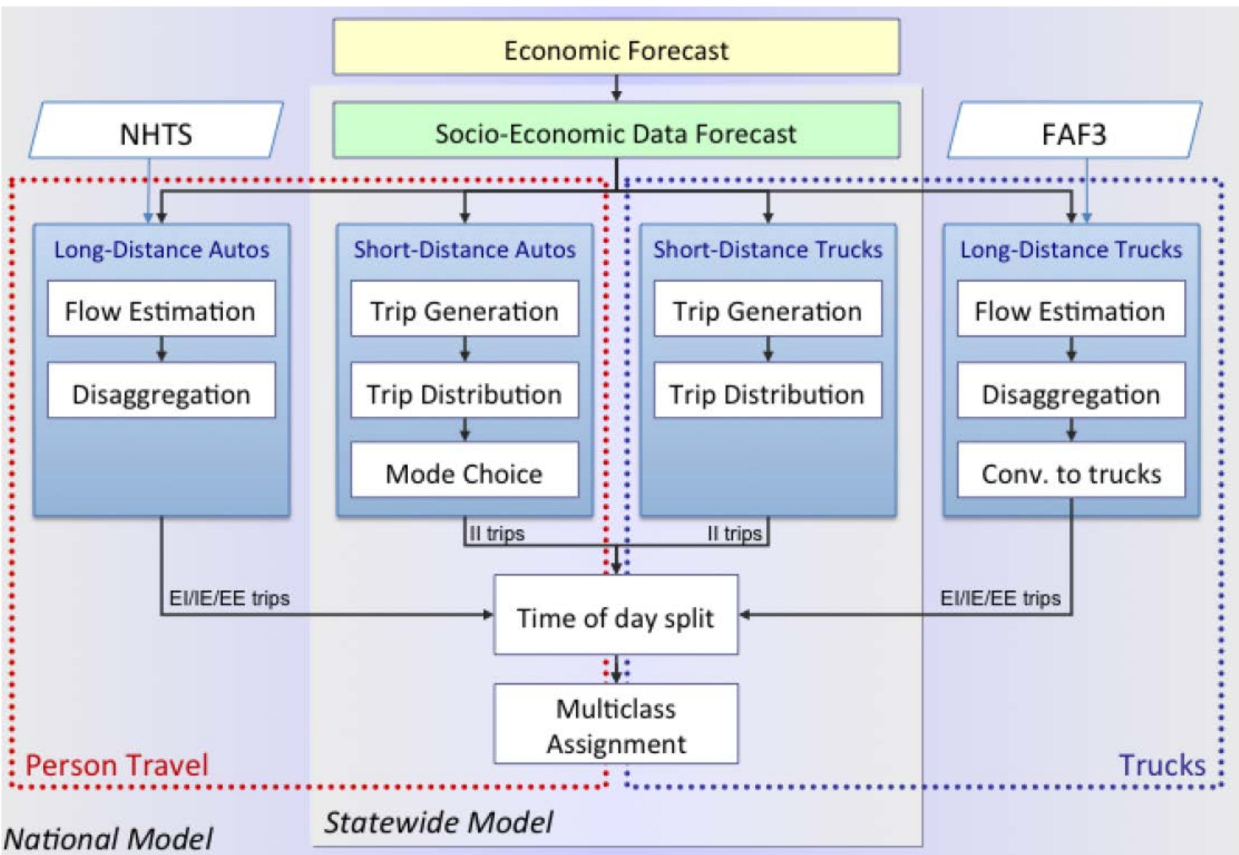


Figure: MSTM Flowchart

An economic forecast (shown with the yellow box in the Figure above) is used to project socioeconomic data. Four sub-models shown in blue boxes cover travel demand of different travel markets:

- The long distance auto model uses the long distance element of the National Household Travel Survey (NHTS) from 2002, expands these data and disaggregates them from states to TAZ.
- The short distance auto model is based on the trip-based model of the Baltimore Metropolitan Council (BMC), but has been revised in several respects. Nonmotorized shares are estimated based on densities. The gravity model was replaced with a logit-based destination choice model. A feedback loop from the assignment to destination choice has been implemented to achieve an equilibrium in destination choice and travel times.
- The short distance truck model is an application of the Quick Response Freight Manual (QRFM), where trip rates were scaled down to better match truck count data.
- The long distance truck model uses freight flow data of the Freight Analysis Framework (FAF), disaggregates these flows to zones and converts tons into trucks. An empty truck model adds trucks traveling with less-than-payload.

Four time periods are distinguished (AM Peak, Midday, PM Peak and Night). A multiclass assignment assigns auto and trucks trips to the network.

The model has been used for a series of policy analysis studies, including alternative growth forecasts, expansion of the Port of Baltimore, network modifications, changes to transit, and others.

Planned Model Improvements

Since its inception in 2006, the MSTM has been improved continuously, and SHA intends to continue this path to advance the state of practice in statewide travel demand modeling. The model improvement phase currently underway focuses on the implementation of a subarea analysis tool and revisions to the person mode choice model. A couple of future model improvements are envisioned, including:

- Refine spatial, temporal and functional resolution of zones and network
- Account for trips that may travel during more than one time-of-day period
- Bike and Pedestrian modeling
- Freight mode choice modeling
- Activity-based travel demand modeling
- Tour-based auto and truck modeling
- Land-use model integration
- Economic model integration
- Integration with water quality impact models
- Analytical dynamic traffic assignments

SHA intends to host the TMIP Peer Review Meeting to obtain guidance in prioritizing theses model improvement options. Given the wide range of expert knowledge provided by the proposed panel, new modeling concepts that have not been considered by SHA yet may arise during the meeting.

NOTICE

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The United State Government assumes no liability for its contents or use thereof.

The United States Government does not endorse manufacturers or products. Trade names appear in the document only because they are essential to the content of the report.

The opinions expressed in this report belong to the authors and do not constitute an endorsement or recommendation by FHWA.

This report is being distributed through the Travel Model Improvement Program (TMIP).

Federal Highway Administration