Multi-level Modeling with the Maryland Statewide Model (MSTM)

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INTRODUCTION

The Maryland Statewide Model (MSTM) was conceived as an evolutionary approach to developing a comprehensive and consistent land use-transportation modeling capability for the state. Originally intended to support Smart Growth studies, the scope of the model is evolving to meet the concurrent needs of the State Highway Administration, other transportation agencies and the research community.

The initial 12-month work effort resulted in a first generation model capable of addressing key analytical needs by mid-year 2010. This satisfies a key goal to quickly produce an operational model using readily available secondary and synthetic data, rather than embarking on a multi-year research and development effort. Its continued evolution will be guided by experience with the initial model, analytical requirements, and parallel advancements in urban travel modeling within state and regional models.

OVERVIEW OF MODEL DESIGN

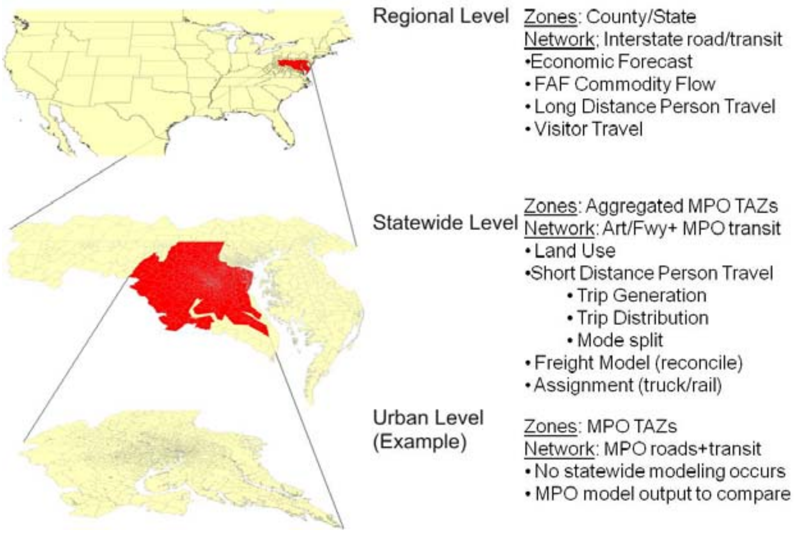
The Maryland Statewide Model (MSTM) encompasses Baltimore, Washington, DC, all of Maryland and Delaware, much of northern Virginia and parts of West Virginia, Pennsylvania and New Jersey. Due to the close interactions between Maryland and its neighbors, the study area had to be extended beyond the state boundaries. Furthermore, land use constraints and prices in one urban region can place unexpected burdens and congestion on the intercity transport system and spill over to adjacent less developed areas. This area contains a significant agglomeration of population (11.5 Mio. in 2000), economic activity, and global connections. The region has a need to evaluate long-distance travel such as the person-travel up and down the coast and goods movement from the Eastern ports and Canada, which are not addressed in urban MPO models, to affect greater efficiencies through regionally coordinated infrastructure and policy.

A primary tenet guiding model design is that choices and patterns at multiple geographic scales give rise to travel and congestion within Maryland. Thus, the framework for the travel model includes person-travel and freight models at the metropolitan, state, and regional scale. The different scales allow the models to better address short- and long-distance travel, and different trip purposes. Every level is simulating travel behavior at an appropriate level of detail. The interaction of the three levels is intended to improve every level by providing simulation results from upper and lower levels.

- A regional level of the model places Maryland within the context of the Eastern USA, and includes all of North America. Long distance and visitor person trips are modeled at this level, as well as commodity flow movements into, out of, and through Maryland. This was important to address SHA’s interest in interstate goods movement, location of state warehousing/distribution centers, and passenger high speed rail.

- A statewide level is the central focus of the model. Maryland, the District of Columbia, Delaware, and parts of adjacent states are included in this level of the model. Short distance person and truck trips are modeled at the statewide level employing a full-featured four-step model. This allows smaller scale impacts such as zoning and development constraints, neighborhood smart growth plans, and transit accessibility to be accommodated at a more appropriate local scale. Provisions are made to ensure consistency with the regional level models and flows at the cordon of the urban area models.
- The urban level includes the MPO travel model networks, traffic analysis zone systems, and unadjusted model outputs. These data are used to develop the statewide model and calibration targets, and in later versions may provide a more dynamic linkage between the urban and regional modeling systems. If desired, the model's regional and statewide level travel demands can be readily disaggregated to MPO level zones for assignment to MPO networks at the Urban Level. MPO models remain the choice for detailed analysis within their jurisdictions.

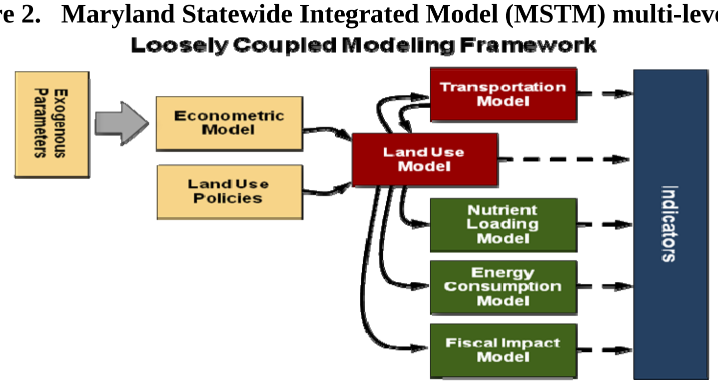
Figure 1. Maryland Statewide Integrated Model (MSTM) multi-level design



Additionally, the travel model is intended to be integrated within a larger modeling framework including the following basic components, as shown in Figure 2. The rest of this paper focuses on the travel demand model:

- **An economic model** will provide the necessary inputs to the Regional model for areas within Maryland and the surrounding states, and will be especially important for modeling freight flows and economic scenarios.
- A **land use model** will interface with the economic and travel demand models at the Statewide level, using their input as factors in allocating growth to sub-areas.
- **Environmental Models** are under development to evaluate energy consumption, nutrient loading (e.g., content of Chesapeake Bay runoff), and fiscal impacts of various scenarios. It will integrate at the Statewide level.

Figure 2. Maryland Statewide Integrated Model (MSTM) multi-level design

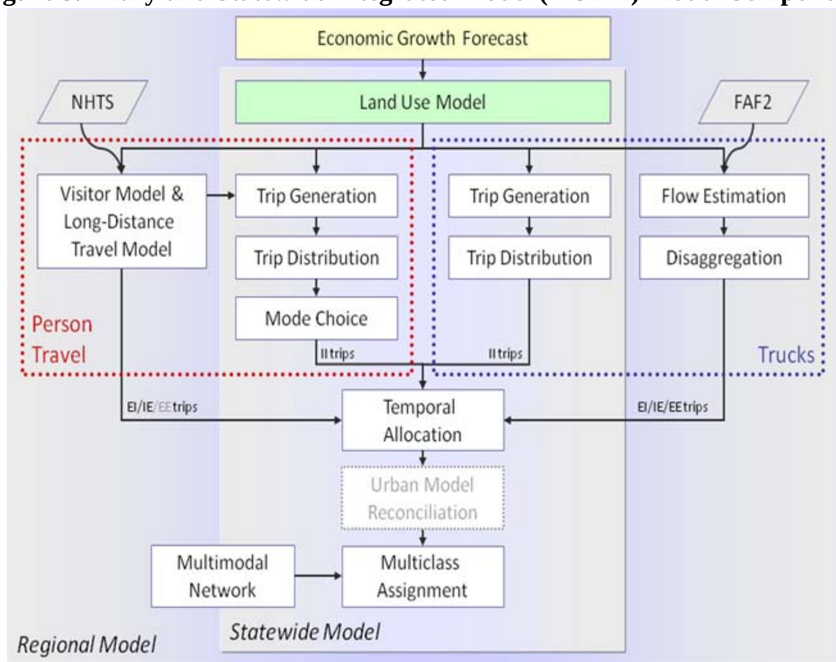


Source: G. Knaap, University of Maryland National Smart Growth Center,
Presentation at MSTM TAC Meeting. 23 March 2009

MSTM TRAVEL MODEL COMPONENTS DETAIL

The MSTM person travel and freight travel model components are outlined in Figure 3. As noted earlier, the Statewide level forms the core of the model. It implements a full four-step process, built on the Baltimore Metro Council's (BMC) MPO travel model. The regional model develops both long-distance person travel and FHWA FAF-derived intercity freight movements. The travel demand from both levels of the model is assigned to the Statewide network, built from MPO roadway and transit networks augmented with networks to cover the rest of the state. Economic and land use inputs provide baseline activity that drives the model. The Urban Model Reconciliation is shown in grey as future plan. The MSTM travel model is outlined in more detail in the remainder of this document.

Figure 3. Maryland Statewide Integrated Model (MSTM) Model Components



REGIONAL MODEL

The Regional model generates long distance person and truck travel, which are combined with shorter distance internal travel derived in the Statewide Model. Travel demands from all sources are brought together for a multiclass assignment to the consolidated network at the statewide level.

- **Person Long-Distance Travel**. This MSTM component accounts for trips by residents of the model that leave the study area. As a micro simulation model, every long-distance traveler is generated individually and the properties of every long-distance trip (trip probability, destination, primary mode) are added as sampled from the National Household Travel Survey (NHTS) conducted by the Federal Highway Administration (FHWA, 2005). If travel is by auto, the destination state is chosen. If the mode is transit, the local transit station is chosen as the external trip end. The total number of long-distance travelers is given exogenously. Based on data regarding ticketed passengers on airplanes and the number of trains and buses leaving the SMZ area as well as a best estimate of car long-distance travelers, the regional control total is set exogenously for every simulated year.
- **Visitor Model**. This MSTM component accounts for trips visitors who travel from outside to a destination within the study area on an average weekday either for business or personal travel. As a micro-simulation, visitors are generated with their origin, destination, mode, party size, income and time of day by sampling from the NHTS dataset. Visitors' internal trip end is selected based on population and employment. Exogenous regional control totals are estimated based on airline statistics, number of buses and trains entering the study area and an estimate of visitors entering the SMZ area by car.

STATEWIDE MODEL

The Statewide model, where much of the MSTM travel activity is generated and all travel is assigned, employs analysis zones that are aggregation of MPO zones (where they exist) and a consolidated network, which contains the full content of the MPO roadway and transit networks with appropriate modifications to eliminate overlap and create consistency in coding conventions and attribution. The person and truck models at the Statewide Level borrow their structure from the Baltimore MPO (BMC) model, including a full nested mode choice capability, which has been recalibrated to reflect the larger geographic extent in the Maryland statewide model with a more aggregate zone system. No new data collection was conducted and no model estimation was completed.

- **Trip Generation**. 2000 Census PUMS data provides the basic relationships for household attributes. Distributions by income groups, number of workers and household size categories are expressed in mathematical form and an iterative proportional fitting procedure is used to develop the joint distributions at the zonal level.

  Initial motorized trip production rates by purpose and household category include work-related trip rates cross-classified by income and number of workers; and the non-work-related trip rates cross-classified by income and number of persons, stratified by area type.

- **Trip Distribution**. Gravity model formulation employing composite travel time functions by purpose, a function of highway and transit time as well as roadway tolls and value of time.

- **Mode Choice**. Person trip mode choice is a nested logit choice model, whose nesting structure is shown in Figure 7. Mode choice is based on generalized utility functions for auto and transit travel, with separate utilities developed to represent peak and off-peak conditions. Auto utilities for each auto mode will include driving time and cost, terminal time and parking costs at the attraction end, and tolls. Transit utilities include walk and drive-access times, initial wait time, in-vehicle time, and transfer time. GIS techniques were used to define the portion of each zone within walking distance of transit stops and stations and related average walk times.

Figure 4: Structure of MSTM Mode Choice Model

```
                          Person
             _____________________|_______________
            |                                     |
          Auto                               Transit(b)
       ___|___                    ____________|____________
      |       |                  |                         |
     SR(b)   DA                 Walk                    Drive(b)
   __|__                   _______|______            ______|______
  |     |                 |       |      |          |      |      |
SR2   SR3+(b)            Bus    Rail(b)  CR(b)     Bus   Rail(b)  CR(b)

(b) = carries bias coefficient
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COMMODITY FLOW AND TRUCK MODEL

To account for truck trips with their origin and/or their destination outside the SMZ study area, a regional truck model has been developed, covering truck trips all over the United States. Additionally, to account for local truck travel, a statewide truck model is developed. Truck trips with origin and destination within the model area use the Statewide model demand, while all other demand is derived from the Regional model.

- **Regional Level Commodity Flow Truck Model**. Long-distance truck trips are generated by commodity flow data provided by the FHWA (2008) in the Freight Analysis Framework Version 2 (FAF2). The FAF2 goods' flows in tons are transformed into truck trips by assuming average payload factors. To achieve a finer spatial resolution, truck trips are disaggregated from trips between FAF regions to trips between counties based on employment patterns and input-output inter-industry coefficients of production and consumption.

- **Statewide Level Local Truck 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 number of households. Truck trip distribution is based on a gravity model formulation using truck generalized cost incorporating truck travel times (off-peak travel times, travel cost and tolls).

ASSIGNMENT

Person and truck travel demand forecasts from both the MSTM statewide and regional model components are assigned to a multi-modal network, following temporal allocation, as discussed below.

- **Time of Day**. Factors were applied to the respective daily trip matrices to derive peak and off-peak trip matrices for network assignment. 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 will 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. Time of Day (TOD) factors for commercial vehicle are derived from auto and truck vehicle counts for Maryland and the adjacent states where available. SHA classification counts are analyzed to determine the extent to which TOD patterns vary by vehicle type.
- **Assignment**. The MSTM model is implemented in CUBE. The statewide model uses CUBE scripts, while the regional model and the statewide truck model are implemented in Java and called from CUBE. Vehicle trips are assigned by time of day period. Separate assignments are done for the AM and PM peak periods and for the rest of the day combined. Transit trips are 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.

TRAVEL MODEL CALIBRATION/VALIDATION

Initial validation of the statewide model against aggregate validation targets has been completed as summarized below. The independent data (not used in model development) to perform similar validation for the regional model is not yet available.

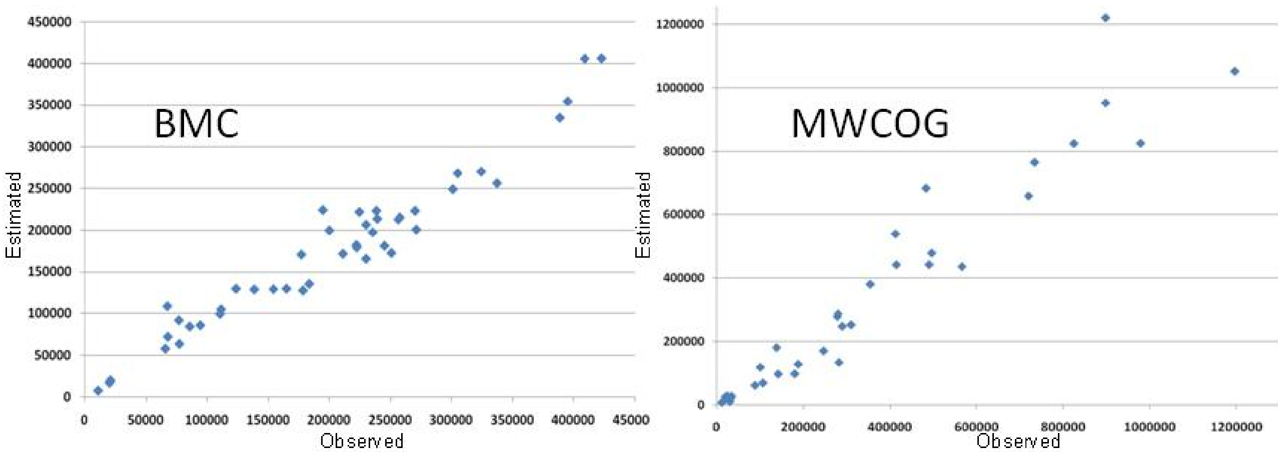
Trip Generation:
- Aggregate trip totals compared to BMC and MWCOG. Trip production rates will be subject to further adjustment as part of the overall model calibration/validation and incorporation of the soon to be completed household travel survey conducted jointly for the Baltimore and Washington regions.

Trip Distribution:
- Trip length (in miles) frequency distributions by trip purpose based on BMC and MWCOG household survey trip records, augmented with MSTM trips distances.
- County to county JTW flows from Census 2000 CTPP, Part 3.
- Total passenger flows across major screen lines and cordons where source data is available.

Mode Choice:
- Average mode shares to the Baltimore and Washington CBDs,
- overall mode shares for the Baltimore and Washington regions and
- average work trip mode shares for other areas derived from Census 2000 JTW data, Parts 1 and 2.

After a 12-month development effort, initial validation indicates surprisingly good results in comparison to screen line counts and other aggregate targets as illustrated in Figure 5.

Figure 6: Estimated versus Observed Screenline Volumes by MPO region (ADT)



CONCLUSIONS

Several successes have been realized in this modeling work to date. The MSTM model design is innovative in its multi-level design, and ability to assemble the model components from existing data and develop a reasonably calibrated sketch-level model for statewide policy analysis in a short period of time.

Clearly, many challenges remain. The bulk of the calibration to date has focused on the Baltimore region. Ongoing calibration will pull together the data from other regions and calibrate other regions of the model for a truly usable model at the statewide level. One difficulty in the calibration process is the fact that part of the travel is generated by the statewide model and the other part by the regional model. Counts do not distinguish local and regional travelers. Special emphasis therefore is put on counts at the external stations of the statewide model to assure that the regional model generates reasonable traffic volumes before the statewide model is fine-tuned.

A major key to develop the MSTM project successfully was the agreement to start with a relatively simple model that gradually improves over time. Instead of being overly focused on finishing one single module to perfection or spending a lot of time in designing the grand scheme upfront, emphasis was put on development of a simpler but comprehensive model at the beginning. This concept called Agile Development in computer science has proven to be very satisfying as early successes were able to proof the model concept. Subsequently, most attention is given to those modules that either performs the least satisfactorily or that are most needed for current policy analysis. Both SHA and the model developers perceived this as an important step to gain credibility and to show progress from early on.

Overall, the MSTM model has demonstrated reasonable validation, consistent with expectations, in the initial calibration and testing. The initial indications are positive, and the expectation is that a version with the few identified enhancements will be available soon to support Agency policy applications.

ACKNOWLEDGEMENTS

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