INCLUSION OF TIME-DEPENDENT NETWORKS IN MARYLAND STATEWIDE TRANSPORTATION MODEL

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EXECUTIVE SUMMARY

This report describes the development steps, results and the lessons learned from the Inclusion of Time-dependent Networks in the Maryland Statewide Transportation Model (MSTM) project. The report covers the following elements:

- Modeling tool selection
- Input data overview
- Generating and Testing Time-Dependent MSTM Model
- Validation
- Scenario testing
- Output visualization
- Conclusions and recommendations

Current static statewide or regional models help planning and decision-making but they lack the level of detail to analyze the temporal aspects of congestion. On the other hand, planning agencies are required/in need of conducting more detailed, project level analyses that require capturing spatial and temporal changes in traffic patterns such as congestion, queue buildup and dissipation. Therefore, for effective planning, representing user response to emerging strategies which require a time dimension such as Travel Demand Management (TDM), congestion management strategies, ITS applications, and emissions modeling, is becoming increasingly important. Dynamic Traffic Assignment (DTA) methodology can provide measures such as time-dependent link volumes, speed, density, queue length, and can track individual vehicles. Modeling the Maryland Statewide Transportation Model (MSTM) in a Dynamic Traffic Assignment (DTA) platform can provide a more realistic analytic capability through the consideration of the time dimension. This will allow the model to analyze the buildup and decline in congestion, shifting of travel times and queueing on the highway network. The applications that a time-dependent modeling approach can be useful at statewide
level include: (i) tracking statewide time-dependent flows, (ii) more accurate representation of congestion, (iii) analyzing impacts of temporal travel restrictions, (iv) impacts of variable tolling, (iv) tracking time-dependent freight flows. For example, the effect of congestion on long distance freight travel can be captured. It may take four to five hours for freight to traverse the State in both peak and off-peak periods. DTA can provide better information on peak spreading and freight routing in anticipation of congestion.

Developing a fully functioning micro- or meso-level statewide or regional model is still a challenge due to extensive data requirements and the expert knowledge such modeling effort requires. Among many difficulties, obtaining and coding signal control data in a regional network is perhaps the most difficult. To the best of authors’ knowledge, application of DTA on a statewide scale has not yet been successfully attempted. This study outlines a method to enable transition from macro-level large scale statewide models to meso- or micro-level subarea or corridor level models with less complexity. It provides greater detail than traditional planning models by utilizing a finer resolution origin-destination (OD) demand data and time-dependent routing information that is obtained from the TRANSIMS Router module. The level of detail obtained from such a multi-resolution approach provides improved input resolution to more detailed micro- or meso-level analysis compared to traditional static models.

The first step in this project was to review available tools for DTA application. For this step a set of functional specifications was developed. Critical elements of the specifications were the ability to track individuals and vehicles, the ability to develop a simplified DTA which did not require detailed network and signal information and the ability to include both highways and transit. Five software packages were reviewed, two proprietary and three open source. The final package selected was Router component of TRANSIMS, primarily due to the maturity of the transit module.

The Maryland Statewide Transportation Model (MSTM) provided the basis for the DTA application. The OD demand data was produced by the MSTM. The network was the same network as used by the MSTM. For validation, the Maryland State Highway Administration (SHA) provided daily and hourly count data and HPMS data. Screenlines were used which had been developed for MSTM validation.
The network was converted from Cube format to TRANSIMS format using TRANSIMS conversion utilities and ArcGIS. TRANSIMS requires that all trips start and end at activity locations and each link normally has multiple activity locations associated with them, representing household or employment locations. Since this is a router-based DTA application with less detail than a simulation-based DTA, all activity locations were placed at centroids. Demand by trip purpose, income and four time periods was taken from the output of the MSTM. Demand was then distributed from four time periods to 96 fifteen minute intervals using a household travel survey.

The MSTM operates at two levels of detail, a statewide level with detailed data including Maryland and immediate surrounding areas and a nationwide level representing the entire United States but with lower levels of network and demand detail. Initial runs were made of the nationwide model to determine the entry and exit points for external trips into the statewide model. Since our focus was on the statewide area and the network detail was lower outside the statewide area, no additional runs of the nationwide model were required. Once external entry and exit points were determined and the trips that use the statewide network are identified, multiple iterations were made of the statewide model. The model used link-based and trip-based relative gap as convergence criteria, comparing link volumes and path costs (typically travel time) on successive iterations. The runs were mostly made on a server with 16 core CPU @2.39GHZ and 12GB of RAM. An iteration took approximately 8.5 hours for the nationwide model and 2 hours for the statewide model. Faster results undoubtedly could have been obtained with improved computational capability. In fact, a 27% improvement was obtained by using a virtual Windows machine with 20 core CPU and 32 GB RAM provided by the National Socio-Environmental Synthesis Center (SESYNC).

Validation primarily focused on comparisons between MSTM and TRANSIMS but also included comparisons to the HPMS and traffic count data. In comparing VMT results, TRANSIMS and the MSTM were very close for Interstates, expressways and major arterials but less close for minor arterials and collectors. This difference may be due to the level of detail in the network or the aggregate characteristics of statewide modeling zones. Also it appeared that while TRANSIMS had higher VMT for lower levels of roads, VHT for TRANSIMS and the MSTM were very close. Screenline and corridor validations were comparable between TRANSIMS and the MSTM with TRANSIMS being slightly lower.
Comparisons were also made between hourly count volumes and hourly estimated volumes. Higher end facilities were very close but the lower end facilities, such as arterials and collectors, tended to be overestimated. Finally, hourly comparisons were made between TRANSIMS assigned volumes and counts on specific links. TRANSIMS generally followed the same pattern as the count data, rising in the morning dropping in mid-day, rising in the evening then dropping off at night. The overall validation was close to the MSTM validation and in addition, the validation favorably compared to the temporal distribution of counts. This type of comparison cannot be done with static models.

Scenario testing consisted of two tests, an incident on one I-95 link closing one lane at 7:30 AM and a work zone which closed one lane on three links for several days. The incident scenario represented short term response to closure and required one additional run of the model, since travelers do not have advance information to adjust routes. The work zone scenario represented long term response, in which travelers do have advance knowledge and can adjust routes, required multiple iterations to account for adjusted responses.

The scenarios behaved as would be expected. The incident scenario lowered volumes on the incident link for about two hours, which reflected the hour length of the incident plus time to clear backups. The work zone scenario lowered travel on the affected links throughout the day. In the work zone scenario speeds and travel times along the length of I-95 between Baltimore and Washington were observed to change. Under the work zone scenario volumes on parallel routes, US 29 and MD 295 were also observed to increase slightly during the time the work zone was in place.

Output visualization plays a crucial role in validating the results, debugging the analyses and presenting the results to users and potential decision makers. Several tools supported visualization including TRANSIMS utilities and ArcGIS. Visualization was conducted at scales ranging from statewide to corridor and link. In some cases animations (3D and 2D) were developed, showing volumes changing at 15 minute intervals throughout the day. In addition the Travel Time Index (TTI) illustrating the ratio of congested travel times to free flow travel times was developed and plotted. Analyses were conducted of congested segments showing speeds and volumes of specific links at 15 minute time intervals. All of
the plots showed increases in volumes and decreases in speed in the AM and PM peaks with moderate effects in mid-day and free flow in the evening.

One of the powerful characteristics of a DTA tool is the ability to show individual vehicle paths between origins and destinations at different times of day depending on the departure times of the vehicles. These plots illustrated that for selected zone pairs the route changed depending on the level of congestion and the time-of-day. Information of this type would be useful to decision makers determining the need for new facilities or considering time-dependent policies such as reversible lanes or carpooling restricted to specific times.

This project clearly demonstrates the benefit of incorporating an analytic DTA into a large scale model. Compared to static assignment, the analytic DTA provides a clearer picture of the location and duration of congestion. The ability to track individual vehicles showed how differing congestion levels affect the temporal aspects of route choice. This powerful tool can help to support decisions related to time-dependent policies such as reversible lanes, carpool lanes restricted to specific times-of-day or variable tolls. While the DTA has major benefits, potential users need to be aware that depending on the model size, model building may be challenging and additional computing power will be required for its use. In addition, technical support from software developers will likely be needed due to ongoing development of these tools and the challenges that may be introduced by the network size.
1 INTRODUCTION

The goal of this project, is to advance statewide transportation modeling practice by demonstrating in a proof of concept improvements offered by using time-dependent, person based analyses in statewide transportation modeling.

The SHA has developed the Maryland Statewide Transportation Model (MSTM), a multi-layer travel demand model representing national, statewide and urban travel. The MSTM forecasts key measures of transportation system performance and provides a very powerful tool for analyzing transportation movements within Maryland and the immediate surrounding areas. The model accounts for nationwide truck movements, interregional external-internal movements and travel within the MSTM study area. The study area includes all of Maryland, Delaware and the District of Columbia, along with adjacent portions of Virginia, Pennsylvania, and West Virginia. The MSTM operates at a very large scale, with more than 167,000 links, 67,000 nodes and over 30,000,000 vehicle trips.

The current model uses the traditional four step approach to modeling; trip generation, trip distribution, mode choice and static highway assignment. Travel is represented in four time periods with multi-class assignment capabilities of person and freight travel in and around the state. The MSTM was developed with technical support from the National Center for Smart Growth Research and Education (NCSGRE) at the University of Maryland in collaboration with Parsons Brinckerhof.

Although, the current MSTM framework assists in planning and decision-making; as is the case with many statewide trip-based travel demand models, these models are static in nature and lack the detail to analyze the spatial and temporal aspects of congestion. Effective planning, representing user response to issues such as peak spreading, freight analysis and congestion requires a time dimension. The applications for which a time-dependent modeling approach can assist the SHA include: (i) tracking statewide time-dependent flows, (ii) more accurate representation of congestion, (iii) analyzing impacts of temporal travel restrictions, (iv) impacts of peak hour tolling, and (v) tracking time-dependent freight flows.

This research provides a linkage between macro- and meso-simulation platforms in that the output from the macro model can be fed into the meso model
to utilize strengths of both models. For example, while travel demand models (macro) are stronger in representing land-use and travel demand patterns, meso-simulation models (DTA) are more responsive to project level improvements or changes. DTA can be applied to investigate impacts of strategies that potentially have long term impacts such as network capacity changes (e.g. long-term work zones, capacity improvements), pricing (which may cause changes in route and departure time choice) and changes in travel demand (whether to travel or not). These types of applications may benefit from the integration of static (macroscopic) and dynamic (mesoscopic) modeling tools to take advantages of the modeling strengths of both models.

1.1 Multi-Resolution Modeling

Models in general, and network models in particular, can be broadly divided into three classes, macroscopic, mesoscopic and microscopic. Macroscopic models typically divide the day into three or four time periods, then use static assignment techniques to analyze traffic conditions in each of these periods. Microscopic techniques have a fine grained level of detail and represent detailed lane change behavior, intersection movements and car following behavior. Mesoscopic models operate between the macroscopic and microscopic, applying macroscopic traffic flow models to individual vehicles, producing more realistic traffic flow measures such as speed and flow, while tracking individual vehicles. Mesoscopic models allow for temporal changes in traffic for a discrete (with small intervals, e.g. 15 minutes) time-of-day representation of traffic conditions without going into the detail of microscopic models.

Mesoscopic models thus provide a bridge between the macroscopic and microscopic; developing an understanding of temporal network conditions without requiring the detailed data and analytic complexity of microscopic network analysis.

Macroscopic, mesoscopic and microscopic models can be nested together, with macroscopic models providing high level origin-destination (OD) demand and network information for input to mesoscopic network models. Mesoscopic models then provide finer resolution time-dependent OD demand and dynamic network conditions, still on a regional basis, and microscopic models, using the output from
mesoscopic models, can provide detailed network conditions on a small area basis. This process is conceptually illustrated in a statewide modeling context in Figure 1-1. The time-dependent OD estimation step from macro level to meso-level is optional; one can use OD demand from macro model as is by just temporally distributing it to smaller time intervals. Again, the boxes lined with red dashed lines can be optional steps; one could directly go from macro-level to micro level modeling as well. The specific needs of an agency, available data and resources would determine whether to follow a full multi-resolution approach or not.
Figure 1-1: Multi-resolution modeling framework

**MACRO LEVEL- REGIONAL/STATEWIDE MODEL**

**INPUT**
- Regional network (Highway and Transit)
- Demand
- HH and Emp. by TAZ

**OUTPUT**
- TD OD Estimation
- Four-Step Planning

**TIME DEPENDENT REGIONAL/STATEWIDE MODEL**

**INPUT**
- Regional network (Highway and Transit)
- Time Dependent OD Tables

**OUTPUT**
- TD Routing Information/DTA
- Time dependent link & path performance measures
- Time Dependent statistics

**MICRO LEVEL-SUBAREA/CORRIDOR MODEL**

**INPUT**
- Subarea network (Highway and Transit)
- Subarea dynamic OD Demand

**OUTPUT**
- Dynamic Micro Simulation
- Time dependent link & path performance measures
- Disaggregate statistics
1.2 **MESOSCOPIC MODELS - DTA**

To provide a better understanding of traffic conditions by time-of-day on a statewide basis, the entire MSTM network must be represented. Since microscopic models are too detailed to represent a network of this size and macroscopic models do not provide time-dependent traffic patterns, mesoscopic models are most appropriate for consideration.

A number of different approaches have been developed to analyze the dynamic movement of vehicles through the network at the mesoscopic level. One of the first major applications of these was the Dynamic Traffic Assignment (DTA) techniques developed by Hani Mahmassani (Mahmassani and Herman, 1984; Mahmassani, 2001). The original term DTA referred to the work by Mahmassani but it has now evolved into a more generic term for models which capture the temporal effects of movement on the network. We will use DTA in that context for the remainder of the report.

DTA models are more advantageous for evaluating scenarios because of their enhanced ability to reproduce traffic congestion and to reflect changes in vehicle routes depending on changing temporal and network conditions (Chiu et al., 2010a). They emphasize the dynamic nature of the network under time-varying demand and try to capture the dynamics of traffic conditions such as congestion buildup and dissipation. Therefore, DTA models can yield useful estimates of state variables such as speed and delay to better understand the functional and environmental impacts of various projects in transportation planning and operations management.

Several DTA approaches have been proposed in the literature based on analytical and simulation techniques. A comprehensive conceptual review of them can be found in Peeta and Ziliaskopoulos (2001). In this study, we focus on DTA models that are based on traffic simulation principles. Simulation-based DTA models use a traffic simulator to replicate the complex traffic flow dynamics, and have emerged because of the inherent mathematical intractability and challenging complexities of analytical methods. A number of these simulation-based approaches have been developed into tools e.g. DynaMIT (Ben-Akiva et al., 2002), DYNASMART (Mahmassani, 2001), DynusT (Chiu et al., 2010b and 2010c),
DTALite (Zhou and Lu, 2013), Dynameq (Tian et. al., 2007), and TransModeler (Caliper, 2009).

1.3 REPORT STRUCTURE

This report describes the development steps, results and the lessons learned from the Inclusion of Time-dependent Networks in the Maryland Statewide Transportation Model (MSTM) project.

The remainder of this report is organized as follows.

- Section 2, Modeling Tool Selection. This section describes the tool selection process (Task 1 of the project) for the time-dependent networks. It includes the identification of the functional requirements (Task 1.a), a description of software packages with the potential to meet the requirements (Task 1.b) and the rational for the selection of the specific tool to be used (Task 1.c).

- Section 3, Input Data Overview. This section introduces the Maryland Statewide transportation Model and describes major inputs to the project, namely network, demand and validation data.

- Section 4, Generating and Testing MSTM-TRANSIMS Model. This section describes the TRANSIMS nationwide and statewide model development processes step-by-step, and presents model run results.

- Section 5, Validation. This section describes validation process and analyzes results.

- Section 6, Scenario Testing. This section introduces two scenarios and presents results.

- Section 7, Output Visualization. This section introduces the tools and methods used in visualizing the outputs of TRANSIMS model. Several visualization examples are presented to demonstrate the visualization methods developed.

- Section 8, Conclusions. This section offers concluding comments and suggestions for future work.
2 MODELING TOOL SELECTION

The first step of the model development was to determine the modeling tool to accomplish the objectives of the project. The following functional requirements were identified for the tool:

- Vehicle based capability
- Capability to run the entire MSTM network
- Subarea analysis capability
- Flexibility to modify software
- Simplified network procedures
- Visualization
- Technical and computational support
- Person based capability (for future use)
- Transit routing and path finding capability (for future use)

For the software review, three open source and two proprietary packages were examined. The open source packages included:

TRANSIMS – Which has both a routing and simulation capability. The routing capability can be used as a stand-alone, low level DTA or can be integrated with the microsimulator. TRANSIMS also has a transit capability more mature than the other open source packages.

DynusT – Which has a fully developed vehicle simulation capability and, when combined with the FAST-TrIPS model has a transit capability.

DTALite – A simplified DTA which can operate with a minimum amount of data and derives transit times from the travel times generated by the network simulation.

The Proprietary packages included:

Cube Avenue – Which has a vehicle simulation capability and can be integrated with other transit models, either static or dynamic.

TransModeler – Which has a full simulation capability and can represent the movement of transit vehicles, including fixed routes and stops, but is not person based.
Software Selection

The proprietary packages generally had better visualization capability and more user-friendly interfaces. However, they were not person-based and their internal workings, such as methods of convergence, were not always available. Note that person-based capability and the transit capability were not required for this project but for considering future extensions, they played a role in our decision.

Of the open source packages, the transit capabilities in DTALite and DynusT were not fully developed at the time this report was prepared. TRANSIMS had the most mature transit capability and the capability had been tested in applications. TRANSIMS also had the advantage of being able to run the Router as a stand-alone, eliminating the need for network detail, a key issue given the 167,000 link size of the MSTM network. Finally, computational and technical support were available from the Transportation Research and Analysis Computing Center (TRACC) at the Argonne National Laboratory and AECOM.

Based on the analysis we recommended TRANSIMS for this project. This recommendation is based on the specific project needs and the software tool capabilities at the start time of this project, and is not a general recommendation for TRANSIMS. Other projects, with different needs, may use other software packages. Please see Appendix A for details for software selection process, which was delivered as an interim report in June 2013.
3 INPUT DATA OVERVIEW (TASK 2)

3.1 OVERVIEW OF TRANSIMS INPUT REQUIREMENTS

To prepare a working TRANSIMS model, several input files must be created or prepared in required format. The data can be derived from a variety of sources. Typically, they are obtained from existing traditional regional travel demand forecasting models and converted to TRANSIMS format. There are typically three main input data categories:

- Network Data (node, link, zone, shape, traffic control data)
- Demand Data (OD demand tables or household activity tables, diurnal trip distributions)
- Validation Data (daily and hourly or more disaggregate traffic counts, screenlines)

Network conversion/preparation typically involves highway and transit networks. Since transit networks are not considered in this project, we will focus on highway network. While there are over twenty network files to define a TRANSIMS network and its characteristics, a subset of these files would be sufficient to obtain a working model, in particular for a statewide model where detailed signal timing is not necessary. A typical highway network preparation starts with converting nodes, links and shape files (optional) from an existing travel demand model. If there are restricted links such as HOV lanes, time-dependent link usage for certain modes (e.g. restricting trucks at peak hours) a lane use file needs to be prepared as well (manually). A number of utilities are available for accomplishing this task in TRANSIMS, such as NetPrep. It is a good practice to make corrections and adjustments in the network before and/or after conversion to reduce potential errors in the model runs. Some studies, such as this project may require a subarea network as well, in such cases, a subarea boundary shape file is also among the input files to be prepared (for details of network preparation, please see TRANSIMS documentation available at https://code.google.com/p/transims).

The demand data is the second major input for a TRANSIMS model. Since this project uses a trip-based approach to input travel demand, our focus will be on trip table conversion. Three major input file groups required for a trip-based TRANSIMS model: trip tables from traditional demand model, diurnal
distributions of trips by time-of-day and activity location files. Activity locations are network components which are either generated by TRANSIMS tools or determined by users to represent beginning and ending points of each trip. They typically represent real world places such as homes, workplaces, schools, hospitals, etc. (TRANSIMS Training Material). A TRANSIMS utility program, ConvertTrips is available to help convert trip tables from the travel demand model format to TRANSIMS format. Before this conversion, other adjustments may be needed to obtain desired level of detail (e.g. trip tables by mode, trip purposes, income levels, time periods) and they need to be done separately. The necessary diurnal distribution files can be created using existing data sources such as household travel surveys. Activity locations file can be obtained using TRANSIMS utilities automatically. However, they may require careful and tedious manual adjustments after being generated automatically, particularly in large and complicated networks. ConvertTrips utility consolidates trip tables, diurnal distribution and activity locations files and generates trip, household and vehicle files that would be input to TRANSIMS Router application (for details, please refer to TRANSIMS documentation at http://code.google.com/p/transims).

Since this study had the objective of adapting existing data into a DTA, centroid connectors were converted to activity locations.

3.2 MSTM OVERVIEW

The MSTM is designed with an integrated multi-layer data structure: (1) national layer consisting of national travel patterns, and (2) intermediate statewide layer representing more detailed travel patterns including local travel. While statewide layer better represents short-distance trips (note that these trips are short compared to national level but they may still be long enough to cross multiple time periods) and mode split using urban transit, the national layer allows modeling long-distance trips that have at least one trip end outside the statewide area. The statewide layer is the main model platform, bringing together detailed knowledge of travel markets from the urban networks and long-distance flows from the national layer.

The MSTM uses a traditional four-step travel forecasting process with the addition of a time-of-day model which divides trips to four time periods, AM Peak, Mid-day (MD), PM peak and night time(NT) (Figure 3-1 illustrates a flow diagram of the MSTM).
Step 1: (Trip Generation) estimating how many trips are made and trip origins and destinations. It is a cross-classified model (by income and number of workers for work trips and by income and household size for other trips) for production and attraction of nineteen types of trips.

Step 2: (Trip Distribution) linking origins to destinations. Linkages are based on generalized travel costs between zones (as travel costs increase the destination zones become less attractive) and the amount and types of activity in the destination zones (as activity increases the zones become more attractive). It is a logit-based destination choice model for distributing trips into trip matrices.

Step 3: (Mode choice) estimating those trips on highway and transit. Mode choice is a nested logit model for splitting trip matrices into eleven travel modes (three automobile modes and eight transit modes). The mode choice model compares the relative attractiveness of the highway and transit modes. Highway attractiveness is based on the travel time and out of pocket costs, gasoline and tolls. Transit attractiveness is based on the fare, number of transfers and time. Time has three components, walk or access time, wait time and in-vehicle time. For short distance truck trips the mode is assumed to be highway (modal choice is not
modeled). Long distance truck trips are estimated using FAF data, which includes both highway and rail movements. Only the highway movements are included.

Step 4: (Time-of-day) is a model for splitting daily travel demand into demand over four daily time periods (AM peak, midday, PM peak, and night).

Step 5: (Assignment) calculating the volume and speeds on links in the highway network. It is based on a user-equilibrium method of assigning trips to the links by minimizing travel time.

On the person travel side, the nationwide model includes a person long-distance travel model for all resident and visitor trips over 50 miles. The trips are combined with Statewide level short distance person trips by study area residents, produced by the four-step model process.

On the freight side, the National model includes a long-distance commodity-flow based freight model of truck trips into/out of and through the study area (External-Internal (EI)/Internal-External (IE)/ External-External (EE) trips). These flows are originally estimated for the entire US and disaggregated to the study area zonal system. These trips are combined with short distance truck trips (Internal-Internal (II) trips) generated at the Statewide level using a trip generation and trip distribution method. The passenger and truck trips from both the Nationwide (long-distance) and Statewide (short-distance) model components provide traffic flows allocated to a time period (AM peak, PM peak or off-peak) and are input to a single Multiclass Assignment.

For more details on the MSTM please see the MSTM Model Documentation Version 1.0 (2013).

### 3.3 MSTM NETWORK DATA

The updated MSTM 2007 Cube model is used for obtaining network data. The original MSTM network, consisted of 68,244 nodes, 167,891 directional links (including centroid connectors and zone centroids), 1588 Statewide Modeling Zones (SMZs), 151 Regional Modeling Zones (RMZs).
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 (MSTM Model Documentation Version 1.0, 2013). Note that MSTM links are coded as uni-directional links for each direction whereas TRANSIMS requires links to be coded as bi-directional links. The directionality issue is addressed when converting to TRANSIMS by developing processes to convert uni-directional links to bi-directional links.

We used highway link attributes of the MSTM in the TRANSIMS model without any changes (see MSTM Model Documentation Version 1.0 for highway complete details of the highway network and link attributes). Various roadway functional classifications are used in the MSTM, 26 in total including highway and rail facilities and associated access roads (see MSTM Model Documentation Version 1.0 for highway complete details of the highway network and link attributes). These functional classes are translated into TRANSIMS functional classes staying true to the MSTM numbering when possible. Note that transit network is not considered in this application, although the capability of representing the transit network was part of the decision to use TRANSIMS (see Appendix A).
Another network attribute used was the area type. Area type was used as a measure of zonal activity. In the MSTM, the households and employment are used to measure activity and area types are classified into nine categories between 9 (high activity area) and 1 (low activity area). The area types are typically used in activity location generation utility of TRANSIMS.

### 3.4 MSTM OD Demand Data

1,588 Statewide Model Zones (SMZs) in the MSTM Statewide level cover all of Maryland and selected counties in adjacent states. 151 Regional Model Zones (RMZs) in the MSTM National model cover the entire US, Canada, and Mexico. These zones are used for the National long distance models only. 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. TRANSIMS models are built using SMZ and RMZs. Demand from these modeling zones are translated into flows assigned to networks.

The Maryland Statewide Transportation Model (MSTM) generates motorized trips only. Walk and bike trips are generated by trip generation, but are not included in trip tables for subsequent modules. The result of the assignment step after six feedback iteration loops are used for preparing demand input for TRANSIMS. These trip tables represent daily trips between all SMZ and all RMZ zones by trip purpose, income category, travel mode and time-of-day.

The MSTM Cube model includes 216 statewide OD trips tables (in .trp format). The large number of tables is due to disaggregating daily OD trip tables into several categories as summarized below:

- Four time periods: AM, MD, PM and NT;
- Six trip purposes: Home-Based-Work (HBW), Home-Based-School (HBSc), Home-Based-Shopping (HBS), Home-Based-Other (HBO), None-Home-Based-Work(NHBW) and Other-Based-Other (OBO),
- HBW, HBO and HBS are further broken down into five income groups each; and
- Three modes: Single Occupancy Vehicle (SOV), High Occupancy Vehicle with two persons (HOV2) and HOV with three persons or more (HOV3+).
In addition to 216 statewide trips, there are 20 Nationwide OD trips tables, grouped into:

- Four peak periods: AM, MD, PM and NT;
- Three truck types: Commercial Vehicle, Medium-Duty Truck and Heavy-Duty Truck; and
- Two Long distance trip types: Long Distance Trucks and Long Distance Personal Trips.

### 3.5 Validation Data

In model validation, model results are compared to independent observed data. If the model results resemble independent observed data, the model is assumed to reasonably represent real-world travel behavior. For this purpose, three classes of data are used: daily traffic count data, hourly traffic count data and screenline data.

#### 3.5.1 Daily Traffic Count Data

There were 4443 directional AADT station volume count data for the year 2007 that were already mapped to MSTM network for validation purpose. The same data has been used for TRANSIMS validation utilizing the existing MSTM validation templates at corridor and screenline levels as well.

#### 3.5.2 Hourly Traffic Count Data

The hourly Automatic Traffic Recorder (ATR) traffic count data (volume) was previously obtained from SHA in a compiled format. The data included 22,858 directional hourly count records for Maryland from year 2000 to 2009. There were 2435 directional count data for the model year 2007. A total of 661 links are identified in MSTM network with hourly count data. As shown in Figure 3-3, the green links are those with 24-hour count data, and the red links are a random selection of a subset of those links for link-based comparison.
The links with count data range from interstate, freeway, expressway, major arterial, minor arterial, collector and others. The proportion of each facility type is as follows (Table 3-1):

**Table 3-1: Proportion of Facility Types in Count Dataset**

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interstate</td>
<td>6.58%</td>
</tr>
<tr>
<td>Freeway</td>
<td>0.54%</td>
</tr>
<tr>
<td>Expressway</td>
<td>0.84%</td>
</tr>
<tr>
<td>Major Arterial</td>
<td>45.72%</td>
</tr>
<tr>
<td>Minor Arterial</td>
<td>30.93%</td>
</tr>
<tr>
<td>Collector</td>
<td>15.06%</td>
</tr>
<tr>
<td>Other</td>
<td>0.33%</td>
</tr>
</tbody>
</table>
The performance of each facility type based on count data is shown in Figures 3-4 and 3-5.

**Figure 3-4: Average Link Volume of each Facility Type**

![Bar chart showing average link volume for different facility types.]

**Figure 3-5: Average Link VMT of each Facility Type**

![Bar chart showing average link VMT for different facility types.]

3.5.3 **Highway Performance Management System (HPMS)**

The HPMS collects data including extent, condition, performance, use and operating characteristics of the highways classified as urban and rural. The facility types include interstate, major arterial, minor arterial, collector, and local/centroid. Urban facilities include expressways as well. While it includes limited data on all public roads, more detailed data is collected for a sample of the arterial and collector facilities. The HPMS provides estimated values and, therefore involves significant uncertainty. The simulated VMT values obtained from the MSTM Cube model and TRANSIMS models are compared to the HPMS data. The MSTM network is a simplified network that only includes major roads, while the HPMS VMT estimate encompasses all roads, including minor residential roads. Differences are therefore expected. Average weekday VMT from HPMS has been used for validation, and it has been summed by facility types before comparison. The total VMT of each facility type in urban and rural areas are shown in Figure 3-6:

![Figure 3-6: Total VMT of each facility type in different area from HPMS](image)

3.5.4 **Screenline Data**

It is common in model evaluation to not only look at single count locations but also at screenlines. Screenlines combine a series of count locations across major corridors, such as across parallel routes between Baltimore and Washington D.C. Screenlines provide an understanding of whether the model replicates major traffic flows between different regions. The same screenline data used in MSTM Cube model is used for validating TRANSIMS model. This data includes 61 screenlines. Figure 3-7 represents all the screenlines in MSTM which is a combination of
screenlines from BMC (Baltimore Metropolitan Council) and MWCODG (Metropolitan Washington Council of Governments) MPO’s and WMDESH (Western Maryland Eastern Shore). Each screenline is an aggregation of several traffic counts. TRANSIMS results are compared against traffic counts for screenline level model validation.

**Figure 3-7: Screenlines in Maryland**
4 GENERATING AND TESTING MSTM-TRANSIMS MODEL (TASK 3)

4.1 TRANSIMS VERSION 6 OVERVIEW

The latest publicly available version of TRANSIMS is version 4.08, released on January 2011. Since then, two recent versions have been developed, versions 5.0 and 6.0, by an AECOM team led by David Roden and have only recently been released on SourceForge. Since TRANSIMS version 6 is used for this project, we will focus our discussion to version 6 (V6 hereafter).

The major changes in the V6 are summarized in Roden (2014) are as follows:

- A generic Matrix interface to process TRANSIMS, TransCAD, and Cube/TPPlus file formats.

- Expanded file format controls to enable input and output of network files in Cube and Arcview formats.

- Designed to work more efficiently with higher number of CPUs and memory (e.g. 64 cores and 64GBs). The idea is to do more processing in memory with many more threads.

- Enables the Router to perform convergence iterations within memory. It can also implement a dynamic user equilibrium process (minimizing vehicle hours of travel) enabling the Router to be applied as a stand-alone dynamic traffic assignment tool without the complexity and data requirements of a traffic simulation.

- An agent-based approach is followed to address issues regarding large parallel computing environments without any change to the coded network.

The TRANSIMS V6 provides many computational advantages and streamlines the application of TRANSIMS by consolidating key functionalities which were previously distributed amongst several programs in version 4.08. However, a GUI platform like TRANSIMS Studio is currently not available to support V6 and therefore is missed.

A TRANSIMS model consists of a series of control (*.ctl) files to conduct model processes, input files (including network files and demand files) and various output files reporting results. It is worth noting that each input/output (I/O) file
will need a companion definition (*.def) file, which specifies variables and format in each I/O file. Without *.def files, I/O files would not be recognized by TRANSIMS utilities. All model files are stored in pre-defined folders under a main model folder. Currently, TRANSIMS V6 utilities are run by DOS-style command line batch (*.bat) files. TRANSIMS utilities are called with command lines with parameters specified in corresponding *.ctl files. A typical *.ctl file is shown in Figure 4-1. Many parameters in a *.ctl file are related with file paths. Thus, model folder setup needs to be done carefully to prevent errors while running .bat or individual .ctl files.

**Figure 4-1: A Typical *.ctl File**

In this project, the Router is applied as a standalone dynamic traffic assignment tool without using the simulation and associated complexities of detailed network data requirements. Figure 4-2 describes three different router applications provided by new V6. The three applications are All-or-nothing Routing/En-route diversion, Dynamic Traffic Routing and Dynamic User Equilibrium. The user can utilize any of these applications individually or a combination of them depending on their needs. Note that the Dynamic User Equilibrium option (grayed out in
Figure 4-2) was under development at the time of this project and therefore, Dynamic Routing and AON routing options are utilized for this project.

**Figure 4.2: TRANSIMS V6 Router Applications**

There are also output post-processing utilities in the TRANSIMS package. Modeling results, primarily the delay files and the plan files can be processed and visualized comprehensively using various post-process utilities. This is a critical feature because usually for larger TRANSIMS models, the modeling output files are several gigabytes in size and therefore very difficult, if not impossible to be viewed using generic text file editors.

4.1.1 Model Structure in TRANSIMS Version 6

It is particularly important to maintain a logical and consistent model file structure for TRANSIMS models. By retaining proper relative file paths, users can utilize many *.ctl files with only minimal revisions between various models. Thus some tedious creation or revision of *.ctl files could be avoided with carefully arranged model structure. In addition, a well-structured directory hierarchy in a TRANSIMS model will help organize input and output files, which tend to easily grow in size and may become difficult to manage.
Figure 4-3 illustrates a sample TRANSIMS model directory structure, where original travel demand model input (0_MSTM Model), software executables (1_Software), network supply (2a_Supply_Conversion), travel demand (2b_Demand_Conversion), assignment (3_Afforniment) and results output (4_Report) are stacked separately in a logical way. As long as this file structure is maintained, system file keys could be written as relative paths in *.ctl files and therefore do not require too much additional modifications during the model development process.

4.2 **NATIONWIDE MSTM-TRANSIMS MODEL**

The Nationwide Model is converted directly from the MSTM Cube model. The conversion process involves supply conversion and demand conversion.
4.2.1 Supply Conversion

Supply conversion, or network conversion, is a relatively straightforward process. It basically takes the link and node ArcGIS shape files (also zone shape files but it is optional), which are exported from the original MSTM Cube model, and converts them into corresponding link, node and zone files. TRANSIMS also creates some default files such as parking locations, pocket lanes, activity locations, process links and if considered, signal and sign warrants with proper TRANSIMS format which are not utilized in this study. Table 4-1 summarizes the total number of records in each supply file in the converted nationwide TRANSIMS model.

Table 4-1: Statistics of Nationwide Model Network

<table>
<thead>
<tr>
<th>Type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Link</td>
<td>84,696</td>
</tr>
<tr>
<td>Node</td>
<td>66,654</td>
</tr>
<tr>
<td>Zone</td>
<td>1,739</td>
</tr>
</tbody>
</table>

Figure 4-4: Coverage of the Nationwide MSTM-TRANSIMS Model
Figure 4-4 shows the geographic coverage of the nationwide MSTM-TRANSIMS model. As seen, the links become sparser as they locate further away from the core statewide area around Maryland (indicated in green color).

One potentially complicated part of supply conversion, particularly for a large model like nationwide MSTM model, is the determination of “activity locations” in the TRANSIMS model. As mentioned earlier (see section 3-1), TRANSIMS is built on an Agent-Based-Model (ABM) framework. Travel demand is loaded onto a TRANSIMS model using records of household/personal activities. Even when an OD trip based demand input is used (see section 3.4 for details), these trip tables are converted to household activities. Table 4-2 shows a few samples of household/personal travel activity record in a trip-based TRANSIMS model.

Many details about a household trip are available in trip activity files, including tour information. The example below is based on trip-based modeling. When activity tables are generated, trips information is derived internally from the given activity pattern. In trip-based modeling, activities and trips belong to individual persons in individual households and arrival times are derived from survey data and estimated by ConvertTrips. Trips start and end at activity locations, in this case, located at zone centroids. This file is created by TRANSIMS by consolidating OD demand input, diurnal trip distributions and zone centroids (in this project, used as activity locations). For example, the first record in Table 4-2 indicates that Household 1, person 1 starts his/her trip at 7:05:29 am and ends at 8:08:44 starting from origin zone 1 to destination zone 2.

| HHOLD | PERSON | TOUR | TRIP | START | END  | ORIGIN | DESTINATION | ...
|-------|--------|------|------|-------|------|--------|-------------|...|
| 1     | 1      | 1    | 1    | 7:05:29 | 8:08:44 | 1      | 2           | ...|
| 2     | 1      | 1    | 1    | 7:23:55 | 9:47:10 | 1      | 21          | ...|
| 3     | 1      | 1    | 1    | 7:24:37 | 7:41:52 | 1      | 32          | ...|

Household trips are loaded into the network through zone centroids that are specified as activity locations. Typically, activity locations are generated by default given selected criteria along the links, in line with driveways along the roadways conceptually. This is a good representation of realities if the modeling scope is microscopic and covers a smaller area. However, for a regional model, it may not be practical to collect and synthesize activity data at such a fine grained...
resolution. Furthermore, even if activity locations are generated along links (as shown in Figure 4-5a, where black dots represent activity locations generated by TRANSIMS) by default rather than at zone centroids (as shown in Figure 4-5b where black dots represent activity locations located at zone centroids) many arbitrary disaggregation of original zone level trip data through placement of locations will have to be involved during demand conversion. In addition, many intra-zonal trips that are not reflected in the MSTM Cube model will be included in the TRANSIMS model, which will make comparison between the two models more difficult. Due to the above reasons, the project team decided to place activity locations at each zone centroid.
Figure 4.5a. Activity Location along Links

Figure 4.5b. Activity Location at Zone Centroid
4.2.2 Demand Conversion

The MSTM Cube model includes 216 statewide OD trip tables. The large number of tables is due to disaggregating daily OD trip tables into several categories, namely four time periods, six trip purposes, five income groups (only for three purposes), three modes. In addition, tables for nationwide long distance truck and person trips and three truck types are also included. For more details about the travel demand input, please refer to Section 3.4.

The travel demand information is stored as matrices in floating number format in Cube. Cube Voyager scripts are written to consolidate these trip tables into three-column, “Origin-Destination-Number of Trips”, format as shown in Table 4-3.

Table 4-3: Converted Trip Tables

<table>
<thead>
<tr>
<th>ORG</th>
<th>DES</th>
<th>TRIPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>2313</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>…</td>
<td>…</td>
<td>…</td>
</tr>
</tbody>
</table>

These converted trip files were then disaggregated based on corresponding diurnal distributions using the ConvertTrip utility in TRANSIMS as trip activity records. The diurnal distributions are prepared from 2007 Household Travel Surveys (2007 HTS), conducted by the Baltimore Metropolitan Council and the Transportation Planning Board at the Metropolitan Washington Council of Governments, covering both the Baltimore and Washington metropolitan regions. The survey data contains records for approximately 14,365 households and 108,110 trips. Due to the nature of household travel surveys, travel times are reported in minutes at the discretion of participants. However, survey participants tend to round their travel times when reporting, thus the original surveyed travel time profiles show a choppy pattern between fifteen minute intervals. Therefore, the diurnal distributions are smoothed using moving-average technique before they are applied to trips between each Origin and Destination pairs. The diurnal distributions (before and after smoothing) for each trip purpose are shown from Figure 4-6a to Figure 4-6f.
Figure 4-6a: Diurnal Distribution of HBW Trips by Departure Time

![HBW Trip (D) Diurnal Profile](image)

Figure 4-6b: Diurnal Distribution of HBSc Trips by Departure Time

![HBSc Trip (D) Diurnal Profile](image)

Figure 4-6c: Diurnal Distribution of HBS Trips by Departure Time

![HBS Trip (D) Diurnal Profile](image)
Figure 4-6d: Diurnal Distribution of HBO Trips by Departure Time

Figure 4-6e: Diurnal Distribution of OBO Trips by Departure Time

Figure 4-6f: Diurnal Distribution of NHBW Trips by Departure Time
Because the trips in the original trip tables, as well as the fraction of trips in each time interval, are floating numbers, the disaggregated numbers of trips during each time interval are also floating numbers. However, the converted activity records must be whole trips. Therefore, some discrepancies in the total number of trips caused by rounding issues are observed. Table 4-4 summarizes the total number of trips in each category before and after the conversion and their differences in percentage.

Table 4-4: Summary of Trip Conversion Results

<table>
<thead>
<tr>
<th>Type</th>
<th>Total Number of Trips in Cube</th>
<th>Total Number of Trips in TRANSIMS</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HBO</td>
<td>5,119,470</td>
<td>5,134,991</td>
<td>0.3%</td>
</tr>
<tr>
<td>HBS</td>
<td>2,999,483</td>
<td>3,005,932</td>
<td>0.2%</td>
</tr>
<tr>
<td>HBW</td>
<td>3,645,271</td>
<td>3,653,149</td>
<td>0.2%</td>
</tr>
<tr>
<td>HBSc</td>
<td>498,186</td>
<td>499,568</td>
<td>0.3%</td>
</tr>
<tr>
<td>NHBW</td>
<td>3,782,176</td>
<td>3,802,487</td>
<td>0.5%</td>
</tr>
<tr>
<td>OBO</td>
<td>5,530,144</td>
<td>5,560,485</td>
<td>0.5%</td>
</tr>
</tbody>
</table>

4.2.3 Preliminary Assignment

If we take trips as the demand and the services that a transportation system could offer as the supply, the assignment process is to find the equilibrium point between supply and demand so that no shifting of demand could cause improvements in level of services. One commonly used measurement of the level of service in a transportation network is the generalized cost, which typically is sum of travel time, out of pocket costs (toll, fare, fuel, etc), and reliability of travel time.

At a network level, the generalized cost on a particular link could be characterized as a function of link flow and some physical link attributes, including geometry, free-flow speed, capacity, access point density, traffic control devices, etc. Usually, the total cost on a link consists of two parts, one represents the average cost that would incur while traveling on a particular link without negative interferences caused by competing road users and the other represents the marginal cost incurred by all road users on the link when a new user is added to it. This type of generalized cost function is also called cost-flow function. One of
the most widely adopted cost-flow functions is the Bureau of Public Roads (BPR) function proposed in 1964 (Ortuzar and Willumsen). The assignment algorithms in both nationwide and statewide MSTM-TRANSIMS models are based on BPR functions.

A BPR function estimates vehicle travel time as a function of free flow speed travel time and volume/capacity ratio in travel demand models. Generally, a BPR function may take the following specification:

\[ T_a = T_0 \left[ 1 + \alpha \left( \frac{V}{C} \right)^\beta \right] \]

Where \( T_a \) is the actual travel time on link \( a \);

\( T_0 \) is the free flow travel time;

\( V \) is assigned traffic volume;

\( C \) is link capacity; and

\( \alpha > 0 \) and \( \beta > 0 \) are parameters.

Given \( \alpha \) and \( \beta \) are both positive parameters, it is intuitive that the actual travel time would be longer than free flow travel time under congested conditions on a particular link.

At the current stage, we adopt all BPR function parameters from the MSTM Cube model without any modifications\(^1\). Table 4-5 lists all BPR function parameters adopted in the nationwide model by facility type. Testing different parameters as well as forms of BPR functions systematically is one of the improvements we plan for future work. In addition, instead of applying same BPR functions across the state and classifying them only by facility type, it will be more realistic to use different BPR functions for facilities in urban, suburban and rural areas. Another classification can be done in different metropolitan areas as well.

\(^1\) The project team conducted sensitivity tests by changing parameters of BPR functions for Freeway and Major Arterial facilities to see the impacts of these parameters on model outputs. Our results did not show significant impact, thus we decided to use exact equations from the MSTM. This also ensured that results are comparable to the MSTM results.
for example, BMC and WASCOG areas may differ. These are also issues to be addressed in the future work.

**Table 4-5: MSTM Cube Model BPR Function Parameters**

<table>
<thead>
<tr>
<th>Link Type</th>
<th>$\alpha$</th>
<th>$\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeway</td>
<td>0.70</td>
<td>8</td>
</tr>
<tr>
<td>Expressway</td>
<td>0.70</td>
<td>8</td>
</tr>
<tr>
<td>Principal</td>
<td>0.55</td>
<td>6</td>
</tr>
<tr>
<td>Major Arterial</td>
<td>0.55</td>
<td>6</td>
</tr>
<tr>
<td>Minor Arterial</td>
<td>0.55</td>
<td>6</td>
</tr>
<tr>
<td>Collector</td>
<td>0.17</td>
<td>4</td>
</tr>
<tr>
<td>Local</td>
<td>0.17</td>
<td>4</td>
</tr>
<tr>
<td>Ramp</td>
<td>0.70</td>
<td>8</td>
</tr>
<tr>
<td>Bridge</td>
<td>0.17</td>
<td>4</td>
</tr>
<tr>
<td>Tunnel</td>
<td>0.17</td>
<td>4</td>
</tr>
</tbody>
</table>

With input converted from MSTM Cube model, we run a nationwide model. We did not seek to achieve convergence in the nationwide model assignment because (a) the entire nationwide model is too big and therefore much more computationally intensive than the statewide model, and (b) the traffic conditions on the external links are not our primary concerns. We used the initial nationwide model run results to determine entry point for trips originated from zones outside of the statewide area. Therefore, achieving convergence is not critical for the nationwide model. Despite this, we still took advantage of a link delay file generated from a twenty-five iteration model run as a warm-start\(^2\) for trip assignment. As a practice protocol, we run the nationwide model for three iterations and then move to the statewide model conversion process.

---

\(^2\) Warm-start is a term used to indicate that a Router run starts with link delay files obtained from a previous model run, thus reflecting congestion impacts compared to a cold-start were model run starts with free flow travel times, where there is no congestion.
4.3 STATEWIDE MODEL

4.3.1 Boundary Setup

As shown in Figure 4-7, the boundary of the statewide model is specified using a polygon shape file in ArcGIS. This is a shape file that is created manually by following statewide model boundaries as close as possible. While doing so, special attention is given to the intersecting links as they provide the main loading points for nationwide model demand to the statewide model. Note that, although the model is named as statewide, the MSTM coverage includes the entire states of Maryland and Delaware, the District of Columbia and portions of southern Pennsylvania, northern Virginia and West Virginia. In Figure 4-7, the shaded area represents the statewide model area and the links contained in the statewide area. The remainder of the figure represents a portion of the nationwide model.

![Figure 4-7: Statewide Model Boundary Shape file](image)

4.3.2 Generating Statewide Model Supply

The supply conversion is realized using a TRANSIMS utility called SubareaNet. This utility takes the nationwide model and cuts it along the
boundary polygon (Figure 4-7). The resulting statewide model network is illustrated in Figure 4-8.

**Figure 4-8: Statewide Model Network**

![Statewide Model Network](image)

**Table 4-6: Statistics of Statewide Model Network**

<table>
<thead>
<tr>
<th>Type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Link</td>
<td>15,049</td>
</tr>
<tr>
<td>Node</td>
<td>21,748</td>
</tr>
<tr>
<td>Zone</td>
<td>1,706</td>
</tr>
</tbody>
</table>

Table 4-6 summarizes the total number of each network component in the converted statewide TRANSIM model. Network outside of the boundary polygon are dropped. Links which sit on the boundary edges are cut in half. As shown in Figure 4-9, new boundary zones are created at the intersections (with a preset offset distance) of truncated links and boundary polygon edges.
4.3.3 Generating Statewide Model Demand

The demand conversion is realized using a TRANSIMS utility called SubareaPlan. This utility takes the assignment result of the nationwide model, the trip plan file, and the converted statewide network files; synthesizes original trip activity records and creates a new trip activity file specifically for the statewide model by selecting trips that utilized links within the statewide network. A total of 24,992,518 trips used the statewide model. Comparing with the total of 50,818,693 trips in the nationwide model, the reduction of trips from nationwide model to statewide model is about 51%.

4.3.4 Dynamic Traffic Assignment

The dynamic user-equilibrium (UE) condition which requires that at equilibrium, the actual travel time or cost experienced by travelers between the same OD pair departing at the same time is equal and minimal (Peeta and Ziliaskopoulous, 2001). A typical DTA process would involve mesoscopic or microscopic simulation of vehicle movements and time-dependent network attributes such as signal control. However, given the large size of a nationwide model, an incremental approach is adopted in the process of converting the static
MSTM Cube model to a time-dependent TRANSIMS model. Note that we deliberately use the term “time-dependent” instead of “dynamic”.

Network assignment in MSTM-TRANSIMS model is done using the V6 Router as a single application wherein successive all-or-nothing least generalized-cost paths are built within each iteration and the link flows (at 15-min increments) are combined between iterations to minimize the vehicle hours of travel. The convergence is defined by user-specified maximum number of iterations and/or link-gap and/or trip-gap. V6 Router retains the paths and link-delay information in memory during iterations towards reduced processing time. The outputs however can be written out at the end of every iteration if so desired. During each iteration, the link travel-times (at 15-min intervals) are updated using the latest combination of link-flows (at 15-min intervals) with the help of volume-delay functions (VDFs). The VDFs used in this application were based on the Bureau of Public Roads (BPR) formulas as applied in the original MSTM model. It may be noted that the link travel times are computed for every 15-minute increment (which is user-configurable) as opposed to a much larger peak-period, this is different from a traditional static traffic assignment model, the link travel times are time-dependent as described above. A DUE condition is established by this Router application because the link travel times essentially converge (link gap reaching a set threshold) which results converged link flows, at the 15-minute increments. However, since this approach involves combining link-flows between iterations, the path-flows, similar to static assignments, are not unique. Hence the final output paths do not represent the (converged) path-flows. For scenario comparisons, all-or-nothing paths are rebuilt using the converged link-flows (converged link delay file) on both the baseline and scenario networks for consistent path-based comparisons.
Figure 4-10: Flowchart of Router-only Assignment

Figure 4-10 shows the process of router-only user equilibrium in TRANSIMS. It is worth noting that the V/C ratios can exceed 1.0 as in traditional BPR functions. According to AECOM (2012), the V/C ratios in fine grained TRANSIMS models are more likely to exceed 1.0 than V/C ratios calculated using peak period or daily volumes. Care needs to be taken in choosing parameters for volume-delay functions. If the travel times become excessive, the Router will have difficulty in completing trips and create scheduling problems for subsequent trips within tours, and move link volumes into much later time periods of the day.

4.3.5 Convergence Criteria

DUE in TRANSIMS is determined by trip-based relative gap and link-based relative gap. According to Chiu et.al (2010), relative gap is a commonly used stopping criterion and an increasingly used convergence criterion for both static and DTA applications.

In TRANSIMS (Volpe Center, 2013), trip-based relative gap is defined as the difference between the trip cost using the most recent trip path and the trip cost using the shortest path:

\[ \text{Trip Gap} = \frac{\sum (CR_x \{C_{mt}\} - CA_x \{C_{mt}\})}{\sum (CR_x \{C_{mt}\})} \]

Where \{C_{mt}\} is the current time varying link costs;

\( CA_x \) is the AON cost of trip \( x \) based on link cost \( \{C_{mt}\} \); and

\( CR_x \) is the reskimmed costs of trip \( x \) along the path used to generate \( \{C_{mt}\} \).

In TRANSIMS\(^5\), link-based relative gap is defined as the difference of vehicle hours between the actual and minimum impedance paths:

\[ \text{Link Gap} = \frac{\sum VE_t \times CE_t - \sum VA_t \times CE_t}{\sum (CR_x \{C_{mt}\}) \sum VA_t \times CE_t} \]

Where \( VE_t \) is the current volume on a given link and time increment;

\( CE_t \) is the travel cost associated with volume \( VE_t \) and
VA is the link volume from an AON assignment based on CE.

Once the relative gaps are less than a pre-set threshold, the DUE solution is assumed to have converged. The stopping thresholds for both link gaps and trip gaps in the statewide model are set at 0.05. Usually they are achievable within twenty-five iterations of model runs.

**Figure 4-11a: Trip Gap Convergence**

Figure 4-11a and 4-11b show the convergence of trip gap and link gap respectively for a twenty-five iteration statewide model run. Since the statewide
model run takes advantage of the nationwide model assignment result as a warm start, both trip gap and link gap tend to drop quickly in the first few iterations. The little jump at the beginning of the link gap line may have been caused by the fact that some of the links are modified during the process of statewide model conversion (e.g. links that intersect with the boundary polygon) and therefore caused some discrepancy of records in the warm start link delay file. However, the link gaps quickly adjust themselves toward convergence.

4.3.6 Computational Performance

Table 4-8: Computational Performance of the TRANSIMS Models

<table>
<thead>
<tr>
<th></th>
<th>Nationwide Model</th>
<th>Statewide Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Vehicles*</td>
<td>27,466,321</td>
<td>24,992,518</td>
</tr>
<tr>
<td>Maximum Iterations</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>Stopping Criteria</td>
<td>Link Gap &lt;= 0.05</td>
<td>Link Gap &lt;= 0.05</td>
</tr>
<tr>
<td></td>
<td>Trip Gap &lt;= 0.05</td>
<td>Trip Gap &lt;= 0.05</td>
</tr>
<tr>
<td>Average Computing Time per Iteration</td>
<td>~8.5 hours</td>
<td>~ 2 hours</td>
</tr>
</tbody>
</table>

* only inter-zonal trips are counted, because intra-zonal trips have not been considered since demand is loaded from activity locations placed at zone centroids.

Table 4-8 summarizes the computational performance of the nationwide and statewide MSTM-TRANSIMS models. The test platform is a moderate server by today’s standard with 16-core CPU @ 2.39 GHZ and 12 GB RAM. We also received computational support from the National Socio-Environmental Synthesis Center (SESYNC). Several test runs on the SESYNC virtual machine with 20-core CPU and 32 GB RAM, show that the average runtime of the statewide model is reduced to about 1.3 hour per iteration. Therefore, it takes less than two calendar days for the statewide model to converge to DUE conditions. Generally speaking, the computational performance could satisfy the needs of planning level analysis.
4.4 SUMMARY

Section 4 documents the process of creating nationwide and statewide TRANSIMS models in detail regarding demand and supply conversions, traffic assignment methodology and computational performance. As mentioned earlier, currently we applied diurnal distributions based on departure times of different trip types from the 2007HTS data. One comment we received from multiple review sessions of the models is that we need to look into applying arrival time based diurnal distributions to certain trip purposes at certain time intervals e.g. HBW trips at AM period, but departure time based diurnal distributions e.g. to work/school related trips for PM period. The rational is that people may be more stringent on arrival time in the morning for work/school related trips in the morning and to departure time in the evening. We attempted to address this issue in our demand conversion process. However, in order to apply diurnal distributions differently for different time periods, the original trip tables need to be further disaggregated not only by trip purposes, but also by time period. This seemed to cause more rounding issues during the demand conversion process and the total converted trip activity records have a relatively large discrepancy (about 5%) with the total number from the original trip tables. Therefore, we chose to stay with the less disaggregated demand input without time-of-day classification and applied departure time-based diurnal distributions only to the 24-hour demand tables for different purposes.
5 VALIDATION (TASK 5)

Model validation is of great importance to advanced transportation analysis tools, especially for DTA models. Rigorous validation must be employed to justify these cutting-edge concepts. The validation work in this project is done against various data sources and at different levels. This preliminary but rather comprehensive validation work indicates that the MSTM-TRANSIMS model generates results comparable to the MSTM, a well validated model, at aggregate levels.

Three datasets were used for validation purpose: daily and hourly traffic volume counts and Highway Performance Management System 2007 (HPMS) estimates of vehicle miles traveled (VMT) (see Chapter 3 for data descriptions). The validation work in this project is conducted in a hierarchical way, from macro- to micro- levels. At network level, VMT and VHT are compared with MSTM results. VMT results are further compared with HPMS data for the State of Maryland only. Due to the reliability of the HPMS data in outside of the Maryland, the comparison is not made for the whole statewide area. Following networkwide level validation, screenline and corridor level results are validated against daily traffic counts at more disaggregate level. Finally, link level results are compared to 24-hour field count data.

5.1 NETWORK-WIDE VALIDATION

5.1.1 The Overall Result Comparison

The network-wide VMT and VHT values for TRANSIMS and MSTM are presented in Table 5-1. The VMT obtained from the TRANSIMS in Maryland is 172.94 million while the results from MSTM is 149.25 million. Compared to HPMS VMT value of 173.51 million, TRANSIMS results give a better approximation with 0.33% difference from HPMS while MSTM with 13.98%. When comparing the VHT between TRANSIMS and MSTM, the VHT is 5.14 million and 5.04 million respectively. It is interesting that there is relatively a big difference in VMT obtained from TRANSIMS and MSTM, while VHT values are fairly close. The reasons that VMT in TRANSIMS is larger than VMT in MSTM while VHT is similar could be that the TRANSIMS finds routes that are longer but takes shorter time to travel. In each time interval, link travel times are updated based on congestion levels and the shortest paths are updated accordingly. The vehicles in
TRANSIMS adjust their routes at each iteration to reduce travel time. So with travel times updated at every 15 min interval, the routes found may be more realistic.

### Table 5-1: Difference of VMT and VHT at Network Level in Maryland

<table>
<thead>
<tr>
<th></th>
<th>VMT (vehicle miles traveled)</th>
<th>VHT (vehicle hours traveled)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRANSIMS</td>
<td>172,944,424</td>
<td>5,137,976</td>
</tr>
<tr>
<td>MSTM</td>
<td>149,251,620</td>
<td>5,045,544</td>
</tr>
<tr>
<td>HPMS</td>
<td>173,511,735</td>
<td></td>
</tr>
</tbody>
</table>

%Diff. from HPMS

| Total | -0.33% | 13.98% |

5.1.2 **Networkwide Results by Facility Types**

The comparison of VMT and VHT between TRANSIMS and MSTM results is illustrated in Figure 5-1 and 5-2. For major facilities like interstate, freeway and expressways, the TRANSIMS and MSTM results are similar. The significant difference occurs in arterial facilities, where TRANSIMS provides higher values than MSTM. The reasons for this could be that 1) the arterial facilities are not adequately represented due to the simplified network characteristics, 2) zone centroids were used as activity locations for each zone and this could load more traffic on arterials and local roads connecting centroids to major facilities. In general, both models provide a similar distribution of VMT and VHT estimation among various facilities.
5.1.3 Networkwide Results by Time-of-day

A day is divided into four periods of time (AM 6:30 am – 9:30 am; MD 9:31 am – 15:30 pm; PM 15:31 pm – 18:30 pm; and NT 18:31 pm – 6:29 am (next day)) in MSTM. Note that while TRANSIMS takes OD trip tables generated from MSTM
assignment step by time-of-day, it consolidates these trips into a continuous 24-hour day using diurnal distributions. Therefore, the number of trips in each time period was not kept constant as it was in the MSTM but TRANSIMS was let to distribute them using trip diurnal distributions by purpose. Figure 5-3 shows how TRANSIMS distributes trips into these time periods compared to MSTM. As seen, trips are distributed fairly closely at each time period with the exception of night time period.

Figure 5-3: Temporal distribution of travel demand

When we look at the distribution of VMT and VHT by time-of-day, the results from TRANSIMS and MSTM are close during the first three time periods but become distinct in NT (Figure 5-4 and 5-5). The reason for this could be that in static MSTM Cube model, the four time periods are independent and trips which cross multiple time periods cannot be represented. However, TRASIMS captures trips that start at one time period and end in the following periods, which is demonstrated in Figure 5-6 and Table 5-2. Figure 5-6 shows the number of trips starting at each time period and ending at each time period in a day in a continuous scale.
Figure 5-4: VMT Comparison among Different Time-of-day

<table>
<thead>
<tr>
<th></th>
<th>AM</th>
<th>MD</th>
<th>PM</th>
<th>NT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRANSIMS</td>
<td>27,116,255</td>
<td>67,198,043</td>
<td>36,608,125</td>
<td>42,022,001</td>
</tr>
<tr>
<td>MSTM</td>
<td>27,063,574</td>
<td>58,321,736</td>
<td>35,289,741</td>
<td>28,576,568</td>
</tr>
</tbody>
</table>

Figure 5-5: VHT Comparison among Different Time-of-day

<table>
<thead>
<tr>
<th></th>
<th>AM</th>
<th>MD</th>
<th>PM</th>
<th>NT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRANSIMS</td>
<td>766,500</td>
<td>2,160,832</td>
<td>1,226,785</td>
<td>1,163,859</td>
</tr>
<tr>
<td>MSTM</td>
<td>917,967</td>
<td>2,061,316</td>
<td>1,342,738</td>
<td>723,524</td>
</tr>
</tbody>
</table>
Table 5-2: Spillover in AM and PM

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Trips Started</th>
<th>Trips Completed</th>
<th>Spillover</th>
<th>% Spillover</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM</td>
<td>3,985,413</td>
<td>3,601,209</td>
<td>676,889</td>
<td>17.0</td>
</tr>
<tr>
<td>PM</td>
<td>5,498,286</td>
<td>5,459,362</td>
<td>859,670</td>
<td>15.6</td>
</tr>
</tbody>
</table>

Table 5-2 depicts the numbers of trips started in AM and PM peak periods, number of trips completed in these periods and trips that continues to the next period (to MD for AM period and NT for PM period trips) because they have not completed within the period. Note that, in static models, including MSTM Cube model, all trips starting in one period are assumed to be completed regardless of the time it takes to travel. Thus, consideration of spillover is a significant benefit of dynamic assignment over static. Table 5-2 shows that 17% trips start in AM period and end in MD; and 15.6% of PM period trips starting in PM period but end in NT. Because of this spillover, the TRANSIMS may be reporting a little lower VHT in AM and PM periods compared to static MSTM Cube model. The results from TRANSIMS are likely more realistic but further evaluation and validation is needed to be conclusive.
5.2 SCREENLINE VALIDATION

A screenline is an imaginary line across a section of freeway or arterials, which is used to determine how much volume is entering or existing a particular area. In Maryland, three sources of screenline data are used: BMC and MWCOG screenlines and screenlines of WMDESH (Western Maryland Eastern Shore) (see Chapter 3 for data description and Figure 3-7 for a map of the screenlines).

The comparison of daily screenline volume between TRANSIMS and count data is shown in Figure 5-7. 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.
The R-square for different coverage level are 0.891 (green, 75%), 0.9042 (yellow, 50%-75%), and 0.9687 (red, <50%) respectively. This indicates that TRANSIMS’s results fit count data on screenline level quite well. The screenline validation results are not compared with MSTM results because there were some changes in screenline data used to validate MSTM and the two results were not comparable.

5.3 CORRIDOR-BASED VALIDATION

Several important corridors in Maryland have been chosen for validation against count data, which includes I-95, I-495 Inner/outer Loop and US-50. Locations of these corridors are shown in Figure 5-8.

Figure 5-8: Corridors for Validation

![Map of Maryland showing corridors for validation](image-url)
Figures 5-9 through 5-12 present the comparison of daily corridor volumes obtained from TRANSIMS with count data for I-95, I-495 inner and outer loop, and US 50 respectively.

Figure 5-9: I-95 Daily Corridor Volume Validation

![Graph showing comparison of daily corridor volumes for I-95.]

Figure 5-10: I-495 Inner Loop Daily Corridor Volume Validation

![Graph showing comparison of daily corridor volumes for I-495 inner loop.]

Figure 5-11: I-495 Outer Loop Daily Corridor Volume Validation

![Graph showing daily corridor volume validation for I-495.]

Figure 5-12: US-50 Daily Corridor Volume Validation

![Graph showing daily corridor volume validation for US-50.]

Table 5-3 presents the statistical results, namely R-squared ($R^2$) and Root-mean-square-error (RMSE) values, obtained for each corridor. $R^2$ is a statistical measure of how close the data are to the fitted regression line. While it is a useful measure, $R^2$ does not necessarily indicate whether a regression model is adequate, so a low $R^2$ does not always mean bad fit and a high $R^2$ does not always mean a very good fit. Other measures, such as residuals will tighten the evaluation of the $R^2$. The RMSE represents the sample standard deviation of the differences between simulated (TRANSIMS) values and observed values (traffic counts). Thus, it serves to aggregate the magnitudes of the errors in predictions into a single measure. The RMSE representing the difference between observed corridor link volumes and
simulated link volumes is calculated as follows, where $v'_a$ is the link volume from TRANSIMS and $v_a$ is the corresponding link volume from traffic counts and $n$ is the number of links in the corridor:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(v'_a - v_a)^2}{|n|}}$$

### Table 5-3: Corridor R-square compared to MSTM validation

<table>
<thead>
<tr>
<th>Corridor</th>
<th>Model</th>
<th>$R^2$</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-95</td>
<td>TRANSIMS</td>
<td>0.71</td>
<td>16,861</td>
</tr>
<tr>
<td></td>
<td>MSTM</td>
<td>0.78</td>
<td>8,729</td>
</tr>
<tr>
<td>I-495 Inner Loop</td>
<td>TRANSIMS</td>
<td>0.51</td>
<td>28,369</td>
</tr>
<tr>
<td></td>
<td>MSTM</td>
<td>0.5</td>
<td>27,311</td>
</tr>
<tr>
<td>I-495 Outer Loop</td>
<td>TRANSIMS</td>
<td>0.64</td>
<td>29,243</td>
</tr>
<tr>
<td></td>
<td>MSTM</td>
<td>0.71</td>
<td>28,340</td>
</tr>
<tr>
<td>US-50</td>
<td>TRANSIMS</td>
<td>0.5</td>
<td>16,908</td>
</tr>
<tr>
<td></td>
<td>MSTM</td>
<td>0.56</td>
<td>15,294</td>
</tr>
</tbody>
</table>

The results presented in table 5-3 suggest that the TRANSIMS provides relatively consistent results with count data and with MSTM Cube model at corridor level, while performance on some corridors are better than others. For example, in I-95 and I-495 Outer Loop, the R-squares of TRANSIMS are 0.71 and 0.64 and RMSEs are 16,861 and 29,243 respectively. While R-squares indicate that TRANSIMS has a good performance in these corridors, the high RMSE indicates that residuals are relatively high. As for US-50, although the performance according to $R^2$ does not look as good, based on the RMSE, it is close to I-95 performance. Note that these results are obtained for the proof-of-concept model without making any adjustments or fine-tuning in the model inputs or parameters. With further testing and fine-tuning, the results can significantly be improved in the future.

### 5.4 LINK-BASED VALIDATION

#### 5.4.1 Comparison against traffic counts

Before going into individual link level, we first looked into all the links with daily count data. All links with AADT count data in the TRANSIMS network are
validated against field count data to test model accuracy, which is also compared with MSTM results.

**Figure 5-13: Comparison between TRANSIMS and Daily Count Data**

![Figure 5-13: Comparison between TRANSIMS and Daily Count Data](image)

**Table 5-4: R-square compared to MSTM validation**

<table>
<thead>
<tr>
<th></th>
<th>TRANSIMS</th>
<th>MSTM</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R^2$</td>
<td>0.83</td>
<td>0.87</td>
</tr>
<tr>
<td>RMSE</td>
<td>11,080</td>
<td>7,212</td>
</tr>
</tbody>
</table>

As shown in Figure 5-13 and Table 5-4, the R-square shows that the results of TRANSIMS is consistent with count data as well as MSTM, with values 0.83 and 0.87 respectively. The lower performance is expected as the TRANSIMS model is a proof-of-concept and not calibrated. 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 11,080 compared to 7,212 for MSTM is obtained. This is reasonable for a proof-of-concept model.

### 5.4.2 Average Link Performance by Facility Type

In order to validate the link performance of each facility type, the average volume and VMT from TRANSIMS and MSTM has been compared with count data. The links with count data has been classified by facility types, including
include interstate, freeway, expressway, major arterial, minor arterial, collector and others, which is consistent with TRANSIMS and MSTM. The results are presented in figures 5-14 through 5-17 as follows.

**Figure 5-14: Average Volume Comparison by Facility Types**

![Bar chart showing average daily vehicle volume comparison by facility type, with columns for Interstate, Freeway, Expressway, Major Arterial, Minor Arterial, Collector, and Other. The bars are color-coded for Count Volume, TRANSIMS Volume, and MSTM Volume.]

**Figure 5-15: Average VMT Comparison by Facility Types**

![Bar chart showing average vehicle miles traveled comparison by facility type, with columns for Interstate, Freeway, Expressway, Major Arterial, Minor Arterial, Collector, and Other. The bars are color-coded for Count VMT, TRANSIMS VMT, and MSTM VMT.]
The order of magnitude in each facility type is shown in Figure 5-16 and 5-17. In terms of difference from counts, interstates, freeways and expressways perform similarly in TRANSIMS and MSTM remaining within 20% range. The difference gets much higher for arterials and local facilities: with TRANSIMS over assigning on these facilities. The reasons could be that the TRANSIMS network is sparser and zone structure is coarser than the actual network where a considerable number of low-level facilities like collector or local roads is not represented in TRANIMS network. As a result, results of high-level facilities like interstates, freeway and expressway are better estimated while those of low-level facilities are overestimated. While the same issue is present in the MSTM, the addition of time variation makes TRANSIMS more sensitive to network representation. The
TRANSIMS model not being calibrated and refined may be another reason for these discrepancies between MSTM Cube model and TRANSIMS models.

5.4.3 **Daily Link Flow by Time-of-day and Facility Type**

The link volume from TRANSIMS and count data has been aggregated by facility types including freeway, expressway, major arterial, minor arterial and local roads. The aggregate daily volume temporal distribution of each facility type are shown in Figures 5-18 through 5-22 as follows.

**Figure 5-18: Temporal Distribution of Freeway 24-hour Volume**

![Temporal Distribution of Freeway 24-hour Volume](image)

**Figure 5-19: Temporal Distribution of Expressway 24-hour Volume**

![Temporal Distribution of Expressway 24-hour Volume](image)
Figure 5-20: Temporal Distribution of Major Arterial 24-hour Volume

Figure 5-21: Temporal Distribution of Minor Arterial 24-hour Volume
For freeways and expressways, the volume temporal distribution of TRANSIMS is in accordance with count data. The volume, start time and duration of peak hour (i.e. AM peak and PM peak) are similar. In major arterial and minor arterials, the start time of peak hour is similar with count data. However, there is a gap between count data and TRANSIMS results, especially during the middle portion of the day. Consistent with networkwide and corridor level results, TRANSIMS model does not perform as well for minor arterials and local roads. This could again be explained by the fact that the MSTM-TRANSIMS (as well as Cube) network is sparser and zone structure is coarser than the actual network where considerable number of low-level facilities like collector or local roads are not represented accurately. As a result, high-level facilities like interstates, freeways and expressways are better estimated while those of low-level facilities are overestimated. However, considering the total volume on minor arterials and local roads is low, this does not have a significant overall impact on analysis.

5.4.4 Validation of Link Volumes by Time-of-day

Several representative links have been selected for the validation of TRANSIMS volumes by time-of-day using hourly traffic volume counts. The links are selected from significant corridors including I-95 S, Capital Beltway–Inner Loop, MD-295 S I-695 S. The performance of TRANSIMS on these links is presented in Figures 5-23 through 5-26 as follows.
Figure 5-23: Volume Temporal Distribution of I-95S (between MD-24 and MD-543)

Figure 5-24: Volume Temporal Distribution of Beltway–Inner Loop (between MD-295 and MD-450)
Figure 5-25: Volume Temporal Distribution of MD-295 S (between MD-32 and MD-198)

Figure 5-26: Volume Temporal Distribution of I-695 S (between US-1 and MD-372)
As seen, most of these links’ volume temporal distribution is consistent with count data. The volume, start time and duration of peak hour is similar with count data as well. However, the TRANSIMS results seem to shift later in time compared to the counts during the AM peak on many links with the exception of I-95 link. This may be due to the fact that the temporal distribution profiles used in this project are constrained only by departure time and trip plans are adjusted accordingly. In general, TRANSIMS results match with 24-hour traffic counts given the proof-of-concept nature of the project.

5.5 SUMMARY

Hourly traffic counts and HPMS 2007 data have been used to validate the model results in four different scales including network wide, screenline, corridor and link. The differences between TRANSIMS and count data are observed, but at acceptable levels given the proof-of-concept nature of this project. The difference of VMT at network-wide level is only 0.33%. Meanwhile, VMT of TRANSIMS in different facility types and by time-of-day is consistent with MSTM. The results from screenline and corridor validations indicate that TRANSIMS can represent the actual traffic conditions nearly as well as MSTM. In link-based validation, links from different parts of Maryland have been selected and the results show that the time distribution of volume is consistent with count data.

However, further model improvements should be done in the future to fine-tune the results. The TRANSIMS assigns higher volume on low-level facility types like minor arterials and locals. When comparing with count data, the results of TRANSIMS are more accurate in interstate, freeway and expressway. However, TRANSIMS overestimates traffic on minor arterial and local roads. On the other hand, the project team thinks that the link-level estimation performance can be improved with fine-tuned diurnal distribution profiles adjusted by arrival time, departure time or mid-trip based on the trip purpose, BPR functions used in the travel time calculations and other relevant model parameters. Thus further sensitivity testing to adjust parameters and fine-tuning the model is recommended.
6 SCENARIO TESTING

6.1 SCENARIO DESCRIPTION

In order to test the model capability in evaluating scenarios that are of importance and relevance to SHA, the project team identified two scenarios in consultation with the SHA staff: incident and work zone scenarios. These scenarios are intended to test short-term and long-term impact analysis capability.

**Scenario 1: Incident**

This scenario tests an incident on I-95 Southbound causing a one lane closure on a single link past exit 39 near Scaggsville Road/MD 216 from 7:31 am to 8:32 am.

**Scenario 2: Work zone**

This scenario designs a work zone at the same location as the incident scenario but covers three consecutive links instead of one, and tests the one lane closure for long term i.e. closed all day for several days.

Figure 6-1 illustrates the location of the scenarios where the yellow highlighted link indicates the incident link and the yellow and blue highlighted links together indicate the work zone links. These scenarios are designed using historical incident and work zone data archives of the Regional Integrated Transportation Information System (RITIS) website (www.RITIS.org).
6.2 Scenario Test Setup

To perform scenario analysis in TRANSIMS, scenario information has to be specified in the lane use file located in the network folder. In this project for instance, information including closed link number, closure time, direction, etc. has to be specified before running the scenario model. Tables 6-1 and 6-2 illustrate how the scenario information is set up in the lane use file for incident and work zone scenarios respectively. Note that these tables only illustrate the relevant link records, not the complete lane use file. Table 6-1, illustrates that one (right most) lane of link 13327 is prohibited to all vehicle types by specifying column “use “ as “ANY” between 7:31 and 8:32 pm. In Table 6-2, in addition to link 13327, one lane from (right most lane) links 13319 and 13325 are also prohibited for all types of vehicles for all day.

**Table 6-1: Incident scenario information**

<table>
<thead>
<tr>
<th>LINK</th>
<th>DIR</th>
<th>LANES</th>
<th>TYPE</th>
<th>USE</th>
<th>MIN TYPE</th>
<th>MAX TYPE</th>
<th>MIN TRAV</th>
<th>MAX TRAV</th>
<th>START</th>
<th>END</th>
<th>LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>13327</td>
<td>0</td>
<td>1</td>
<td>PROHIT</td>
<td>ANY</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7:31</td>
<td>8:32</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 6-2: Work Zone scenario information

<table>
<thead>
<tr>
<th>Link</th>
<th>Dir</th>
<th>Lanes</th>
<th>Type</th>
<th>Use</th>
<th>Min_Type</th>
<th>Max_Type</th>
<th>Min_Trav</th>
<th>Max_Trav</th>
<th>Start End</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>13316</td>
<td>0..1</td>
<td>1..1</td>
<td>PROHIBIT ANY</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0:00</td>
<td>24:00:00</td>
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<td>0..1</td>
<td>1..1</td>
<td>PROHIBIT ANY</td>
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<td>0</td>
<td>0</td>
<td>0:00</td>
<td>24:00:00</td>
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<tr>
<td>13327</td>
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<td>1..1</td>
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<td>0</td>
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</table>

6.3 SCENARIO RUNS

6.3.1 Incident scenario

Incident scenario is used to capture the route changing behaviors within a short time period in response to a disruption. To reflect the immediate reactions of the travelers to a temporary shock, the router is run so that the route changes of the individual vehicles (the same vehicles) can be determined from base case to scenario case. For this purpose, first, a converged router run is taken as “baseline”. An additional iteration is run on this baseline model to reflect the steady state conditions before a disruption occurs and to record vehicle paths. This router run forms the “new baseline” case for the incident scenario, which gives the vehicle paths without an incident. Using the “baseline” case, another router iteration is conducted with incident input (through lane use file, see table 6-1). This way, it is possible to compare paths of same vehicles in “new baseline” case and in incident scenario case. As shown in the Figure 6-2, the blue line reflects the “new baseline” condition, which is one iteration ahead of the original converged simulation results (the “baseline”).

6.3.2 Work zone scenario

Since the work zone scenario is designed to reflect the long-term impacts, it is assumed that the network change specified in lane use file (Table 6-2) has been in effect for a time long enough for users to adjust their behavior and find a new equilibrium given the road closure. Thus, the run starts without using a previous delay file (i.e. as a cold start) and runs until convergence. Note that, due to capacity reduction, running to convergence takes more iterations and longer time in this scenario.
6.4 Scenario Testing Results

The link closure definitely has impacts not only on the closed links but also on the links nearby. This section first looks at how different scenarios directly impact the restricted links and then influence on the whole segment, parallel corridors and even areas.

Figure 6-2 describes how the volume on the closed link (link number 13327) is affected under both incident and work zone scenarios. The grey line represents the volume change under incident scenario. In comparison to the base case, the incident volume drops around 6:30 am and recovers after 10:00 am. This short-term one-lane closure incident only has impacts on a short period of time and is recoverable. Looking at the orange line, however, the 24-hour closure work zone scenario has long-lasting influence, which sees a volume reduction when the volume reaches 6,000 veh/hr.

Figure 6-2: Incident and Work Zone impacts

Figure 6-3 demonstrates the trajectories of all the trips potentially impacted by the incident between 6:00 am to 9:00 am. In other words, these trips pass through the incident link on I-95 between 6:00 and 9:00 am and have potential to be...
impacted by the incident at different levels depending on the time they use the link.

**Figure 6-3: Trips Potentially Impacted by Incident between 6:00 AM – 9:00 AM**

On the work zone scenario side, the project team first examined how the speed changes at the restricted link (# 13327) and how the travel time varies on the whole I-95 segment compared to the base case. In Figure 6-4, the graph on the left hand side shows the I-95 segment selected for the travel time comparison. The comparison result is listed in the upper-right graph. The travel time goes up in this corridor because of the one-lane-closure work zone. In the lower-right graph, the speed on the restricted link is dramatically reduced compared to the normal condition.
Due to the closure in I-95, detours are expected in this area. In Figure 6-5 and 6-6, the scenario impact on the major parallel corridors and parallel links are demonstrated respectively. We can observe a slight increase on the work zone scenario caused by the detours. The volume increase is more noticeable on the parallel link on US 29 as shown in Figure 6-6.
Figure 6-5: Workzone Scenario – Impact on Parallel Corridors

Figure 6-6: Workzone Scenario – Impact on a Parallel Link
6.5 SUMMARY

In this project, both short-term and long-term scenarios are evaluated in TRANSIMS model. The preliminary results suggest that TRANIMS is capable of analyzing different scenarios. However, further scenario testing and results analysis is needed to better understand the behavior of the models. As preliminary results, the project team observed that the models behave in the right direction. Thus, it can be concluded that the TRANSIMS is suitable for policy analysis compared to detailed operational micro- or mesoscopic models providing a cost-effective large-scale policy impact analysis. We recommend further analysis to test the accuracy of the router-based DTA application in handling various scenario analysis, including the ones tested out in this project.
7 OUTPUT VISUALIZATION (TASK 6)

Output visualization is crucial to representing information and understanding different performance measures of the network operations. The importance of visualization has been increasingly recognized by researchers and practitioners to facilitate the information communication between the planner/modeler, users and decision makers. The main purpose of data visualization in this study is to make the information easily explicable, especially to the non-technical audience, by displaying results in a visual context, which will later shed light on problem solving and decision making. This section introduces the tools and methods used in visualizing the outputs of TRANSIMS model. Several visualization examples are presented to demonstrate the visualization methods developed.

7.1 VISUALIZATION TOOLS

The visualization tools used in this project are a combination of TRANSIMS utility programs and spatial analysis software ArcGIS. The TRANSIMS visualizer software TransimsVIS could not be utilized for this project since it was developed to be used in TRANISMS Studio\(^4\) environment. As a result, the process we followed for visualizing TRANSIMS Version 6 results starts with running TRANSIMS utility programs (i.e. relevant control files) to select outputs, export them to shape file formats, and then use ArcGIS for visualizing as a postprocessor.

The TRANSIMS utility programs that are used for visualization in conjunction with ArcGIS are:

LinkSum — for calculating link performance measures (e.g. volumes, speeds, travel times, volume capacity ratio, etc.).

ArcDelay — for converting link performance measures obtained from LinkSum to shape file format and customizing selection criteria (e.g. by facility types and time period).

\(^4\) The TRANSIMS Studio application is described as an integrated development environment for the TRANSIMS which combines a run time environment to execute TRANSIMS and a full featured graphical user interface (GUI) (Source: http://transimsstudio.sourceforge.net/)
ArcPlan— for selecting vehicle trips and generating trip plan files (e.g. vehicle trajectory, travel time information) in shape file format.

Finally shape files are further processed in ArcGIS by adding background, labels and legends. Link performance measures can be drawn using color (2D) or extrusion (3D) to show values and individual vehicle trajectories can be displayed using different colors. The animation graphs in this project are in gif format and edited in gif making software using a series of graphs exported from ArcMap (2D) and ArcScene (3D).

7.2 Visualization Strategy

As discussed above, output visualization helps communicate information effectively and give an overall feeling of different performance measures of the network operations. DTA models in general and TRANSIMS model developed in this project in particular can provide large amount of information that can be processed in different various ways. Therefore, it is critical to visualize results in a systematic way that the audience can have a clear understanding of the network operations and various performance measures while not getting lost in the details.

The output of MSTM-TRANSIMS model is visualized at different scales, namely networkwide, screenline, corridor, segment and link levels. On the macroscale, networkwide performance indicators (e.g. volume and speed) help understand the system performance from a broad perspective. Based on networkwide results, with help of empirical evidence as well, congested segments can be identified and more detailed information (e.g. volume, average speed and travel by time-of-day) can be visualized to better demonstrate how these congested segments perform. Similar performances can be visualized for selected corridors for corridor level analysis. Finally, link level performance measures can be visualized on selected links. Link level performance measures are used typically for scenario analysis. At the micro level, visualization of selected vehicle paths is possible due to vehicle-based assignment method used. Various examples of time-dependent paths are presented to demonstrate the dynamics of transportation system and the time-dependent shortest path, which traditional static assignment models are not capable of.
7.2.1 **Networkwide performance measures**

Different from the conventional static traffic assignment model, the DTA model in this study captures the dynamics of transportation networks with a finer time resolution (15 min intervals in this study). In order to illustrate how measures like volume and speed change by time-of-day, these performance measures are animated on major facilities using both 2D and 3D effects. Figure 7-1 is generated as a 3D animation illustrating the volume change by 15 minute intervals. Only major facilities, interstates and expressways are represented in the animation for effective visualization.

![Figure 7-1: Link Volume by Time-of-day (3D)
8:15 - 8:30](image)

In 3D animation, interstate and expressway volumes are represented at 15-minute interval for the morning rush hours (5:30 – 9:30). Figure 7-1 is a snapshot of the animation at 8:15, which vividly illustrates that I-495 (Capital Beltway), I-95...
and I-695 see heavier traffic in the morning peak. Link volume is also animated using 2D representation at 15-minute interval for 24 hours including interstate, expressway and major arterial links. Figure 7-2a is a snapshot of the link volumes in the network at 7:30 am. Figures 7-2b and 7-2c give detailed view for Washington, DC and Baltimore respectively. The animations give a clear idea of how the network performs during the day and what parts of the network suffer more from congestion.

Figure 7-2a: Link Volume by Time-of-day (2D)
Figure 7-2b: Link Volume by Time-of-day (2D) - Washington, DC

Figure 7-2c: Link Volume by Time-of-day (2D) - Baltimore
Figure 7-3a: Travel Time Index by Time-of-day

Figure 7-3b: Travel Time Index by Time-of-day - Washington, DC
Another performance measure animated for 24 hours is Travel Time Index (TTI). TTI is a concept that has been used in the Maryland State Highway Mobility Report\textsuperscript{5}. It represents the ratio of congested travel time to free flow travel time and is a common measure to quantify congestion. The index describes how much longer the travel times are during congestion compared to free flow travel. The higher the TTI number, the worse the condition is (MD SHA Mobility Report, 2013). As shown in Figure 7-3a, the traffic congestion in northern I-495 and MD-295 is clearly more severe than the rest of the network in the evening rush hours (17:00 – 17:30). Figures 7-3b and 7-3c give detailed view for Washington, DC and Baltimore respectively.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure7-3c.png}
\caption{Travel Time Index by Time-of-day-Baltimore}
\end{figure}

\textsuperscript{5} Available online at http://sha.maryland.gov/OPPEN/2013_Maryland__Mobility.pdf
7.2.2 Congested segment analysis

With the help of networkwide analysis in Section 7.2.1, two congested segments are identified to be further analyzed with more detailed measures: the northern of I-495 and MD-295.

The northern part of I-495 connecting I-270 and I-95 is considered most congested segment in DC metropolitan area. As shown in Figure 7-4, the green line represents the congested segment (I-495 Outer Loop) selected for further analysis. The volume and average speed change by time-of-day on this segment are displayed in figure 7-5 and 7-6. Morning and afternoon peaks are clearly observed in these figures. The volume starts to increase sharply after 6:00 am, indicating the beginning of the morning rush hours. Corresponding to that, the average speed on this segment begins to fall after around 6:00 am. The dissipation of the evening peak can also be witnessed in these figures.

![Figure 7-4: Selected Congested Segment on I-495 Outer Loop](image)
The second selected segment is MD-295 (Baltimore – Washington Parkway), used heavily for commuting between Baltimore and Washington D.C. The morning and evening rush peaks are observed on this segment also. On this segment, we demonstrate a different measure than speed and volume, the average travel time, to provide another example of corridor level visualization. As shown in figure 7-8, in MD-295 North Bound, higher average travel times can be observed in the evening peak than in the morning peak. This commuting pattern indicates that more commuters work in the Washington D.C area and live in the subarea near Baltimore, which is the case in Washington D.C metropolitan area.
7.2.3 Time-Dependent Vehicle Paths

At individual vehicle level, several time-dependent path examples are given to demonstrate the capability of the DTA model in tracking vehicles and representing...
the time varying performance measures such as speed at different segments, which are not feasible to obtain from conventional trip-based static traffic assignment models.

Figure 7-9: Time-Dependent Path across Maryland in the Morning peak
With the help of dynamic traffic assignment model, the time dimension is added to the network analysis, enabling us to understand the temporal evolution of the traffic pattern. TRANSIMS is also a person and vehicle-based model allowing tracking every individual traveler. With the help of this powerful tool, we can have detailed information about the distribution of the traffic in the network by looking at specific traveler’s path.

Figure 7-9 and 7-10 are examples of time-dependent paths in the morning and evening peak. Segments with different colors indicate the vehicle trajectory within 30 minutes. For one specific traveler, we are now capable of analyzing where the traveler was within specific time interval, how long he/she traveled and how fast this traveler was during this time interval. Based on where this traveler was and how fast he/she traveled, we can indirectly infer the congestion level of different facility types at different time of the day.
In this time-dependent network, another feature is the time-dependent shortest path. Based on Dynamic User Equilibrium, for the same OD pair, the experienced travel time must be the same if the departure time is identical. As shown in figure 7-11, for a typical trip from west Washington, D.C. to downtown Baltimore, the traveler chooses different routes when the departure times are not the same, which indicates that the shortest path is changing over time. If the traveler departs in the morning (in purple), the traveler would choose I-95 because I-95 North Bound is less congested at that time. Even though the traveler has to travel a longer distance, the experienced travel time is less. As MD-295 becomes less congested in the afternoon, the travelers will choose to take MD-295 (in green), which is consistent with observations. This graph reflects the dynamics of the system and time-dependent shortest paths, which is an important feature of the DTA models.
Another good example to illustrate the dynamics of the transportation system is shown in figure 7-12. Figure 7-12 illustrates that the vehicles that depart from the same origin region to a destination region, may choose different routes depending on their departure time. In this graph, travelers depart from Gaithersburg, MD area to north of Baltimore. It is observed that vehicles that start their travel in morning peak, when the congestion level is high, chose major roads e.g. vehicle departing at 7:32 am takes US-29 (purple path) and vehicle departing at 9:53 am takes I-495 and I-95 (orange path). At relatively uncongested times, they prefer routes that include arterials e.g. vehicle leaving very early at 5:45 am takes arterials first to reach I-270 and then takes I-695 (green path). We see vehicle leaving at 11:24 am also follows a similar path (pink path).

7.3 SUMMARY

This chapter presented the tools, methods and logic behind output visualization and several examples of visualized results. The main objective of visualizing the outputs is to facilitate the information communication between
The examples in this chapter focus on two objectives: demonstrating the performance measures of the network and pointing out the characteristics of the DTA model that conventional static traffic assignment model is not capable of. Figures 7-1, 7-2 and 7-3 are snapshots of networkwide volume and speed animations, which aim at describing the network operation from a board perspective. Figures 7-4 to 7-8 represent the performance indicators for selected segments so as to better understand how these segments actually perform by showing the changes in volume, speed and travel time by different time-of-day. Figures 7-9 to 7-12 are individual path examples that clearly imply the dynamic characteristic of the transportation system and the ability to track individual traveler, which are beyond the reach of traditional four-step travel demand model. Meanwhile, some important concepts in DTA modeling like dynamic user equilibrium and time-dependent shortest path are also represented in these examples.
8 CONCLUSIONS

This project has successfully demonstrated a proof of concept for the application of dynamic traffic assignment (DTA) methodology to a statewide model. The demonstration contains two major accomplishments; using existing statewide models and data sets to develop the DTA and showing that the DTA can provide greatly improved information on temporal characteristics of travel within the state. The statewide travel patterns can be represented in a continuous day with higher time resolution i.e. 15 min intervals (can be finer as well). In addition, by tracking individual vehicles and travelers, a much better picture of travel characteristics and temporal characteristics emerges. It also demonstrated the scenario analysis capability with higher temporal resolution. As a result of this study the project has also revealed challenges such as computational issues associated with such effort. We summarize these benefits and challenges herein to guide future research and practice.

8.1 BENEFITS

8.1.1 Use of existing Data sets.

The Maryland Statewide Transportation Model (MSTM), formed the basis for this study (see section 3.2 for a short description of the MSTM). The very large MSTM network, along with the MSTM demand data, formed the primary input to the DTA. The study team used this data, combined with survey data from the Baltimore and Washington areas, to construct a temporally distributed trip table for input to network analysis. The network analysis procedures were based on the TRANSIMS Router, which uses the BPR curve to update speeds and vehicle positions throughout the day. In using this methodology, the need for detailed intersection and signalization data was bypassed while still providing a much clearer behavior of the temporal aspects of travel.

The MSTM represents travel across the entire county, with travel outside the State of Maryland and surrounding states represented at a much coarser level. To avoid conflicting levels of resolution, a two stage process was developed. The initial stage applied the Router to the entire Country, identifying entry and exit points to the study area external travel. The second stage ran multiple iterations of the Router in the study area until convergence was reached.
Both trip and link convergence tests were applied and each showed results in appropriate ranges. The model was also validated and the results were comparable to static assignment validations for the MSTM.

These results demonstrate that it is possible, using existing models and data, to construct an analytic DTA on a statewide basis.

8.1.2 Improved understanding of temporal traffic patterns

This project has clearly demonstrated the benefits of incorporating an analytic DTA into a large scale model. This is illustrated in our case study, including a baseline run and a scenario demonstration. There are multiple issues which can be better addressed by the DTA.

Traffic congestion and traffic delay are major problems within Maryland. However, these have different effects at different times of the day. As shown in Figures 7-11 and 12, trips from just outside Washington D.C. to the suburbs of Baltimore use different routes depending on the time-of-day of travel and experience different travel times, again depending on the time-of-day the trip is made. While not specifically tested in this project, policies which deliberately affect the time-of-day of travel can easily be tested with the DTA. These include reversible lanes, HOV lanes and lane restrictions by time-of-day. The DTA approach better reflects the response to these policies and also shows how trip makers will either anticipate the onset of these actions or the time it takes for the network to readjust when these conditions have been removed.

When compared to static assignment, the DTA provides a better picture of the location and duration of congestion. Using the DTA the buildup of congestion in anticipation of the peak hour, and the spillover of traffic from the peak hour to off peak hours can be estimated. This is illustrated in Table 5-2 that 17% of trips originating in the AM peak hour do not arrive at their destinations within the AM peak but spill over into midday travel. Similarly, 15.6% of PM period trips starting in PM period but end in NT. This same effect was observed in spillover from the PM peak to evening travel. In addition, many trips, particularly long distance freight trips, have trip lengths which span multiple time periods. The DTA provides a more accurate picture of how long it takes to complete a trip, during which times of the day the trip occurs and the speeds for different components of the trip. Figure 7-12 illustrates the differing routes and speeds of several trips from
the Gaithersburg area to Baltimore. As can be seen, even slight shifts in departure
time can affect the trip route and the speeds along the route.

8.1.3 Tracking Individual vehicles

In addition to providing better information on the temporal aspects of travel,
the DTA tracks the travel of individual vehicles and trip makers, estimating the
routes and speeds. This provides a more accurate estimate of the impacts of
different actions and conditions. Using this feature, Figure 6.3 shows which trips
are potentially affected by travelers needing to pass through a link with an
cident. This feature can also provide more detailed analysis by illustrating what
happens to different vehicle types, such as trucks or passenger vehicles, and by
identifying which vehicles are associated with drivers of different income groups.
It can also show how trucks would reroute based on lane restrictions,
differentiating truck rerouting from rerouting by other vehicles.

The above capabilities, the better representation of the location and duration of
congestion, the ability to test time-of-day policies such as HOV restrictions, the
ability to examine peak spreading and the ability to track the routes of individual
vehicles combine to provide a much improved picture of travel on a statewide
basis.

8.2 CHALLENGES

8.2.1 Model Building- Level of detail in network and
demand representation

As a multi-tier statewide transportation model with large number of links,
nodes and zones, generating TRANSIMS model for MSTM was challenging. The
network and demand conversion from MSTM Cube model to TRANSIMS platform
required some preliminary work before using TRANSIMS conversion tools e.g.
preparing the bi-directional network link file as TRANSIMS required, and
consolidating OD demand matrices. Generating activity location file before the
project team decided to locate them on zone centroids was also a tedious task that
required manual adjustments. The large size of the MSTM Cube model, even at the
statewide level, made network and demand conversion somewhat cumbersome
which would otherwise be straightforward task. The generated files in general
were very large, e.g. 2-3 GB and therefore, it was not possible to work with them
without processing and selecting a subset of records. The large size of data files
required high storage hard drive processing capacity. For example, a model folder can be ~40 GB in size. The model size also made model debugging rather challenging due to difficulties in processing the large files, visualizing the results and long run times. As discussed in Chapter 7, visualization needed to be done using ArcGIS, outside of TRANSIMS platform, typically after processing output files in TRANSIMS environment.

8.2.2 Run and Processing Times

While this project provided a major improvement in the ability to analyze travel, it also requires greater computing power to run the DTA. Initially we used computers hosted at AECOM to run the nationwide model. Later, we used an in house server with 16 cores and 12GB memory to achieve run times of approximately 2 (8 hours) hours per iteration for statewide (nationwide) model. Later we obtained access to the University of Maryland’s SESYNC computer system, a virtual machine with Windows operating system, 20 cores and 32GB memory. This reduced the run time by approximately 27% and additional memory would further reduce these run times. In addition, more experimentation with methods to incorporate the external areas of the model with the study area also has the potential to improve run time. Finally, computers continue to evolve and despite fears of repeal, Moore’s Law remains in place with computing speeds continually increasing. In the future we can expect continual improvements in computing hardware and software, making for faster and faster DTA run times.

8.3 Recommendations

The results from networkwide, screenline and corridor level validations indicate that TRANSIMS can represent the actual traffic conditions nearly as well as MSTM. However, further model improvements should be done in the future to fine-tune the results. For example, when comparing with count data, the results of TRANSIMS are more accurate in interstate, freeway and expressway while

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Moore's law is the observation that, over the history of computing hardware, the number of transistors on integrated circuits doubles approximately every two years. The capabilities of many digital electronic devices are strongly linked to Moore's law: processing speed, memory capacity, sensors and even the number and size of pixels in digital cameras. All of these are improving at roughly exponential rates as well. This exponential improvement has dramatically enhanced the impact of digital electronics in nearly every segment of the world economy. Moore's law describes a driving force of technological and social change in the late 20th and early 21st centuries.
overestimating minor arterial and local roads. The results can potentially be improved with fine-tuned diurnal distribution profiles adjusted by arrival time, departure time or mid-trip based on the trip purpose, BPR functions used in the travel time calculations and other relevant model parameters. Thus, further sensitivity testing to adjust parameters and fine-tuning the model is recommended.

Thus, this study demonstrated that DTA can be an effective tool in statewide transportation planning. However, we recommend that the potential users beware of the challenges of such and effort. Attention must be paid to identify the type of questions an agency needs to be answered, what type of scenarios they need to conduct and whether a statewide DTA model is a suitable tool to address those questions or not. The size of the planning model determines the computational requirements, thus the agency needs to consider computational resources and technical staff expertise beforehand. It has been our experience that, help is needed from the software developer to address unknown challenges that the large model size introduces both from software and hardware sides.
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