Development of the Maryland Statewide Transportation Model and its Application in Scenario Planning

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Abstract

Maryland has a long history of being a leader in land use planning and was an early adopter of the concept of smart growth for sustainable development. The Maryland Statewide Transportation Model (MSTM) is the first statewide travel demand model developed for the Washington-Baltimore region. Its primary development has occurred through the course of the last three years (2009-2012). A summary of the model structure is presented in this paper. The rationale for the MSTM's development is discussed in the paper followed by a description of the study area and model structure. The novelty of the MSTM is the use of a three-layer structure. The first layer includes macro scale travel patterns from the entire U.S. and the third layer includes travel patterns at a finer urban level detail. The second layer is statewide in scope and is an amalgamation of the first and third layer. The trip-based model consists of eighteen trip purposes that are cross-classified by five income categories, eleven modes of travel, and four time-of-day periods. The model components have been estimated and calibrated using the results of household travel surveys done across the major metropolitan areas in the state during 2006 and 2007. The MSTM has been validated against traffic counts and vehicle miles travel data for the year 2007. Further, the model is used in scenario planning by analyzing the model sensitivity to various policies currently being considered at the statewide level with a 2030 planning horizon. Four scenarios are considered in the sensitivity analysis and each scenario was compared to a reference case. All scenario results provide greater insights to policy decision making. This tool can be used as an instrument for statewide travel demand modeling in Maryland and policy decision making for scenario planning.

1. Introduction

Statewide travel demand and forecasting models address significant planning needs by estimating, for a future date, the number of vehicles that use major transportation facilities in a state. Statewide models can forecast both passenger and freight flows, and include a variety of modes including highways, urban transit systems, intercity passenger services, airports, seaports, and railroads. The earliest experiments in statewide travel forecasting began in the 1970s and adopted methods that had been developed specifically for urban travel forecasting; however, early statewide modeling efforts had limited capability to reflect realistic land use development and travel patterns because of difficulties in adequately covering large geographic areas in sufficient detail. In the past 10 years statewide transportation planners have seen dramatic improvements in socioeconomic and network databases, tools for accessing these databases, and exponential growth in computational power (NCHRP, 1998).

Few examples of statewide travel demand models are from Ohio (ODOTa, 2010), Oregon (ODOTb, 2010), Michigan (MDOT, 1999), California (Caltrans, 2010) and Kentucky (KTC, 1997). These models have undergone a considerable amount of refinement over the years and share many similarities. Ohio and Oregon, in particular, have exhaustively documented each step in the model and each assumption made, so it is possible to use these models as an indicator of the "state of the practice." Other states with existing models include Arizona (Erhardt, 2012), Connecticut (ConnDOT, 1997), California (Caltrans, 2010), Florida (FDOT, 2008), Vermont (VAT, 2010), and others. To date, a total of 30 states throughout the U.S. are actively using statewide transportation models. A number of other states have models that are in various stages of development (NCHRP, 2006).

The need for development of the Maryland Statewide Transportation Model (MSTM) is many-fold. The two major Metropolitan Planning Organizations (MPOs) in the region are the

Baltimore Metropolitan Council (BMC) and Metropolitan Washington Council of Governments (MWCOG), which currently have transportation models for planning purposes. Figure 1(a) shows the extent of the BMC and MWCOG areas.

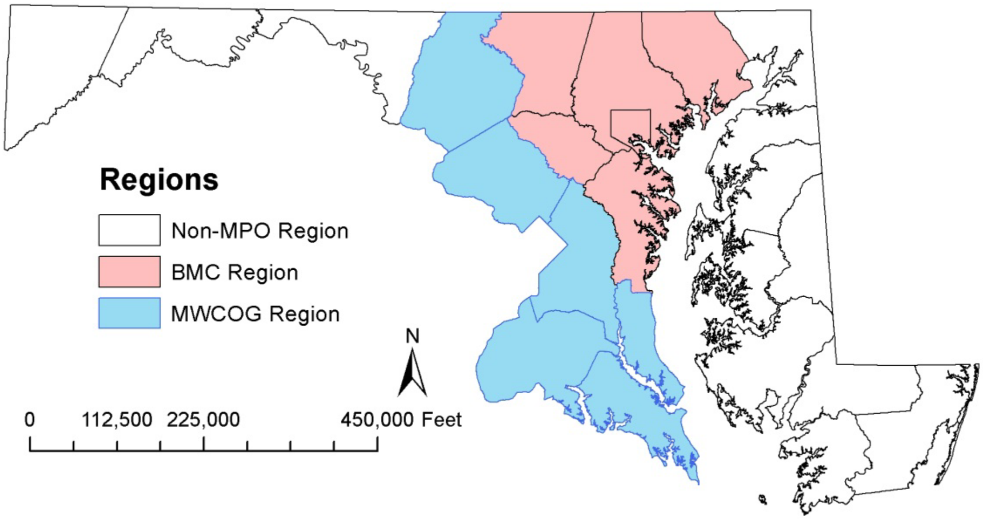

FIGURE 1(a) Topological Map Maryland

The travel demand models of BMC and MWCOG are well suited for their respective jurisdictions. However, there are issues that must be addressed in the context of a multi-state region. These include: (1) the interaction of travel at the boundary between the two MPOs, (2) modeling of transportation in regions outside the MPO boundaries such as Western Maryland or the Eastern Shore of the Chesapeake Bay, (3) estimating the impact of travel which passes through the multi-state area, particularly freight travel with heavy trucks that are often a large share of traffic on rural interstate highways, (4) on major functional highway classes out-of-state traffic contributes a large share of vehicle miles traveled (5) long distance travel is more significant in statewide travel and may have very different travel characteristics than urban area trips. For these reasons, a number of states have developed statewide models that are heavily used to aid transportation planning and travel demand decision-making (Giaimo and Schiffer 2005, NCHRP 2006, Parsons Brinckerhoff 2010, Donnelley et al. 2010, Erhardt 2012). Figure 1(b) shows the full study area of the MSTM, including the state of Maryland and selected counties of surrounding states, including Washington D.C. These issues can be partially addressed by MPO models (or in some cases to a limited degree). To fully address the issues it requires a broader view, such as one supported by multi-state analytic procedures.

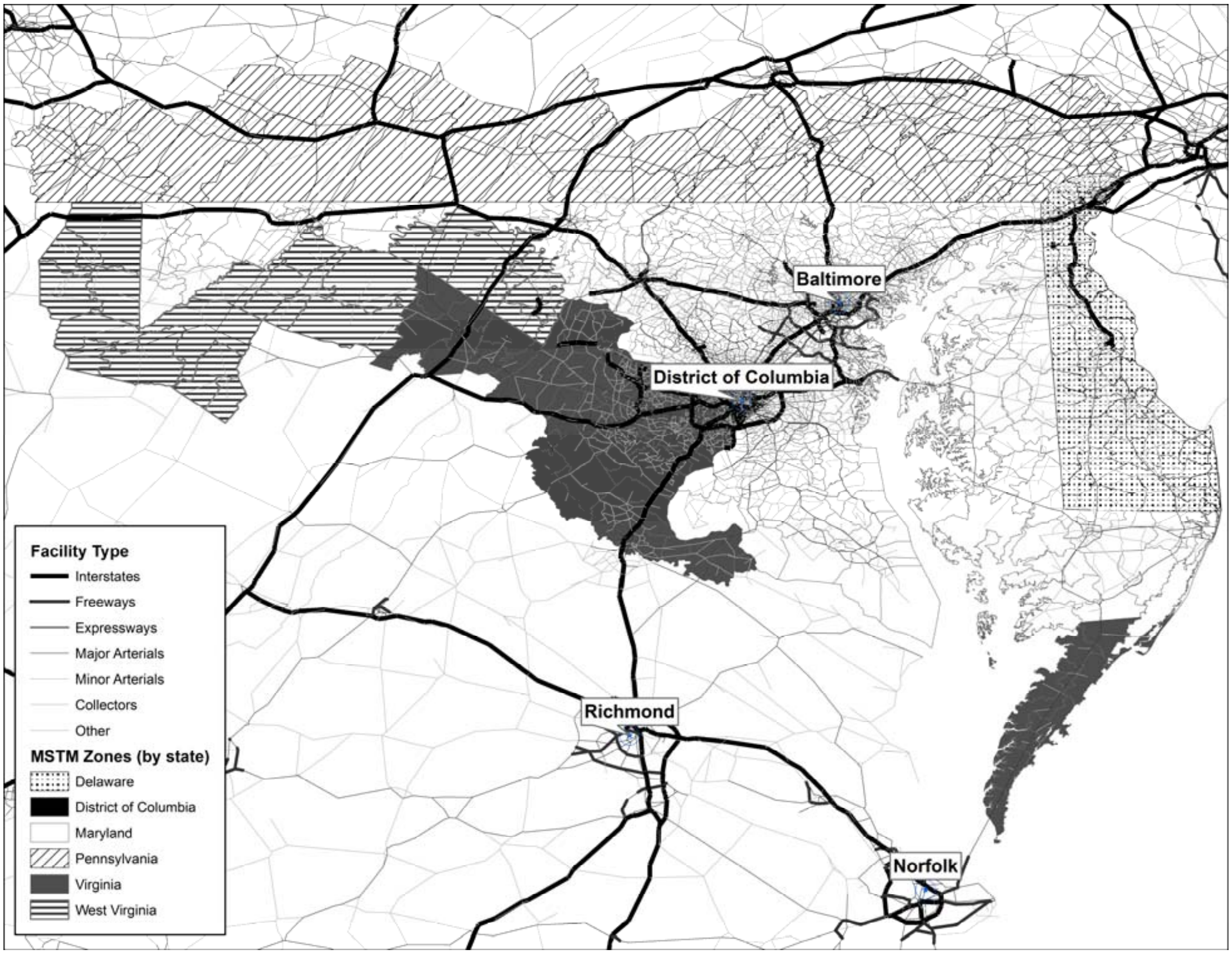

FIGURE 1(b) Topological Map Showing Zone System and Network of the Study Area

2. Importance of Scenario Planning

The term scenario is quite commonly used across a range of planning disciplines, from business-strategic planning to urban-transportation planning. In this paper we define scenario planning as it relates to land use transportation applications. For instance, in travel-demand forecasting, it is common to develop scenarios of land uses that have a certain probability of developing in the future. Various scenarios of economic growth, or fuel efficiency improvements, or price changes are often used to develop ranges of future possibilities, i.e., the high-growth scenario and the low-efficiency scenarios (Zegras et al. 2004). FHWA scenario planning guidelines suggests that transportation planning requires a comprehensive and holistic approach to guide the future of a state or region (FHWA 2012). Considering future uncertainties, scenario planning enhances this regional planning process by realistically evaluating a wider variety of potential futures to determine the performance measure outcomes. Table 1 shows a schematic of scenario planning exercises. Five land use and transportation scenarios are presented in Table 1. Each cell in the matrix represents an integrated land use transportation scenario. The number of cells in the matrix will increase if a larger number of scenarios are considered.

TABLE 1 Scenario Planning Matrix

Transportation Scenario / Land Use Scenario	Baseline (CLRP)	Increased Gas Price	Increased Transit Ridership	Toll Lanes	Increased Demand
Baseline (CLRP)	√	√	√	√	√
High Energy Price (HEP)	√	√	√	√	√
Transit Friendly Development (TFD)	√	√	√	√	√
Market Driven Change (MDC)	√	√	√	√	√
Build Out Growth (BO)	√	√	√	√	√

From Maryland's perspective, scenario planning is essential, as the state receives a significant amount of growth both in terms of land use and transportation. A number of external factors are uncertain as well. For example, the Maryland Department of Planning (MDP) in the state released a policy establishing a new zoning system called Priority Funding Areas (PFAs) to receive significant growth in near future. In another instance, the Maryland Transportation Authority (MDTA) increased the toll rates on Interstate 95 three-fold, which may have caused a rethinking of household and employment locations of many travelers. There are a number of examples of a similar nature. Scenario planning can assist state and local governments to better plan in conjunction with future external forces such as effects from changes in the global and national economy, fuel price fluctuations, housing regulations, or uncertainty in land use and transportation policies. In addition, scenario planning is expected to provide a guiding vision as well as set goals and priorities of the state and local agencies. In the current economy there is a need to optimize outcomes with a limited availability of resources. This optimization is focused on system efficiency (e.g. matching projects with needs), performance measurement and establishing linkages with the broader economy. All of this is generally possible with the aid of scenario planning.

3. Overview of MSTM

The MSTM is designed with a three-layer model structure. The schematic of this structure is presented in Figure 2. The first layer represents the regional layer, which consists of national travel patterns. The second layer is an interim layer, considered the statewide layer. The third layer is the urban layer representing more detailed travel patterns including local travel. The regional or the urban models alone would not be suitable for statewide modeling. By integrating three different layers, different travel markets can be represented at the appropriate scale. While urban models are strong in representing short-distance trips and mode split using urban transit, the regional layer allows modeling long-distance trips that have at least one trip end outside the state of interest. The statewide layer is at the center of the model, bringing together detailed knowledge of travel markets from the urban layer and long-distance flows for the regional layer.

This core layer models land-use changes as well as all trips that have both trip ends within the study area of the statewide model.

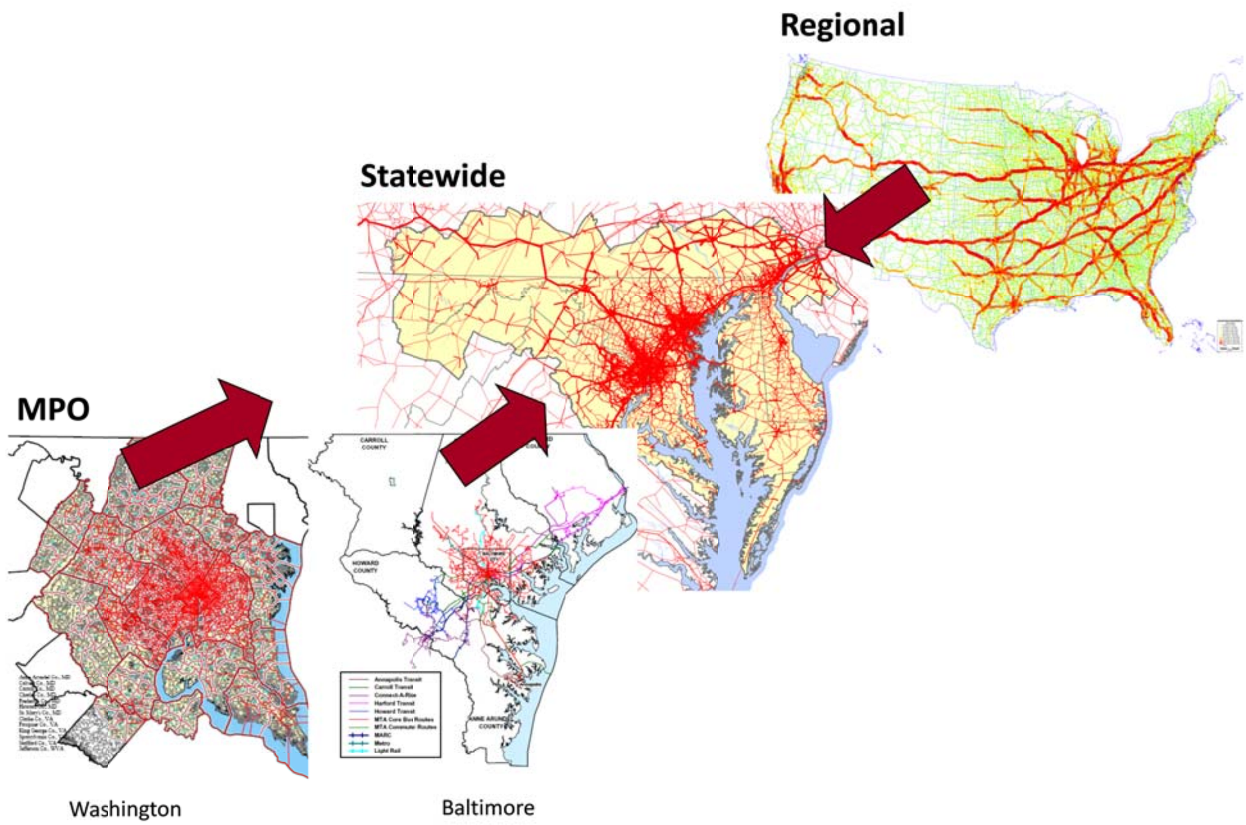

FIGURE 2 Three-Layer Model Structure

Figure 3 summarizes the MSTM model components within the Statewide and Regional levels. Economic and Land Use assumptions drive the model. On the person travel side, the Regional model includes a person long-distance travel model for all long-distance trips of 50 miles or more, including through (external to external) trips with neither trip end within Maryland. These trips are combined with statewide level short-distance person trips classified by study area residents, produced by using trip generation, trip distribution, and mode choice components. On the freight side, the Regional model includes a long-distance commodity-flow based freight model of truck trips that are 50 miles or longer. These flows, which are based on the FHWA's Freight Analysis Framework Version 3 (FAF3) data, was originally estimated for the entire US and further disaggregated to the study area zone system. These trips are combined with short distance truck trips (internal to internal trips) generated at the statewide level using a trip generation and trip distribution method, also called the Quick Response Freight Manual (QRFM) method. The passenger and truck trips from both the regional (long-distance) and statewide (short-distance) model components provide traffic flows that area allocated to four time periods (AM peak, PM peak, mid-day off-peak and night off-peak) and serve as input to a single multi-class assignment.

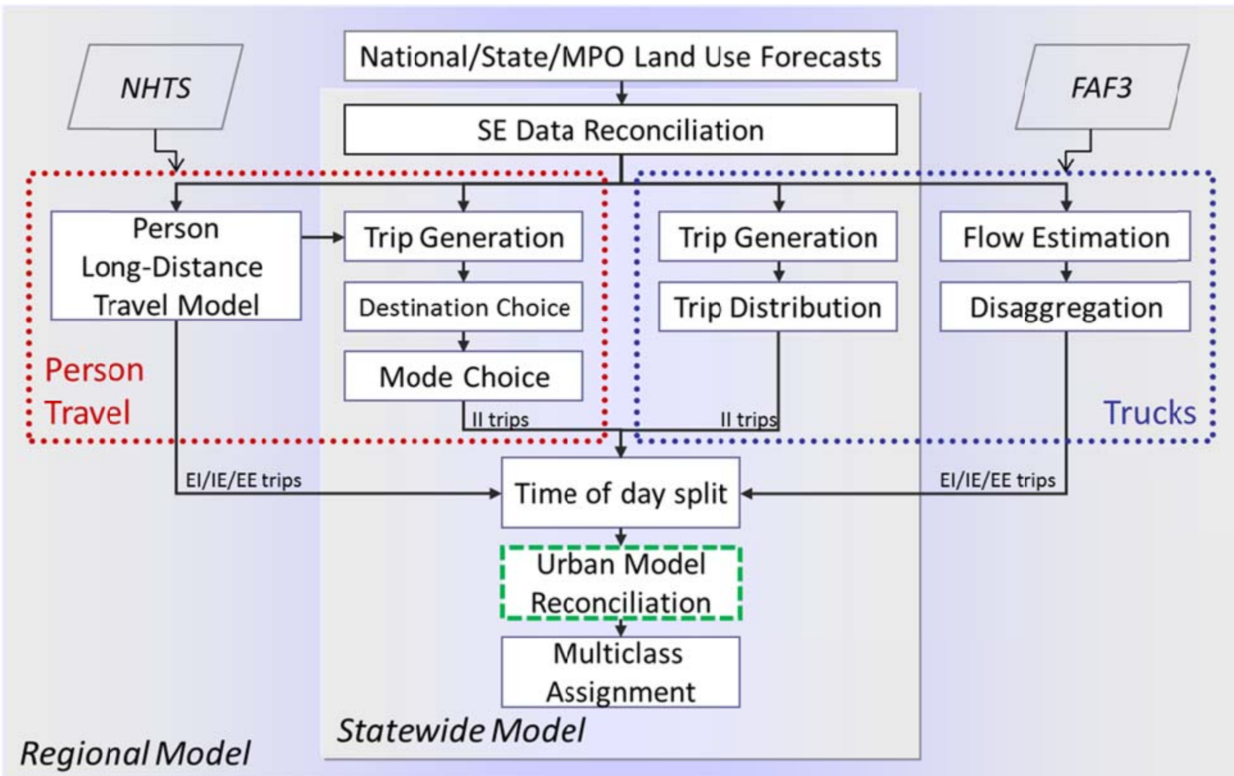

FIGURE 3 Overview of MSTM-Phase III

4. Data

Data for the MSTM is collected from a number of national, state, and local agencies. The socioeconomic data for the MPO regions in the Maryland and Washington region are collected from the cooperative forecast data from BMC and MWCOG. The non-MPO region socioeconomic data in Maryland are collected from the census, Census Transportation Planning Package (CTPP), and Quarterly Census Employment and Wages (QCEW[1]). The land use for outside the Maryland/Washington region is collected from a number of sources including the Departments of Transportation in Virginia, Pennsylvania, and Delaware. The socioeconomic data is classified by households and further classified by the number of workers, household size, and household income. Five income categories are considered (i.e. less than 20,000; 20,000-40,000, 40,000-60,000, 60,000-100,000, and more than 100,000). Four types of employment are considered including retail, office, industrial, and other. The base year (2007) socio-economic (SE) data is collected from the aforementioned agencies. The horizon year (2030) SE data is obtained by the three-stage land use model approach. The transportation network is built on a regional scale after combining portions of the networks received from various agencies. In addition to socio-economic data, the following crucial datasets are used for model development, calibration and validation.

[1] QCEW data is collected in quarterly basis from the Department of Labor and Licensing Regulations (DLLR) in the state of Maryland.

- Household Travel Survey (HTS) data collected in the year 2007-2008 in Baltimore and Washington region by two MPOs: BMC and MWCOG. HTS was used to develop trip rates, calibrate trip length, origin destination flows, mode choice, and time of day travel.
- National Household Travel Survey (NHTS) data for year 2002 and 2009 for long distance travel. It is stripped of detailed location information, making it limited for spatial analysis, but it provides a high-level picture of long distance travel in the U.S.
- Bureau of Transportation Statistics (BTS) air travel data from 1993 to 2010 for long distance travel estimation.
- Freight Analysis Framework, Version 3 (FAF3) data: The FAF3 data are published by FHWA and include commodity flows by mode and commodity between 130 zones. Maryland consists of three zones: Baltimore, Washington, and rest of Maryland.
- Maryland State Highway Administration (MSHA) traffic count data: SHA provided available traffic counts throughout the state, approximately about 5,000 locations. These locations include interstates, freeways, expressways, major and minor arterial.
- Highway Performance Monitoring System (HPMS) 2007 data for Vehicle Miles of Travel (VMT) validation.

The base year network consists of more than 167,000 links, and contains sixteen functional classifications including all highway, transit, walk access, and transfer links. For external travel all the freeways are included outside the modeling region. The toll roads and Highway Occupancy Vehicle (HOV) lanes are coded in the network with the current user charges. The network also contains all transit facilities in the region including metro rail, light rail transit (LRT), bus, and commuter rail (both MARC and AMTRAK). Proper linkages have been established between highway and transit in the form of park-and-ride, access, and transfer links.

5. Model Performance

The critical aspect of any transportation demand model is its ability to accurately replicate existing travel patterns and conditions. An evaluation of model performance in this regard is presented for MSTM in the following sections. In the first section traffic volumes for all facilities are presented with additional details on different functional classes. Figure 3(a) shows the traffic plot data between estimated volume and observed volume for all facility types in the highway network. The r-square value shows the degree of fitness. It can be observed from plots of other similar and well-known models, that the MSTM reasonably matches the count data.

Figure 3(b) shows the same simulated to observed volume plot for freeways, interstates and expressways. The shaded area surrounding the central trend-line marks an upper and lower bound for a 20% deviation from the observed link volume. Most of the simulated volumes fall within the 20% bound, with an r-square of 0.907 indicating a close relationship between the observed and modeled volumes. Figures 3(c) and 3(d) are similar to the previous figure, but provide volumes for lower volume facilities including major and minor facility types. In both cases the r-square shows that the simulated volume reasonably matches the observed count data, without any major outliers. As is common for travel demand models, higher-volume facilities tend to match observed traffic volumes better than lower capacity facilities. The lower capacity facilities often deviate from count volumes, as the simplified network and zone system tends to funnel traffic on selected paths.

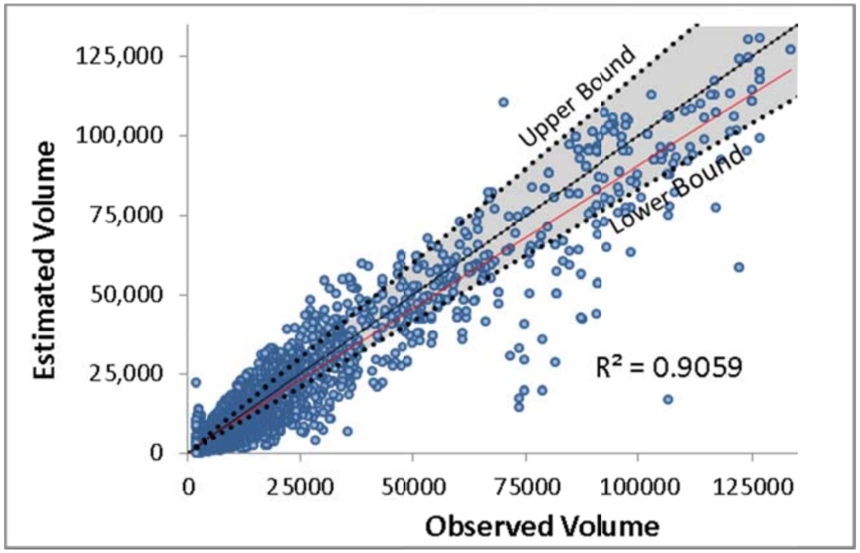

Figure 3(a) For all locations

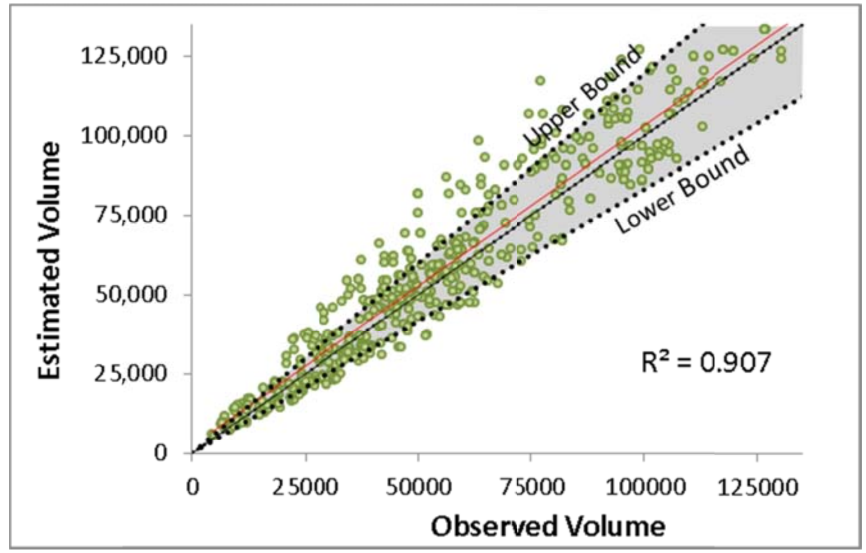

Figure 3(b) For Freeways, Interstates, and Expressways

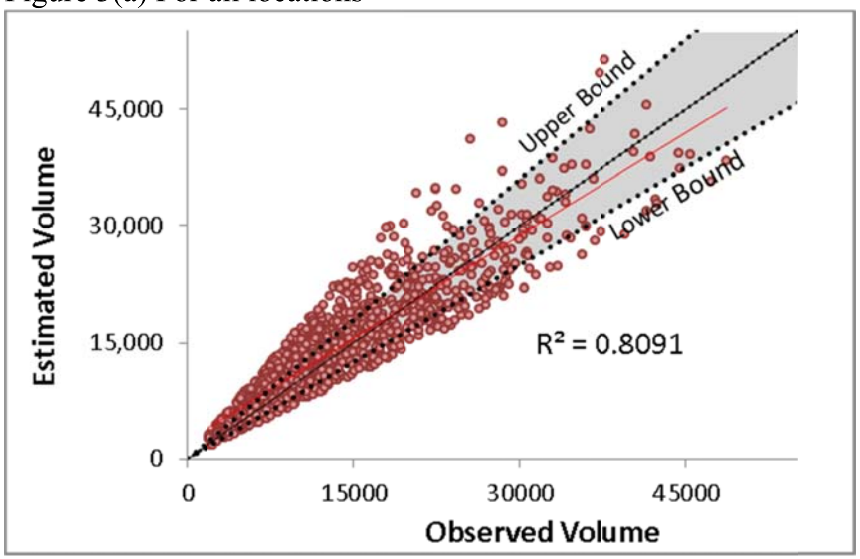

Figure 3(c) For Major Arterials

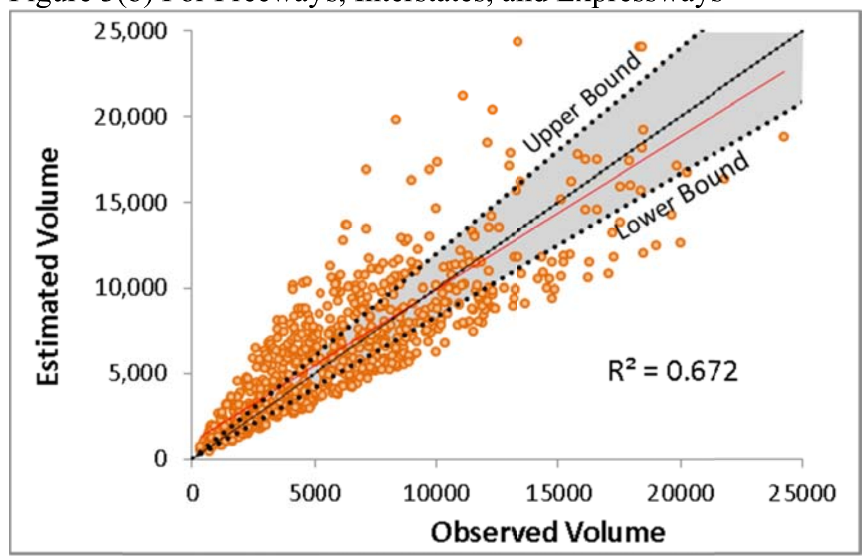

Figure 3(d) For Minor Arterials

The VMT validation results are shown in Table 2. Estimated and observed VMT for six facility types are shown. Observed VMT is collected from the Maryland HPMS data. Estimated results are from the MSTM. For interstates estimated VMT is 42.02 million, and corresponding observed VMT is 43.25 million. The percent difference is 2.84%. The FHWA reasonableness check manual suggests that a deviation of three percent is acceptable (Cambridge Systematics 2010). In terms of VMT percentage, interstates carry about 29 percent of the VMT from the model, and the corresponding observed VMT is 30 percent. Similar results are presented for other facility types. The error difference is smaller for facilities carrying higher volume and vice versa. Overall deviation for all facilities is 1.97 percent.

Table 2: VMT Results by Functional Class

Facility Type	VMT (million)		Error		Distribution	
	Estimated	Observed	Difference	Percent	Estimated	Observed
Interstates	42.02	43.25	-1.23	-2.84%	29%	30%
Freeways	11.95	12.38	-0.43	-3.48%	8%	9%
Major Arterials	36.76	38..47	-1.89	-4.86%	26%	27%
Minor Arterials	22.24	23.18	-0.94	-4.03%	16%	16%
Collectors	11.99	11.42	0.53	4.95%	8%	8%
Other	17.83	16.79	1.04	6.18%	12%	12%
Total	142.79	145.66	-2.86	-1.97%	100%	100%

Other statewide models are studied to compare the performance of MSTM. Figure 4 shows a percent RMSE comparison to the mid-point volume range. The reasonableness check manual is used to obtain the data for other states such as Ohio, Oregon, and Florida. The FHWA compiled Task 91 report is used for other states. Figure 4 shows that the performance of the MSTM is reasonable. As expected the RMSE is higher for lower volume classes and smaller for higher volume classes. While there is room for further improvement, the MSTM performs well compared to the performance of other statewide models. A number of other validation strategies were adapted but not reported in the paper for brevity but can found in the User's Guide (MSTM 2011).

6. Scenario Planning Results

In the scenario planning exercise, we analyzed four transportation scenarios using a forecasted 2030 base model. The 2030 base model was developed with consideration towards each locality's constrained long-range plan (CLRP). The CLRPs were developed in conformity with federal requirements that funding sources be identified for all strategies and projects included in long range plans. The plans are updated at least every five years (every three years in air quality attainment areas) and include only those projects and strategies that can be implemented over the planning period with funds that are "reasonably expected to be available" (Kramer, 2005). Each of these plans was incorporated into the 2030 CLRP model and used to develop the 2030 transportation network. Several models were developed to test various alternative growth scenarios in the study area, each of these scenarios is explained below.

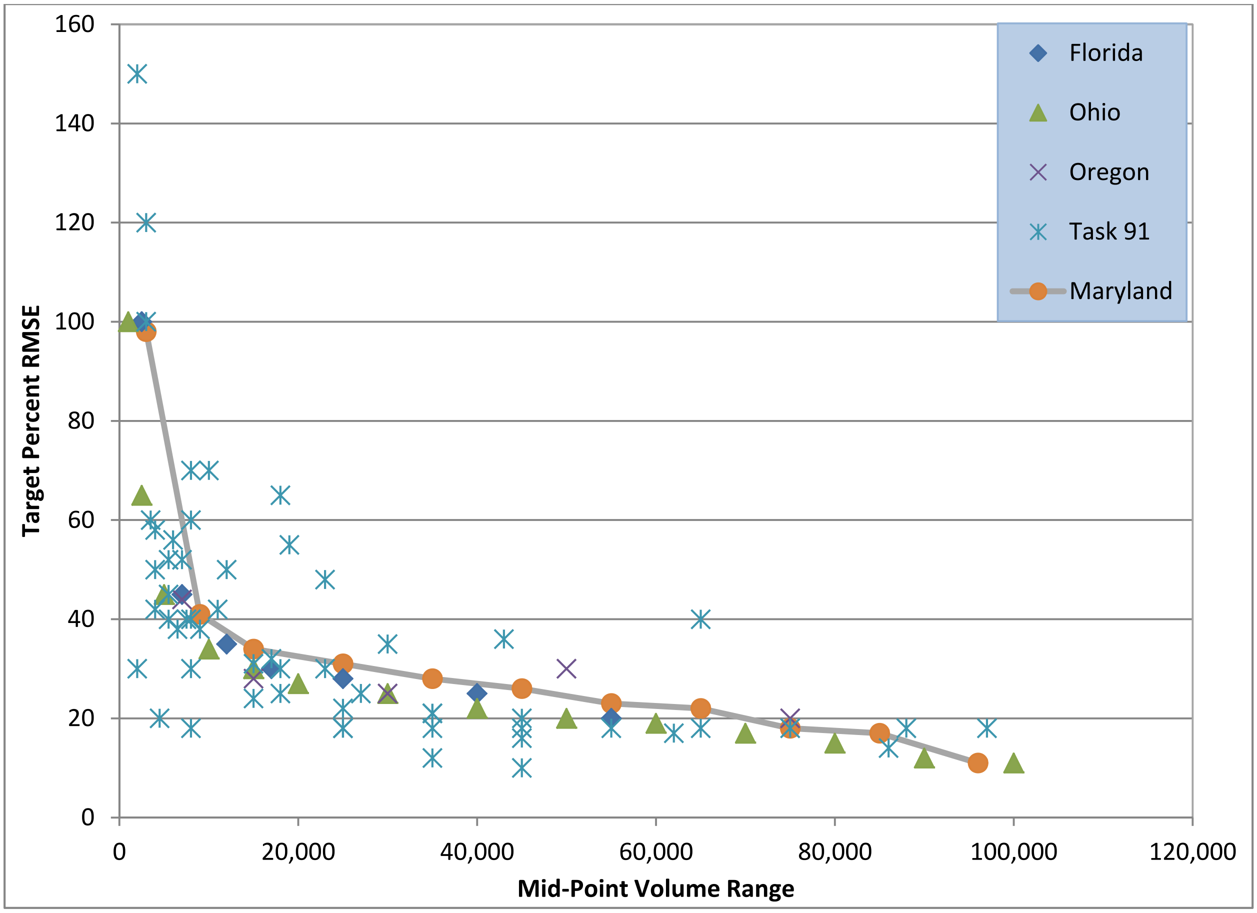

FIGURE 4 Target Percent RMSE Comparison

Note: Source data for other states (Giaimo 2001; Cambridge Systematics 2010; NCHRP 2010, MSTM 2011)

Highway Scenario

Transportation planning includes envisioning future growth in a CLRP scenario, where highway network capacity is appropriately expanded to keep up with future demand. On the other hand, planners would like to see future traffic conditions with little or no improvements in the transportation network. This scenario is referred as "No Build." In this case the 2030 network is identical to the 2007 network. In the alternative, the state of Maryland has proposed a network of toll roads to reduce auto travel and alleviate congested on non-tolled routes. We have developed a scenario in accordance with this proposal that creates a network of tolled travel lanes. This is referred to as the "Toll Road" scenario.

Fuel Price Scenario

With the significant uncertainty in fuel prices and fluctuations in national supply, travelers are concerned about using automobiles that are almost entirely dependent on oil verses public transit as the mode of travel. A travel demand model is the ideal tool to analyze travel behavior under the conditions of various future fuel prices. The MSTM mode choice component contains a variable for auto-operating cost, which enables the model user to experiment with anticipated fuel prices. In this paper, double and triple current gas prices are considered for two of the scenarios.

Increased Transit Ridership Scenario

Over the years increasing transit ridership has been the goal of many planning agencies. For this scenario group, we consider the effect of doubling and tripling transit ridership in exchange for reducing single occupancy vehicle trips. The transit ridership scenarios analyzed in this paper do not develop ways in which higher transit ridership can be achieved. Rather the goal of the scenario is to estimate the effect on highway travel if policies are designed to support a substantial increase in transit ridership.

Increased Demand

Based on Maryland's geography, a large portion of travel is through interstate and external-to-external trips. A number of large-scale transportation improvements are in the works that have the potential to affect travel in the MSTM study area. Such projects like the expansion of the Panama Canal, dedicated freight corridors, expansion of all major freeways in the state, specifically on Interstate-95, and others have a significant potential to impact travel demand in Maryland. In addition to these projects the Baltimore-Washington region has experienced rapid and continued growth. This growth in the study area may result in increased travel demand for the state. This scenario is designed to address the possibility that demand may increase more than what is currently expected in the CLRP. These scenarios also assess whether the existing and proposed transportation infrastructure is sufficient to provide a reasonable level of service under conditions of significantly more travel demand. To address this, we develop two scenarios. The first scenario models conditions with a 25 percent increase in demand while the second scenarios models a 50% travel demand increase.

Scenario Results

The above four scenario groups are analyzed, and VMT results are presented in Figure 5. The x-axis represents the scenarios and y-axis represents the resulting VMT. The base year in this graphic is 2007, with VMT of 142.79 million. A dotted horizontal line is drawn in Figure 5 to represent the base year VMT. Similarly, 2030 VMT is 187.13 million and is shown with a solid horizontal line. The comparison among scenarios is shown in four categories. The Highway scenario consists of No-Build and Toll lanes. The No-Build scenario suggests that if no investment will be made then the expected VMT increase of 4.3 percent. With many facilities in the state already operating close to capacity, the existing infrastructure may not be able to sustain this increase, and drivers will have to take detours to avoid the worst congestion. This will increase not only vehicle-miles traveled but also vehicle-hours traveled. The toll lane scenario resulted in a decrease in VMT by 0.5 percent. This is intuitive, as an increase in user cost will encourage travelers to change modes and reduce highway travel.

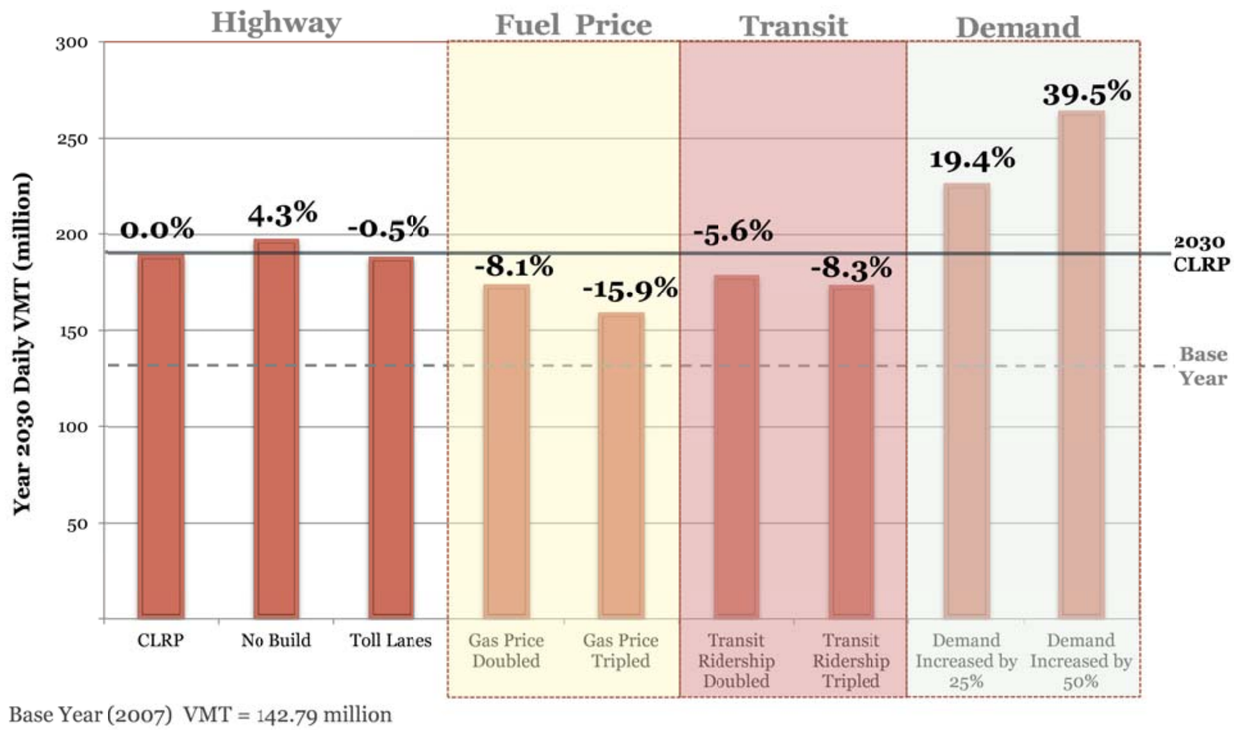

FIGURE 5 VMT from Transportation Scenarios

The double gas price scenario shows a decrease in VMT of 8.1 percent. With an increase in gas price travelers are sensitive to higher automobile operating costs. The reduction in VMT is attributable to shorter trip making and a change of mode from highway to transit. The results show that the model is sensitive to such policies. Another scenario examined the possibility if tripling gas prices. This scenario resulted in 15.9 percent reduction in VMT. An increase of transportation costs, which could be due to rising prices of crude oil or to increased gasoline taxes, is most effective in reducing travel demand. An analysis of network conditions if transit ridership where to double or triple, found marginal change with a 5.6 percent and 8.3 percent VMT reduction, respectively. The last scenario analyzed the impact increased travel demand. In this case, the number of trips produced in each modeling zone was increased by a specified percentage. If the assumed increase in demand is 25 percent, the resulting VMT is expected to rise by 19.4 percent. Similarly with increase in demand of 50 percent the VMT is expected to rise by 39.5 percent. The scenario analysis provides insights on expected in VMT with various growth assumptions. With such a toll the planning agency can envision expected outcome with analysis of a specific scenario. Figure 5 shows only a set of scenarios examined for the state of Maryland whereas the scenarios may vary from state to state.

An analysis of the transportation network at the link level allows for a better understanding of how travel behavior is affected by the change created in each scenario. Figure 6 provides a three dimensional representation of modeled VMT on all highway links in Maryland for the 2030 CLRP scenario compared to differences in VMT from each scenario. Each part of Figure 6 has four layers. The first layer represents the underlying transportation network. Above that, are the 2030 CLRP VMT results (in blue). Stacked above the base layer are two corresponding scenarios. The legend lists each scenario with the first one on the left and the second to the right.

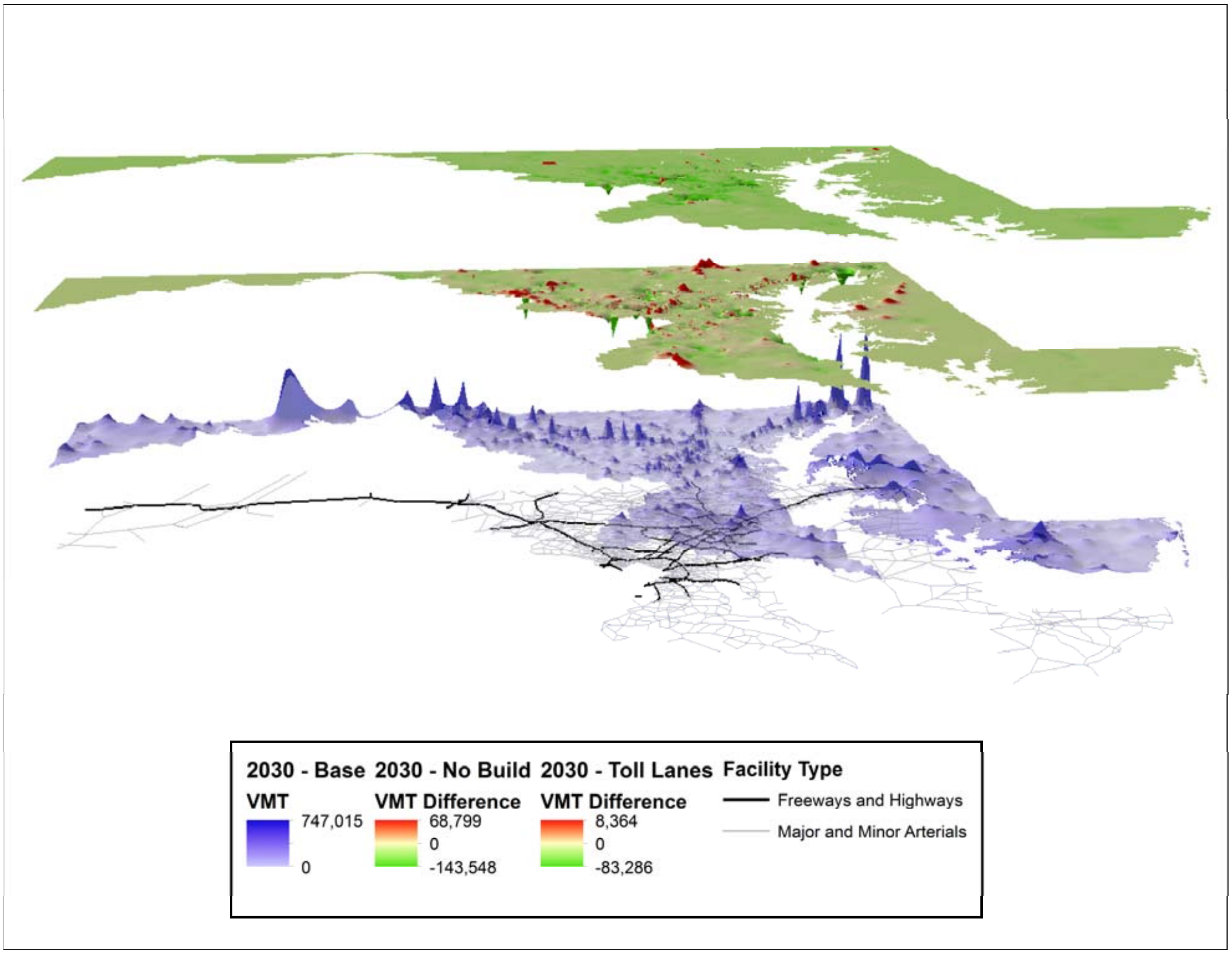

FIGURE 6(a) VMT change from No Build and Toll Road Scenarios

In figure 6(a) the base VMT is compared with the change as a result of the No Build scenario (second layer) and the network of toll roads scenario (top layer). These maps provide a spatial view of the change reported in the previous bar graph. For the No Build scenario, the map shows that many of the major freeways have a greater VMT while the outlying areas (to the west and east) have little or no change. In the Toll Road scenario, VMT is reduced, primarily in locations outside of major urbanized areas and only to a small degree.

Figure 6(b) shows the link level VMT change resulting from the scenarios that model either a doubling or tripling of gas price. In the case of double gas price, VMT is primarily reduced in areas such as the urbanized central core, where alternative modes are available. For double gas price scenario VMT appears to increase along Interstate corridors such as I-95, I-270, and I-70. In addition, for long distance travel corridors like US-301 increase in VMT is observed. The increase in VMT in these corridors is because of the fact that with availability of alternate modes total congestion is less, but the existing trips are shifted to routes that use interstates because they become more attractive with a lower relative travel time to reach destination. This happened mostly in urban areas. As shown in the figure all other facility types end up with with less VMT.

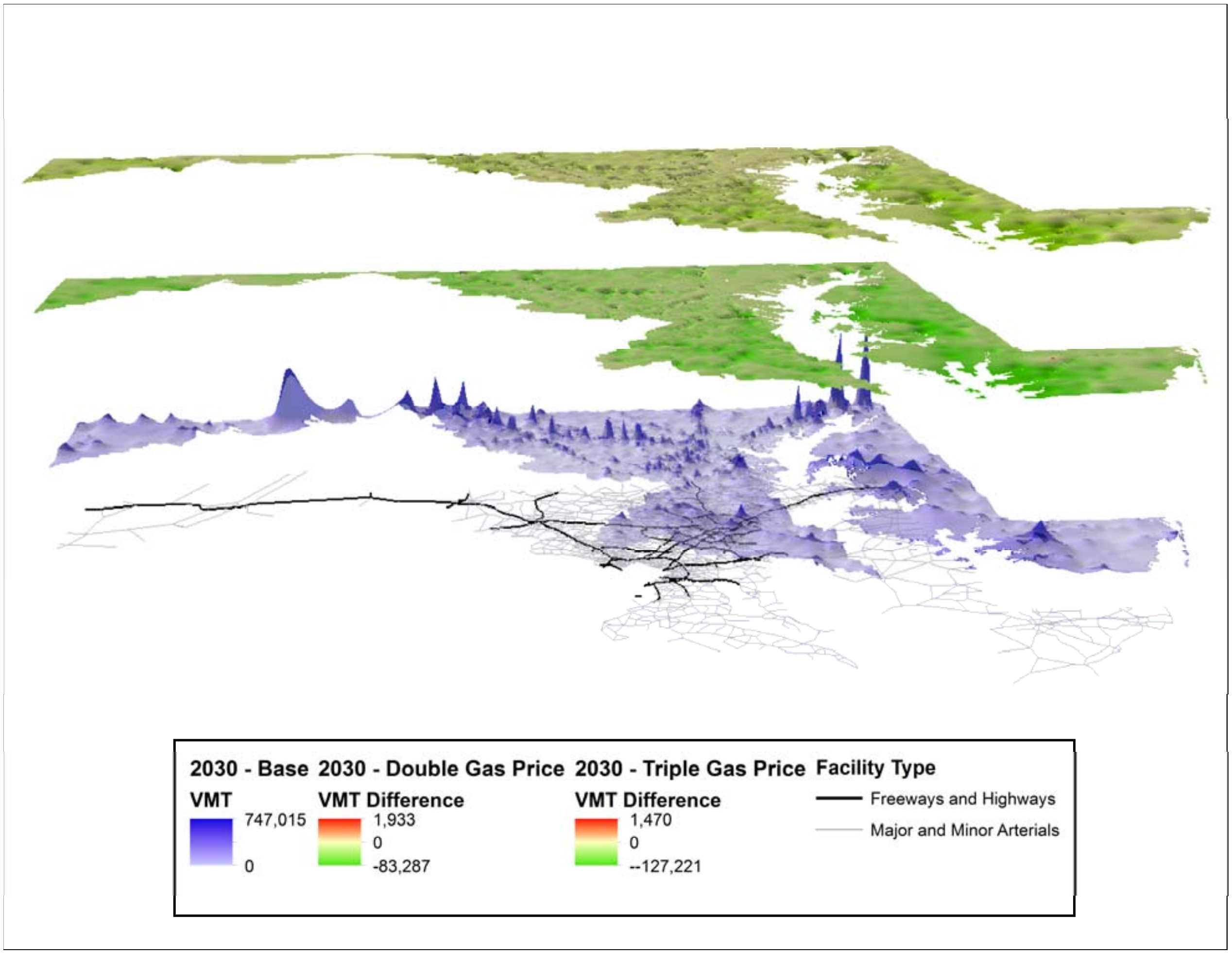

FIGURE 6(b) VMT change from Double and Triple Gas Price Scenarios

On the eastern shore and in western Maryland where trip lengths are reduced, travelers attempt to find activities closer to their trip origin. When the gas price is tripled the reduction in VMT occurs more uniformly throughout the state as all travelers attempt to reduce travel cost by finding alternate modes of travel and make shorter trips to destinations for activities.

When transit ridership is doubled or tripled, as shown in figure 6(c), the effects on VMT are much more localized. In both cases, the central core and the urban areas that have high capacity transit networks see significant VMT reductions. The central core consists of the suburban areas of Washington D.C and the urban area that covers the Baltimore metropolitan area. Two large transit systems, namely the Washington Metropolitan Area Transit Authority (WMATA), and Maryland Transit Administration (MTA) cater to the transit needs of these two regions. WMATA has the second highest rail ridership in the US with over 950,000 passengers per day (second to New York). MTA carries over nearly 300,000 passengers along with other services that include light rail, Metro subway, and the MARC commuter train. With an increase in transit ridership these areas appear to have significant reductions in VMT. On the other hand, outlying area with little or no transit service, see either no effect or increases in VMT.

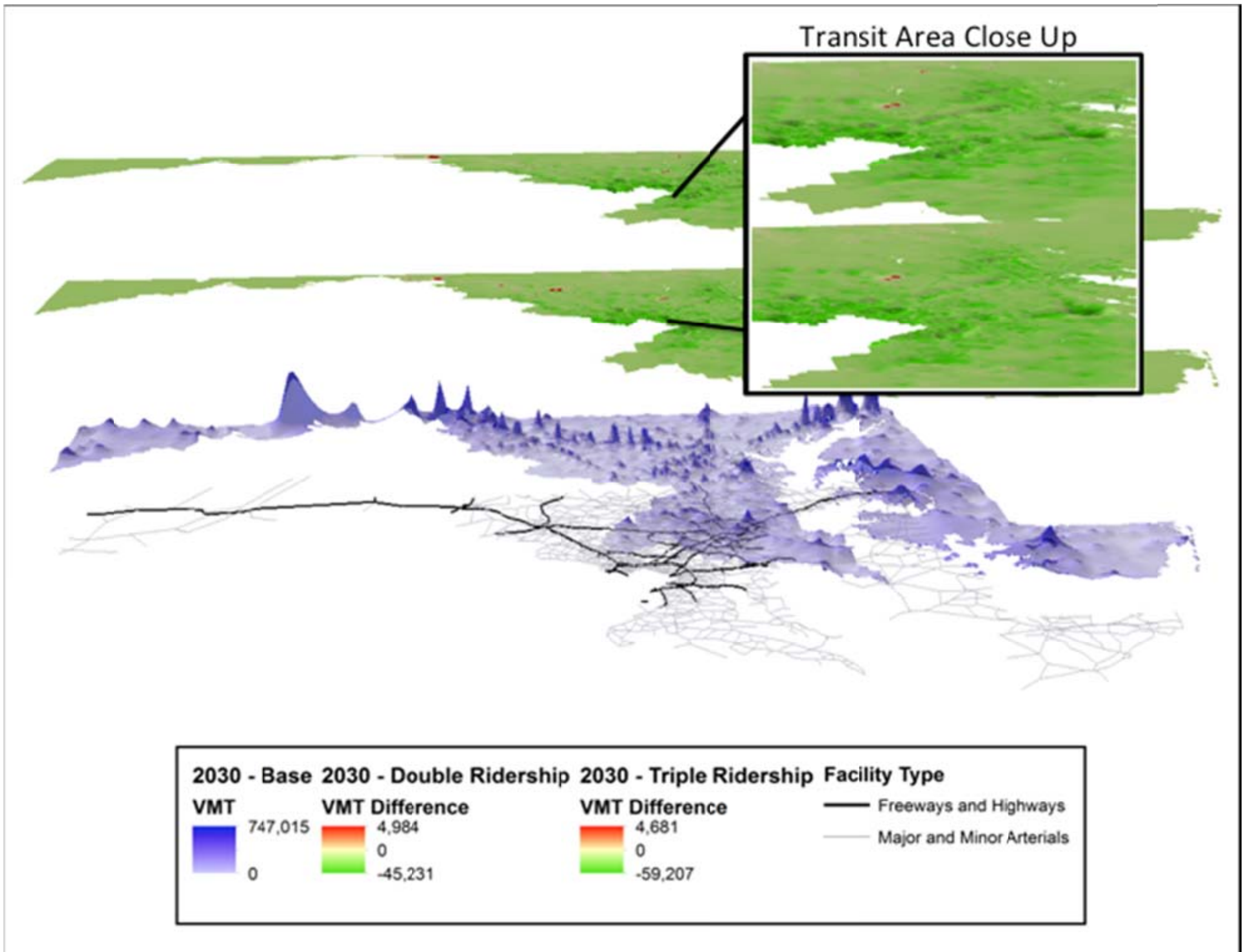

FIGURE 6(c) VMT change from Double and Triple Transit Ridership Scenarios

Figure 6(d) shows the dramatic impact on VMT if travel demand were to increase by either 25 percent or 50 percent beyond the currently projected 2030 demand. In these scenarios, the outlying areas of Maryland, which include the western and eastern regions, show significant VMT increases. This large spike in the middle of the map in both scenarios represents the large VMT increase that would occur in the city of Baltimore.

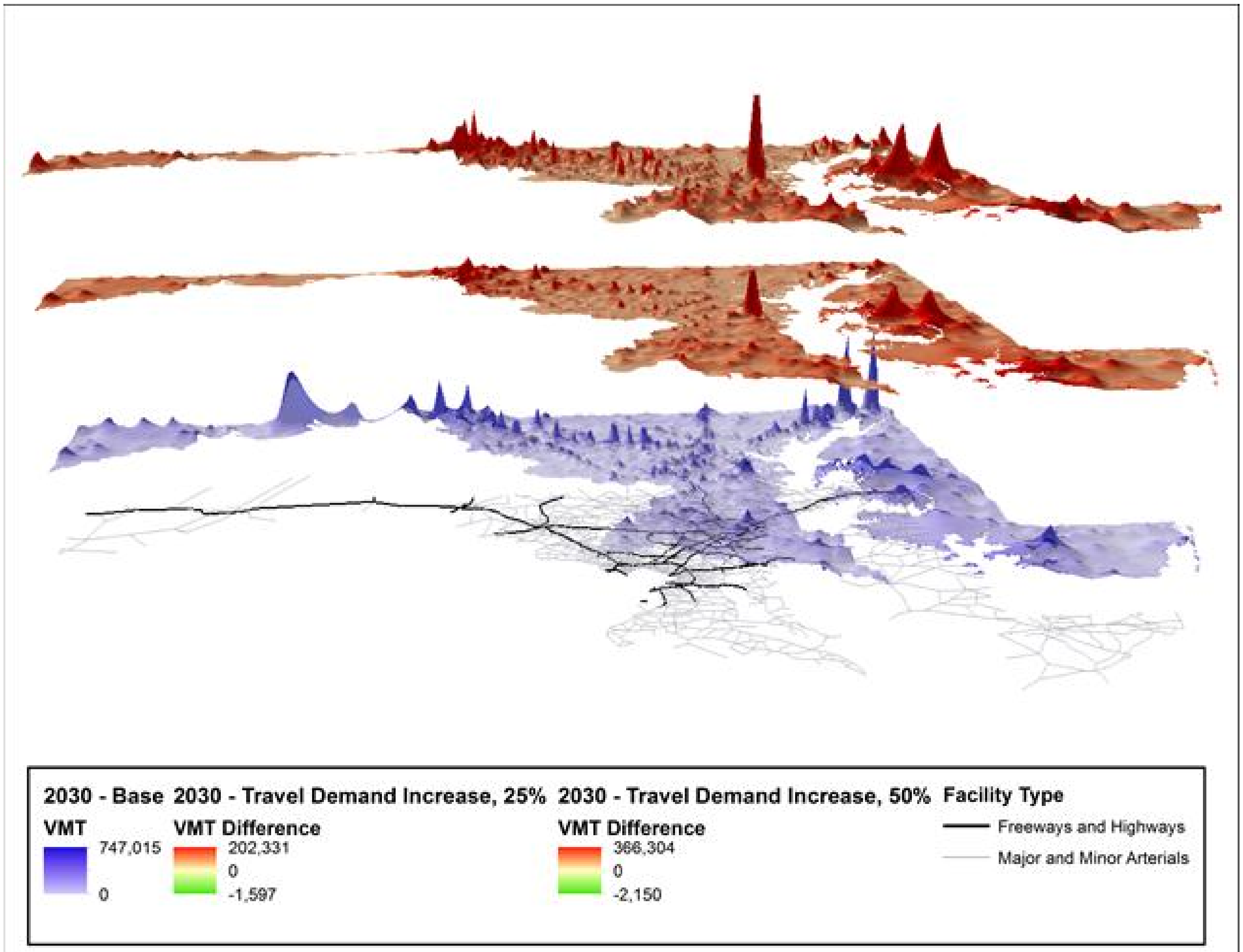

FIGURE 6(d) VMT change from 25% and 50% Travel Demand Increase Scenarios

Change in VMT in reference to the 2030 CLRP case for all scenarios by facility type is shown in Table 3 (note: some facilities were left out of the analysis, thus the total percent change in VMT may differ slightly from that shown in Figure 5). For the No-Build scenario, there is an increase in VMT for all facility types and an overall increase of 4.3%. The greatest increase in VMT is for interstates (8.9%). Intuitively this result makes sense because there is no new capacity available to accommodate the higher growth in the number of trips. Interstates, because of their larger capacity, are the most prone to congestion among all other facility types. For the toll road scenario, there is an overall decrease in VMT with all facility types also showing reduced VMT. The network of toll roads resulted in a larger mode shift from highway to transit, which in-turn reduced highway VMT. The double gas price scenario resulted in an overall reduction in VMT with the exception of increased VMT for interstates. The probable reason for increased VMT on interstates is due to shorter destination travel time compared to other facility types. However this trend does not appear when gas price is tripled. Because of a tripling in gas price, overall there is reduction in the number of trips for all facility types. Gas prices tend to drive transit ridership, at least in the short term and this trend has been replicated in the transportation model. The double transit ridership scenario shows a reduction in overall VMT and a reduction for all facility types. Overall, in 2010, the state has about 2 to 3 percent transit trips with greater percentages of transit trips only in Baltimore and Southern Maryland regions.

However with triple transit ridership there is reduction in VMT for all facility types. For both 25% and 50% increase in demand there is a substantial increase in VMT for all facility types as the roadways become swamped with travel and users are unable to optimize travel behavior on a single facility type.

TABLE 3 Change in VMT by Facility Type

Facility Type	% Change in VMT Compared to No Build	Toll Roads	Double Gas Price	Triple Gas Price	Double Ridership	Triple Ridership	25% Demand Increase	50% Demand Increase
Interstates	8.9%	-3.6%	2.3%	-4.1%	-1.4%	-2.9%	23.2%	35.6%
Freeways	2.8%	-4.2%	-6.0%	-12.3%	-1.5%	-4.2%	15.8%	28.7%
Major Arterials	2.8%	-10.1%	-14.5%	-22.1%	-12.5%	-16.2%	15.4%	36.2%
Minor Arterials	1.6%	-9.9%	-15.3%	-23.2%	-10.9%	-13.6%	20.4%	48.4%
Collectors	1.0%	-3.7%	-16.8%	-24.8%	-10.9%	-13.5%	23.4%	55.5%
Other	3.9%	-4.8%	-7.1%	-13.1%	-5.6%	-8.7%	15.7%	31.5%
Total	**4.3%**	**-5.0%**	**-8.8%**	**-16.0%**	**-5.4%**	**-8.3%**	**19.6%**	**39.5%**

Overall, The MSTM scenario planning exercise has demonstrated reasonable and consistent travel demand measures. However, more scenario analysis needs to be conducted to affirm the robustness of the model performance. Each model and scenario run takes approximately 3.5 hours on an Intel® Xeon 3 GHz CPU with 32GB RAM computer with the Microsoft Server 2008 operating system (64-bit). CUBE Voyager was used to build the model structure and CUBE cluster was used for each model run which reduced the run time from about 24 hours to 3.5 hours.

7. Conclusion

The development of MSTM is described in this paper followed by an examination of its ability to serve as a platform for scenario evaluation. A significant innovation of this approach is a three-layer design, with a national layer for long-distance travel, an urban level for detailed short-distance analysis, and a statewide layer as the core of this model that merges information from the statewide and the urban layer. The rationale for MSTM development is threefold. It was developed to expand the modeling capability beyond the MPO models in the region, to better understand through-region travel patterns and to better comprehend non-MPO region travel patterns. A trip-based model is developed over last three years to meet the need for a working statewide travel model. Validation results show that the model performs and matches well with observed count data, and HPMS VMT estimates by facility type. When compared to other statewide models, the MSTM performs reasonably well.

One of the primary uses of travel demand models is to ensure that they can be applied to measure policy sensitivity. Scenario planning is one such application, which in itself consists of an array of applications in terms of land use and transportation modeling possibilities. In this paper, one land use scenario and four transportation scenarios are considered. The CLRP land use scenario consists of housing and employment as produced in the cooperative forecasts of the respective counties in the study area. The first transportation scenario includes a No Build highway network where no investment in future transportation infrastructure takes place. This scenario resulted in increased VMT. As expected, with no new supply of transportation infrastructure the future year links are more congested by catering to a greater number of trips, resulting in larger VMT. At the link level, highways suffer from significantly higher congestion, as the constrained supply is unable to meet the expanded travel demand.

The network of toll roads scenario resulted in lower VMT since the tolls made the transportation network more expensive to travel. Though the overall reduction in VMT is not significant, considerably lower VMT is observed on the links functioning as toll roads. In the double gas price scenario, lower VMT results, as automobile travel becomes expensive, and mode shift to transit significantly aided in the VMT reduction. A similar result is observed, but with a larger magnitude for the triple gas price scenario. In the double transit ridership scenario, a reduction in VMT resulted as expected, and similar trends (as expected) for the triple transit ridership scenario. Though at the statewide level the reduction does not appear significant, at transit service locations, significantly lower VMT is observed at the link level. Lastly, both travel demand increase scenarios (one by 25 and the other by 50 percent) resulted in higher VMT.

Overall, the MSTM has demonstrated reasonable performance, consistent with expectations, in the scenario planning exercise presented in this paper. The ability to function reasonably in scenario planning is a critical test in taking the MSTM from development to implementation and policy application. Further application of the model in scenario planning will be instrumental in increasing confidence in the model. The initial indications are positive, and the expectation is to incorporate other challenging policies to cater the needs of the state and local agencies. The performance of the MSTM appears reasonable on the policy evaluations conducted thus far. The direction of predicted changes as well as relative magnitudes of the change pass the initial test of reasonableness, but further investigation must be carried out as the model development and application progresses over time.

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