Maryland Scenarios Project
Final Report

Prepared by: The National Center for Smart Growth Research and Education at the University of Maryland* in partnership with Maryland Department of Transportation

Fredrick W. Ducca, Senior Research Scientist
Sevgi Erdogan, Faculty Research Associate
Patricia Gallivan, GIS Coordinator
Gerrit J. Knaap, Professor; Director, National Center for Smart Growth Research & Education
Sabyasachee Mishra, Faculty Research Associate
Graham Petto, Graduate Research Assistant
Yanli Wang, Visiting Graduate Research Assistant from Tongji University, Shanghai, China.
Timothy Welch, Graduate Research Assistant

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EXECUTIVE SUMMARY

The Maryland Scenarios project is a multi-year effort led by the National Center for Smart Growth (NCSG) in consultation with Maryland Department of Transportation (MDOT) and Maryland Department of Planning (MDP) to explore alternative futures for the State of Maryland and to identify policy interventions that would lead to more desirable transportation-related outcomes. The project began in 2006 with four large public participation events called Reality Check Plus and continued for the next two years under the guidance of a multi-stakeholder Scenario Advisory Group. During this period, the NCSG began developing advanced econometric, land use, and transportation models to build and more carefully examine alternative development scenarios. Central to this work was the development of the Maryland Statewide Transportation Model funded by the Maryland State Highway Administration. When the Transportation Policy Research Group (TPRG) was established at the NCSG in 2009, with support from the Maryland Department of Transportation, the NCSG began to focus on alternative land use and transportation scenarios using the Maryland State Transportation Model. This report presents the results of that work.

Much of the work of the TPRG during its first three years was spent building and refining an integrated econometric, transportation, and land use modeling framework. The econometric model was developed jointly with Inforum, a research center at the University of Maryland, and the transportation model was developed jointly with Parsons-Brinkerhoff, a private consulting firm, with funding from State Highway Administration (SHA). Although not the focus of this report, the models have subsequently been calibrated, refined, and demonstrated to produce plausible results (TPRG, 2011).

This report presents analyses of statewide land use and transportation scenarios conducted using the statewide modeling framework. The purpose of this analysis was not to test specific or proposed land use or transportation policies

but instead was to examine broad alternative land use and transportation scenarios. Both the land use and transportation scenarios reflect trends and ideas frequently discussed and in that sense they represent important and useful enquiries. They lay the foundation for more specific analysis in the future.

Scenarios

Toward these ends, the report presents and analyzes four land use scenarios, three transportation scenarios, a high energy price (HEP) scenario which affects both land use and transportation and the impact of rising sea level (Climate Change) on land use and transportation.

The land use scenarios are:

- *Constrained Long Range Plan (CLRP)* – The combined long range plans (and transportation networks) of the Washington and Baltimore MPOs along with plans from other jurisdictions. This represents the "official" version of the future.
- *Buildout (BO)* –New development is allocated according to existing zoning until all vacant, buildable land is developed.
- *Transit Friendly Development (TFD)* – One half of all the household and employment growth projected in 2030 is reallocated to Designated Transit Areas and to other transit areas served by rail.
- *Market Driven Change (MDC)* – This allowed growth to occur unconstrained by zoning patterns or existing zoning plans.

The CLRP, TFD and MDC scenarios are all projected for year 2030 while BO did not have a specific time frame. The High Energy Price (HEP) scenario, described below, also has a 2030 time frame.

The MDC and HEP scenarios are developed using econometric and land use models to allocate growth. These are used primarily to test the effects of alternative economic forces, especially energy prices. The BO and TFD scenarios are rule-based, allocating growth in accordance with local zoning policy and concentrating growth in transit station areas, respectively. These are used primarily to test the effects of hypothetical land use policies.

The Transportation scenarios are:

- *Shifting of long distance truck travel to other modes, truck diversion* (*TD*) - Long distance truck travel diverts to other modes, primarily rail. Long distance travel was assumed to be trips greater than 400 miles in length.
- *Regionwide network of express toll lanes along the interstates* (*ETL*) – Two express toll lanes were added to interstates within the region, including I-270, I-95 between Baltimore and Washington and the Baltimore and Capital Beltways. Tolls of fifteen, thirty and sixty cents per mile were tested.
- *Improved transit operations* (*TRNS*) - For all transit lines in the system (including the Purple and Red Lines), headways and fares were both reduced by 50%. This made transit more attractive due to reduced times and costs. The transit improvements were limited to operational improvements in the current transit system and did not include adding service to currently unserved areas or increasing the operating speed, both of which could have major impacts.

Other Scenarios:

Two other scenarios involved changes to both transportation and land use.

- *Climate Change* - Assumed a two foot sea level rise in 2030, forcing those living in low lying areas to relocate and making low lying links impassable.
- *High Energy Prices* (*HEP*) – The price of energy rises significantly. This affects both residential and employment locations, with people locating closer to activities to save travel cost, and changes in travel behavior due to increased auto operating cost. The change in travel behavior includes shorter trips and more frequent use of transit.
- *Current Conditions* (*CC*) - In addition to the above scenarios, a Current Conditions scenario, which represents the current distribution of jobs and households, was developed for the year 2007.

An initial analysis was done comparing the 2007 current conditions and the 2030 CLRP. This analysis showed growth in travel primarily due to growth in employment and households, not to changes in behavior.

All other comparisons are made between the 2030 CLRP and the individual scenarios. By comparing the CLRP to the scenarios the effects of 23 years of population and employment growth are removed, more clearly capturing the effect of the scenario.

Methods

All analyses were conducted using the Maryland Statewide Transportation Model, a four step travel forecasting model developed for the Maryland State Highway Administration. The steps include trip generation, estimating the origins and destinations of trips; destination choice, relating trip origins to destinations; mode choice, estimating whether trips travel by highway or transit; and assignment, placing trips on the network and calculating travel times. Travel was divided into four time periods, AM Peak, Mid-day, PM peak and night.

All analyses were conducted for all time periods, with the greatest impact shown during the peaks. Tolls were fixed for each time period. The analyses included all planned transit and highway improvements in 2030, including the Intercounty Connecter (ICC), Cross County Connector (CCT) in Montgomery County, express toll lanes on I-95, the Red Line and the Purple Line. Due to the large size of the traffic analysis zones and the structure of the model results for transit usage the model does not fully account for fine grained land use factors such as urban design and mix of uses, although density does affect the number of trips originating in a zone. Induced (or suppressed) travel due to infrastructure changes is partially accounted for through changes in trip routes, changes in destination and changes in mode usage. The model does not change the number of trips due to changes in infrastructure. The analyses did not include measures of cost effectiveness or cost-benefit and these should obviously be considered when deciding on specific projects.

Results

Results were reported on a statewide, system wide basis. Were the results reported for specific subareas or corridors or projects the impacts could be more pronounced depending on the specifics of the context.

Highlights of the results for the various individual scenarios follow. Except where noted, all results reflect comparisons with the CLRP:

Market Driven Change – Market Driven change creates a more dispersed residential pattern than CLRP, resulting in slightly more Vehicle Miles of Travel (VMT) with minor increases in congestion.

Buildout – In the buildout scenario population and employment increased more than 30% each. This resulted in significant increases in VMT and even larger increases in Vehicle Hours of Delay (VHD) and Congested Lane Miles (CLM).

Transit Friendly Development – Under this scenario VMT declined and transit trips increased. Both of these would be expected. While there were declines in VMT compared to the CLRP, when compared to growth in VMT from 2007 to 2030, transit friendly development reduced the rate of growth in VMT by 13%.

Truck diversion – This scenario had little impact on travel. There were not enough long distance truck trips to make a significant difference.

Express Toll Lanes – This reduced VHT by facilitating faster travel along the interstates. The added capacity also allowed more vehicles on the interstates, removing traffic from parallel roads and increasing speeds on those highways. No appreciable reduction in VMT occurred.

Improved Transit Operations – Reducing headways and fares had modest impacts on VMT. While not tested, scenarios which provided new transit to areas currently unserved or provided transit which operated faster than highway alternatives would likely have had greater impact.

High Energy Prices – This scenario reduced VMT, VHT and VHD significantly. The reductions resulted from two factors; activities locating closer together to reduce travel cost and changes in travel choices due to increased auto operating costs. Changes in travel behavior included more use of transit and shorter trips.

Climate Change – Under a 2′ sea level rise climate change showed minor impacts on the transportation system, making links in low lying areas unusable. It also caused portions of the population living in low lying areas to relocate due to the land being underwater.

Overall, the results suggest that the transit friendly development and high energy prices can reduce total travel, decreasing congestion and reducing highway travel delay. The removal of long distance trucks did not have a significant impact on travel as there were not sufficient long distance trucks in the model to significantly affect congestion. A region-wide network of toll roads improved travel times both on the routes where toll lanes have been added as well as parallel routes. Improving transit operations could increase transit ridership by ten percent to 28 percent, depending on where the service improvements occurred.

Combined Scenarios

When transportation improvements were combined with land use changes (i.e. all the possible combinations of four land use, three transportation and the HEP scenarios), the impacts of the transportation scenarios were similar in magnitude when compared with all other scenarios. That is, when transit improvements or express toll lanes were added to a land use scenario such as TFD, the order of magnitude of the impacts was similar to adding the transportation improvements to the CLRP. Among the transportation scenarios, the largest reductions in highway usage measures were obtained from transit improvement scenarios. The ETL scenario does not impact transit ridership as ETLs and transit serve different markets.

Among the combination scenarios, the HEP with transit improvements provided the greatest reduction in highway usage measures, 27% VMT reduction and a 30% reduction in greenhouse gas emissions. TFD with transit improvements is the second best of the combination alternatives, reducing VMT by 3.6%.

The scenarios are also analyzed from the behavioral perspective by trip origins and destinations, by purpose, by income and by mode. The results showed that transit trip destinations are heavily oriented to compact sites along rail lines and in downtown, while origins are scattered across the region. Ridesharing is most common for non-work trips. Rail transit serves all income groups but low-income groups form the majority of the bus riders.

The results clearly demonstrate that the process provides valuable information to officials on the impacts of various land use and transportation alternatives. It also shows the ability of the process to address issues of land use and transportation, economic and environmental development, homeland security, infrastructure financing through tolls and climate change. Specific policy decisions will require further refinement and testing of alternatives.

1 BACKGROUND

The Maryland Scenarios project is a multi-year effort led by the National Center for Smart Growth (NCSG) in consultation with Maryland Department of Transportation (MDOT) and Maryland Department of Planning (MDP) to explore alternative futures for the State of Maryland and to identify policy interventions that would lead to more desirable outcomes. The project began in 2006 with four large public participation events held around the state called Reality Check Plus, and continued for the next two years under the guidance of a multi-stakeholder Scenario Advisory Group. During this period the NCSG began developing advanced econometric, land use, and transportation models to build and carefully examine alternative develop scenarios. When the Transportation Policy Group (TPRG) was established within the NCSG in 2009, with support from the Maryland Department of Transportation, the TPRG began to examine alternative land use and transportation scenarios using the Maryland State Transportation Model. This report presents the results of that work.

Transportation is a critical issue for Maryland, both as the foundation for the state's economy and for meeting the travel needs of Maryland residents. Maryland also lies within a key corridor of the nation's transportation system, situated in the middle of the north-south I-95 corridor, and bisected by the I-81 corridor and at the eastern end of the east-west I-70 corridor. Maryland's transportation system also features extensive intra-urban travel within two major metropolitan areas and inter-urban travel that can traverse the Appalachian Mountains and the Chesapeake Bay. Traffic volumes on all modes of travel continue to rise causing many areas of the State to experience significant congestion and concomitant impacts on the economy, personal travel, and the overall quality of life.

Work by the TPRG proceeded as follows. In year 1, the primary work of the TPRG was focused on collecting and organizing data and constructing and refining the transportation, land use, and econometric model. The results of the first year of work are presented in the Year One Final Report (TPRG, 2010). In year 2, the TPRG began exercising the models and developing independent land use and transportation scenarios. The results of the second year of TPRG work are presented in the Year Two report (TPRG, 2011). In year 3, the TPRG continued to develop and refine models and constructing integrated land use and transportation scenarios. The results of that work, as well as a summary of previous years' work are presented in this report.

The remainder of this report is organized as follows.

- Section 2, Land Use Scenarios. This section introduces, describes and analyzes the five land use scenarios.
- Section 3, Transportation Scenarios. This section introduces, describes, and analyzes three transportation scenarios.
- Section 4, Climate Change Scenario. This section describes and analyzes the climate change scenario.
- Section 5, Integrated Land Use and Transportation Scenarios. This section describes and analyzes eight integrated transportation and land use scenarios.
- Section 6, Policy Implementation. This section discusses how the results of the scenario analysis could be used in analyzing policies for the State of Maryland.
- Section 7, Conclusions. This section offers concluding comments and suggestions for future work.

2 LAND USE SCENARIOS

This section describes six scenarios: four land use scenarios, a high energy price scenario, a current conditions scenario and the methods used to develop each. The land use scenarios are called: Constrained Long Range Plan (CLRP), Buildout (BO), Transit Friendly Development (TFD) and Market Driven Change (MDC). The High Energy Price (HEP) scenario is a policy scenario which affects both land use and transportation through increased gasoline prices. Although it is not solely a land use scenario, due to its impacts on the land use, HEP is considered among the land use scenarios throughout this report. The Current Conditions (CC) scenario represents an estimate of the existing distribution of jobs and households across the State. The CC scenario represents conditions in 2007 as the latest data available were for 2007. The CLRP represents the future (2030) distribution of jobs and households according to official local, state and regional government estimates and serves as the basis for comparison for all other scenarios.

Two approaches are used in developing the other scenarios. The first approach, used for the BO and TFD scenarios, is a rule-based approach that allocates growth in accordance with local zoning policy and directly concentrates growth in transit station areas, respectively. These are used primarily to test the effects of alternative land use policies. The MDC and HEP scenarios are developed using econometric and land use models to allocate growth (Appendix A1). These are used primarily to test the effects of alternative economic forces, especially energy prices.

2.1 CURRENT CONDITIONS (CC)

The distribution of jobs and households under Current Conditions are estimated for the year 2007 and based on data from a variety of sources including the Census Bureau, the Baltimore and Washington metropolitan planning organizations (MPOs), and the Maryland Department of Planning. Jobs and household estimates of Current Conditions are assigned to Statewide Modeling Zones (SMZs), a key component of the statewide transportation model. SMZ's are polygon structures that are the basis for Maryland Statewide Transportation Model (MSTM) transportation assignment and input land use assumptions. They nest within counties and they are equivalent to Traffic Analysis Zones (TAZs) in high-density areas or aggregations of TAZs in low-density areas.

Estimates of 2007 household distributions are based primarily on linear extrapolation of 2000, 2005, and 2010 Census data. Estimates of 2007 employment are based on data from a variety of sources, which use a variety of employment definitions. Considerable effort was required to assure consistency between definitions and types of jobs from disparate sources. The resulting Current Conditions scenario includes full time equivalent jobs for office, retail, and other jobs for each SMZ (NCSGRE, 2012).

Current Conditions are illustrated in Figures 2.1-1 and 2.1-2 below for households and jobs, respectively.

Figure 2.1-1. Household Density-Current Conditions

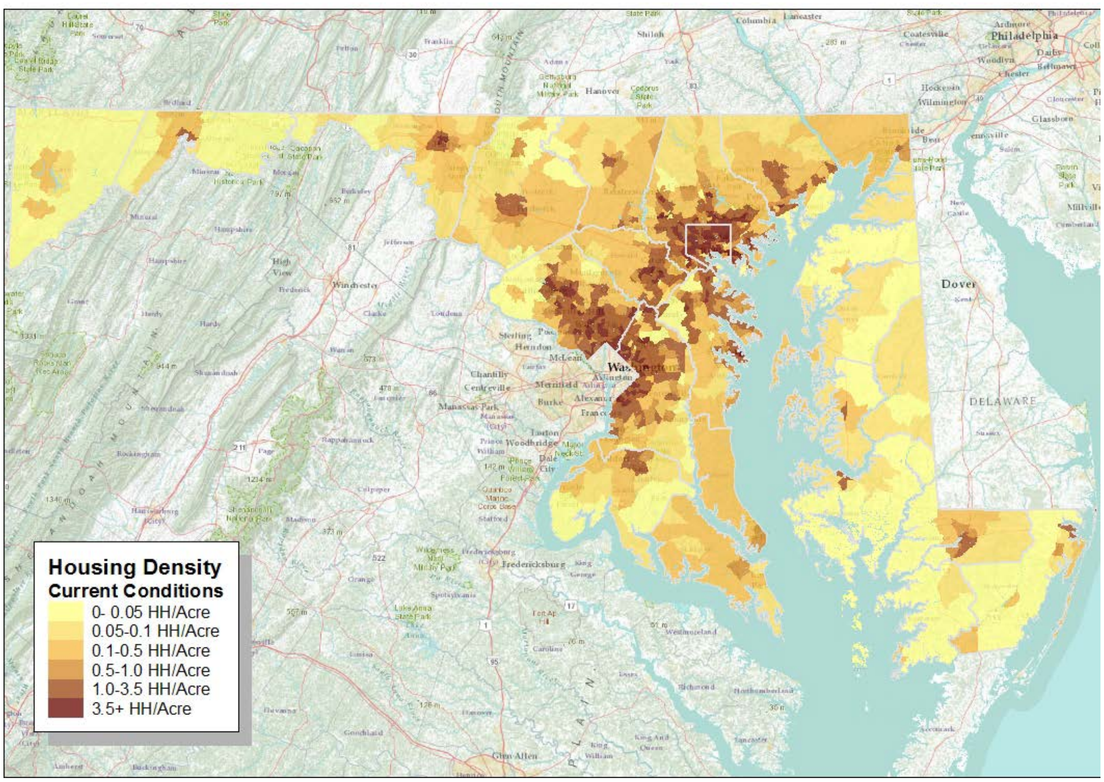
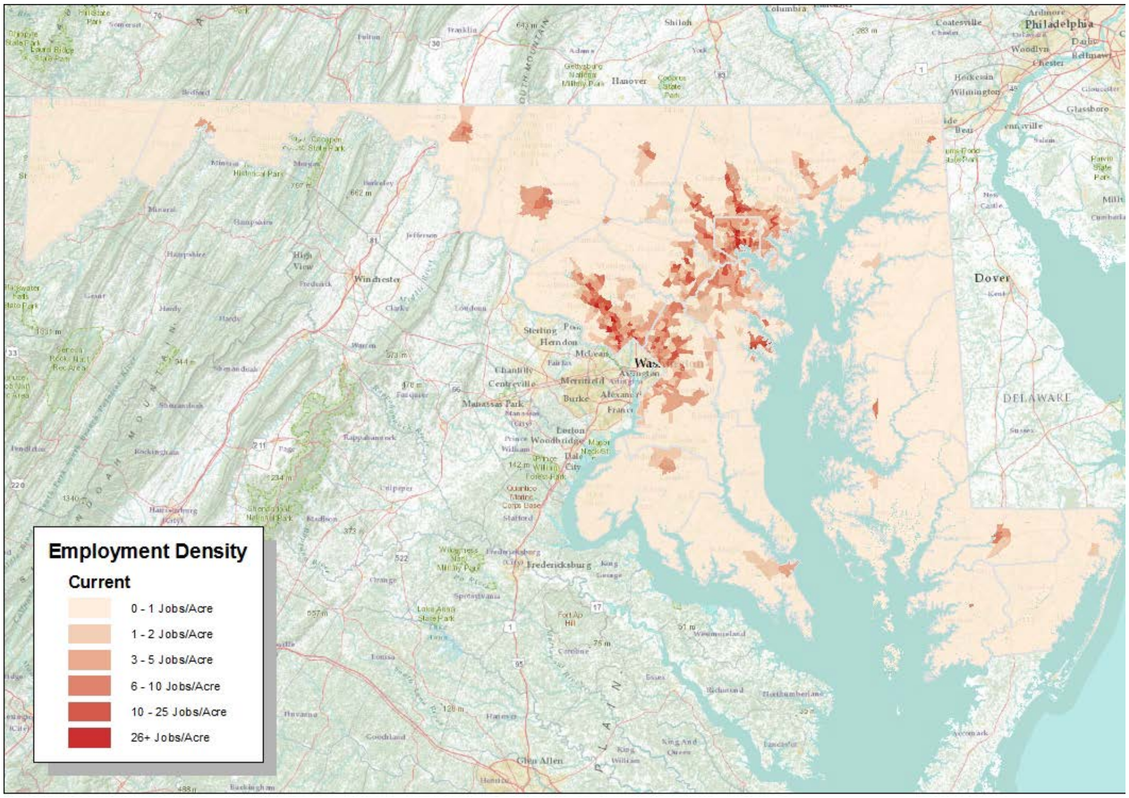


Figure 2.1-2. Employment Density-Current Conditions

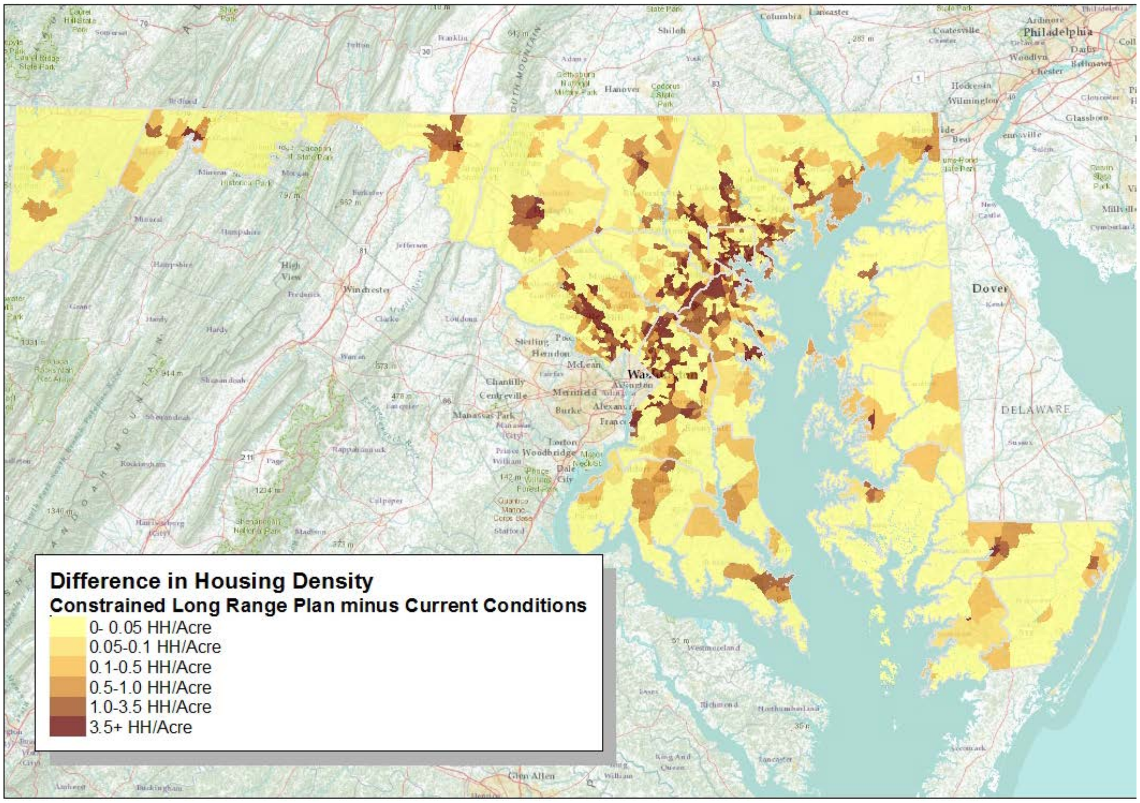


2.2 CONSTRAINED LONG RANGE PLAN (CLRP)

The Constrained Long Range Plan is used as a baseline scenario. This scenario is based on 2030 household and employment projections from the Baltimore and Washington MPOs developed through a process called cooperative forecasting. For areas outside the MPO regions, household and employment estimates are based on projections from the Maryland Department of Planning. The CLRP scenario represents the allocation of jobs and households that most closely reflects official forecasts adopted by state, regional, and local governments and is consistent with those used for other transportation and planning purposes (NCSGRE, 2012).

Differences in the distribution of jobs and households between the CLRP scenario and Current Conditions is illustrated in Figure 2.2-1 and 2.2-2 below, respectively.

Figure 2.2-1. Difference in Household Density between CLRP and CC

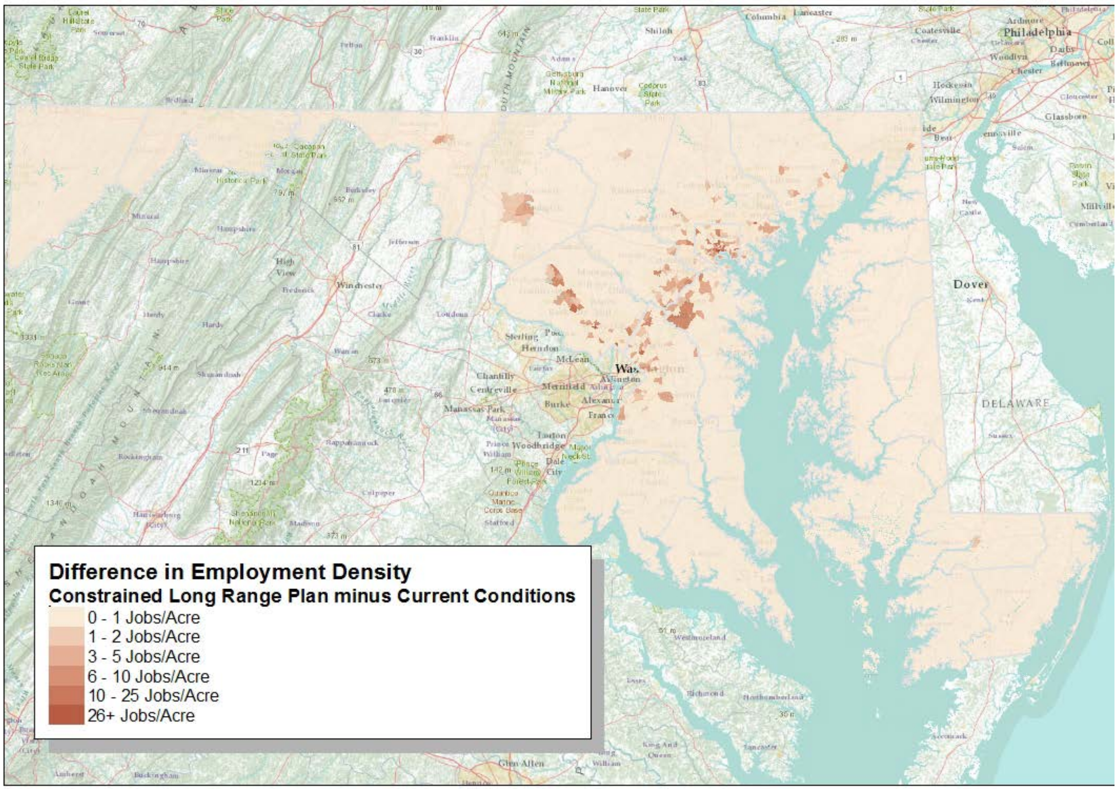


Under the Constrained Long Range Plan scenario, the State of Maryland experiences a 16 percent growth in the number of households over current conditions. This growth occurs around the State, but there are some key areas that experience the greatest increases in households over current conditions. These include the following areas:

- Interstate 270 corridor in Montgomery County
- Inner beltway areas of Prince George's County
- Baltimore City
- Inner beltway areas of Baltimore County
- Harford County US-40/I-95 corridor
- Municipalities: Bel Air, Frederick, Hagerstown, Salisbury, Waldorf and Westminster

Low-density growth is also projected to occur in Anne Arundel and Howard Counties and in rural parts of Carroll, Frederick and Harford counties. Southern Maryland and Cecil County, in addition to other parts of the Eastern Shore, also experience some additional household growth.

Figure 2.2-2. Difference in Employment Density between CLRP and CC



The State experiences an 11 percent increase in the number of jobs under the CLRP scenario relative to Current Conditions. Jobs remain concentrated in a few key areas under both the Current Conditions and CLRP scenarios. These include the following areas:

- Interstate 270 Corridor in Montgomery County
- The Baltimore-Washington Corridor along I-95 and I-295
- Metropolitan Baltimore, with centers in Towson-Hunt Valley and Owings Mills in addition to Baltimore City

- Other centers include Annapolis, Bel-Air, Frederick, Hagerstown

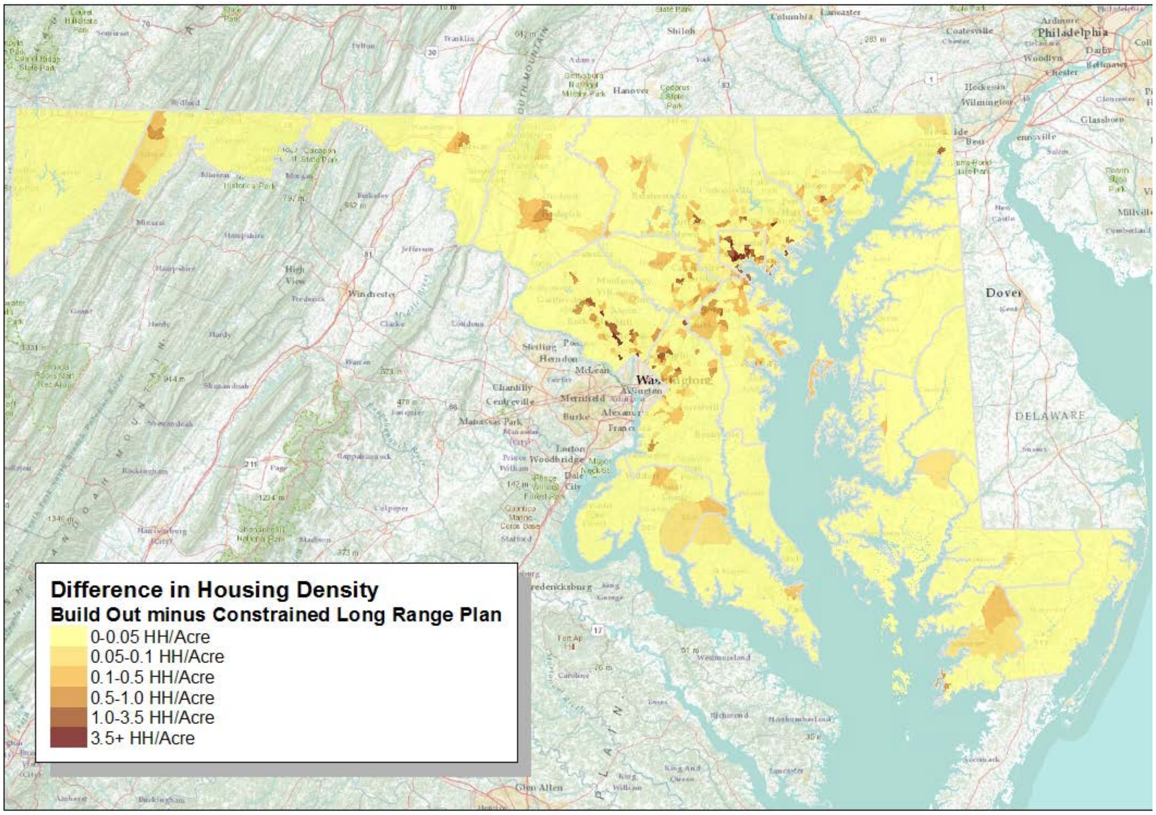
2.3 BUILDOUT (BO)

The Buildout scenario represents the distribution of jobs and households prescribed by local zoning regulations adopted by local jurisdictions. The BO scenario has no terminal date. Residential growth under the BO scenario was estimated in part using the residential growth model developed by the Maryland Department of Planning. With the assistance of an advisory panel of local government planners, however, the NCSG adjusted the MDP growth model estimates to reflect tax-exempt development in residential zoning districts, such as schools, fire and police stations, etc. This resulted in a slight reduction of residential capacity from MDP growth model estimates.

Estimates of job distributions under the Buildout scenario were derived using a model developed by the NCSG with the assistance of a local government advisory panel. These estimates are based on the assumption that future employment on undeveloped land in commercial and industrial zones will occur at the same densities as currently developed land in commercial and industrial zones. The scenario does not allow for employment densification on land already developed (Appendix A2).

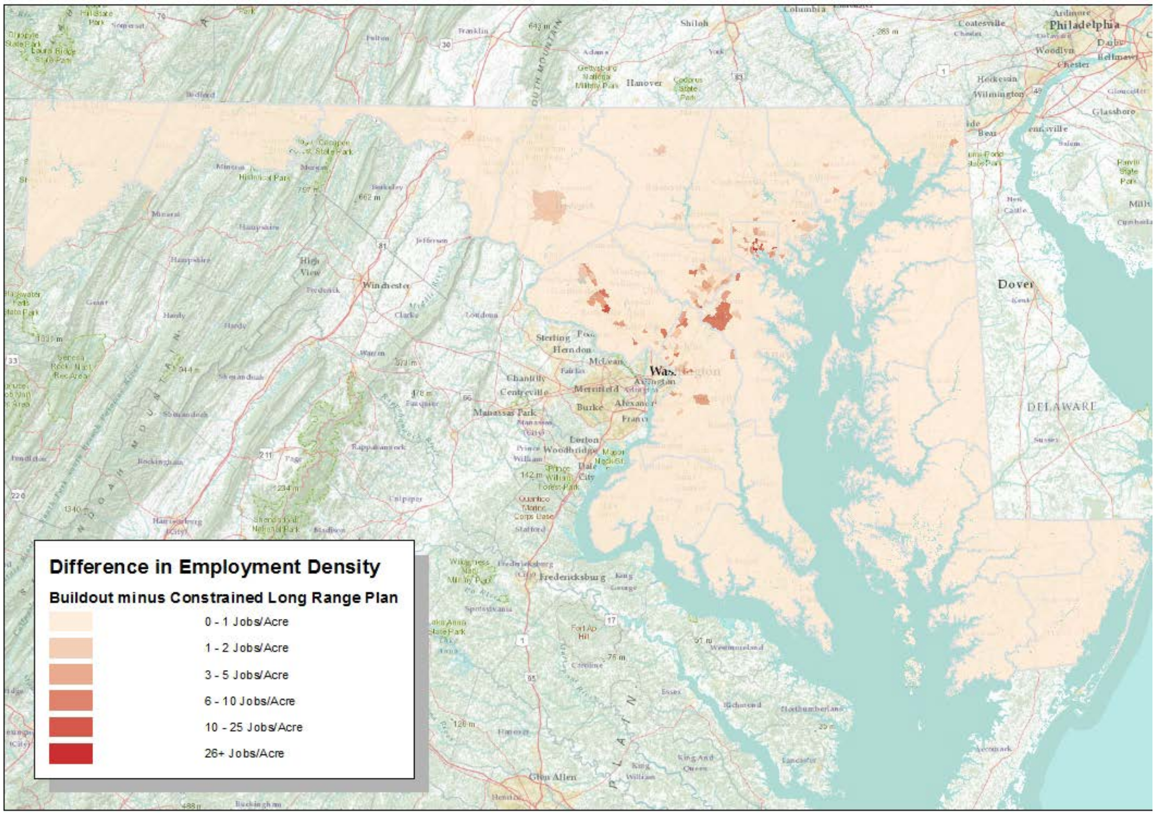
Differences in the distribution of jobs and households between the BO and CLRP scenarios is illustrated in Figures 2.3-1 and 2.3-2 below, respectively.

Figure 2.3-1. Difference in Household Density between BO and CLRP



The total number of households under the Buildout scenario is 466,145 more than under the CLRP scenario (Table 2.7.1-1). This occurs for two reasons. First, the BO scenario has no end date, while the CLRP is based on a 30-year projection. Second, there is considerable development capacity in the rural parts of the state that is not forecast to be developed under the CLRP scenario. For this reason, the BO scenario distributes more household growth to Western Maryland, the Eastern Shore, and other rural parts of the State.

Figure 2.3-2. Difference in Employment Density between BO and CLRP



The total number of jobs under the BO scenario is 835,759 greater than in the CLRP scenario (Table 2.7.1-1). The spatial distribution of jobs, however, is nearly the same: jobs in both scenarios are concentrated in Baltimore and the I-270 corridor and other urban areas of the State.

2.4 TRANSIT FRIENDLY DEVELOPMENT SCENARIO

The Transit Friendly Development scenario was developed to explore the effects of development patterns on travel behavior—especially transit ridership. For this reason, the TFD scenario allocates more development to areas served by transit, especially rail transit. Working with Maryland Department of Transportation staff, three geographic areas were defined to create the TFD scenario:

1. Designated Transit Areas (DTA) : Those transit station areas established by the State of Maryland as Designated Transit Oriented Development areas (Appendix A3).

2. Other Transit Areas (OTA) : Other dedicated right-of-way, rail served areas.

3. Non-Transit Areas (NTA) : Those areas in the Baltimore and Washington metropolitan areas not served by dedicated right-of-way, rail transit.

The TFD scenario was developed from the CLRP scenario as follows. First, for the Baltimore and Washington metropolitan areas, one quarter of all the growth under the CLRP is shifted to Designated Transit Areas; another quarter of growth is shifted to Other Transit Areas. To offset the increased growth in transit areas; growth in the Non-Transit Areas was reduced by a corresponding amount.

Tables 2.4-1 and 2.4-2 below illustrate the reallocation of households and jobs within each respective metropolitan area. Figures 2.4-1 and 2.4-2 illustrate the differences in the allocation of household and jobs between the TFD and CLRP scenarios, respectively.

Table 2.4-1. Allocation of Households in TFD with respect to CLRP

Metro Area	Change in HH, CC 2007 to CLRP 2030	Designated Transit Areas (DTA)	Other Transit Areas (OTA)	Non Transit Areas (NTA)
Baltimore	160,335	+40,084	+40,084	-80,168
Washington	123,654	+30,913	+30,913	-61,827
Total Metro Maryland	283,989	+70,997	+70,997	-141,995

The Table 2.4-2 below illustrates the number of jobs to be shifted to each area within each respective metropolitan area.

Table 2.4-2. Allocation of Employment in TFD with respect to CLRP

Metro Area	Change in Jobs, CC 2007 to CLRP 2030	Designated Transit Areas (DTA)	Other Transit Areas (OTA)	Non Transit Areas (NTA)
Baltimore	276,992	+69,248	+69,248	-138,496
Washington	90,211	+22,553	+22,553	-45,106
Total Metro Maryland	367,023	+91,801	+91,801	-183,602

Figure 2.4-1. Difference in Household Density between TFD and CLRP

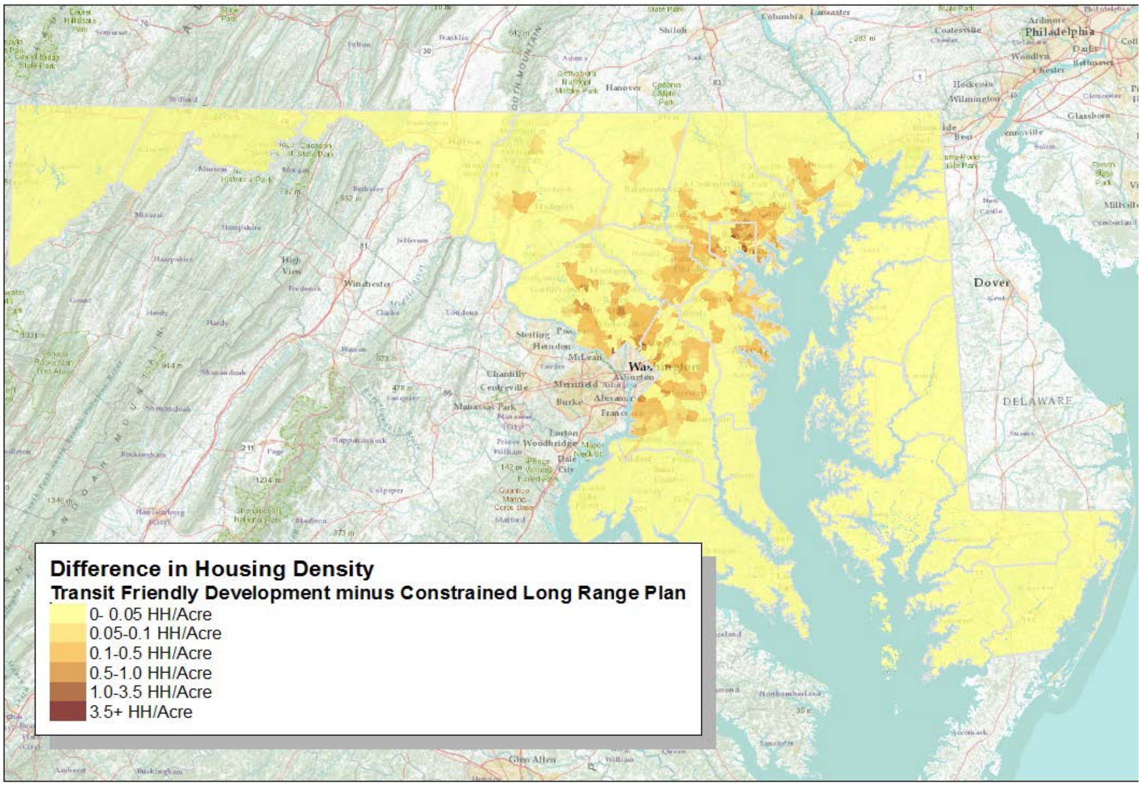
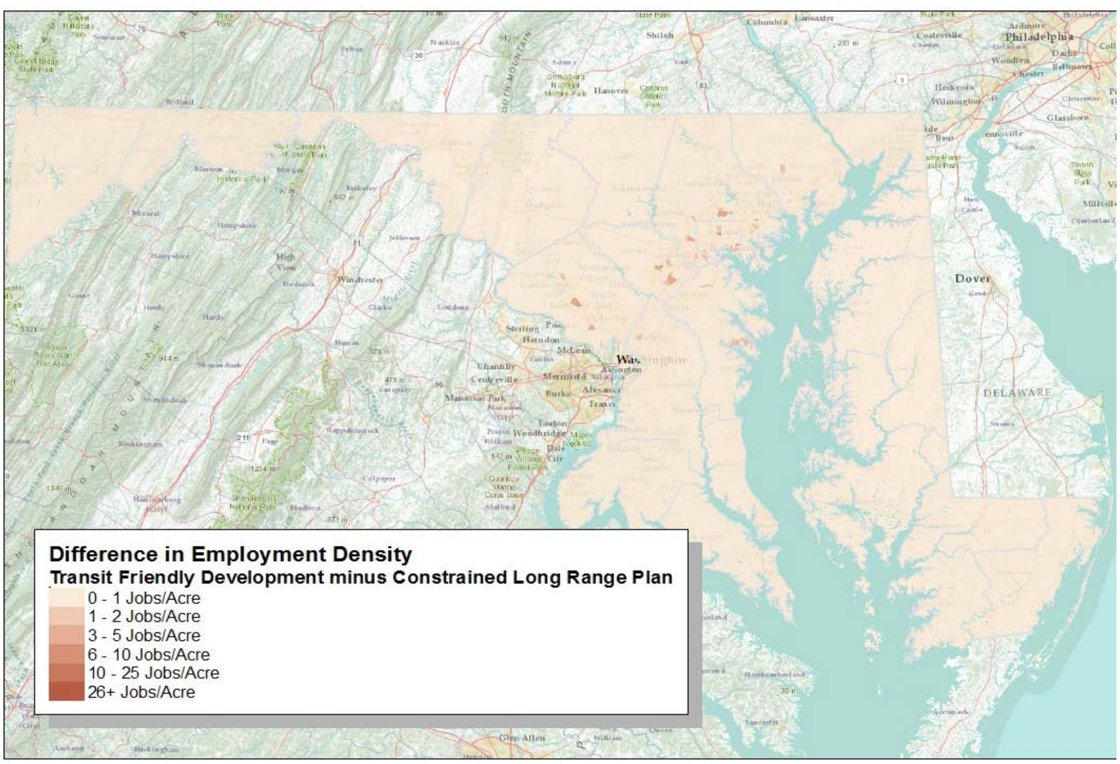


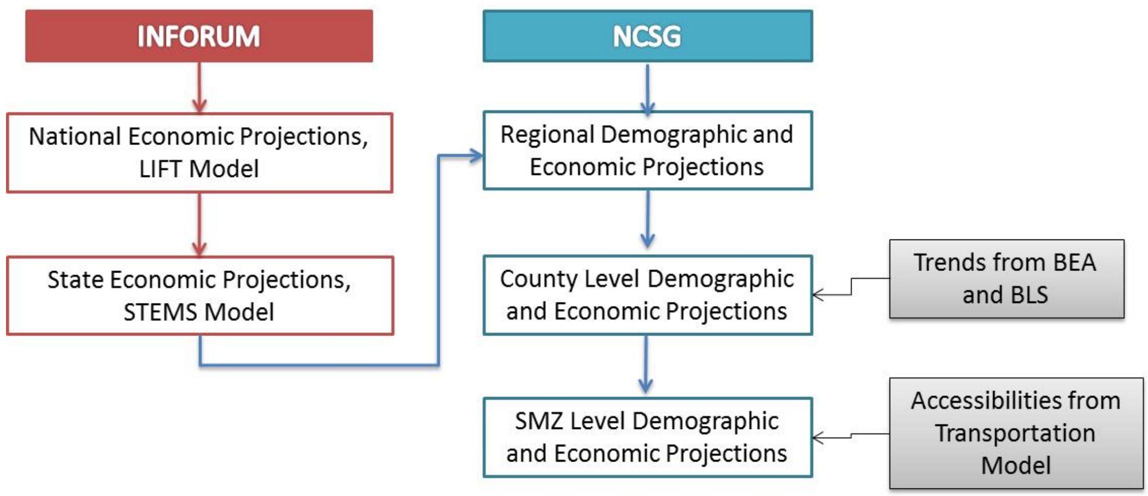
Figure 2.4-2. Difference in Employment Density between TFD and CLRP



2.5 Market Driven Change Scenario

The Market Driven Change scenario was developed to explore the effects of market forces on development patterns and travel behavior. For this reason, the MDC scenario is derived entirely using land use and econometric models and disregards local land use regulations. The MDC scenario is derived from a national economic forecast of households and employment for the year 2030 provided by the Inforum LIFT model at the University of Maryland (Inforum, 2010).

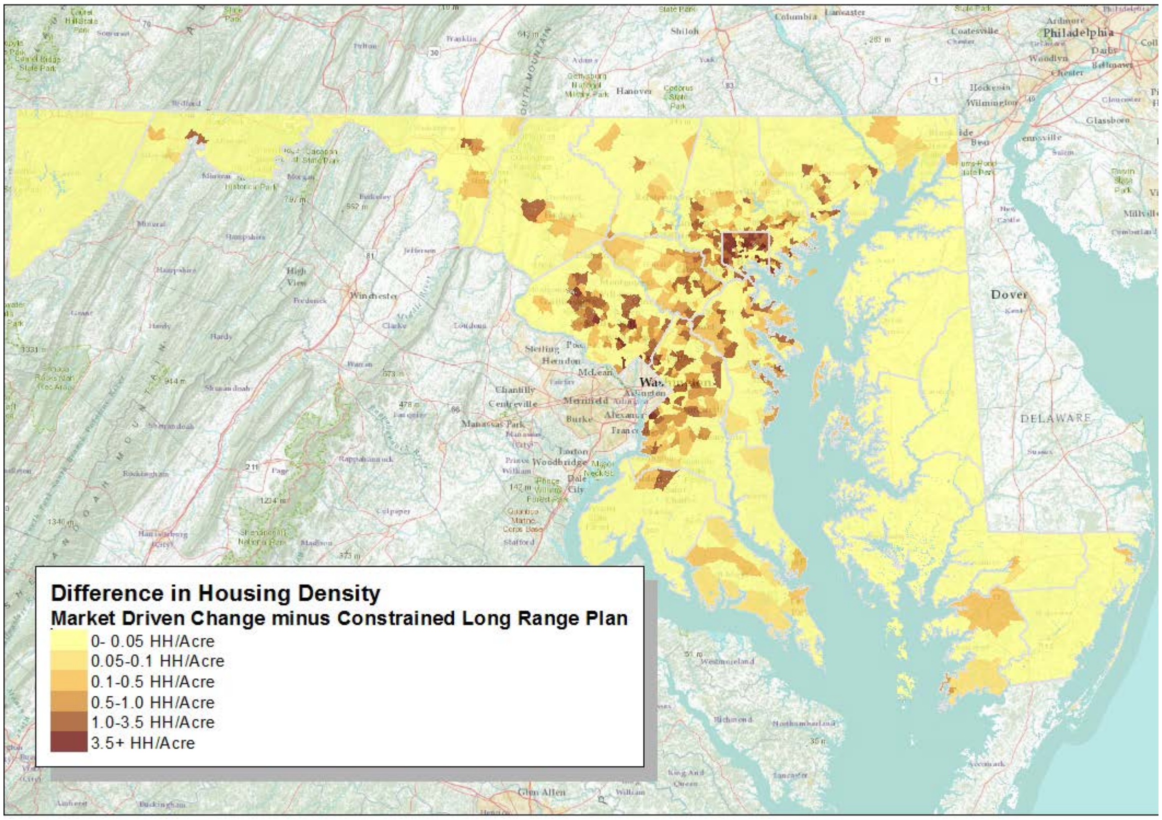
Figure 2.5-1. Schematic of the Employment and Population Projections



As shown in Figure 2.5.1, the MDC scenario derives population and employment from national forecasts of economic activity. These forecasts are then disaggregated to states using Inforum's STEMS model (Inforum, 2010). A land use distribution model is then used to distribute population and employment first to counties, then to individual SMZs. To allocate new employment, the model uses both the current levels of population and employment and travel time and travel cost between counties and zones (Appendix A1). As travel cost declines, employment and population spreads out. As the travel cost increase, employment and population concentrates. In this scenario an auto operating cost of $.12 per mile was assumed (TPRG, 2011).

Figures 2.5-2 and 2.5-3 illustrate the differences in the allocation of household and jobs between the MDC and CLRP scenarios, respectively.

Figure 2.5-2. Difference in Household Density between MDC and CLRP



The number of households under the MDC is six percent higher than in the CLRP scenario.   Compared to the CLRP, the MDC allocates more growth to the following the following areas:

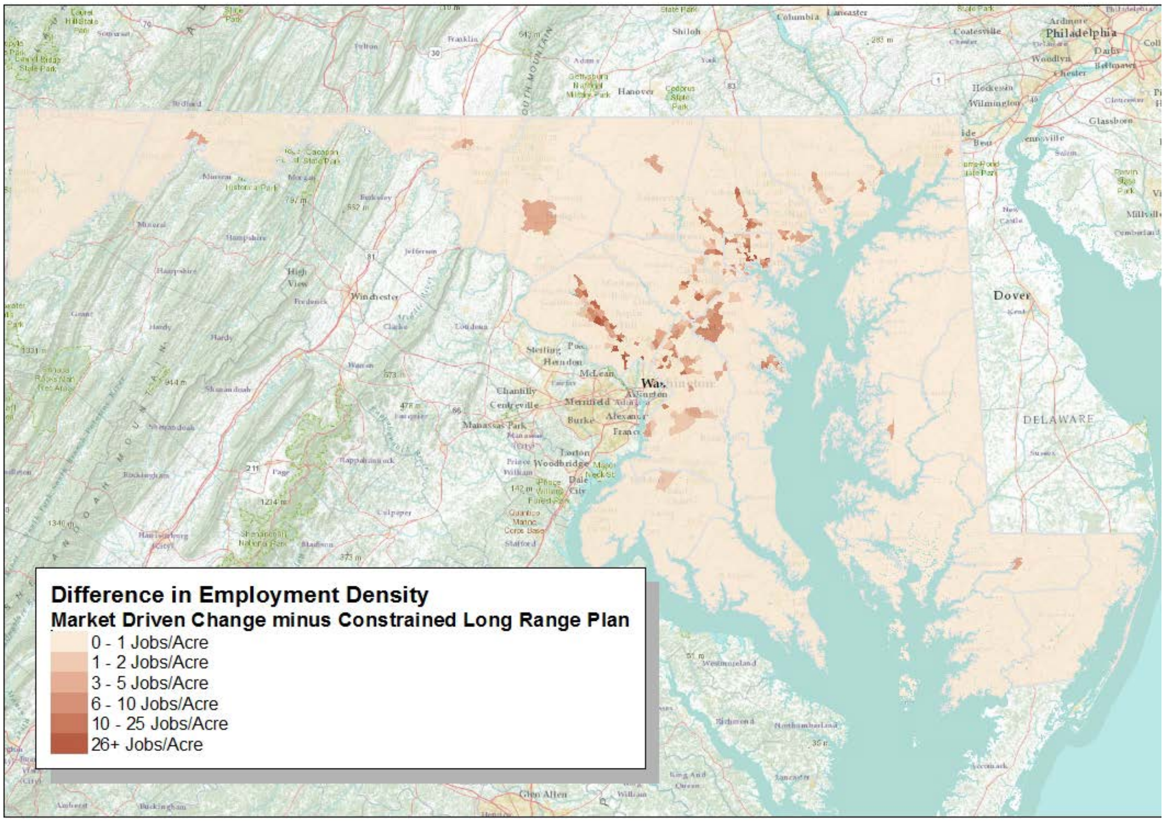
- Metropolitan DC Suburbs
- Interstate 270/WMATA Red Line Corridor in Montgomery County
- Baltimore City
- Glen Burnie area of Anne Arundel County
- White Marsh-Parkville-Hunt Valley areas of Baltimore County

- Other municipalities including Hagerstown and Salisbury

The MDC also allocates low density residential growth to the following counties:

- Frederick
- Carroll (outside Westminster)
- Harford
- Cecil (outside Elkton)
- Caroline
- Queen Anne's
- Charles (outside Waldorf)

Figure 2.5-3. Difference in Employment Density between MDC and CLRP



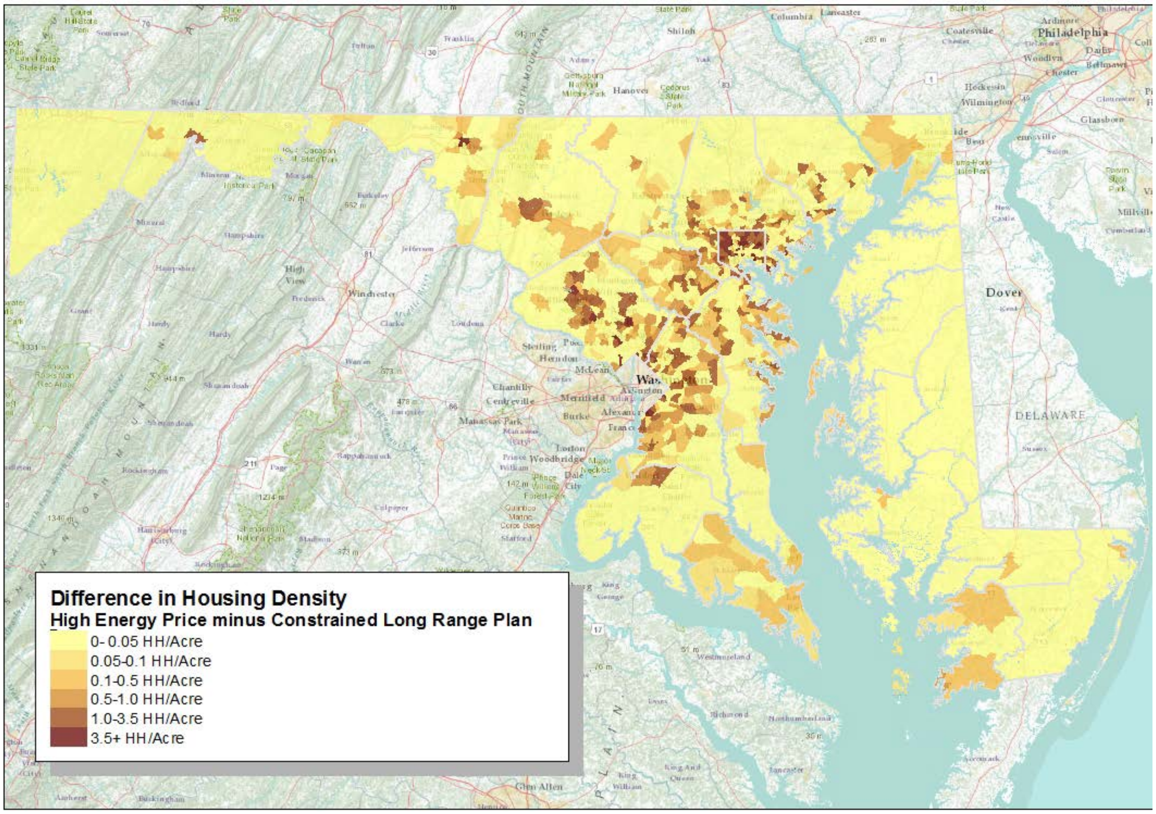
The number of jobs under the MDC scenario is five percent lower than the CLRP scenario. This occurs because the CLRP is based on forecasts produced by local officials while the MDC scenario is based on national and regional economic forecasts.

The distribution of jobs under the MDC differs little from the CLRP scenario. Employment remains concentrated in the central Baltimore, the DC suburbs and along the Baltimore-Washington and Interstate 270 corridors.

2.6 HIGH ENERGY PRICE SCENARIO (HEP)

The high-energy price scenario was created primarily to explore the effects of high energy prices on development patterns and travel behavior. As in the MDC scenario, this scenario derives population and employment from national forecasts of economic activity provided by the Inforum LIFT model (Appendix A1). These forecasts are then disaggregated to individual states, counties, and SMZs. Under the HEP scenario however, travel costs are set at $.42 per mile rather than the $.12 per mile under the MDC scenario. This results in a more concentrated distribution of activity, with population and employment centers closer together. In addition, high energy prices cause a slight decline in the total population and increase in employment compared to population and employment under the MDC scenario.

Figure 2.6-1. Difference in Household Density between HEP and CLRP

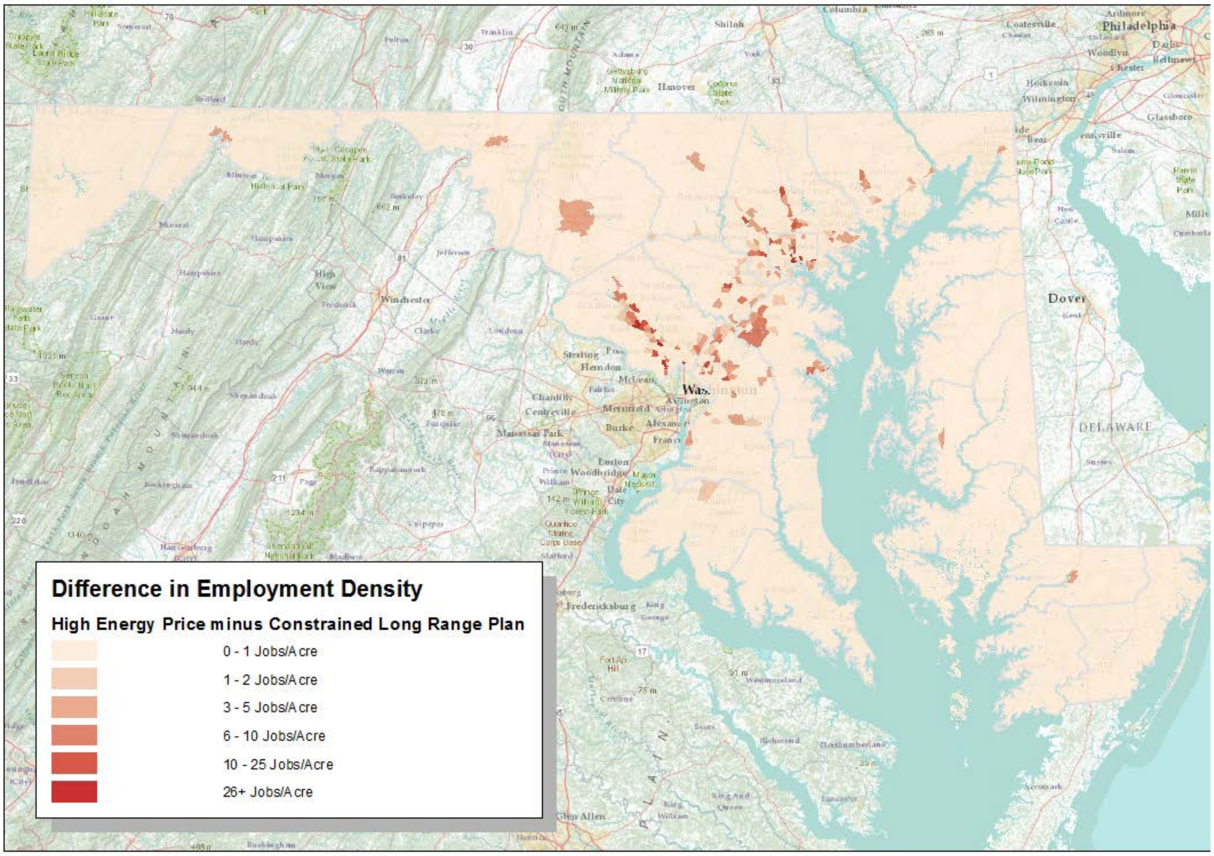


The number of households is about one percent lower in the HEP scenario than the CLRP scenario. This is due to the depressing effects of high energy prices on overall economic activity. Household growth under the HEP scenario is concentrated along rail served transit lines and in already developed areas. Increases in density are experienced in the following areas:

- Along the WMATA Red Line in Montgomery County
- The Metropolitan DC Suburbs
- Glen Burnie in Anne Arundel County
- Baltimore City
- Hunt Valley/Towson area of Baltimore County along the MTA Light Rail
- Harford County rail corridor (between Edgewood and Havre de Grace)

Some areas have fewer households under the HEP scenario than in the CLRP scenario. In particular, Columbia in Howard County experiences a decrease in density compared to the CLRP scenario. Other reductions are experienced in rural areas of Baltimore, Frederick, Harford, Prince George's and Washington Counties as well as parts of the eastern shore; all areas not served by transit.

Figure 2.6-2. Difference in Employment Density between HEP and CLRP



The High Energy Price scenario realizes a roughly four percent increase in total jobs over the Constrained Long Range Plan scenario. This is due to a number of economic factors, as it is rooted in a national economic model which shifts employment to Maryland from other parts of the country due to broader push/pull effects.

The distribution of jobs around the State under the HEP scenario does not differ much from the CLRP scenario. There are some areas that experience more employment growth, particularly the transit served areas in the DC and Baltimore metropolitan areas.

Other areas outside the traditional employment corridors experience a decrease in the number of jobs. These include:

- Municipalities: Chestertown, Cumberland, Easton, Salisbury, Waldorf & Westminster

- The central section of the Baltimore-Washington corridor, particularly around Columbia; results from jobs shifting to areas closer to the rail lines in the corridor and away from Columbia proper.

2.7 Scenario Performance Measures

To compare the land use scenarios described above a series of measures were computed to serve as performance measures. These include aggregate measures such as total jobs and household as well as spatially specific measures such as the share of jobs and households in particular geographic areas.

2.7.1 Total Employment and Households

The five future scenarios are derived using different methods. The Constrained Long Range Plan, Buildout and Transit Friendly scenarios are rule based and employ a "bottom-up" development strategy. In contrast, the Market Driven Change and High Energy Price scenarios are informed by national economic forecasts and thus use a "top-down" process. This variation in development and reliance on different levels of inputs creates differences in total household and employment yields under each scenario.

Table 2.7.1-1. Household and Employment Projections, Land Use Scenario Alternatives

Scenario	Households	Employment
Current Conditions (2007)	2,294,196	3,465,912
Constrained Long Range Plan (2030)	2,669,063	3,835,246
Buildout (No defined date)	3,135,208	4,671,005
Transit Friendly Development (2030)	2,669,063	3,835,246
Market Driven Change (2030)	2,818,601	3,648,040
High Energy Price (2030)	2,630,390	4,000,278

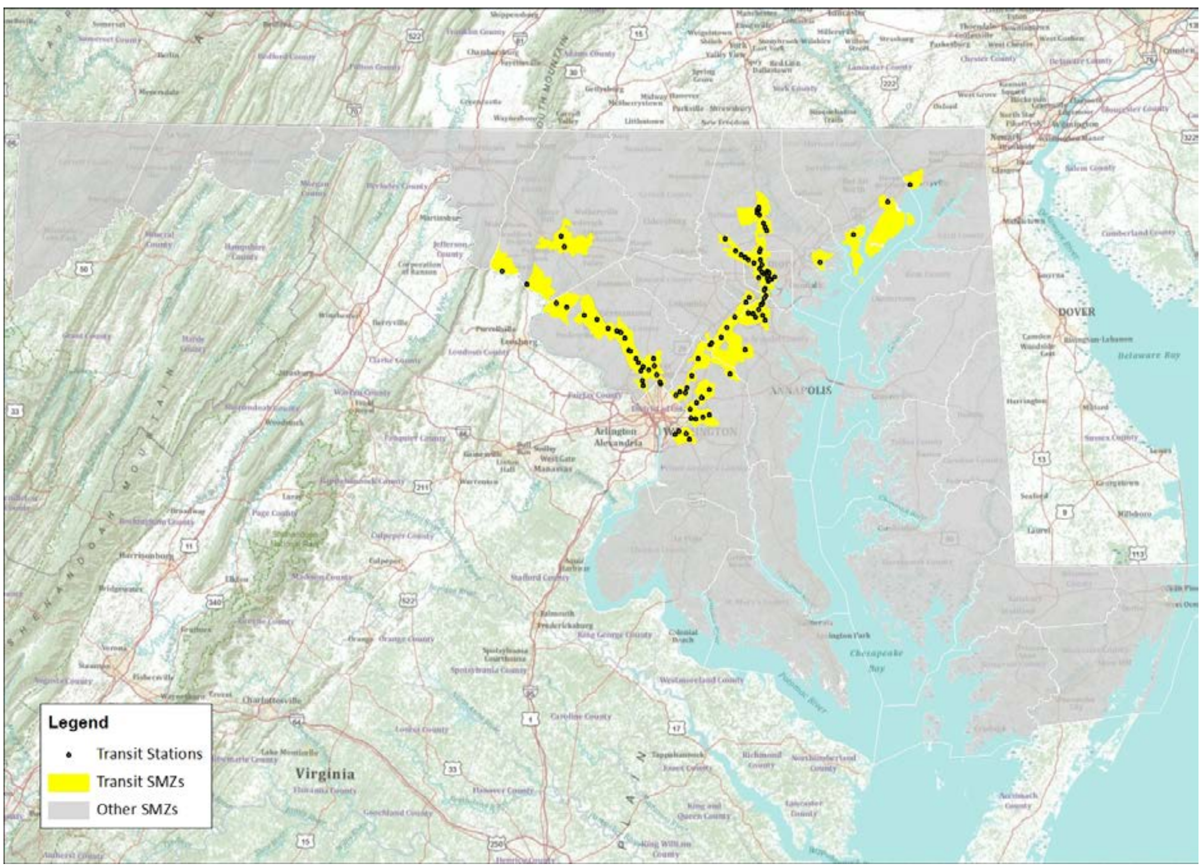
Table 2.7.1-1 above illustrates the total number of households and jobs projected under each scenario. In general there are not great differences in the total number of households between the CLRP, TFD, MDC, and HEP scenarios; none greater than 300,000. The number of households under the BO scenario, however, because it has no end date, is significantly higher than the other scenarios.

There is greater variation in employment between the scenarios. Again, this can be attributed to differences in how the scenarios were developed and that estimates of employment is more sensitive to these differences than estimates of households.

2.7.2 Geographic Performance Measures

Figure2.7.2-1 illustrates the areas included in transit served areas.

Figure 2.7.2-1. Transit Served SMZs



Inner Beltways

The share of jobs and households within the inner beltways of Baltimore and Washington are presented in Table 2.7.2-1. The HEP and TFD scenarios have the highest proportion of total housing units located within inner beltway areas. This is to be expected. The TFD scenario was developed specifically to do so. Under the HEP scenario, high auto-operating costs cause residents to locate near transit accessible areas. The BO scenario has the lowest proportion of housing within the inner beltway areas. This largely reflects the amount of development capacity that exists in the rural parts of the State.

Table 2.7.2-1. Housing and Employment in Inner Beltways

Scenario	Housing Units	Share of Total Housing	Employment	Share of Total Employment
Current Conditions	593,257	26%	968,195	28%
Constrained Long Range Plan	664,935	25%	1,012,318	26%
Buildout	667,634	21%	1,213,991	26%
Transit Friendly Development	764,094	29%	1,093,361	28%
Market Driven Change	769,289	27%	1,032,600	28%
High Energy Price	767,064	27%	1,186,208	26%

The total share of employment does not vary widely across the five scenarios. The highest proportion is represented by the TFD scenario, which again decreases the distance between housing and employment due to increased transit availability. The other three scenarios illustrate consistency in the representative proportion of total employment within the inner beltway areas. One additional note, the BO scenario yields the greatest difference in the proportion of jobs to the proportion of households of all of the scenarios. This further emphasizes the separation of households and employment under this scenario.

Transit Served SMZs

The share of jobs and households located in transit served areas in each of the five scenarios is presented in Table 2.7.2-2. The MDC and HEP scenarios feature the greatest proportion of total households within transit served areas. The CLRP and BO scenarios, conversely, feature the smallest proportions of househoulds in these areas.

Table 2.7.2-2. Housing and Employment in Transit Served SMZs

Scenario	Housing Units	Share of Total Housing	Employment	Share of Total Employment
Current Conditions	540,286	24%	1,311,446	38%
Constrained Long Range Plan	667,239	25%	1,564,521	41%
Buildout	653,748	21%	1,738,204	37%
Transit Friendly Development	821,903	31%	1,768,022	46%
Market Driven Change	842,856	30%	1,226,553	34%
High Energy Price	826,786	31%	1,412,255	35%

Employment distributions under the four scenarios illustrate different growth patterns. The MDC and HEP scenarios feature small shares of employment within transit served area while the TFD and CLRP scenarios feature the largest share of employment in transit served areas. The MDC scenario features the smallest share of employment in transit served areas. In contrast to the distribution of households, the market driven scenarios feature the lower concentration of jobs while the rule-based scenarios feature the greater concentration of jobs. This would appear to reflect the tendency of jobs to decentralize under market forces, even with high energy prices.

2.8 SUMMARY

This section of the report presented the spatial distribution of jobs and households under current conditions and five alternative future development scenarios. Three scenarios were rule-based and two were derived using econometric and land use models. The total number of jobs and household did not differ much between most of the scenarios, with the exception of BO. This occurred because all the future scenarios had 2030 horizons while BO had no horizon end date. The spatial distribution of jobs and household varied largely as expected. Households were most dispersed under the BO scenario and most concentrated under the TFD and HEP scenarios. Jobs were also most dispersed under the BO scenario but most concentrated under the TFD and CLRP scenarios. At a cursory level, this suggests that market forces tend to concentrate households, especially under high energy prices, and disperse jobs. By most measures of performance, the CLRP (see section 2.2 for details), the scenario that most closely reflects official government forecasts, fell in the mid range of the performance measures. In general, however, the scenarios appear to provide reasonable platforms for estimating travel behaviors under alternative land development patterns. That is the focus of the next sections of the report.

3 TRANSPORTATION SCENARIOS

The transportation scenarios examine the capability of the existing transit and highway networks to relieve congestion within Maryland. Four transportation scenarios have been developed: Baseline, Truck Diversion, Improved Transit Service and Express Toll Lane Network. All scenarios estimate travel activity in the year 2030.

Baseline: The Baseline scenario uses the 2030 Constrained Long Range Plans (CLRP) of the BMC and MWCOG, along with planned transportation network improvements, both transit and highway, including the ICC, expresses toll lanes on I-95, the Red Line and Purple Line. The Baseline serves as the basis of comparison for all other alternatives. These comparisons allow for the estimation of changes and impacts.

Alternative Scenario I (Truck Diversion): Many areas perceive trucks, particularly long distance trucks, as a critical factor in congestion. This scenario examines the effect of removing long distance truck trips from the highway network.

Alternative Scenario II (Improved Transit Service): Transit improvements can have the effect of increasing transit use and removing automobile trips from the highway network and reducing congestion. Under this scenario, the transit improvements, both rail and bus, are limited to operational improvements in the current transit system and do not include adding service to currently unserved areas or increasing the operating speed, both of which could have major impacts.

Alternative Scenario III (Express Toll Lane Network): New toll roads are often viewed as a method to relieve congestion. Many proposals for toll roads assume that funding for the roads can be provided through tolling. In this scenario, a network of toll roads, including some new capacity in the Baltimore and Washington areas, is developed and the impacts are analyzed.

Note that while Alternative Scenario II (Improved Transit Service) and -III (Express Toll Lane Network) are performed using the latest MSTM model and compared to the Baseline (CLRP) scenario, Alternative Scenario I (Truck

Diversion), Climate Change Scenario and Tolling Existing Lanes Scenarios are performed using an earlier version of the MSTM model. Since these scenarios are policies that are not considered for implementation, they are not re-run with the latest model.

3.1 ANALYTIC BASIS

The Maryland Statewide Transportation Model (MSTM), developed by the National Center for Smart Growth and Education (NCSGRE) at the University of Maryland and Parsons Brinckerhoff (PB) with the Maryland State Highway Administration (MD SHA), forms the analytic basis for the transportation analyses. The model is a three-level statewide transportation model. It covers the entire states of Maryland and Delaware, the District of Columbia, and adjacent portions of Southern Pennsylvania, Northern Virginia and West Virginia (see Figure 3.1-1 for MSTM coverage). In order to correctly estimate travel demand among Maryland, surrounding states and the rest of the United States, the MSTM represents travel with each of the other states. The MSTM has close linkages with the Baltimore Metropolitan Council (BMC) and Metropolitan Washington Council of Governments (MWCOG) travel forecasting models. Within the BMC and MWCOG areas the State Model Zones (SMZ) are identical to the MPO zones. Documentation on the MSTM will be available in the Fall of 2012.

The MSTM uses a traditional four-step travel forecasting process composed of:

Step 1: (Trip Generation) estimating how many trips are made and trip origins and destinations.

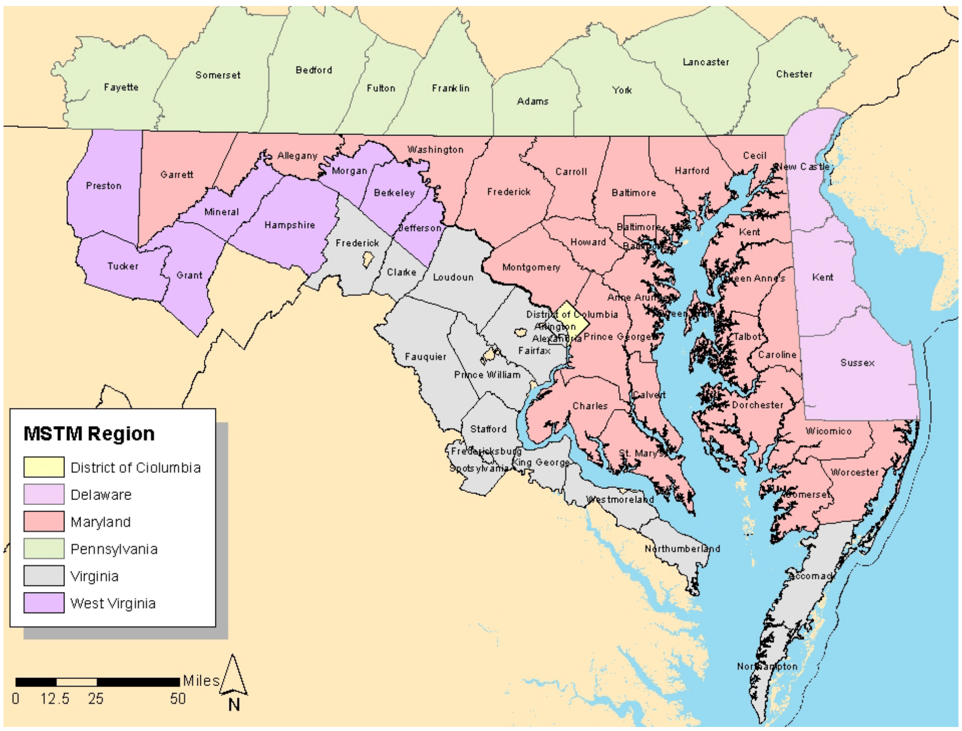
Step 2: (Trip Distribution) linking origins to destinations. Linkages are based on generalized travel costs between zones (as travel costs increase the destination zones become less attractive) and the amount and types of activity in the destination zones (as activity increases the zones become more attractive).

Step 3: (Mode choice) estimating those trips on highway and transit. 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.

Step 4: (Assignment) calculating the volume and speeds on links in the highway network.

Figure 3.1-1. Map of the MSTM study area



A more detailed description of the analytic procedures used in mode choice can be found in Appendix B2 and B3.

The MSTM includes both passenger and freight travel within the coverage area (Figure 3.1-2) as well as travel in the remainder of the United States bound for the study area. The MSTM estimates travel for four time periods: AM peak, PM peak, mid-day (MD) and evening (night) time (NT). While non-motorized travel is not specifically modeled, trip generation is a function of density and denser areas produce fewer trips. The reduction in travel due to density includes the shift from motorized to non-motorized travel.

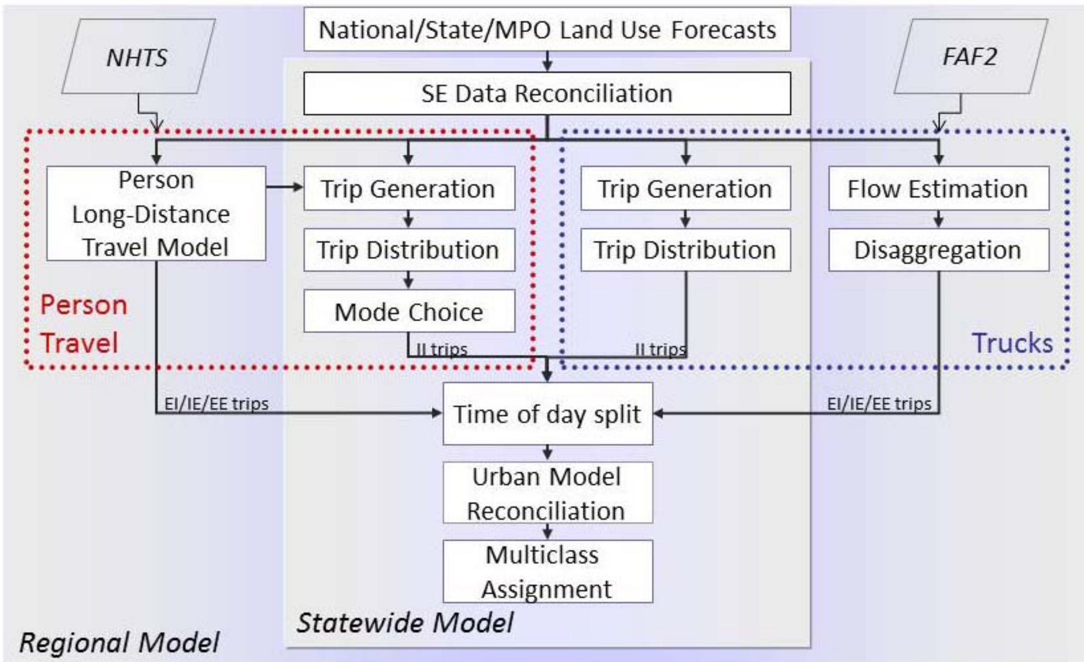
Key input data to the MSTM includes the population and employment, by income category, for each traffic zone, long distance person travel obtained from the National Estimate of Long Distance Travel (NELDT), Long distance truck movements derived from FHWA's Freight Analysis Framework (FAF) and a short distance freight model. The highway network is based on the networks from the Baltimore and Washington MPOs, supplemented by the statewide network and networks from surrounding states. The transit networks are derived from the Baltimore and Washington MPO networks and include WMATA, the MTA system, MARC and all local transit systems within the Baltimore-Washington area. The transit networks include the Baltimore Red Line, Montgomery to Prince Georges County Purple Line and the Cross County Connector in Montgomery County (see appendix B2 for a list of transit services in the 2007 network). Shore Transit in Salisbury Maryland, critical transit service but one which carries a very small portion of total travel, was not included due to data not being available at the time of model development.

All analyses were conducted using the Maryland Statewide Transportation Model, a four step travel forecasting model developed for the Maryland State Highway Administration. The steps include trip generation, estimating the origins and destinations of trips; destination choice, relating trip origins to destinations; mode choice, estimating whether trips travel by highway or transit; and assignment, placing trips on the network and calculating travel times. Travel was divided into four time periods, AM Peak, Mid-day, PM peak and night.

All analyses were conducted for all time periods, with the greatest impact shown during the peaks. Tolls were fixed for each time period. The analyses included all planned transit and highway improvements in 2030, including the Intercounty Connecter (ICC), express toll lanes on I-95, the Red Line and the Purple Line. Due to the large size of the traffic analysis zones and the structure of the model results for transit usage the model does not fully account for fine grained land use factors such as urban design and mix of uses, although density does affect the number of trips originating in a zone. Induced (or suppressed) travel due to infrastructure changes is partially accounted for through changes in trip routes, changes in destination and changes in mode usage. The model does not change the number of trips due to changes in infrastructure. The analyses did not include measures of cost effectiveness or cost-benefit and these should obviously be considered when deciding on specific projects.

An initial comparison was made between the 2007 current conditions and the 2030 CLRP. All other comparisons were between the 2030 CLRP and specific scenarios.

Figure 3.1-2. Flow diagram of the MSTM model

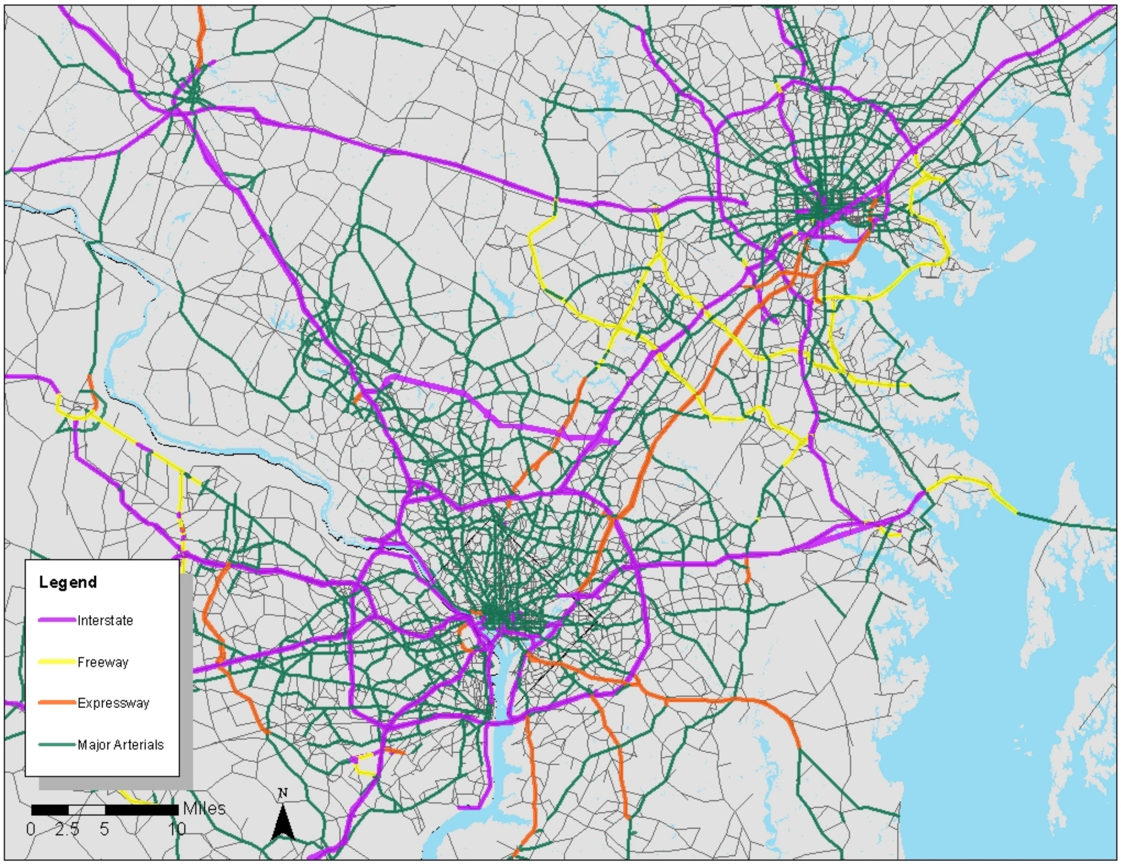


Source: Maryland Statewide Transportation Model (MSTM): User Guide. Baltimore, State Highway Administration, (2011).

3.2 ANALYSIS FRAMEWORK

The scenario analysis is conducted comparing the results with the Baseline scenario. Three main performance measures are used for analysis: Vehicle Miles Traveled (VMT), Vehicle Hours Traveled (VHT) and Vehicle Hours Delay (VHD). These measures are reported for AM and PM peak periods for six major road facility types, namely interstate, freeway, expressway, major arterial, minor arterial and collector for each scenario (Appendix B1, Tables B1-1 through B1-13). In addition, percent changes that each scenario provided with respect to the Baseline scenario are also presented (Appendix B1, Tables B1-1 through B1-13) and utilized while discussing impacts of each scenario. Note that in all figures in Section 3 and 4, four major road facility types are presented for ease of presentation and the term “Total” is used to represent the sum of ten road facility statistics. These four facilities, namely interstates, freeways, expressways and major arterials are illustrated in Figure 3.2-1 below.

Figure 3.2-1. Layout of four major facility types in the region

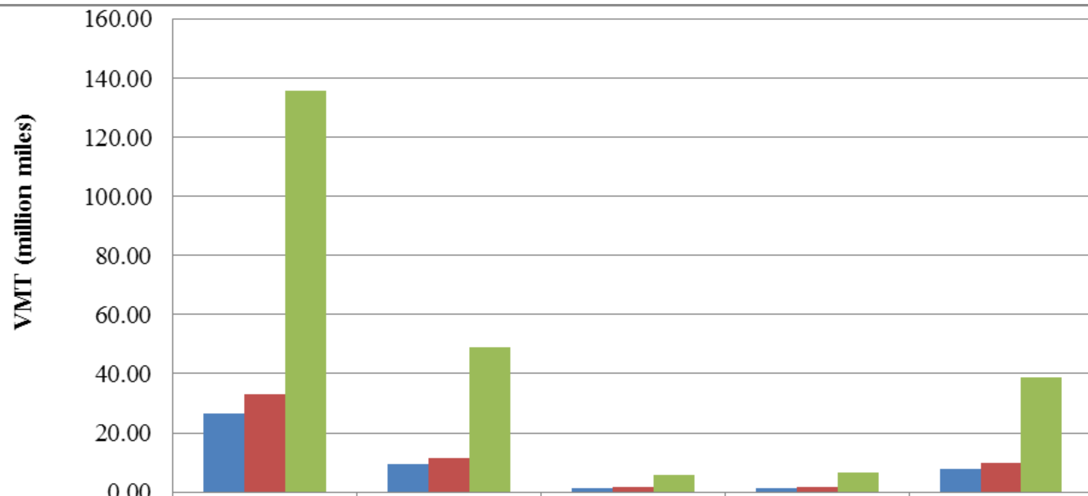


3.3 CURRENT CONDITIONS

The Current Conditions scenario is formed by using the 2007 MSTM transportation network and observed land use data. The MSTM was built on 2007 data so 2007 model is assumed as the existing conditions scenario as it was built with the latest available data. In the current conditions, 1.66% of all trips are made by bus and 2.99% are made by rail while 41.94% are made by HOV and remaining 53.41% are made by SOV vehicles.

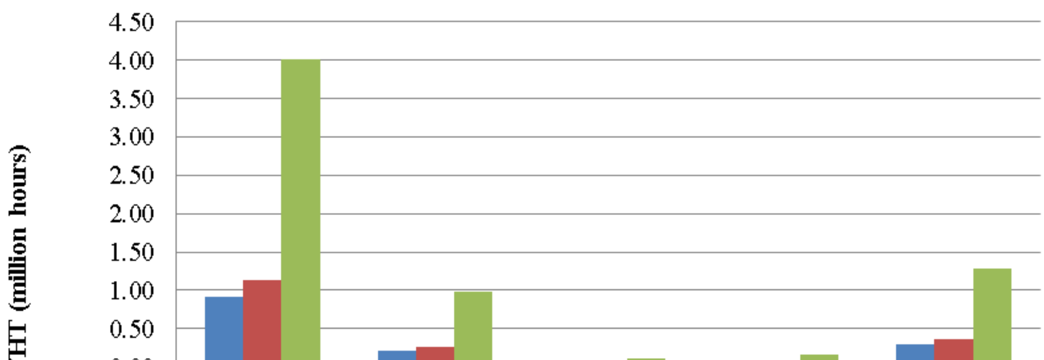
The majority of the vehicle miles occur on interstate and major arterial roads in the AM and PM peak periods (Figure 3.3-1). While VMT is higher on interstate roads, the time spent traveling on major arterial roads is higher (Figure 3.3-2). This is likely due to the delays caused by lower speeds and the existence of controlled intersections along the arterial roads. Comparing AM and PM periods, it is observed that VMT values in the PM period are slightly higher than the AM period. This may be due to additional trips in the PM peak period, such as shopping on the way back home. The VHT values are also slightly higher for PM period while VHD remains slightly higher for AM peak period (Figures 3.3-2 and 3.3-3).

Figure 3.3-1. Current Conditions-VMT (million miles)



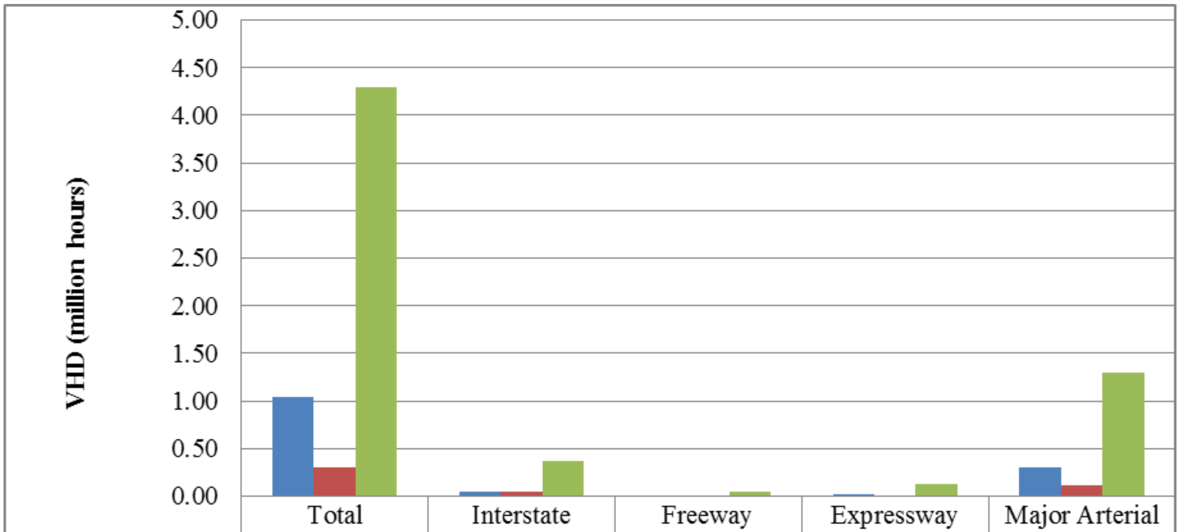
	Total	Interstate	Freeway	Expressway	Major Arterial
AM	26.713	9.213	1.222	1.201	7.870
PM	33.003	11.239	1.466	1.458	9.822
ALL PERIODS	135.747	48.788	5.700	6.380	38.897

Figure 3.3-2. Current Conditions -VHT (million hours)



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	0.909	0.216	0.027	0.036	0.293
PM	1.129	0.261	0.032	0.045	0.364
ALL PERIODS	4.013	0.988	0.110	0.155	1.285

Figure 3.3-3. Current Conditions -VHD (million hours)



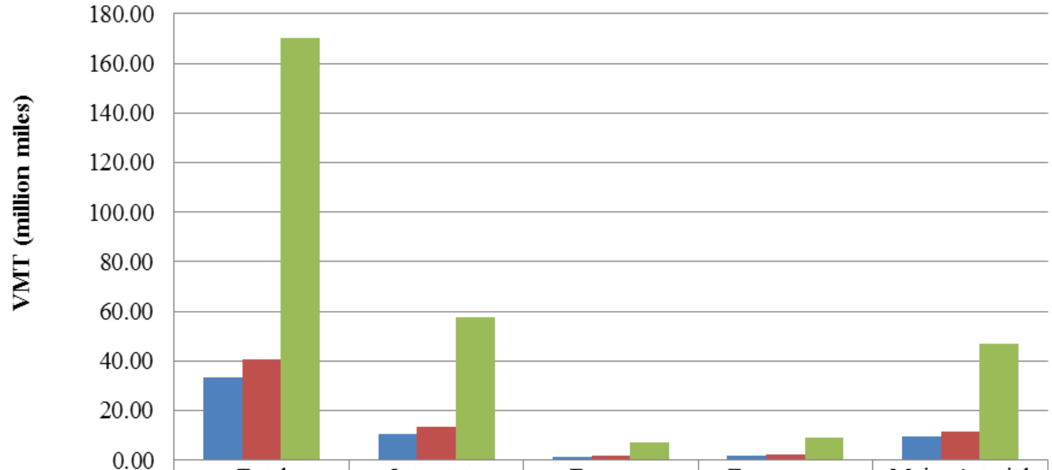
	Total	Interstate	Freeway	Expressway	Major Arterial
AM	1.046	0.050	0.008	0.021	0.299
PM	0.299	0.051	0.001	0.006	0.114
ALL PERIODS	4.292	0.375	0.049	0.123	1.299

3.4 BASELINE SCENARIO

The Baseline scenario is formed by using the 2030 Constrained Long Range Plan (CLRP) transportation network and projected land use data. This scenario provides a basis for comparison for all other alternative scenarios. According to the Baseline scenario, 0.99% of all trips are made by bus and 4.16% are made by rail while 41.66% are made by HOV and remaining 53.18% are made by SOV vehicles.

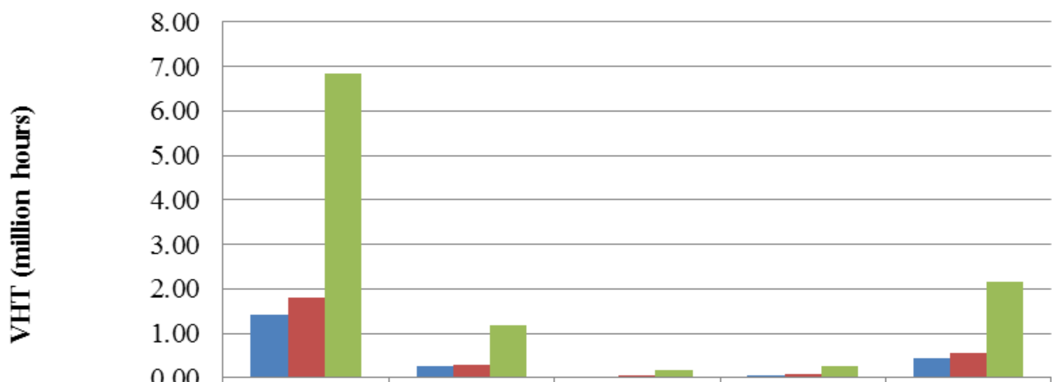
In the Baseline scenario, similar to the CC scenario, it is observed that the majority of the vehicle miles are traveled on interstate and major arterial roads in the AM and PM peak periods (Figure 3.4-1). While VMT is higher on interstate roads, the time spent traveling on major arterial roads is higher (Figure 3.4-2). VMT, VHT and VHD values are relatively lower for freeway and expressway facilities likely due to their limited access, high-speed characteristics as well as the limited supply.

Figure 3.4-1. Baseline-VMT (million miles)



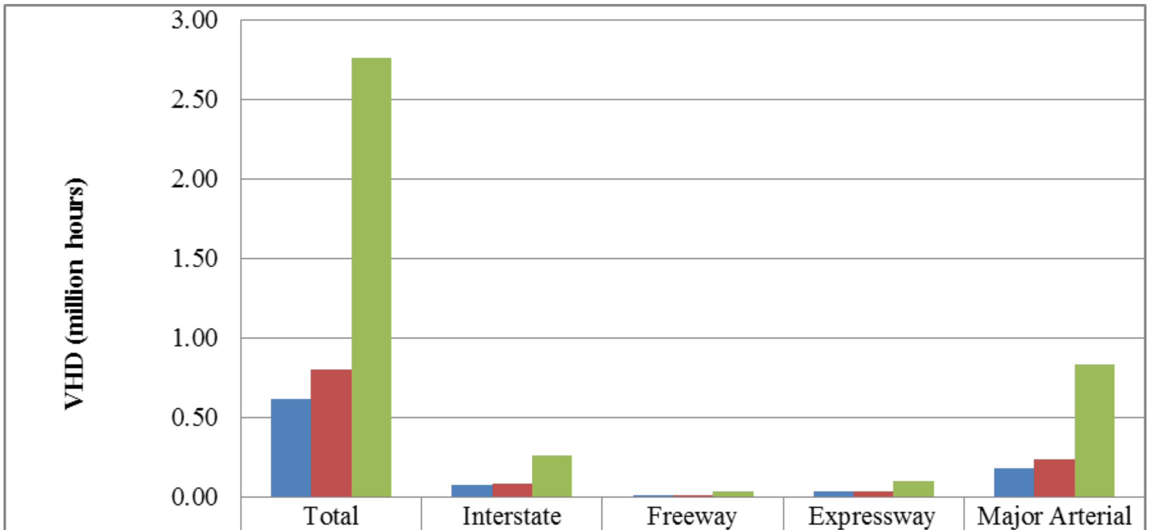
	Total	Interstate	Freeway	Expressway	Major Arterial
AM	33.130	10.756	1.446	1.717	9.447
PM	40.780	13.195	1.771	2.095	11.595
ALL PERIODS	170.174	57.605	7.091	9.180	47.058

Figure 3.4-2. Baseline-VHT (million hours)



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	1.422	0.250	0.039	0.068	0.452
PM	1.795	0.302	0.047	0.074	0.565
ALL PERIODS	6.852	1.198	0.164	0.269	2.160

Figure 3.4-3. Baseline-VHD (million hours)



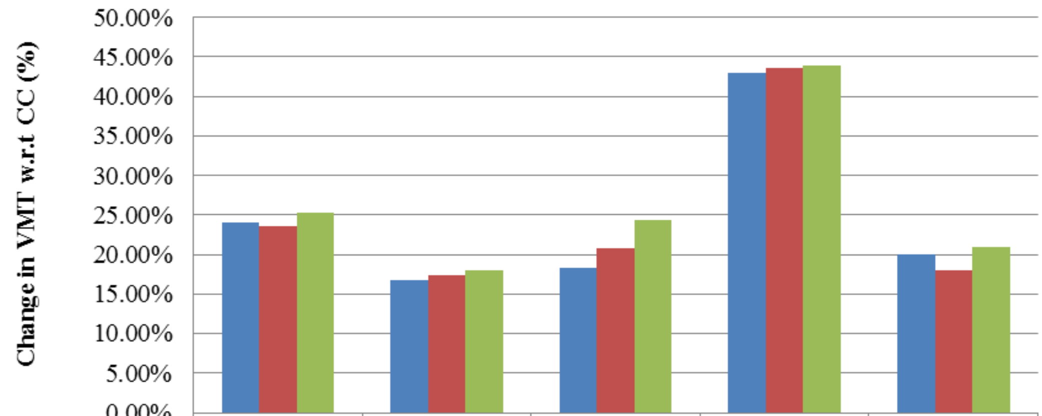
	Total	Interstate	Freeway	Expressway	Major Arterial
AM	0.618	0.075	0.013	0.036	0.184
PM	0.802	0.086	0.016	0.035	0.236
ALL PERIODS	2.764	0.262	0.038	0.098	0.834

AM and PM periods also show similar characteristics to Current Conditions scenario except the VHD. VMT values in the PM period are slightly higher than the AM period. This may be due to additional trips in the PM peak period, such as shopping on the way back home. The VHT and VHD values are also slightly higher for PM period. This is most likely due to the dispersed nature of the destinations in the PM period as opposed to more focused trip destinations in the AM peak period (e.g. AM trips are destined to work locations and central business districts (CBDs)). As seen in Figures 3.4-2 and 3.4-3, VHT and VHD are higher in evening peak, indicating that congestion is more severe in the PM peak.

3.4.1 Comparing Baseline Scenario with 2007 Conditions

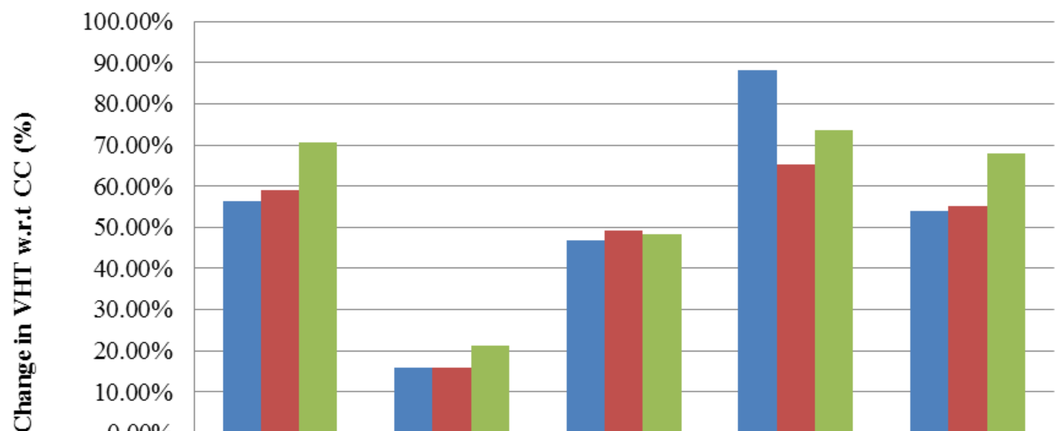
From 2007 to 2030, the population and employment continues to grow in the region. As seen in Figure 3.4.1-1 below, much of the increase in VMT and congestion in 2030, when compared to Current Conditions, is due to the growth in households and employment. Households will grow by about 16% and employment by 11%, making for more driving, more traffic and more congestion in the region (see Table 2.7.1-1 in Section 2.7.1 for growth projections). The increase in VMT varies from 17% to 43% by facility types in the AM peak period. The highest VMT increase is observed on expressways while interstates saw the lowest. The increase in VHT and VHD are much more significant varying from 16 to 88% for VHT and 11 to 120% for VHD in the AM peak period (Figures 3.4.1-2 through 3.4.1-3).

Figure 3.4.1-1. Difference in VMT between CLRP and Current Conditions



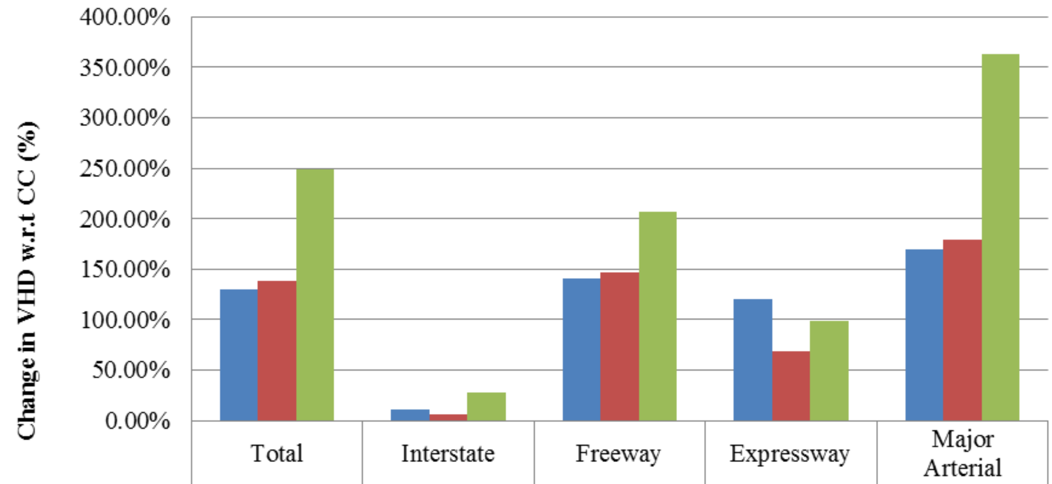
	Total	Interstate	Freeway	Expressway	Major Arterial
AM	24.02%	16.75%	18.25%	42.97%	20.04%
PM	23.56%	17.40%	20.82%	43.66%	18.05%
ALL PERIODS	25.36%	18.07%	24.39%	43.88%	20.98%

Figure 3.4.1-2. Difference in VHT between CLRP and Current Conditions



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	56.42%	15.93%	46.74%	88.29%	54.00%
PM	58.94%	15.76%	49.31%	65.25%	55.07%
ALL PERIODS	70.75%	21.28%	48.31%	73.52%	68.02%

Figure 3.4.1-3. Difference in VHD between CLRP and Current Conditions



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	130.37%	10.66%	141.26%	120.56%	169.88%
PM	138.07%	6.38%	146.47%	68.16%	179.69%
ALL PERIODS	249.14%	27.90%	206.85%	98.24%	362.76%

Figures 3.4.1-4 and 3.4.1-5 below illustrate change in daily link volume and congested link speeds in AM peak period between the 2030 Baseline and the 2007 conditions. As seen, most of the facilities on the region sees significant increases on link volume and speeds while some decreases are also observed. These decreases could be attributed to the additional transit services e.g. Red and Purple Lines in the region.

Figure 3.4.1-4. Difference in link volume between CLRP and CC

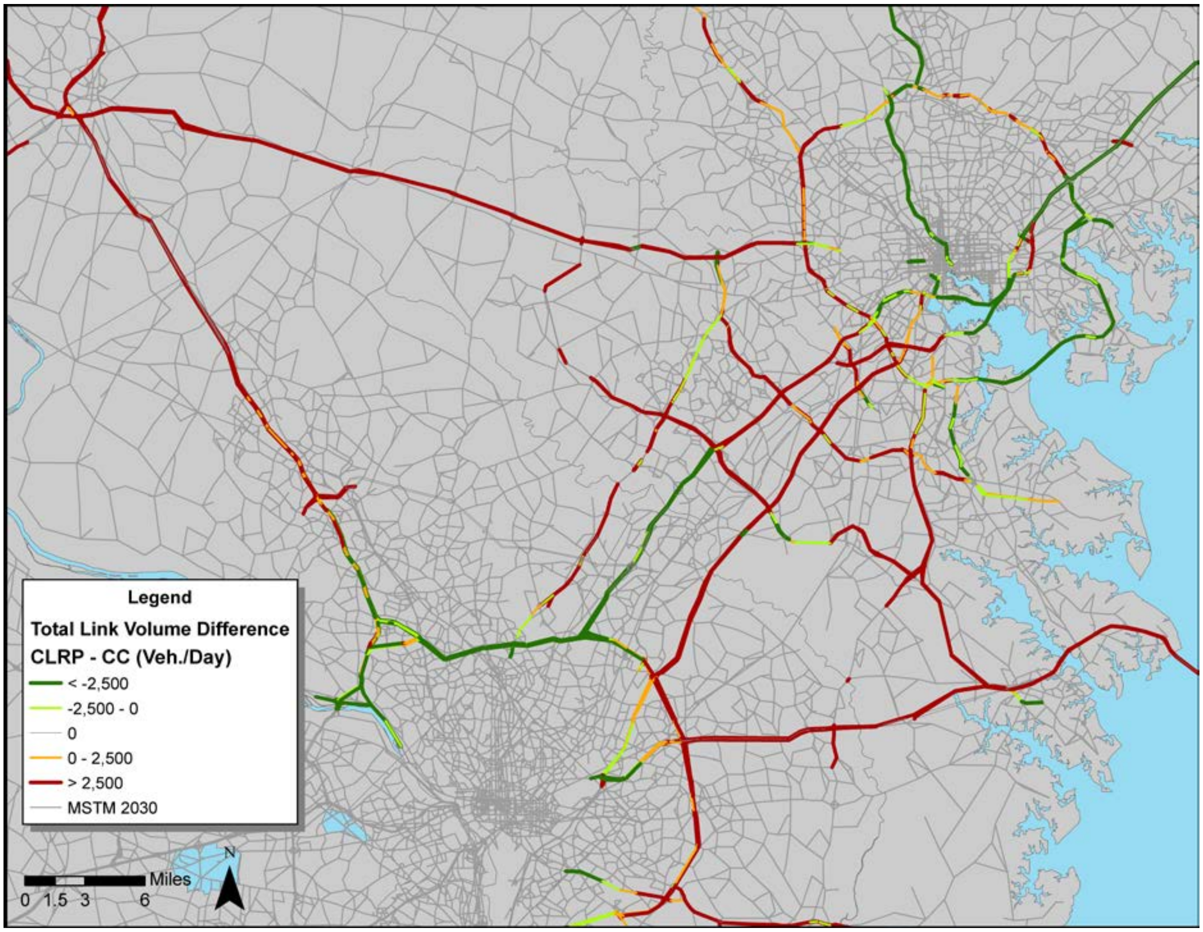
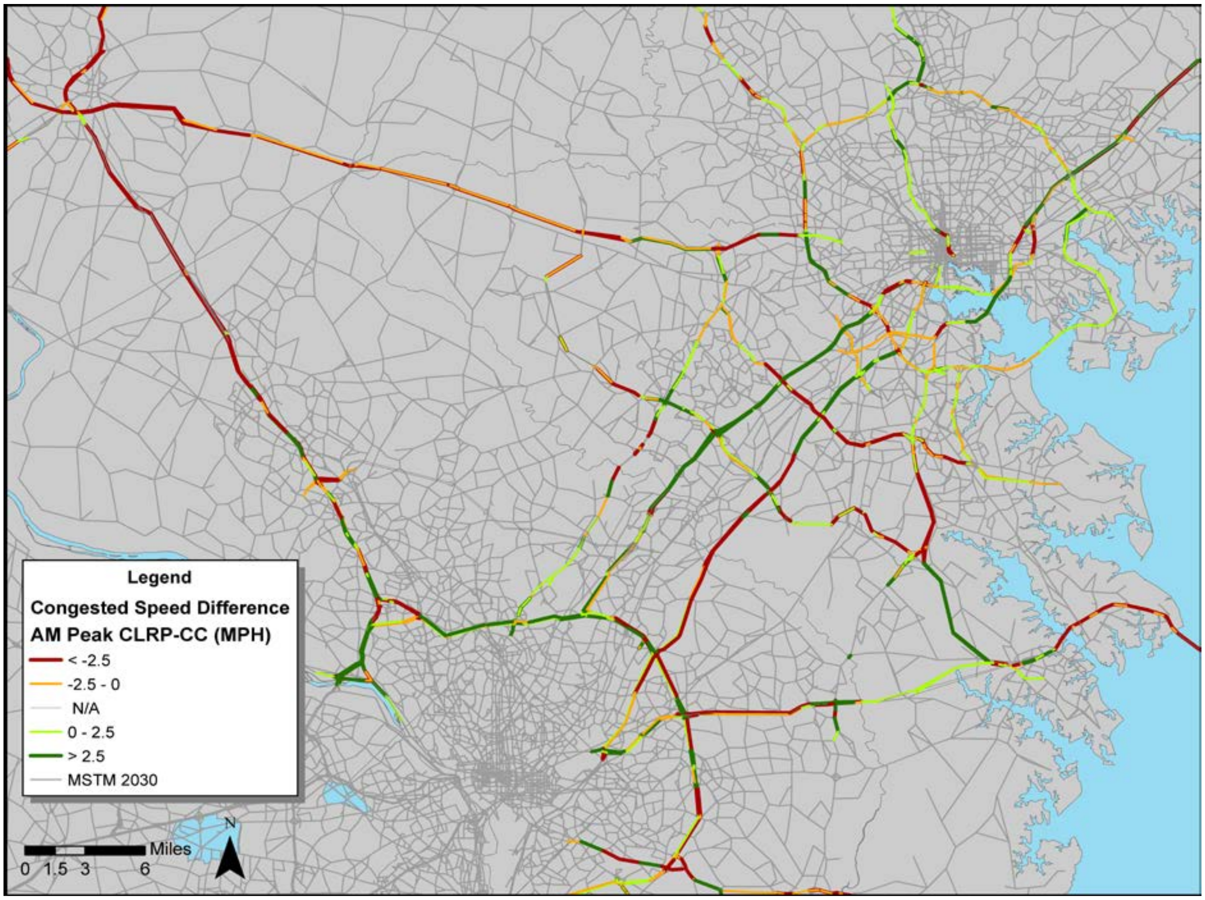


Figure 3.4.1-5. Difference in congested link speed between CLRP and CC, AM Peak Period



For some links the speeds increase and volummes decrease in 2030. This is usually due to capacity being added to the netowrks in 2030. For example, the ICC was not a part of the netowrk in 2007 but is included in the 2030 network.

3.4.2 Summary

In the future the area will see significant increases in congestion in both the morning and evening peak periods. The increase will be greatest on major arterials but also occur on freeways, expressways and interstates. Most of the increase will be due to the growth in households and employment. In certain cases, the conditions on specific links improve. This is due to changes in transportation system and new capacity being added.

3.5 ALTERNATIVE SCENARIO I: TRUCK DIVERSION

Maryland's truck traffic is growing and will continue to grow. With planned multi modal connections the rate of growth will likely increase. This scenario focuses only on long distance truck trips and the potential impact of diverting them to rail. This scenario is not a comprehensive examination of the impact of truck travel on traffic.

The Truck Diversion[1] scenario examines the potential of diverting truck travel to other modes as a method of reducing congestion and improving travel time. The scenario involves first determining how many truck trips could be diverted from the highway to other modes and second, since not all trips would shift, estimating a portion that would actually divert. The scenario did not examine mechanisms to accomplish the diversion or whether the other modes', mainly the rail system had the capacity to carry the increased load, rather the scenario examined whether such a diversion would produce a desirable outcome on the roadways.

Our analysis examined the impact of diverting long distance truck trips, those greater than 400 miles in length, to rail. In analyzing the data, it was found that truck trips are evenly distributed throughout the day. In the three hour AM peak, there were 6,268,000 total trips but only 45,000 were long distance truck trips. In the three hour PM peak, there were 7,384,000 total trips but only 45,000 of them were long distance truck trips. The AM and PM peak periods were selected for analysis based on their carrying the greatest amount of traffic. The mid-day and

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[1] In order to properly construct the scenario, planning staff at the Port of Baltimore were initially interviewed to determine factors involved in choosing between highway and rail modes. Generally rail shipments are dominated by low unit value bulk commodity movements which are not time sensitive, such as coal and grain. High unit value items, such as expensive electronic equipment, travel almost exclusively by truck. It is only shipments in the mid-range which may shift between truck and rail. In addition, except for the very low value bulk commodities, shipments of less than 400 miles nearly always travel by truck. The cost and time involved with unloading cargo at a rail terminal and shipping by truck to the final destination make rail shipments of short duration less desirable.

evening travel times did not have sufficient traffic to merit analysis. Table 3.5-1 below summarizes truck trip shares in AM and PM peak periods.

Table 3.5-1. Long Distance Trucks as a Percentage of Total Travel

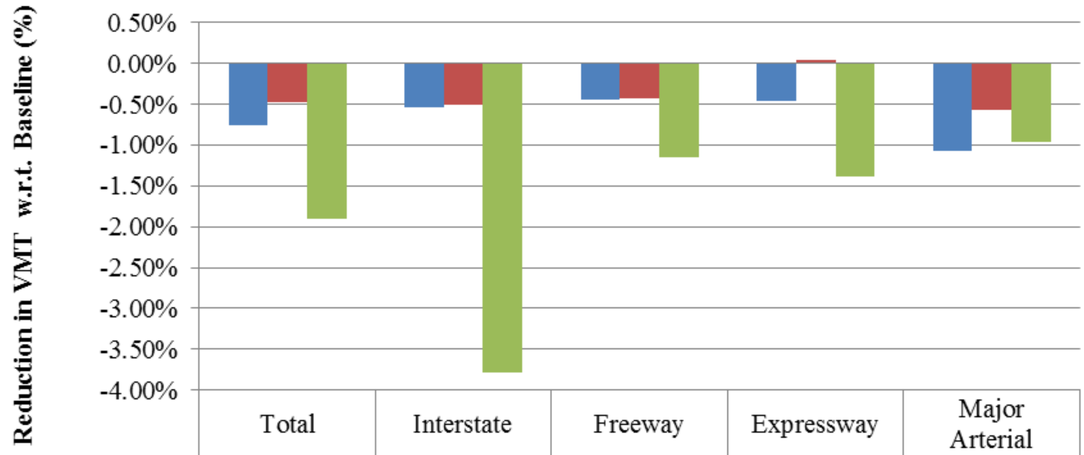
Period	Total Trips	Auto Trips (%)	Short Distance Truck (%)	Long Distance Truck (%)
AM Peak	6,268,000	92.00%	7.28%	0.72%
PM Peak	7,384,000	93.44%	5.95%	0.61%

The analysis is conducted using VMT, VHT and VHD and comparing them with the Baseline. The percent changes with respect to the Baseline scenario are illustrated in Figures 3.5-1, 3.5-2 and 3.5-3 below. Detailed VMT, VHT and VHD measures are given in Appendix B1, Tables B2.

As seen in Figures 3.5-1, 3.5-2 and 3.5-3, diversion of long distance truck trips does not significantly reduce VMT on the four major road facilities. The highest reduction is about 1% on major arterials while a slight increase is observed in expressway VMT. The reduction in VMT is higher in the AM period, especially for expressways and major arterials (Figure 3.5-1).

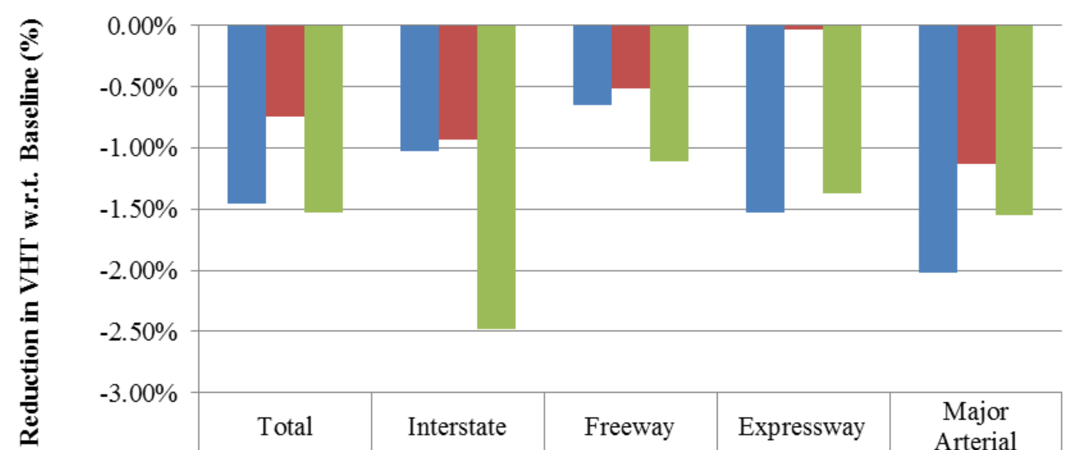
Reduction in VHT and VHD are observed but again not at a significant level. The highest VHD reduction is observed at 2.5% for the AM peak on major arterials. Note that these reductions are likely due to reducing truck travel as opposed to eliminating truck-auto interaction. The PM peak for expressways does not show a significant change because not many trucks are removed.

Figure 3.5-1. Reduction in VMT provided by truck diversion scenario



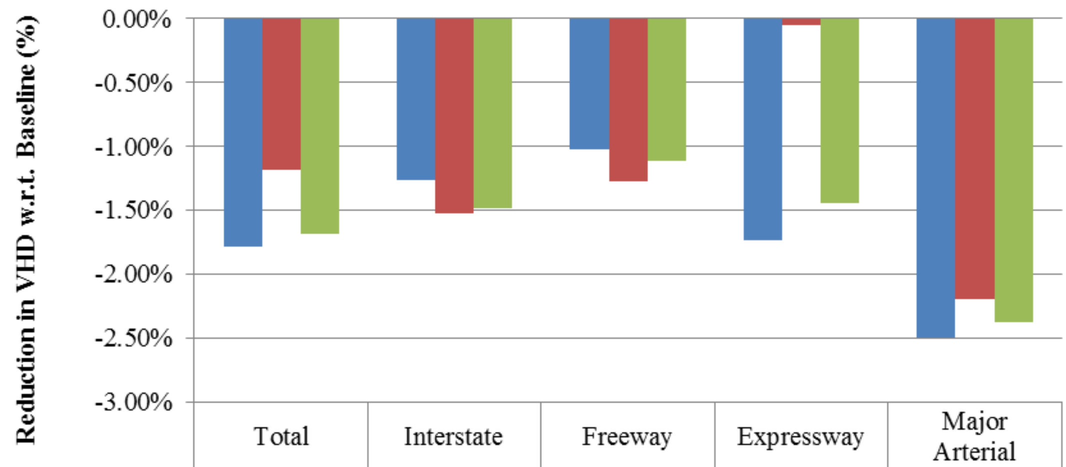
	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-0.76%	-0.54%	-0.44%	-0.46%	-1.07%
PM	-0.48%	-0.50%	-0.43%	0.04%	-0.56%
ALL PERIODS	-1.90%	-3.79%	-1.14%	-1.39%	-0.97%

Figure 3.5-2. Reduction in VHT provided by truck diversion scenario



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-1.45%	-1.03%	-0.65%	-1.53%	-2.02%
PM	-0.75%	-0.94%	-0.51%	-0.03%	-1.13%
ALL PERIODS	-1.53%	-2.48%	-1.11%	-1.37%	-1.55%

Figure 3.5-3. Reduction in VHD provided by truck diversion scenario



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-1.79%	-1.26%	-1.03%	-1.74%	-2.50%
PM	-1.18%	-1.53%	-1.28%	-0.06%	-2.19%
ALL PERIODS	-1.68%	-1.48%	-1.11%	-1.44%	-2.37%

3.5.1 Summary

The results show that even diverting all long distance truck travel from highway to other modes would not have an appreciable impact on roadway congestion. Long distance trucks represent a very small portion of the total travel and do not significantly impact congestion. Ameliorating congestion through truck diversion will require actions which encourage shorter distance truck trips and higher value cargos to move from highway to rail. The state is currently looking to increase multi-modal connections which will support more efficient freight movements and easier transfers between truck and rail. When implemented, a separate analysis can be done on the potential impact of these connections on truck and rail traffic.

3.6 Alternative Scenario II: Improved Transit Service

This Improved Transit Service scenario examines the potential of enhanced transit service to improve traffic flow and the overall transportation system performance, decreasing headways and fares. The scenario focuses on existing transit routes and represents the likely maximum improvements which a transit operator could make to an existing transit system. Thus, they are limited to operational improvements in the current transit system and do not include adding service to currently unserved areas or increasing the operating speed, both of which could have major impacts.

In some cases increasing service frequency may have little or no effect. In Washington DC, on the Metro, peak hour service on some lines typically has 3 minute headways. Decreasing these headways to 90 seconds will likely have little effect on ridership when all other factors involved in choosing transit are considered. The results of the scenario thus provide guidelines on the overall potential of the existing transit system to reduce congestion. They are not meant to recommend improvements to specific transit lines or routes. [2]

To understand the results of the scenario, we first provide a description of the transit market and how the transit market share is determined in Appendix B2. Note that transit market is primarily defined as the Baltimore Washington Metropolitan area for the analysis.

3.6.1 Testing of Transit Alternatives

Three alternative transit improvement scenarios were tested. These scenarios include reducing the fare, reducing the headways, and reducing both the fare and headways. These were system-wide improvements applied to every transit route in the 2030 network in the entire modeling area. The transit networks include the Baltimore Red Line, Montgomery to Prince Georges County Purple Line and the Cross County Connector in Montgomery County[3]. Two additional scenarios were tested; the first arbitrarily doubles the rail speeds and the second doubles the transit ridership, both obtained from earlier runs of the MSTM. All of these scenarios were then compared to the Baseline scenario representing the existing operating conditions of the system. The feasibility of implementing this type of change was not addressed nor was a transit line by transit line analysis conducted.

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[2] For a more detailed description of the analytic methods and transit lines included see section 3.1 Analytic Basis and Appendices B2 and B3.

[3] Shore Transit in Salisbury Maryland, critical transit service but one which carries a very small portion of total travel, was not included due to data not being available at the time of model development.

The types of service improvements described here would require major capital improvements on the part of transit operators and would stretch the operating capability of rail transit systems.

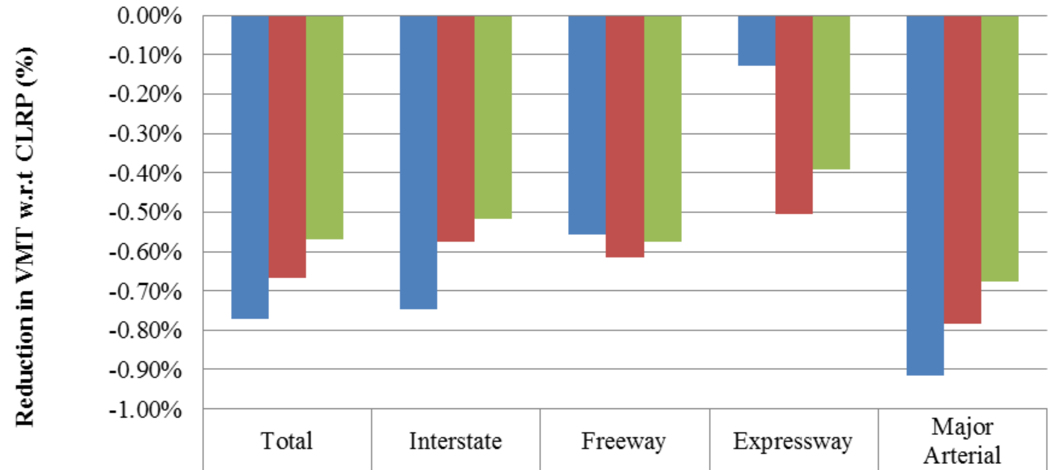
The modeling of traveler decisions to use auto or transit involves a complex comparison between the two modes. On the highway side it includes drive time plus cost, including parking. On the transit side it includes access time (walk or park and ride), wait time, in-vehicle time, fare and the number of transfers. These scenarios only affect wait time and fares, leaving access time, in-vehicle time and highway time and highway cost the same. In some scenarios, and for some trips, changes in transit wait time (headways) or fares may have limited impact on total transit utility. In addition, a large portion of transit riders may be transit captives, that is without access to an automobile. Transit captives will take transit regardless of the cost and time. This is discussed further in Appendix B3 and in the conclusions.

Transit Improvement Scenario (TIS-1) – Decrease Fare 50%

This Transit Improvement Scenario investigates the impacts of a reduced fare on traffic conditions. Figures 3.6.1-1 through 3.6.1-3 below illustrate the impacts of fare reduction on VMT, VHT and VHD in comparison to the Baseline scenario. As seen, reducing the fare by 50% provides slight reductions in VMT, VHT and VHD for all reported road types in all time periods. While the reductions in VMT and VHT are not significant (less than 3%), the reduction in VHD is slightly higher (less than 6%).

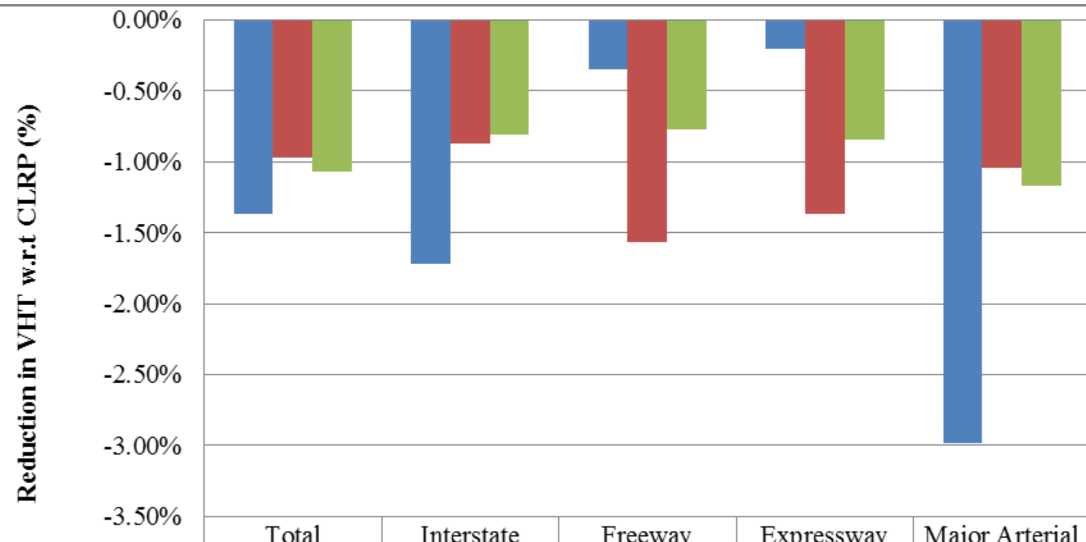
Note: In estimating transit ridership, transit travel time and cost are compared to highway time and cost. In cases where transit fares are already low, lowering them further is not likely to have an impact. Also, for trips where time is a major factor, lowering costs is not likely to have a significant impact. For a more detailed discussion of the factors influencing transit choice see appendix B2.

Figure 3.6.1-1. Change in VMT for Transit Scenario- Decrease fare 50%



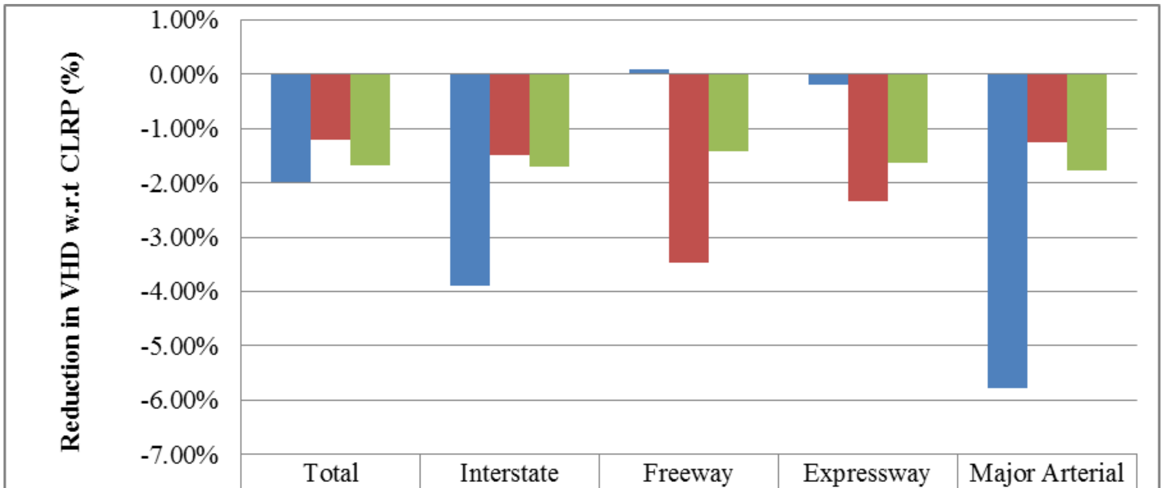
	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-0.77%	-0.75%	-0.56%	-0.13%	-0.91%
PM	-0.67%	-0.58%	-0.62%	-0.50%	-0.78%
ALL PERIODS	-0.57%	-0.52%	-0.57%	-0.39%	-0.68%

Figure 3.6.1-2. Change in VHT for Transit Scenario- Decrease fare 50%



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-1.37%	-1.72%	-0.34%	-0.20%	-2.98%
PM	-0.97%	-0.87%	-1.57%	-1.37%	-1.05%
ALL PERIODS	-1.07%	-0.81%	-0.77%	-0.85%	-1.17%

Figure 3.6.1-3. Change in VHD for Transit Scenario- Decrease fare 50%

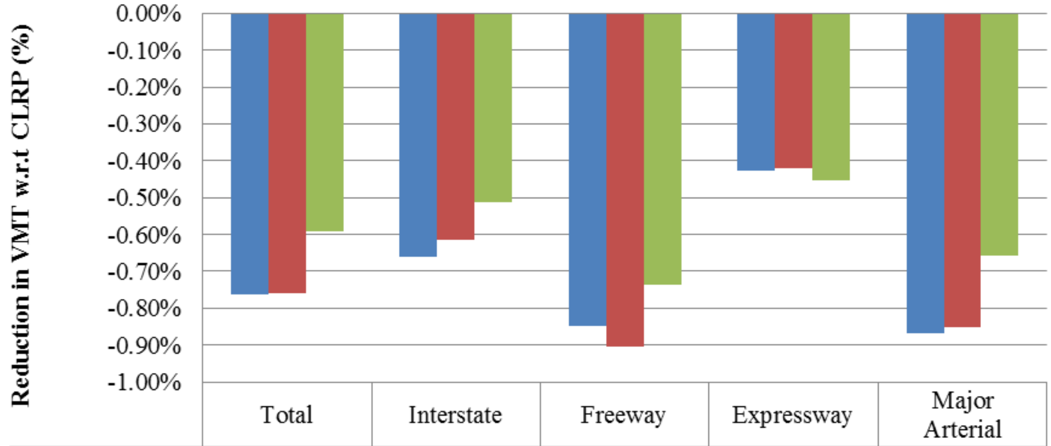


	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-1.99%	-3.88%	0.08%	-0.20%	-5.77%
PM	-1.21%	-1.50%	-3.46%	-2.34%	-1.24%
ALL PERIODS	-1.68%	-1.70%	-1.41%	-1.62%	-1.76%

Transit Improvement Scenario (TIS-2) – Decrease Headway 50%

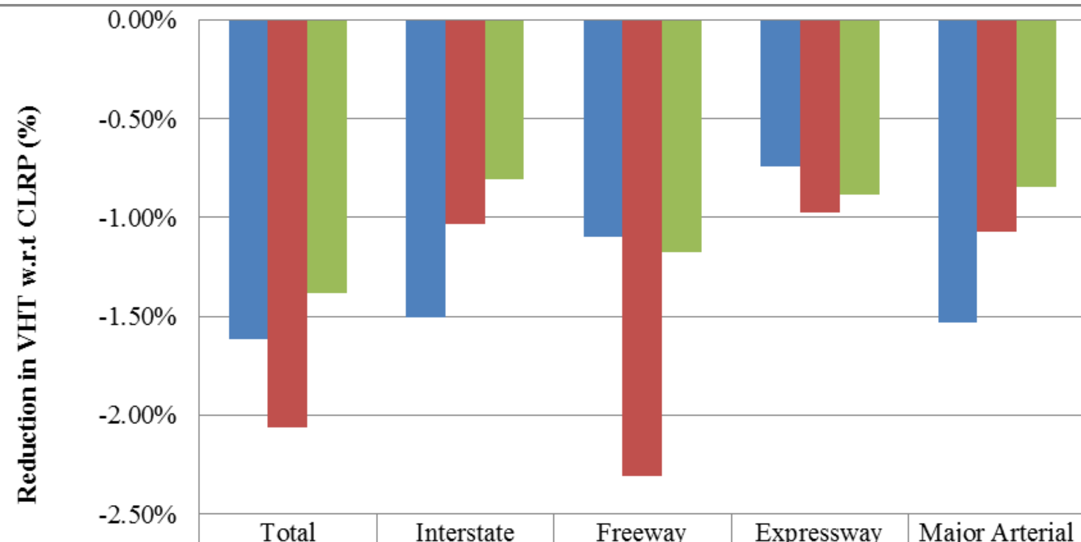
In this second Transit Improvement Scenario, transit service is improved by reducing headways by 50% across the bus and fixed rail systems. As seen in Figures 3.6.1-4 through 3.6.1-6, this improvement also did not result in significant improvements in terms of VMT (less than 1%). The decline in VHT and VHD are slightly higher. However, they are not at a significant level (e.g. maximum 5% reduction in VHD on freeways in PM peak).

Figure 3.6.1-4. Change in VMT for Transit Scenario- Decrease headways 50%



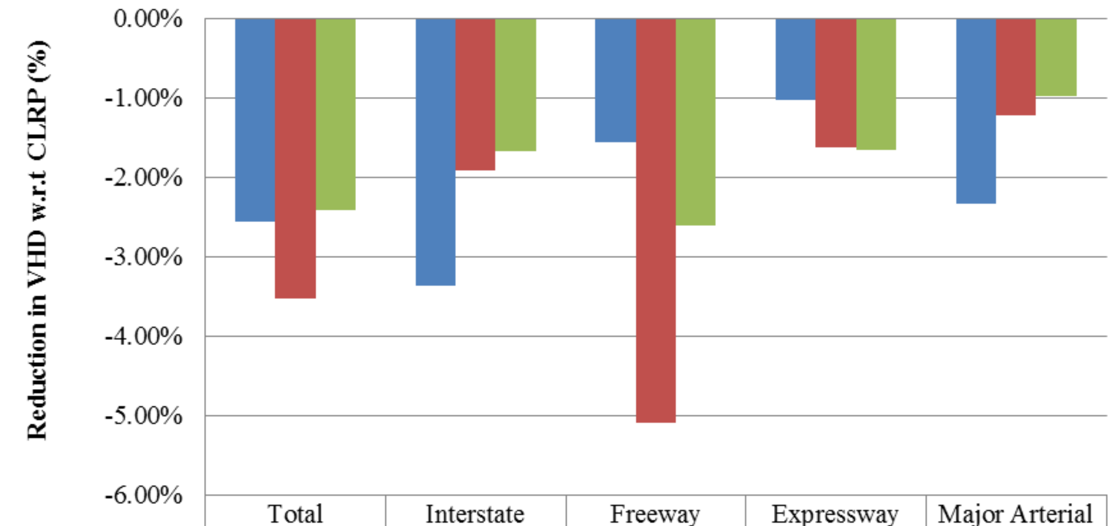
	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-0.76%	-0.66%	-0.85%	-0.43%	-0.87%
PM	-0.76%	-0.62%	-0.90%	-0.42%	-0.85%
ALL PERIODS	-0.59%	-0.51%	-0.74%	-0.45%	-0.66%

Figure 3.6.1-5. Change in VHT for Transit Scenario- Decrease headways 50%



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-1.61%	-1.50%	-1.10%	-0.74%	-1.53%
PM	-2.06%	-1.03%	-2.31%	-0.98%	-1.07%
ALL PERIODS	-1.38%	-0.81%	-1.18%	-0.89%	-0.84%

Figure 3.6.1-6. Change in VHD for Transit Scenario- Decrease headways 50%

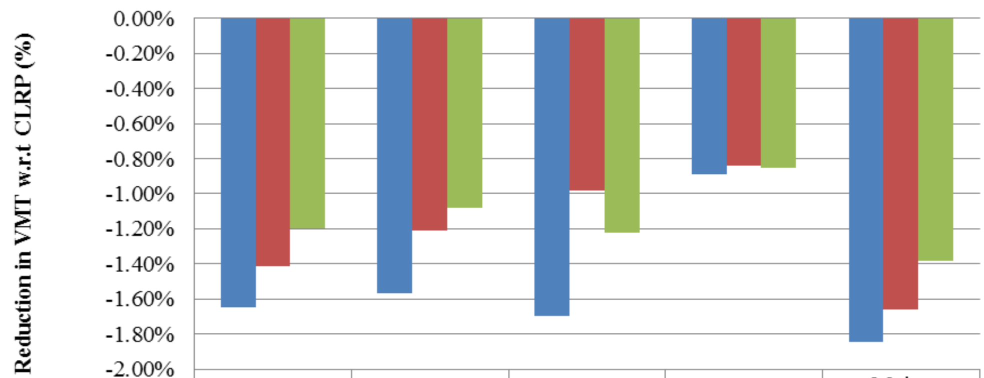


	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-2.56%	-3.36%	-1.55%	-1.03%	-2.33%
PM	-3.53%	-1.91%	-5.08%	-1.63%	-1.22%
ALL PERIODS	-2.42%	-1.68%	-2.61%	-1.65%	-0.99%

Transit Improvement Scenario (TIS-3) – Decrease headways and fares 50%

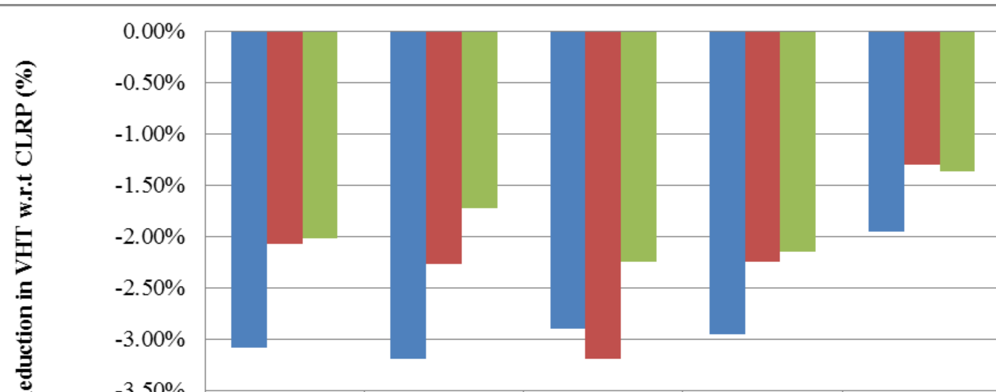
The third Transit Improvement Scenario combined the reduction in headways with the reduction in fares. As seen in Figures 3.6.1-7 through 3.6.1-9, the headway and fare reduction combination scenario is more effective than the two scenarios applied alone i.e. TIS-1 and TIS-2. Change in VMT is not significant, similar to the previous scenarios but it is higher relative to the TIS-1 and TIS-2. The highest impact on VMT is observed on major arterial facilities. The reason might be that when transit service frequency is increased and fare is reduced, the shift to transit may occur for relatively short distance trips on arterial roads. For longer distance travel that uses interstates, the shift is not as high, possibly due to the service availability or longer trip times. As seen in Figures 3.6.1-8 and 3.6.1-9, the impact in VHT and VHD is also higher in this scenario (up to 7.4%), possibly the result of a shift to transit from the highway.

Figure 3.6.1-7. Change in VMT for Transit Scenario- 50% headway and fare reduction



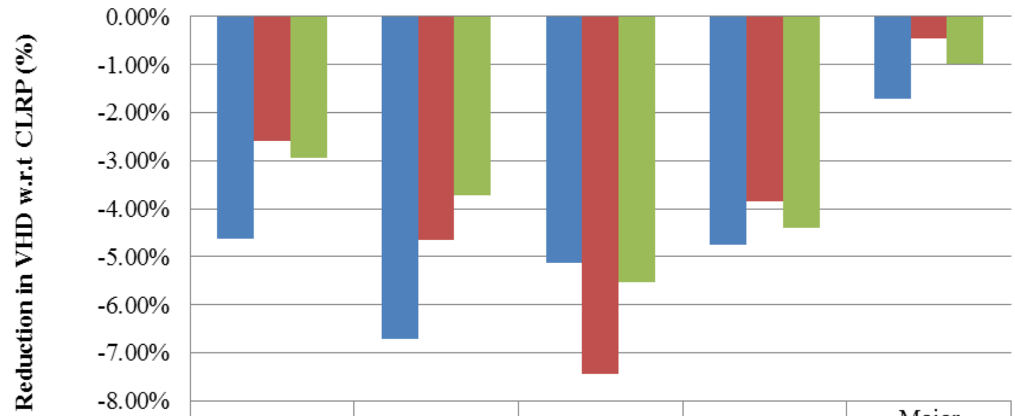
	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-1.65%	-1.57%	-1.69%	-0.89%	-1.85%
PM	-1.41%	-1.21%	-0.98%	-0.84%	-1.66%
ALL PERIODS	-1.20%	-1.08%	-1.22%	-0.85%	-1.38%

Figure 3.6.1-8. Change in VHT for Transit Scenario- 50% headway and fare reduction



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-3.09%	-3.19%	-2.89%	-2.95%	-1.95%
PM	-2.07%	-2.27%	-3.18%	-2.25%	-1.29%
ALL PERIODS	-2.02%	-1.72%	-2.25%	-2.15%	-1.36%

Figure 3.6.1-9. Change in VHD for Transit Scenario- 50% headway and fare reduction



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-4.62%	-6.72%	-5.13%	-4.76%	-1.71%
PM	-2.58%	-4.64%	-7.44%	-3.84%	-0.45%
ALL PERIODS	-2.96%	-3.71%	-5.53%	-4.40%	-0.97%

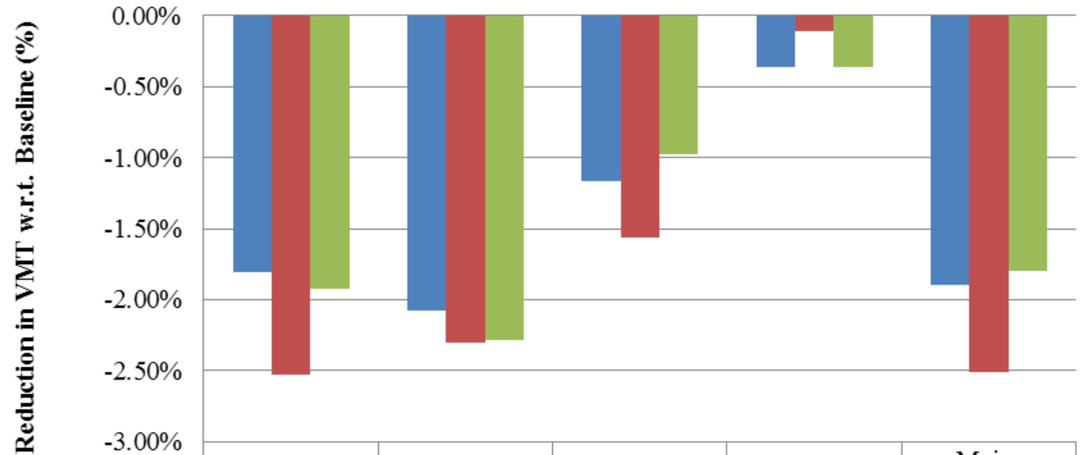
Additional Transit Improvement Scenarios

Two transit improvement scenarios are tested to examine the impacts of doubling the rail speed and transit ridership on traffic and travel patterns. These scenario runs are performed using an earlier version of the MSTM model.

Double rail speed

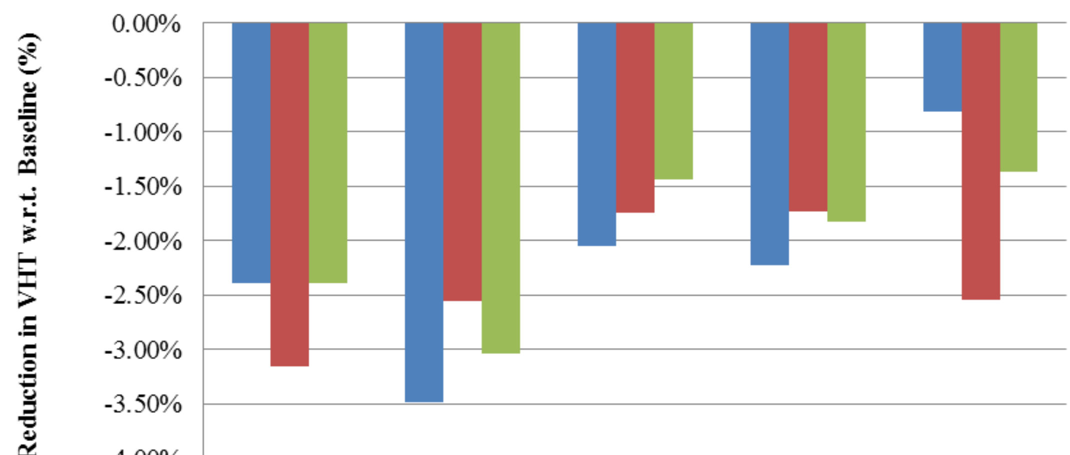
In this additional Transit Improvement Scenario, we tested the impact of doubling the speed of rail service. This scenario provided a modest reduction in VMT (Figure 3.6.1-10). The results demonstrate that rail is the most competitive transit mode to auto due to its fast service characteristics (i.e. due to the exclusive guideway, the run times are not subject to congestion). VHT and VHD also show a decline, especially on interstate and freeway facilities (Figures 3.6.1-11 and 3.6.1-12). This can be explained by the reduced congestion on highway facilities possibly due to the shifts from auto to rail.

Figure 3.6.1-10. Change in VMT for Transit Scenario- Double rail speed



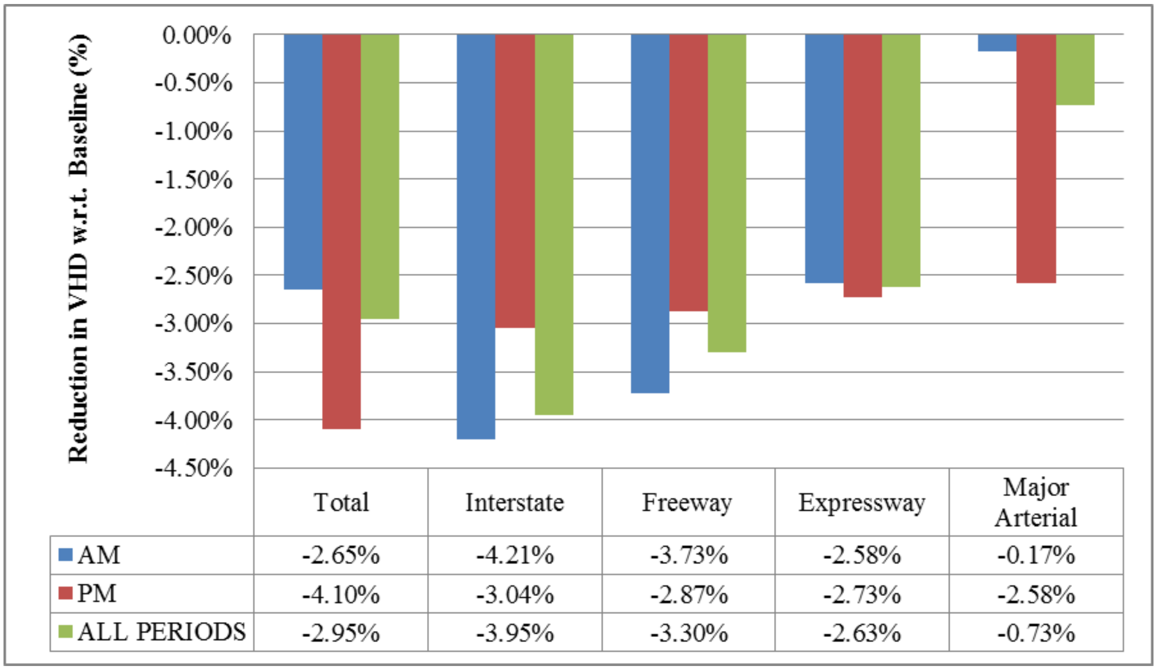
	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-1.80%	-2.08%	-1.17%	-0.37%	-1.90%
PM	-2.53%	-2.30%	-1.56%	-0.11%	-2.51%
ALL PERIODS	-1.92%	-2.28%	-0.97%	-0.36%	-1.80%

Figure 3.6.1-11. Change in VHT for Transit Scenario- Double rail speed



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-2.39%	-3.49%	-2.05%	-2.22%	-0.82%
PM	-3.16%	-2.55%	-1.75%	-1.73%	-2.54%
ALL PERIODS	-2.39%	-3.03%	-1.43%	-1.82%	-1.37%

Figure 3.6.1-12. Change in VHD for Transit Scenario- Double rail speed



Double Ridership

In this second additional Transit Improvement Scenario, we doubled transit ridership between all zone pairs. Thus if 1,000 people rode transit between two zones, in this scenario, we assumed 2,000. This scenario did not address what actions would cause the ridership to double and the scenario impacts are focused around existing transit routes.

As can be seen from Figures 3.6.1-13 and 3.6.1-15, the most significant impact occurs in the Washington DC area. The DC area has a larger share of transit riders than Baltimore and thus doubling the share will have a significant impact. It is also apparent that there are travel time improvements along I-270 and along US 15 – US 340 near Frederick, Maryland. These are likely due to diversions of highway travel to the MARC line extending from Washington DC to Martinsburg, West Virginia. Impacts are not as pronounced in Baltimore area (Figure 3.6.1-15).

Figure 3.6.1-13. Impact of doubling transit ridership on highway travel time (AM peak)

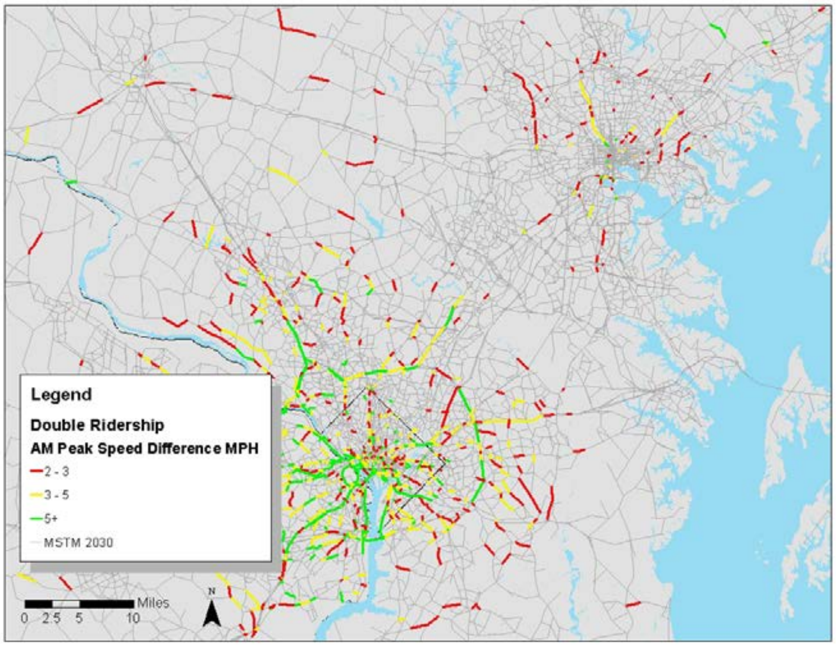


Figure 3.6.1-14. Impact of doubling transit ridership on highway travel time, Washington DC detail (AM Peak)

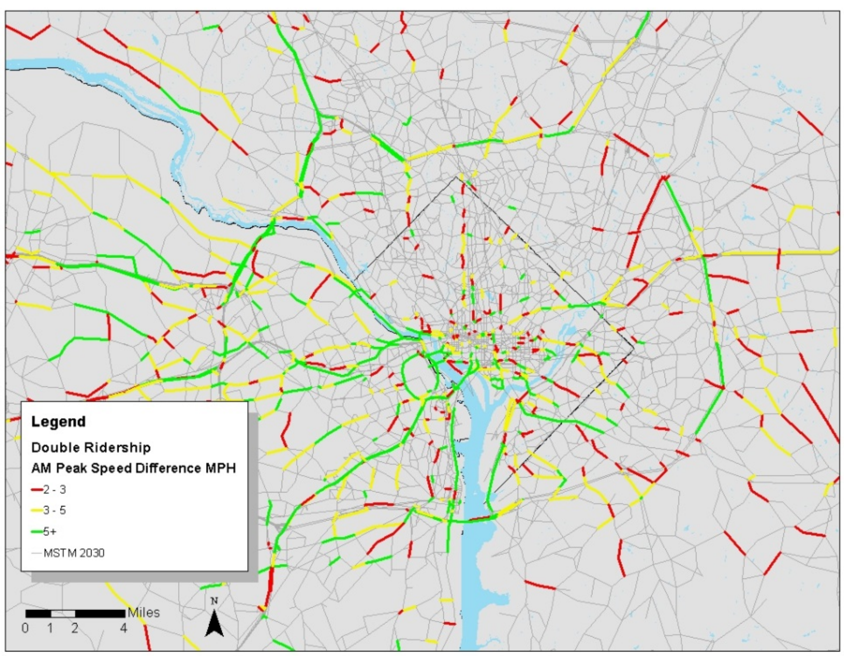
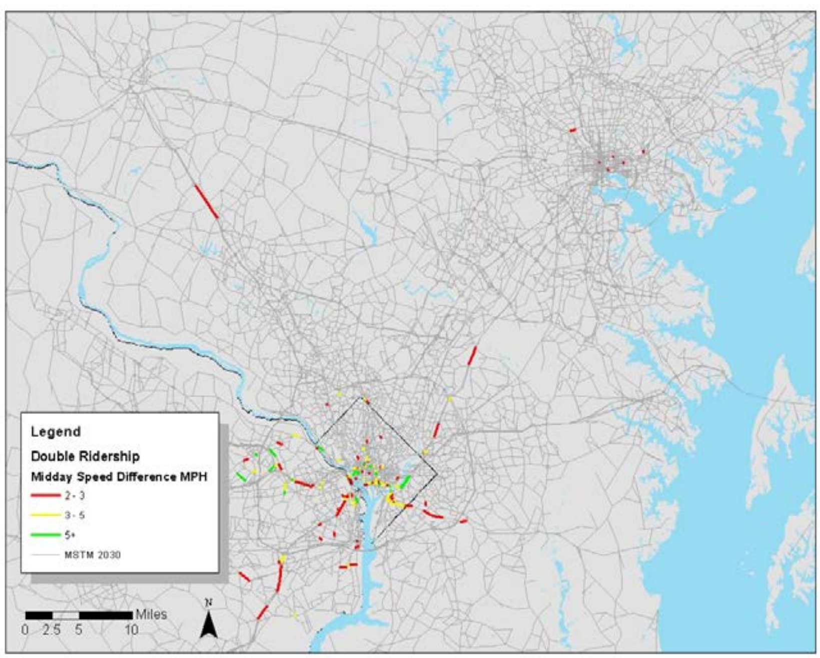


Figure 3.6.1-15. Impact of doubling transit ridership on highway travel time, Baltimore detail (AM Peak)

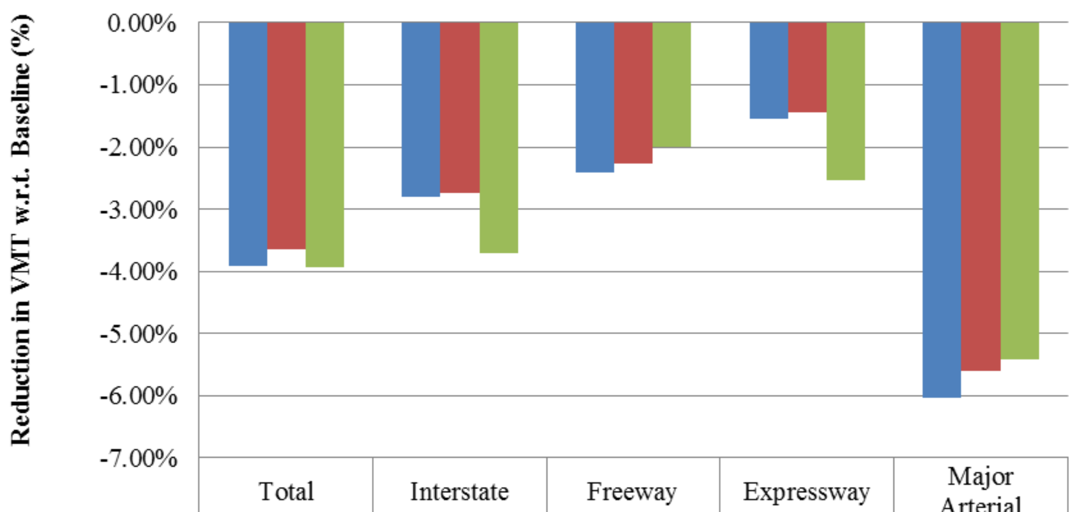
Figure 3.6.1-16. Double transit ridership, Mid-day impact on link speeds



Doubling transit ridership during the mid-day travel period had effects on auto travel in the Washington DC area but little effect in Baltimore (Figure 3.6.1-16). The lower effect in Baltimore is likely due to a lower portion of trips on transit in Baltimore and thus a doubling of transit usage has less impact. This alternative also produces a less pronounced overall effect on link speeds than the peak hour alternative. In the off-peak, highways are less congested, operating at a faster speed than in the peak. Congestion relief therefore has less of an impact.

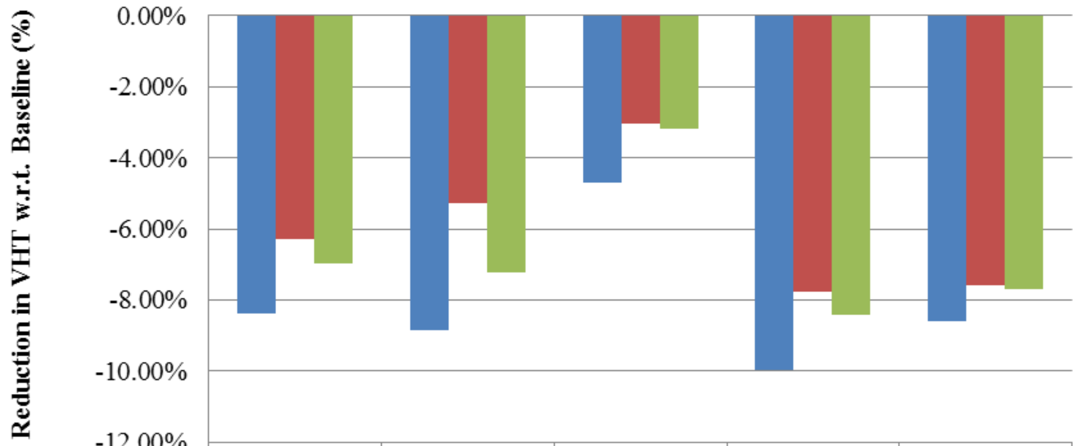
Figures 3.6.1-17 through 3.6.1-19 illustrate changes in VMT, VHT and VHD as a result of doubling transit ridership. The impacts are more significant than doubling the rail speed scenario likely as a result of reduced automobile traffic. If this scenario could be achieved, there would be significant decline in delays on almost all reported facilities (Figure 3.6.1-19).

Figure 3.6.1-17. Change in VMT for Transit Scenario- Double transit ridership



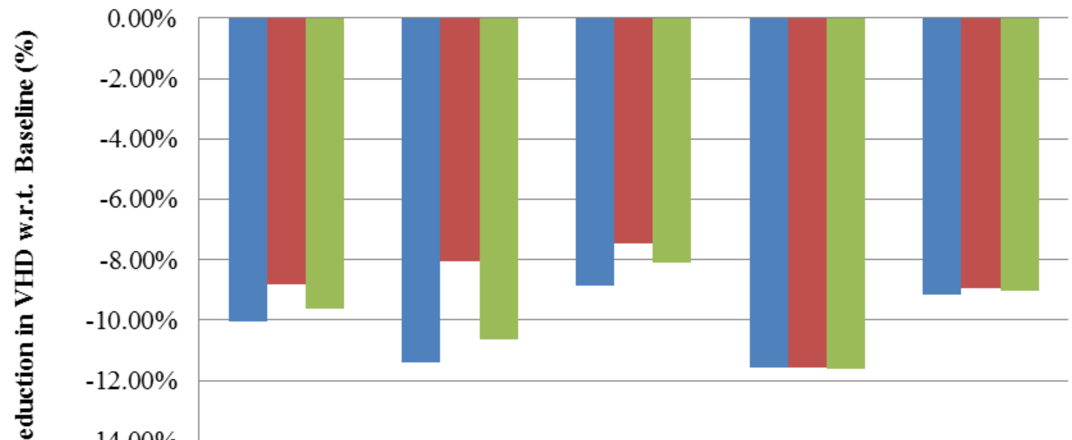
	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-3.91%	-2.80%	-2.42%	-1.54%	-6.03%
PM	-3.64%	-2.74%	-2.27%	-1.44%	-5.60%
ALL PERIODS	-3.94%	-3.70%	-1.99%	-2.54%	-5.41%

Figure 3.6.1-18. Change in VHT for Transit Scenario- Double transit ridership



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-8.37%	-8.84%	-4.69%	-9.95%	-8.58%
PM	-6.27%	-5.28%	-3.05%	-7.77%	-7.57%
ALL PERIODS	-6.98%	-7.23%	-3.18%	-8.42%	-7.69%

Figure 3.6.1-19. Change in VHD for Transit Scenario- Double transit ridership



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-10.05%	-11.41%	-8.85%	-11.56%	-9.17%
PM	-8.82%	-8.04%	-7.47%	-11.58%	-8.94%
ALL PERIODS	-9.64%	-10.62%	-8.11%	-11.60%	-9.04%

3.6.2 Analysis of Transit Improvement Scenarios

In reviewing the results of the alternatives, the 50% fare reduction and 50% headway reduction, when taken individually, did not divert enough travel from the highway network to provide a noticeable increase in highway speeds.

Table 3.6.2-1 below presents the number of trips made by each mode and percent change in mode share of total trips (28.72 million). Transit Improvement Scenario (TIS-1) where fare is reduced 50% diverts over 162,000 trips from the highway network to transit out of a total of more than 27 million highway trips. This alternative scenario increased the rail transit share of total trips by 0.45% and the bus share of total trips by 0.12%. This resulted in a decline in SOV travel of 0.43% and in HOV travel of 0.14% (Table 3.6.2-1). This decline in highway travel was not sufficient to produce noticeable changes in congestion or improvements in highway speed as discussed in Section 3.6.1. In addition, the diverted trips are scattered across multiple areas, further diluting the impact on the highway system.

Similar results are observed for Transit Improvement Scenario (TIS-2) where headway is decreased 50%. This alternative scenario increased the rail share of total traffic by 0.42% and the bus share of total traffic by 0.15% (Table 3.6.2-1). As with lowering the fares, these changes did not produce results which would have a significant impact on speeds on specific highway routes.

Table 3.6.2-1. Percent change in share of all trips under each transit scenario.

	SOV		HOV		Rail		Bus	
Market Share	**Number of trips (million)**	**Change from Baseline (%)**	**Number of trips (million)**	**Change from Baseline (%)**	**Number of trips (million)**	**Change from Baseline (%)**	**Number of trips (million)**	**Change from Baseline (%)**
Baseline (Share)	**15.28 (53.18%)**	**-**	**11.97 (41.66%)**		**1.20 (4.16%)**		**0.28 (0.99%)**	
Reduce fare 50% (TIS-1)	**15.15**	**-0.43**	**11.93**	**-0.14**	**1.32**	**+0.45**	**0.32**	**+0.12**
Reduce headway 50% (TIS-2)	**15.16**	**-0.40**	**11.92**	**-0.14**	**1.32**	**+0.42**	**0.33**	**+0.15**
Reduce fare and headway 50% (TIS-3)	**15.02**	**-0.88**	**11.88**	**-0.31**	**1.46**	**+0.91**	**0.37**	**+0.28**

The combination Transit Improvement Scenario (TIS-3) where decreasing headway and reducing fare 50% applied simultaneously performed better than all other individual scenarios.

While reducing fares and headways has a small impact on overall highway travel, these actions have a significant impact on the transit system operations. Implementing these actions would require that the transit operator purchase new equipment, hire additional personnel and build additional facilities. Table 3.6.2-2 below compares the Baseline transit ridership with the ridership under each of the TIS alternative scenarios. As seen in Table 3.6.2-2, percent changes in transit ridership compared to the Baseline are significant. However, base numbers are small. For example, although there is a 28% increase in bus ridership in TIS-3, the actual number is just increased to 0.37 million from 0.28.

Table 3.6.2-2. Impacts of transit improvement scenarios on ridership compared to Baseline ridership

	Rail trips (millions)	% change from Baseline	Bus trips (millions)	% change from Baseline
Baseline	**1.20**		**0.28**	
Reduce fare 50% (TIS-1)	1.32	+10.78	0.32	+12.02
Reduce headway 50% (TIS-2)	1.32	+10.00	0.33	+14.70
Reduce fare and headway 50% (TIS-3)	1.46	+21.86	0.37	+28.36

Table 3.6.2-3 below summarizes the percent change in VHD in comparison to the Baseline for all TIS scenarios. As seen, reducing the fare and headway 50% (TIS-3) provides the highest reduction (-4.62%) for all roadway facilities (comprised of 10 facilities) in AM peak period. Looking at the major facility types, TIS-3 is identified as the most beneficial alternative in reducing VHD.

Table 3.6.2-3. Comparison of change in VHD w.r.t Baseline for transit improvement scenarios

	AM Peak			PM Peak		
Facility Type	**Half Headway (TIS-1)**	**Half Fare (TIS-2)**	**Half Fare and Half Headway (TIS-3)**	**Half Headway (TIS-1)**	**Half Fare (TIS-2)**	**Half Fare and Half Headway (TIS-3)**
Interstate	-3.36%	-3.88%	-6.72%	-1.91%	-1.50%	-4.64%
Freeway	-1.55%	0.08%	-5.13%	-5.08%	-3.46%	-7.44%
Expressway	-1.03%	-0.20%	-4.76%	-1.63%	-2.34%	-3.84%
Major Arterial	-2.33%	-5.77%	-1.71%	-1.22%	-1.24%	-0.45%
Total	***-2.56%***	***-1.99%***	***-4.62%***	***-3.53%***	***-1.21%***	***-2.58%***

Among the transit improvement scenarios, we found that TIS-3 (reducing the fare and headway 50%) is the most effective scenario in increasing transit share. Table 3.6.2-4 below presents mode share (in person trips). Among TIS scenarios, TIS-3 has the highest impact in both reducing the SOV trips (1.65%) and increasing transit use (28.36% increase in bus and 21.86% in rail). However, it should be noted that, although these percentages are high, the actual numbers are still low. Another important point is that all transit improvement scenarios reduced the HOV share, meaning that they caused not only shifts from SOV trips but also from HOV trips.

Table 3.6.2-4. Mode Share (in person trips)

Scenario	SOV	% change from Baseline	HOV	% change from Baseline	BUS	% change from Baseline	RAIL	% change from Baseline
Baseline	**53.18%**		**41.66%**		**0.99%**		**4.16%**	
TIS-1	**52.75%**	-0.80%	41.52%	-0.34%	1.11%	12.02%	4.61%	10.79%
TIS-2	**52.78%**	-0.76%	41.51%	-0.38%	1.14%	14.70%	4.58%	10.00%
TIS-3	**52.31%**	-1.65%	41.35%	-0.76%	1.27%	28.36%	5.07%	21.86%

3.6.3 Transit Operational Improvements - Conclusions

With growing congestion and the goals of increasing transit ridership, it is critical that Maryland improve transit service. The transit scenarios examined two possible methods for improving transit service, increasing transit frequency and lowering fares but did not consider alternatives such as improved run times and providing service to areas currently not served by transit[4]. These results reflect the most that could be expected from operational improvements to the existing transit system. The scenarios had a major impact on transit ridership, increasing it by as much as 28%, but did not reduce congestion to a great degree. Further, implementing actions of this type could place a major burden on the transit operator, requiring additional vehicles and drivers. Several factors explain why the congestion reduction is not greater:

- Only those living near to a transit line would benefit from the service improvements. Those without ready access to transit will still continue to drive.

- Even with the service improvements there may not be a sufficient improvement to make transit more attractive than the auto. For example, if a person can get to work in 30 minutes by car and the bus run time is 45 minutes, the bus trip will be 15 minutes longer regardless of changes in transit headways. Also in this case reducing the fare by 50% may not be enough to overcome a 15 minute difference in travel time.

- In some cases headways may be short enough that decreasing them would not make an appreciable difference to the rider. For example in Washington, D.C. the headways on the METRO are 3 minutes during the peak hour. Cutting these in half to 90 seconds is not likely to have an appreciable impact given all other factors involved in choosing between highway or transit. Moreover, the improvements proposed, particularly

[4] The model did not include the effect of fine grained land use factors such urban design and mix of uses in zones, although density does affect the number of trips originating in a zone.

decreasing headways by 50%, may not be technically feasible. For example, as stated previously portions of the Washington Metro rail operate at three minute headways during the PM peak. It may not be possible to improve operations to the point where trains are running every 90 seconds[5].

Appendix B3 contains a further description of how the mode choice is estimated.

To increase transit ridership further will likely require one or more of the following actions:

- Providing new transit routes to areas currently unserved or underserved by transit
- Upgrading existing transit service to become faster than the automobile, providing a travel time advantage for transit
- Altering land use patterns so that residents and employees have better access to transit. This scenario will be tested in the next phase.

3.7 ALTERNATIVE SCENARIO III: TOLL LANES

The toll road scenario hypothetically tests whether a network of express toll lanes (ETL) can reduce congestion and improve travel times. In this scenario, two lanes in both directions were added to the major interstates in the Baltimore-Washington area. This included I-270, I-495, the Capital Beltway, I-695, the Baltimore Beltway and I-95 between Baltimore and Washington. In addition, ETLs were added to MD 10, southeast of Washington. Figure 3.7-1 below illustrates the locations of the ETLs. In addition to the ETLs, we also tested the impact of tolling existing Interstate lanes as another scenario[6]. The toll routes shown in Figure 3.7-1 are in addition to the preexisting tolls not shown; Baltimore Harbor Tunnels, Bay Bridge, Harry Nice Bridge and I-95 above Havre De Grace.

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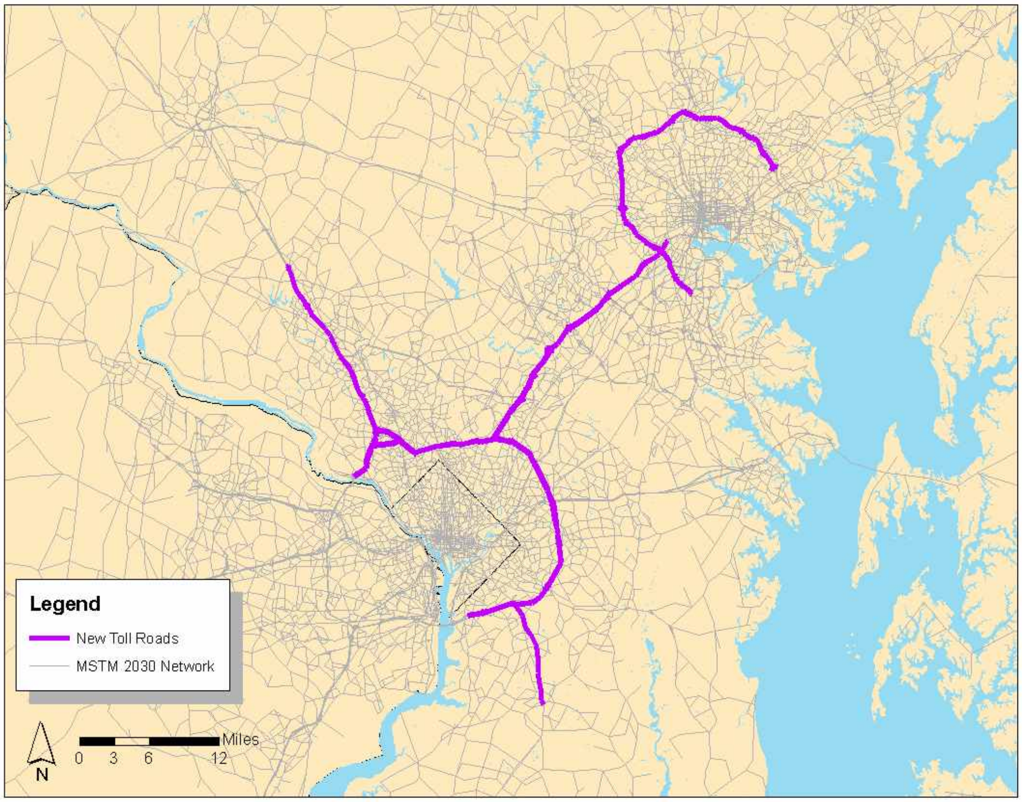
[5] The model does not explicitly account for transit dependent riders (those without access to an automobile) but does account for travel by income class, with the lower income groups having more transit riders.

[6] Note: This scenario was analyzed with a previous version of the MSTM which had minor change in the demand. The conclusions remains the same.

Figure 3.7-1. Express toll lanes added to the system



3.7.1 Methodology

Three alternative tolling scenarios were tested; $0.15 per mile, $0.30 per mile and $0.60 per mile. Note that the toll fees at the Intercounty Connector (ICC) in Maryland range from $0.10 to $0.35 per mile. Vehicles select particular routes based on impedance, and a combination of travel time and auto operating cost. Auto operating cost is typically a function of maintenance costs and per mile charges due to gasoline consumption. High MPG vehicles will have a lower operating cost. In areas with major congestion, causing significant delays, the impedance will be more sensitive to changes in travel time than operating cost. We would therefore expect that in areas with heavy congestion, vehicle operators will be more willing to pay the tolls.

For each toll scenario, we chose the AM peak period for analysis. Note that figures in the following sub-sections illustrate the speed on lanes without tolls.

3.7.2 **Express toll lanes**

Express toll lanes (ETL-15) : $0.15 per mile toll

Figure 3.7.2-1 below shows the impact of a $0.15 toll on the AM peak travel. Note that the two additional new toll lanes in each direction provide traffic flow improvements throughout the region, especially on parts of the Washington DC and Baltimore Beltways, in the I-95 corridor and on I-270. However, no significant impact is observed in downtown areas (Figures 3.7.2-2 and 3.7.2-3). The reason may be that the toll lanes do not serve downtown, therefore cannot relieve congestion in downtown.

Figure 3.7.2-1. Impact of a $0.15 toll on AM peak travel speeds

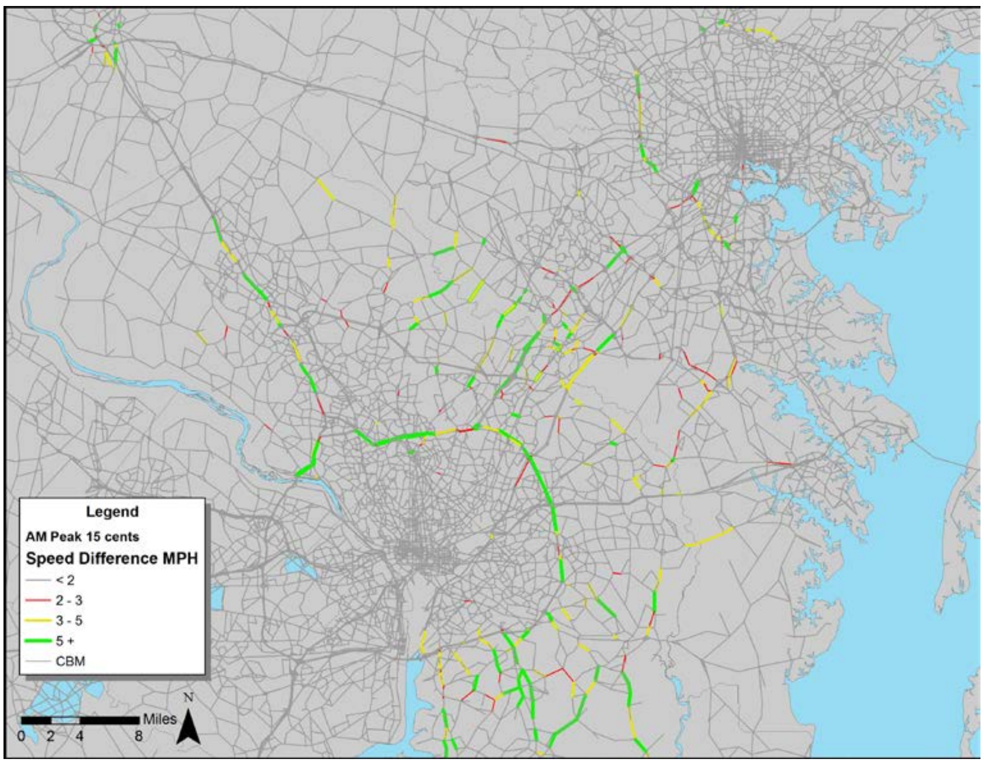


Figure 3.7.2-2. Impact of a $0.15 toll on AM peak travel speeds, Washington DC detail

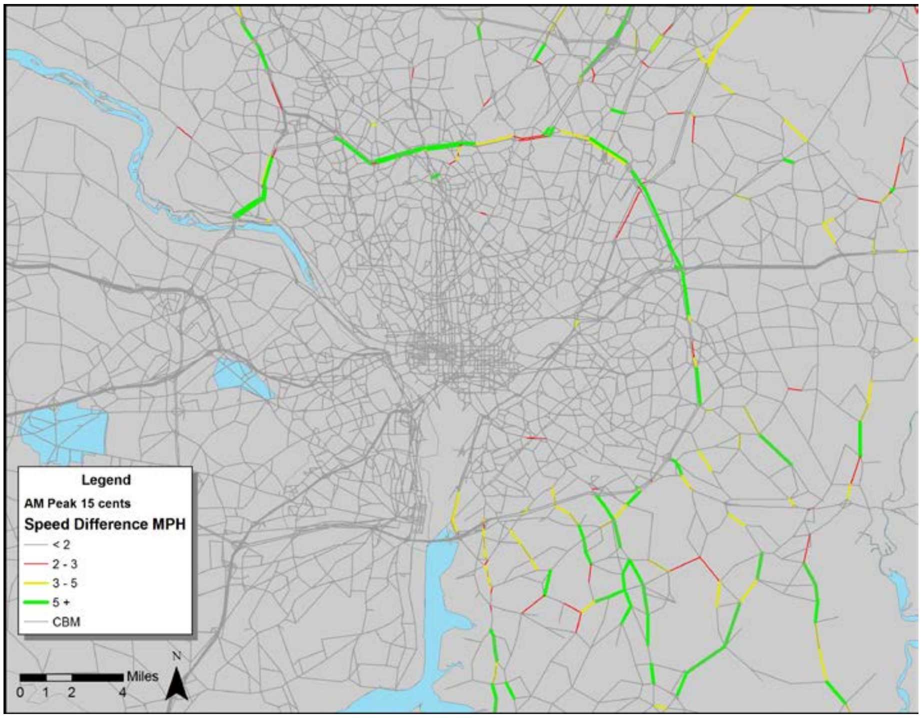


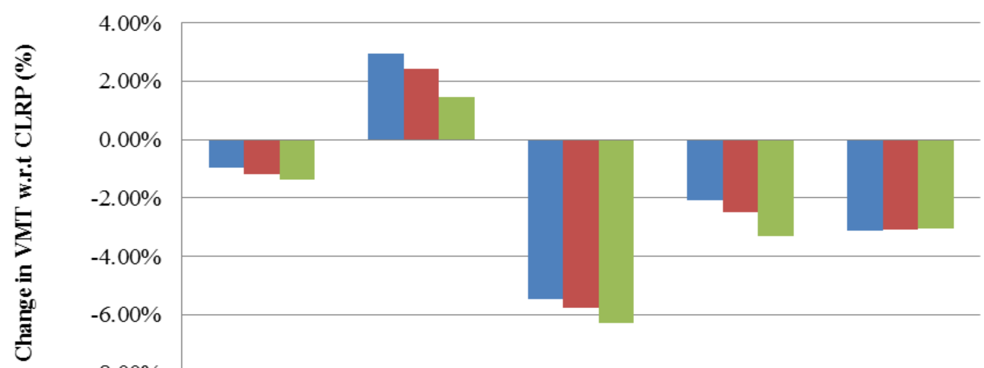
Figure 3.7.2-3 Impact of a $0.15 toll on AM peak travel speeds, Baltimore detail

Under this scenario, traffic on parts of the newly tolled roads shows significant improvement (5 miles per hour or more increase in speed). These results also show congestion relief on parallel routes, such as those parallel to I-95. Both the Baltimore-Washington Parkway and US -29 see some improvement in speed. Speed on I-270 shows an improvement due to diversion to the ETLs. Routes near I-270 also show improvements in travel time due either to diversion to the ETLs or diversion to a faster I-270. The same types of improvement can be seen southeast of Washington in the area of MD 10. Some improvements are observed on I-695, the Baltimore Beltway as well. However, in the Baltimore area outside the Baltimore Beltway, no significant impacts are observed (Figure 3.7.2-3).

Figures 3.7.2-4 through 3.7.2-6 below illustrate impacts of a $0.15 toll on VMT, VHT and VHD respectively. As seen, the addition of express toll lanes to interstate roads increases the VMT up to 3% in AM period on interstate roads. There are modest decreases in VMT on other facilities possibly due to the shift to tolled roads or to other modes. The changes in VHT and VHD are more significant, especially on expressways, over 13% and 23% respectively, as seen in Figures 3.7.2-5 and 3.7.2-6. VHT and VHD on major facilities decrease possibly due to ETLs.

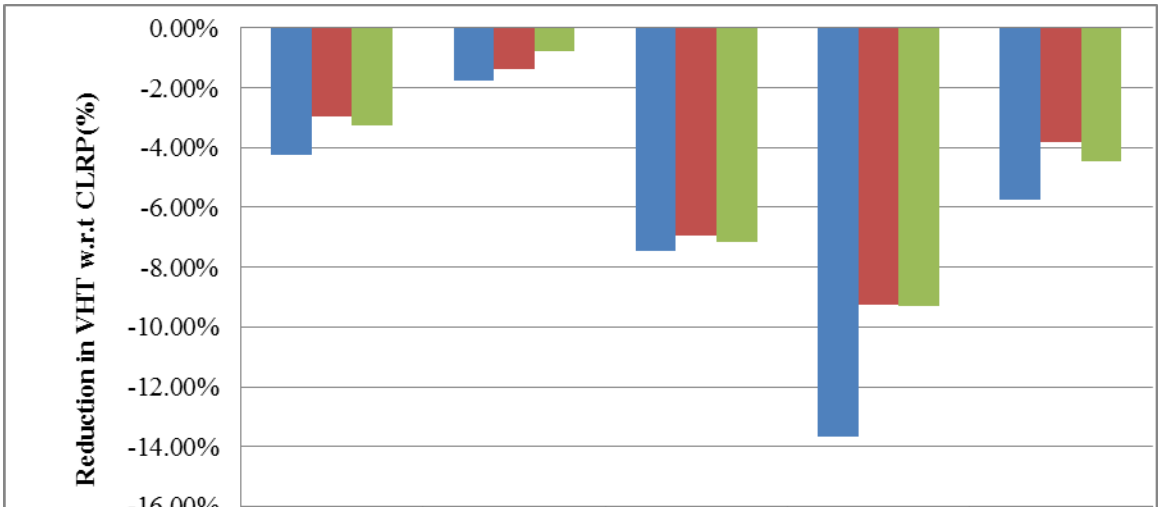
The VMT increase on the toll roads and major interstates results from the increased capacity provided by toll roads. As more vehicles use the toll roads fewer remain on interstates and the interstate speed increases plus the interstates become a more attractive alternative than parallel routes.

Figure 3.7.2-4. Change in VMT for Express Toll Lane Scenario- $0.15 toll



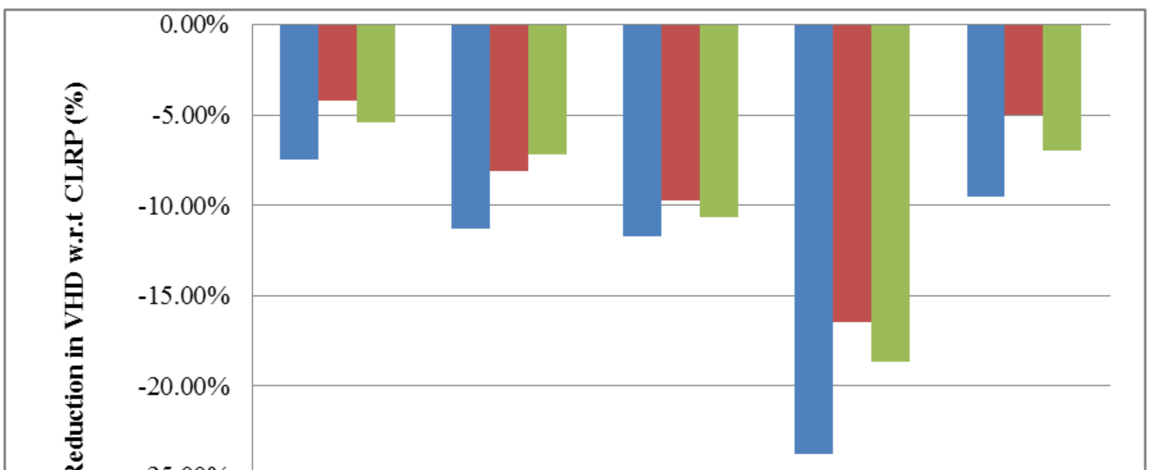
	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-0.97%	2.95%	-5.48%	-2.08%	-3.14%
PM	-1.19%	2.43%	-5.76%	-2.50%	-3.08%
ALL PERIODS	-1.35%	1.45%	-6.28%	-3.31%	-3.03%

Figure 3.7.2-5. Change in VHT for Express Toll Lane Scenario- $0.15 toll



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-4.24%	-1.75%	-7.48%	-13.68%	-5.74%
PM	-2.97%	-1.39%	-6.93%	-9.25%	-3.82%
ALL PERIODS	-3.27%	-0.78%	-7.14%	-9.28%	-4.47%

Figure 3.7.2-6. Change in VHD for Express Toll Lane Scenario- $0.15 toll



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-7.48%	-11.32%	-11.76%	-23.74%	-9.54%
PM	-4.21%	-8.14%	-9.77%	-16.51%	-4.96%
ALL PERIODS	-5.43%	-7.21%	-10.69%	-18.70%	-6.97%

In addition to impacting travel on the interstates, ETLs affect other facilities as well. By drawing more traffic to interstates through increased capacity, trips are diverted from parallel routes, causing congestion and delays on those routes.

Express toll lanes (ETL-30): $0.30 per mile toll

Figure 3.7.2-7 below shows the impact of a $0.30 per mile toll on the AM peak travel. The pattern of impacts is similar to the $0.15 per mile toll, but not as pronounced. For example, there are speed improvements on I-495, the Capital Beltway, but most sections of the Beltway do not show changes. Improvements in traffic flow in the Baltimore area are much less compared to the Washington DC area and to the $0.15 scenario (Figures 3.6.2-8 and Figure 3.6.2-9).

Change in VMT, VHT and VHD also show similar characteristics to $0.15 scenario, with slightly lower impact (Figures 3.7.2-10 through 3.7.2-12).

Figure 3.7.2-7. Impact of a $0.30 toll on AM peak travel speeds

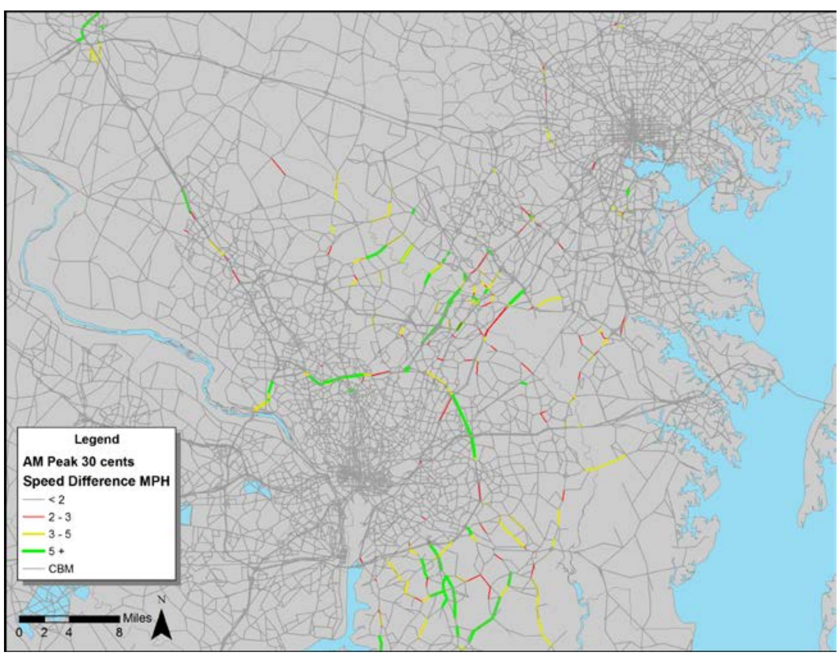


Figure 3.7.2-8. Impact of a $0.30 toll on AM peak travel speeds, Washington DC detail

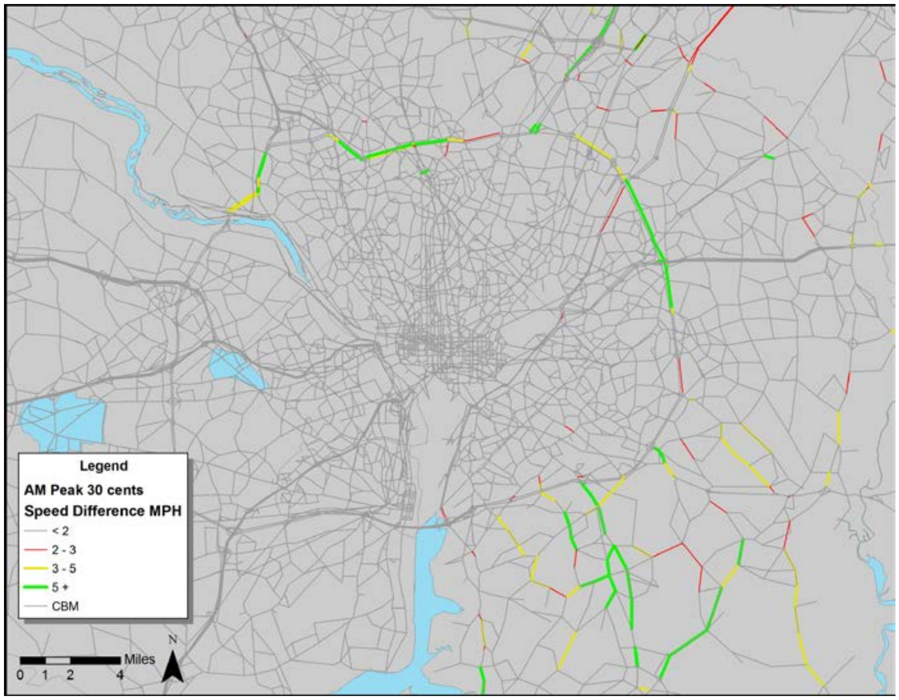


Figure 3.7.2-9. Impact of a $0.30 toll on AM peak travel speeds, Baltimore detail

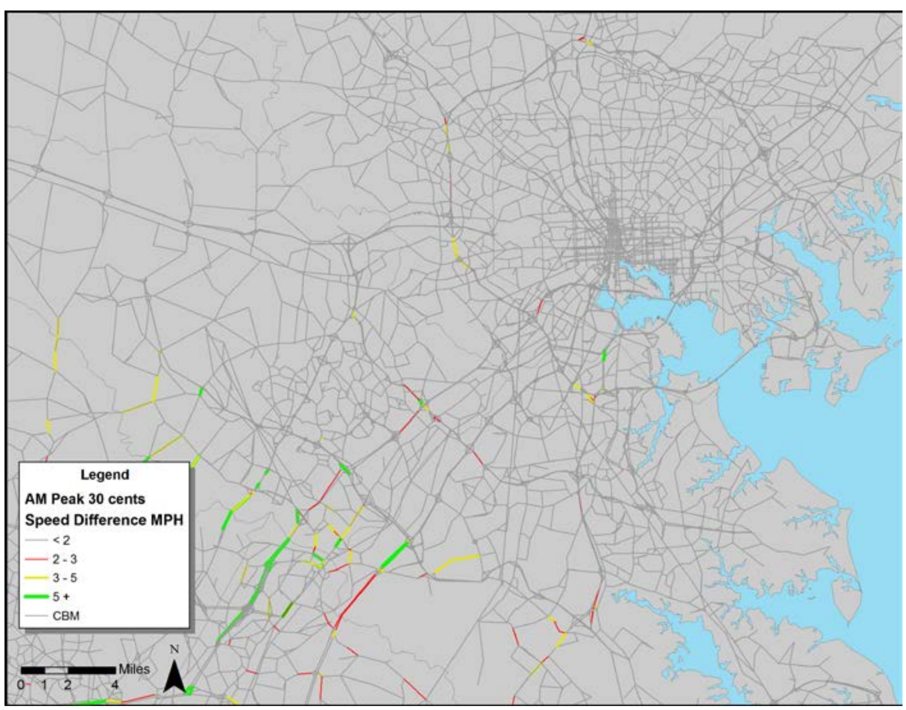
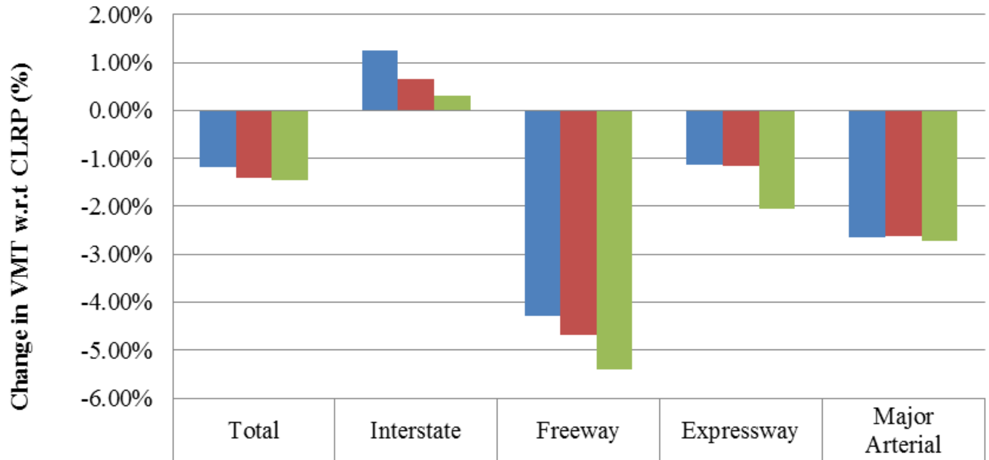
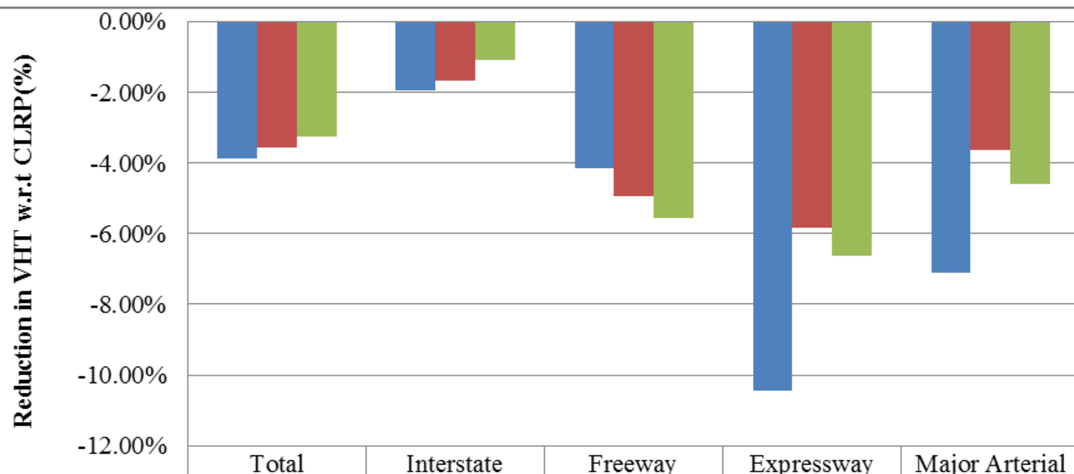


Figure 3.7.2-10. Change in VMT for Express Toll Lane Scenario- $0.30 toll



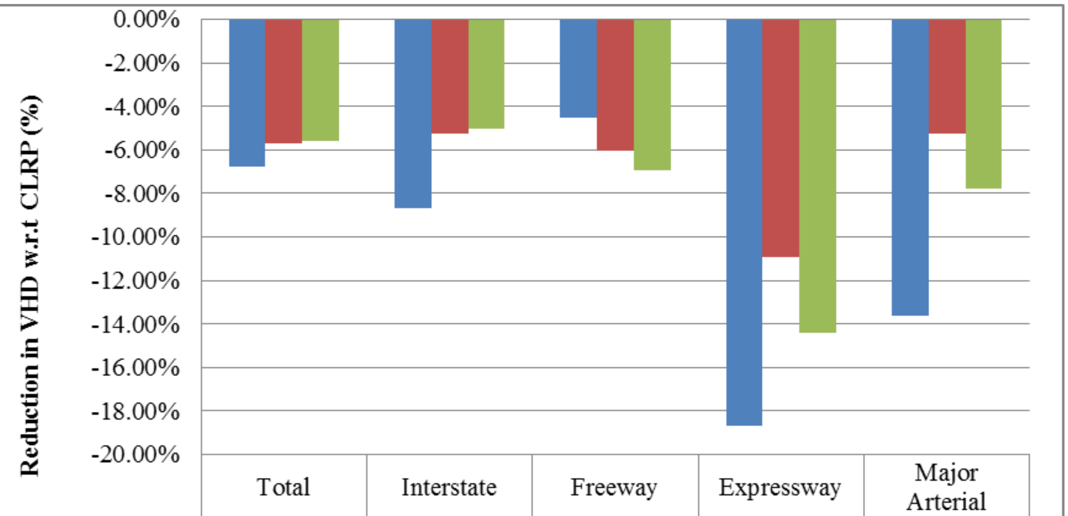
	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-1.19%	1.26%	-4.28%	-1.14%	-2.66%
PM	-1.40%	0.65%	-4.69%	-1.15%	-2.63%
ALL PERIODS	-1.46%	0.32%	-5.41%	-2.04%	-2.73%

Figure 3.7.2-11. Change in VHT for Express Toll Lane Scenario- $0.30 toll



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-3.86%	-1.95%	-4.15%	-10.46%	-7.09%
PM	-3.57%	-1.68%	-4.93%	-5.83%	-3.63%
ALL PERIODS	-3.26%	-1.07%	-5.54%	-6.63%	-4.58%

Figure 3.7.2-12. Change in VHD for Express Toll Lane Scenario- $0.30 toll



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-6.76%	-8.65%	-4.54%	-18.68%	-13.64%
PM	-5.69%	-5.23%	-6.05%	-10.95%	-5.23%
ALL PERIODS	-5.57%	-5.03%	-6.92%	-14.39%	-7.79%

Express Toll Lanes (ETL-60): $0.60 per mile toll

Figures 3.7.2-13 through 3.7.2-15 below show the impact of a toll of $0.60 per mile on travel speeds in the region.

Under this scenario, there is little or no relief on the Baltimore and Capital Beltways and slight improvements in speed on I-95 and parallel routes and on I-270. The links showing improvement are often single lane roads which can show significant speed improvements with modest reductions in vehicle travel.

Figures 3.7.2-16 through 3.7.2-18 show the impacts on VMT, VHT and VHD respectively. This scenario provides lower reductions in VMT, VHT and VHD compared to ETL-15 and ETL-30 scenarios. However, this scenario does not cause increase in VMT on interstates as opposed to ETL-15 and ETL-30 scenarios.

Figure 3.7.2-13. Impact of a $0.60 toll on AM peak travel speeds

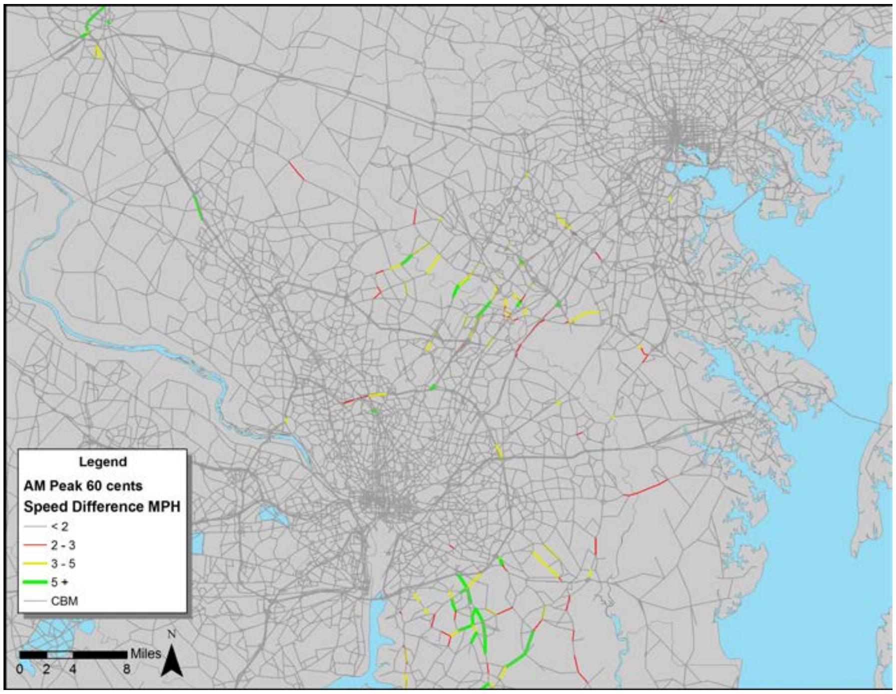


Figure 3.7.2-14. Impact of a $0.60 toll on AM peak travel speeds, Washington DC detail

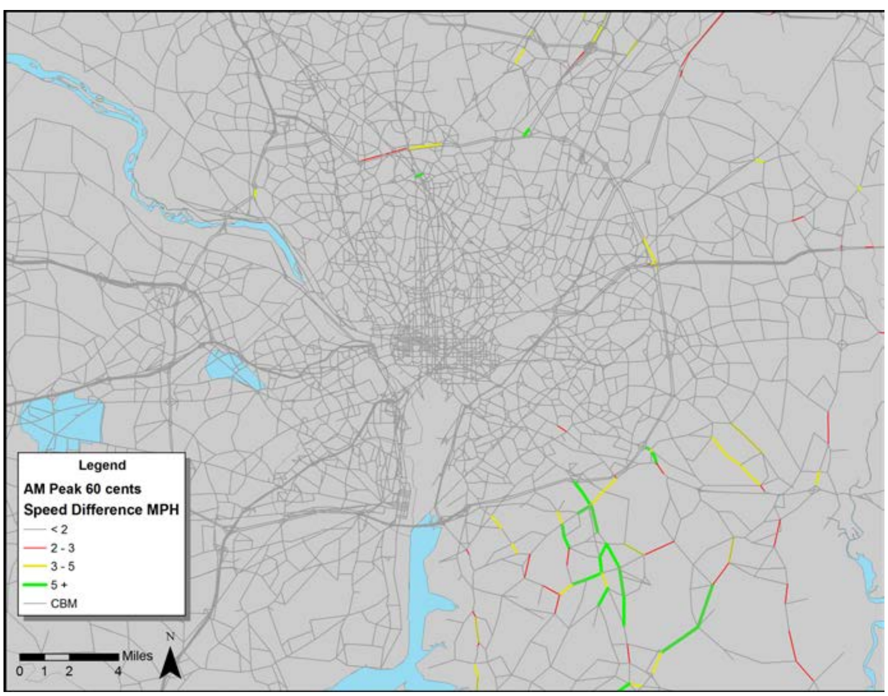


Figure 3.7.2-15. Impact of a $0.60 toll on AM peak travel speeds, Baltimore detail

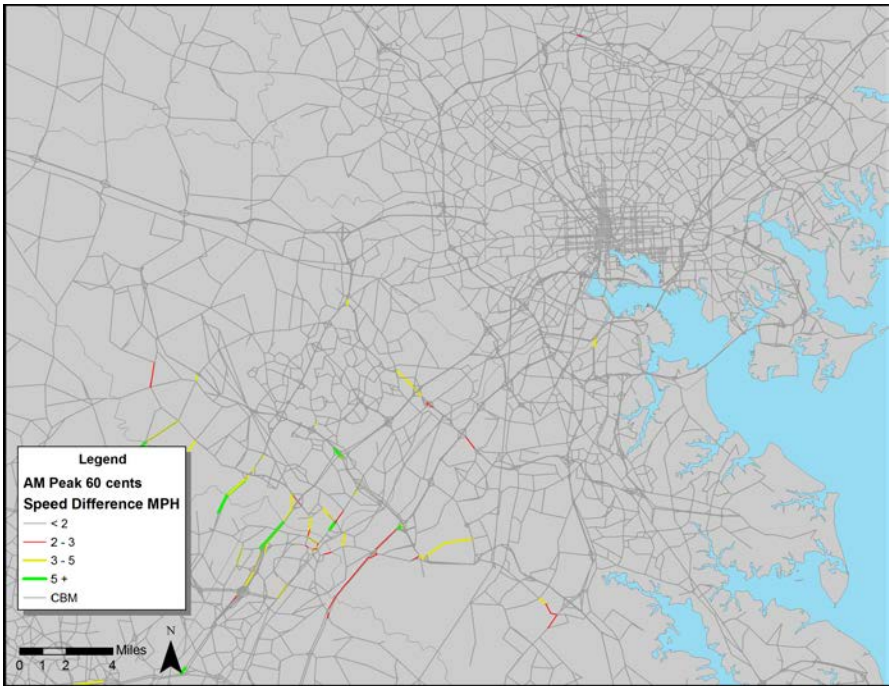
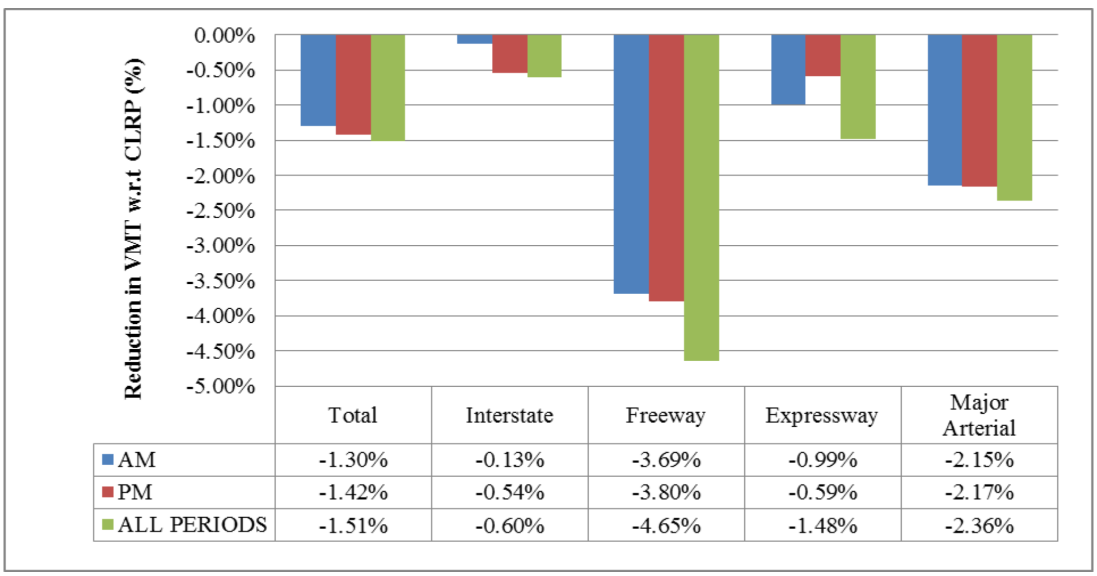
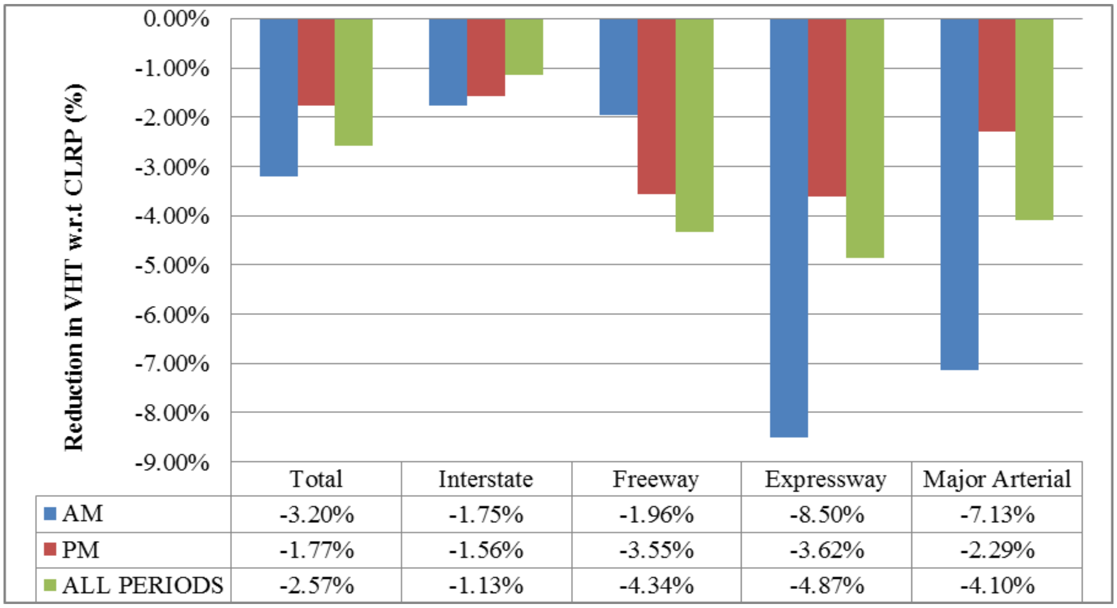


Figure 3.7.2-16. Change in VMT for Express Toll Lane Scenario- $0.60 toll



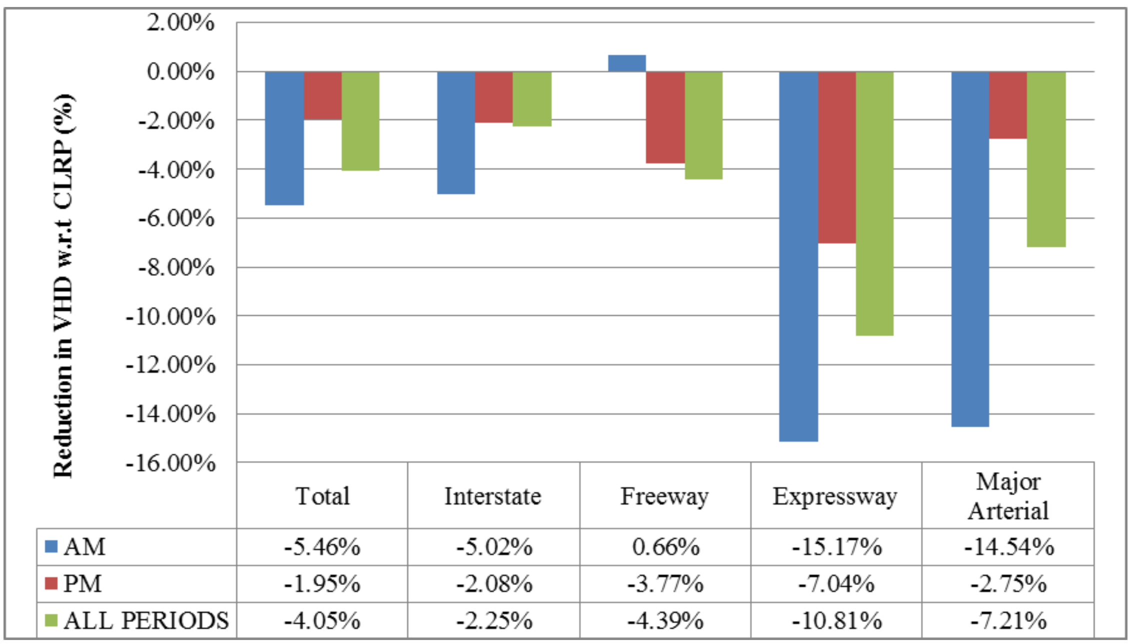
	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-1.30%	-0.13%	-3.69%	-0.99%	-2.15%
PM	-1.42%	-0.54%	-3.80%	-0.59%	-2.17%
ALL PERIODS	-1.51%	-0.60%	-4.65%	-1.48%	-2.36%

Figure 3.7.2-17. Change in VHT for Express Toll Lane Scenario- $0.60 toll



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-3.20%	-1.75%	-1.96%	-8.50%	-7.13%
PM	-1.77%	-1.56%	-3.55%	-3.62%	-2.29%
ALL PERIODS	-2.57%	-1.13%	-4.34%	-4.87%	-4.10%

Figure 3.7.2-18. Change in VHD for Express Toll Lane Scenario- $0.60 toll



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-5.46%	-5.02%	0.66%	-15.17%	-14.54%
PM	-1.95%	-2.08%	-3.77%	-7.04%	-2.75%
ALL PERIODS	-4.05%	-2.25%	-4.39%	-10.81%	-7.21%

Revenue from Express Toll Lane Scenarios

Table 3.7.2-1 below shows the revenues from different tolling options. As can be seen, the revenues increase as the tolls rise. At the same time, the ETLs carry less traffic since VMT on the ETLs declines as tolls increase.

Table 3.7.2-1. Revenue under different express lane tolling options

	ETL-15 (15 cents/mile)	ETL-30 (30 cents/mile)	ETL-60 (60 cents/mile)	ETL-90 (90 cents/mile)
AM (6:30 – 9:30)	$174,577	$224,708	$290,970	$353,965
Mid-day (9:30 – 16:30)	$146,316	$177,328	$238,392	$313,266
PM (16:30 – 19:30)	$205,244	$258,473	$339,833	$424,770
Night (19:30 – 6:30)	$83,034	$109,858	$152,371	$185,247
Total Revenue	**$609,170**	**$770,367**	**$1,021,566**	**$1,277,248**
Total VMT	***4,061,133***	***2,567,890***	***1,702,610***	***1,419,164***

Compared to ETL-15, the ETL-30 scenario reduces the VMT on tolled lanes by about 37%, ETL-60 reduces by 58%, while ETL-90 further reduces the VMT by 65% (Table 3.7.2-1). We did not test scenarios with tolls greater than $0.90 but it is likely that there will be diminishing returns as tolls increase further. Also at a certain point, total revenue will decline with an increase in tolls. Note that mid-day and evening periods both show low revenue from tolls. Since these time periods do not have significant amounts of congestion and trips made are typically non-work trips, there is little or no incentive for vehicles to use the ETLs at these times.

Often times, toll lanes are considered as a low cost option for congestion relief. They can be financed through public/private partnerships and at the same time will improve travel flow. The results above confirm that ETLs can reduce traffic flow, however, if private sector financing is relied on to fund them, there can be conflicts between maximizing revenue and reducing congestion. For example, the $0.15 per mile toll provides the greatest congestion relief while $0.60 per mile maximizes revenues. Decision makers must have a clear understanding of the tradeoffs between these two objectives and decide accordingly.

3.7.3 Tolling Existing Interstate Lanes

We also experimented with analyzing the impact of placing tolls on existing lanes. These lanes are located at the same roadway facilities as in the ETL scenario as demonstrated in Figure 3.6.1 in section 3.6. All the existing lanes on the facilities are tolled in the scenario. It should be made clear that this option is not under consideration; however, we wanted to test the model's response to a scenario of this type. The results were obtained from the previous version of the MSTM model in this scenario.

Tolling Existing Lanes (TEL-15): $0.15 toll

Figure 3.7.3-1 illustrates the impact of imposing a $0.15 toll on existing interstate lanes. These lanes are illustrated in Figure 3.6.1. In this scenario travel speeds on the tolled links made a significant improvement. However, as seen in Figure 3.7.3-2, travel speed on other links showed reductions up to 3 miles per hour. This is to be expected since establishing tolls on existing routes will divert travel from the tolled links to non-tolled links, thus improving travel on the tolled links but worsening the conditions on the links without tolls. As can be seen, in most cases, speeds on the tolled links improve by three miles per hour or more while they decrease on others.

Figures 3.7.3-3 through 3.7.3-5 show the impacts on VMT, VHT and VHD respectively. As seen, while there is reduction in interstate VMT, VHT and VHD, all other facilities see increases. This is because vehicles are diverted from tolled interstates to facilities that are not tolled.

Figure 3.7.3-1. Impact of a $0.15 toll on existing Interstate lanes on AM travel speeds (speed increase)

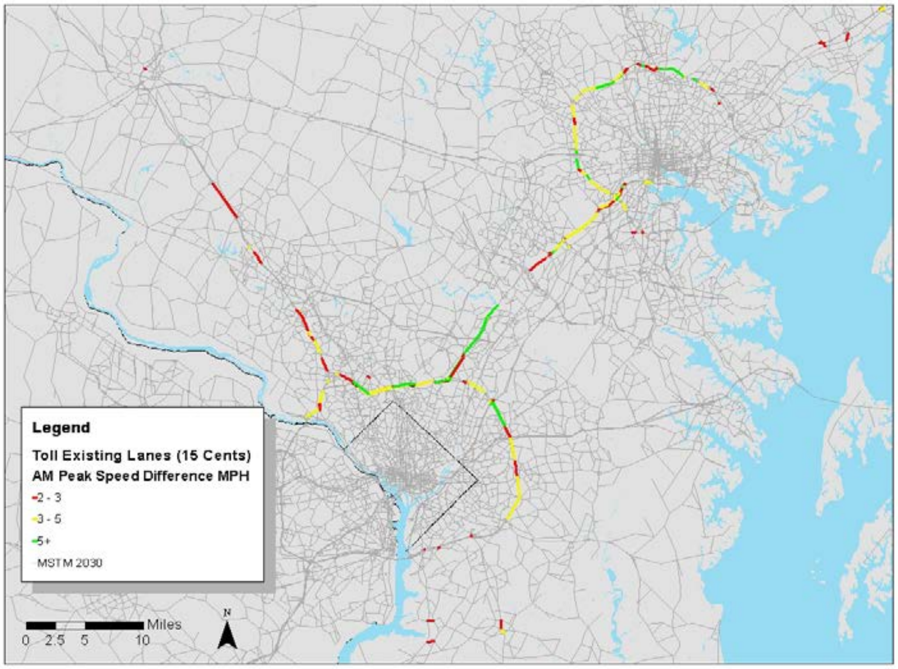


Figure 3.7.3-2. Impact of a $0.15 toll on existing Interstate lanes on non-tolled AM travel speeds (speed decrease)

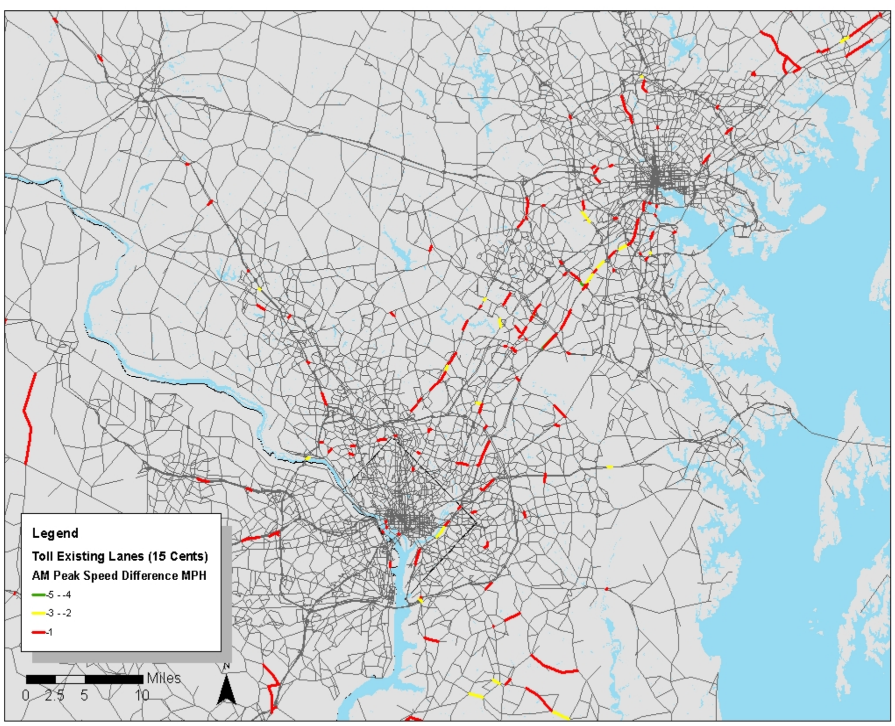
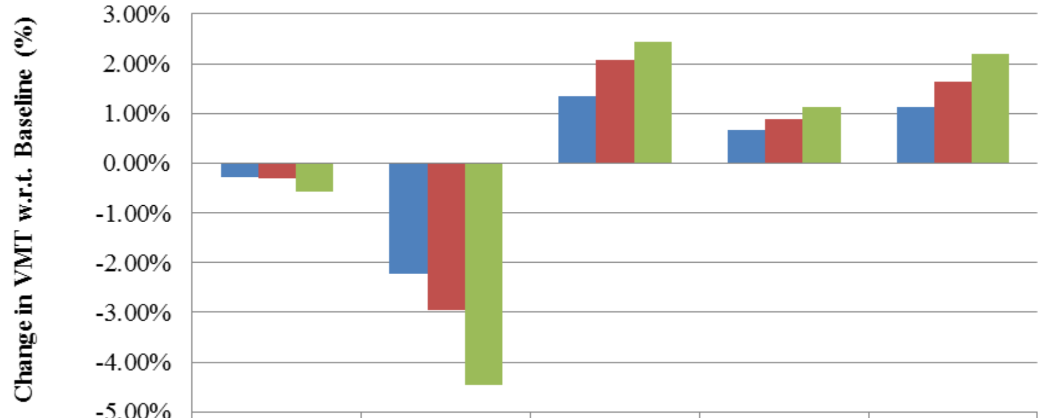
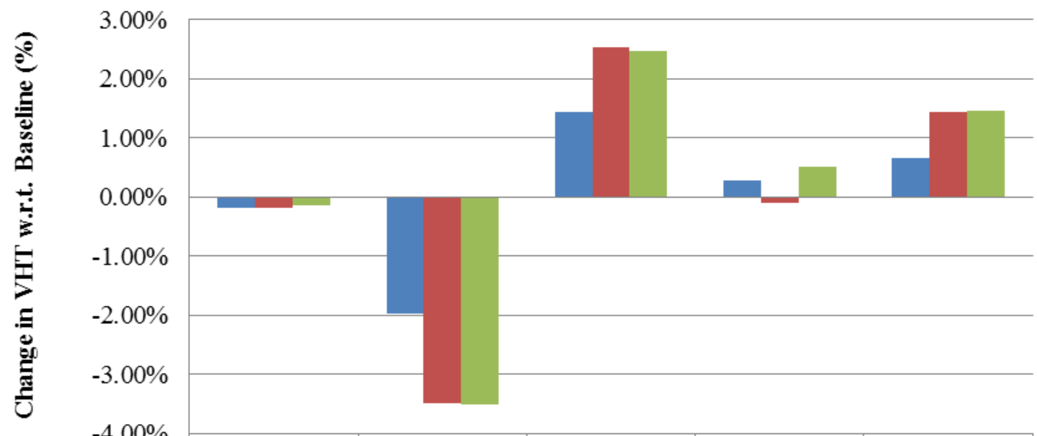


Figure 3.7.3-3. Change in VMT for Tolling Existing Lane Scenario- $0.15 toll



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-0.28%	-2.22%	1.36%	0.66%	1.14%
PM	-0.31%	-2.96%	2.08%	0.88%	1.64%
ALL PERIODS	-0.57%	-4.47%	2.44%	1.12%	2.21%

Figure 3.7.3-4. Change in VHT for Tolling Existing Lane Scenario- $0.15 toll



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-0.19%	-1.98%	1.45%	0.28%	0.66%
PM	-0.19%	-3.49%	2.54%	-0.09%	1.45%
ALL PERIODS	-0.13%	-3.51%	2.47%	0.52%	1.47%

Figure 3.7.3-5. Change in VHD for Tolling Existing Lane Scenario- $0.15 toll

	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-0.33%	-1.79%	1.36%	0.20%	0.33%
PM	-0.74%	-3.72%	4.39%	-0.69%	0.74%
ALL PERIODS	-0.45%	-2.31%	1.82%	0.27%	0.37%

Tolling Existing Lanes (TEL-30): $0.30 toll

Figure 3.7.3-6 below shows the impact of a $0.30 per mile toll on AM peak highway speeds. The pattern of impacts is similar to the $0.15 per mile toll, but it is more pronounced. For example, there are speed improvements over 5 mph or more in most sections of the I-495, the Capital Beltway, I-695, the Baltimore Beltway and I-95 corridor. Improvements are also more significant on I-270 compared to TEL-15 scenario (greater than 3 mph on most links). However, tolls negatively affect other facilities that are not tolled, causing speed reductions of 1 to 3 miles per hour on most links (Figure 3.7.3-7).

Change in VMT, VHT and VHD also show similar characteristics to TEL-15 scenario, but the impact is higher (Figures 3.7.3-8 through 3.7.3-10). In this scenario, significant reductions are observed in VMT, VHT and VHD on interstate roads while increases are observed on all other facilities (up to about 5%). This is expected because traffic that avoids higher toll values diverts to other facilities causing congestion and delays.

Figure 3.7.3-6. Impact of a $0.30 toll on existing Interstate lanes on AM travel speeds (speed increase)

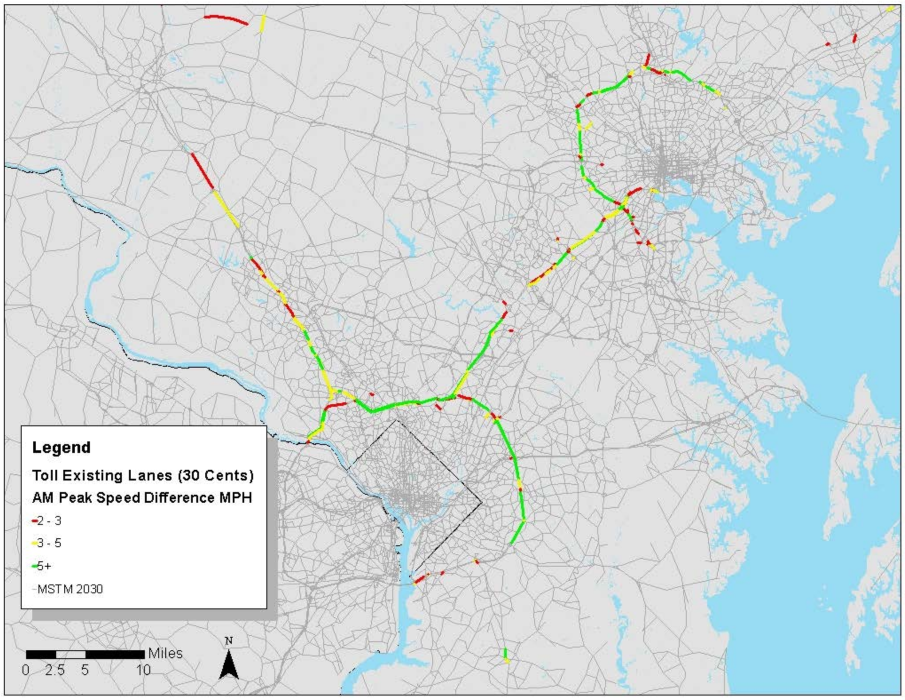


Figure 3.7.3-7. Impact of a $0.30 toll on existing Interstate lanes on AM travel speeds (speed decrease)

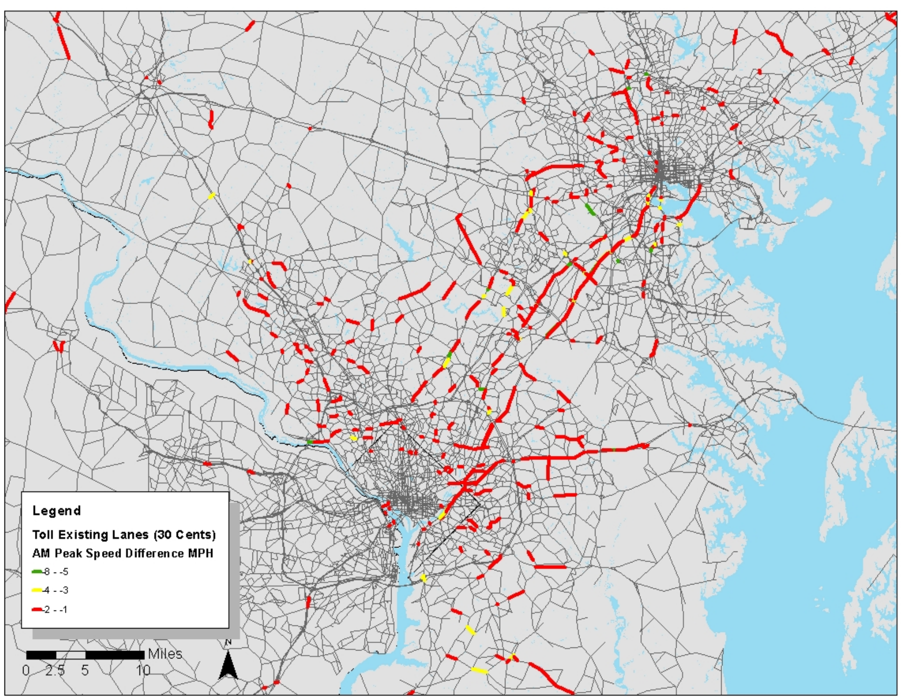
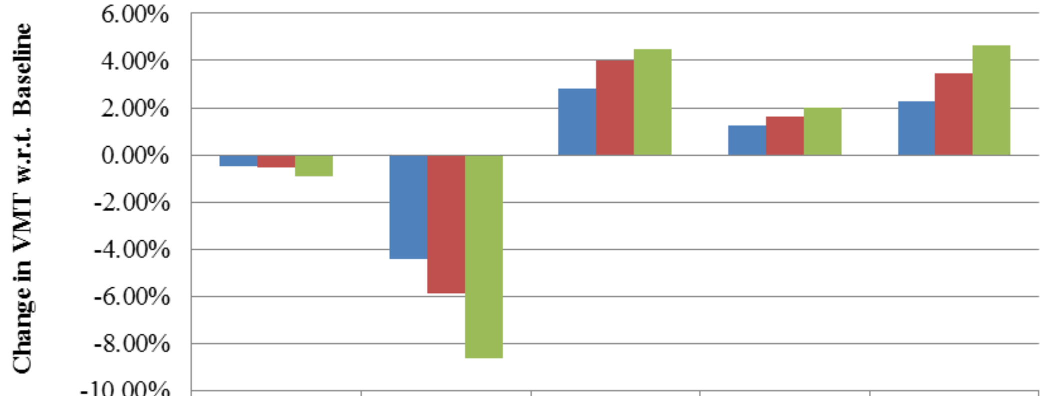
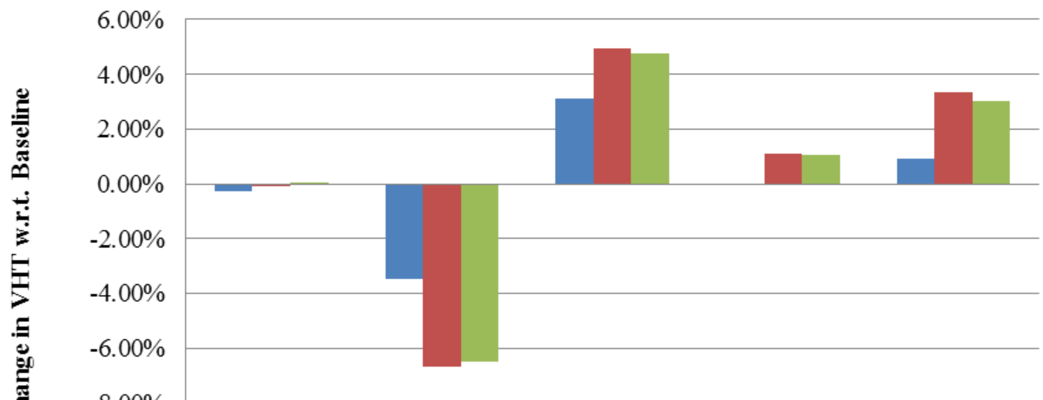


Figure 3.7.3-8. Change in VMT for Tolling Existing Lane Scenario- $0.30 toll



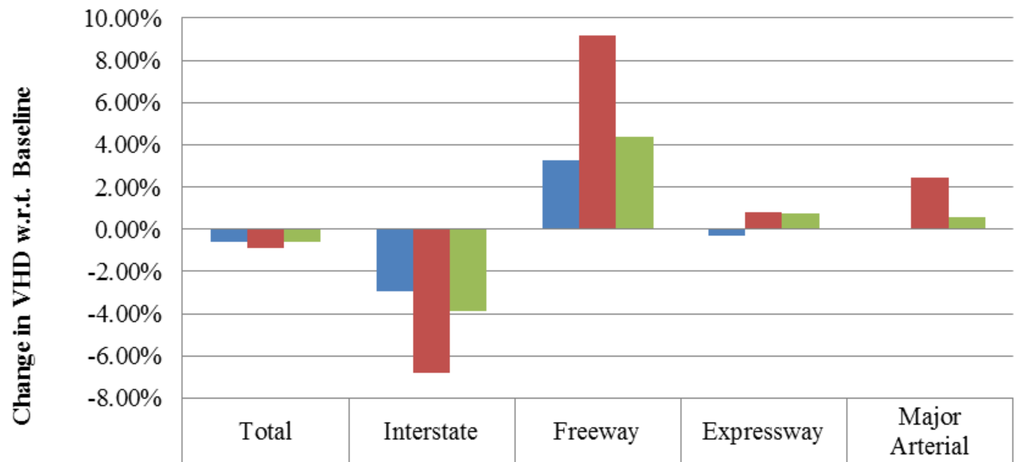
	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-0.48%	-4.43%	2.80%	1.26%	2.29%
PM	-0.55%	-5.89%	4.01%	1.65%	3.47%
ALL PERIODS	-0.90%	-8.61%	4.51%	2.00%	4.63%

Figure 3.7.3-9. Change in VHT for Tolling Existing Lane Scenario- $0.30 toll



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-0.29%	-3.50%	3.11%	-0.05%	0.90%
PM	-0.10%	-6.70%	4.96%	1.10%	3.36%
ALL PERIODS	0.01%	-6.51%	4.74%	1.07%	3.01%

Figure 3.7.3-10. Change in VHD for Tolling Existing Lane Scenario- $0.30 toll



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-0.58%	-2.93%	3.26%	-0.30%	0.06%
PM	-0.91%	-6.80%	9.15%	0.78%	2.42%
ALL PERIODS	-0.57%	-3.86%	4.38%	0.76%	0.60%

3.7.4 Analysis of tolling scenarios

Table 3.7.4-1 below summarizes the impacts of express toll lane scenarios based on the change in VHD with respect to the Baseline (CLRP). As seen in Table 3.7.4-1, in both the AM and PM peak periods, ETL-15 provide higher reduction in VHD on all facilities except major arterial roads. It is noted that while express toll lanes provide better results with lower toll values (i.e. $0.15 per mile), tolling existing lanes (TEL) did better with higher toll values (i.e. $0.30 per mile), though only on interstates. Results demonstrate that tolling existing lanes reduces delays on tolled roads while causing delays on others.

Table 3.7.4-1. Comparison of VHD w.r.t Baseline for toll scenarios

	AM Peak (%)			PM Peak (%)		
Facility Type	**ETL-15**	**ETL-30**	**ETL-60**	**ETL-15**	**ETL-30**	**ETL-60**
Interstate	-11.32	-8.65	-5.02	-8.14	-5.23	-2.08
Freeway	-11.76	-4.54	0.66	-9.77	-6.05	-3.77
Expressway	-23.74	-18.68	-15.17	-16.51	-10.95	-7.04
Major Arterial	-9.54	-13.64	-14.54	-4.96	-5.23	-2.75
Total	***-7.48***	***-6.76***	***-5.46***	***-4.21***	***-5.69***	***-1.95***

3.7.5 Summary

Toll roads can play a significant role in improving system performance and reducing traffic congestion. As results showed, toll roads can have significant impact on facilities that are not tolled. They can also be used to manage traffic flow. When combined with new construction, tolls can be very effective. If tolls are applied to existing lanes, the traffic flow on the tolled links will improve but travel times on adjacent links will likely decrease. Often tolls are thought of as a method of congestion reduction with low cost to the government; with toll revenues funding the cost of new construction. While this can be a viable source of funding, care must be taken that the tolls not be set so high as to discourage travel on the tolled facility. The conflicting objectives of maximizing revenue and smoothing traffic flow need to be reconciled.

3.8 Summary of Transportation Scenario Results

These scenarios, namely truck diversion, transit service improvements and express toll lane networks, addressed the issue of how transportation improvements could help to relieve traffic congestion and improve travel speeds. The scenario results also can serve as a guideline for decision makers in policy development and implementation.

The first alternative scenario considered, the long distance truck diversion scenario, is found to be the least effective in reducing congestion. This is due to the very low portion of long distance trucks of the total travel they represent in the peak period. Thus, relieving congestion through truck diversion will require actions which encourage shorter distance truck trips and higher value cargos to move from highway to rail.

Among the transit improvement scenarios, we found that TIS-3 (reducing the fares and headways 50%) is the most effective scenario. The improvements proposed provide the upper bound of the ability of the existing transit system to relieve traffic congestion through better service. However, it should be noted that capacity constraints and operational constraints such as required fleet size, number of additional staff and the ability of rail lines to handle additional vehicles are not taken into account in the analysis. It is highly likely that existing facilities, fleets and staff may not have the capability of providing the additional service and would need to significantly expand.

The tolling scenarios also provided insight on the impact of applying tolls either on new express toll lanes or on existing lanes. Among the tolling scenarios, ETL-15, adding two express toll lanes to interstates and applying a $0.15 per mile toll is found to be the best pricing scenario. Results showed that adding express toll lanes increases highway capacity and relieves congestion both on tolled roads and the adjacent roadways.

The tolling scenarios revealed clearly that there is competition among modes. Thus, increasing transit ridership will likely require one or combination of the following actions:

- Providing new transit routes to areas currently unserved or underserved by transit
- Upgrading existing transit service to become faster than the automobile, proving a travel time savings for transit
- Altering land use patterns so that residents and employees have better access to transit.

4 CLIMATE CHANGE SCENARIO

Rising sea levels have the potential to disrupt travel through flooding of the transportation network and to alter land use patterns due to areas becoming less habitable. The climate change scenario assumes a two-foot sea level rise by 2030, causing flooding in tidal Virginia and the Maryland Eastern Shore and disabling portions of the highway network. Note that this scenario differs from all others as it investigates the transportation network's response to climate change, whereas all other scenarios are designed to investigate improvements in traffic flows in response to applied strategies such as tolling, improving transit service or changing land use.

4.1 CLIMATE CHANGE – SCENARIO ASSUMPTIONS

Global warming, with the anticipated change in climate and the accompanying rise in sea level, is a critical issue facing the State of Maryland and the entire world. In this scenario, we address the effect of rising sea level on the location of population and employment, along with the impact on the transportation system. In one key respect this scenario differs from the others. The other scenarios all analyze what happens if the State takes specific actions to change policies and affect the future. In climate change we address what happens if the State fails to act, rather than if it does act.

There have been multiple forecasts about climate change, its impact and the speed at which sea level rise will occur. Perhaps the most widely accepted forecasts are those of the Intergovernmental Panel on Climate Change (IPCC), which projected a sea level rise anywhere from 7" to 23" by 2100. Other forecasts take a more aggressive approach, estimating either a faster sea level rise or a higher overall rise. The objective of this scenario is to demonstrate the potential impact of sea level rise on the transportation system, not to prepare a precise forecast of specific changes in sea level at specific times.

The scenario assumes that the sea level will rise by 2′ in 2030. While this is an aggressive scenario in terms of sea level rise, it is within the range of the more aggressive forecasts. Further, we do not have land use scenario data available beyond 2030. Also, storm surges will have a major impact on transportation, possibly greater than sea level rise. However modeling storm surges is beyond the resources available to this project.

The sea level rise will have two effects on the transportation system; removing population and employment from low lying areas and making portions of the transportation system unusable due to flooding. The specific implementation of each is described below:

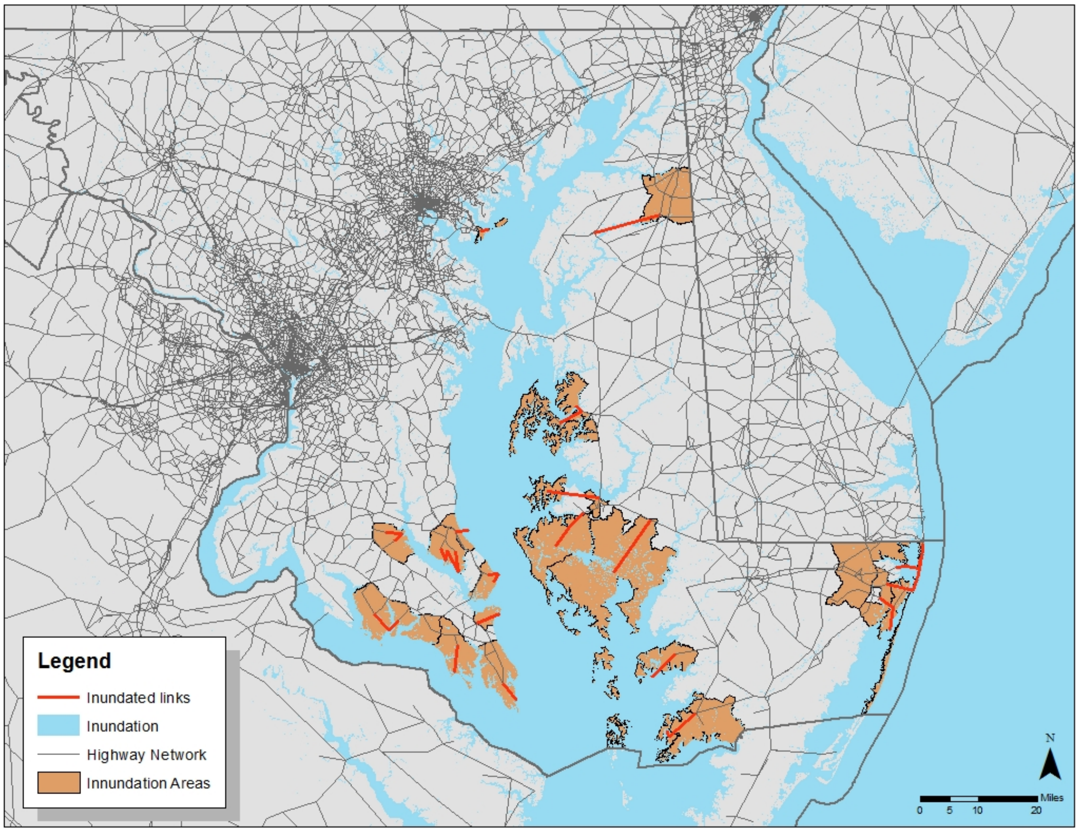
Land Use – Certain zones, and portions of zones, will be underwater with a two-foot rise in sea level. For those zones entirely underwater, we assume that one half the anticipated population and one half the anticipated employment will locate in other parts of the State and one half will locate outside the region.

Transportation Network – Under this scenario rising sea level will place specific links in the transportation system under water, making them unusable. If any part of a transportation link floods, the entire link will be unusable. The impact of flooding of a link depends on the location of the link relative to the rest of the network. Flooding of a two-lane link connecting a small town on the eastern shore with the rest of the State would have minimal impact, while flooding of a portion of I-95 would have a major impact. In the scenario, all rail links and major bridges remain in place. We assume that the relevant agencies or owners would act to ensure their continued usability.

4.2 RANGE OF IMPACT

Figure 4.2-1 below shows the highway links and the modeling zones affected by a 2′ sea level rise.

Figure 4.2-1. Inundation modeling zones and highway links



The zones in orange reflect zones which would be completely flooded and therefore unusable. As can be seen, nearly all of the affected zones are on the Maryland Eastern Shore or in tidal Virginia. The highway links, shown in red, indicate links which are unusable under this scenario.

This scenario can also be used to address adjustment of low-lying bridges in the area to possible sea level rise in the future.

4.3 CLIMATE CHANGE SCENARIO

A climate change scenario has been constructed. The scenario assumes that population and employment relocates and that all major highway links are improved to be functional with a 2′ sea level rise. While storm surges due to climate change would have a significant impact, due to availability of resources, the scope of this project was limited to the effects of sea level rise.

4.3.1 Climate Change

Figure 4.3.1-1 below illustrates the effect of a 2′ sea level rise on transportation network (PM peak). In this figure, it can be seen that highway links in tidal Virginia and a few highway links on the Maryland Eastern Shore show improvements in travel speed. This results in low lying areas having less population and employment, thus generating fewer trips and producing less traffic. At the same time, there is additional congestion on smaller links North of Baltimore near the Susquehanna River. This is due to the population of inundated zones being located in other areas. This scenario shows that rising sea levels will have an impact on specific areas but will not have a system wide major impact.

As seen in Figures 4.3.1-2 through 4.3.1-4, improvements in VMT, VHT and VHD are observed. There is significant reduction in expressway and major arterial VHT and VHDs.

Figure 4.3.1-1. Impact of climate change scenario (PM peak)

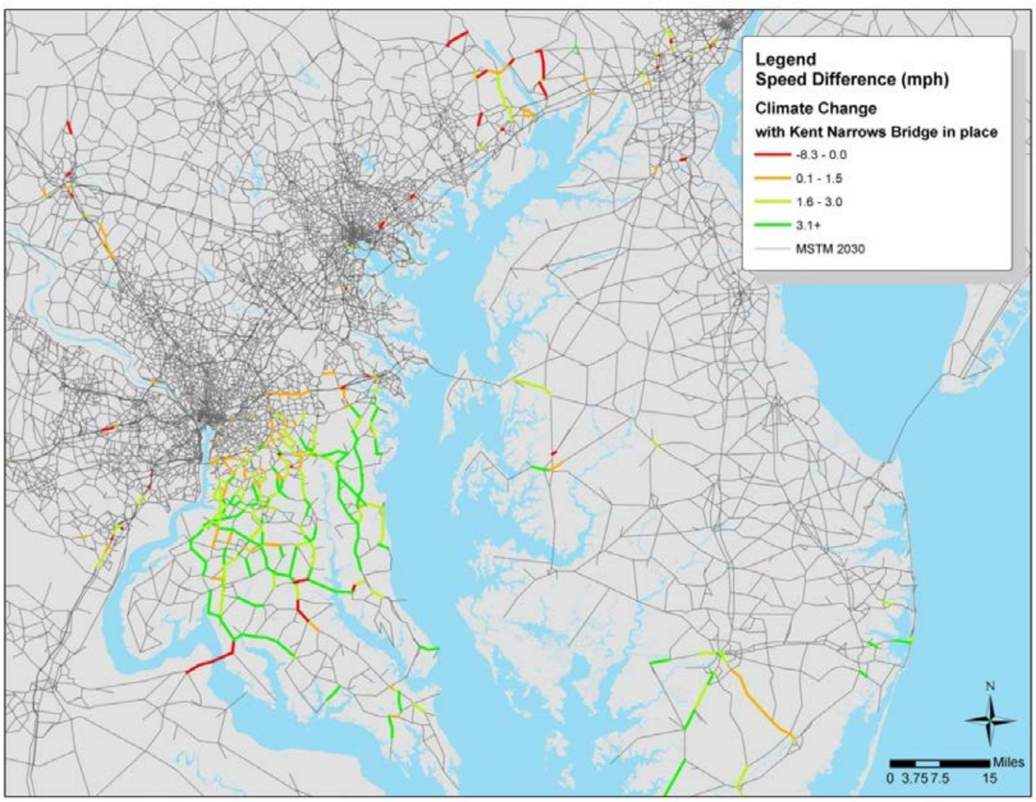
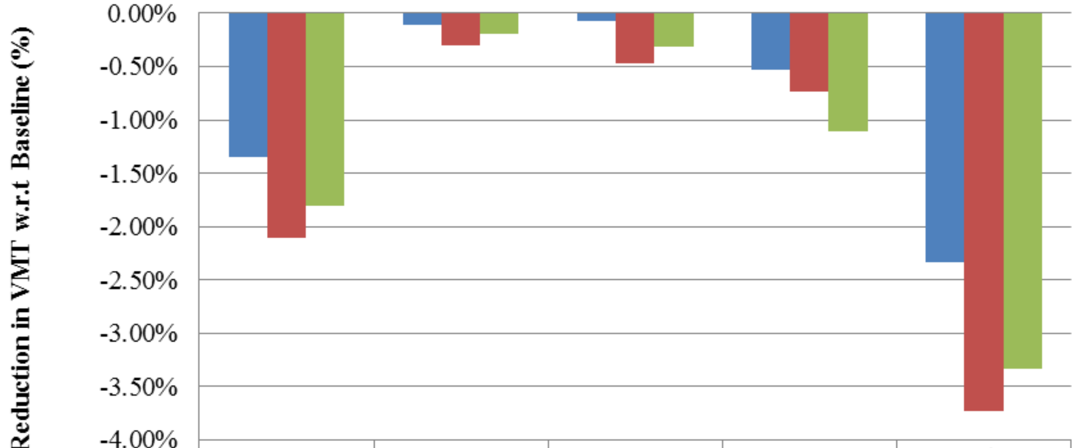
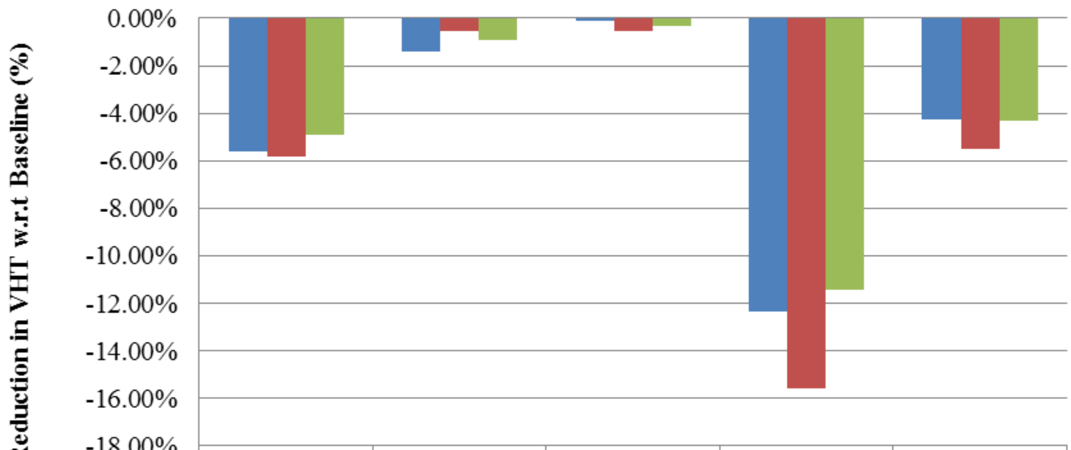


Figure 4.3.1-2. Change in VMT - Climate Change Scenario



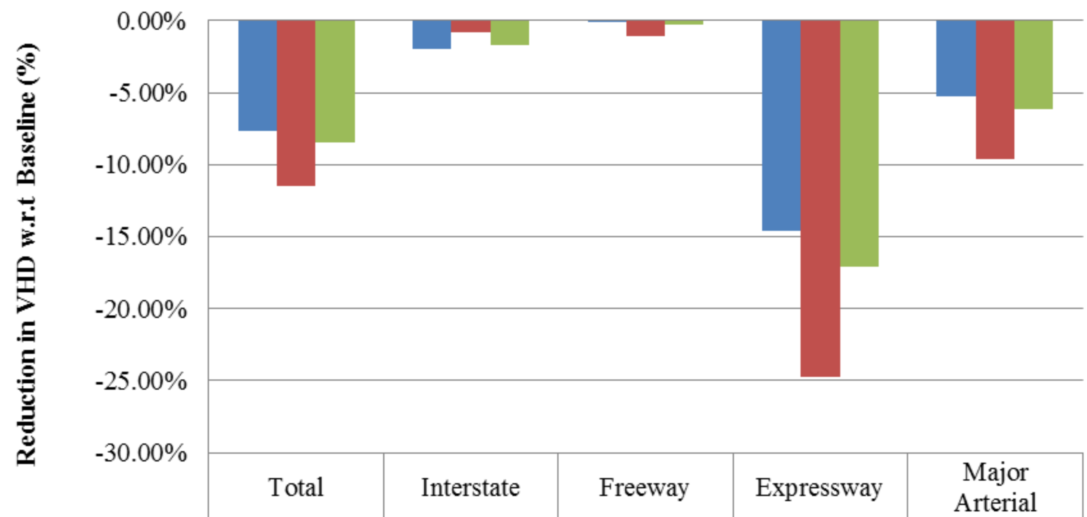
	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-1.35%	-0.10%	-0.08%	-0.53%	-2.34%
PM	-2.11%	-0.31%	-0.47%	-0.74%	-3.73%
ALL PERIODS	-1.80%	-0.19%	-0.32%	-1.11%	-3.33%

Figure 4.3.1-3. Change in VHT for Climate Change Scenario



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-5.61%	-1.43%	-0.09%	-12.32%	-4.26%
PM	-5.85%	-0.53%	-0.55%	-15.56%	-5.52%
ALL PERIODS	-4.92%	-0.94%	-0.31%	-11.42%	-4.34%

Figure 4.3.1-4. Change in VHD for Climate Change Scenario



	Total	Interstate	Freeway	Expressway	Major Arterial
AM	-7.62%	-2.00%	-0.08%	-14.63%	-5.28%
PM	-11.49%	-0.81%	-1.04%	-24.72%	-9.61%
ALL PERIODS	-8.47%	-1.71%	-0.29%	-17.12%	-6.19%

4.3.2 Summary

The climate change scenario, by assuming a 2′ rise in sea level by 2030, made portions of the highway network unusable, with the potential to change travel patterns. In addition, a sea level rise also causes very low lying areas to become uninhabitable. A portion of the population living in those areas is assumed to move to other parts of the State, placing a greater demand on the transportation network.

This scenario assumed that the State would take action to preserve all the major links in the transportation system. If a major link in the system became unavailable, wide ranging impacts would occur throughout the State and in neighboring states.

5 INTEGRATED LAND USE AND TRANSPORTATION SCENARIOS

The integrated land use and transportation scenarios analyze impacts of previously examined transportation alone and land use alone scenarios in combination. These scenarios are formed by combining two selected transportation scenarios with five land use scenarios (Table 5-1). The transportation scenarios are selected based on their capability of relieving congestion and improving measures such as VMT, VHT and VHD. Specifically, Transit Improvement Scenario-3 (TIS-3), where headways and fares are reduced 50% and Express Toll Lanes Scenario (ETL-15), where a $0.15 per mile toll is applied, are selected for integration. For the sake of simplicity in representation, TIS-3 is denoted as TRNS and ETL-15 is denoted as ETL in this section. All scenarios estimate travel activity in the year 2030.

The Baseline scenario uses the 2030 Constrained Long Range Plans (CLRP) of the BMC and MWCOG, along with planned transportation network improvements. The Baseline serves as the basis of comparison for all other alternatives. These comparisons allow for the estimation of changes and impacts. However, the Baseline Scenario (CLRP) in this section includes Red Line, Purple Line, Inter County Connector (ICC) and Corridor Cities Transitway (CCT) in the 2030 network. Therefore impacts of these services are captured by the model.

Table 5-1. Integrated transportation and land use scenarios

		Transportation Scenarios		
		CLRP	**Improved Transit (TRNS)(*)**	**Express Toll Lanes (ETL)(**)**
Land Use Scenarios	**Baseline (CLRP)**	CLRP	CLRP-TRNS	CLRP-ETL
	Buildout (BO)	BO	BO-TRNS	BO-ETL
	Transit Friendly Development (TFD)	TFD	TFD-TRNS	TFD-ETL
	Market Driven Change (MDC)	MDC	MDC-TRNS	MDC-ETL
	High Energy Price (HEP)	HEP	HEP-TRNS	HEP-ETL

(*) Reduce headways and fares by 50%
(**) ETL 15 cents per mile scenario

5.1 Analysis Framework

The scenario analysis is conducted comparing the results with corresponding Baseline scenarios which are CLRP and its combinations CLRP-TRNS (CLRP land use scenario combined with improved transit scenario, TRNS) and CLRP-ETL (CLRP land use scenario combined with Express Toll Lane scenario, ETL). For example TFD-TRNS is compared with CLRP-TRNS instead of CLRP to account for impacts of transit improvements in both land use scenarios. These scenarios are analyzed from two different perspectives: (1) System-wide performance, (2) Behavioral analysis for selected scenarios.

The system wide results are presented using highway usage measures, namely Vehicle Miles Traveled (VMT), Vehicle Hours Traveled (VHT), Vehicle Hours Delay (VHD) and Congested Lane Miles (CLM). These measures are reported for a day. In addition to the highway usage measures, we also report the percent change in the greenhouse gas emission estimates and the distribution of trips among modes for each scenario. The percent changes that each scenario provided with respect to the corresponding Baseline scenarios are also presented and utilized while discussing impacts of each scenario.

Behavioral results are analyzed on selected scenarios with greater detail. This analysis is performed for the scenarios which are found to have greatest impact on travel. Four trip characteristics are used for the analysis, namely trip origins and destinations, trip purpose, trip mode and travelers' income group. Six trip purposes are used for the analysis:

HBW	Home Based Work
HBS	Home Based Shop
HBO	Home Based Other
HBSC	Home Based School
NHBW	Non Home Based Work
OBO	Other Based Other

The available modes are SOV (Single Occupancy Vehicle), HOV (High Occupancy Vehicle), BUS and RAIL. The change in behavior in mode choice among the scenarios is analyzed by looking into total trips made by each mode. Finally, the trips are analyzed by the user income categories. Five income quintiles are used for the analysis:

1. Low income (less than $30,000)
2. Medium-Low income ($30,000-$60,000)
3. Medium income ($60,000-$90,000)
4. Medium-High income ($90,000-$150,000)
5. High income ($150,000 and more)

5.2 SYSTEM-WIDE RESULTS ANALYSIS

The system-wide results are first analyzed for the land use scenarios. The analysis then focused on transportation scenarios. Finally, a comparative analysis of combination scenarios is made. In addition, the combination scenarios are evaluated by the amount of percent reduction in GHGs. Tables 5.2-2 through 5.2-5 present the results of system-wide analysis namely VMT, VHT, VHD and CLM.

The percentages in Tables 5.2-1 through 5.2-5 should read as follows: percent change from CLRP for the scenarios in the first column (CLRP), percent change from CLRP-TRNS for the scenarios in the second column (TRNS) and percent change from CLRP-ETL for the scenarios in the third column (ETL).

Table 5.2-1 summarizes the total number of vehicle trips made under each scenario. Except the BO scenario, all scenarios cause reduction in number of trips compared to the corresponding Baseline scenario. The HEP scenario causes the greatest decline in number of trips followed by the TFD scenario. Improved transit service causes modest changes in the number of trips and the magnitude of changes are similar across all land use scenarios.

Table 5.2-1. System-wide Results - Total Number of Vehicle Trips (in millions)

	NUMBER OF VEHICLE TRIPS (IN MILLIONS)		
	CLRP	**Improved Transit (TRNS)**	**Express Toll Lanes (ETL)**
Baseline (CLRP)	301.66	297.27	301.81
Buildout (BO)	322.63 (6.95%)	318.09 (7.00%)	323.31 (7.12%)
Transit Friendly Development (TFD)	286.71 (-4.96%)	281.19 (-5.00%)	285.20 (-5.51%)
Market Driven Change (MDC)	298.86 (-0.93%)	294.61 (-0.90%)	298.90 (-0.97%)
High Energy Price (HEP)	208.37 (-30.93%)	202.72 (-31.81%)	208.40 (-30.95%)

Among the land use alternatives, as seen in Tables 5.2-2 through 5.2-5, the HEP scenario provides the greatest reduction in VMT, VHT, VHD and CLM. The second best scenario after HEP is TFD which also provides reduction in highway measures but less pronounced. The only scenario that causes increases in all the measures is the BO scenario where existing zoning schemes were allowed to be used to capacity. The MDC scenario also shows a very slight increase in VMT and CLM while reducing other measures. An important observation made is that while the direction of impacts is consistent among the measures, their magnitudes may differ significantly. For example while TFD reduced VMT by 3.57%, it led to 6.36%, 12.31% and 10.60% reduction in VHT, VHD and CLM respectively.

The impacts of transportation scenarios on travel are not as pronounced as land use scenarios. As seen, the impacts are within low to moderate range. A worthwhile observation available from the results is that the impacts of transportation alternatives are similar in magnitude across the land use alternatives. The greatest reductions in VMT and VHT (in absolute values) are obtained from improved transit scenarios (-TRNS). The impacts of transit improvements are moderate because the improvement scenario did not consider new service or expanded service areas but only improved the existing service. The ETL scenario increased VMT but reduced VHT, VHD and CLM. In fact, ETL led to the greatest reduction in CLM. This could be a result of added capacity to the interstate roads by Express Toll Lanes. The improved conditions on the interstates led to less congested conditions in the network.

Examining the results for the combinations of scenarios by looking at the absolute values, we see that HEP-TRNS provides the greatest reduction in VMT, VHT and VHD. When we look at the CLM, we see that HEP-ETL and TFD-ETL provide slightly greater reduction in CLM. This can be a result of added capacity in the ETL scenarios as explained above. BO-TRNS and BO-ETL scenarios cause increases in all the measures despite the improvements. The impact is much worse for the VHD measure. This suggests that if growth is allowed to reach maximum levels under current zoning policies, the regional traffic will be impacted negatively and travelers will experience long delays.

Table 5.2-2. System-wide Results- Vehicle Miles Traveled (VMT, in millions)

	VMT		
	CLRP	**Improved Transit (TRNS)**	**Express Toll Lanes (ETL)**
Baseline (CLRP)	193.97	191.94	194.28
Buildout (BO)	215.74 (11.22%)	213.62 (11.30%)	216.32 (11.35%)
Transit Friendly Development (TFD)	187.04 (-3.57%)	185.03 (-3.60%)	185.03 (-5.28%)
Market Driven Change (MDC)	194.05 (0.04%)	191.99 (0.03%)	194.31 (0.02%)
High Energy Price (HEP)	142.23 (-26.68%)	140.19 (-26.96%)	142.27 (-26.77%)

Table 5.2-3. System-wide Results- Vehicle Hours Traveled (VHT, in millions)

	VHT		
	CLRP	**Improved Transit (TRNS)**	**Express Toll Lanes (ETL)**
Baseline (CLRP)	7.68	7.54	7.55
Buildout (BO)	9.68 (26.14%)	9.54 (26.56%)	9.55 (26.40%)
Transit Friendly Development (TFD)	7.19 (-6.36%)	7.06 (-6.32%)	7.00 (-7.29%)
Market Driven Change (MDC)	7.19 (-6.38%)	7.07 (-6.22%)	7.05 (-6.68%)
High Energy Price (HEP)	4.30 (-44.05%)	4.19 (-44.35%)	4.24 (-43.86%)

Table 5.2-4. System-wide Results- Vehicle Hours of Delay (VHD, in millions)

	VHD		
	CLRP	**Improved Transit (TRNS)**	**Express Toll Lanes (ETL)**
Baseline (CLRP)	2.91	2.82	2.80
Buildout (BO)	4.96 (70.59%)	4.84 (71.58%)	4.85 (73.47%)
Transit Friendly Development (TFD)	2.55 (-12.31%)	2.49 (-11.75%)	2.50 (-10.51%)
Market Driven Change (MDC)	2.64 (-9.15%)	2.51 (-10.77%)	2.51 (-10.41)
High Energy Price (HEP)	0.89 (-69.56%)	0.87 (-69.21%)	0.89 (-68.31%)

Table 5.2-5. System-wide Results- Congested Lane Miles (CLM, in miles)

	CLM		
	CLRP	**Improved Transit (TRNS)**	**Express Toll Lanes (ETL)**
Baseline (CLRP)	3784.84	3631.64	3523.79
Buildout (BO)	4784.19 (26.40%)	4552.41 (25.35%)	4544.19 (28.96%)
Transit Friendly Development (TFD)	3383.51 (-10.60%)	3240.15 (-10.78%)	3121.64 (-11.41%)
Market Driven Change (MDC)	3788.5 (0.10%)	3650.23 (0.51%)	3565.46 (1.18%)
High Energy Price (HEP)	1237.57 (-67.30%)	1206.09 (-66.79%)	1198.31 (-65.99%)

5.2.1 Greenhouse Gas Estimates

The GHG estimates are obtained from the model results by coupling the MSTM with EPA's MOVES 2010 model to analyze the effect of transportation on emissions and greenhouse gases (GHGs[7]). The details of GHG estimation procedure followed in this project are reported in Appendix C.

As seen in Table 5.2.1-1, each scenario is evaluated by the percent change in CO_2Eq (Carbondioxide equivalent[8]) from the Baseline scenario. As the results illustrate, HEP-TRNS scenario provides the greatest reduction in GHGs compared to CLRP-TRNS. TFD-TRNS also provides a decline in GHGs but not as pronounced as HEP. Similar to the other system-wide performance measures, BO combination scenarios cause an increase in GHGs. It is also noted that the difference between transit improvements and express toll lane impacts is not significant.

Figure 5.2.1-1. System-wide Results- Greenhouse Gas Estimates (% change in CO_2Eq from the CLRP)

	GHG ESTIMATES (% change in CO_2Eq)		
	CLRP	**Improved Transit (TRNS)**	**Express Toll Lanes (ETL)**
Baseline (CLRP)	-	(-1.38%)	(-3.24%)
Buildout (BO)	11.52%	11.59%	11.98%
Transit Friendly Development (TFD)	-4.01%	-4.20%	-3.08%
Market Driven Change (MDC)	-0.06%	-0.12%	-0.0%
High Energy Price (HEP)	-30.11%	-30.38%	-29.34%

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[7] However, since the regions are still in transitioning to the MOVES, the model work that the MSTM does is not directly comparable to the model results available through MDOT. For example assumptions made in this work maybe slightly different.

[8] "A metric measure used to compare the emissions from various greenhouse gases based upon their global warming potential (GWP). Carbon dioxide equivalents are commonly expressed as "million metric tons of carbon dioxide equivalents (MMTCO2Eq). The carbon dioxide equivalent for a gas is derived by multiplying the tons of the gas by the associated GWP. " Source: http://www.epa.gov/climatechange/glossary.html#C

5.2.2 **Mode Choice**

Analyzing the distribution of trips among modes gives additional information on how different scenario combinations impact the mode choice of travelers in the region. Similar to the analysis in Section 5.2, the results are first analyzed for the land use alternatives and then for the transportation alternatives. Finally, a general evaluation of the combination scenarios is made from the mode distribution perspective.

Figures 5.2.2-1 through 5.2.2-4 demonstrate the person trips made by each mode for land use and transportation combinations scenarios, -CLRP, -TRNS and –ETL respectively. For a closer look, Tables 5.2.2-1 through 5.2.2-4 present the results of modal distribution of trips among four modes namely SOV, HOV, BUS and RAIL for each land use and transportation scenario combination. In Tables 5.2.2-1 through 5.2.2-4, the percentages given in the first row, for Baseline (CLRP) scenario, present the absolute mode shares for CLRP, CLRP-TRNS and CLRP-ETL respectively. The percentages listed for other scenarios present the percent change in mode share from the corresponding baseline scenario i.e. CLRP, CLRP-TRNS or CLRP-ETL. The percentages should read as follows: percent change in mode share from CLRP for the scenarios in the first column (CLRP), percent change in mode share from CLRP-TRNS for the scenarios in the second column (TRNS) and percent change in mode share from CLRP-ETL for the scenarios in the third column (ETL).

Figure 5.2.2-1.Comparison of trips by mode for combination scenarios

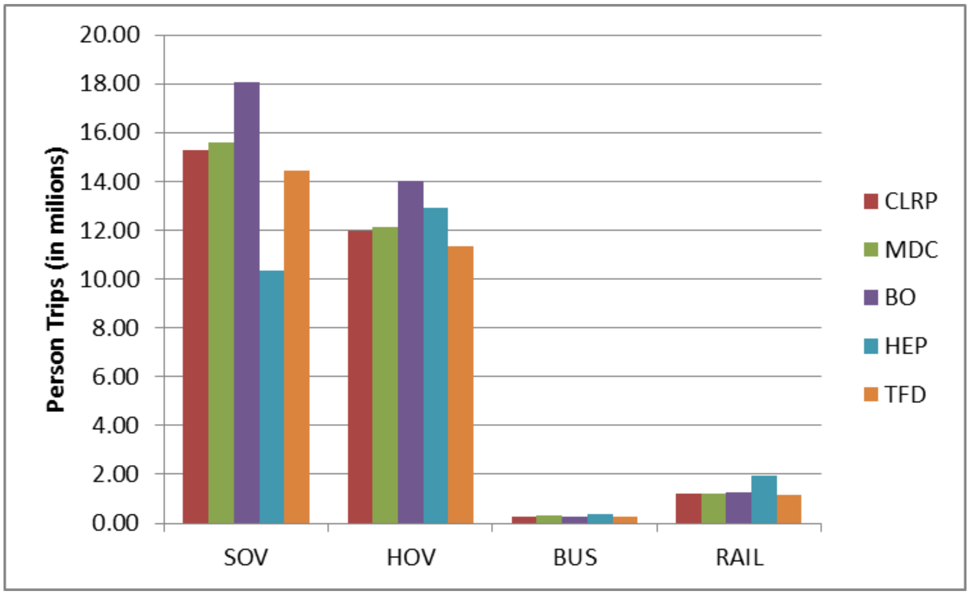


Figure 5.2.2-2. Comparison of trips by mode for land use-TRNS combination scenarios

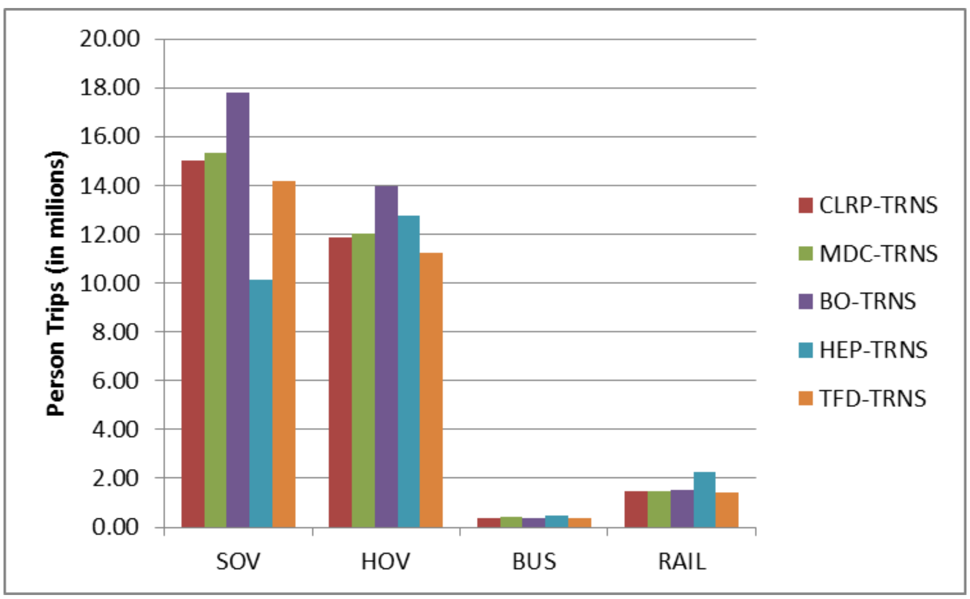
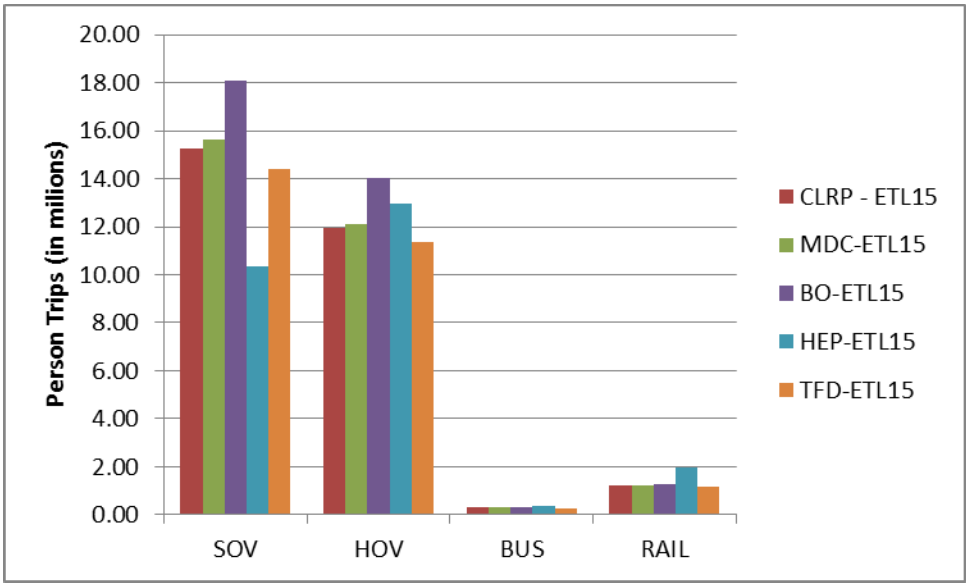


Figure 5.2.2-3. Comparison of trips by mode for land use-ETL15 combination scenarios



Among the land use alternatives, as seen in the Tables 5.2.2-1 through 5.2.2-4, HEP land use pattern provides the greatest reduction in SOV trips while increasing the trips made by all other modes (HOV, BUS and RAIL). TFD results are also similar to the HEP results but the impacts are less compared to the HEP scenario. For example while HEP scenario reduces SOV share by 24.13% from the Baseline (CLRP), TFD reduces it by 0.27%). In the TFD scenario, HOV, BUS and RAIL mode share also increases slightly compared to the Baseline, 0.10%, 1.23% and 2.14% respectively. As explained in Section 2.4, TFD scenario strategically relocates growth in employment and population around 20 transit stations in the region. BO and MDC scenarios cause increases in SOV mode as well as others (except MDC decreases HOV share slightly). The increase results from the increase in population and total number of trips; however, the increase in SOV trips is not desired.

The impacts of transportation scenarios are not as pronounced as land use scenarios. Very slight changes are observed between –TRNS and –ETL scenarios. We observe that the impacts of transportation alternatives are similar in magnitude across the land use alternatives. Transit improvements through reducing fare and headway provide further reduction in SOV and HOV trips and increase in BUS and RAIL trips. The impact of improved transit service is moderate since the scenario did not consider new transit service or expended service area but only improved the existing service.

Table 5.2.2-1. System-wide Results- Number of Single Occupancy Vehicle Trips (millions)

	SOV TRIPS (MILLIONS)		
	CLRP	**Improved Transit (TRNS)**	**Express Toll Lanes (ETL)**
Baseline (CLRP) (Mode Share)	15.28 (53.18%)	15.02 (52.31%)	15.27 (53.17%)
Buildout (BO) (% change in share)	18.06 (0.93%)	17.80 (1.14%)	18.05 (0.93%)
Transit Friendly Development (TFD) (% change in share)	14.42 (-0.27)	14.18 (-0.29)	14.42 (-0.27)
Market Driven Change (MDC) (% change in share)	15.61 (0.30%)	15.35 (0.32%)	15.60 (0.29%)
High Energy Price (HEP) (% change in share)	10.34 (-24.13%)	10.12 (-24.46%)	10.33 (-24.12%)

Table 5.2.2-2. System-wide Results- Number of High Occupancy Vehicle Trips (millions)

	HOV TRIPS (MILLIONS)		
	CLRP	**Improved Transit (TRNS)**	**Express Toll Lanes (ETL)**
Baseline (CLRP) (Mode Share)	11.96 (41.66%)	11.87 (41.35%)	11.96 (41.67%)
Buildout (BO) (% change in share)	14.05 (0.19%)	13.95 (0.29%)	14.05 (0.19%)
Transit Friendly Development (TFD) (% change in share)	11.34 (0.10%)	11.26 (0.09%)	11.34 (0.10%)
Market Driven Change (MDC) (% change in share)	12.11 (-0.68%)	12.02 (-0.67%)	12.11 (-0.68%)
High Energy Price (HEP) (% change in share)	12.94 (21.25%)	12.76 (20.47%)	12.94 (21.24%)

Table 5.2.2-3. System-wide Results- Number of Bus Trips (millions)

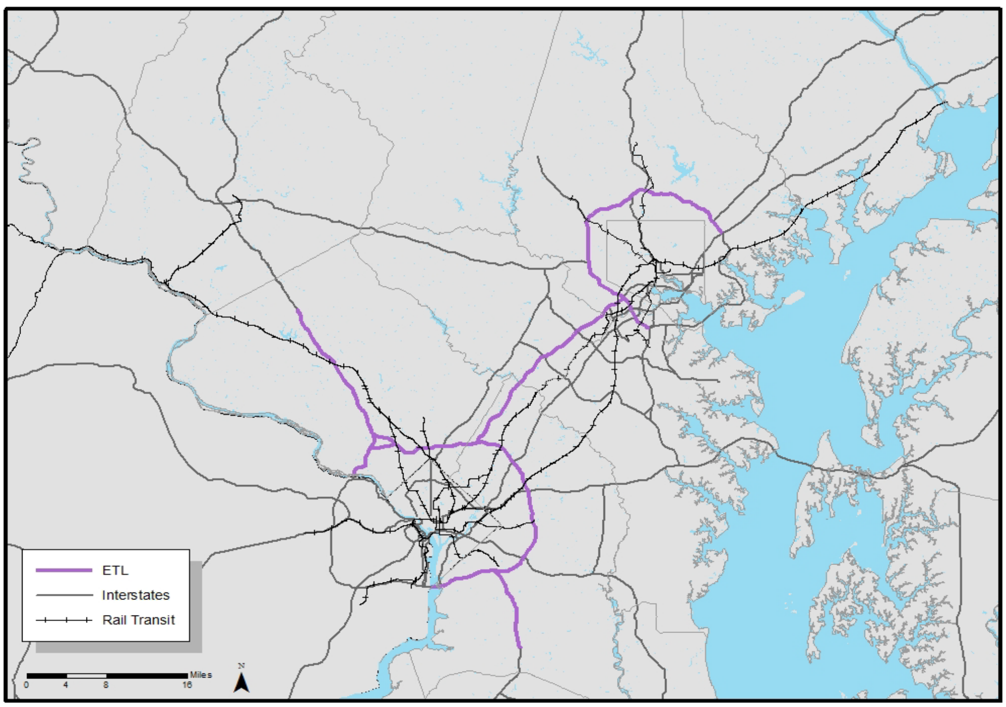
	BUS TRIPS (MILLIONS)		
	CLRP	**Improved Transit (TRNS)**	**Express Toll Lanes (ETL)**
Baseline (CLRP) (Mode Share)	0.28 (0.99%)	0.36 (1.27%)	0.28 (0.99%)
Buildout (BO) (% change in share)	0.29 (-13.86%)	0.37 (-12.95%)	0.28 (-13.85%)
Transit Friendly Development (TFD) (% change in share)	0.27 (1.23%)	0.35 (1.14%)	0.27 (1.25%)
Market Driven Change (MDC) (% change in share)	0.31 (7.64%)	0.40 (7.25%)	0.31 (7.65%)
High Energy Price (HEP) (% change in share)	0.37 (47.20%)	0.47 (45.47%)	0.37 (47.18%)

Table 5.2.2-4 System-wide Results- Number of Rail Trips (millions)

	RAIL TRIPS (MILLIONS)		
	CLRP	**Improved Transit (TRNS)**	**Express Toll Lanes (ETL)**
Baseline (CLRP) (Mode Share)	1.19 (4.16%)	1.45 (5.07%)	1.19 (4.16%)
Buildout (BO) (% change in share)	1.25 (-10.55%)	1.52 (-10.91%)	1.25 (-10.54%)
Transit Friendly Development (TFD) (% change in share)	1.16 (2.14%)	1.41 (1.92%)	1.16 (2.16%)
Market Driven Change (MDC) (% change in share)	1.23 (1.21%)	1.49 (0.40%)	1.23 (1.23%)
High Energy Price (HEP) (% change in share)	1.96 (84.29%)	2.26 (73.95%)	1.96 (84.21%)

It is observed that the ETL scenario does not have a significant impact on the distribution of trips among modes. To better understand the underlying reasons, the markets they serve are illustrated in Figure 5.2.2-4 below. As seen in Figure 5.2.2-4, transit and ETLs serve different markets. While rail transit serves the urban core, carrying the travelers to the Baltimore and Washington DC business districts, ETLs serve mostly the highway users around Baltimore and Capital Beltways as well as I-95 corridor. Therefore, they do not have a noticeable influence on each other. These conclusions about transit and ETL apply for each land use scenario.

Figure 5.2.2-4. ETL and RAIL transit



Examining the results for the combination scenarios, we see that HEP-TRNS provides the greatest reduction in SOV and the greatest increase in BUS and RAIL trips. The increase in rail trips is much higher compared to bus trips. TFD-TRNS is the second best scenario in reducing SOV and increasing transit trips. This scenario differs from HEP-TRNS as it reduces HOV trips too in addition to the SOV trips.

5.3 BEHAVIORAL ANALYSIS

The selected land use scenarios and their combinations with selected transportation scenarios, are analyzed in detail from the behavioral perspective. The scenario selection is based on the system-wide performance results of the alternatives. First, a detailed analysis of CLRP is made for comparison purposes, as it is the Baseline scenario. Then, HEP and TFD scenarios are selected from the land use scenarios as they have the greatest impact on system performance. These scenarios and their combinations are analyzed focusing particularly on impacts on transit ridership by using various trip characteristics. These characteristics are:

- Trip origin and destination
- Trip purpose *(HBW, HBS, HBO, NHBW, HBSC, OBO)*
- Mode (SOV, HOV, BUS, RAIL)
- Income group (from 1 to 5, five income quintiles)

5.3.1 Analysis of Baseline Scenario, CLRP

Transit Trips by Origins and Destinations

First, bus and rail transit trips are examined by looking into trip densities (number of trips per acre) by their origins and destinations. Then, a comparison between bus and rail transit trips is made. Note that transit trips include walk or drive to transit trips, thus origins are more scattered likely due to park and ride facilities.

As Figure 5.3.1-1 illustrates, bus trip densities (origin) are very low in the areas outside of city cores, both in Baltimore and Washington DC. The densities are higher in the cities and around the transit corridors e.g. in Montgomery County, I-270 corridor. As seen in Figure 5.3.1-2, bus trip densities by destination are more concentrated in the city cores, inside and around both beltways and I-270 corridor.

Figure 5.3.1-1. Density of BUS trips by their origins-CLRP

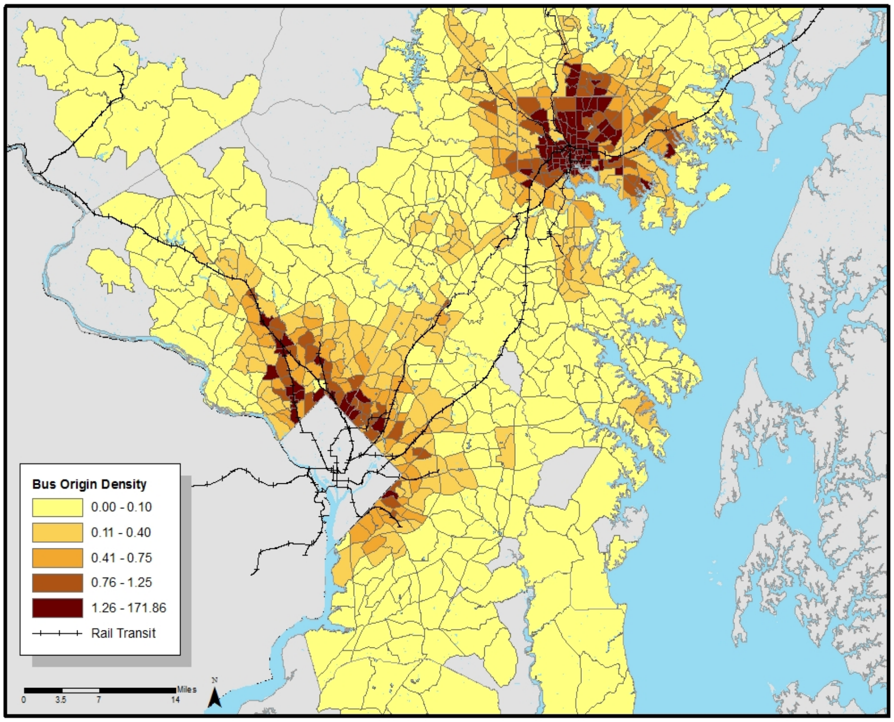
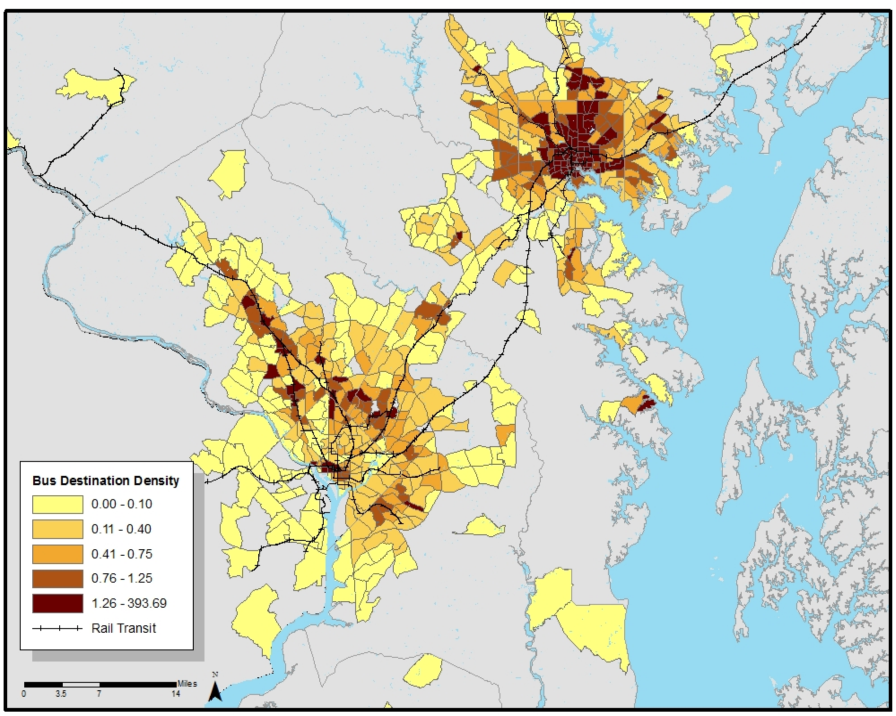


Figure 5.3.1-2. Density of BUS trips by their destinations - CLRP



The rail trips by origin and destination,[9] as seen in Figures 5.3.1-3 and 5.3.1-4 respectively, are much denser compared to the bus trip densities. This is likely a result of the good rail service coverage in the Baltimore-Washington Metropolitan Area. The Washington DC metro system, operated by WMATA (Washington Metropolitan Area Transit Authority), serves 86 stations in Virginia, Maryland and Washington DC. On the other hand, Maryland Transit Authority operates one of the largest multi-modal transit systems in the United States, providing Light Rail, Metro Subway, and Maryland Area Regional Commuter (MARC) Train Service in Maryland. The figures also reveal that rail trip origins are also more scattered and destinations are concentrated. While rail stations attract trips from a larger area through drive access, the destinations need to be directly accessible from the end station on foot or with short bus trips.

It is also noted that, both for bus and rail trips, the trip origins are consistent with housing densities while trip destinations are consistent with employment densities in the area.

[9] Trip origin data was only available for trips originating within Maryland. Destination information was available for the entire region.

Figure 5.3.1-3. Density of RAIL trips by their origins - CLRP

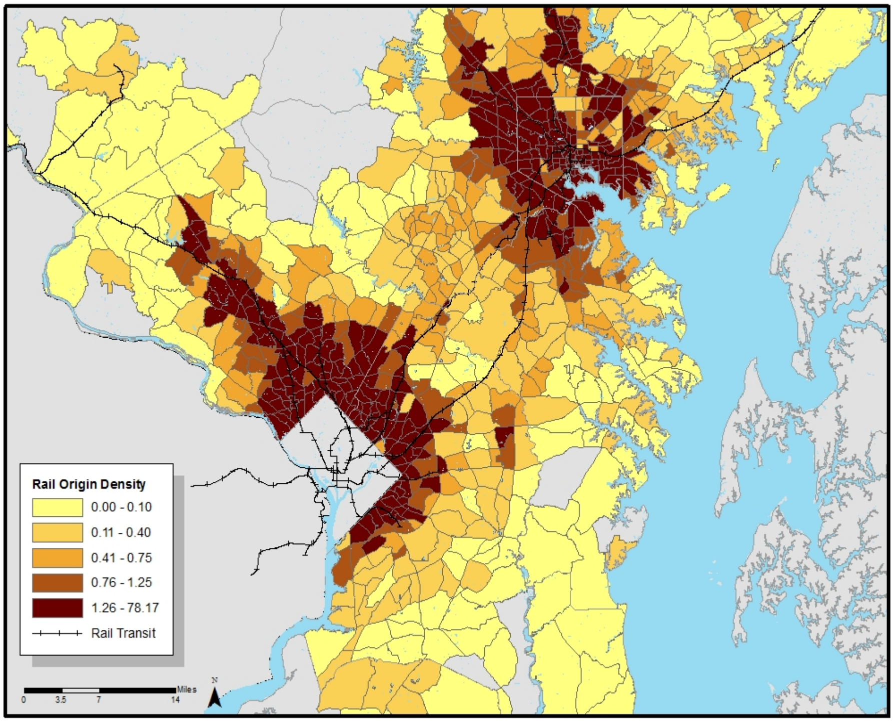
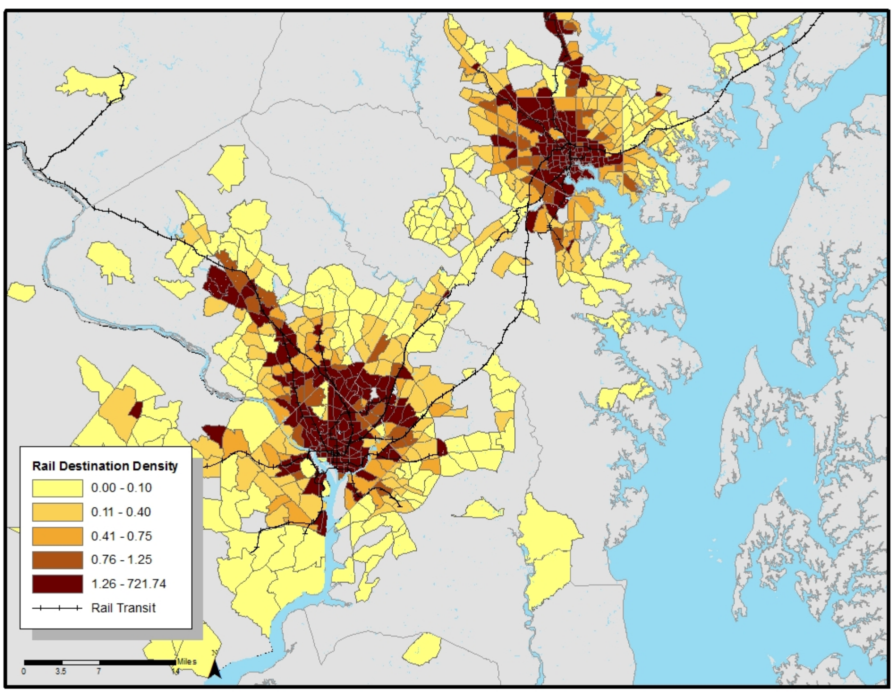


Figure 5.3.1-4. Density of RAIL trips by their destinations - CLRP



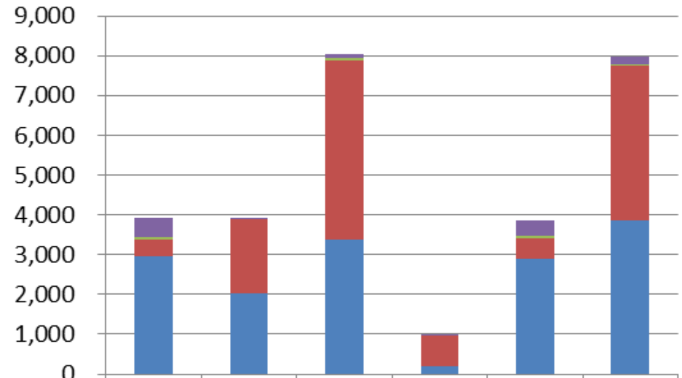
Trip Distribution among Modes

The trips are analyzed based on their distribution among four modes, namely SOV, HOV, Rail and Bus for the Baseline (CLRP) land use scenario. The analysis is further extended to investigate mode distribution by six trip purposes (Figure 5.3.1-5) and five income groups (Figure 5.3.1-6).

As seen in Figure 5.3.1-5, transit is primarily used for work trips. The number of work trips completed with rail is much higher than bus trips. Other (OBO) trips also show a high transit share. As seen in Figure 5.3.1-6, the number of rail trips changes by income. The higher rates are observed at the low and high-income quintiles. It is also noted that rail trips are higher than bus trips for all income groups. This may be considered as a reflection of auto availability. Although auto ownership is not modeled in the MSTM, it is known from other studies conducted in the region that low income groups are less likely to have immediate access to an automobile and bus ridership may be in part due to lack of availability of an auto alternative. However, when we look at the number of bus trips individually, we see that it is higher for low-income groups. Low income transit usage, and bus ridership, appears to be related to automobiles being less available for low-income groups. At the same time transit ridership for higher income results from the travel time-savings provided by rail transit when compared to the automobile.

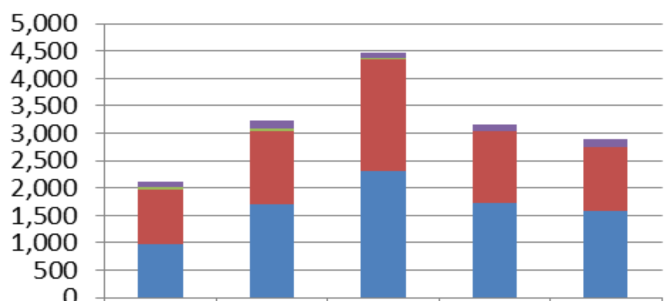
Similarly, when we look at the automobile mode, we see that SOV is used for all trip purposes with moderate differences among income groups. HOV on the other hand is primarily used for non-work related trips. It also shows moderate differences by income groups. However, we see that largest percent of SOV trips are made by high-income groups. The reason for SOV mode domination can be explained by the inconvenience of transit trips which likely require multiple stops, making transit less desirable. Another and highly likely reason is that the trip destinations may not be served by transit, leaving the SOV use as the only option for travel in the region.

Figure 5.3.1-5. Trip Distribution among modes by purpose (in thousands) - CLRP



	HBW	HBS	HBO	HBSC	NHBW	OBO
rail	476	17	109	11	383	199
bus	76	14	60	16	70	48
hov	421	1,879	4,513	765	521	3,869
sov	2,945	2,012	3,364	195	2,887	3,874

Figure 5.3.1-6. Trip Distribution among modes by income groups (in thousands) - CLRP



	income 1	income 2	income 3	income 4	income 5
rail	105	136	101	118	142
bus	45	41	21	20	22
hov	989	1,347	2,040	1,295	1,142
sov	985	1,701	2,309	1,733	1,593

Analysis of Baseline Transit Improvement Scenario, CLRP-TRNS

This section presents the results of CLRP and Transit Improvement Scenario (TIS-3, Reduce headway and fare in half) combination. As figures 5.3.1-7 and 5.3.1-8 illustrate, transit improvements increase the number of transit trips for all trip purposes and for all income groups. The increase is more for work trips and other trips. It should be noted that although percent increases are high (e.g. up to 40% for bus and 30% for rail), the absolute numbers of transit trips are low. Thus, these increases do not represent a dramatic increase in trip numbers.

Improved transit service by reducing fare and headways caused the number of HOV and SOV trips to decline for all trip purposes and income groups. One can infer that the reduction in number of SOV and HOV trips may be due to a shift to transit modes.

Figure 5.3.1-7. Percent change in number of trips in CLRP-TRNS compared to CLRP (by mode)

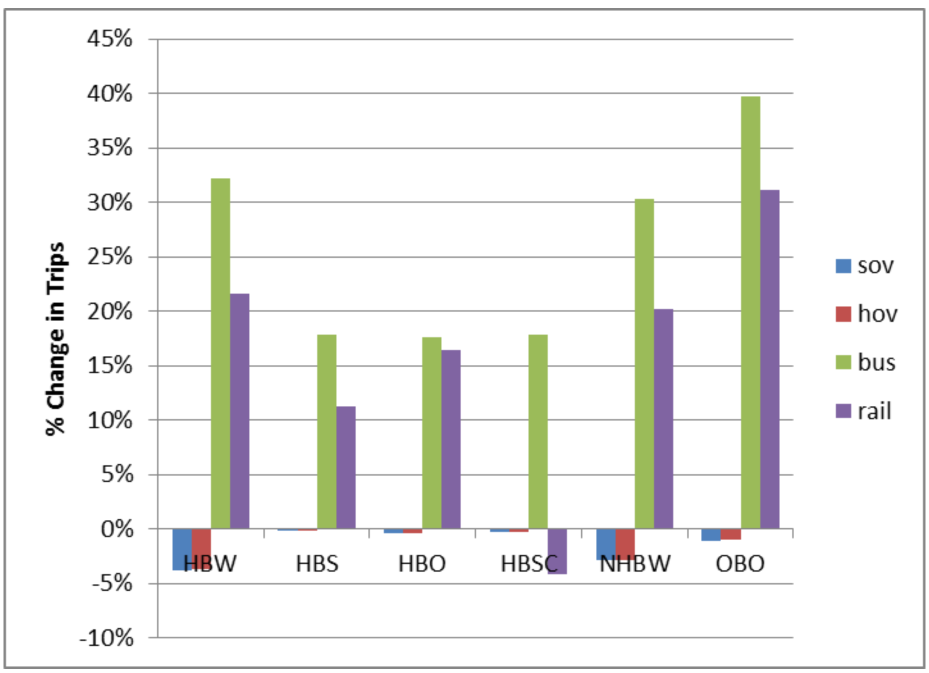
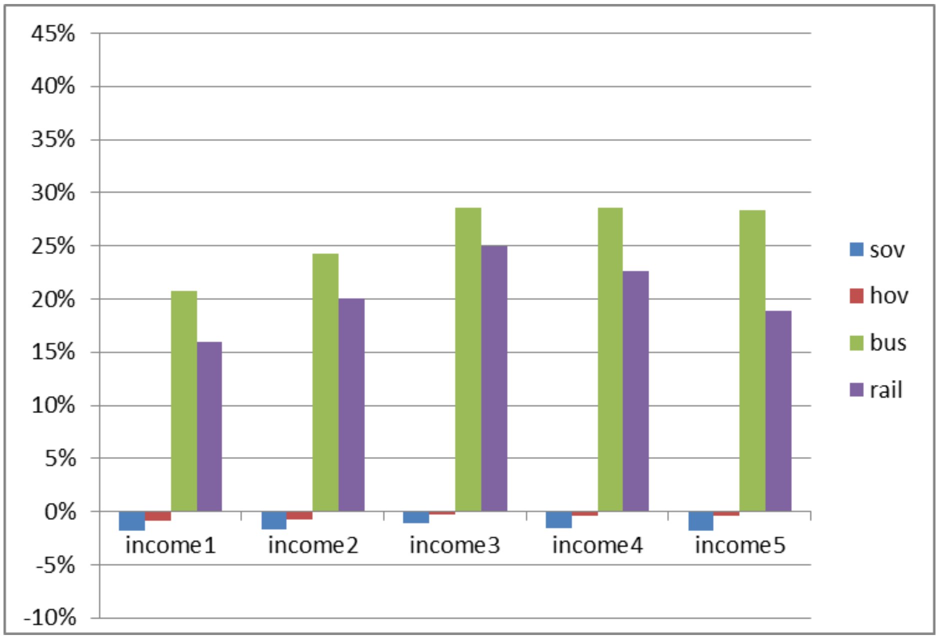


Figure 5.3.1-8. Percent change in number of trips in CLRP-TRNS compared to CLRP (by purpose)



Analysis of Baseline Express Toll Lane Scenario, CLRP-ETL

Similar analysis of trips by trip purpose and income group is made for CLRP and ETL combination scenarios. However, impacts on transit usage are not found to be significant. In fact, impacts were less than 0.25% for all purposes and income groups. Therefore, we do not present related figures in this report. The reason for this explained in Section 5.2.2 but summarized herein as well.

By looking at the markets ETL and transit service, we see that they serve different markets. The ETL lanes tested in the project serve areas along the major interstates and beltways while transit service is oriented toward the downtown. Thus ETLs and transit service do not significantly affect each other.

These conclusions about transit and ETL are same for each land use scenario. Therefore, in the rest of the combination scenario analysis, we did not include ETL combination scenarios.

Baseline Scenario CLRP, CLRP-TRNS and CLRP-ETL Summary Conclusions

Both system-wide results (Section 5.2) and detailed analysis of CLRP, CLRP-TRNS and CLRP-ETL scenarios show that the impacts of transit operational improvements show similar patterns in all land use scenarios. TRNS scenario included the Red and Purple Lines and the CCT. According to the results, transit improvement increases transit trips especially work related trips. While increasing transit trips, these improvements cause declines in SOV and HOV trips for all purposes and income groups. ETLs do not have a significant impact on transit ridership.

Results show that work trips are more responsive to the changes in transit service. This could be related to the characteristics specific to work trips. For example, work trips have recurring characteristics; they typically occur daily during peak hours and at the same time. Work trips also usually involve the same destination every day with one stop at the destination. Therefore, they are easier to serve by transit. On the other hand, the irregular characteristics of non-work trips make them hard to serve by transit. For example, non-work trips typically do not have a recurring schedule, they may occur at different times and they may or may not be daily. Besides, they typically involve multiple stops and different destinations each time. Also, non-work trips often have multiple occupants thus, they are hard to be served by transit, e.g. recreation trips.

The results also indicated that the rail mode is more responsive than bus transit to service improvements. This could be because bus primarily serves lower income groups and these groups may have limited options (e.g. lack of auto ownership). Buses also operate in mixed traffic and thus cannot operate faster than automobile or rail. On the other hand, rail typically serves for all income groups and can operate faster than automobile. Therefore, it is attractive to higher income groups as well.

As results demonstrate, improving existing transit service by reducing headway and fare has modest impact on transit mode share (bus trips increased 1% to 1.3%, rail trips increased 4.2% to 5%). While new transit routes and increased transit speeds were not tested, it appears these would be required to increase significantly increase the transit share.

Based on these results, the detailed analysis of combination scenarios are focused on TFD and HEP scenarios and their combinations with transit improvement scenarios TFD-TRNS and HEP-TRNS respectively.

5.3.2 Analysis of HEP Scenario

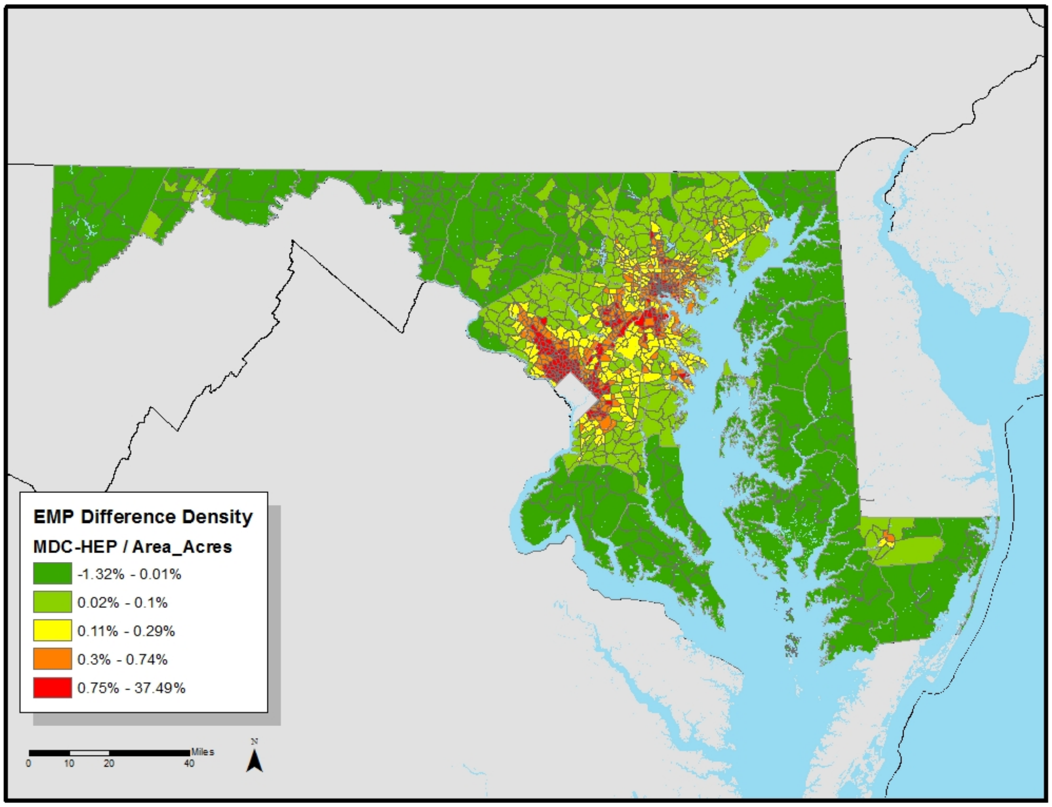
Rising energy prices, the HEP scenario, will affect both land use and travel behavior through the increase in energy prices. In analyzing the results of the HEP scenario we will first show the effects on land use, then on transportation.

Land Use Effects

As described in Section 2.6 in detail, this scenario illustrates the impacts upon land use patterns in Maryland as a result of increased auto operating costs. Figure 5.3.2-1 below shows the change in employment density (number of jobs per acre) with respect to the MDC scenario. We used MDC scenario as a basis for comparison in this case, instead of CLRP because both MDC and HEP are developed using land use model results as opposed to local zoning decisions used to develop CLRP scenario. As seen in Figure 5.3.2-1, most increases in employment density occur in both Baltimore and Washington DC city cores and around I-270 and I-95 corridor. This confirms that increased energy prices pushed employment to more urbanized, core areas where travel distances are relatively short and more transit options are available.

(Note: Under a high energy price scenario there would be multiple responses to increases in energy price including change in location, change in housing type, change in travel behavior and change in vehicle fuel economy. The models used in this scenario focused on the likely changes in location and travel behavior. Calibration of the model showed that lower income groups were more sensitive to travel costs than mid level and upper income groups. The scenario illustrates the likely types of responses under a high energy scenario and is not meant to replicate a detailed specific outcome.)

Figure 5.3.2-1. Difference in EMP Density between HEP and MDC

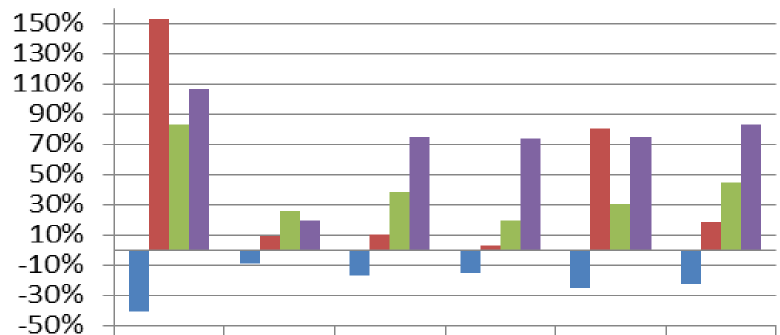


Transportaton effects

Trip Distribution among Modes

Figure 5.3.2-2 demonstrates the percent change in number of trips by trip purpose made by each mode under HEP compared to the CLRP scenario. As it is seen, transit and HOV share increases under the HEP scenario while SOV share declines for all trip purposes. The reason might be that the auto operating costs positively affects the demand for transit and ridesharing modes. The greatest impacts are observed for work trips. Particularly, HOV and rail modes see the largest shifts while SOV mode sees the largest decline. The high shift to HOV mode is likely a function of work trip characteristics. Typically, work trips are made regularly every day at the same time and they are easier to schedule. The increase in the transit use could also be attributed to a combination of reasons such as increased cost of driving and reduced travel distances due to concentrated employment and household locations.

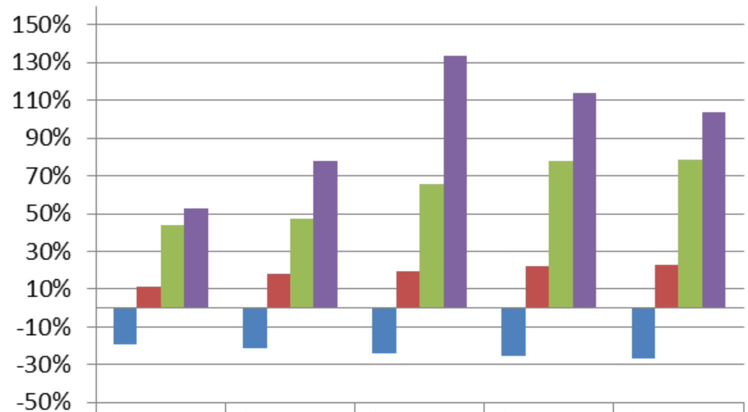
Figure 5.3.2-2. Percent Change in Mode Share in HEP w.r.t CLRP (by purpose)



	HBW	HBS	HBO	HBSC	NHBW	OBO
SOV	-41%	-9%	-17%	-15%	-25%	-23%
HOV	153%	9%	11%	2%	80%	18%
BUS	83%	26%	38%	19%	30%	44%
RAIL	106%	19%	75%	74%	75%	82%

Similar impacts are observed when we look at the percent change in number of trips made by each mode under HEP compared to CLRP scenario by income categories (Figure 5.3.2-3). Transit and HOV trips see high increases for all income groups, but more so for upper income groups. In the high-energy price scenario, there is a greater shift to transit among upper income groups than lower income groups. This may be due to upper income groups being more sensitive to changes in auto costs while lower income groups choose transit more on the basis of auto availability (or lack of availability).

Figure 5.3.2-3. Percent Change in Mode Share in HEP w.r.t CLRP (by Income)

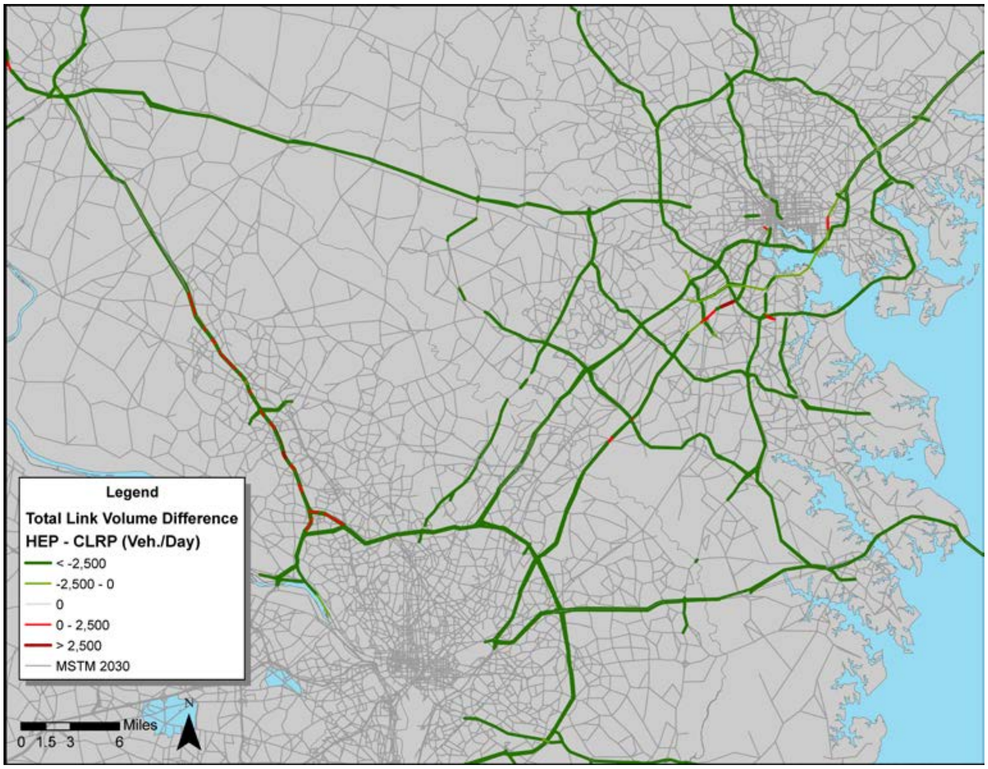


	income1	income2	income3	income4	income5
SOV	-19%	-22%	-24%	-25%	-27%
HOV	12%	18%	20%	22%	23%
BUS	44%	47%	66%	78%	79%
RAIL	53%	78%	134%	114%	104%

Impacts on Traffic

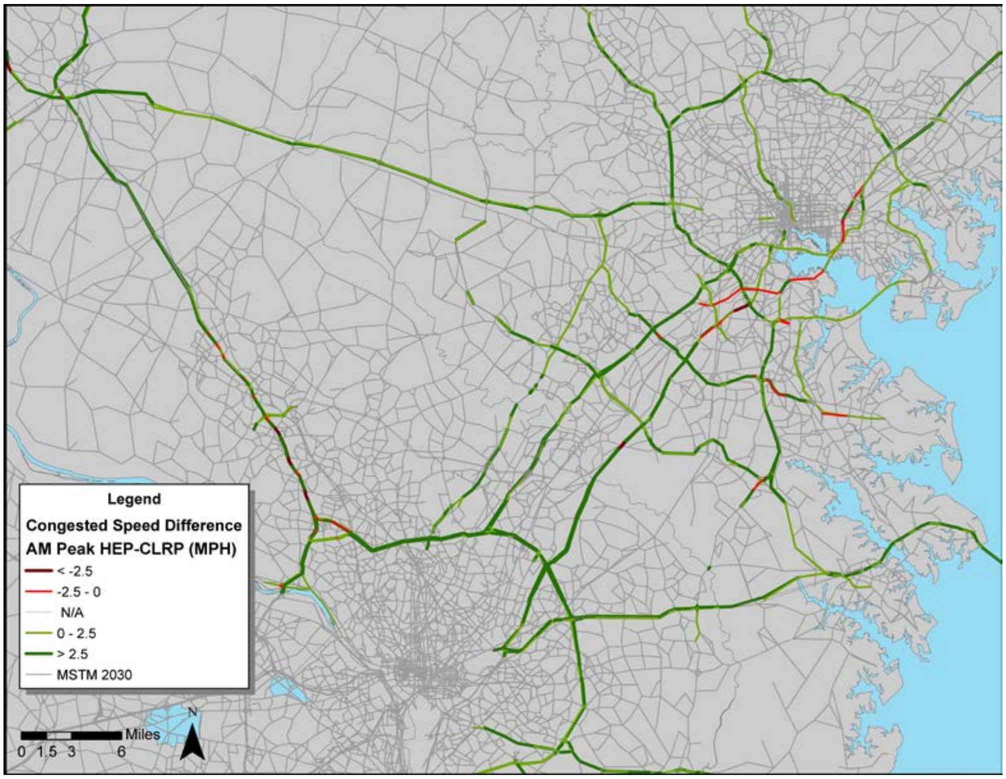
HEP scenario impacts on traffic measures such as link volume and congested speed are discussed in this section. Figure 5.3.2-4 illustrates the difference in total link volume (vehicles per day) between the HEP and the CLRP land use scenarios. As seen, the daily total link volume on the Capital Beltway and Baltimore Beltway, I-95, I-270 and other freeway and expressway links in the region see a decrease more than 2500 vehicles per day. This may be due to a shift to transit and HOV modes in the area where there is relatively rich transit service available. Also, HOV mode may become more attractive for work trips because of the increased auto operating cost under the HEP. The link volumes on arterial links in the city cores and most of the region do not see a decline. This is likely a result of the concentration of employment and households close to the city centers and around the beltway and the main corridors in the region under the HEP scenario.

Figure 5.3.2-4. Difference in Total Link Volume between HEP and CLRP



Figures 5.3.2-5 below shows the difference in link congested speeds between HEP and the CLRP scenarios in the AM peak period. As seen, the majority of the area links see a decrease (up to 2.5 mph and over) in congestion speeds. Despite the concentrated employment and households in and around the beltway areas, the reductions in the congested speeds may be a result of shifts to HOV and transit modes related to the higher cost of travel by auto.

Figure 5.3.2-5. Difference in congested link speed between HEP and CLRP, AM Peak



5.3.3 HEP Scenario Summary Conclusions

One of the most significant results of the HEP e scenario is that it reduces the total number of vehicle trips in the region by 30.93% from CLRP (see Section 5.2, Table 5.2-1). This is likely due to the concentration of employment and households to the city cores and around beltway areas. Denser growth may have reduced the trip lengths and eliminated some of the trips that otherwise were made by using motorized modes. Some other trips may have shifted to transit and HOV modes. Increases in transit and HOV shares support this conclusion.

The results show that number of trips made by transit and HOV increase under HEP for all trip purposes and income groups, while number of SOV trips decline. The greatest change in number of trips made by SOV (decline) and HOV (increase) observed for work trips. This also could be a result of concentrated employment locations and thus shorter trip lengths. Rail share increases more than bus, likely because of the good rail service coverage in the region. It should be noted that, although bus ridership is higher in Maryland, the model results do not distinguish services by providers (i.e. WMATA versus MTA) thus rail share is higher likely due to the Washington DC metro service. Table 5.3.3-1 below illustrates the transit ridership and mode share separately for WMATA and MTA based on the APTA (American Public Transportation Association) reports.

Table 5.3.3-1. APTA Reported Ridership By Agency and Mode

Agency	Mode	Unlinked Trips	Share
Washington Metropolitan Area Transit Authority(WMATA)	**Rail**	287,304	68.71%
	Bus	130,821	31.29%
Maryland Transit Administration(MTA)	**Rail**	29,530	28.34%
	Bus	74,661	71.66%
Rest of Maryland (excluding WMATA and MTA Ridership)	**Rail**	0	0.00%
	Bus	180,789	100.00%
Total System	***Rail***	*316,834*	*45.06%*
	Bus	*386,271*	*54.94%*

5.3.4 Analysis of TFD Scenario

The Transit Friendly Development scenario illustrates the impacts of allocating projected growth in employment and households to the areas that are served by rail transit. The details of the scenario development are given in Section 2.4 and Appendix A3. Figures 5.3.4-1 and 5.3.4-2 below show the changes in household and employment density (number of households/employment per acre) under TFD with respect to the CLRP scenario respectively. As seen, increases in household and employment density occur in SMZs around rail stations, which are selected for growth allocation in TFD scenario (please see figure 2.7.2-1 for transit served SMZs in Section 2.7.2).

Figure 5.3.4-1. Difference in HH Density between TFD and CLRP

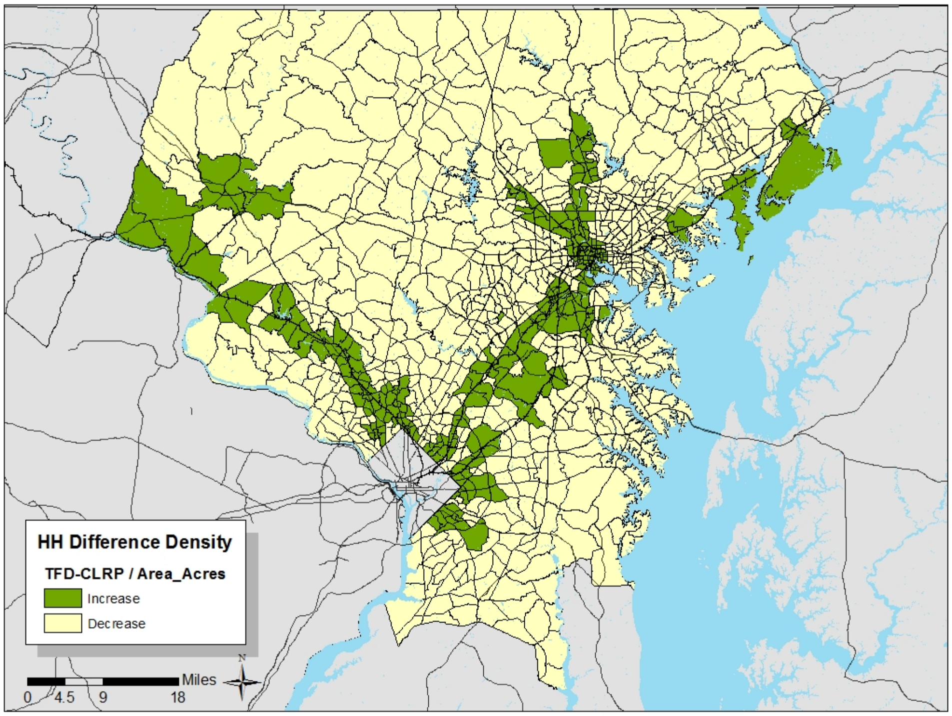
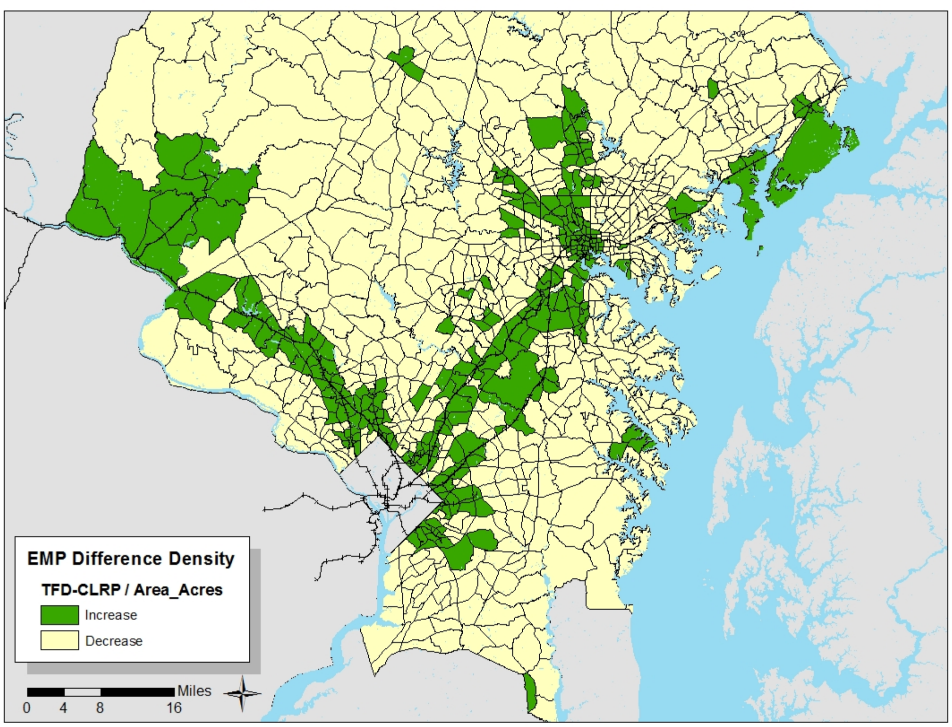


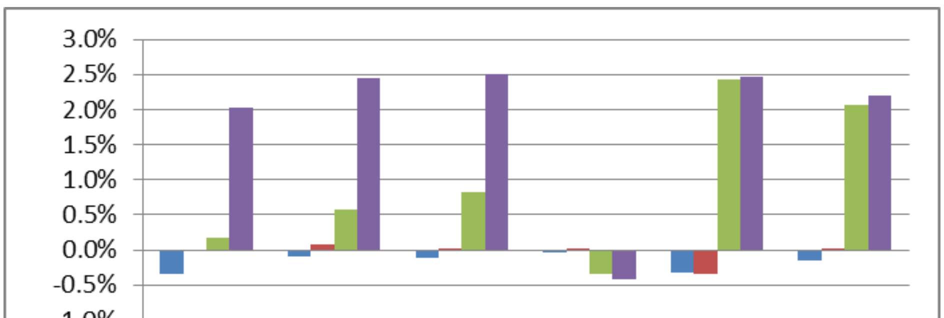
Figure 5.3.4-2. Difference in EMP Density between TFD and CLRP



Trip Distribution among Modes

Figure 5.3.4-3 demonstrates the percent change in number of person trips by trip purpose made by each mode under TFD compared to the CLRP scenario. As seen, transit share increases under TFD scenario while SOV sharedecline slightly for all trip purposes except school trips. Impact on HOV is not significant. This may be because allocation of growth to transit served SMZs leads to a slight mode shifts to transit while reducing SOV shares. The reduction of SOV trips are more for work trips but not significant. The impacts are more pronounced for work trip purpose. Particularly, the rail mode sees the largest increase (up to 2.5%) while bus mode sees slightly lower (up to 2.4%) increase. It should be noted that the TFD scenario increases the transit share for all purposes except the school trips. This may be a result of some school trips shifting to non-motorized travel modes as SOV and HOV share does not show a change. Slight increase in shopping and other trips could indicate that when transit friendly, mixed development (both households and employment) is encouraged around transit served areas, transit becomes more attractive for all trip purposes. This could likely be due to shorter travel distances and increased accessibility to non-work destinations.

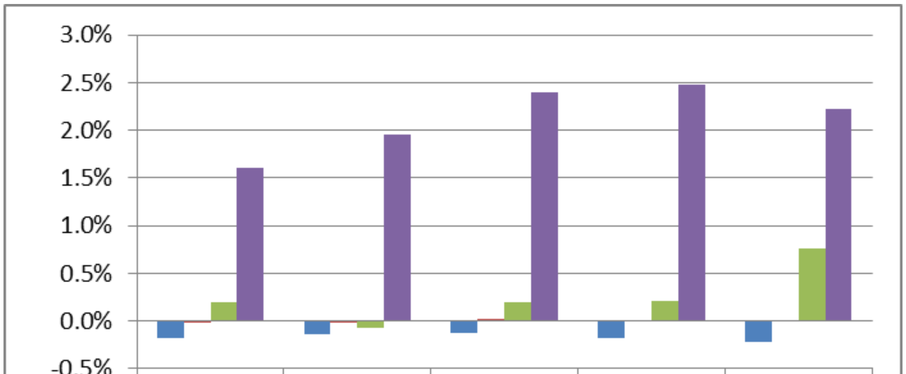
Figure 5.3.4-3. Percent Change in Mode Share in TFD w.r.t CLRP (by Purpose)



	HBW	HBS	HBO	HBSC	NHBW	OBO
SOV	-0.3%	-0.1%	-0.1%	0.0%	-0.3%	-0.2%
HOV	0.0%	0.1%	0.0%	0.0%	-0.3%	0.0%
BUS	0.2%	0.6%	0.8%	-0.3%	2.4%	2.1%
RAIL	2.0%	2.4%	2.5%	-0.4%	2.5%	2.2%

Similar impacts are observed when we look at the percent change in number of trips made by each mode under the TFD compared to the CLRP scenario by income categories (Figure 5.3.4-4). Transit trips see slightly higher increases for all income groups more so for medium income groups. The increase in transit trips is not as high for the low-income group.

Figure 5.3.4-4. Percent Change in Mode Share in TFD w.r.t CLRP (by Income)



	income1	income2	income3	income4	income5
SOV	-0.2%	-0.1%	-0.1%	-0.2%	-0.2%
HOV	0.0%	0.0%	0.0%	0.0%	0.0%
BUS	0.2%	-0.1%	0.2%	0.2%	0.8%
RAIL	1.6%	2.0%	2.4%	2.5%	2.2%

Impacts on Traffic

The TFD land use scenario impacts on traffic measures in the area are discussed in this section. Figure 5.3.4-5 illustrates the difference in total link volume (vehicles per day) between the TFD and the CLRP land use scenarios. As seen, the daily total link volume on majority of the area interstates and the Beltways see a decline (up to or more than 2500 vehicles per day) under TFD scenario. A few links only see an increase up to 2500 vehicles per day. Even though a large portion of (25% to PTAs and 25% to OTAs, a total of 50%) the employment and households are located to the areas that are served by rail transit, mode shift to transit is not as high (up to 2.5%) compared to the HEP scenario (up to 106%) under TFD. We look into this in further detail in the next section.

Figure 5.3.4-5. Difference in Total Link Volume between TFD and CLRP

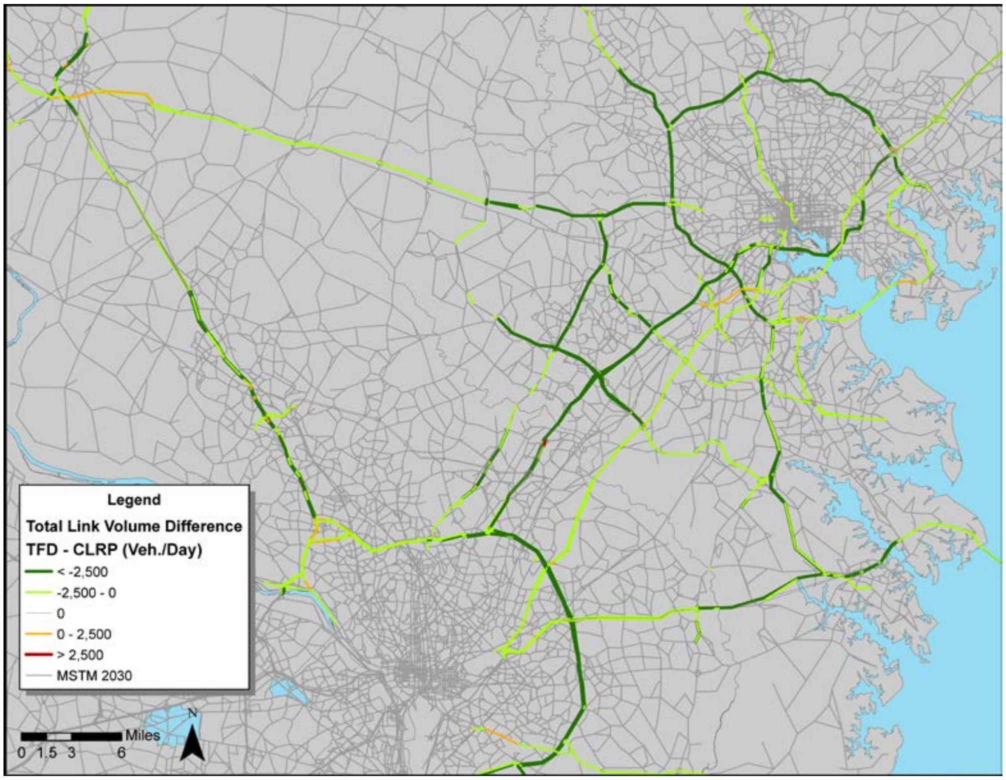
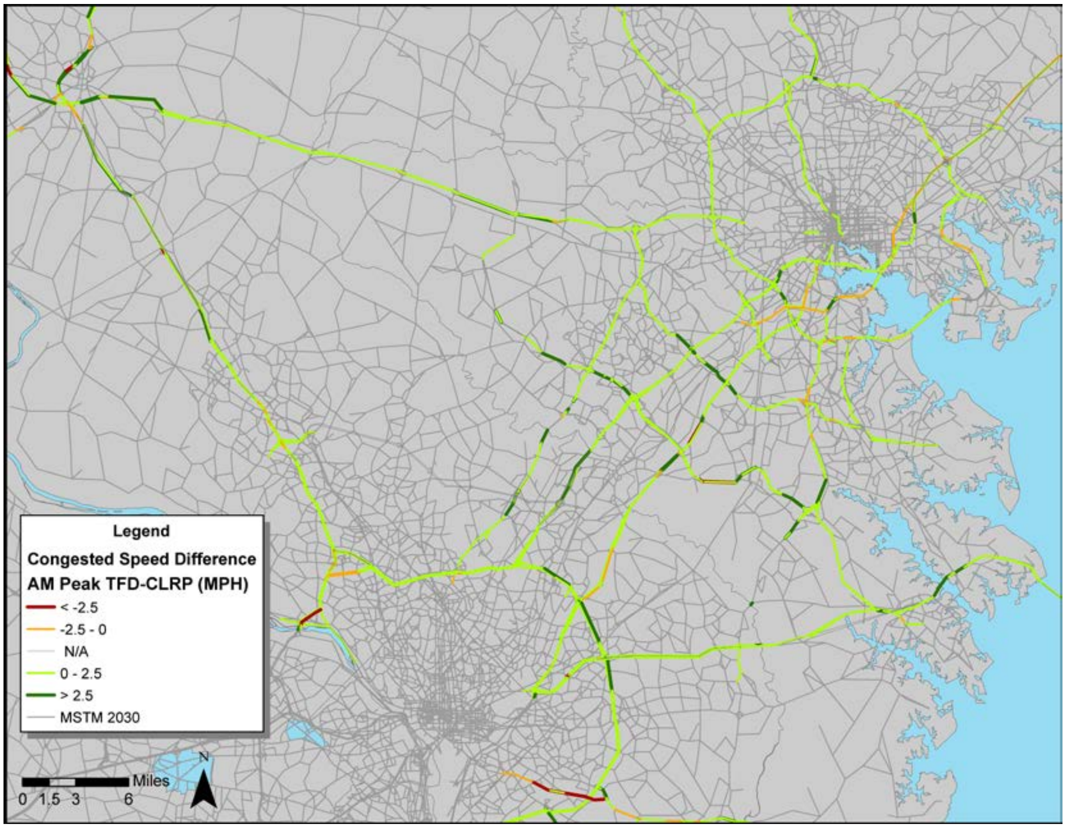


Figure 5.3.4-6 below show the difference in link congested speeds between the TFD and the CLRP land use scenarios. As seen, the majority of the interstate links in the area see a slight decrease (up to 2.5 mph) in congested speeds. Few links experience decreases in congested speeds over 2.5 mph and a few experience an increase. These results show that the impacts of TFD scenario may not only affect the areas where the TFD is applied but also that traffic may decline throughout the region due to lowered growth outside the TFD areas.

Figure 5.3.4-6. Difference in congested link speed between TFD and CLRP, AM Peak



Incremental Analysis

In order to fully assess the ability of TFD to reduce congestion, we compared the incremental growth rates from 2007 to 2030 for the CLRP and TFD scenarios. For the CLRP, VMT grew form 143 million in 2007 to 190 million in the 2030 CLRP Scenario. For the TFD scenario VMT grew to 183 million in 2030. The incremental growth was 47 million for the CLRP scenario and 40 million for the TFD scenario. This is illustrated in Table 5.3.4-1, below.

Table 5.3.4-1. Incremental VMT Growth in TFD Scenario

	CC 2007	CLRP 2030	TFD
Total VMT	**142,868,627.46**	**189,725,586.08**	**182,920,357.23**
Increase in VMT (2007-2030)		**46,856,958.62**	**40,051,729.77**
Absolute Change			***-6,805,228.85***
% change			***-3.59%***
%change (incremental)			***-14.52%***

As can be seen, VMT grew 14.5% less in the TFD scenario than in the CLRP. While the TFD scenario reduced overall VMT by 3.6%, it plays a major role in reducing the growth in VMT.

5.3.5 TFD Scenario Summary Conclusions

The TFD scenario also reduces total number of vehicle trips in the region by 4.96% from CLRP (see Section 5.2, Table 5.2-1). This reduction may have resulted from increased density in the TFD areas. The higher density, as known from literature, increases transit accessibility and encourages non-motorized modes. . The TFD scenario likely caused reductions in average trip lengths in the designated areas again due to increased density. Reduced average trip distances may also have encouraged some trips to shift to non-motorized modes.

Under this scenario, transit share increases for all income groups and purposes. The increase is higher for rail transit. This maybe because the TFD scenario is designated around rail stations. TFD reduces both SOV trips but the reduction is not significant (0.3%).

5.4 SUMMARY OF INTEGRATED SCENARIO RESULTS

This section summarizes the general findings of the integrated scenario results. These scenarios examined the interactive effects of location changes, changes in population and employment and transportation improvements.

5.4.1 System-wide Results

Land Use Perspective

The changes in land use have the largest impact on travel and traffic patterns in the region. There are also significant differences between impacts of each land use scenarios. The HEP provides the greatest reductions in highway usage measures (VMT, VHT, VHD and CLM) and in SOV trips, while increasing trips made by all other modes. TFD results are also similar but less pronounced. In the TFD scenario, HOV trips also reduce. The BO and the MDC scenarios cause increase in number of trips by all modes, more by SOVs.

Transportation Perspective

The impacts of transportation alternatives are not as pronounced as the impact of land use scenarios. Their impacts are similar in magnitude across the land use alternatives. The greatest reductions in highway usage measures are obtained from transit improvement scenarios (-TRNS). However, the impacts are moderate. The -ETL scenario increased VMT but reduced congestion measures. The –ETL scenario do not impact transit ridership as ETLs and transit serve different markets.

When we look at the distribution of trips among modes, we again see that the impacts of transportation scenarios are modest and are similar in magnitude across the land use alternatives with very slight changes between–TRNS and –ETL scenarios. Transit improvements scenario (-TRNS) however provide further reduction in SOV and HOV trips and increase in BUS and RAIL trips.

Combination

Among the land use combination scenarios, the HEP-TRNS provided the greatest reduction in highway usage measures. TFD-TRNS is the second best of the combination alternatives. The HEP-ETL and TFD-ETL combinations provide slightly greater reduction in congestion (CLM). This also is likely a result of added capacity in the -ETL scenarios. BO-TRNS and BO-ETL scenarios cause increases in all the measures. The impact is worse for congestion measures indicating that if growth is allowed to reach its maximum under current zoning policies, the regional traffic conditions would worsen.

In terms of environmental impacts, the HEP-TRNS scenario provided the greatest reduction in GHGs compared to CLRP-TRNS. TFD-TRNS also provide decline in GHGs but not as pronounced as HEP-TRNS. Similar to the other system-wide performance measures, BO combination scenarios cause increase in GHGs. No significant difference between –TRNS combinations and -ETL combination scenarios are observed.

5.4.2 Behavioral Results

Transportation

By Origin-Destination

The analysis of transit trip characteristics in the region by origin and destination densities showed that origins are scattered in the region while destinations are concentrated within and around the Beltways. It is also observed that rail trip origins are more scattered and destinations are more concentrated compared to bus trips. Both for bus and rail trips, the trip origins are consistent with housing densities, while trip destinations are consistent with employment densities in the area.

By Purpose

Trip purpose is critical factor determining the mode. When trips are analyzed by purpose, work trips were found to be more responsive to the changes in the transit service. This is likely a result of work trip characteristics such as regularity, same destination everyday etc. HOV is used primarily for non-work trips.

By Mode

The results showed that changes in rail transit ridership are more pronounced than bus transit. This is likely due to the rich rail service in the area as well as the faster travel speeds by rail. Analysis results showed that SOV is the dominant mode, used for all trip purposes and by all income groups. This may be an indication that most HOV trips are made by family members for school or shopping type of trips.

By Income

Similarly, upper income groups were found to be more responsive to the changes in transit service. It is likely that there are more options available for upper income groups, as they typically have access to automobile and live in areas that are transit accessible. The results also showed that the larger portion of the bus riders are from lower income groups. Most HOV trips are found to be made by lower income groups. This is likely because reducing trip cost is one of the important motivations for ride sharing.

Land Use

The analysis of land use alternatives focused on the two most effective scenarios, HEP and TFD. The High Energy Price (HEP) scenario is a policy scenario which affects both land use and transportation through increased gasoline prices. Although it is not solely a land use scenario, due to its impacts on the land use, HEP is considered among the land use scenarios. These scenarios are compared to the Baseline (CLRP) scenario. The analysis results of TFD-TRNS and HEP-TRNS (TFD and HEP scenario combinations with transit improvement scenario) are summarized below.

The analysis of CLRP-TRNS scenario compared to CLRP shows that improving existing transit service by reducing headway and fare has modest impact on transit mode share. These improvements increase transit trips, especially work related trips while decreasing SOV and HOV trips for all purposes and income groups. It is also observed that the changes in transit service affect rail transit more than bus transit. These results are observed for all land use scenarios as well.

CLRP-ETL combination on the other hand does not have a significant impact on transit ridership.

HEP

The results showed that HEP scenario is the most effective for improving traffic conditions. This alternative not only reduces total number of trips (by 30.93% from CLRP) but also shortens the trip lengths. HEP scenario increases transit and HOV shares while reducing SOV for all income groups and purposes. Particularly, transit and HOV sees the largest increase, more for higher income groups. The greatest impacts are observed for work trips. This scenario helps reduce traffic volume on the area links, particularly on arterial links in the city cores.

TFD

Transit Friendly Scenario also reduces number of trips in the region (by 5.97% from CLRP). This scenario also shortens average trip lengths particularly in the TFD designated areas. The results show that TFD designated areas become attractive as destination from non-TFD areas. The analysis also revealed that behavioral response to TFD in Baltimore and Washington areas are similar.

The TFD increases transit usage up to 20% for all trip purposes, income groups and transit modes. The increase is higher for rail transit. While increasing transit share, the TFD reduces SOV and HOV trips slightly (up to 3%). The decline is higher for SOV and for work trips.

6 POLICY IMPLEMENTATION

This project met its objective of examining the impacts of alternative land use and transportation scenarios on travel within the State of Maryland. In the course of analyzing these impacts, the project also demonstrated the ability of the scenario modeling process to inform decision makers of the effects of actions designed to implement policies. Five objectives of the Maryland Transportation Plan and three of the Governor's recently stated goals identify potential issues that the models are well suited to address. What follows is a discussion of each of these and how the modeling process can inform decision makers about these goals and objectives.

6.1 MARYLAND TRANSPORTATION PLAN

The Maryland Transportation Plan, developed in 2009, lays out a long-term vision for transportation system within the State. The Plan forms a framework for the efficient allocation of the State resources to ensure that the transportation system will remain well maintained, safe, secure, efficient and reliable for a sustainable future. The State also supports Smart Growth policies on land use and transportation decisions to accomplish the State's sustainability goal. This project, can inform many aspects of the Plan through scenario analysis.

Transportation and the Economy – The price of gasoline, and the ability to move quickly and easily through the transportation system, are closely tied to the viability of the State's economy. The high energy price scenario demonstrates that with higher energy prices (increased energy prices cause higher auto operating costs), land use will likely develop in more compact patterns, trips will shorten, more people will ride transit, and modest reductions in employment may also occur. All of these would have an effect on the economy of Maryland, particularly influencing the location of employment and population. The high energy price scenario includes the effects of energy prices on housing location choice and travel behavior. It does not reflect the impact of high energy prices on the overall economy.

While not part of this exercise, the NCSGRE has tools under development that can be used to look at how increases in congestion on specific links in the transportation system can affect the ability of regional economies to function.

Freight Demand – Freight and freight movements form a critical part of Maryland's economy and a major concern for MDOT. This study shows that under current economic conditions, only long distance truck freight (freight moving more than 400 miles) can feasibly be diverted from truck to rail. The study also shows what portions of truck traffic have an origin and/or destination in Maryland and how much of it is through traffic. Also, as mentioned in the section on the economy, above, the ability of the transportation system to support truck movements, and hence the economy, can be analyzed.

Planning for Development – The scenarios related to land use changes; Buildout, market driven change, high-energy prices and transit friendly development, illustrate how the modeling process can be used to analyze alternative land use patterns. They also demonstrate that the process can analyze the effect of alternative land use patterns on the transportation system. One early conclusion is that to increase transit ridership, land use changes and transit friendly development should focus on the destination or work end of the trip, rather than the origin end. The model results also indicated that transit service, which operates faster than the highway, is an essential component of significantly increasing transit ridership. The same tools that can be used to analyze the specified land use scenarios can also analyze the how other development patterns, such as changes in local policies, BRAC, rapid growth in specific areas and re-population due to climate change, impact the transportation system.

Transportation and the Environment – Once travel patterns and congestion have been calculated, the resulting mobile source emissions can be easily estimated. Actions such as reducing VMT and reducing congestion will generally have positive impacts on air quality. The modeling system provides the ability to examine alternative strategies for reducing Greenhouse gases and has shown that increasing energy prices or improved transit service will help in this regard. However, care must be taken in using the models to examine the effect of alternative policies on criteria pollutants, since these are normally part of a conformity determination and may require more detailed analysis[10].

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[10] The analytic tool used for estimating Greenhouse Gase emissions was MOVES, developed by EPA. For the scenarios, only running emissions were considered.

Transportation Funding – There is concern across the country about the ability to fund capital improvements to the transportation system, and Maryland is no exception. The express toll lane scenarios demonstrate that the scenario modeling process can forecast potential revenues from various tolling strategies along with reductions in VMT, VHT and congested highway conditions associated with each strategy. This allows the testing of alternative policies such as maximizing toll revenue or reducing congestion and for analyzing the tradeoffs between these strategies. For example, the estimates of toll revenue presented in the study demonstrate that while increasing tolls increases revenues, there is a point of diminishing returns as tolls rise. The models can analyze these policies at the large-scale regional level. A more fine-grained effort would be required to estimate the effect of tolls on specific links.

6.2 GOVERNOR'S GOALS

The Governor has identified three major goals for his Administration; making Maryland a leader in Homeland Security, doubling transit ridership by 2020, and reducing greenhouse gas emissions by 2020. The processes used in the scenario project can help to identify effective methods to further the Governor's goals.

Leader in Homeland Security – Scenarios involving Homeland Security can easily be tested. As an example, the Climate Change scenario removed several minor links from the highway system and analyzed the impacts of the removal. Scenarios simulating terrorist or natural disaster events can also be simulated using the same methodology and the methodology could be expanded to major links in the system. Plans for emergency evacuation can also be developed. Homeland Security events in areas adjacent to Maryland, such as north-central Virginia and Pennsylvania would likely have spillover effects on Maryland and the impact of these could be analyzed. An example would be the need to move large volumes of material on interstates to and from neighboring areas and how this would affect traffic in Maryland.

Doubling Transit Ridership -The goal of doubling transit ridership on the MTA by 2020 poses a major challenge to the State, the MDOT and the MTA. The scenarios tested demonstrate that decreasing transit fares and headways have a modest effect on ridership and alternative actions such as changing land use patterns, faster transit service and expanding service coverage must be tried. The scenario approach can help to analyze which of these actions would be most effective at increasing ridership. The initial results of the scenarios pointed out that focusing on the trip to work and on the destination end of the trip has the greatest effect on transit ridership. With this information scenarios can be developed and tested which focus on the work trip as a method for increasing ridership.

Reducing Greenhouse Gases by 25% by 2020 – All of the scenarios tested influenced greenhouse gas emissions. As demonstrated in our scenarios, the modeling process can estimate the impact of land use and transportation actions on Mobile Source emissions of greenhouse gases. Additional scenarios can also be developed with the target of reducing emission. Finally, the scenarios can test policies which would increase the number of fuel efficient vehicles in the vehicle fleet mix.

7 CONCLUSIONS

Three groups of alternative scenarios, transportation, land use and integrated transportation and land use, demonstrate the impact of alternative land use and transportation alternatives on travel in Maryland. The transportation scenarios include removing long distance trucks from the network, improving existing transit service and tolling selected parts of the network. Land use scenarios include the Constrained Long Range Plan (CLRP-Baseline), Buildout (BO), Transit Friendly Development (TFD), Market Driven Change (MDC) and High Energy Price (HEP). The integrated scenarios are TFD and HEP combined with transit improvement (–TRNS) and express toll lane (–ETL) scenarios. The Constrained Long Range Plan is the baseline and all conclusions are based on comparisons to the CLRP.

The result of this project led us reach some general conclusions summarized below:

Land Use

- Land use changes are most effective in changing travel patterns in the region.
- TFD encourages transit ridership within the TFD area but also encourages the use of the TFD as a destination for trips originating outside the TFD areas.

Transportation:

- When compared to the CLRP, the impacts of transportation alternatives are similar in magnitude when implemented with each of the land use alternatives.
- In all land use scenarios, improving transit service by reducing fares and headways has a modest influence on travel and traffic conditions.
- The ETL lanes tested in the project serve areas along the major interstates and beltways while transit service is oriented toward the

downtown. Thus ETLs and transit service do not significantly affect each other.

- While new transit routes and increased transit speeds were not tested, it appears these would be required to significantly increase transit share. These alternatives could be tested in future work.

Combined Transportation and Land Use:

- Combining high-energy prices with transit provides the greatest reduction in congestion as measured by VMT, VHT and VHD.
- Combining transit friendly development with transit improvements also provides a reduction in congestion.
- HEP and transit improvement scenarios also generate the largest decrease in greenhouse gases.
- Even though VMT increases with ETLs, they help reduce congestion by providing additional highway capacity.

Behavior:

- Work trips have the greatest response to changes in transit service.
- Transit trip destinations are heavily oriented to compact sites along rail lines and in downtown, while origins are scattered across the region. Efforts to increase transit ridership through land use changes should focus on the destination end of the trip.
- Ridesharing is most common for non-work trips.
- Rail transit serves all income groups but low-income groups form the majority of the bus riders. Other studies have pointed out that low-income groups are less likely to have immediate access to an automobile and bus ridership may be in part due to lack of availability of an auto alternative.

The results clearly demonstrate that the process provides valuable information to officials on the impacts of various land use and transportation alternatives. It also shows the ability of the process to address issues of land use and transportation, economic and environmental development, homeland security, infrastructure financing through tolls and climate change. Specific policy decisions will require further refinement and testing of alternatives. At this point, however, we are confident that we have developed a sound and appropriate tool for doing so.

8 REFERENCES

Inforum, 2010. Statewide Employment Modelings (STEMS) and Long- term Inter Industry Forecasting Tool (LIFT) Model. Available online at http://www.inforum.umd.edu/services/models.html

TPRG, 2010. Maryland Scenarios Project Final Year 1 Report, March 2010.

TPRG, 2011. Maryland Scenarios Project Draft Final Year 2 Report, November 2011.

Baltimore Metropolitan Council (BMC), 2010. 2007 On Board Transit Survey: BMC Analysis. Task Report 10-1, June 2010.

National Center for Smart Growth and Education (NCSGRE), 2012. Maryland Statewide Transportation Model (MSTM): User Guide. Prepared for the State Highway Administration. Working Draft Report, available through NCSGRE.