Overview, Trends, and Models

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Introduction

The multi-year goal for this project is to develop, disseminate, and promote the implementation of a sustainable development strategy for the Baltimore-Washington region. Well known examples of similar efforts include privately financed and promoted plans such as the Burnham plan for Chicago, the Wallace-McHarg plan for the Valleys, and the series of plans for greater metropolitan New York prepared by the Regional Planning Association. These plans or strategies were not prepared for or adopted by any public agency but were highly influential for decades after they were released.

Our first-year goal for the project is to stimulate a science-based conversation about sustainability in this region and to develop one or more baseline scenarios. We will stimulate the dialog by considering the key driving forces that will shape the future of the region and by deploying a highly developed set of data and analytic tools to develop baseline scenarios.

The specific objectives of the exercise are as follows:

Year 1:

- Identify the key driving forces that will shape the future sustainability of the region.
- Develop one or more baseline scenarios.
- Demonstrate quantitatively and qualitatively the effects on regional sustainability of growth continuing in its current form.

Future years:

- Develop alternative, more sustainable scenarios.
- Identify policy decisions that will lead to a more sustainable future.
- Demonstrate quantitatively and qualitatively the effects of growth occurring in a more sustainable fashion.
- Stimulate an informed public dialog on sustainability.
- Promote the adoption of policies that lead to more sustainable futures.

What do we mean by Sustainability?

There is no universally agreed upon definition on what sustainability means. There are many different views on what it is and how it can be achieved. The idea of sustainability stems from the concept of sustainable development, which became common language at the World’s first Earth Summit in Rio in 1992.

The original definition of sustainable development is usually considered to be:

"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Bruntland Report for the World Commission on Environment and Development (1992)

Since then, there have been many variations and extensions on this basic definition. None are perfect. For our purposes, however, we chose to adopt the six principles promoted by the federal Sustainable Communities Partnership. These are:

- Provide more transportation choices.
- Promote equitable, affordable housing.
- Enhance economic competitiveness.
- Support existing communities.
- Coordinate and leverage federal policies and investment.
• Value communities and neighborhoods.

For each of these principles the Sustainable Communities partnership has identified a large set of indicators that can be used to measure progress towards sustainability. These measures can be found at http://smartgrowth.umd.edu/indicatorsproject.html. The indicators we will use in this project overlap extensively with these indicators, although for three reasons they are a much smaller set. First, because our study area is large and diverse, it is not possible to collect all these indicators. Second, and more importantly, many of these indicators are difficult if not impossible to forecast to any reasonable degree of certainty. Third, our modeling tools cannot measure all the desired indicators and even a qualitative approach will not be able to achieve this. We focus, therefore, on nine general areas of sustainability:

• Population
• Economic Productivity
• Land Use
• Transportation
• Housing
• Access to opportunity
• Air emissions, including greenhouse gases
• Nutrient loading into to water bodies and
• Energy Consumption

For each of these areas we have collected an extensive set of historical data and some projected trends. Then, based on a carefully considered set of assumptions, we will forecast values for each of these variables using our loosely coupled modeling system, first for one or more baseline scenarios, then for alternative more sustainable scenarios.

Modeling and Scenario building

While the above nine areas will be modelled, we acknowledge that non-modelled elements or driving forces are also critical to our scenario work. The following diagram captures the relationships among our modeling tools and between them and non-modeled elements of our process.

The Model-Driven Elements incorporate many assumptions, noted under the Scenario Elements, which will be made explicit as part of the BAU and other scenarios. For example, energy price assumptions embedded in economic and employment forecasts will be teased out or fleet mix and vehicle fuel efficiencies in the model will be made explicit. In the course of developing alternative scenarios, the assumptions will be varied based on creating a set of
plausible, coherent stories around different futures. Some of these assumptions will generate inputs into our model suite but others will not be able to be absorbed into our models and will need to be reflected in other ways to be discussed and determined. Qualitative or quasi-quantitative approaches and methodologies will be worked out as part of the project process.

Our assumptions in the scenario process can be considered as “driving forces” to highlight their significance. An example of such a driving force of particular significance to our region is federal employment and economic spinoff, responsible for about 40% of the region’s economic activity. This is also a driving force fraught with great uncertainty – federal agency shrinkage is certainly plausible and can have multiple effects (e.g. less public sector employment but perhaps more private sector spinoff taking up the slack with very different implications for Northern Virginia vs. Maryland). Not only is its uncertainty great but its relative impacts would also be great.

While the driving forces, their degree of uncertainty, their relative impacts and the policy options that respond to or shape such outcomes are the essence of this overall project, in the first stage we will be concerned with defining the BAU scenario. To do this effectively, however, also means that we must also consider alternative futures or scenarios briefly so as to place the BAU scenario in some context for future phases of this project. We have designed the four meetings of this first phase around the concurrent development of the models as well as the scenario assumptions and inputs that accompany them.

Meetings and their Purpose during the First Phase of Work

The meetings are framed around the overall purpose of this project: What can and should be done to achieve a more sustainable future by 2040 for the Baltimore Washington Region?

The objectives of four meetings, each in two parts, are outlined below and in the diagram following this description. One part is making recommendations/decisions; the second part is preparing for interim work and for the next meeting. The last meeting, however, contains only recommendations/decisions since it has no follow-up at this time.

1. Meeting #1
   a. Agree on purpose, plan, and conceptual and operational definitions of sustainability and major assumptions of trends, models and previous work that are likely to be different in the future.
   b. Brainstorm the major driving forces for change in the region (for Meeting #2), major assumptions of trends, models and previous work that are likely to be different in the future (for Meeting #3) and possible policy options (for Meeting #4).

2. Meeting #2
   a. Agree on the effect of the major driving forces that lead to the BAU scenario, the BAU outcomes of models that use those forces, and the degree of sustainability of those outcomes.
   b. Agree on the major uncertainties in the driving forces and other assumptions that are likely to be different over the next 25 years (for the next meeting).

3. Meeting #3
   a. Agree on the major alternative scenarios based on the uncertainties, the outcomes of models based on the uncertainties, and the degree of sustainability of those outcomes.
   b. Agree on potential policy options that might move the outcomes toward more sustainability.

4. Meeting #4
   a. After reviewing the effect of the potential policy options on the model outcomes, agree on which policy options are most effective, most feasible, fastest to achieve results and least costly.
The above sequence is captured in this diagram:
Trends and Projections

The data and trends presented below are divided into driving forces and outcomes. The driving forces are described under the headings of economy, employment and demographics. Variables within these categories reflect an understanding of forces underlying growth within the region. Each variable is presented historically and with projections of their future values. The US Census and the Bureau of Economic Analysis provide the history for each variable while other public sources and various research efforts supplied the presented projection. The outcomes data, which relate to the eight general areas of sustainability cited earlier, include transportation, housing, land consumption, energy & carbon, and water quality. These categories were chosen for their relevance to sustainability and the viability of capturing their future values with the NCSG modeling suite. The data, as available, come from various sources including Maryland State Stat, the US Energy Information Agency, the US Farm Census, and the WMATA ridership report.

Regional Definition

For the data to elucidate change within the region, the counties in the Baltimore Washington Region are divided in two ways. First, the data divided into two metropolitan areas that correspond with the Baltimore and Washington Metropolitan areas. Second, the region is divided into core, inner suburban, and outer suburban jurisdictions. The borders of each metropolitan area could be extended, but the chosen divisions are sufficient to demonstrate trends within the region. The divisions are as follows (see figure 1 for visual):

- **Washington Core**: District of Columbia (DC); Alexandria City, VA; Arlington County, VA
- **Washington Inner Suburbs**: Montgomery County, MD; Prince George’s County, MD; Fairfax County. Fairfax City, and Falls Church, VA (Fairfax)
- **Washington Outer Suburbs**: Fauquier County, VA; Loudoun County, VA; Prince William, Manassas, and Manassas Park, VA (Prince William); Stafford County, VA
- **Baltimore Core**: Baltimore City, MD
- **Baltimore Inner Suburbs**: Anne Arundel County, MD; Baltimore County, MD; Howard County, MD
- **Baltimore Outer Suburbs**: Carroll County, MD; Harford County, MD

Figure 1 also superimposes the extensive geography of the NCSG travel demand model which incorporates a larger geography, to capture the effects of travel to and from adjacent states.
The Projections

Eight economic and/or demographic projections were examined in the compilation of data, but not all projections were available for all geographies. The organizations that created the projection included the following: the Baltimore Metropolitan Council (BMC), the Metropolitan Washington Council of Governments (MWCOG), the Maryland Department of Planning (MDP), George Mason University’s Center for Regional Analysis (GMU), Woods and Poole (WP), and the University of Virginia’s Weldon Cooper Center (UVA), the US Census Bureau, and Dr. Thomas Hammer (TH) for Parsons Brinckerhoff. Throughout this packet the name of the group performing the projection will stand in as the title of the projection. Each projection covers different geographies and covers different topics as seen in Tables 1 and 2. It was possible, however, to compare data from different projections for most variables.

The projections fall into three general types: cohort/population driven forecasts, bottom up cooperative forecasts, and economic forecasts.

**Population Cohort Forecasts:** The MDP, Virginia, and Census forecasts are all driven by trends in population. These projections segment the population into cohorts of age, race, location, etc. The population within each cohort changes according to birth rate, death rate, inmigration, and outmigration. Population cohort forecasts rely on current trends within the population but often fail to respond to forces driving those changes, such as the economy and government policies.

**Bottom Up Cooperative Forecasts:** the MWCOG and BMC population projections both result from a cooperative forecasting process. In each, the regional council and the local jurisdictions use their own methodologies to develop population projections which they then reconcile through negotiation. These projections often account for local policies but do less to capture the underlying forces driving regional growth. With Maryland jurisdictions, the regional projections fall close to the MDP projections in the long term, but differ in the short term. The two regional forecasts differ in that MWCOG uses control totals to distribute population throughout the region in the short term while BMC does not.

**Economic Forecasts:** Woods & Poole and Hammer both start with forecasts of the national economy that project change within each sector of the economy. The growth in national economic sectors is translated to economic and employment change at the regional level. These employment numbers then drive the population growth within each region, which is further allocated to the local jurisdictions. Woods & Poole differs from Hammer methodologically in that national population growth is unconstrained. In the Hammer projection, the national census population projection serves as a control total for the allocation of growth to local jurisdictions.
Driving Forces

Demographics

Figure 2: All forecasts project population growth throughout the region with the Washington Metro area growing faster than the Baltimore Metro area. Woods and Poole projects the highest growth rate over the next thirty years while Hammer projects the lowest growth rate. The forecasts of MWCOG and BMC fall in between.

Figure 2 - Population History and Projections - Baltimore Washington Region

Figure 3: The location of future growth will have implications for regional sustainability. The Woods and Poole forecast is bullish on growth in inner and outer suburban jurisdictions. The regional forecasts expect growth rates to taper slightly in the suburbs while core jurisdictions reverse population decline.

Figure 3 - Population History and Projections: Core, Inner, Outer Jurisdictions - Baltimore Washington Region
**Figure 4**: The forecasts differ most dramatically in core jurisdictions, as exemplified by the population projections for Washington DC. Will DC grow? Will DC shrink? Will DC stagnate?

**Figure 5**: Population projections differ more subtly for Baltimore but they still indicate disagreement as to whether Baltimore will grow or continue to shrink over the next thirty years.
**Figure 6:** MDP, UVA, the US Census, and Woods and Poole all provided projections of population age. MDP is comparable to Woods and Poole at the County level. The following chart compares MDP age projections to Woods and Poole for the Baltimore Washington region counties in Maryland. Though this leaves out Virginia jurisdictions, it reflects the general aging of the population throughout the region as 2040 approaches. Woods and Poole expects a slightly older population than the MDP projections.

**Figure 7:** MDP and UVA provided projections by race for limited categories: white and non-white. The region will be majority non-white by 2020. Non-white populations will continue to grow dramatically while the white population stagnates. Projections do not include Washington DC.
Figure 8: The Woods and Poole projections for non-white proportions lie close to MDP’s and UVA’s. Woods and Poole also provides a thorough breakdown of race in their population projections. In core jurisdictions, white population remain level while black population dips slightly. Asian and Hispanic populations increase.

Figure 9: In the inner suburban jurisdictions White populations nearly halve by 2040. Whites will be the third largest racial group in the inner suburbs behind Blacks and Hispanics.
Figure 10: In outer suburban jurisdictions, White populations grow dramatically. In a sense, the center of White population in the region will continue to move further from the core.

Figure 11: In the Woods and Poole forecasts inner suburban jurisdictions change racial composition most dramatically. Increasing Asian American and Hispanic populations increase diversity throughout the region.
Economy and Employment

The forecasts that informed the data do not project GDP for the counties within the Baltimore Washington Region. Woods and Poole does, however, project the growth in total earnings which we use as an approximation for total volume of economic activity.

Figure 12: Woods and Poole projects total earnings to increase substantially over the next thirty years. The vast majority of the growth will occur in the Washington Metropolitan area.

Figure 13: Inner suburban jurisdictions have surpassed core jurisdictions as the primary location for earnings within the region. Though earnings will grow throughout the region, inner suburban jurisdiction will increasingly dominate economic activity, accounting for more than half of earnings in 2040.
Figure 14: One important disagreement among the various forecasts is employment growth. Woods and Poole is bullish on growth throughout the region, expecting nearly 300,000 new jobs in the Baltimore Washington Region.

Figure 14 - Woods and Poole Projected Employment - Baltimore Washington Region

Woods and Poole

Figure 15: The metro area projections from BMC and MWCOG are less optimistic about employment growth, particularly in inner and outer suburban jurisdictions. Some, but not all the difference can be attributed the different measures of employment used in the MWCOG forecast. Woods and Poole reliance on Bureau of Economic Analysis measures while MWCOG utilizes the Bureau of Labor Statistics.

Figure 15 - Regional Forecast Projected Employment - Baltimore Washington Region

BMC, MWCOG
**Figure 16:** As with earnings, Woods and Poole is the only forecast that projects jobs by sector. In this forecast federal and local government will shrink relative to regional employment. Government growth might continue as new jobs through contract employment in the expanding professional and technical service sector. Health and social services will also grow in proportion to total employment.

![Figure 16 - Total Employment History and Projections By Sector - Baltimore Washington Region](image1)

*Woods and Poole*

**Figure 17:** Earnings per employee, rather than GDP per capita, is our available measure of average economic wellbeing. According to Woods & Poole, earnings growth will continue to outstrip population growth. By 2040 the average employee in the Baltimore Washington Region will earn over $90,000 in 2012 dollars.

![Figure 17 - Earnings Per Employee ($) - Baltimore Washington Region](image2)

*Woods and Poole*
**Figure 18:** Since 1979, incomes have risen for most Marylanders. The 90th percentile earns 30% more than in 1979 and the 50th percentile earns over 10% more than 1979. Low income workers, those in the 10th percentile, however, earn less than they did in 1979.

![Cumulative percent real wage growth for selected deciles, Maryland workers, 1979-2012](image)


**Figure 19:** Woods and Poole forecasts income levels. The projections indicate that high income level households will increase dramatically while lower income families will remain similar in absolute terms but less in percentile terms. This would reverse the long standing stagnation for low income workers seen in the above chart.

![Figure 19 - Total Households by Income Level Historic and Projected - Baltimore Washington Region](image)

Woods and Poole
Outcomes

Transportation

Transportation data are largely derived from the Maryland State Stat Website

**Figure 20:** Vehicle miles traveled increased for over a century. Starting around 2005, that increase leveled off. This reflects a well-recognized trend throughout the nation. The cause of VMT decline and the future of VMT remain a point of contention.

![Figure 20 - VMT Relative to 1980 - Maryland](image)

**Figure 21:** The Washington Metropolitan Area Transit Authority system accounts for the majority of transit riders in the region. The Maryland Transit Authority, which operates the Baltimore bus system, the Baltimore metro, MARC commuter rail, light rail and commuter bus, accounts for 100,000,000 annual riders.

![Figure 21 - 2012 Ridership - Baltimore Washington Region](image)
**Figure 22:** Within the MTA system transit usage has slightly increased on all modes except for bus. In spite of these moderate increases, bus trips still predominate and the use of the bus system has the greatest impact on overall transit ridership. In the aggregate, transit usage has remained flat. According to the 2007 Baltimore Metropolitan Council On-Board Transit Survey 55% of bus riders have no personal vehicle use and another 28% experience competition for vehicle use. Lower income individuals are also over represented in bus ridership.

![Figure 22 - Transit Trips per Year - MTA System](image)

**Housing**

**Figure 23:** The US Census tracks residential building permits for all counties, including the total number of permits drawn for single family units and total number of units on all permits. It is then possible to calculate the proportion of new units that are single family units. In the early 1990s over 80% of new units in the region were in single family homes. In three most recent years, that proportion has fallen to less than 60%.

![Figure 23 - Proportion of Total New Units that are in Single Family Homes- Baltimore Washington Region](image)
Figure 24: The proportion of new units that are single family units has declined in core, inner, and outer jurisdictions. The rate of new single family units remains lowest in the core, while more than 50% of new units in both the inner and outer suburbs remain single family units.

![Proportion of Total New Units that are in Single Family Homes: Core, Inner, Outer - Baltimore Washington Region](image1)

US Census

Figure 25: The rate of single family home is better understood in the context of the total units delivered. For example, single family homes spiked as a proportion of total units in core jurisdictions at a time when core jurisdictions introduced less than 1000 new units per year.

![Location of Total New Units: Core, Inner, and Outer Jurisdictions - Baltimore Washington Region](image2)

US Census
Land Consumption

**Figure 26**: Developed land in the Maryland portion of the Baltimore Washington Region has displaced farm and undeveloped land. Farm land continues to shrink over the past 10 years while land that is neither developed nor farmed has remained stable.

**Figure 27**: The region has lost more than 500,000 farm acres over 25 years. Farmland has declined most precipitously in Washington DC’s outer suburban jurisdictions.
Energy & Carbon

The energy information comes from the Maryland State Stat website and the US Energy Information Agency.

Generation by Source

**Figure 28**: Maryland has decreased proportionally its generation of coal energy in the past 10 years, replacing it primarily with nuclear from Calvert Cliffs and natural gas.

**Figure 29**: PJM, the regional power company, provides information on coal plants that will be decommissioned and a queue of energy generation facilities that are expected to come online. Though not all plants in the queue will be built but the queue demonstrates where investment is anticipating future capacity. The figures are prior to the adoption of the most recent EPA regulations affecting coal plants.
Figure 30: Though the state generates energy primarily from coal plants, the largest energy consumption remains gasoline used in vehicles. Also important, Maryland is a net energy importer. Maryland’s emissions impact will depend largely on the fuel source for energy generation facilities within the larger PJM grid.

![Figure 30 - Current Energy Consumption Estimates (Trillion Btu) - MD](image)

US Energy Information Agency

Average Peak Demand

Figure 31: Peak energy demand is decreasing in Maryland. The state appears to be meeting the goals established by the current administration.

![Figure 31 - Peak Demand and Official State Reduction Goals (kW) - MD](image)

MD State Stat
**Figure 32**: The state is not meeting its target for greenhouse gas emissions reduction. The projections in the following graph are all state provided without a transparent methodology. Tim Welch, in his PhD thesis, estimated that the state’s targets fall well short of meeting the reductions necessary to preventing the 2° warming threshold.

![Figure 32 - HG Emissions and Future Goals (tonnes) - MD](image)

**Water Quality**

**Figure 33**: Maryland has reduced the total loads of water pollutants since 1985. This has been achieved primarily through the regulation of point source pollution such as power plants and industrial sites. Future reductions will require reduction in non-point sources such as farm fertilizer and urban stormwater runoff.

![Figure 33 - Total Loads of Water Pollutants Relative to 1985 and State Targets (lbs) - Maryland](image)
Models

A critical element to PRESTO is the analysis of variables that impact the sustainability of the region. Most of these variables will be forecasted using NCSGs loosely coupled modeling suite. The models are described below:

Maryland Statewide Transportation Model (MSTM)

**Purpose:** The MSTM is an analytic tool designed to address Maryland statewide transportation issues. These issues include traffic in rural areas outside the Baltimore and Washington MPOs, Baltimore and Washington, freight traffic, and activity in the interface between Baltimore and Washington. The model allows consistent and defensible estimates of how different patterns of future development change key measures of transportation performance. MSTM coverage includes the entire states of Maryland and Delaware, the District of Columbia and portions of southern Pennsylvania, northern Virginia and West Virginia. The MSTM also covers the remainder of the United States (primarily for freight) but in less detail.

**Inputs:**
- **Zones:** All socioeconomic data (for 2007 and 2030) are divided into zones. Statewide Modeling Zones (SMZ) cover the inner area of Maryland, Delaware, and portions of immediately surrounding areas and regional modeling zones (RMZ) cover the rest of the country.
- **Networks:** The model includes a highway and transit network covering the entire state of Maryland and portions of surrounding states for 2007 and 2030. The entire national highway network is represented in lesser detail.
- **Socio-economic Data:** Population and employment are represented for each zone. Data sources include MPOs, state DOTs, the Census and Quarterly Census of Employment and Wages.
- **Travel Data:**
  - For short distance travel: 2007-2008 MWCOG and BMC Household Travel Survey (HTS) data, Census Transportation Package (CTPP)
  - For long distance person travel (regional): 2002 National Household Travel Survey (NHTS) for long distance travel, Air travel data from 1993 to 2010
  - For regional truck model: Freight Analysis Framework, Version 3 (FAF3) data published by FHWA
  - For statewide truck model: Employment and Households by SMZ, Quick Response Freight Manual (QRFM)
- **Data for calibration and validation:** Maryland State Highway Administration (MSHA) traffic count data, Highway Performance Monitoring System (HPMS) 2007 data for Vehicle Miles of Travel (VMT) validation and MPO screenlines.

**Assumptions:** Major assumption areas are: (1) economic forecast, (2) land-use forecasts or assumptions, (3) data processing e.g. HH income and trip purpose categories, (4) aggregation-disaggregation of data to different geographic resolutions, (5) behavioral assumptions regarding mode, route and time of day choices, (6) time-of-day assumptions, (7) trip cost assumptions (operating cost and fixed cost).

**Structure:** The MSTM is designed with an integrated three-layer data structure: (1) national layer consisting of national travel patterns, (2) intermediate statewide layer (3) urban layer representing more detailed travel patterns including local travel. While urban models are strong in representing short-distance trips and mode split using urban transit, the national layer allows modeling long-distance trips that have at least one trip end outside the state of interest. The statewide layer is at the center of the model, bringing together detailed knowledge of travel markets from the urban layer and long-distance flows from the regional layer.
The MSTM uses a traditional four-step travel forecasting process with the addition of a time-of-day model which divides trips to four time periods, AM Peak, Mid-day (MD), PM peak and night time (NT).

Step 1: (Trip Generation) estimating how many trips are made and trip origins and destinations. It is a cross-classified model (by income and number of workers for work trips and by income and household size for other trips) for production and attraction of nineteen types of trips.

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

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

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

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

Long Distance Travel
On the person travel side, the Regional model includes a person long-distance travel model for all resident and visitor trips over 50 miles. The trips are combined with Statewide level short distance person trips by study area residents, produced by the process above. On the freight side, the Regional model includes a long-distance commodity-flow based freight model of truck trips into/out of and through the study area (EI/IE/EE trips). These flows are originally estimated for the entire US and disaggregated to the study area zonal system. These trips are combined with short distance truck trips (II trips) generated at the Statewide level using a trip generation and trip distribution method. The passenger and truck trips from both the Regional (long-distance) and Statewide (short-distance) model components provide traffic flows allocated to a time period (AM peak, PM peak or off-peak) and are input to a single Multiclass Assignment.

Output: Results of the model report traffic impacts on the overall system, corridors or individual links. Main performance measures obtained from MSTM are: Vehicle Miles Traveled (VMT), Vehicle Hours Traveled (VHT) and Vehicle Hours Delay (VHD), number of trips, trip length, congested speeds, congested lane miles and travel times,
daily and peak hour volumes, volume-capacity ratio, and shape files for visualization. These measures can be reported for different time periods, vehicle types (modes), facility types, trip purposes and income categories.

Mobile Emissions Model (MEM)

**Purpose:** This is an integrated model that calculates total emissions by applying emission rates calculated by the MOVES2010 EPA model to MSTM-produced trip tables and loaded networks (VMT and speeds for each network link). The model outputs both running and non-running emissions.

**Inputs:** The MEM model requires the following main input data and parameters:

- **Timeframe:** A model year and relevant inputs to reflect changes in VMT and the underlying highway network.
- **Geographic Scale:** Covers the same area as the MSTM.
- **Roads:** All roads in the MSTM network: major collectors, arterials, highways and interstates and centroid connectors for minor trips within zones (intrazonal trips).
- **Vehicles:** Includes all vehicle trips within the region based on the vehicle trip tables produced by the MSTM transportation model. The mix of vehicle types (truck, small truck, auto etc.) and the age distribution of the vehicles is also required.
- **Meteorology:** Temperatures gathered by month and hour for each county in the study area, and humidity.
- **Average speed distribution:** The MEM uses the congested roadway speeds developed in the traffic assignment portion of the MSTM.
- **Road type distribution:** The vehicle miles traveled (VMT) on varied road types (five categories).
- **Fuel formulation and supply:** Fuel formulation (chemical composition) and fuel supply (formulations) at the county level for the area being modeled.

**Assumptions:** Assumptions on model inputs both for current and future year e.g. vehicle fleet mix, vehicle types, vehicle fleet efficiency, temperature and humidity, fuel and supply.

**Structure:** The MEM model has four explicit steps that must be run to calculate total MSTM area emissions.

- **Step 1 (MOVES):** First, county level emissions rate factors from MOVES2010 are calculated. Emissions are categorized by speed bin, pollutant, and model year. The MEM reformats MOVES emissions factors to be used with MSTM model outputs.
- **Step 2 (MSTM):** This step categorizes congested speeds from the assigned MSTM network by MOVES predefined speed bins. Vehicle miles traveled within the network are calculated for application to the running emission rates. MOVES road types are matched and appended to the MSTM network based on facility type and area type.
- **Step 3 (MEM):** Running emissions are calculated by applying emissions factors per mile to model VMT for each link.
- **Step 4 (MEM):** Non-running emissions are calculated by applying emissions factors/vehicle to the pre-calculated vehicle population. Link level emission rates are added to the MSTM loaded network.
are appended to the MSTM network and running and non-running emissions by road functional class by pollutant are summed.

**Outputs:** The MSTM-ME measure two types of emissions across the entire network, running (when vehicle is in motion) and non-running (when vehicle is stationary). For running emissions tailpipe exhaust, crankcase (engine) and evaporative emissions are calculated. For non-running emissions, start exhaust, refueling and evaporative emissions are calculated. These emissions include:

- **Emissions related to Ozone formation:** oxides of nitrogen (NOx), volatile organic compounds (VOC) e.g. carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate,
- **Emissions related to Greenhouse Gas (GHG) formation:** Carbon Dioxide Equivalents, Methane (CH4), Nitrous oxide (N2O)

### SILO Land Use Model

**Purpose:** The Simple Integrated Land Use Orchestrator (SILO) simulates household relocation, demographic changes and developers who add, upgrade or demolish dwellings.

**Inputs:** SILO uses the Public Use Microdata Sample (PUMS) to create individual households and their dwellings. The transportation model MSTM provides the employment data and the zone system and zone-to-zone travel times by auto and public transit. Development capacity is borrowed from the Maryland Growth Model, which provides available space for future development subject to existing densities and zoning. A Household Travel Survey is used to calculate the work trip length frequency distribution.

**Assumptions:** While SILO models natural population growth (i.e., birth and death), assumptions on immigration into the region and outmigration out of the region need to be provided. Employment is not modeled endogenously, and thus, needs to be provided as an exogenous input. The average acres of developable land consumed for one housing unit for every dwelling type need to be provided. Demographic probabilities (such as birth rate, marriage rate, divorce rate, death rate, household relocation rate, etc.) are also an exogenous input.

**Structure:** SILO is designed as a microscopic discrete choice model. Microscopic, because every household, person and dwelling is treated as an individual object. Discrete choice means that decisions to relocate or develop a new dwelling are modeled explicitly. All decisions that are spatial (household relocation and development of new dwellings) are modeled with Logit models. Initially developed by Domencich & McFadden (1975), such models are particularly powerful at representing the psychology behind decision-making. Other decisions (such as getting married, giving birth to a child, leaving the parental household, upgrading an existing dwelling, etc.) are modeled by Markov models that apply transition probabilities.

First, a synthetic population that lists individual households, persons, dwellings and jobs with all attribute information is created from PUMS data. The demographic module simulates aging, marriage, divorce, birth of children, children leaving the parental household, death, etc. Many demographic events trigger a household relocation, such as the couple that is looking for a larger apartment after their first child is born. Every household considers relocating every year in the model. If the expected utility of other dwellings (in terms of price, size,
accessibility, distance to work location, etc.) is significantly larger than the utility in the current dwelling, a household is likely to relocate. The real estate module simulates the behavior of developers. Based on current demand of housing by five dwelling types, developers may decide to construct new residential floorspace if developable land is available. When choosing a location for new dwellings, the developers mimic the location choice of households to provide marketable housing.

**Outputs:** SILO generates a synthetic population with households, persons, dwellings and jobs for every simulation period from 2000 to 2040 in one-year increments. These data can easily be fed into the MSTM. In addition, SILO creates two aggregate summary files, one with detailed data for the entire study area (such as persons by age and gender, number of dwellings by type, average commute distance, etc.) and one with selected zonal data (such as households or dwellings by zone, zonal accessibility, etc.).

### Building Based Energy Consumption and Emissions Model (BBCEM)

**Purpose:** The purpose of this model is to determine CO2 emissions and energy consumption from the built environment within the state of Maryland. This comprehensive model, developed in 2013 by Dr. Tim Welch while at the NCSG, coupled with the MOVES model, determines total CO2 emissions within the state.

**Inputs:** Current year inputs are derived from parcel level data from Maryland’s Property View database and the Quarterly Census of Employment and Wages (QCEW) micro data. Future inputs are totals at the Statewide Modeling Zone (SMZ) level. Each property has three central characteristics: building, location, and climate (summarized by the acronym BLC).

- **Building (B):** Type of structure, square footage, structure age, single unit or multiunit, heating fuel, heating/cooling equipment, building construction materials, fireplaces, bedrooms, bathrooms, building use (residential, commercial, industrial, ‘other’), business attributes – if applicable (type of business and number of employees).
- **Location (L):** The built environment density of a parcel location (defined by urban or rural).
- **Climate (C):** Heating degree days, cooling degree days.

**Assumptions:** Future year building energy efficiency, rate of retrofit and weatherization, composition of energy generation sector (fuel, efficiency, number of plants).

**Structure:** The model begins by using the BLC variables to determine whether the structure is likely to combust fossil fuels on site. If the probability is greater than 50%, then the model calculates CO2 emissions from local combustion based on a set of BLC variable related multipliers derived from a regression of the national building energy consumption survey data. The CO2 and energy totals are then aggregated to the zone level. At this point, the user assigns future growth to zones within the state and calculates the additional CO2 and energy impact from growth. Because the power generation sector does not reduce output automatically as demand falls, CO2 from this sector
is calculated through energy to CO2 multipliers for each plant operating in the system. CO2 emissions from plants do not change much with short term energy demand.

**Outputs:** CO2 emissions and energy consumption are the two primary outputs of the BBCEM model.

- **CO2 Emissions:** The model measures CO2 emissions produced directly in the built environment and through power generation at central locations within the grid. CO2 emissions can be determined at the parcel level or aggregated to higher levels such as SMZs or Counties. The emissions can also be tabulated to energy generation, transportation, residential, commercial, industrial, and ‘other’ sectors.
- **Energy Consumption:** The model measures energy consumption in BTUs from the built environment. As with CO2 emissions, energy consumption can be tabulated by geography or attributed to sectors.

**Chesapeake Bay Land Change Model (Chesapeake Bay Program, USGS)**

The water quality models consist of two phases. In Phase 1, the land cover model takes population, employment and land use data at the county or zone level and disaggregates it into 30 meter grid cells and estimates land cover. In Phase 2, the Watershed model uses information on land cover and hydrologic models to estimate runoff into the Chesapeake Bay.

**Land Cover**

**Purpose:** This model disaggregates county level or zone level population and employment data down to the 30 meter grid cell level of detail. It also estimates the land characteristics of each grid cell including residential, commercial, industrial and agricultural land. The amount of forest land is estimated based on conversion of forest land to other uses.

**Input:**

- SMZ or county level activity - patterns including population, employment and residential, commercial industrial land use along with available land.
- Future Population and employment estimates
- Accessibility measures
- Land area suitable for development
- Census
- Density, current and anticipated zoning policies
- Forecasts of Population and Employment

**Assumptions:** Relationship of population and employment growth to land consumption

**Structure:** Population and employment projections combine with census data to create housing demand and demand for infill development. These also combine with land suitable for development and density assumptions to create residential and commercial demand. Finally, combining demand with accessibility estimates the probability of development at the 30 meter grid cell scale.

**Note:** The model is a Monte-Carlo simulation and must be run multiple times to develop a final forecast.

**Output:** Land use and land cover, by type, at the 30 meter grid cell level of detail.

**Watershed Model**

**Purpose:** The Watershed Model incorporates information about land use, fertilizer applications, wastewater plant discharges, septic systems, air deposition, farm animal populations, weather and other variables to estimate the amount of nutrients and sediment reaching the Chesapeake Bay and where these pollutants originate

**Inputs**
- Land cover by 30 meter grid cells including commercial, residential, industrial, agriculture, forest (from land cover model)
- Soil type (Impervious, sand, etc.)
- Weather including temperature, humidity, rainfall

**Assumptions:** Prevailing weather, manure disposal technology

**Structure:** The hydrologic sub-model uses rainfall, evaporation, meteorological data and land use type to calculate runoff and sub-surface flow for all land uses, including forest, agricultural and urban lands. The surface and sub-surface flows ultimately drive the non-point source sub-model, which simulates soil erosion and pollutant loads from the land to rivers. The river sub-model routes flow and associated pollutant loads from the land through lakes, rivers and reservoirs to the Chesapeake Bay.

**Outputs:** Runoff into the Chesapeake Bay including nutrient loading and pollutant loads.

**Opportunity Mapping Tool (OppMap)**

While OppMap is not really a model, we include it here because it is an important analytical tool developed by NCSG covering the entire State of Maryland that helps understand access to opportunity for residents of Maryland in a way different than the models and data described so far. In particular, it provides a lens on current aspects of *equity* in the region, deploying over 100 variables that display how different geographic areas fare with respect to access to six categories of opportunity.

**Purpose:** The Opportunity Analysis Tool is a web-based tool that enables users to identify relative access to economic, social, and environmental opportunities by place of residence anywhere in the state of Maryland. The tool can be used to determine which residents have access to opportunity as a means of evaluating social equity. The tool can also be used to identify where and what kind of strategic investments can be made in the region to enhance and equalize access to opportunity.

**Inputs:** The Opportunity Analysis tool uses data from a variety of sources—including the US census, Maryland Department of Education, the Maryland State Transportation Model, the Quarterly Census of Employment and Workforce, the US EPA, and the Maryland Department of Housing and Community Development, to generate measures of opportunity in six distinct categories:

- Education
- Housing and Neighborhood Quality
- Social Capital
- Public Health and Safety
- Employment and Workforce
- Transportation and Mobility

**Assumptions:** The model assumes that access to opportunity is determined by place of residence and that opportunity is determined by a combination of the social, economic, and environmental attributes of that place.
**Structure**: Opportunity scores are computed using four steps:

**Step 1: Variable Selection.** The determinants of opportunity include variables that capture the quality of local public services, including education; access to employment, environmental quality, and housing and neighborhood quality. Users can choose from over 100 different variables.

**Step 2: Geographic assignment.** Variables are assigned to census tracts. Accessibility is measured using the Maryland State Transportation Model. Data that do not come as attributes of census tracts are assigned using proportional allocation or using spatial interpolation methods, such as kriging or inverse-distance weighting that estimate accessibility levels at unobservable locations.

**Step 3: Normalization and ranking.** All measures are converted to z-scores and ranked in quintiles.

**Step 4: Aggregation and weighting.** Opportunity indices are computed for each six categories by adding weighted z scores. Users can choose to what variables to include and how to weight each variable within each category. An overall opportunity index can be computed by weighting and aggregating category rankings.

**Outputs**: The Opportunity Analysis Tool produces for each census tract in the region rankings of opportunity for each indicator variable, each opportunity category, and overall access to opportunity.
Appendix: Prior Work

The National Center for Smart Growth has extensive experience with scenario analysis and modeling. Even before joining the NCSG, several members of the NCSG staff were engaged in some of the pioneering land use and transportation scenario analyses around the nation, including Portland Metro 2040, Chicago 2020, and LUTRAQ. As an institution, NCSG began its scenario analysis work as part of several “Reality Check” exercises throughout the Baltimore-Washington region. These large public engagement exercises produced a series of maps that illustrated where citizens wanted to see growth and development occur. Immediately after the Reality Check exercises the NCSG launched the Maryland Scenario Project with the assistance of a stakeholder-based Scenario Advisory Group. For this project the NCSG began to develop and link advanced econometric, land use, transportation, nutrient loading, and air emissions models. With the early versions of these models the NCSG tested the impacts of several alternative statewide development scenarios—including a Business as Usual, Transit-Oriented Development, High Energy Price, and Official Projections scenarios—on outcome variables such as vehicle miles traveled, land consumed, water quality, air quality, and economic growth. Most recently, the NCSG developed an opportunity-mapping tool for the Baltimore metropolitan area that facilitates the analysis of social equity in the form of access to opportunities such as jobs, good education, environmental quality, social capital, and more. The products of this tool will inform the Regional Sustainable Community Plan for the Baltimore metropolitan area. Some of the publications and reports from previous work are listed below.

Over the course of a decade NCSG has improved, expanded, and enhanced its data and models as well as its technical capacity. It has worked closely with several Maryland state agencies and regional governments. By launching PRESTO the NCSG intends to offer a new, science-based analysis that will lead to more sustainable Baltimore-Washington region.

Journal Publication


Referred Conference Proceedings


Project Reports

