Smarter Roads, Smarter Cars, Smarter Growth: Baltimore-Washington 2040

Modeling Documentation for the Project, 2018 – 2020 July 2020

This document is designed to accompany and support the analysis conducted in the above report produced by the NCSG in July 2020. It provides more technical detail than can be found in that report. We first describe the models used in the work, then the modeling process and the model parameters used and finally describe various changes and adjustments made in the modeling work over the course of the project.

The reader should also consult the rest of this report website which has further detail on some model elements (e.g. SILO) and contains the full tables for all the model run options including for runs with MSTM only and runs with MSTM plus SILO that capture the transportation and land-use interaction effects of the scenarios.

1. Model Descriptions

The modeling for this report used a version of the PRESTO modeling suite that has been used for several previous analyses. Three inter-linked models were used, (1) The Simple Integrated Land Use Orchestrator (SILO) for population movement, (2) The Maryland Statewide Transportation Model for vehicular and transit use; and (3) The Mobile Emissions Model that calculates total vehicular emissions.

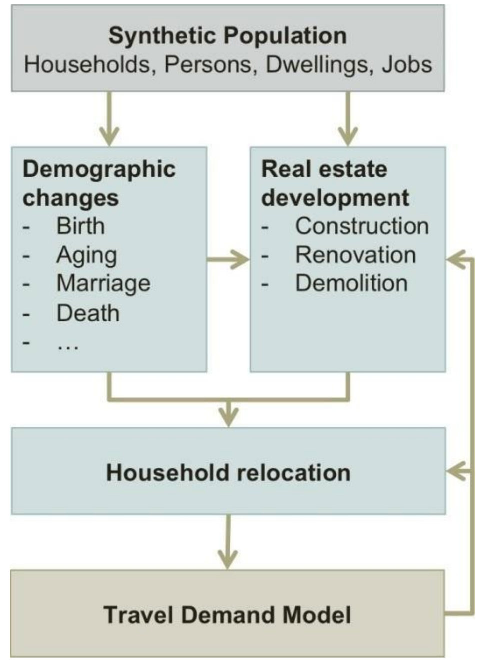
Simple Land Use Orchestrator (SILO)

SILO is a microscopic land use model that simulates population movement and housing development. It is microscopic because it models each person and households as discrete decision-making units. Those households also live in individually represented dwelling units. Households' relocation decisions and development decisions are modeled using a utility maximizing logit discrete choice model. Demographic changes such as getting married, giving birth, dwelling upgrades are modeled using Markov chain transition probabilities.

SILO generates a synthetic population of persons, households, and dwelling units from the Public Use Microdata Sample (PUMS) and the American Communities Survey. The Maryland Household Travel Survey is used to determine the work trip length frequency distribution, which influences where a household will relocate.

SILO models future population and housing movements based on several key assumptions. Aggregate in- and out-migration are set based on population projections. Future employment locations are exogenous and taken from MPO and state projections. The available acres of developable land influence housing construction geography, which are also set by the modelers. Within the state of Maryland, these estimates come from the Maryland Growth Model. Outside the state, we provided a buffer around official projections. Birth and death rates for the entire modeling area are set from national data and assumed to be constant throughout the modeling period.

For every simulated year, all households consider relocation. Households enter the market if the expected utility of a different dwelling based on its price, size, or access to work eclipses the utility of the current dwelling. For example, the birth of a child will cause a household to place higher value on a larger unit. SILO's dwelling construction and demolition simulation is based on real estate developer behavior, which considers revealed dwelling preferences of the simulated households and the price of units. SILO is particularly useful because it models real constraints in household budgets and in travel time budget to work. Notably, our implementation of SILO also incorporates the behavioral effects of racial segregation, school quality, crime, and development constraints represented by zoning.



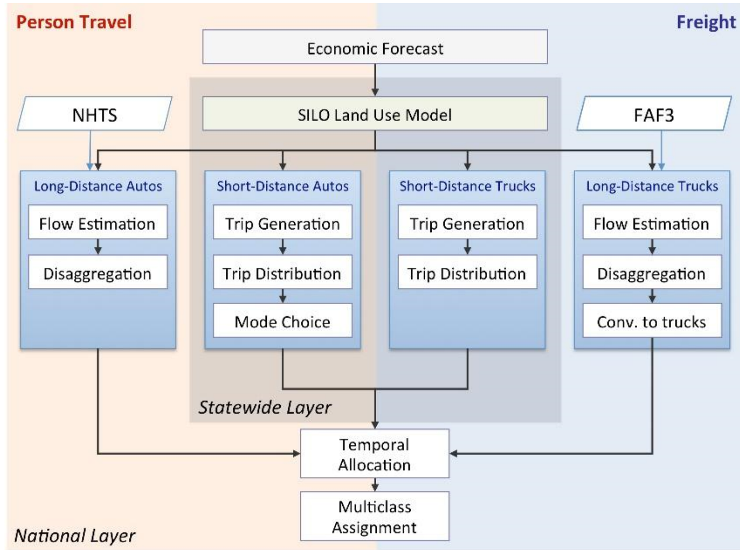
SILO generates spatial data for population, households and dwellings for every year from 2015 to 2040. SILO does not generate employment locations but uses such data as an exogenous input, one of the factors to which the model responds. In this case, it is provided by MPO and Maryland Department of Planning sources. These household, population, and housing results are then used by MSTM to simulate traffic and transit use.

Maryland Statewide Transportation Model (MSTM)

MSTM is a traditional four-step transportation model that covers Maryland and surrounding areas including Washington DC, Delaware and parts of Pennsylvania, West Virginia, and Virginia. The model consists of three interacting geographic layers: (1) a national layer, (2) a regional layer that includes Maryland and parts of bordering states, and (3) an urban layer. Traffic detail increases as the geographic layer shrinks. The urban layer provides details on short-distance trips and mode split for transit, while the national layer covers long-distance trips that either begin or end within the regional layer. The regional layer serves as the intermediate section that combines the detailed trips modeled in the urban layer and the long-distance trips modeled in the national layer.

The model aggregates the TAZs (Transportation Analysis Zones) for the State of Maryland into larger SMZs (Statewide Modeling Zones) and aggregates population, housing, and jobs within the zones into the four larger subareas used in the study. The road and transit networks used in the project's 2040 Baseline include all existing and committed projects (such as the pending circumferential Purple Line connecting Montgomery and Prince George's Counties inside the Beltway).

MSTM uses a modification of the standard four-step travel forecasting process, which divides the day up into four time periods, as described below:



Step 1: Trip Generation. This estimates the number of trips made at a particular time of day and the origin and destination of the trip. Trips are classified by a number of categories, including income quintile, household size, trip origin and destination type (home, work or other).

Step 2: Trip Distribution. This step uses a logit-based model to determine the trip destinations. Factors such as travel time and the activity types of destination zones determine the distribution. Areas with high activity values attract more trips.

Step 3: Mode Choice. This step determines whether each trip will be taken by auto (drive alone or shared ride) or by a transit mode (bus, express bus, rail e.g. light and metro rail, and commuter rail). This is determined by a nested logit model based on variables including travel time, monetary travel cost, and parking cost. Transit mode selection also includes time to access/egress the transit station, the number of transfers and transfer time and wait time.

Step 4: Time of Day. This component splits the daily travel demand over four time periods: AM Peak, Mid-day, PM peak, and Nighttime. This report uses the PM peak traffic results, as that is usually when the region's roads experience the heaviest traffic volumes.

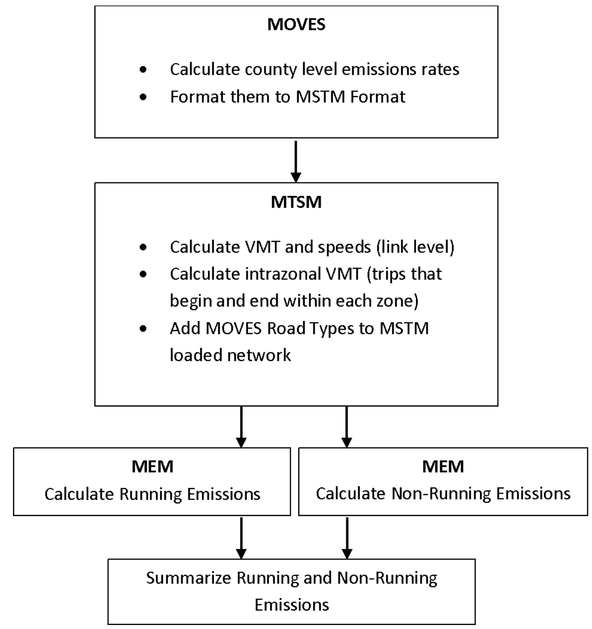
Step 5: Assignment. This step calculates the volume and speeds on the road network.

MSTM outputs include vehicle miles traveled (VMT), vehicle hours traveled (VHT), and vehicle hours of delay (VHD) for each individual road link, as well as the number of trips, trip length, congested speeds, contested lane miles, and volume-to-capacity ratios for each of the four time periods. The model is run for the PM peak in this project.

Mobile Emissions Model (MEM)

The Mobile Emissions Model (MEM) uses the results of MSTM to determine the level of emissions from vehicular traffic. In particular, VMT and vehicle speeds are the primary inputs that determine emissions. County-level emission rates are calculated and categorized by speed category and pollutant type in EPA's MOVES model. Then these rates are formatted so that they can be used with MSTM model outputs. Then congested speeds collected from MSTM are put into categorical "bins". Then the model calculates running emissions for each link, while non-running emissions are calculated based on vehicle population.

MEM, which is a customized version of the US EPA's Motor Vehicle Emissions Simulator (MOVES), provides both running and non-running emission outputs for three types of greenhouse gases: (1) oxides of nitrogen (NOx), (2) volatile organic compounds (VOCs) which include carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate; and (3) carbon dioxide equivalents.



2. Modeling Process and Parameters

SILO and MSTM models were run twice, and MEM was run once. The initial SILO run simulated population movement and housing construction from 2015 to 2030 with travel times from the ??? year run of the MSTM, from which it calculates gravity-based accessibility to jobs. Then, SILO's population distribution, together with exogenous employment projections for 2030, were used as the base inputs for MSTM for the year 2030. The auto and transit accessibility from MSTM 2030 were then used as inputs for a second SILO run from 2030 to 2040. Again, the population and employment projections for SILO in the year 2040 were used as inputs to run MSTM for the year 2040. Finally, the results from MSTM for the year 2040 were used as inputs for MEM, which produced modeled mobile greenhouse gas values for the year 2040.

SILO

Land Capacity

The Capacity input determines the amount of land available for new housing development in each SMZ, measured in housing units. SILO does not have a redevelopment function but the Maryland Growth Model attempts to include easily redeveloped land in its tabulation. Land capacity was varied between scenarios based on the assumptions made on both the impact of AVs and the smart growth policies. For the Baseline, Toll Lane (free) and Toll Lane ($0.40) scenarios, the land capacity was kept constant. For the AV scenarios (AV, AV + Tolls (free), and AV + Tolls ($0.40) that increase highway capacity, we increase development capacity in the outer and remaining subareas. In Smarter Growth (no AV) scenarios we increased capacity by 20% in the Core and Inner subregions, but did not change it in the outer or remaining subareas. For SG with AVs we both increased capacity 20% in the inner and core areas and in the outer and remaining areas by 20% as well.

Accessibility by Auto Parameter (Beta)

Accessibility to jobs by automobile is calculated using a gravity model given by the following equation:

$$acc_{e,a,i} = \sum_{i \neq j} \propto * \, Emp_j * \, exp\,(-\beta * t_{ij})$$

where:

$acc_{e,a,i}$ is accessibility to employment by auto in zone i

Emp_j is the total employment in zone j

t_{ij} is the travel time from zone i to zone j

$\propto$ a parameter that determines the value an additional job in a zone contributes to accessibility

β are parameters that determines the value of additional travel time to accessibility

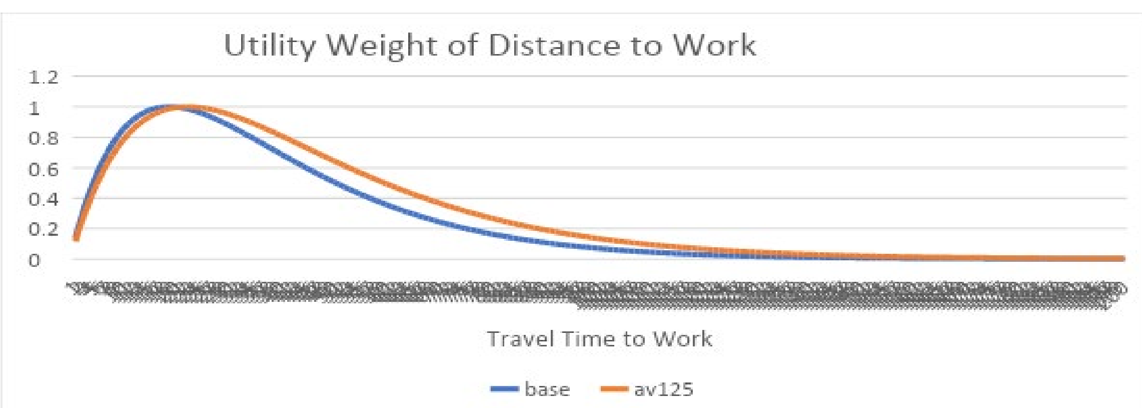
Increasing β from -3 to -.275 reduces the disutility of travel time in accessibility calculations. This means that households experience a flatter accessibility map, placing less value on nearby employment locations. This is an example of one of the potential consequences of less onerous travel time in an AV.

Auto Operating Costs

Auto Operating Costs determine the cost of using automobiles for transportation. This value was decreased by 33% for the four AV scenarios as it is assumed that the emergence of AVs will decrease auto operating costs as automated vehicles will operate in a significantly more fuel efficient manner and other operating costs will decline.

Household Distance to Work Preferences

Over time households have demonstrated remarkably consistent preferences for their travel time to work. Thus, SILO includes the travel time to work in the household location choice model. The dwelling unit utility contribution of this factor in all baseline scenarios is based on the actual distribution of travel times to work from the Maryland Household Travel Survey. The AV scenarios push this distribution slightly to the right, reflecting a willingness to locate further from the work place. The distributions are shown in the Figure following.



Real Estate Development Discrete Choice Model

This model determines the value that real estate developers place on developing new units by type and location. The coefficients are the relative contribution of various characteristics. In the autonomous vehicle runs, developers are assumed to weigh employment accessibility 12.5% less when choosing the location to build new units.

Household Moves Discrete Choice Model

The Household Move Model is a discrete choice model that determines the utility that households place on living in different regions and units. Using the utilities, SILO determines the likelihood that a household will look for a new dwelling, the probability of looking at units in a specific region (generally the size of a county), and the probability of them selecting a specific unit? from the choice set (10 selected from region). Thus, the coefficients are important for determining where individuals will see the greatest value. In the AV region choice model, the value of auto accessibility to jobs was decreased by 12.5%. In the AV unit choice model, the value of auto accessibility and travel time to work were decreased by 12.5%. This essentially means that households simply care less about optimizing access to employment and their specific job site.

Racial Factor and Other Adjustments

Without recognizing the reality of white-black segregation patterns in the cities of Baltimore and Washington, SILO attempts to fill these places up with new growth given their capacity for development, especially Baltimore. We thus created a filter to dampen this effect by assuming that white-black integration occurs more readily as both black and white incomes rise. For similar reasons, we also created factors to reflect crime and school quality issues.

MSTM

Transit Expansion

For the two Smart Growth Scenarios, the MARC commuter rail line was expanded to Elkton, MD and the VRE was extended to Gainesville, VA. In addition, the Baltimore Red Line was added that runs east-west through the Baltimore region, while a Core Loop line was added to the DC Metro. In addition, MARC and VRE commuter rail lines were made continuous.

Toll Lanes on I-270 and I-495

Toll lanes were added to the MSTM road network on I-270 and I-495 for the four toll lane scenarios corresponding the closest to Alternative 9 in the MDOT Traffic relief Plan’s Alternatives Analysis.

Highway Capacity

It is assumed that AVs will allow for more capacity on roads, particularly on freeways, as recommended safe distances between vehicles are reduced and vehicles operate more efficiently. For the four AV scenarios, maximum capacity on freeways was increased by 25%. AVs were not assumed to operate autonomously on arterial or collector roads by 2040 so their capacities were not changed.

Toll Pricing on I-270 and I-495

For two of the four scenarios with toll lanes, toll prices were set to $0.00 in order to examine just the impact of the additional lanes. For the other two toll lane scenarios, toll prices were set at $0.40/mile, which approximates the toll rate on the existing tolled lanes on I-495 in Virginia. Tolls of 0.90c/mile were also tried and these massively reduced toll lane usage, which showed that our model is very price-sensitive.

Value of Time

The Value of Time (VOT) is the amount of money that individuals are willing to pay to reduce their travel time by a specified amount. It was assumed that the emergence of AVs would reduce the value of time by 33% for all income levels, as travelling in an AV allows one to do things other than drive. This means that travelers are less inclined to pay in order to shorten their travel times.

Parking Costs

The value of parking spaces is reduced by 50 percent under the four AV scenarios, as it is assumed that AVs will need fewer parking spaces and will be able to seek out cheaper spaces after dropping off their passenger.

Table 1: Scenario Parameters

		No AV			25% AV			
	Baseline	**Toll Lane ($.00)**	**Toll Lane ($.40)**	**SG**	**AV**	**Toll Lane ($.00)**	**Toll Lane ($.40)**	**SG**
SILO								
Capacity	Baseline	Baseline	Baseline	+20% in Core and Inner	RON	RON	RON	+20% in Core and Inner
Auto Access	-0.3	-0.3	-0.3	-0.3	-0.275	-0.275	-0.275	-0.275
Auto Operating Costs	8.4	8.4	8.4	8.4	6.3	6.3	6.3	6.3
Household Trip to Work	Baseline	Baseline	Baseline	Baseline	Decrease	Decrease	Decrease	Decrease
Real Estate Probabilities	Baseline	Baseline	Baseline	Baseline	Decrease	Decrease	Decrease	Decrease
Household Moves	Baseline	Baseline	Baseline	Baseline	Decrease	Decrease	Decrease	Decrease
MSTM								
Transit Expansion	No	No	No	Yes	No	No	No	Yes
Toll Lanes on I-270 and I-495	No	Yes	Yes	No	No	Yes	Yes	No
Highway Capacity	Baseline	Baseline	Baseline	Baseline	+25%	+25%	+25%	Baseline
Toll Price on I-270 and I-495	NA	$0.00	$0.40	NA	NA	$0.00	$0.40	NA
Value of Time (lower income)	21.1	21.1	21.1	21.1	15.9	15.9	15.9	15.9
Value of Time (upper income)	62.7	62.7	62.7	62.7	47.0	47.0	47.0	47.0
Parking Costs	Baseline	Baseline	Baseline	Baseline	-50%	-50%	-50%	-50%

Changes in the Modeling Process

During this analysis, we changed several aspects of our models from how they were applied in our previous PRESTO study (April 2018, NCSG…and give website link) in order to produce the most accurate, consistent and comprehensible scenarios for analysis. Many of these are mentioned previously but this section highlights how we have adjusted SILO to our region's dynamics.

Changes to SILO

1. Growth Capacity Input: The original version of SILO does not use a growth capacity layer. Our version includes one as a hard cap on development, as measured in units. Changes were made to the Baseline—SILO 2030 and SILO 2040 were given the same capacity input. In addition, the two Smart Growth scenario capacity files were modified to create a uniform increase of 20% in the Core and Inner subareas.
2. Population Control Input: Population Control determines the number of people entering and leaving the study area. In previous PRESTO work different population control inputs were used for AV scenarios because of the broader assumptions involved in those scenarios. In the interest of consistency, we decided to use the same population control file for all eight scenarios. SILO may still generate slightly different total populations if households attempting to move to the region cannot find a suitable dwelling unit in some scenarios but they can in others.
3. Household Distance to Work Preferences: The household distance to work preferences were reduced slightly from previous PRESTO AV scenarios. The previous scenarios assumed more generous adoption of AVs.
4. Demographic Probabilities: In the previous PRESTO work demographic probabilities input for AV scenarios was different based on longer lifespan assumptions but in the interest of consistency, they were all made uniform. The previous AV scenario included a number of economic factors not included in this one.
5. Real Estate Development Discrete Choice Model: In previous PRESTO work, developers in the AV scenario placed less value on accessibility than they do in this current modeling. This reflects the 25% adoption assumed in this research, less than in previous research.
6. Household Move Discrete Choice Model: In previous PRESTO work, households in the AV scenario placed less value on accessibility and travel time to work. This reflects the 25% adoption assumed in this research, less than in previous research.

Changes to MSTM

1. Value of time change: The value of time was substantially changed in order to produce toll lane usages that were more realistic. There are two values of time parameters assigned to two income levels, low and high. We made two value of time assignments for AV and non-AV scenarios for each income group. [Below are the old and new values of time]
2. Zero Emission Vehicles: In previous PRESTO work, we assumed that electric vehicles would be a higher proportion of the AV fleet, reflecting co-deployment of these technologies. But to maintain consistency, the percentage of ZEVs was reduced in these scenarios to match the non-AV scenario assumption of 10% of the vehicle fleet.

Initially, the MSTM-only scenarios were run using population data from SILO baseline outputs for each unique scenario. In order to maintain consistency for these MSTM solo scenarios, identical population and housing numbers were used.