PRESTO

PROSPECTS FOR REGIONAL SUSTAINABILITY TOMORROW

Can our region maintain its dynamic economy and quality of life if the future promises inexorable traffic gridlock? We tackle the congestion part of this question by creating scenarios of possible futures that address congestion in various ways. The prospect of autonomous vehicles sharply differentiates these scenarios. We assess policies that do very little, add new tolled roads, or assume smarter growth patterns. We analyze their impacts on population location, travel patterns, transit ridership, and greenhouse gases. We develop policy recommendations, some of which differ from ones currently being considered.

Smarter Roads, Smarter Cars, Smarter Growth?

Baltimore-Washington 2040

Table of Contents

September 2020

This report is dedicated with much honor and respect for the memory of Andrew McMillan who led and conducted much of the critical technical work for this report with commitment and care. We couldn’t have completed this work without him.

Letter from our Executive Director

The National Center for Smart Growth Research and Education is pleased to contribute this report to the ongoing dialog on the proposal to add toll lanes to Interstates 495 and 270. Of course, we are not the first organization to analyze this question. Our intent is not to challenge the analyses of other organizations, but to offer a new approach and to raise new issues of timing and technology that have not yet undergone critical analysis.

Toward this end, we employ a well-tested set of computer models, used by us and others, to examine how alternative transportation scenarios address traffic flows, traffic congestion, transit ridership, development patterns, greenhouse gas emissions, and more. What makes our analysis unique is the simultaneous examination of those issues in loosely coupled models that permit feedback between the models, including how transportation expansions indirectly affect population redistribution. Also unique is our consideration of autonomous vehicles to explore how this disruptive technology might influence the choice of alternative strategies. While our analysis is far from comprehensive and the insights we uncover are not definitive, we believe they are worthy of serious consideration.

First, we suggest that the adoption of autonomous vehicles has the potential to alter the relative efficacy of alternative transportation strategies well within the planning horizon. More specifically, we suggest that the case for new tolled freeway lanes is less compelling if autonomous vehicles alone provide significant increases in freeway capacity.

Second, with or without autonomous vehicles, we find the case for new lanes on I-495 to be stronger than the case for new lanes on I-270. This suggests it might be wise to consider these lane expansions as two distinct decisions, and perhaps decide on I-495 before deciding to expand I-270.

Finally, we find that smart growth strategies that provide for more development or redevelopment in core cities and inner suburbs plus selective transit expansion can provide some congestion relief, with smaller increases in vehicular travel and greenhouse gas emissions, if autonomous vehicles are rapidly adopted.

Like most of the work at the NCSG, this report represents the collaboration of many faculty, students and staff but does not reflect the views or perspectives of the University of Maryland or the four schools with which the NCSG is affiliated. We also acknowledge the Town Creek Foundation, which has generously supported our work in this area for nearly a decade. We alone, however, bear responsibility for the contents of this report.

To stay in touch or find additional information go to **www.umdsmartgrowth.org/projects/presto** and click on Keep in Touch.

Sincerely,

Gerrit Knaap
National Center for Smart Growth

Introduction

Growth in the Baltimore-Washington region continues to fuel debate about the best ways to address the resulting traffic congestion. This congestion, among the worst in the nation, is seen as an individual burden in wasted time and productivity as well as a barrier to regional economic development. Multibillion-dollar proposals to overhaul and expand the region's Metro system vie with even larger plans to add tolled lanes to major expressways, as proposed in the Maryland Traffic Relief Plan (TRP).[1]

Debates swirl around the impacts of these initiatives on transit, air quality, and land use. On the last point, county land use plans, over the past decades, have taken a smart growth approach and advocate for denser development around transit nodes in the name of congestion reduction and improved job access for all. Looming in the background is speculation about the impacts of autonomous vehicles (AVs) on congestion, travel behavior, transit viability, and land use. Furthermore, congestion solutions are increasingly viewed through the wide-angle lens of sustainability, with its emphasis on reduced energy consumption, resource conservation, and access to opportunity.

To explore the interplay of these uncertainties and forces, we present here an exploratory scenario approach, with the intent to identify both robust strategies, or policies that could work with all of these futures, and contingent strategies, that would help only under certain conditions.

We've created five scenarios for the year 2040 depicted as the various combinations in Figure 1. They are the result of combining two possibilities over which the State has little influence—the penetration of autonomous vehicles, at zero or at 25 percent—and three policy options: implementing existing plans, adding tolled freeway lanes, and adopting an even smarter growth land use and transit strategy. The maintenance of existing plans trends yields a 2040 baseline case against which the impacts of the other scenarios are measured.

Even though our focus is the greater Baltimore-Washington region, the potential impacts of transportation and other policy changes will reach beyond this region.

Figure 1. The Baseline and the Five Scenarios

	External Factors	
Policy Options	**No AVs**	**25% AVs**
Trends	Baseline	x
Additional Tolled Lanes	x	x
Smarter Growth	x	x

Modeling a larger study area captures these effects and allows for a broad consideration of impacts. The study area thus extends into the neighboring states of Virginia, West Virginia, southern Pennsylvania, Delaware and into D.C. By 2040 this study area will have a population of 15.6 million, with the Baltimore-Washington region at about 10.6 million residents.

We use various models to analyze selected impacts of the scenarios, as measured by primarily six indicators:

- Population growth shifts
- Traffic (measured as Vehicle Miles Traveled or VMT)
- Travel time (measured as Vehicle Hours Traveled or VHT)
- Delay (measured as Vehicle Hours of Delay or VHD)
- Transit ridership
- Vehicular emissions (greenhouse gases or GHG in tons per day)

After describing the models and indicators, we present the baseline conditions for the region's population, job distribution, and transportation conditions in 2015 and as projected to 2040, absent any significant policy and infrastructure interventions. We then test the five scenarios, organized by different geographies, and highlight key findings. We conclude with policy recommendations.

The report presents scenario results in percentage differences from the baseline, color coded for clarity, while the Appendix presents numerical results and a more detailed narrative of traffic impacts. Full tabular model results are online at **https://www.umdsmartgrowth.org/projects/presto/**. There, we present results in absolute numbers and as percentages, with and without AVs, and adding four lanes, both with and without tolls to see their land use and other impacts. On the website, we also present these impacts (called MSTM only) without assuming any indirect population or land use changes that might result from the proposed toll facilities, which is the way such analysis is conventionally done. We also include the full tables for transit and GHG Impacts.

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1. https://www.roads.maryland.gov/mdotsha/pages/pressreleasedetails.aspx?newsId=2979&PageId=818

Models, Assumptions, and Indicators

We divide the region into four subareas (Figure 2) with impacts reported for the region as a whole and for each subarea. The four subareas are the core cities of Baltimore and Washington, DC, (where the core includes both Arlington County and Alexandria City); the six inner counties around the cores; the eleven outer counties; and the remainder of the study area beyond the Baltimore-Washington region. We also report impacts for the proposed I-495 and I-270 toll and untolled facilities. We believe that their impacts, however, should be viewed within a larger, regional context to create a balanced picture of where and how changes are felt.

Modeling the future, or alternative futures, is a challenging enterprise. As is often said: all models are wrong; some models are useful. This section describes our models, some key assumptions, and our indicators. These indicators are not comprehensive and omit analyses needed for a proper understanding of sustainability, such as environmental, economic, fiscal or social impacts. Our analysis we believe, however, adds new and useful information. While much of it is relevant to the TRP's four proposed additional toll lanes on I-495 and I-270 (Figure 3) our models also incorporate the effects of autonomous vehicles on the region's freeways, as well as the effects of extending current smart growth plans and transit networks.

The Models

Our models include the Maryland Statewide Transportation Model (MSTM), a Mobile Emissions Model (MEM), and a land use model called the Simple Land Use Orchestrator (SILO) all of which cover the study area (Figure 2). These models interact so that shifts in population locations influence travel behavior and, likewise, changes in transportation networks or policies influence land use by changing accessibility.

This two-way interaction is a key aspect of this study since most analyses of new highway capacity ignore its potential effects on population redistribution and thus land use. This produces results for delay and congestion, for example, that vary significantly from the standard modeling approach that considers only transportation impacts, as a comparison of outcomes on the relevant website tables attests. Capturing these effects is an important strength of our analysis.

Figure 2. The Region and Subareas

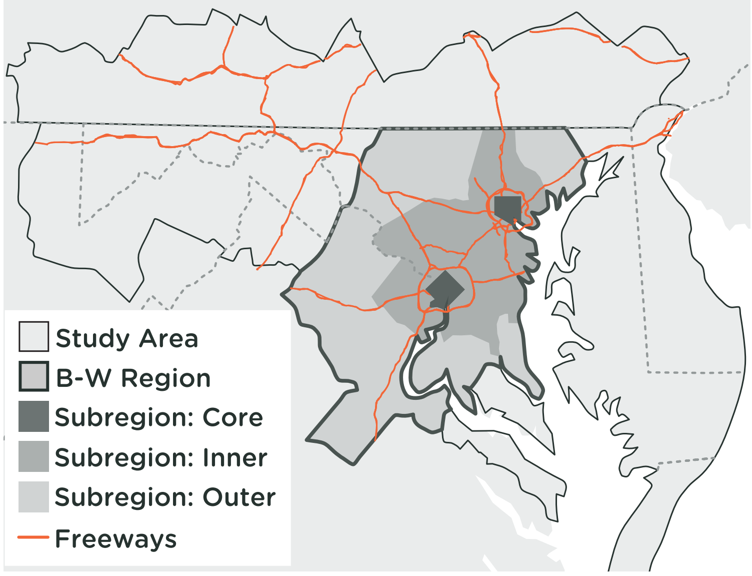
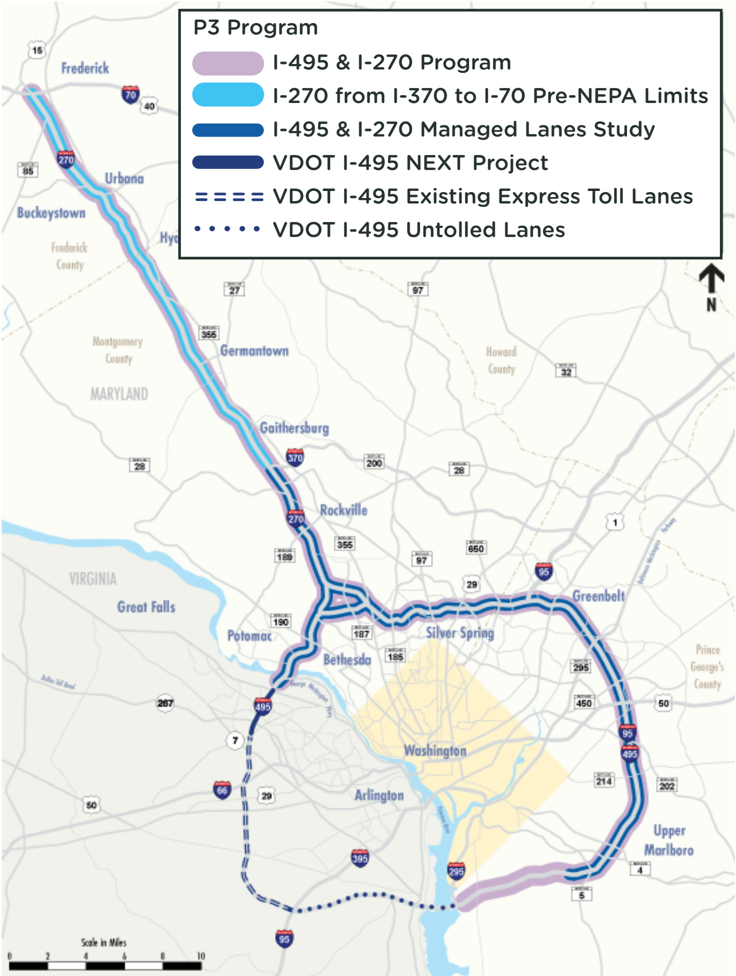


Figure 3. MDOT's Proposed Traffic Relief Plan



Source: Maryland Department of Transportation I-495 & I-270 P3 Program https://495-270-p3.com/

MSTM This statewide four-step travel demand model was developed for the Maryland State Highway Administration (SHA) for the entire study area. It was built by Parsons Brinkerhoff (now WSP) and the University of Maryland's National Center for Smart Growth (NCSG) between 2010-2013 and has been used in several studies by NCSG, SHA, and MDOT. The road and transit networks used in this report'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). Our model does not add detail such as interchange reconfiguration or ramp metering. It is a broad brush tool suitable for the level of analysis applied in this study

MEM The Mobile Emissions Model is a customized tool where the emission rates are applied from the US EPA's Motor Vehicle Emissions Simulator (MOVES) to MSTM-generated traffic flows to model transportation emissions. In the baseline and in all the scenarios, we make the conservative assumption that by 2040 zero-emission vehicles (ZEVs)[2] will comprise 10 percent of the vehicle fleet.[3]

SILO This model, initially developed as a research project by Parsons Brinckerhoff, Inc. for Minneapolis/St. Paul, was later implemented for Maryland, and has now been applied in seven metropolitan areas across the globe.[4] It micro-simulates individual decisions by developers and households within a region, based on housing costs, transportation costs (including accessibility measures), and household budget tradeoffs. The model allocates housing units and households throughout a study area. SILO is particularly useful because it models real constraints in household budgets and in travel time to work. Notably, our implementation of SILO also incorporates the behavioral effects of racial segregation tendencies, school quality, crime, and development constraints represented by zoning. (Technical detail on SILO is provided on the project website.)

In this study we influence, rather than mechanically direct, SILO's residential growth allocation. We do this by modifying land development capacity by assuming zoning changes, a tool under the control of local policy makers. Because of central Maryland's constrained supply of developable land, land capacity is an important factor influencing growth allocation.[5] For the smarter growth (SG) scenario, we allow more growth and density in the core and inner subareas. The model then allocates growth based on this changed capacity and households' decisions.

Assumptions Regarding Autonomous Vehicles

Despite the growing consensus that Autonomous Vehicles (AVs) will be adopted more slowly than earlier imagined,[6] their inevitability is widely accepted, as is their impact as a disruptive technology. The extent of AV adoption and its impacts are topics of extensive research and debate. AVs are seen as having at least two impacts on travel. First, they increase capacity on freeways by enabling vehicles to operate closer together. Second, because AVs allow drivers to do other things while driving, (reading, working, meeting remotely, relaxing etc.), time spent in the vehicle is less onerous and drivers are more willing to tolerate longer travel times and delays; this lowers the implicit cost of driving. The delay or congestion (VHD or V/C ratios) indicators in our AV analysis should thus not be seen as having the same adverse impacts for time in spent in AVs as time spent in conventional vehicles.

In reviewing relevant AV research and modeling, including our own, we make the following conservative but plausible assumptions for travel and land use modeling.

- By 2040, 25 percent of the passenger car fleet will be AVs.
- AVs will increase vehicle capacity on all freeways by 25 percent because they operate closer together in narrower lanes.
- No capacity changes occur on arterial or collector roads.
- The value of time driving will fall by 33 percent for AVs, reflecting a more efficient or pleasurable use of travel time.
- Auto operating cost per mile will fall by 25 percent, reflecting expected cost savings from AV operations, such as lower fuel costs.
- Parking costs will fall 50 percent since AVs can seek lower cost, remote parking or can return home
- The value of general accessibility as a factor in household location decisions will fall by 15 percent.
- The value of travel time to work as a factor in household location decisions will fall by 15 percent.

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[2] A vehicle that never emits exhaust gas from the onboard source of power.

[3] Fan, W., Erdogan, S., Welch, T.F., Ducca, F.W., 2017. Use of Statewide Models as a Decision Tool for Zero-Emission Vehicles Deployment. Transportation Research Records, 2828, 78-86.

[4] https://wiki.tum.de/display/silo

[5] NCSG, Engaging the Future, 2018, 27

[6] Kuhr, J.; Juri, N.R.; Bhat, C.R.; Archer, J.; Duthie, J.C.; Varela, E.; Zheng, H. Travel Modeling in an Era of Connected and Automated Transportation Systems: An Investigation in the Dallas-Fort Worth Area; Data-Supported Transportation Operations; University of Texas at Austin: Austin, TX, USA, 2017

Indicators

The indicators are defined below. The first four travel metrics are applied at the regional and subregional scale. We introduce and apply the congestion metric of volume-to-capacity ratios (V/C) in discussing impacts on the Interstates, where we also present data on traffic volumes and volume per lane. Given the finer scale and issues of the toll lanes, these are appropriate indicators at the facility rather than at the subregional scale. All travel metrics are for the PM peak, the heaviest travel period of the day.

Impact Indicators and their Definitions:

Population growth shifts

The number of people who move into or leave the study area and its subareas in response to changes in land use capacity and accessibility.

Traffic: Vehicle Miles Traveled (VMT)

Calculated by multiplying the number of vehicles using a roadway link by the length of roadway link. This common measure of how much travel occurs says nothing about travel quality.

Travel time: Vehicle Hours Traveled (VHT)

Calculated by multiplying the number of vehicles on a road link by the time spent on the link. It does not address the nature of the time spent.

Delay: Vehicle Hours of Delay (VHD)

Calculated by comparing travel time without congestion (free flow) to travel time with congestion. A trip may be two hours with congestion and one hour without congestion, yielding one hour of delay.

Transit ridership

The counts of transit ridership on all existing and proposed transit networks in a scenario, broken out by bus, commuter rail, and other rail (heavy and light).

Vehicular emissions of GHG

These primarily comprise three measured GHGs - Atmospheric CO2, Methane (CH4), and Nitrous Oxide (N2O). They are expressed in terms of Carbon Dioxide equivalents (CO2Eq), a combined measure of GHGs weighted according to the global warming potential of each gas, relative to CO2. Among the criteria pollutants, we output emissions of Nitrous Oxides (NOx) and Volatile Organic Compounds (VOCs).

Value-Explicit Presentation of Findings

We have sought to be sensitive to language and value bias in presenting our findings. For example, we use the word “decentralization” rather than the “sprawl.” In a similar vein, increased traffic is often considered a negative impact because it generates more pollution, wasted time, and congestion. But more traffic throughput on a freeway can also be interpreted as an economic development gain for a region, implying more freedom of movement and choice for employees and employers and so we make this point explicitly when presenting results. Furthermore, fleet electrification and autonomous vehicles, with their lower emissions and increased road capacity, could upend the typical negatives associated with increased traffic, travel time, and delay. We thus note explicitly that in an AV world, delay should not be viewed in the conventional way.

Existing Conditions and Baseline Projections

We compare our scenario results not to current conditions (the travel model's base year of 2015) but to a future in 2040, called the baseline. While this makes for a useful apples-to-apples comparison, it requires an imaginative leap. To support that leap by grounding the reader in current realities, this section provides a snapshot of where population and travel measures are today and in the 2040 baseline.

Our baseline scenario incorporates the study area's population, housing, and jobs projections, as officially adopted by the region's two Metropolitan Planning Organizations (BMC and MWCOG). These projections are reflected in the 2040 baseline indicators. But because our modeling links the population and land use effects of transportation or land use policy changes, our scenario projections vary slightly from the "official" baseline projections (Figure 4).

Population Distribution with and without AVs

Using SILO, we model existing and projected population distribution in the region with and without AVs, but without adding lanes, tolls, or transit, which is done later in the scenarios. Unlike population, job locations are held constant in our 2040 scenarios and reflect official State projections. Job projections reflect an annual average increase of 1 percent per year while population increases at a much slower pace, about 0.25 percent per year. Figure 4 shows the 2015 and SILO-projected 2040 populations for the subareas and their change over this time.

In both 2015 and 2040, about 40 percent of the region's more than 10 million people are located in the six-county inner subarea. Since the added toll lanes run through this subarea, it may be expected to experience the largest impacts. This, however, is not the case.

Figure 4. Existing and Projected Baseline Population

	Population				
	2015	2040		Change	
		No AVs	25% AVs	No AVs	25% AVs
Core	2,259	2,576	2,535	317	276
Inner	6,098	6,334	6,299	236	201
Outer	1,573	1,769	1,813	196	240
Region	9,930	10,678	10,647	748	717
External	4,672	4,931	5,029	258	357
Total	**14,602**	**15,609**	**15,676**	**1,007**	**1,074**

1/1000

We find that development patterns respond strongly to the accessibility changes generated by AVs—increased highway capacity, reduced travel time penalties, and a reduced value of accessibility—by pushing new growth farther out. Without AVs, the increment of growth going to the outer and external subareas totals 49 percent; with AVs it totals 57 percent, an increase of 8 percent. This, of course, is the same growth percentage lost by the core and inner subareas. These percentages equate to about 100,000 people who are redistributing themselves.

Traffic Conditions without AVs

In 2015 and 2040, Vehicle Miles Traveled (VMT) in the Baltimore-Washington region (the core, inner, and outer subareas) amounts to about 60 percent of all VMT in the study area, impacting a very large portion of drivers. Figure 5 shows travel indicators in 2015 and in 2040. Most striking in the projections is the virtual doubling of delay on all roads in the region. This highlights the importance of addressing congestion in our scenarios.

Figure 5. Existing and Projected Traffic Conditions

		2015	2040	% Change
VMT	Freeways	22,388,116	25,390,851	13.41
	Other Roads	26,103,701	32,391,042	24.09
	Total	**48,491,817**	**57,781,893**	**19.16**
VHT	Freeways	501,145	649,010	29.51
	Other Roads	1,257,780	1,863,816	48.18
	Total	**1,758,924**	**2,512,826**	**42.86**
VHD	Freeways	115,860	210,138	81.37
	Other Roads	420,398	814,181	93.67
	Total	**536,258**	**1,024,319**	**91.01**

1/1000

The Scenarios and their Impacts

Given the relatively slow rate projected for population growth, we would not normally expect dramatic population shifts or travel pattern changes over the 2015 to 2040 timeframe. In land use-transportation studies of large metropolitan regions with modest rates of growth, changes in travel indicators are typically in the plus-or-minus 5 to 15 percent range. In this study, however, we test policies that add significant capacity to two key freeways, assume that AVs enhance capacity on these freeways, and also include a strong smarter growth scenario. We may, therefore, expect to produce much larger changes in travel patterns than usual.

In experimenting with tolls, we found that travel behavior is very sensitive to toll pricing. Accordingly, we assume a moderate, fixed, three-hour peak toll charge of $0.40/mile for the proposed toll roads. In the smarter growth scenario, we also add significant new transit capacity (Figure 10 on page 10) and remove the added tolled freeway lanes included in the other scenarios. This reveals the effects of land use and transit changes without any new lanes. We test smarter growth in both AV and non-AV futures to see their separate effects.

Population Impacts

The study area will grow by just over one million people, from 14.6 million in 2015 to 15.6 million in 2040. The metropolitan region is anticipated to grow by between 713,000 and 783,000 people. We earlier presented the distribution of this growth for the baseline condition. Figure 6 shows how our different scenarios affect population shifts in 2040.

Toll Lanes vs. AV Impacts

Adding tolled lanes, but not AVs, significantly adds to growth in the external areas (22 percent more than baseline) and shrinks it slightly in the core and inner areas. With more freeway capacity, people choose to decentralize. Interestingly, just adding AVs has an even stronger decentralization effect in the external subareas (38 percent). This reduces core and inner area growth more noticeably, by about 30 percent, or about 80,000 people. Adding tolled lanes to the AV scenario has a similar decentralizing effect (42 percent).

Impacts of Changing Development Capacity

SILO shows that AVs strongly encourage decentralization. In the absence of AVs, however, the housing market's strong pressure for growth in the inner and core subareas is very evident when these subareas' development capacity is increased by 20 percent, as in the SG scenario. Almost a third more people move into these subareas than in the baseline case. When AVs are added into the mix, however, and all subareas increase their capacity by 20 percent, then the centralizing effects of SG are much dampened, with only 7 percent more people in the core and inner areas than in the baseline, but decentralization is still strongly checked (only 15 percent move to the external and outer subareas vs. 62 percent in the AVs only case). This scenario also attracts slightly more people into the region and many more into the study area—over 800,000. Within the region the smarter growth policy grows the core and inner areas by one third more than the baseline case, equating to about 93,000 people. This recentralizing effect is much reduced when the policy is coupled with AVs.

A 2007 study[7] suggested that significant freeway lane additions might show, on average, a 9% shift in land uses after eight years, with the great majority of shifts falling between 0 and 18%. Our analysis is in the ballpark with an overall maximum population shift of 5%. This same research suggested that much of the new capacity from new freeway lanes does not remain freely available but is absorbed by general growth in population and jobs as well as through route shifts, mode shifts and time of day shifts in response to the new capacity. Our models capture all these shifts except time of day shifts.

Figure 6. Population Redistribution in 2040 from Policy Options

			No AVs		25% AVs		
		Baseline	Tolls	SG	AV	Tolls	SG
Population	Core	317	310	380	276	272	325
	Inner	236	227	266	201	197	247
	Outer	196	201	137	240	241	178
	Region Subt.	748	739	783	717	710	750
	External	258	315	305	357	368	320
	Total Study Area	**1,007**	**1,054**	**1,088**	**1,074**	**1,078**	**1,071**
Percentages	Core		-2.0	20.0	-12.9	-14.2	2.5
	Inner		-3.6	12.7	-14.7	-16.4	4.8
	Outer		2.7	-29.8	22.4	23.0	-8.9
	Region Subt.		-1.3	4.7	-4.2	-5.1	0.3
	External		21.8	18.0	38.3	42.3	23.9
	Total Study Area		**4.7**	**8.1**	**6.7**	**7.1**	**6.3**

1/1000 people

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7. Avin, Cervero, Moore and Dorney, Program Forecasting the Indirect Land Use Effects of Transportation Projects, National Cooperative Highway Research, 2007

Note that while population changes imply land use change, these relationships are not proportional in terms of land consumption. Land consumption from population growth in the core is limited and is often achieved through redevelopment while population growth in the outer and external subareas is typically at low densities. In short, adding AVs has much more impact on population redistribution patterns and, as we'll see, on travel behavior than the added lanes.

Travel Impacts

Results from the travel indicators should be viewed in relation to each other to properly understand their impacts. For example, increases in travel miles (VMT) would likely be accompanied by increases in travel time (VHT), although if there are more trips, but they are faster, travel time could actually decrease. This may or may not produce more delay (VHD) depending on road capacities. More traffic and increased travel time but on an expanded road network may actually still yield reduced delay.

Figure 7 is composite summary of all regional and subregional impacts. The figure shows percentage change compared to the baseline. The actual numbers are presented in Appendix C and other additional data are on the project website. In our narrative, we use the terms significant, moderate etc. consistent with the numerical thresholds of the color legend of Figure 7.

The two left hand columns of Figure 7, showing results with conventional vehicles (No AVs), supports our earlier observation that most transportation studies in large, mature regions yield insignificant (<5 percent change) to moderate (5 to 15 percent change) travel behavior impacts. This picture changes noticeably, however, when we look down the 25 percent AV columns and see numerous instances of changes in the significant (>15 to <25 percent) and very significant (+25 percent) categories, especially in freeway delay changes, and most markedly at the subarea scale.

In several of the scenarios, the core realizes the most reductions in travel time and delay, especially on freeways. The inner subarea realizes increases in travel changes, except for some significant freeway reductions. The outer subarea sees some of the largest increases or decreases. Results for

Legend: Percentage Changes from Baseline

<-25	25+	Very Significant
-15 to -24.9	15 to 24.9	Significant
-5 to -14.9	5 to 14.9	Moderate
-0.1 to -4.9	0 to 4.9	Insignificant

Figure 7. Summary of Scenario Impacts (% Change)

			No AVs		25% AVs		
			Tolls	SG	AV	Tolls	SG
Region		Population	4.7	8.1	6.7	7.1	6.3
	VMT	Freeway	1.2	-1.7	14.6	17.2	7.3
		Other Roads	-0.7	0.9	3.5	3.7	-0.8
		Total	0.1	-0.3	8.4	9.6	2.8
	VHT	Freeway	-0.5	1.2	3.3	5.5	-4.9
		Other Roads	-0.8	5.7	11.1	11.7	-0.4
		Total	-0.7	5.3	9.1	10.1	-1.6
	VHD	Freeway	-3.6	6.0	-20.1	-18.6	-31.5
		Other Roads	-0.8	14.4	21.6	22.8	2.4
		Total	-1.4	12.7	13.0	14.3	-4.6
	Transit Ridership		0.0	22.0	-18.8	-19.4	1.4
	GHG		-0.1	-3.8	8.1	7.1	0.3
Outer		Population	2.7	-29.8	22.4	23.0	-8.9
	VMT	Freeway	-0.3	-4.2	15.2	16.9	8.6
		Other Roads	-0.4	-4.9	11.1	11.4	2.0
		Total	-0.4	-4.6	12.6	13.4	4.3
	VHT	Freeway	-0.3	-3.1	8.0	11.0	-0.3
		Other Roads	-1.0	-4.3	29.7	30.3	6.0
		Total	-0.8	-4.0	25.4	26.5	5.6
	VHD	Freeway	0.0	-10.5	-22.0	-14.1	-38.9
		Other Roads	-1.9	-3.7	60.2	61.2	12.7
		Total	-1.7	-4.5	50.8	52.6	6.8
	Transit Ridership		-0.8	43.8	-21.3	-25.8	5.5
	GHG		-0.5	-2.6	13.8	12.4	4.5
Inner		Population	-3.6	12.7	-14.7	-16.4	4.8
	VMT	Freeway	1.9	0.1	15.4	18.2	7.5
		Other Roads	-0.7	7.6	1.3	1.6	-2.8
		Total	0.6	3.9	8.3	9.9	2.3
	VHT	Freeway	-0.5	5.6	4.8	6.7	-4.9
		Other Roads	-0.2	16.2	7.7	8.8	-2.3
		Total	-0.3	12.8	6.8	8.1	-3.1
	VHD	Freeway	-4.6	15.0	-15.9	-15.6	-29.7
		Other Roads	-0.6	28.0	16.8	19.0	-1.3
		Total	-0.8	24.5	8.0	9.7	-9.0
	Transit Ridership		-0.1	16.3	-21.1	-0.1	-0.7
	GHG		0.4	-0.8	8.6	7.5	3.0
Core		Population	-2.0	20.0	-12.9	-14.2	2.5
	VMT	Freeway	-0.2	-8.7	8.9	11.4	3.1
		Other Roads	-1.2	-11.0	-3.0	-3.4	1.0
		Total	0.0	-5.3	1.1	1.6	2.6
	VHT	Freeway	-0.6	-16.5	-9.9	-7.2	-10.3
		Other Roads	-2.0	-8.0	0.7	0.2	-2.4
		Total	-1.7	-9.4	-1.1	-1.0	-16.8
	VHD	Freeway	-1.2	-23.9	-37.3	-34.1	-35.1
		Other Roads	-2.6	2.6	3.9	3.4	2.0
		Total	-2.4	-0.8	-1.4	-1.5	-21.6
	Transit Ridership		0.2	28.7	-15.5	-15.5	4.1
	GHG		-1.1	-18.3	-2.1	-2.3	-17.0

The Region

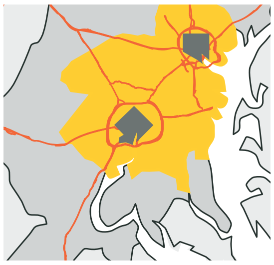
At the regional scale, without AVs, the traffic impact of adding freeway toll lanes is insignificant—traffic and travel time increase marginally. In the smart growth scenario, traffic and travel time also increase very slightly but delay increases notably. Inserting AVs magnifies the impacts on traffic and travel time and, notably, on delay, where significant freeway traffic reductions are counterbalanced by significant arterial/collector increases in traffic. This outcome seems puzzling. Typically, one would expect to see the added capacity on freeways result in delay reductions on local roads as more traffic is attracted to the freeways. This does happen in the No AV tolls scenario where freeway delay drops by 4 percent and other roads reduce by almost one percent. As noted, however, AVs, both increase freeway capacity and reduce the value of time and these two factors together reduce freeway delay significantly but because travelers care less about delays, and choose these shorter and cheaper routes overall, we see an increase in delay on other roads.

Note that, regionally, adding toll lanes with AVs has very similar delay reductions to just adding the AVs alone. Coupling AVs with SG, however, yields similar delay on freeways but does not increase delay on other roads as much. This is also a seemingly a puzzling outcome. The explanation is that the combined effects of SG's shorter work trips (concentrating more people in the core and inner subareas, near most jobs) plus the transit enhancements cause these large reductions in delay. These large impacts are masked by the insignificant reduction in overall delay

Adding tolled lanes doesn't affect transit ridership overall but adding AVs significantly reduces it. GHG impacts range from insignificant reductions from tolls plus SG to moderate increases from AV plus tolls.

Outer Subarea

This subarea is the most affected by the various scenarios. As the least populous (1.5 million people) of the subareas and the farthest from job centers, the impacts of changes in population and transportation loom largest here. The large reduction here in population (30 percent) in SG (No AVs), for example, helps explain the slight lessening of traffic impacts. The contrasts between No AV tolls and 25 percent AV tolls is very striking but the tolls add very slightly to the overwhelming impact of AVs. The AVs result in very big differences in travel behavior—moderately increasing traffic, very significantly increasing travel time and dramatically increasing congestion. This congestion, however, really occurs on arterials and collectors, while freeways actually see significant reductions in delay. SG plus AVs seem to capture the best of both worlds with generally moderate increases in traffic, travel time, and delay but very significant reductions in freeway delay. Transit, especially rail, sees very significant percentage reductions in ridership under AV and AV tolls, reflecting the small existing ridership base. However, transit from SG (with No AVs) realizes very significant increases, especially in buses. The AV and AV plus tolls scenarios moderately increase GHG.



Inner Subarea

In this subarea, adding tolled lanes has an insignificant effect on traffic, travel time, and delay. Only SG has some impact, causing moderate to significant increases in travel time but significant to very significant increases in delay, especially on other roads. With AVs, traffic increases moderately overall but signficantly on freeways. Tolled lanes cause a moderate increase in travel time. AVs cause a slight decline in travel time but have a very mixed impact on delay, reducing it signficantly on freeways but significantly increasing it on other roads. We addressed these unusual outcomes when explaining the similar results for the region overall. Adding tolls does not change these mutually offsetting impacts. In this subarea, SG plus AVs reduces freeway delay even further but with an insignificant increase on other roads for an insignificant reduction in overall delay. Transit use is essentially unaffected by the tolls but all AV scenarios reduce ridership. Only SG strengthens transit but this is cancelled when coupled with AVs. GHG emissions are unaffected by tolls and SG; adding AVs, with or without tolled lanes, moderately increases emissions.

Core Area

As in other subareas, the toll lanes have an insignificant effect on traffic, travel time, and delay. Inserting AVs, however, with and without new lanes, confers on the core the region's most significant percentage reductions in delay, albeit small in absolute terms (Figure C.4). Only the core subarea realizes significant travel time and delay reductions from SG, with or without AVs, but these do not approach the reductions of AVs alone or AVs plus tolls. Shorter trips and enhanced transit likely account for these SG benefits. Transit is unaffected by the toll lanes and is very significantly enhanced by SG, but this gain is cancelled by coupling SG with AVs. The core benefits the most of any subarea in GHG reductions from all scenarios, most significantly from SG, but insignificantly from AVs plus tolls.

Interstate 495

Adding just the extra lanes causes traffic to increase moderately, as expected, but travel time to drop slightly; delay, however, is very significantly reduced, by over a third (Figure 8). SG produces moderate to significant declines in traffic, travel time, and volumes but no real reduction in Beltway delay. Inserting AVs attracts significantly more volume but a lot less than adding the toll lanes. Adding tolls plus AVs, however, boosts volumes, which then equal those induced by the lanes alone. Travel time increases moderately with AVs but is halved by the addition of toll lanes. Reductions in delay from AVs alone are moderate but adding toll lanes reduces delay very significantly—by one third. SG produces moderate increases in traffic, insignificant declines in travel time and moderate declines in delay. (See Figure C.5 in Appendix C for data comparing traffic volumes and congestion on the free vs. the toll lanes.)

Figure 8. Summary of Scenario Impacts: I-495

	No AVs		25% AVs		
I-495 % change	Tolls	SG	AV	Tolls	SG
Traffic	14.6%	-6.5%	21.0%	30.0%	7.0%
Travel Time	-6.3%	-7.1%	8.4%	4.4%	-3.6%
Delay	-35.9%	2.7%	-10.2%	-32.7%	-12.9%
Total Volume	**19.9%**	**-2.3%**	**20.0%**	**33.2%**	**10.6%**

Interstate 270

Toll lanes add a moderate amount of traffic but no travel time to this interstate compared to the Beltway (Figure 9). The new toll lanes also carry a smaller percentage of the traffic than do the Beltway's (Figure C.6 in Appendix C). The new lanes do reduce congestion very significantly, by over a quarter. Interestingly, SG moderately reduces congestion in this corridor. Adding AVs amplifies these impacts and adding the toll lanes does so even more, yielding a reduction in delays of almost a quarter compared to the baseline. Implementing SG without lanes but with AVs produces moderate reductions in delay compared to the baseline. (See Figure C.6 in Appendix C for data comparing traffic volumes and congestion on the free vs. the toll lanes.)

Figure 9. Summary of Scenario Impacts: I-270

	No AVs		25% AVs		
I-270 % Change	Tolls	SG	AV	Tolls	SG
Traffic	11.6%	-1.2%	15.1%	21.3%	12.1%
Travel Time	-1.1%	-4.0%	7.1%	8.2%	9.9%
Delay	-28.7%	-6.4%	-13.7%	-24.2%	-15.2%
Total Volume	**17.9%**	**-0.1%**	**14.9%**	**21.2%**	**13.5%**

Transit Impacts

The transit additions in the SG scenario are extensive (Figure 10) but are limited to major rail transit system expansions. For the Smarter Growth scenario, the MARC commuter rail line was expanded to Elkton, MD and the VRE was extended to Gainesville, VA. In addition, the Baltimore Red Line, that runs east-west through the Baltimore region, was added while a Core Loop line was added to the DC Metro. Also, MARC and VRE commuter rail lines were merged. We did not add or modify bus routes. While transit impacts were noted in the traffic impacts for each subarea, this section brings these impacts together for an overall perspective.

The great majority of transit trips (81 percent) captured in our model are via heavy rail (Metro) and light rail. Only 2 percent are via commuter rail (MARC and VRE). Our model understates transit ridership, particularly for buses, because our mode-choice model does not consider car ownership as a factor and thus doesn't properly capture transit dependent populations, especially prevalent among bus riders. We made no extra efforts to allocate growth or jobs to TOD areas. Neither did we adjust the first mile/last mile interface or service characteristics such as frequencies to improve transit performance.

In the baseline, 57 percent of the region's projected 2040 peak hour transit trips occur in the inner suburbs, 41 percent in the core and only 2 percent in the outer subarea. The very small existing ridership in the outer subarea explains why scenario impacts there are so large in percentage terms.

In general, adding toll lanes reduces transit use only marginally (Figure 11). SG significantly increases transit use (above 20 percent) in all transit modes, especially in the outer subarea. Introducing AVs, both with and without toll lanes, significantly reduces transit ridership by just over 20 percent regionally, most in the outer subarea (approaching 30 percent) and least in the cores (around 18 percent). Coupling SG with AVs cancels out transit ridership increases, leaving transit ridership essentially the same as in the baseline.

Figure 10. Smarter Growth Scenario Transit Additions

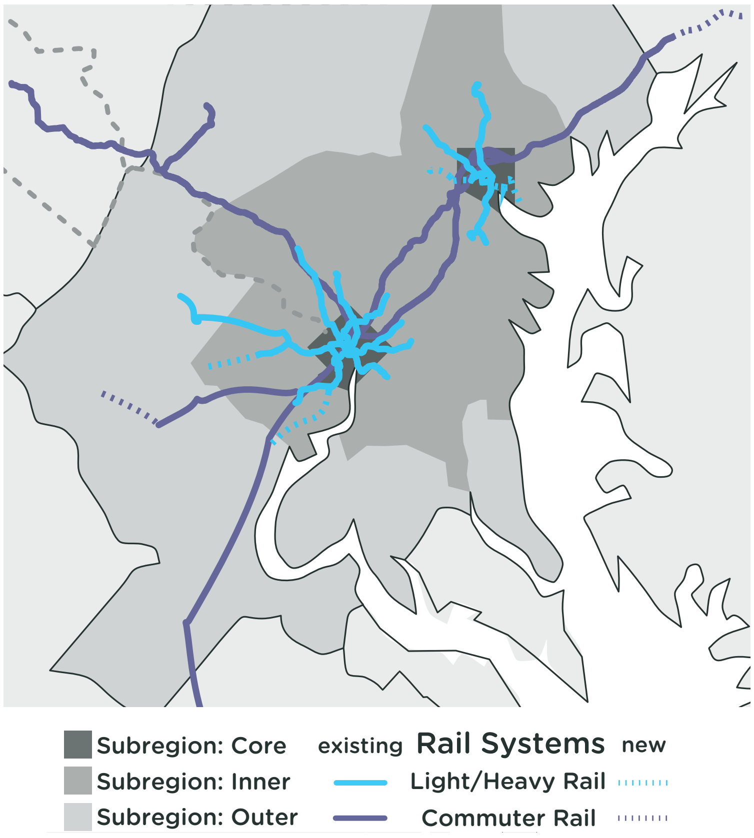


Figure 11. Scenario Impacts: Transit Ridership (%)

	No AVs		25% AVs		
	Tolls	SG	AV	Tolls	SG
Region	0.0	22.0	-19.5	-20.7	1.4
Bus	0.0	26.9	-10.0	-10.6	4.5
Commuter Rail	-0.6	22.8	-27.9	-28.4	1.2
Light/Heavy	0.0	21.0	-21.3	-22.5	0.8
Outer	-0.8	43.8	-26.6	-30.7	-1.5
Bus	-1.0	147.1	-8.0	-11.0	56.7
Commuter Rail	-0.3	41.7	-21.4	-22.6	-8.2
Light/Heavy	-0.8	38.2	-28.1	-32.5	-4.2
Inner	-0.1	16.3	-21.7	-22.4	-1.2
Bus	-0.1	15.1	-7.0	-7.5	-0.4
Commuter Rail	-0.6	19.7	-28.5	-30.2	-2.5
Light/Heavy	-0.1	16.3	-23.4	-24.1	-1.3
Core	0.2	28.7	-17.7	-15.6	0.8
Bus	0.1	33.2	-12.8	-11.4	4.2
Commuter Rail	-0.4	34.5	-16.4	-15.1	-2.1
Light/Heavy	0.2	27.2	-19.2	-17.0	-0.3

GHG Impacts

Figure 12 shows the GHG impacts in terms of carbon dioxide equivalent (CO2Eq). For the detailed emissions output, please see the project website. Note that GHG impacts accrue at a global level, making them the primary measure used in evaluation of climate change mitigation efforts. The impacts of criteria pollutants such as Nitrous Oxides (NOx) and Volatile Organic Compounds (VOCs), on the other hand, accrue at a local level varying spatially, making them the primary measure of air quality, thus closely related to public health.

We see a wide range in emissions. Regionally, they range from insignificant to moderate. Apart from vehicle and fuel characteristics, GHGs are a function of congestion and driving patterns, which can be increased by stop-and-go and high-speed driving. (While emissions impacts move generally in the same direction as traffic, they don't mirror traffic because of these factors.) In the baseline, 57 percent of the region's projected 2040 peak hour transit trips occur in the inner suburbs, 41 percent in the core and only 2 percent in the outer subarea. The very small existing ridership in the outer subarea explains why scenario impacts there are so large in percentage terms.

The core exhibits the most dramatic impacts with significant declines in all scenarios but most markedly for smarter growth. This reflects shorter commute trips and more transit use in the core. The outer subarea sees some of the most significant impacts, reflecting increased AV travel and the large percentage increases in traffic above low baseline traffic. The differences in emissions among scenarios in the entire study area are insignificant, however - under one percent in non-AV or just over 2 percent in AV conditions. The project website provides the actual numbers behind the percentages.

Figure 12. Summary of Scenario Impacts: GHG (%)

	No AVs		25% AVs		
	Tolls	SG	AV	Tolls	SG
Region	-0.1%	-3.8%	8.1%	7.1%	0.3%
Outer	-0.5%	-2.6%	13.8%	12.4%	4.5%
Inner	0.3%	-0.8%	8.6%	7.5%	3.0%
Core	-1.1%	-18.3%	-2.1%	-2.3%	-17.0%
Total	**0.0%**	**-0.9%**	**2.1%**	**2.0%**	**0.5%**

Key Findings

The previous sections compared the impacts of several transportation and land use scenarios for the Baltimore-Washington region and described their impacts in some detail at both the regional and facility levels. Here we try to synthesize our key findings from this analysis and move them toward policy options that can work across all scenarios as well as those that will work for more specific outcomes.

Impact of AVs on Regional Travel

The analysis clearly shows the potentially significant impact of AVs on regional traffic and development patterns. In fact, given AVs, a technology bound to become more commonplace, adding lanes makes little difference to travel outcomes. Regionally, AVs alone or AVs plus toll lanes both attract moderate amounts of new traffic (8 and 10 percent respectively) and increase delay by similarly moderate amounts (13 and 14 percent respectively). However, they reduce regional freeway delay by a significant amount (20 and 19 percent respectively). And while they manage to add traffic and still reduce freeway delay, they also significantly increase traffic delay on the region's local roads (22 and 23 percent respectively). These countervailing impacts make for a difficult tradeoff, even though the value of time is reduced in an AV world.

The significant impact of AVs raises the the whole cost-benefit question of building tolls if AVs are on the horizon. One answer is that on the Beltway and I-270, AVs and AVs plus toll lanes have much greater impacts than they do at the regional scale and these impacts suggest different policy decisions and actions.

Impact of AVs Plus Toll Lanes

On the Beltway, adding lanes attracts more traffic than AVs alone (30 vs. 21 percent) but provides three times the reduction in delay than AVs alone—a decrease of 33 rather than 10 percent. On I-270 the differences are less dramatic. Adding lanes attracts less traffic than AVs alone—21 vs. 15 percent—but doubles the reduction in delay that AVs alone provide—24 vs. 14 percent.

Impact of AVs Plus Smarter Growth

What is the impact of AVs when combined with smarter growth land use strategies? Regionally, smarter growth attracts less traffic into the region than AVs plus toll lanes (3 vs. 10 percent) and reduces regional freeway delays slightly more than AVs plus tolls—22 vs. 19 percent. Moreover, local traffic does not increase, and the region overall sees delay increase only insignificantly.

These benefits are not as marked for the Beltway and I-270. This scenario only provides a third of the congestion relief on the Beltway compared to the AV plus tolls scenario (a 13 percent reduction vs. a 33 percent reduction). Similarly, on I-270, SG plus AVs yields a 15 percent reduction in delay vs. a 24 percent reduction with AVs plus tolls. On the other hand, SG plus AVs adds only 12 percent to I-270 traffic vs. 21 percent for AVs plus tolls.

Tolls and Smarter Growth Without AVs

But what if AVs are not going to arrive anytime soon? Then we have a rather different set of impacts and possibilities to consider. These vary by region and road.

At the regional level, toll lanes and SG make very little difference in freeway or arterial road traffic. Tolls very slightly reduce delay on freeways and other roads. SG adds a moderate 6 percent to freeway delay but adds 12 percent to overall delay because of increased delays on arterial roads. SG seems to fare poorly as a delay reduction strategy at the regional level.

On the Beltway and I-270, the differences between tolls and SG impacts grow. On the Beltway, tolls increase traffic by a significant 15 percent while SG decreases traffic by 7 percent. Delay is a different story. Tolls reduce delay on the Beltway by a very significant 36 percent while SG increases it insignificantly (3 percent). Traffic and delay impacts are less clear on I-270. Here, tolls increase traffic moderately—by 12 percent, but SG reduces it slightly—by 2 percent. Tolls and SG both reduce delay, but tolls achieve a very significant reduction of 29 percent and SG achieves only a moderate reduction of 6 percent.

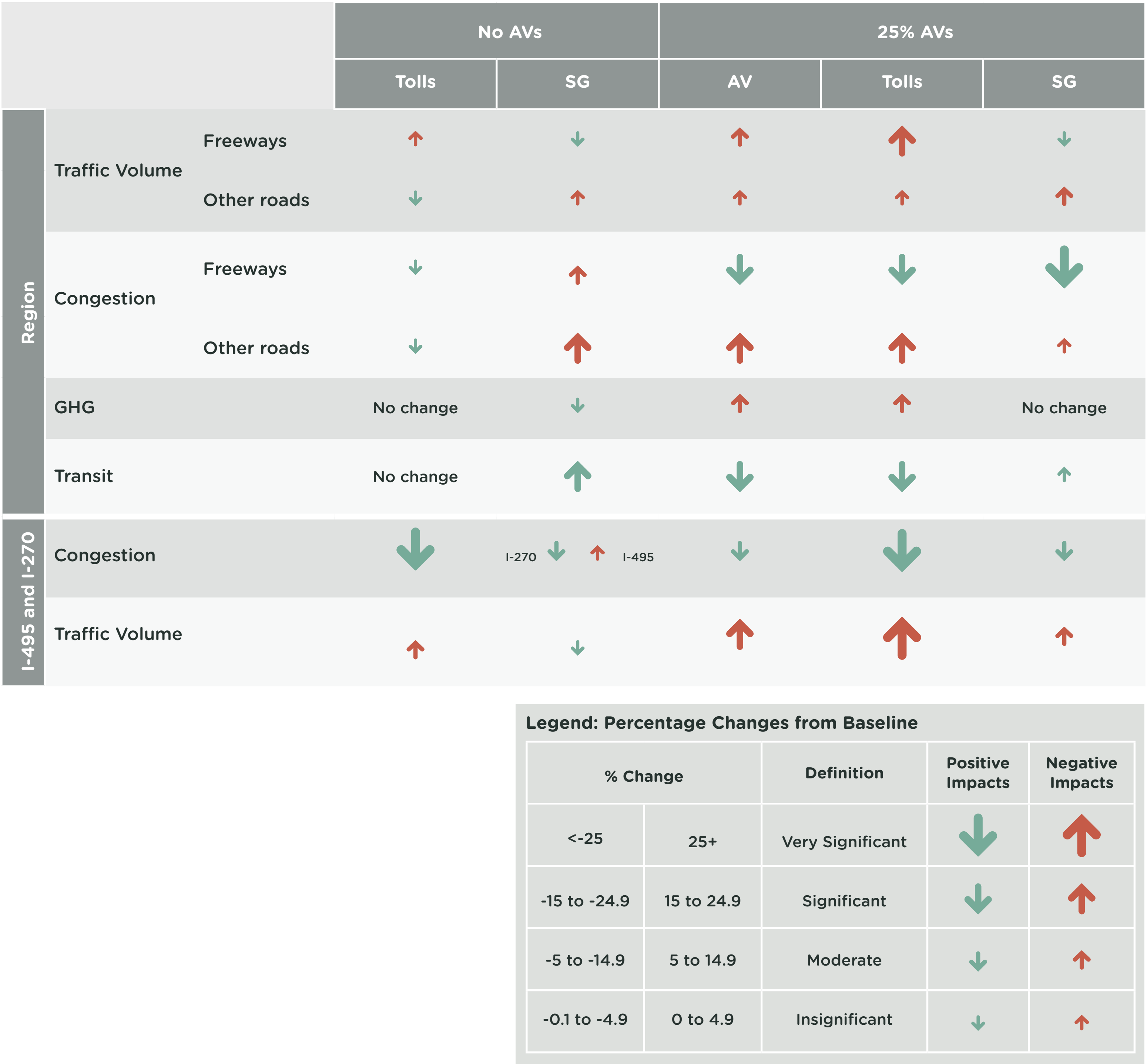
Scenario Impacts in Summary

Figure 13 summarizes all the above impacts at both the regional and facility scales. Regionally, without AVs, the toll lanes help a little, SG does not. The impact of 25 percent AVs is similar to those of tolls; both help freeways but worsen local travel; SG helps all round, sometimes more, sometimes less. At the facility level, the summary suggests that tolled lanes make sense on the Beltway under any of the future scenarios considered; they provide more congestion relief regionally and at the facility scale than SG. On I-270, while tolls still perform better than AVs or SG, their relative benefits are less pronounced and therefore the cost-effectiveness of this initiative is open to question.

Figure 13 implies some appropriate strategies if congestion reduction were the primary criterion for policy choices. But it is fair to ask how much reduction is enough. At 65 mph, it only takes an additional 20 percent in traffic to drop from the good Level of Service C to a less desirable LOS D, but from there, another 13 percent increase in traffic brings us to a poor LOS E. In other words, traffic reductions of 15 percent may be adequate, depending on the congestion level, if the cost of getting to a 25 percent reduction is extremely high.

Beyond congestion, there are other indicators that should be weighed in policy making against one's concerns and values. Some of those we've presented in this study and we summarize in Figure 13. Note that we show more traffic as a negative impact although increased traffic throughput can be viewed positively as well. As noted earlier, the importance of delay may be moot in an AV world.

Figure 13. Generalized Summary of Scenario Impacts



			No AVs		25% AVs		
			Tolls	SG	AV	Tolls	SG
Region	Traffic Volume	Freeways	↑	↓	↑	↑	↓
		Other roads	↓	↑	↑	↑	↑
	Congestion	Freeways	↓	↑	↓	↓	↓
		Other roads	↓	↑	↑	↑	↑
	GHG		No change	↓	↑	↑	No change
	Transit		No change	↑	↓	↓	↑
I-495 and I-270	Congestion		↓	I-270 ↓ ↑ I-495	↓	↓	↓
	Traffic Volume		↑	↓	↑	↑	↑

Legend: Percentage Changes from Baseline

% Change		Definition	Positive Impacts	Negative Impacts
<-25	25+	Very Significant	↓	↑
-15 to -24.9	15 to 24.9	Significant	↓	↑
-5 to -14.9	5 to 14.9	Moderate	↓	↑
-0.1 to -4.9	0 to 4.9	Insignificant	↓	↑

Policy Recommendations

Facing ever-increasing congestion, should Maryland invest in new tolled lanes, in smarter land use, or let things play out as AVs begin to shape a new reality? Is there some combined approach that can provide both robust and contingent strategies for an uncertain future? To help sort the jigsaw of outcomes and shift the previous section's key findings into policy directions, we surface five recommendations. The first two recommendations affect decision-making in the short and medium terms. The other three are longer term policies in response to the advent of AVs.

Revisit toll lanes in light of AVs.

By 2040, a 25 percent ownership rate of AVs and a resultant 25 percent increase in freeway lane capacity, seem like reasonable, even conservative, assumptions. Since even this modest level of AV adoption yields significant reductions in delays, especially on freeways, the AV trajectory must be considered seriously as substituting for toll lanes. Monitoring their progress and preparing for their adoption is crucial. The State has a role in shaping how AVs use the roadway system with actions such as incentives for shared fleets, ZEVs, new types of curbside management, and disincentives for single-occupancy vehicles in denser neighborhoods. This suggests that I-270 could be the State's pilot corridor to explore different AV approaches—personal, shared, transit-supportive, electric and combinations thereof.

Decouple decision-making on I-495 and I-270.

Based on our findings, summarized in Figure 13, the case for toll lanes on I-270 is somewhat weaker than for I-495. Their different impacts suggest that separating the implementation and phasing of the toll lanes requires further research and that other options for traffic management in the I-270 corridor deserve more consideration.

Provide more housing capacity in the cores and inner suburbs.

Since AVs will increase development pressure on the outer subareas and beyond the region, land use measures to increase the development capacity of the inner and core subareas must be considered. More capacity, including modest expansion of urbanized areas or increasing infill and redevelopment capacity, will mitigate congestion, support transit, and help relieve high housing prices. Housing demand in these areas is substantial and will remain so, as evidenced by escalating housing prices (see Appendix A for prior NCSG work on this point) even when some households choose to live farther out.

Anticipate development pressure from AVs on the outer suburbs and hinterlands.

Some outer jurisdictions may choose to accommodate this growth and some may resist. If most resist, regional housing prices may rise faster and farther flung counties and neighboring states may absorb this growth. If jurisdictions accommodate this growth, new forms of rural and suburban clustering and innovative public or private utilities and technologies may be needed.

Develop smarter growth and expanded transit as surgical initiatives, not blanket policies.

Maryland's land use is already concentrated within and around its metropolitan beltways and local land use planning has implemented this concentrated pattern for over four decades. We find that further intensifying that pattern across the board while concurrently investing billions in heavy rail transit expansion increases congestion significantly in the inner suburbs, does not relieve it in the core (though it lowers emissions there), but does boost transit ridership. These transit gains would be undermined by AVs without any strong mitigation and adaptation policies. Therefore, both selective densification and transit expansion must be careful initiatives to balance cost-effectiveness, equity considerations, and broad public benefit (See Appendix A for prior studies which address this point).

Appendices

Appendix A. Findings in Perspective

The nexus of transportation, land use, and sustainability has been a topic of considerable interest in the Baltimore-Washington region over the past 15 years. The NCSG has conducted several in-depth studies that address these issues. Our findings in this report are generally consistent with our prior work. These previous studies also created scenarios that systematically varied aspects of the future and then tested their impacts using simulation models. Our previous scenarios, for example, have varied transportation investments, economic assumptions, travel costs, development capacity, and transit-oriented development intensity. On the output side, we have measured impacts such as travel characteristics, land use change, environmental impacts, housing affordability, and mobile and building emissions (See Engaging the Future, 2018). Figure A.1 summarizes the findings of these prior studies in the Baltimore-Washington region.

All these studies find that pricing mechanisms have the greatest impact on travel behavior, consistent with other studies. The greatest reductions in highway congestion result from a regional network of toll roads. Where new toll roads parallel non-tolled roads they provide congestion relief on the non-tolled roads by drawing traffic onto the tolled segments. (Note that the introduction of AVs changes these relationships). Changing transit headways and fares has minimal impact on transit ridership; however, significant increases in transit speed can have a major impact on transit ridership. Changes in land use such as transit-friendly development can have a small impact, provided it is strategically located, but the fact that most future land uses are already in place very much dampens the impacts of land use change. Finally, all of these studies were done with behavioral models that rely on somewhat old survey data (i.e. 2008) and do not include newer options such as ridesharing, microtransit, BRT, micromobility etc.

Figure A.1 Findings from Prior NCSG Studies

Projects, Sponsors, Dates	Variables Adjusted	Key Outcomes and Findings
Maryland Scenarios MDOT 2010-2012	Land use location, transit speeds and fares, toll roads	• Increasing transit speed has the greatest effect on shifting travel from vehicle to transit, thus reducing freeway travel, and thereby VMT and VHT. • Reducing transit fares and headways has small impacts on transit use. • Toll road revenues rise, then fall with toll increases. • Maximizing toll road revenues is not always best for congestion reduction. • New, transit friendly development has modest impact on total travel, since most development in 2040 is in place today.
PRESTO **Engaging the Future** Town Creek Foundation 2013-2018	Fuel cost, technology innovation (AVs), land use regulations (zoning)	• Development capacity (zoning) and its location proves important given development capacity constraints of the inner suburbs. • AVs significantly reduce transit use, especially outside the core and inner suburbs. • Favoring forest land protection over farmland protection reduces nutrient runoff. • For GHG building emissions, retrofitting existing structures is more effective than merely constructing new green buildings.
Two Decades of Smart Growth in Maryland Urban Planning and Transport Research, Rolf Moeckel and Rebecca Lewis, NCSG affiliates 2017	New development only in PFAs/new development only in TODs auto operating costs increased/ parking costs doubled	• Transit ridership increases by 1% in TOD scenario. • Increased auto operating costs marginally increase transit ridership. • Travel (VMT and VHT) increase in PFA and TOD scenarios.
Regional Scenarios Greater Washington Partnership 2017-2019	Toll network, rail schedules and speeds, cordon fees to enter downtown DC.	• Population and employment locations were the same in all scenarios, with the greatest congestion reduction from a toll road network; but toll roads can cause congestion on access routes. • The cordon benefits downtown DC but causes congestion elsewhere. • Faster rail service may relieve congestion on parallel routes.

Appendix B. Comparison with the MDOT Study

[This analysis was conducted before MDOT's release of the July 2020 DEIS for the Managed Lane Study]

In September 2017, Maryland's Governor announced planning for a Traffic Relief Plan (TRP), a $9+ billion project described as the largest public-private partnership (P3) for highway construction in North America. The plan aims to reduce Maryland's lengthy commute times, high congestion rankings, and the increasing financial burden of congestion by expanding some key highways in the greater Baltimore-Washington region.

The TRP proposals have been advanced through MDOT's Managed Lanes Study that is focused on the Beltway and I-270. We use one of the stronger-performing alternatives in that study, Alternative #9, for our comparisons. This alternative would add four new tolled "express" lanes on each of those highways (two in each direction), while retaining the existing footprint of untolled lanes on each road. The planned additions in Maryland would be coordinated with recent investments in highway infrastructure in neighboring Virginia. I-495's course around Washington through its suburbs takes it twice over the Potomac River. Facing ever worsening traffic congestion and continued economic and demographic growth, Virginia chose to invest in highway expansion through P3 projects in the early part of the last decade and has now mostly completed a similar expansion of its regional highways. In Virginia, I-495, I-95, and I-395 have been expanded with added toll lanes; and by 2022, I-66 west of I-495 will have been expanded in a similar fashion.

The current MDOT study for the TRP cites the reduction of congestion as its primary goal and states that indirect effects will be improved regional economic competitiveness and savings in personal travel time and cost. While our study, using different methods and tools, incorporates an analysis of the TRP's congestion impacts, we have also looked at other impacts. These include probable indirect population effects, the likely impact of autonomous vehicles, and the impacts of a smarter growth land use/transit initiative. Despite different models and methodologies, our results show similar impacts to MDOT's or at least ones that move in the same direction, despite specific differences. The MDOT results shown in Figure B.1 are culled from information presented by MDOT at a public meeting in Spring 2019.

Figure B.1 Comparison of MDOT TRP and NCSG Outcomes

MDOT feature compared	TRP	NCSG	Comments
Percent increase in people moved vs. 2040 no-build "people through-put"			We assume these indicators measure actual increases in volume comparing our pm peak to MDOT's.
• I-270 at Montrose Road	+10%	+13%	
• American Legion Bridge (north side)	+35%	+30%	
• I-495 west of I-95	+40%	+11%	
• I-495 at MD Route 5	+15%	+3%	
Congestion relief (reduction in delay) on combined facilities (I-495 and I-270) at pm peak	**-33%**	**-27%**	Seems like a straightforward apples-to-apples comparison.
Reduced daily delay on local network	**-6.8%**	**-1.0%**	We use regional pm peak combined reduction for arterials and collectors, not daily reduction.

Appendix C. Population Impacts

Figure C.1 shows the entire study area population by subarea for 2015 and as projected to 2040 by scenario. It also presents this information as percentages of the total population by subarea and scenario. Of note are the relatively small percentage changes when seen as part of the total population rather than as part of the incremental growth as in Figure 6.

Figure C.1 Share of Incremental Population Growth by Subarea

	No AVs			25% AVs		
	Baseline	Tolls	SG	AV	Tolls	SG
2015 Population						
External	4,672	4,672	4,672	4,672	4,672	4,672
Outer	1,573	1,573	1,573	1,573	1,573	1,573
Inner	6,098	6,098	6,098	6,098	6,098	6,098
Core	2,259	2,259	2,259	2,259	2,259	2,259
Total	14,602	14,602	14,602	14,602	14,602	14,602
Total Population, 2040						
External	4,931	4,987	4,977	5,029	5,040	4,992
Outer	1,769	1,774	1,710	1,813	1,814	1,751
Inner	6,334	6,325	6,364	6,299	6,295	6,345
Core	2,576	2,569	2,639	2,535	2,531	2,584
Total	15,609	15,656	15,609	15,676	15,680	15,609
% Share of Total Population, 2040						
External	25.7%	29.9%	28.0%	33.3%	34.1%	29.9%
Outer	19.5%	19.1%	12.6%	22.3%	22.4%	16.7%
Inner	23.4%	21.6%	24.4%	18.7%	18.3%	23.1%
Core	31.4%	29.4%	34.9%	25.7%	25.2%	30.3%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Population values = 1/1,000

Appendix D. Travel Analysis

The five scenarios were evaluated using the following indicators:

- Population growth shifts
- Traffic (measured as Vehicle Miles Traveled or VMT)
- Travel time (measured as Vehicle Hours Traveled or VHT)
- Delay (measured as Vehicle Hours of Delay or VHD)
- Transit ridership
- Vehicular emissions

The sections below offer a more detailed and complete narrative than that in the body of the report. Each area's results are described in the order of the indicators, first for without AVs, then with 25 percent AVs. These tables show absolute values while those in the body of the report show percentage change from the baseline.

D.1 The Region (see Figure D.1)

Travel Impacts without AVs. Adding toll lanes does not affect overall regional VMT although it increases it slightly on freeways (1.6 percent). Likewise, the effects on VHT and VHD are marginal; although a small decrease (4 percent) is registered for freeways, likely the result of the added toll lanes drawing traffic from the free lanes. This pattern generally holds in the other subareas as well. Transit ridership is unaffected by the added lanes.

In a smart growth scenario (adding transit, no new lanes), VMT is essentially unaffected but freeway VMT decreases 2 percent and VHT overall increases 5 percent. VHD, however, increases substantially (13 percent), likely the result of increased population concentration in the core and inner subareas, where drivers use already-congested roads, and the larger growth increment resulting from SILO's indirect transportation impacts that attract more people into the region.

SG's population redistribution and transit expansion also contribute to a significant increase of 22 percent in transit ridership, spread evenly across all modes. Adding tolls doesn't affect transit ridership but assuming AVs significantly reduces it. GHG impacts show marginal reductions from added tolls and from SG.

Travel Impacts with AVs. Adding AVs changes results across the board. Even without added toll lanes, they add 8 percent to regional VMT, mostly due to more freeway travel (14 percent). With toll lanes, the AV effect increases both overall and freeway VMT by only 2 percent (from 8 to 10 percent and 15 to 17 percent). In other words, introducing AVs has a much larger impact than adding toll lanes on regional travel behavior. Adding AVs increases VHT by 9 percent; AVs plus toll lanes increases VHT by 10 percent, particularly on collectors.

The impacts on regional delay are interesting. AVs alone increase VHD by 13 percent overall but is reduced by 20 percent on freeways. This riddle is explained by the equally large increase in delay on arterials and collectors. Travelers will tolerate delay on arterials and collectors to access faster travel on freeways. This same pattern is evident when adding toll lanes; delay increases 14 percent overall, freeway delay declines by 19 percent, while arterial and collector delay increases by 22 percent. AVs, with or without added toll lanes, also reduce transit trips—overall by 19 percent and on rail between 21 and 27 percent.

In the SG scenario, introducing AVs has a small impact on VMT—a 3 percent increase overall and a 7 percent increase on freeways. The SG plus AV scenario's impacts on delay are noteworthy; overall delay is increased by 2 percent but freeway delay is reduced by 21 percent, reversing the 6 percent increase in congestion from SG alone. Without added lanes and using a SG population distribution brings transit ridership back to the baseline.

AVs plus tolls generate a moderate increase in GHG impacts.

Figure D.1 Regional Outcomes by Scenario

			No AVs		25% AVs		
		Baseline Totals	Tolls	SG	AV	Tolls	SG
Population*		10,678	739	783	717	710	750
VMT (mi.)	Freeway	25,390,851	25,694,625	24,953,732	29,106,461	29,754,722	27,240,924
	Other Roads	32,391,042	32,166,390	32,668,657	33,533,074	33,588,577	32,142,402
	Total	57,781,893	57,861,015	57,622,389	62,639,536	63,343,299	59,383,326
VHT (hrs.)	Freeway	649,010	645,968	656,735	670,444	684,805	617,065
	Other Roads	1,863,816	1,849,354	1,970,833	2,071,026	2,081,911	1,855,848
	Total	2,512,826	2,495,321	2,627,568	2,741,471	2,766,716	2,472,913
VHD (hrs.)	Freeway	210,138	202,659	222,688	167,949	171,141	163,600
	Other Roads	814,181	807,546	931,376	989,985	999,434	876,318
	Total	1,024,319	1,010,205	1,154,065	1,157,934	1,170,576	1,039,919
Transit Ridership		3,017,301	3,017,991	3,681,686	2,383,512	2,393,573	3,004,920
GHG**		27,993	27,976	26,927	30,256	29,971	28,072

*All values /1,000

**All values /1,000,000

D.2 Outer Subarea (see Fig. D.2)

Travel Impacts without AVs. With only 11 percent of the baseline population, these 11 counties still generate about 26 percent of regional peak hour travel (VMT). This is because residents commute longer distances to central job locations and have few transit options. Since the new lanes are far from these outer jurisdictions, however, they have almost no effect on VMT, VHT, or VHD.

SG produces a modest increase in VMT and VHT of 4 and 5 percent respectively. It also decreases overall delay by 5 percent and freeway delay goes down 11 percent.

Transit ridership is unaffected by added lanes, but the SG scenario generates more impact in the outer subarea than anywhere else; overall ridership increases by 44 percent with buses being the beneficiary of a massive increase in ridership (see transit ridership by mode on the project website). This anomaly is a result of a very small existing base of bus ridership in this subarea.

GHG emissions are reduced only marginally from tolls plus SG.

Travel Impacts with AVs. Adding AVs increases VMT significantly—13 percent overall and 15 percent on freeways. New toll lanes reduce this marginally. VHT increases even more, by 26 percent, especially on arterials and collectors, and adding the tolled lanes slightly increases these numbers. VHD sees the biggest increases, 51 percent without new lanes and 52 percent with them. VHD also increases very significantly on arterials and collectors, between mid-50 and mid-60 percent, with or without toll lanes. These are among the largest percentage impacts found in this study and can be attributed to the relatively small existing population base. Freeways, on the other hand, decongest by 22 percent without toll lanes and 14 percent with toll lanes. In the outer suburbs, longer distance trips benefit at the expense of more local trips, more markedly than in any other subarea.

Coupling SG with AVs delivers the “best” travel outcomes in the outer subarea: small increases in VMT and VHT (4 and 6 percent respectively), very significant VHD reductions on freeways (30 percent), but with significant increases in overall delay (21 percent). Transit use increases by 6 percent overall, but bus ridership increases by 62 percent.

Transit ridership suffers losses of 21 percent with AVs alone and 26 percent with added lanes, most notably for rail, with buses much less affected (losses of between 5 and 8 percent).

GHG shows moderate increases in the AV and AV plus tolls scenarios.

Figure D.2 Outer Subarea Outcomes by Scenario

			No AVs		25% AVs		
		Baseline Totals	Tolls	SG	AV	Tolls	SG
Population*		1,769	201	137	240	241	178
VMT (mi.)	Freeway	25,390,851	5,208,611	5,006,621	6,020,039	6,108,418	5,677,833
	Other Roads	32,391,042	9,546,227	9,118,930	10,654,358	10,683,268	9,778,153
	Total	57,781,893	14,754,838	14,125,551	16,674,397	16,791,686	15,455,986
VHT (hrs.)	Freeway	649,010	104,037	101,059	112,642	115,771	103,692
	Other Roads	1,863,816	425,277	411,260	557,063	559,551	455,193
	Total	2,512,826	529,314	512,319	669,705	675,322	558,885
VHD (hrs.)	Freeway	210,138	20,491	18,337	15,980	17,611	14,391
	Other Roads	814,181	156,774	153,952	256,017	257,684	203,031
	Total	1,024,319	177,265	172,289	271,998	275,295	217,422
Transit Ridership		3,017,301	69,782	101,108	51,645	48,754	69,270
GHG**		27,993	6,095	5,969	6,973	6,887	6,404

*All values /1000

**All values /1,000,000

D.3 Inner Subarea (see Fig. D.3)

Travel Impacts without AVs. This subarea produces 60 percent of all regional VMT giving it an outsized effect on regional travel behavior. As with the regional and outer subarea impacts, adding toll lanes has almost no effect on overall VMT, VHT, and VHD. Freeway VHD stands out here, declining by 5 percent.

SG has progressively larger impacts, from a minor increase in VMT of 4 percent, a notable increase in VHT of 13 percent, and a very significant increase in VHD of 25 percent. Transit ridership, as in the other subareas, is unaffected by the added lanes. SG produces modest 16 percent increase here, transit being more established than in other subareas. GHG is essentially unaffected in the no-AV policies.

Travel Impacts with AVs. As in the region and outer subarea, adding AVs alone increases VMT overall (8 percent), especially on freeways (15 percent). AVs plus toll lanes increases these impacts marginally. A similar pattern is evident in VHT and is spread more evenly across road types. Unlike the outer subarea, overall VHD impacts are moderate (8 percent increase without tolled lanes and 10 percent increase with lanes). A reduction in freeway VHD (16 percent) is more than offset by increased delays on arterials and collectors, though much less than the percentage reductions in the outer subarea. The large existing population and established travel patterns mute the impacts of added growth.

SG plus AVs marginally increases VMT (2 percent) and marginally reduces VHT (3 percent). The interesting impacts occur in VHD where overall delay is reduced by 4 percent but freeway delay goes down by a significant 22 percent. Transit ridership drops the same amount with AVs and with AVs plus toll lanes (20 and 21 percent respectively). SG plus AVs restores ridership to the baseline.

GHG increases moderately in the AV scenarios and only marginally in the SG scenario.

Figure D.3 Inner Subarea Outcomes by Scenario

			No AVs		25% AVs		
		Baseline Totals	Tolls	SG	AV	Tolls	SG
Population*		6,334	227	266	201	197	247
VMT (mi.)	Freeway	25,390,851	17,707,368	17,403,851	20,055,275	20,545,946	18,691,966
	Other Roads	32,391,042	17,353,621	18,805,858	17,705,856	17,756,965	16,976,714
	Total	57,781,893	35,060,990	36,209,709	37,761,131	38,302,912	35,668,681
VHT (hrs.)	Freeway	649,010	454,451	482,107	478,483	487,330	434,411
	Other Roads	1,863,816	991,205	1,153,474	1,069,413	1,080,012	969,621
	Total	2,512,826	1,445,656	1,635,582	1,547,896	1,567,342	1,404,032
VHD (hrs.)	Freeway	210,138	147,377	177,565	129,923	130,346	121,315
	Other Roads	814,181	420,273	534,595	488,031	497,057	430,086
	Total	1,024,319	567,650	712,160	617,954	627,403	551,402
Transit Ridership		3,017,301	1,710,049	1,990,495	1,339,733	1,328,443	1,690,292
GHG**		27,993	17,405	17,208	18,834	18,646	17,861

*All values /1000

**All values /1,000,000

D.4 Core Area (see Fig. D.4)

Travel Impacts without AVs. This subarea contains about 26 percent of the region's population and produces about 23 percent of its VMT. Adding the tolled lanes has a marginal effect on VMT, VHD, and VHD.

However, in this subarea SG pays dividends with a large decrease in freeway congestion (24 percent) and no increases on collectors or arterials. In these dense areas, trips tend to be short and transit enhancements have some payoff. The effect of SG on enhancing transit ridership is marked overall (29 percent increase), but especially noticeable on bus and commuter rail.

GHG is essentially unaffected without AVs.

Travel Impacts with AVs. AVs add 1 percent to overall VMT in this subarea but on freeways they add 9 percent alone and 11 percent with toll lanes. Unlike in other subareas, VHT is marginally reduced overall (1 percent) but significantly for freeways (10 percent for AVs alone and 7 percent for AVs with lanes).

VHD sees modest overall decreases of 1 percent but very significant freeway decreases occur both with and without added lanes—34 percent and 37 percent respectively. A small amount of freeway traffic occurs in the cores on freeway spurs so that these large percentage reductions really reflect small absolute numbers.

SG, despite increasing growth and VMT in the cores, produces significant reductions in overall VHT (17 percent), and an insignificant reduction in delay overall but a significant reduction in freeway delay (21 percent). By enhancing transit and moving people closer to their workplaces, the SG scenario shortens trips, lowering VMT and probably VHT.

AVs reduce transit ridership by about 16 percent overall but SG offsets this, adding 4 percent to ridership.

GHG increases moderately in the AV scenarios and slightly in the SG scenario.

Figure D.4 Core Subarea Outcomes by Scenario

			No AVs		25% AVs		
		Baseline Totals	Tolls	SG	AV	Tolls	SG
Population*		2,569	310	380	276	272	325
VMT (mi.)	Freeway	25,390,851	2,778,646	2,543,260	3,031,148	3,100,357	2,871,124
	Other Roads	32,391,042	5,266,542	4,743,869	5,172,860	5,148,343	5,387,535
	Total	57,781,893	8,045,188	7,687,129	8,204,008	8,248,701	8,258,659
VHT (hrs.)	Freeway	649,010	87,480	73,569	79,320	81,704	78,962
	Other Roads	1,863,816	432,872	406,099	444,550	442,347	431,034
	Total	2,512,826	520,352	479,667	523,870	524,051	440,618
VHD (hrs.)	Freeway	210,138	34,791	26,786	22,046	23,184	27,894
	Other Roads	814,181	230,499	242,830	245,936	244,693	243,201
	Total	1,024,319	265,290	269,616	267,982	267,877	271,595
Transit Ridership		3,017,301	1,238,159	1,181,674	751,120	748,702	926,500
GHG**		27,993	4,180	3,454	4,139	4,130	3,508

*All values /1000 **All values /1,000,000

D.5 Interstate 495 (see Fig. D.5)

Note that for the Interstate impacts we add an indicator for traffic volume and volume to capacity ratios (V/C ratios) and compare free lane to toll lane performance. Volume should not be confused with VMT (Vehicle Miles Traveled), which multiplies volumes by trip length and which we call traffic.

Travel Impacts without AVs. As might be expected, the added toll lanes create large changes on the Beltway in all indicators. The added tolled lanes increase traffic volumes by a very significant 39 percent. Toll lanes carry 30 percent of the volume of free lanes. On a per lane basis, however, this ratio increases to 52 percent. VMT increases by 15 percent with toll lanes carrying 19 percent of the VMT of the free lanes. Beltway VHT decreases by 6 percent.

The biggest impact of the added lanes is realized in changes in delay. VHD goes down by a very significant 36 percent overall, with essentially no delay on the toll lanes. The V/C ratios that measure congestion show that the free lanes would operate at an average V/C ratio of 0.80 (LOS C) and the toll lanes at an average V/C ratio of 0.39 (LOS A).

With SG, volumes actually decline by 2 percent but VMT declines by 7 percent. VHT declines by 7 percent and VHD increases by 3 percent.

Travel Impacts with AVs. Introducing AVs without adding toll lanes increases traffic volumes (not VMT) by 21 percent. Adding the tolled lanes boosts this increase to 38 percent. The toll lanes carry 18 percent of the total volume of free lanes, which increases to 41 percent on a per lane basis.

VMT increases by 21 percent just by inserting AVs and by 30 percent when adding toll lanes, which carry only 10 percent of the VMT of the free lanes. Beltway VHT increases 8 percent but drops to 4 percent with added toll lanes since they take pressure off the free lanes; lowering the value of time makes the toll price more acceptable.

VHD from AVs alone decreases by 10 percent, and when adding toll lanes, to a very significant 33 percent, though not quite the 36 percent without AVs reported above. This can be explained by the larger increase in volumes and VMT attracted by the capacity increases from AVs plus new lanes. Congestion, measured in V/C ratios, sees the free lanes operating at an average V/C ratio of 0.81 (LOS C) and the toll lanes at an average V/C ratio of 0.37 (LOS A).

SG with AVs produces some interesting results; while volumes and VHT increase by 5 and 7 percent respectively, VHT decreases by 4 percent and delay by a noteworthy 11 percent.

Figure D.5 I-495 Outcomes by Scenario

		No AVs		25% AVs		
		Tolls	SG	AV	Tolls	SG
VMT (mi.)	Free Lane	1,850,549	1,844,488	2,322,808	2,276,132	2,052,838
	Toll Lane	349,164	NA	NA	218,196	NA
	Total	2,199,713	1,844,488	2,322,808	2,494,329	2,052,838
	% Change from Baseline (Total)	14.6%	-3.9%	21.0%	30.0%	7.0%
VHT (hrs.)	Free Lane	45,029	48,628	58,507	52,973	49,843
	Toll Lane	5,570	NA	NA	3,371	NA
	Total	50,599	48,628	58,507	56,345	49,843
	% Change from Baseline (Total)	-6.3%	-9.9%	8.4%	4.4%	-7.7%
VHD (hrs.)	Free Lane	13,214	21,479	18,792	14,063	18,721
	Toll Lane	199	NA	NA	14	NA
	Total	13,412	21,479	18,792	14,078	18,721
	% Change from Baseline (Total)	-35.9%	2.7%	-10.2%	-32.7%	-10.5%
VOLUME (cars)	Total Volume Free Lane*	3,214	3,030	4,062	3,941	3,571
	Total Volume Toll Lane*	844	0	0	567	0
	Total Volume*	4,058	3,030	4,062	4,508	3,571
	% Change from Baseline (Total Volume)	38.52%	-13.10%	21.02%	38.20%	5.25%
	Ratio of free lane to toll lane	0.30	NA	NA	0.18	NA
	Free Lane Vol/Lane	5,553	6,089	7,254	7,038	7,302
	Toll Lane Vol/Lane	2,894	NA	NA	2,894	NA
	Toll to Free Lane Ratio	0.52	NA	NA	0.41	NA
	Volume/Capacity ratio Free Lanes	0.80	0.88	0.84	0.81	0.84
	Volume/Capacity ratio Toll Lanes	0.39	NA	NA	0.37	NA

*Volume numbers 1/1,000

D.6 Interstate 270 (see Fig. D.6)

Note that for the Interstate impacts we add an indicator for traffic volume and volume to capacity ratios (V/C ratios) and compare free lane to toll lane performance. Volume should not be confused with VMT (Vehicle Miles Traveled), which multiplies volumes by trip length and which we call traffic.

Travel Impacts without AVs. Compared to the Beltway, I-270 toll lanes attract less new volume (adding 18 percent compared to 39 percent) and see lower VMT increases (adding 12 percent compared to 15 percent). Toll lanes carry 16 percent of this overall volume, increasing to 33 percent on a per lane basis. VMT increases by 12 percent.

VHT sees a marginal decline but VHD is very substantially reduced (29 percent). Congestion, measured in V/C ratios, shows the free lanes operating at an average ratio of 0.79 (LOS C) and the toll lanes at an average ratio of 0.36 (LOS A).

The SG story in this corridor shows modest declines in volumes, VMT, VHT and VHD.

Travel Impacts with AVs. Inserting AVs attracts more traffic volume (15 percent), which adding lanes increases to 21 percent; the toll lanes carry 10 percent of this volume and 11 percent of the VMT.

As on the Beltway, VHT increases modestly (7 percent) with AVs, which goes up to 8 percent with toll lanes, reflecting the increased volumes and VMT from the added lanes. Delay drops significantly (14 percent) from AVs alone and much more substantially (24 percent) when adding toll lanes. Congestion, measured in V/C ratios, sees the free lanes operating at an averagea ratio of 0.92 (LOS E), the lowest in this analysis, and the toll lanes at an average of 0.19 (LOS A).

Combining AVs with SG adds moderately to volumes (14 percent), VMT (12 percent), and VHT (10 percent) but reduces congestion by 10 percent.

Figure D.6 I-270 Outcomes by Scenario

		No AVs		25% AVs		
		Tolls	SG	AV	Tolls	SG
VMT (mi.)	Free Lane	539,783	537,146	630,078	646,151	633,978
	Toll Lane	117,226	44,291	47,638	67,920	38,321
	Total	657,010	581,437	677,716	714,071	632,550
	% Change from Baseline (Total)	11.6%	-1.2%	15.1%	21.3%	12.1%
VHT (hrs.)	Free Lane	12,764	13,538	15,147	15,002	14,945
	Toll Lane	1,904	691	733	1,046	702
	Total	14,669	14,159	15,880	16,048	16,048
	% Change from Baseline (Total)	-1.1%	-4.5%	7.1%	8.2%	9.9%
VHD (hrs.)	Free Lane	2,864	3,894	3,589	3,151	3,710
	Toll Lane	101	0	0	1	0
	Total	2,964	3,530	3,589	3,152	3,710
	% Change from Baseline (Total)	-28.7%	-6.4%	-13.7%	-24.2%	10.1%
VOLUME (cars)	Total Volume Free Lane*	1,621	1,662	1,922	1,940	1,916
	Total Volume Toll Lane*	311	99	107	201	102
	Total Volume*	1,932	1,761	2,029	2,140	2,018
	% Change from Baseline (Total	17.9%	-0.1%	19.4%	35.4%	13.5%
	Toll to Free Lane Ratio	0.19	0.06	0.06	0.10	0.05
	Free Lane Vol/Lane	5,410	5,540	6,405	6,466	6,386
	Toll Lane Vol/Lane	2,672	2,598	2,060	1,928	1,960
	Free to Toll Lane Ratio/ Lane	0.49	0.47	0.32	0.30	0.31
	Volume/Capacity ratio Free Lanes	0.79	0.63	0.91	0.92	0.93
	Volume/Capacity ratio Toll Lanes	0.36	0.19	0.20	0.43	0.19

*Volume numbers /1,000

Caveats

The modeling of transportation impacts is always a fraught enterprise. It is important, therefore, to be transparent about the limitations of our work. Despite the caveats noted below, however, we believe that our analysis and findings are valid and useful. They are quite consistent with the AV impacts found in similar studies, which tend to be less conservative than ours. If anything, then, we understate their impacts.

Travel Model Limitations

Our four-step travel demand model is the type most commonly used by metropolitan planning agencies. However, more sophisticated models called Activity Based Models (ABMs) are increasingly used by large agencies because they show more realistic and dynamic aspects of travel behavior (such as combined trips for different purposes called trip chaining). Furthermore, Dynamic Traffic Assignment (DTA) models that capture the time of day of travel on a second-by-second basis are also coming into wider use. Because the four-step model does not capture these nuances, the results from our model cannot be readily compared to results from ABMs or DTA models. We also do not attempt to model the potential long term effects of COVID, teleworking and e-commerce. Certainly the recent, large, COVID-related trip reductions suggest that in a post-COVID world, a 20% regional telework share is plausible. If so, with less AVs than assumed, this alone might modify how and when toll lanes are implemented.

AV Model Limitations

Given the high uncertainty around AV adoption and their impacts on travel, our study projects their potential impacts based on well-established assumptions in the research literature. Therefore, rather than treating AVs as a separate mode, we reflect their impacts by changing model inputs and parameters based on assumptions about freeway capacity, value of time, operating cost, etc. However, AVs may also encourage more travel by the elderly and very young or more discretionary trips, since capacity and time penalties are removed, which might offset some of the additional freeway capacity. We do not explore these important possibilities here as they remain speculative and hard to bracket. We do not address the possibility that households will reduce car ownership with the adoption of a fleet of on-demand AVs or Shared AVs (SAVs). Furthermore, we also don't address the potential of AVs outside the study area, and so assume that AVs don't affect the points at which vehicles enter or leave the study area.

Transit Ridership

MSTM produces overall transit ridership on bus, rail, and commuter rail but does not reflect changes in transit service and fares. As noted, our model somewhat underestimates transit ridership, especially for buses. Despite substantial investments in new or extended heavy rail lines, our transit ridership results did not show a significant increase. Though some research has shown that improved rail service will influence long-term land use by changing the locations of population and employment, the land use impacts of improved rail service were not considered. Nor did we adjust service characteristics such as frequencies to improve transit performance.

Toll Charges

The scenarios are based on a non-variable toll charge of 40 cents/mile. Because tolls are dynamically adjusted, they would, in reality, vary significantly during the day. Current toll rates on the Virginia Beltway can range from 20 cents/mile in the off-peak to up to $2.00/mile in peak periods. We tested alternative toll charges in our modeling (e.g. from 20 to 90 cents/mile) and found that results are very sensitive to toll costs. Since our model cannot incorporate those dynamic changes, we used a moderate toll value of 40 cents/mile. Our analysis assumes the added toll lanes are complete by 2040.

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The Center, with the support of the Town Creek Foundation, has developed PRESTO, a futures testing framework to inform Maryland's citizens, advocacy groups, and decision-makers about the major forces that will affect the region's development over the next 25 years. By examining these forces and combining them into scenarios, PRESTO provides a picture of their potential impact, individually and in combination.

For more information on the PRESTO project, data and the models: https://www.umdsmartgrowth.org/projects/presto

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