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Metropolitan Washington Council of Governments

GEN3 MODEL PHASE 2 SENSITIVITY TESTING RESULTS

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1.0 INTRODUCTION

The National Capital Region Transportation Planning Board (NCRTPB or TPB), staffed by the Metropolitan Washington Council of Governments (MWCOG or COG), is the federally designated metropolitan planning organization (MPO) for metropolitan Washington. COG/TPB staff, with consultant assistance, develops, maintains, applies, and improves the TPB's family of regional travel demand forecasting models, which are used for regional, long-range transportation planning in the metropolitan Washington region. In 2018, COG/TPB set out to develop a next-generation travel demand model. The project team, consisting of RSG and Baseline Mobility Group (BMG), recommended that COG transition from its current aggregate, trip-based travel demand model (i.e., Gen2 Model) to a simplified activity-based model (ABM) implemented in the open-source ActivitySim software platform. COG's new ABM is to be known as the Generation 3, or Gen3, Model.

The model is being implemented in two phases. Phase 1 was a prototype model that was tested by COG/TPB staff and was used as a learning tool to develop a work plan for creation of a production-ready model. Phase 2 is an updated version that addresses any issues found with the Phase 1 model and which, at the end of a period of COG staff usability testing, should become a production-use model that can be used for regional planning work, such as the air quality conformity analysis and scenario studies. The purpose of a phased approach to model development is to use the initial deployment and calibration efforts to inform the scope of final model development and calibration/validation tasks, rather than scope the entire model development project at the project initiation. This allows the project team to learn from the initial deployment and prioritize resource allocation in Phase 2, to ensure that the final delivered Gen3 Model meets the needs of MWCOG, partner agencies, and decision-makers.

In Phase 1, a synthetic population for the modeled region was created, and the ActivitySim model system was transferred from the Southeast Michigan Council of Governments (SEMCOG) region (Detroit, Michigan) to MWCOG. Under Phase 1 deployment, tour mode choice and tour destination choice models were estimated. After implementation of the estimated models, several model components such as auto ownership, tour mode choice, trip mode choice, individual non-mandatory tour frequency and intermediate stop frequency models were calibrated to the observed distributions from the 2017-18 MWCOG Regional Travel Survey (RTS) and the 2018-19 Maryland Travel Survey (MTS) data.[1] The processing of RTS/MTS data was documented in the Phase 1 data development report.[2] The 2018 traffic counts and transit boarding counts that are used for Phase 1 model validation were provided by MWCOG staff and

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[1] Gen3 Phase 1 Data Development Report, December 29, 2021 (https://app.box.com/s/xe5vb28daox1aqtw895iy2r5ocy584w8)
[2] RSG, "Gen3 Data Development" (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, December 29, 2021), https://app.box.com/file/863253528678?s=xe5vb28daox1aqtw895iy2r5ocy584w8.

were documented separately.[3] Thus, the preparation of the count data is not covered in this report.

In Phase 2, several more model components were estimated including the transit subsidy model, the auto ownership model, the telecommute frequency model, the coordinated daily activity pattern model, the mandatory and fully joint tour frequency models, and the trip mode choice model. The entire system was re-calibrated and validated until model validation against traffic counts and transit boardings met or exceeded validation of the Gen2/Ver. 2.4 trip-based model.

FIGURE 1 shows the general structure of the ActivitySim portion of the Gen3 Travel Model. As noted in the figure legend, boxes with the red borderline indicate models that were estimated as part of the Phase 1 development and boxes with the yellow borderline were estimated as part of the Phase 2 development. Other models were either borrowed from the Southeast Michigan Council of Governments or the initial ActivitySim model, developed from the Metropolitan Transportation Commission's Travel Model One and calibrated to local data.

[3] Martha Kile to Mark Moran et al., "Hourly Traffic Volume and Classification Counts Linked to 2018 Highway Network," Memorandum, June 3, 2021; Martha Kile to Mark Moran et al., "Hourly Traffic Volume and Classification Counts Linked to 2018 Highway Network," Memorandum, June 21, 2021; Meseret Seifu to Feng Xie, "2018 Daily and Hourly Traffic Counts," Memorandum, June 22, 2021.

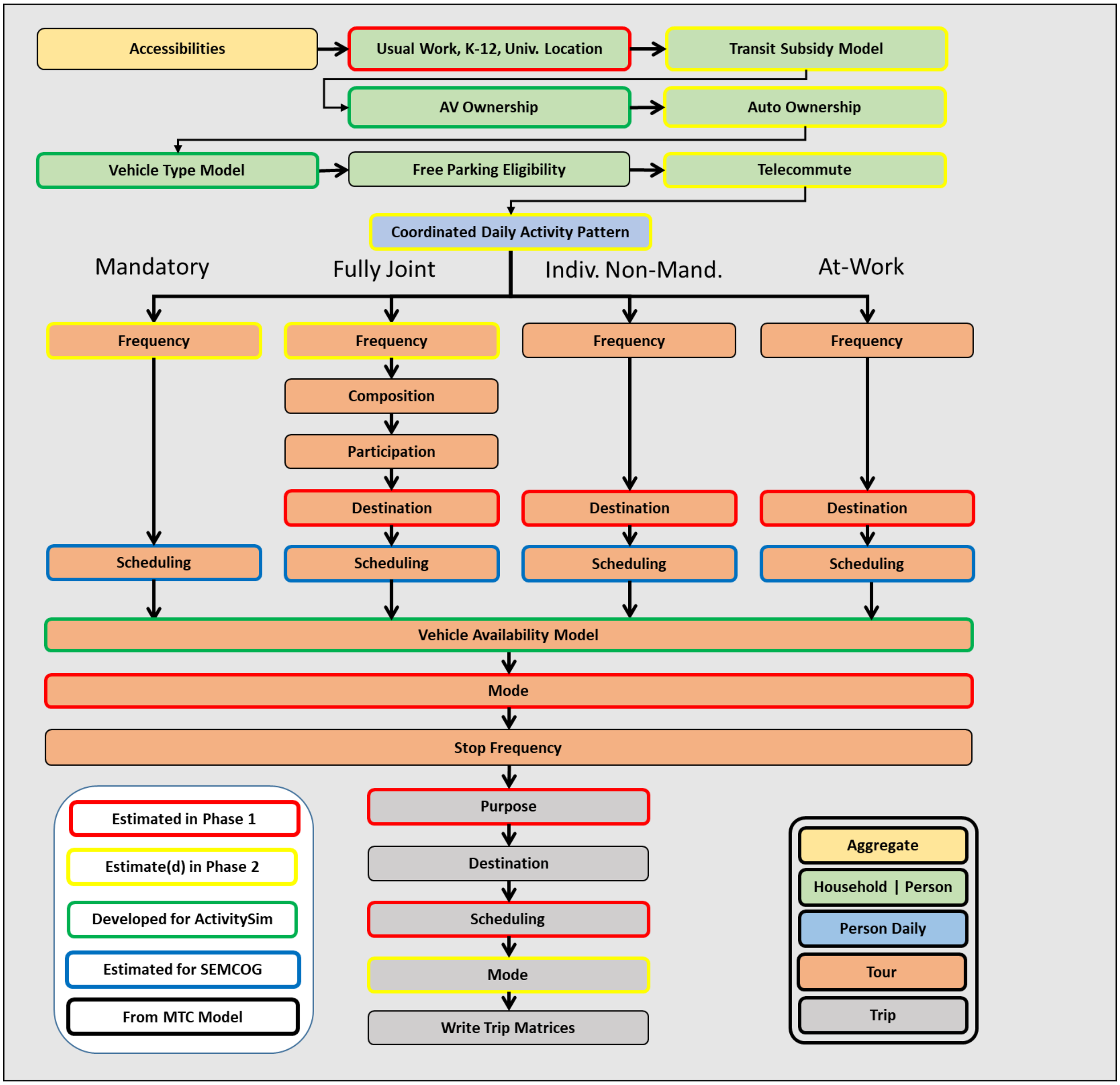

FIGURE 1: MWCOG GEN3 ACTIVITYSIM MODEL FLOWCHART

In both phases of model development, the models were run through a series of sensitivity tests. This report describes Gen3 Phase 2 sensitivity testing results. Similar to the tests run in Phase 1, the following four sensitivity tests were run by Baseline Mobility Group in Phase 2 using the Gen3 Phase 2 Model (Version 0.9 dated May 23, 2023[4]):

[4] Note that changes continue to be made to version 0.9 of the model to improve calibration and validation, add features, and/or address software bugs since these sensitivity tests were run.

- An auto operating cost (AOC) test, in which auto operating cost was increased by 10 cents per mile to reflect a vehicle miles traveled (VMT) tax or increase in fuel cost. BMG ran this sensitivity test, referred to as the *AOC* test in this document.
- An increase in telecommuting to the District of Columbia (DC) test, in which the telecommute frequency model was adjusted to reflect a higher share of telecommuting workers with a workplace in DC. BMG ran this sensitivity test, referred to as the *Increased DC Telecommute* test in this document.
- A highway capacity reduction test, in which the Arlington Memorial Bridge was closed to auto use. BMG ran this sensitivity test, referred to as the *Bridge Closure* test in this document.
- An increased transit capacity test, in which the frequency of all high-capacity transit (HCT) services was doubled. HCT includes transit routes of Metrorail (Mode 3), commuter rail (Mode 4), light rail (Mode 5), streetcar, and bus rapid transit, or BRT (Mode 10). BMG ran this sensitivity test, referred to as the *Double HCT Frequency* test in this document.

COG staff ran an additional sensitivity test scenario to examine the impact of autonomous vehicles (AVs) using another interim version of the Gen3, Phase 2, Model (dated July 12, 2023[5]). Specifically, it models:

- A hypothetical scenario analysis that examined the impact of having an overall 20% market share of AVs in the metropolitan Washington region in the horizon year of 2045. This scenario analysis was prepared in two steps: 1) run a 2045 baseline scenario that executed the 2045 land use/network files and the extended vehicle type file, and 2) run a 2045 AV scenario by re-calibrating the AV ownership model to match target shares of AV-owning households by income segment.

Each test is described in a separate chapter of this report. Each chapter describes the changes made to inputs in order to run the test, a priori expectations for model results, and the actual model results for the test.

The 2018 base-year was used as the Baseline scenario for all the BMG tests. As mentioned before, the Baseline scenario applied in the sensitivity tests run by BMG was the pre-release version (Version 0.9 dated May 23, 2023) of the final Gen3 Phase 2 Model. Each sensitivity test was carried out by modifying the inputs from this pre-release Baseline scenario, executing model runs for the baseline/alternative scenarios, and examining the travel shifts between each sensitivity test and the Baseline scenario.

[5] There were a number of minor bug fixes and calibration updates to the code between the version of the model used by BMG for sensitivity tests dated May 23, 2023 and the version used by COG dated July 12, 2023. Most of the calibration updates affected destination choice and mode choice.

Both baseline and alternative scenarios use the same random number seed in order to reduce Monte Carlo simulation variance[6] between the two runs. These random number seeds are specific to households and persons, so Monte Carlo variance is significantly reduced in the comparison of model results. If the probability distributions between two model runs are exactly the same, the chosen alternatives will be exactly the same. In the model system, Monte Carlo variance occurs because model choices made in the upper level of the model system affect lower-level choices. For example, auto ownership affects tour generation, which affects tour mode, etc. So, if the auto ownership choice in the sensitivity test alternative is different for a subset of households, people in those households may generate different numbers of tours, with different destinations, modes, etc. To some extent these changes are consistent with the change in auto ownership, but some of these changes could still be attributed to Monte Carlo simulation variance that is not directly associated with changes in model inputs.

Furthermore, the speed feedback process, in which the entire model system is run iteratively, results in travel time changes between iterations. Due to imperfect convergence, the travel time changes can lead to changes in travel patterns that also may not be obviously traced back to the change in model inputs. In such cases, we refer to the “signal-to-noise” ratio in the model; we expect that the signal (the changes that are directly related to changes in inputs) is much higher than the noise (Monte Carlo simulation variance and imperfect model convergence) but this may not always be the case; particularly with respect to changes in inputs that affect only a very small subset of decision-makers. In such cases it may be necessary to run the model multiple times, varying the random number seed in each run, and averaging the results, in order to decrease the Monte Carlo simulation variance and model convergence noise and achieve something closer to an “expected” or average model outcome.

In support of model calibration and validation, RSG implemented a visualization tool (ABM Visualizer) to compare ActivitySim outputs against observed data (e.g., RTS/MTS). The ABM Visualizer creates a static HTML dashboard of summary comparisons of various models in the ActivitySim framework. **FIGURE 2** shows the screenshot of the overview page. In this case, the comparison is between a survey and model output. During Phase 2, this tool was enhanced for sensitivity testing to allow comparing two different model runs. Some of the graphics in this document are taken from this tool. Other summaries include trip origin-destination flows, highway assignment, and transit assignment results.

[6] Monte Carlo simulation variance relates to the different outcomes that one obtains from a probabilistic simulation model due to the use of random number sequences to draw discrete alternatives from probability distributions.

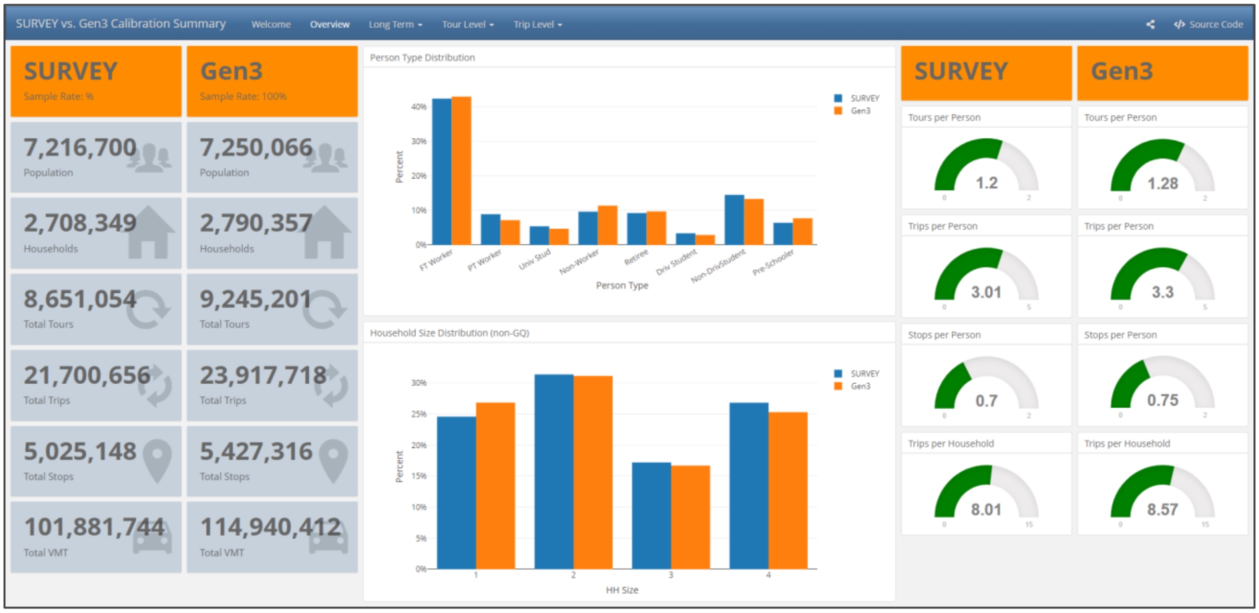

FIGURE 2: ABM VISUALIZER OVERVIEW PAGE

2.0 INCREASED AUTO OPERATING COST

This chapter describes the results of the increased Auto Operating Cost (AOC) scenario.

2.1 DESCRIPTION

In this scenario, auto operating cost used in tour and trip mode choice models was increased by 10 cents per mile, from 19.26 cents per mile in the base scenario to 29.26 cents per mile, in order to emulate a vehicle-miles-traveled (VMT) tax policy scenario. This was implemented by making the following changes in two files:

1. changing line 94 in the *constants.yaml* file (saved in the …\source\configs\activitysim\configs\ folder), from `costPerMile: 19.26` to `costPerMile: 29.26`.
2. uniformly adding 10 cents for all 500 vehicle types in the "auto_operating_cost" attribute column of the "vehicle_type_data.csv" file (saved in the …\source\configs\activitysim\configs\ folder)

It should be noted that the base auto operating cost used in the model was obtained from the American Automobile Association (AAA) published 2018 Edition pamphlet entitled "YOUR DRIVING COSTS, How Much Are You Really Paying to Drive?" This auto operating cost includes the cost of fuel, maintenance, repair, and tires and is averaged across all vehicle types, namely Small Sedan, Medium Sedan, Large Sedan, Small SUV, Medium SUV, Minivan, Pickup Truck, Hybrid Car, and Electric Car. The auto operating cost per mile reported in the AAA report ranged from 11.28 cents for Electric Car and 17.57 cents for Small SUV to 23.18 cents for Pickup Truck.

2.2 EXPECTED OUTCOMES

By increasing auto operating cost, we expect the following outcomes:

- We do not expect auto ownership to be affected because auto operating cost is not taken into account in the auto ownership utility equations or in the accessibility terms currently used in the auto ownership model.
- We would expect very small changes to tour frequency (especially mandatory tour frequency) since these models are affected by tour mode choice logsums, reflecting a decrease in accessibility as the cost of auto is increased.
- We expect decreased tour length and stop out-of-direction length due to the increased cost of auto which will affect tour and trip mode choice logsums.
- We do not expect significant changes to time-of-day choices since the increased auto operating cost is not differentiated by time of day.
- We expect mode shifts from auto to non-motorized, transit, and ride-hail modes.

- We expect somewhat fewer stops generated per tour as tour lengths decrease.
- We expect decreased vehicle miles of travel (VMT) and total estimated traffic due to decreases in the magnitude of travel, decreased tour and trip length, and decreased auto mode share.
- We expect increased transit boardings due to increased transit mode share.

2.3 ACTUAL OUTCOMES

In this section we document the observed outcomes of the AOC scenario compared to the Baseline scenario. We first compare Gen3 Model (ActivitySim) results between the scenarios using the activity-based model visualizer tool. In order to keep the discussion concise, we show visualizer outputs for only those model components that exhibit some noticeable change between the Baseline and the sensitivity test scenario. The full visualizer file is available on Box for those interested in further investigating differences.

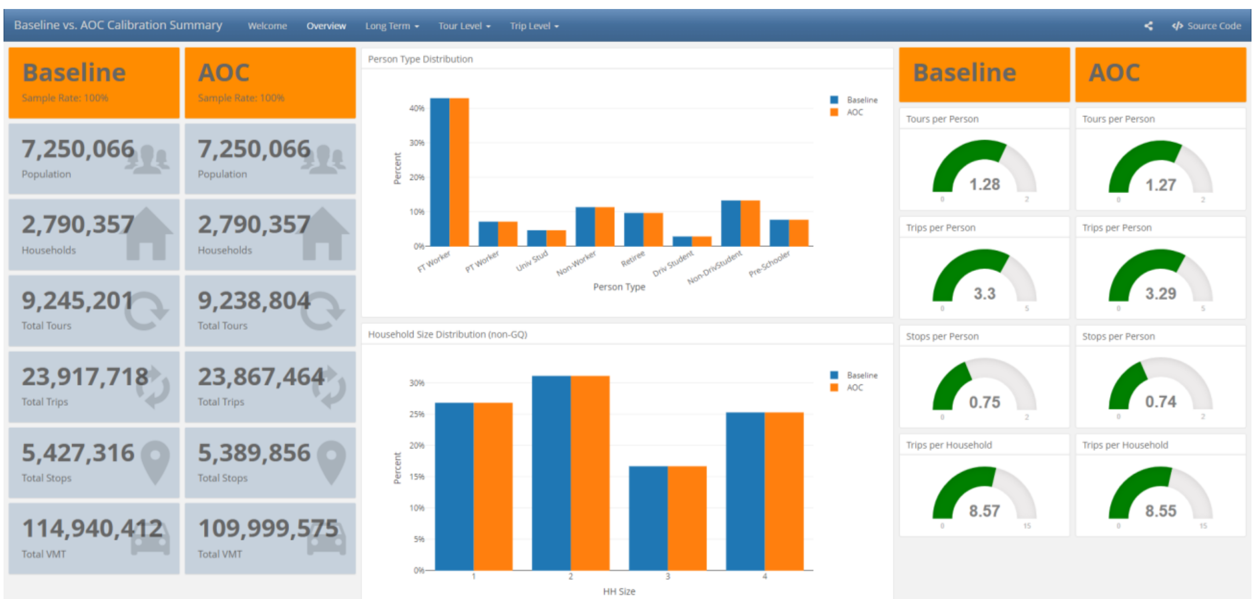

FIGURE 3: VISUALIZER SUMMARY – AOC VS. BASELINE

FIGURE 3 shows the visualizer summary page comparing the AOC scenario to the Baseline scenario. The visualizer shows that the population and households are exactly the same between the alternatives. There are 6,397 fewer tours in the AOC scenario, which is a 0.07% decrease over the Baseline. This is an expected result as the tax on auto travel has increased in the AOC scenario. There are 37,460 fewer stops generated in the AOC scenario compared to the Baseline scenario, a decrease of 0.7%. This is consistent with our priori expectations for decreased stop generation, due to shorter auto tour lengths. This leads to a decrease of 50,254 total trips generated, which is a decrease of 0.2%.

VMT generated by households decreases by 4,940,837 miles per weekday or 4.3% in the AOC alternative compared to the Baseline alternative. This is the result of the small decrease in total trips, the decreased tour and trip lengths, and the shifts from auto modes to non-motorized and transit modes that are described below.

TABLE 1 compares the mandatory tour length (one-way distance between home and work, university, or K-12 school location) between the Baseline and AOC scenarios. The table shows that home-work distance decreased by 1.32% for work location choice, and 1.08% for K-12 school location choice. By contrast, home-university distance slightly increased by 0.05% for university location choice. Jurisdictions with a longer average mandatory location choice distance tended to be more affected by the increased AOC, as might be expected given that it is applied on a per-mile basis.

TABLE 2 compares the tour length for non-mandatory tour purposes between the Baseline and AOC scenarios. Across all non-mandatory purposes, the average tour length decreased by 0.41 miles or 7.30%. The decreases in tour length are correlated with the average tour length; joint discretionary tours have the longest average tour length in the Baseline scenario and also had the largest percentage decrease (10.05%) in tour length in the AOC scenario. Other variables, such as household income, the spatial distribution of activities, and availability of alternative modes of transportation also affect the elasticities of tour length to auto operating cost.

TABLE 3 shows total tours by tour mode and auto sufficiency for the Baseline scenario and the AOC scenario while **TABLE 4** shows the difference and percent difference in total tours by mode and auto sufficiency between the Baseline scenario and the AOC scenario. As expected, the Gen3 Phase 2 Model estimates a decrease in the number of auto tours in the AOC scenario, with increases in non-motorized and transit tours. The percent decrease in auto tours is higher for auto-insufficient and 0-auto households, possibly due to increased price sensitivity for lower income households, and also possibly due to those households being located in Transportation Analysis Zones (TAZs) with better transit accessibility than auto-owning households. Walk mode tours increase by 2.78% and bike mode tours increase by 5.22% in the AOC scenario. Walk-transit tours increase by 2.59%, park-and-ride transit tours increase by 12.69%, and kiss-and-ride transit tours increase by 6.86%. Park-and-ride and kiss-and-ride tours increased despite the inclusion of auto operating cost in their utility, due to the more significant decrease in utility for auto mode. School bus tours increase by 4.18% and ride-hail tours increase by 5.88% in the AOC scenario. Note that the cost of ride-hailing services was not increased as part of this scenario, though, in reality, some portion of a mileage-based tax would likely be passed on to customers.

TABLE 1: MANDATORY TOUR LENGTH IN MILES - BASELINE VERSUS AOC

	Baseline Scenario			AOC Scenario			Difference			Percent Difference		
Jurisdiction	Work	University	K-12	Work	University	K-12	Work	University	K-12	Work	University	K-12
District of Columbia	5.42	3.94	4.42	5.39	4.59	4.24	-0.03	0.65	-0.18	-0.52%	16.40%	-3.97%
Montgomery County	11.51	11.28	4.69	11.37	11.25	4.49	-0.13	-0.03	-0.19	-1.15%	-0.26%	-4.14%
Prince George's County	12.61	9.22	5.39	12.46	9.22	5.27	-0.15	0.00	-0.11	-1.20%	0.00%	-2.11%
Arlington County	7.17	3.85	3.60	7.11	3.78	3.62	-0.06	-0.07	0.01	-0.85%	-1.74%	0.32%
City of Alexandria	8.48	4.63	3.47	8.40	4.48	3.47	-0.08	-0.14	-0.01	-0.93%	-3.11%	-0.16%
Fairfax County	11.08	6.44	4.15	10.95	6.19	4.15	-0.13	-0.25	0.00	-1.16%	-3.93%	0.03%
Loudoun County	15.06	10.57	4.43	14.85	10.36	4.37	-0.21	-0.21	-0.06	-1.41%	-1.96%	-1.28%
Prince William County	16.84	6.44	3.92	16.63	6.42	3.94	-0.21	-0.03	0.02	-1.26%	-0.43%	0.55%
Frederick County	20.71	16.89	6.88	20.45	16.88	7.06	-0.27	-0.01	0.18	-1.29%	-0.06%	2.55%
Howard County	14.58	19.00	5.13	14.30	18.88	5.11	-0.27	-0.12	-0.02	-1.87%	-0.62%	-0.37%
Anne Arundel County	15.18	14.89	5.32	14.90	15.14	5.37	-0.28	0.25	0.05	-1.87%	1.71%	1.03%
Charles County	21.02	20.72	7.29	20.70	20.45	7.36	-0.32	-0.27	0.06	-1.50%	-1.28%	0.85%
Carrol County	22.05	23.12	6.53	21.86	22.74	6.45	-0.18	-0.38	-0.08	-0.83%	-1.64%	-1.19%
Calvert County	23.38	43.15	7.18	22.92	42.27	7.11	-0.46	-0.88	-0.07	-1.95%	-2.04%	-1.02%
St. Mary's County	17.33	40.35	9.81	16.77	39.92	9.67	-0.57	-0.44	-0.14	-3.26%	-1.08%	-1.47%
King George County	27.00	31.98	8.51	26.29	30.51	8.44	-0.72	-1.47	-0.07	-2.65%	-4.59%	-0.80%
City of Fredericksburg	12.69	2.48	5.97	12.74	2.49	5.99	0.06	0.00	0.02	0.45%	0.14%	0.29%
Stafford County	22.02	17.66	5.38	21.71	17.06	5.30	-0.32	-0.61	-0.08	-1.45%	-3.43%	-1.55%
Spotsylvania County	18.23	6.14	5.80	18.05	5.99	5.74	-0.18	-0.15	-0.06	-0.97%	-2.48%	-0.97%
Fauquier County	24.41	16.97	7.22	24.21	16.13	7.10	-0.20	-0.84	-0.12	-0.83%	-4.93%	-1.63%
Clarke County	33.84	41.67	7.24	33.23	40.10	7.42	-0.61	-1.57	0.18	-1.79%	-3.77%	2.54%
Jefferson County	29.42	14.71	7.94	29.18	13.97	7.94	-0.24	-0.74	0.00	-0.83%	-5.00%	0.04%
Total	**13.35**	**10.32**	**5.01**	**13.17**	**10.32**	**4.96**	**-0.18**	**0.01**	**-0.05**	**-1.32%**	**0.05%**	**-1.08%**

TABLE 2: NON-MANDATORY TOUR LENGTH IN MILES - BASELINE VS. AOC

Purpose	Baseline Scenario	AOC Scenario	Difference	Percent Difference
Escorting	4.40	4.11	-0.29	-6.68%
Individual Maintenance	5.27	4.93	-0.33	-6.34%
Individual Discretionary	6.29	5.70	-0.59	-9.43%
Joint Maintenance	6.09	5.70	-0.39	-6.47%
Joint Discretionary	6.86	6.17	-0.69	-10.05%
At-Work	5.07	4.94	-0.12	-2.44%
Total	**5.65**	**5.24**	**-0.41**	**-7.30%**

TABLE 3: TOTAL TOURS BY TOUR MODE AND AUTO SUFFICIENCY - BASELINE VS. AOC

	Baseline Scenario				AOC Scenario			
Tour Mode	0 Auto	Autos < Workers	Autos >= Workers	Total	0 Auto	Autos < Workers	Autos >= Workers	Total
Drive-Alone	0	337,979	3,105,480	3,443,459	0	330,511	3,081,699	3,412,210
Shared 2	19,496	307,394	1,632,434	1,959,324	17,934	302,064	1,614,470	1,934,468
Shared 3+	27,710	197,536	1,485,124	1,710,370	25,852	192,059	1,459,482	1,677,393
Walk	106,956	201,221	528,815	836,992	107,539	205,282	547,468	860,289
Bike	7,727	48,219	47,950	103,896	7,998	50,071	51,250	109,319
Walk-Transit	202,459	93,904	151,093	447,456	203,334	96,758	158,975	459,067
PNR-Transit	0	8,209	85,061	93,270	0	9,278	95,832	105,110
KNR-Transit	4,654	10,393	15,388	30,435	4,706	11,077	16,739	32,522
School Bus	14,322	46,180	411,438	471,940	14,350	48,612	428,699	491,661
Ride Hail	31,247	50,012	66,800	148,059	32,547	53,310	70,908	156,765
Total	**414,571**	**1,301,047**	**7,529,583**	**9,245,201**	**414,260**	**1,299,022**	**7,525,522**	**9,238,804**

TABLE 4: CHANGES IN TOTAL TOURS BY TOUR MODE AND AUTO SUFFICIENCY - BASELINE VS. AOC

	Difference				Percent Difference			
Tour Mode	0 Auto	Autos < Workers	Autos >= Workers	Total	0 Auto	Autos < Workers	Autos >= Workers	Total
Drive-Alone	0	-7,468	-23,781	-31,249		-2.21%	-0.77%	-0.91%
Shared 2	-1,562	-5,330	-17,964	-24,856	-8.01%	-1.73%	-1.10%	-1.27%
Shared 3+	-1,858	-5,477	-25,642	-32,977	-6.71%	-2.77%	-1.73%	-1.93%
Walk	583	4,061	18,653	23,297	0.55%	2.02%	3.53%	2.78%
Bike	271	1,852	3,300	5,423	3.51%	3.84%	6.88%	5.22%
Walk-Transit	875	2,854	7,882	11,611	0.43%	3.04%	5.22%	2.59%
PNR-Transit	0	1,069	10,771	11,840		13.02%	12.66%	12.69%
KNR-Transit	52	684	1,351	2,087	1.12%	6.58%	8.78%	6.86%
School Bus	28	2,432	17,261	19,721	0.20%	5.27%	4.20%	4.18%
Ride Hail	1,300	3,298	4,108	8,706	4.16%	6.59%	6.15%	5.88%
Total	**-311**	**-2,025**	**-4,061**	**-6,397**	**-0.08%**	**-0.16%**	**-0.05%**	**-0.07%**

TABLE 5 compares the intermediate stop out-of-direction distance by tour purpose between the Baseline scenario and the AOC scenario. The stop distance slightly decreases for some tour purposes such as work, school and discretionary over the Baseline scenario, but for a few other purposes, stop distance slightly increases, such as for university, escorting, and maintenance tours. These mixed results were not as expected. In Phase 1, stop distances all decreased due to the increased cost of auto travel in the AOC scenario. The stop frequency models have interaction terms with total tours generated; less tours can lead to more stops per tour. It is possible that the purposes in which stops increased are due to a greater influence of those relationships compared to the decrease in utility due to increased auto operating cost.

TABLE 5: INTERMEDIATE STOP OUT-OF-DIRECTION DISTANCE BY TOUR PURPOSE - BASELINE VS. AOC

Tour Purpose	Baseline Scenario (mile)	AOC Scenario (mile)	Difference (mile)	Percent Difference
Work	3.027	3.021	-0.006	-0.21%
University	4.062	4.074	0.013	0.31%
School	5.052	4.878	-0.173	-3.43%
Escorting	3.016	3.043	0.026	0.87%
Individual Maintenance	3.462	3.484	0.022	0.64%
Individual Discretionary	3.163	3.127	-0.036	-1.13%
Joint Maintenance	3.305	3.367	0.062	1.88%
Joint Discretionary	3.253	3.217	-0.036	-1.12%
At-Work	2.393	2.383	-0.010	-0.42%
Total	**3.314**	**3.300**	**-0.014**	**-0.42%**

TABLE 6 shows a comparison of trips by trip mode between the Baseline scenario and the AOC scenario. The changes in trips by trip mode are similar to the changes of tours by tour mode observed in **TABLE 3**: auto trips decrease, while non-motorized trips, transit trips, school bus trips, and ride-hail trips increase as a result of the increase in auto operating cost.

TABLE 6: DAILY TRIPS BY TRIP MODE - BASELINE VS. AOC

Trip Mode	Baseline Scenario	AOC Scenario	Difference	Percent Difference
Drive-Alone	11,312,502	11,201,453	-111,049	-0.98%
Shared 2	5,234,366	5,193,668	-40,698	-0.78%
Shared 3+	3,491,106	3,448,641	-42,465	-1.22%
Walk	1,762,665	1,804,271	41,606	2.36%
Bike	219,064	230,770	11,706	5.34%
Walk-Transit	778,747	797,140	18,393	2.36%
PNR-Transit	186,540	210,220	23,680	12.69%
KNR-Transit	60,870	65,044	4,174	6.86%
School Bus	471,878	491,599	19,721	4.18%
Ride Hail	399,980	424,658	24,678	6.17%
Total	**23,917,718**	**23,867,464**	**-50,254**	**-0.21%**

Highway Traffic Shifts

A comparison of highway network level travel demand shifts due to the AOC increase is summarized in several tables, as listed below:

- Daily traffic volume shifts by screenline (**TABLE 7**)
- Daily vehicle miles traveled (VMT) shifts by time period (**TABLE 8**)
- Daily vehicle miles traveled (VMT) shifts by area type (**TABLE 9**)
- Daily vehicle miles traveled (VMT) shifts by facility type (**TABLE 10**)
- Daily vehicle miles traveled (VMT) shifts by jurisdiction (**TABLE 11**)

Overall, these highway comparison tables reveal a modest reduction of highway travel demand, by around 3.1% due to the increase in auto operating cost, with somewhat higher reductions in high-density population and employment centers, along freeways and collector streets, in the suburbs of the DC region (most notably in Arlington County, Fairfax County, Prince George's County, and Montgomery County), and along the screenlines that are located closer to the urban core. These findings are consistent across daily traffic volumes as well as VMT comparisons as the two measures are correlated.

Overall, the Gen3 Model is predicting a reduction of VMT by 5.03 million vehicle-miles traveled, or by 3.1%, from a Baseline VMT of 160.3 million in the region in 2018, due to the 10-cent increase in the auto operating cost (**TABLE 11**). Note that this reduction is less than the 4.3% reduction in VMT for just resident travel indicated by the ABM visualizer tool, since non-resident and commercial vehicle VMT is only indirectly affected by the increased auto operating cost, through feedback.

Regarding mode choice, the Gen3 Model shows travel demand reductions, as expected, in the Single-Occupant Vehicle (SOV) mode as well as the High-Occupancy Vehicle (HOV2 and HOV3+) modes due to the increase in the auto operating cost (**TABLE 4**). However, the Gen3 Model shows relatively higher percent reductions in the HOV modes than the SOV mode, which was unexpected. Also, the Gen3 Model shows relatively higher percent reductions during the midday and night time periods than the AM and PM peak periods, which were unexpected (**TABLE 8**). It appears that the Gen3 Model's mode choice component is more sensitive to AOC for mid-day and night time periods and for the shared-ride modes.

The AOC scenario run also shows truck trips slightly increased (results reviewed but not summarized in the report for brevity), despite the fact that truck trips are actually not directly impacted by the AOC increase as the truck model is a separate model. Hence, the slight increase in truck trips is attributable to secondary impacts due to reduced traffic congestion. It should be noted that the AOC increase was not reflected through all downstream and auxiliary models.

TABLE 7: DAILY TRAFFIC VOLUME BY SCREENLINE– BASELINE VS. AOC

Screenline	Baseline	AOC	Difference	% Difference
1	745,753	718,233	-27,520	-3.7%
2	1,090,314	1,062,571	-27,743	-2.5%
3	885,336	854,310	-31,026	-3.5%
4	1,101,902	1,068,972	-32,930	-3.0%
5	1,184,973	1,143,386	-41,587	-3.5%
6	1,723,789	1,665,173	-58,616	-3.4%
7	1,169,988	1,123,311	-46,677	-4.0%
8	1,818,296	1,751,714	-66,582	-3.7%
9	1,058,698	1,018,232	-40,466	-3.8%
10	606,416	589,608	-16,808	-2.8%
11	319,271	310,486	-8,785	-2.8%
12	589,783	572,121	-17,662	-3.0%
13	491,781	476,675	-15,106	-3.1%
14	279,446	267,104	-12,342	-4.4%
15	299,932	286,532	-13,400	-4.5%
16	188,476	179,179	-9,297	-4.9%
17	519,384	495,937	-23,447	-4.5%
18	731,884	706,614	-25,270	-3.5%
19	690,960	670,056	-20,904	-3.0%
20	1,088,303	1,035,283	-53,020	-4.9%
22	1,729,199	1,661,322	-67,877	-3.9%
23	223,114	214,491	-8,623	-3.9%
24	474,321	457,601	-16,720	-3.5%
25	147,162	140,500	-6,662	-4.5%
26	484,351	470,277	-14,074	-2.9%
27	442,025	427,047	-14,978	-3.4%
28	210,511	202,576	-7,935	-3.8%
31	173,450	168,920	-4,530	-2.6%
32	127,118	124,087	-3,031	-2.4%
33	282,947	270,977	-11,970	-4.2%
34	146,169	138,478	-7,691	-5.3%
35	919,576	909,733	-9,843	-1.1%
36	81,974	78,955	-3,019	-3.7%
37	45,208	43,881	-1,327	-2.9%
38	271,942	265,825	-6,117	-2.2%
Total	**22,343,752**	**21,570,167**	**-773,585**	**-3.5%**

Note: Daily traffic volumes were added for selected set of model links with traffic counts

TABLE 8: DAILY VEHICLE MILES TRAVELED (VMT) BY TIME PERIOD – BASELINE VS. AOC

Time Period	Baseline	AOC	Difference	% Difference
AM	36,193,886	35,524,491	-669,395	-1.85%
MD	50,227,550	50,404,870	-1,064,373	-2.07%
PM	51,469,243	48,850,508	-1,377,042	-2.74%
NT	40,113,407	38,030,485	-2,082,922	-5.19%
Total	**178,004,086**	**172,810,354**	**-5,193,732**	**-2.92%**

Note: VMT values were added for all modeled links.

TABLE 9: DAILY VEHICLE MILES TRAVELED (VMT) BY AREA TYPE– BASELINE VS. AOC

Area Type	Baseline	AOC	Difference	% Difference
1	2,310,738	2,233,730	-77,008	-3.3%
2	11,165,462	10,791,337	-374,125	-3.4%
3	15,365,691	14,938,211	-427,480	-2.8%
4	9,958,667	9,631,677	-326,990	-3.3%
5	16,635,113	16,123,458	-511,655	-3.1%
6	17,259,329	16,740,381	-518,948	-3.0%
Total	**72,695,000**	**70,458,794**	**-2,236,206**	**-3.1%**

Notes:

1. Area Type codes are defined in the model based on population and employment densities, with 1 representing high employment and population densities, and 6 reflecting low employment and population densities[7].
2. Daily VMT values were added for a select set of model links with traffic counts

TABLE 10: DAILY VEHICLE MILES TRAVELED (VMT) BY FACILITY TYPE – BASELINE VS. AOC

Facility Type	Baseline	AOC	Difference	% Difference
Freeway	33,085,660	31,925,904	-1,159,756	-3.5%
Major Arterial	17,435,220	16,974,436	-460,784	-2.6%
Minor Arterial	14,189,411	13,811,435	-377,976	-2.7%
Collector	2,522,445	2,443,503	-78,942	-3.1%
Expressway	5,434,486	5,276,105	-158,381	-2.9%
Ramp	27,778	27,411	-367	-1.3%
Total	**72,695,000**	**70,458,794**	**-2,236,206**	**-3.1%**

Note: Daily VMT values were added for a select set of model links with traffic counts

[7] Area Type definitions: 1 = High mixed employment and population density; 2 = Medium/high mixed density; 3 = Medium employment density; 4 = Medium population density; 5=Low density; 6 = Rural.

TABLE 11: DAILY VEHICLE MILES TRAVELED (VMT) BY JURISDICTION – BASELINE VS. AOC

Jurisdiction	Baseline	AOC	Difference	% Difference
0 District of Columbia	8,941,362	8,659,999	-281,363	-3.1%
1 Montgomery County	20,328,674	19,606,660	-722,014	-3.6%
2 Prince George's County	22,858,203	21,951,882	-906,321	-4.0%
3 Arlington County	4,115,028	3,962,936	-152,092	-3.7%
4 City of Alexandria	2,276,859	2,196,274	-80,585	-3.5%
5 Fairfax County	26,522,312	25,524,974	-997,338	-3.8%
6 Loudoun County	7,681,832	7,478,814	-203,018	-2.6%
7 Prince William County	9,353,674	9,048,689	-304,985	-3.3%
9 Frederick County	7,864,143	7,639,932	-224,211	-2.9%
10 Howard County	11,213,399	10,975,874	-237,525	-2.1%
11 Anne Arundel County	15,570,936	15,236,453	-334,483	-2.1%
12 Charles County	3,101,885	2,982,107	-119,778	-3.9%
14 Carrol County	4,113,457	4,048,529	-64,928	-1.6%
15 Calvert County	1,465,150	1,405,084	-60,066	-4.1%
16 St. Mary's County	1,894,029	1,820,527	-73,502	-3.9%
17 King George County	660,149	640,680	-19,469	-2.9%
18 City of Fredericksburg	809,963	795,649	-14,314	-1.8%
19 Stafford County	3,575,635	3,442,594	-133,041	-3.7%
20 Spotsylvania County	2,339,762	2,321,760	-18,002	-0.8%
21 Fauquier County	3,206,525	3,152,363	-54,162	-1.7%
22 Clarke County	1,029,370	1,018,403	-10,967	-1.1%
23 Jefferson County	1,380,098	1,357,297	-22,801	-1.7%
Total	**160,302,445**	**155,267,480**	**-5,034,965**	**-3.1%**
TPB Planning Area	113,043,972	109,052,267	-3,991,705	-3.5%
Non-TPB Member Area	47,258,473	46,215,213	-1,043,260	-2.2%
Air Quality Nonattainment Area (8-Hour Ozone)	**114,509,122**	**110,457,351**	**-4,051,771**	**-3.5%**

Note: Daily VMT values were added for all HPMS links in the model

Transit Ridership Shifts

Transit network travel demand shifts due to the AOC increase are summarized in several tables, listed below:

- Transit boardings by mode (**TABLE 12**)
- Transit boardings by operator (**TABLE 13**)
- Metrorail Station entries by station group (**TABLE 14**)

Overall, these transit comparison tables reveal a noticeable increase of transit ridership, by around 4.8% or over 78,777 new riders. The increase in AOC results in higher percent increases (in the range of 6 to 12%) for local bus within and beyond the WMATA service area.

The ridership of Metrorail is increased by 4.1%, or 38,816 new riders due to the AOC increase, which is expected (**TABLE 12**). Among the various Metrorail lines, the Orange Line – VA Fairfax and Silver Line stations show the highest percent increase of over 9.1% for around 2,974 new daily riders combined, and the Orange/Blue Line stations in the Virginia/DC core area and the Red Line stations in the DC core area show the top two highest increase of new riders, 7,919 new riders combined, but only reflecting percent increases in the 3-4% range (**TABLE 14**).

The ridership of Amtrak/Virginia Rail Express (VRE) commuter rail is predicted to go up by 3,104 new daily riders, or a 20.7% increase (**TABLE 13**). In addition, MARC commuter trains also show an increase of 3,688 new riders, an increase by 8.2%.

TABLE 12: TRANSIT BOARDINGS BY MODE– BASELINE VS. AOC

Transit Mode	Baseline	AOC	Difference	% Difference
Local Metrobus	336,825	347,975	11,149	3.3%
Express Metrobus	39,306	41,165	1,859	4.7%
Metrorail	948,667	987,482	38,816	4.1%
Commuter Rail	59,906	66,699	6,793	11.3%
Other Local Bus in the WMATA Area	161,473	171,614	10,141	6.3%
Other Express Bus in the WMATA Area	5,629	6,081	452	8.0%
Other Local Bus beyond the WMATA Area	25,341	27,249	1,908	7.5%
Other Express Bus beyond the WMATA Area	61,643	69,188	7,545	12.2%
Bus Rapid Transit (BRT) and Streetcar	4,603	4,717	114	2.5%
All Bus	630,217	663,272	33,055	5.2%
Total	**1,643,393**	**1,722,171**	**78,777**	**4.8%**

TABLE 13: TRANSIT BOARDINGS BY OPERATOR/SERVICE – BASELINE VS. AOC

Transit Operator/Service	Baseline	AOC	Difference	% Difference
WMATA Metrorail	948,667	987,482	38,816	4.1%
AMTRAK/ VRE commuter rail	14,974	18,078	3,104	20.7%
MARC commuter rail	44,932	48,621	3,688	8.2%
Arlington Transit ART / Alexandria DASH / Fairfax Connector / Prince George's County TheBus / Montgomery County RideOn / WMATA bus	497,675	519,460	21,785	4.4%
Alexandria DASH / Fairfax Connector / WMATA bus	58,539	62,771	4,232	7.2%
DC Circulator bus	6,876	7,060	184	2.7%
Annapolis Transit / Calvert County CCPT / Carroll County / Fairfax City Bus / GMU Shuttle / Loudoun County Local / Saint Mary's County STS / Frederick County TransIT / Charles County VanGO bus	22,350	23,688	1,338	6.0%
Washington Flyer Coach / Loudoun County Commuter Bus / MARTZ Bus / Maryland Commuter Bus	48,039	53,663	5,624	11.7%
DC OKLAH	1,341	1,347	7	0.5%
Total	**1,643,393**	**1,722,171**	**78,777**	**4.8%**

TABLE 14: METRORAIL STATION ENTRIES BY STATION GROUP – BASELINE VS. AOC

Station Group	Baseline	AOC	Difference	% Difference
Red Line - "A" route MD outside Beltway	28,862	31,222	2,360	8.2%
Red Line - "A" route MD inside Beltway	28,721	29,857	1,136	4.0%
Red Line - "A" route DC non-core	25,769	26,386	617	2.4%
Red Line - DC core	145,497	149,701	4,204	2.9%
Red Line - "B" route DC non-core	28,248	28,827	579	2.1%
Red Line - "B" route MD	29,514	31,272	1,758	6.0%
Green Line - "E" route MD	15,993	16,841	848	5.3%
Green Line - "E" route DC non-core	18,992	19,165	173	0.9%
Green Line - DC core	41,296	42,329	1,033	2.5%
Green Line - "F" route DC non-core	24,857	26,031	1,175	4.7%
Green Line - "F" route MD	15,841	16,471	630	4.0%
Blue/Yellow Line - VA Fairfax	18,809	20,307	1,497	8.0%
Blue/Yellow Line - VA Alexandria	15,505	16,415	910	5.9%
Blue/Yellow Line - VA Core	32,966	34,328	1,363	4.1%
Orange Line - VA Fairfax	11,148	12,227	1,079	9.7%
Orange/Silver Line - VA Arlington non-core	41,425	42,860	1,435	3.5%
Orange/Blue/Silver Line - VA/DC core	114,078	117,793	3,715	3.3%
Orange/Blue/Silver Line - DC non-core	16,624	16,944	319	1.9%
Orange Line - DC/MD	16,576	17,419	843	5.1%
Blue/Silver Line - DC/MD	20,296	21,269	974	4.8%
Silver Line - Phase I & Phase 2	20,784	22,678	1,895	9.1%
Total	**711,801**	**740,342**	**28,541**	**4.0%**

Trip Flow Shifts

Trip origin-destination flow changes due to the AOC increase are summarized, at the jurisdiction level, in several tables, as listed below:

- Intra-jurisdictional WORK trips using the SOV mode (TABLE 15)
- Inter-jurisdictional WORK trip ORIGINS using the SOV mode (TABLE 16)
- Inter-jurisdictional WORK trip DESTINATIONS using the SOV mode (TABLE 17)
- Intra-jurisdictional SHOPPING trips using the SOV mode (TABLE 18)
- Inter-jurisdictional SHOPPING trip ORIGINS using the SOV mode (TABLE 19)
- Inter-jurisdictional SHOPPING trip DESTINATIONS using the SOV mode (TABLE 20)

In these tables, the term "intra-jurisdictional" means the cell values on the diagonal of the origin-destination (OD) flow matrix, and the term "inter-jurisdictional" means the sum of the row and column totals minus the values in the cells on the diagonals of the OD flow matrix. The intra-jurisdictional work trips using the SOV mode (TABLE 15) shows a decrease for a majority of the jurisdictions in the TPB Planning Area including the DC area, which had the highest decrease of 5,920 trips. The exceptions to this trend are several jurisdictions, including Howard County, Charles County, St. Mary's County, and King George County. This decrease in local work trips using the SOV mode accounted for an overall 0.7% decrease against the backdrop of 3.05 million local work trips using the SOV mode in year 2018 travel conditions.

Similarly, the inter-jurisdictional work trip origins using the SOV mode (TABLE 16) show a decrease, which meets expectations, in trips due to the increase in the auto operating cost for all jurisdictions in the model area, including DC, Fairfax County, Montgomery County, and Prince George's County. Overall, these reductions add to nearly 63,736 trips, or 3.0% decrease from the 2.2 million trips in the Baseline scenario. The same trend of SOV trip reductions was also evident when the inter-jurisdictional work trip destinations using the SOV mode were compared (TABLE 17) between the Baseline and AOC scenario.

The intra-jurisdictional shopping trips using the SOV mode (TABLE 18) show an increase for a majority of the jurisdictions in the model area including the Prince George's County, Anne Arundel County, and Prince William County, which had the highest three increases in the range of 1,301-1,749 trips. This increase in intra-jurisdictional shopping trips using the SOV mode accounted for an overall 0.8% increase against the backdrop of 1.36 million shopping trips using the SOV mode in year 2018 travel conditions.

In contrast, the inter-jurisdictional shopping trip origins using the SOV mode (TABLE 19) show expected decrease in trips due to the increase in the auto operating cost for all jurisdictions in the model area, including Fairfax County, Prince George's County, Montgomery County, and DC. Overall, these reductions add to nearly 11,673 trips, or 4.7% decrease from the 0.25 million trips in the Baseline scenario. The same trend of SOV trip reductions was also evident when the inter-jurisdictional shopping trip destinations using the SOV mode were compared (TABLE 20) between the Baseline and AOC scenarios.

TABLE 15: INTRA-JURISDICTIONAL WORK TRIPS USING SOV MODE – BASELINE VS. AOC

Jurisdiction	Baseline	AOC	Difference	% Difference
0 District of Columbia	217,906	211,986	-5,920	-2.7%
1 Montgomery County	483,071	478,336	-4,735	-1.0%
2 Prince George's County	311,826	309,162	-2,664	-0.9%
3 Arlington County	55,779	54,815	-964	-1.7%
4 City of Alexandria	35,566	35,066	-500	-1.4%
5 Fairfax County	587,547	582,040	-5,507	-0.9%
6 Loudoun County	174,788	174,363	-425	-0.2%
7 Prince William County	212,768	212,130	-638	-0.3%
9 Frederick County	122,371	121,663	-708	-0.6%
10 Howard County	148,366	148,547	181	0.1%
11 Anne Arundel County	324,645	323,223	-1,422	-0.4%
12 Charles County	60,270	60,429	159	0.3%
14 Carrol County	77,155	77,086	-69	-0.1%
15 Calvert County	32,992	33,088	96	0.3%
16 St. Mary's County	72,816	73,087	271	0.4%
17 King George County	7,423	7,764	341	4.6%
18 City of Fredericksburg	11,387	11,351	-36	-0.3%
19 Stafford County	41,088	41,066	-22	-0.1%
20 Spotsylvania County	32,328	32,240	-88	-0.3%
21 Fauquier County	19,710	19,635	-75	-0.4%
22 Clarke County	2,287	2,347	60	2.6%
23 Jefferson County	18,337	18,345	8	0.0%
Total	**3,050,426**	**3,027,769**	**-22,657**	**-0.7%**

TABLE 16: INTER-JURISDICTIONAL WORK TRIP ORIGINS USING SOV MODE – BASELINE VS. AOC

Jurisdiction	Baseline	AOC	Difference	% Difference

0 District of Columbia	274,515	263,622	-10,893	-4.0%
1 Montgomery County	242,131	234,209	-7,922	-3.3%
2 Prince George's County	277,633	269,781	-7,852	-2.8%
3 Arlington County	139,994	135,951	-4,043	-2.9%
4 City of Alexandria	101,398	98,872	-2,526	-2.5%
5 Fairfax County	359,870	350,840	-9,030	-2.5%
6 Loudoun County	116,078	113,271	-2,807	-2.4%
7 Prince William County	129,497	126,180	-3,317	-2.6%
9 Frederick County	54,737	52,923	-1,814	-3.3%
10 Howard County	103,205	100,031	-3,174	-3.1%
11 Anne Arundel County	105,200	101,466	-3,734	-3.5%
12 Charles County	42,205	40,868	-1,337	-3.2%
14 Carrol County	32,737	31,972	-765	-2.3%
15 Calvert County	22,562	21,973	-589	-2.6%
16 St. Mary's County	17,290	16,455	-835	-4.8%
17 King George County	7,724	7,508	-216	-2.8%
18 City of Fredericksburg	21,947	21,569	-378	-1.7%
19 Stafford County	41,832	40,704	-1,128	-2.7%
20 Spotsylvania County	25,929	25,327	-602	-2.3%
21 Fauquier County	17,496	17,112	-384	-2.2%
22 Clarke County	4,379	4,323	-56	-1.3%
23 Jefferson County	12,689	12,355	-334	-2.6%
Total	**2,151,048**	**2,087,312**	**-63,736**	**-3.0%**

TABLE 17: INTER-JURISDICTIONAL WORK TRIP DESTINATIONS USING SOV MODE – BASELINE VS. AOC

Jurisdiction	Baseline	AOC	Difference	% Difference
0 District of Columbia	274,252	263,314	-10,938	-4.0%

1 Montgomery County	242,050	234,077	-7,973	-3.3%
2 Prince George's County	277,663	269,479	-8,184	-2.9%
3 Arlington County	139,955	135,951	-4,004	-2.9%
4 City of Alexandria	101,317	98,767	-2,550	-2.5%
5 Fairfax County	359,336	350,672	-8,664	-2.4%
6 Loudoun County	116,074	113,305	-2,769	-2.4%
7 Prince William County	130,208	126,818	-3,390	-2.6%
9 Frederick County	54,623	52,793	-1,830	-3.4%
10 Howard County	103,081	100,020	-3,061	-3.0%
11 Anne Arundel County	105,128	101,559	-3,569	-3.4%
12 Charles County	42,165	40,789	-1,376	-3.3%
14 Carrol County	32,777	32,021	-756	-2.3%
15 Calvert County	22,605	21,952	-653	-2.9%
16 St. Mary's County	17,358	16,542	-816	-4.7%
17 King George County	7,762	7,561	-201	-2.6%
18 City of Fredericksburg	22,060	21,685	-375	-1.7%
19 Stafford County	42,150	40,941	-1,209	-2.9%
20 Spotsylvania County	25,977	25,366	-611	-2.4%
21 Fauquier County	17,477	17,093	-384	-2.2%
22 Clarke County	4,349	4,297	-52	-1.2%
23 Jefferson County	12,681	12,310	-371	-2.9%
Total	**2,151,048**	**2,087,312**	**-63,736**	**-3.0%**

TABLE 18: INTRA-JURISDICTIONAL SHOPPING TRIPS USING SOV MODE – BASELINE VS. AOC

Jurisdiction	Baseline	AOC	Difference	% Difference
0 District of Columbia	67,405	67,111	-294	-0.4%
1 Montgomery County	211,334	211,909	575	0.3%
2 Prince George's County	161,501	163,250	1,749	1.1%
3 Arlington County	30,137	30,075	-62	-0.2%
4 City of Alexandria	22,063	22,200	137	0.6%
5 Fairfax County	234,154	234,774	620	0.3%
6 Loudoun County	66,251	67,090	839	1.3%
7 Prince William County	103,107	104,408	1,301	1.3%
9 Frederick County	58,799	59,355	556	0.9%
10 Howard County	68,564	69,425	861	1.3%
11 Anne Arundel County	135,723	137,157	1,434	1.1%
12 Charles County	32,405	33,149	744	2.3%
14 Carrol County	39,890	40,289	399	1.0%
15 Calvert County	19,038	19,458	420	2.2%
16 St. Mary's County	25,808	26,057	249	1.0%
17 King George County	4,491	4,575	84	1.9%
18 City of Fredericksburg	5,997	5,993	-4	-0.1%
19 Stafford County	23,635	24,159	524	2.2%
20 Spotsylvania County	17,902	18,173	271	1.5%
21 Fauquier County	13,634	14,011	377	2.8%
22 Clarke County	3,039	3,106	67	2.2%
23 Jefferson County	13,889	14,044	155	1.1%
Total	**1,358,766**	**1,369,768**	**11,002**	**0.8%**

TABLE 19: INTER-JURISDICTIONAL SHOPPING TRIP ORIGINS USING SOV MODE– BASELINE VS. AOC

Jurisdiction	Baseline	AOC	Difference	% Difference
0 District of Columbia	22,706	22,145	-561	-2.5%

1 Montgomery County	26,523	25,023	-1,500	-5.7%
2 Prince George's County	36,961	35,349	-1,612	-4.4%
3 Arlington County	22,389	21,502	-887	-4.0%
4 City of Alexandria	20,820	20,347	-473	-2.3%
5 Fairfax County	43,638	41,521	-2,117	-4.9%
6 Loudoun County	10,920	10,412	-508	-4.7%
7 Prince William County	10,045	9,173	-872	-8.7%
9 Frederick County	3,348	3,063	-285	-8.5%
10 Howard County	10,335	9,672	-663	-6.4%
11 Anne Arundel County	9,903	9,208	-695	-7.0%
12 Charles County	4,431	4,194	-237	-5.3%
14 Carrol County	2,765	2,630	-135	-4.9%
15 Calvert County	1,899	1,760	-139	-7.3%
16 St. Mary's County	1,564	1,450	-114	-7.3%
17 King George County	584	540	-44	-7.5%
18 City of Fredericksburg	6,445	6,312	-133	-2.1%
19 Stafford County	5,824	5,559	-265	-4.6%
20 Spotsylvania County	5,174	5,004	-170	-3.3%
21 Fauquier County	2,025	1,859	-166	-8.2%
22 Clarke County	510	484	-26	-5.1%
23 Jefferson County	629	558	-71	-11.3%
Total	**249,438**	**237,765**	**-11,673**	**-4.7%**

TABLE 20: INTER-JURISDICTIONAL SHOPPING TRIP DESTINATIONS USING SOV MODE– BASELINE VS. AOC

Jurisdiction	Baseline	AOC	Difference	% Difference
0 District of Columbia	22,767	22,163	-604	-2.7%
1 Montgomery County	26,480	25,006	-1,474	-5.6%
2 Prince George's County	37,032	35,438	-1,594	-4.3%

3 Arlington County	22,328	21,476	-852	-3.8%
4 City of Alexandria	20,954	20,443	-511	-2.4%
5 Fairfax County	43,614	41,490	-2,124	-4.9%
6 Loudoun County	10,824	10,330	-494	-4.6%
7 Prince William County	10,033	9,158	-875	-8.7%
9 Frederick County	3,338	3,039	-299	-9.0%
10 Howard County	10,232	9,578	-654	-6.4%
11 Anne Arundel County	9,979	9,282	-697	-7.0%
12 Charles County	4,421	4,187	-234	-5.3%
14 Carrol County	2,806	2,662	-144	-5.1%
15 Calvert County	1,901	1,755	-146	-7.7%
16 St. Mary's County	1,554	1,443	-111	-7.1%
17 King George County	595	549	-46	-7.7%
18 City of Fredericksburg	6,484	6,374	-110	-1.7%
19 Stafford County	5,798	5,528	-270	-4.7%
20 Spotsylvania County	5,162	4,989	-173	-3.4%
21 Fauquier County	2,005	1,838	-167	-8.3%
22 Clarke County	504	477	-27	-5.4%
23 Jefferson County	627	560	-67	-10.7%
Total	**249,438**	**237,765**	**-11,673**	**-4.7%**

3.0 INCREASED TELECOMMUTING TO D.C.

This chapter describes the results of the Increased Telecommuting to District of Columbia (DC) scenario.

3.1 DESCRIPTION

An increased telecommuting to District of Columbia (DC) scenario was developed for Gen3 Model sensitivity testing by adjusting the telecommute frequency model (shown in the green box at the top of FIGURE 1) to reflect a higher share of telecommuting for workers with a workplace in the District of Columbia (DC) jurisdiction. This scenario could be used to represent the types of travel changes that might be expected if there were a large increase in telecommuting to DC, which could occur during a pandemic or in reaction to a strategy designed to lower greenhouse gas (GHG) emissions due to the transportation sector.

The terms “telework” and “telecommute” are often used interchangeably, but, for this study, we make a distinction between the two terms. For this study, “telework” means that the worker does not have a usual workplace outside home. Telework is represented in ActivitySim using the new work-at-home model, which is part of work location choice. This model determines for each worker whether the worker has a usual, out-of-home work location or works regularly at their home. If the worker’s work location is home, then they do not generate work tours.[8] “Telecommute,” on the other hand, applies to only those workers with a usual workplace outside home who participate in a telecommute program, which involves telecommuting at least one day a week.

The telecommute frequency model predicts the frequency of telecommuting for every worker in the synthetic population. There are four alternatives in the multinomial logit model, as follows:

- No telecommuting or less than 1 day per week
- Telecommutes 1 day per week
- Telecommutes 2-3 days per week
- Telecommutes 4 or more days per week

The model was estimated using household travel survey data collected for the San Diego Association of Governments in 2016-17.[9] Explanatory variables include employment type of the worker (Services, Sales/Office, Resource/Construction, or Transportation/Materials), number of adults in the household, household income, number of household vehicles, whether there are children in the household, whether

[8] They might generate work-related tours, but those are classified as other maintenance tours, rather than work-related tours because ActivitySim does not have a work-related activity purpose, which is a current shortcoming of ActivitySim.
[9] For more information on the survey, see San Diego Regional Transportation Study
Volume I: Technical Report, Prepared for San Diego Association of Governments by RSG, accessed 2/24/2022 at https://www.sandag.org/uploads/publicationid/publicationid_2145_23025.pdf.

the worker also attends college, the work status (full or part-time) of the worker, whether the worker pays for parking at their workplace, and the distance to the workplace. There are also a set of alternative-specific constants for each telecommute alternative. For the MWCOG implementation of the model, the employment type was turned off in the model, since these are not controlled in the synthetic population.

In order to adjust the telecommute frequency model to reflect a higher percentage of telecommuting for workers who work in DC, the following ActivitySim configuration files were adjusted[10]:

- Telecommute_frequency_annotate_persons_preprocessor.csv: This is a preprocessor that runs before the telecommute frequency model. It has just one line in it, where it calculates a variable "workplace_in_dc" equal to 1 if the work TAZ is in JURCODE 0 (DC), else 0.
- Telecommute_frequency.yaml: Updated to run the above preprocessor before running the telecommute frequency model, using the person data and the land-use data table
- Telecommute_frequency_coeffs.csv: Updated to include three new alternative-specific constants, one for each telecommute frequency choice, to be applied to workers where workplace_in_dc==1. The alternative-specific constants are named "coef_dc_test_asc_1day", "coef_dc_test_asc_23day", and "coef_dc_test_asc_4day".
- Telecommute_frequency.csv: Updated to apply the alternative-specific constants added to the coefficients file if the workplace_in_dc==1.

After these changes were made to the ActivitySim input configuration files, the telecommute frequency alternative-specific constants for workers with a work TAZ in DC were calibrated to match target values defined in Phase 1. The target telecommuting shares from Phase 1 and the expected telecommute shares are shown in **Table 21**.

TABLE 21: TELECOMMUTE FREQUENCY SHARES FOR WORKERS WITH A WORK TAZ IN DC FOR THE INCREASED TELECOMMUTING TO DC SCENARIO

Telecommute Frequency	Target Share	Expected Share
Less than 1 day per week	32%	35%
1 day per week	3%	3%
2-3 days per week	17%	16%
4+ days per week	48%	46%
Total	**100%**	**100%**

3.2 EXPECTED OUTCOMES

The increased telecommuting to DC scenario was expected to produce the following travel demand outcomes:

[10] Note that the changes described here were performed for Phase 1. For Phase 2, we simply transferred the already calibrated telecommute frequency coefficients to the Phase 2 model.

- A decrease in the share of workers who work in DC with a mandatory activity pattern, and a corresponding decrease in work travel for those workers
- An increase in non-mandatory travel for workers who work in DC, since people who work from home are more likely to make non-work trips during the day
- Some offsetting changes to non-mandatory travel in terms of less trips per tour (since non-mandatory travel for telecommuting workers tends to be less complex than for others)
- A decrease in total trips to DC, vehicle miles of travel, and transit boardings

3.3 ACTUAL OUTCOMES

Since this test focuses on increasing the telecommute share for workers with a workplace in DC, we look at three key summaries created specifically for these workers, then explore highway and transit assignment results, compared to the Baseline scenario. The summaries are: 1) the share of workers by daily activity pattern; 2) the share of workers by mandatory tour frequency, and 3) the share of workers by non-mandatory tour frequency.

TABLE 22 and **TABLE 23** compare the results of the Coordinated Daily Activity Pattern model for workers who work in DC between the Baseline scenario and the Increased Telecommuting to DC scenario. The alternatives in this model are as follows:

- Mandatory: At least one work or school tour
- Non-Mandatory: No work or school tours, but at least one non-work or school tour
- Home: No travel

As expected, there are significant decreases in the shares of workers who have a Mandatory activity pattern due to the increase in telecommuting in the telecommute scenario. There are corresponding increases in non-mandatory travel and in the share of workers who stay at home. Note that the telecommute frequency effects on the Coordinated Daily Activity Pattern model and all other downstream models were estimated using pre-COVID data. In the 2017/2018 Regional Travel Survey (RTS), workers who participated in telecommute programs were approximately equally likely to have non-mandatory travel as they were to stay at home on days that they did not go to work. Post-COVID conditions may have different downstream effects on travel that can be taken into account by re-estimating the model system using post-COVID travel data or calibrating the telecommute frequency effects to observed post-COVID data.

In the Phase 1 testing of this model, we found a significant increase in the number of workers who work in DC in the telecommute scenario (13,514 more workers than the baseline). This was likely due to the lack of any simulation constraint in the Phase 1 model (where shadow pricing method was used). In the Phase 2 model (where a simulation constraint was implemented), there are only 339 more workers with a work TAZ in DC in the Increased DC Telecommute scenario than in the Baseline scenario, which is a marginal increase of only 0.04% as expected. The Phase 1 model showed a much higher increase because of the effect of congestion improvements and the lack of convergence in the shadow pricing mechanism that attempted to match workers to input jobs in the Phase 1 models. In the Phase 2 models, we implemented a new simulation constraint mechanism to match workers to jobs which does a much better job of constraining to the model than the shadow pricing mechanism used in Phase 1. Thus, the results are much more reasonable in Phase 2.

TABLE 22: WORKERS BY WORK STATUS AND DAILY ACTIVITY PATTERN - BASELINE VS. INCREASED DC TELECOMMUTE

	Baseline				Increased DC Telecommute			
Person Type	**Mandatory**	**Non-Mandatory**	**Home**	**Total**	**Mandatory**	**Non-Mandatory**	**Home**	**Total**
Full-time worker	556,160	60,921	50,302	667,383	508,153	91,363	68,296	667,812
Part-time worker	30,631	37,261	22,566	90,458	23,718	42,760	23,890	90,368
Total	**586,791**	**98,182**	**72,868**	**757,841**	**531,871**	**134,123**	**92,186**	**758,180**

TABLE 23: CHANGE IN WORKERS BY WORK STATUS AND DAILY ACTIVITY PATTERN - BASELINE VS. INCREASED DC TELECOMMUTE

	Scenario - Baseline				Percent Change			
Person Type	**Mandatory**	**Non-Mandatory**	**Home**	**Total**	**Mandatory**	**Non-Mandatory**	**Home**	**Total**
Full-time worker	-48,007	30,442	17,994	429	-8.63%	49.97%	35.77%	0.06%
Part-time worker	-6,913	5,499	1,324	-90	-22.57%	14.76%	5.87%	-0.10%
Total	**-54,920**	**35,941**	**19,318**	**339**	**-9.36%**	**36.61%**	**26.51%**	**0.04%**

TABLE 24 and **TABLE 25** compare the results of the Mandatory Tour Frequency model for workers with a work TAZ in DC between the Baseline scenario and the Increased DC Telecommute scenario. The Mandatory Tour Frequency Model predicts the exact number of Mandatory (work and school) tours for each person with a Mandatory daily activity pattern. The tables show that the share of workers with 1 work tour and the share of workers with 2 work tours decreases from the Baseline alternative, and that work tour shares decrease more for part-time workers than for full-time workers. There are no full-time or part-time workers with a school tour, since students are coded as one of other person types in the model. Note that the total difference in workers across the two scenarios is consistent with the decrease in workers with a Mandatory activity pattern in the Coordinated Daily Activity Pattern model shown in **TABLE 23**.

TABLE 24: WORKERS BY WORK STATUS AND TOTAL WORK TOURS - BASELINE VS. INCREASED DC TELECOMMUTE

	Baseline			Increased DC Telecommute		
Person Type	**1 Work Tour**	**2 Work Tours**	**Total**	**1 Work Tour**	**2 Work Tours**	**Total**
Full-time worker	535,696	20,464	556,160	489,453	18,700	508,153

Part-time worker	30,138	493	30,631	23,334	384	23,718
Total	**565,834**	**20,957**	**586,791**	**512,787**	**19,084**	**531,871**

TABLE 25: CHANGE IN WORKERS BY WORK STATUS AND TOTAL WORK TOURS - BASELINE VS. INCREASED DC TELECOMMUTE

	Scenario - Baseline			Percent Change		
Person Type	**1 Work Tour**	**2 Work Tours**	**Total**	**1 Work Tour**	**2 Work Tours**	**Total**
Full-time worker	-46,243	-1,764	-48,007	-8.63%	-8.62%	-8.63%
Part-time worker	-6,804	-109	-6,913	-22.58%	-22.11%	-22.57%
Total	**-53,047**	**-1,873**	**-54,920**	**-9.38%**	**-8.94%**	**-9.36%**

TABLE 26 and **TABLE 27** compare the results of the Non-Mandatory Tour Frequency model for workers with a work TAZ in DC between the Baseline scenario and the Increased DC Telecommute scenario. The table summarizes the results of both the Individual Non-Mandatory Tour Frequency model (which predicts the number of individual escort, shop, other maintenance, social/recreational, and other discretionary tours), the Joint Tour Frequency Model (which predicts the number of non-mandatory tours where two or more household members participate in the entire tour), and the At-work Subtour Frequency model (which predicts the number of tours that start and end at work). The tables show that the number of workers with no non-mandatory tours decreases by 3,924 workers in the Increased DC Telecommute scenario, or 0.86% (Note: Phase 1 test showed a decrease of 30,068 workers, or 6% decrease) . The share of workers with 1 non-mandatory tour increases by 0.14% and the share of workers with 2 or more non-mandatory tours increases by 5.25% in the Increased DC Telecommute scenario (Note: Phase 1 test showed 11% and 18.5% increases, respectively). These findings are different from Phase 1 but are consistent with expectations because the re-estimated coordinated daily activity pattern model did not find significant coefficients on daily activity patterns for workers who telecommute more than 2-3 days per week. Coefficients for this segment were adjusted after running these sensitivity tests as a result.

TABLE 26: WORKERS BY WORK STATUS AND TOTAL NON-MANDATORY TOURS - BASELINE VS. INCREASED DC TELECOMMUTE

	Baseline				Increased DC Telecommute			
Person Type	**0 Non-Mandatory Tours**	**1 Non-Mandatory Tour**	**2+ Non-Mandatory Tours**	**Total**	**0 Non-Mandatory Tours**	**1 Non-Mandatory Tour**	**2+ Non-Mandatory Tours**	**Total**
Full-time worker	413,764	196,078	57,541	667,383	412,473	195,124	60,215	667,812
Part-time worker	42,568	30,095	17,795	90,458	39,935	31,360	19,073	90,368

Total	**456,332**	**226,173**	**75,336**	**757,841**	**452,408**	**226,484**	**79,288**	**758,180**

TABLE 27: CHANGE IN WORKERS BY WORK STATUS AND TOTAL NON-MANDATORY TOURS - BASELINE VS. INCREASED DC TELECOMMUTE

	Scenario - Baseline				Percent Change			
Person Type	**0 Non-Mandatory Tours**	**1 Non-Mandatory Tour**	**2+ Non-Mandatory Tours**	**Total**	**0 Non-Mandatory Tours**	**1 Non-Mandatory Tour**	**2+ Non-Mandatory Tours**	**Total**
Full-time worker	-1,291	-954	2,674	429	-0.31%	-0.49%	4.65%	0.06%
Part-time worker	-2,633	1,265	1,278	-90	-6.19%	4.20%	7.18%	-0.10%
Total	**-3,924**	**311**	**3,952**	**339**	**-0.86%**	**0.14%**	**5.25%**	**0.04%**

Regarding mode choice, the Gen3 Model shows travel demand reductions, as expected, in the Single-Occupant Vehicle (SOV) mode as well as the High-Occupancy Vehicle (HOV2 and HOV3+) modes due to the increase in telecommuting to DC (**TABLE 28**).

TABLE 28: CHANGE IN TOURS BY MODE - BASELINE VS. INCREASED DC TELECOMMUTE

Tour Mode	Baseline	Increased DC Telecommute	Difference	Percent Difference
Auto SOV	22,625,004	22,553,692	-71,312	-0.3%
Auto 2 Person	9,285,628	9,267,834	-17,794	-0.2%
Auto 3+ Person	5,597,954	5,589,462	-8,492	-0.2%
Walk	3,498,968	3,475,110	-23,858	-0.7%
Bike/Moped	416,806	414,450	-2,356	-0.6%
Walk-Transit	1,550,514	1,534,592	-15,922	-1.0%
PNR-Transit	373,080	369,320	-3,760	-1.0%
KNR-Transit	121,740	121,004	-736	-0.6%
Ridehshare	726,272	723,162	-3,110	-0.4%
School Bus	943,756	943,116	-640	-0.1%
Total	**45,139,722**	**44,823,757**	**-315,965**	**-0.7%**

Highway Traffic Shifts

Highway network level travel demand shifts due to the telecommuting increase to DC are summarized in several tables, as listed below:

- Daily traffic volume shifts by screenline (**TABLE 29**)
- Daily vehicle miles traveled (VMT) shifts by time period (**TABLE 30**)

- Daily vehicle miles traveled (VMT) shifts by area type (**Table 31**)
- Daily vehicle miles traveled (VMT) shifts by facility type (**Table 32**)
- Daily vehicle miles traveled (VMT) shifts by jurisdiction (**Table 33**)

Overall, these highway comparison tables reveal a marginal reduction of highway travel demand, by around 0.8% due to the increase in telecommuting to DC, with slightly higher reductions in DC (**Table 33**). These findings are consistent across daily traffic volume as well as VMT comparisons as the two measures are correlated. Also, the Gen3 Model shows relatively higher percent reductions during the PM and Night time periods than the AM and MD peak periods, likely due to the increase in non-mandatory travel for telecommuting workers.

Overall, the Gen3 Model is predicting a reduction of VMT by 0.89 million vehicle-miles traveled, or by 0.6%, from a Baseline VMT of 160.3 million in the region in year 2018 conditions due to an increase in telecommuting to DC (**Table 33**).

TABLE 29: DAILY TRAFFIC VOLUME SHIFTS BY SCREENLINE – BASELINE VS. INCREASED DC TELECOMMUTE

Screenline	Baseline	Increased DC Telecommute	Difference	% Difference
1	745,753	738,066	-7,687	-1.0%
2	1,090,314	1,071,163	-19,151	-1.8%
3	885,336	876,264	-9,072	-1.0%
4	1,101,902	1,083,116	-18,786	-1.7%
5	1,184,973	1,175,976	-8,997	-0.8%
6	1,723,789	1,705,530	-18,259	-1.1%
7	1,169,988	1,164,608	-5,380	-0.5%
8	1,818,296	1,801,812	-16,484	-0.9%
9	1,058,698	1,056,464	-2,234	-0.2%
10	606,416	606,063	-353	-0.1%
11	319,271	319,316	45	0.0%
12	589,783	588,120	-1,663	-0.3%
13	491,781	489,623	-2,158	-0.4%
14	279,446	276,551	-2,895	-1.0%
15	299,932	297,604	-2,328	-0.8%
16	188,476	186,503	-1,973	-1.0%
17	519,384	516,524	-2,860	-0.6%
18	731,884	729,903	-1,981	-0.3%
19	690,960	689,970	-990	-0.1%
20	1,088,303	1,075,371	-12,932	-1.2%
22	1,729,199	1,711,525	-17,674	-1.0%
23	223,114	221,926	-1,188	-0.5%
24	474,321	470,507	-3,814	-0.8%
25	147,162	146,281	-881	-0.6%
26	484,351	481,037	-3,314	-0.7%
27	442,025	437,947	-4,078	-0.9%
28	210,511	208,982	-1,529	-0.7%
31	173,450	172,586	-864	-0.5%
32	127,118	126,865	-253	-0.2%
33	282,947	282,182	-765	-0.3%
34	146,169	145,051	-1,118	-0.8%
35	919,576	917,258	-2,318	-0.3%
36	81,974	81,980	6	0.0%
37	45,208	45,405	197	0.4%
38	271,942	270,887	-1,055	-0.4%
Total	**22,343,752**	**22,168,966**	**-174,786**	**-0.8%**

Note: Daily traffic volumes were added for a select set of model links with traffic counts

TABLE 30: DAILY VEHICLE MILES TRAVELED (VMT) SHIFTS BY TIME PERIOD – BASELINE VS. INCREASED DC TELECOMMUTE

Time Period	Baseline	Increased DC Telecommute	Difference	% Difference
AM	36,193,886	36,020,196	-173,690	-0.48%
MD	50,227,550	51,285,146	-184,097	-0.36%
PM	51,469,243	50,118,334	-109,216	-0.22%
NT	40,113,407	39,640,365	-473,042	-1.18%
Total	**178,004,086**	**177,064,041**	**-940,045**	**-0.53%**

Note: VMT values were added for modeled network links

TABLE 31: DAILY VEHICLE MILES TRAVELED (VMT) SHIFTS BY AREA TYPE– BASELINE VS. INCREASED DC TELECOMMUTE

Area Type	Baseline	Increased DC Telecommute	Difference	% Difference
1	2,310,738	2,275,616	-35,122	-1.5%
2	11,165,462	11,085,932	-79,530	-0.7%
3	15,365,691	15,298,630	-67,061	-0.4%
4	9,958,667	9,905,337	-53,330	-0.5%
5	16,635,113	16,556,817	-78,296	-0.5%
6	17,259,329	17,185,416	-73,913	-0.4%
Total	**72,695,000**	**72,588,118**	**-106,882**	**-0.1%**

Notes:

1. Area Type codes are defined in the model based on population and employment densities, with 1 representing high employment and population densities, and 6 reflecting low employment and population densities.
2. Daily VMT values were added for a select set of model links with traffic counts.

TABLE 32: DAILY VEHICLE MILES TRAVELED (VMT) SHIFTS BY FACILITY TYPE – BASELINE VS. INCREASED DC TELECOMMUTE

Facility Type	Baseline	Increased DC Telecommute	Difference	% Difference
Freeway	33,085,660	33,034,314	-51,346	-0.2%
Major Arterial	17,435,220	17,414,835	-20,385	-0.1%
Minor Arterial	14,189,411	14,173,380	-16,031	-0.1%
Collector	2,522,445	2,517,865	-4,580	-0.2%
Expressway	5,434,486	5,420,186	-14,300	-0.3%
Ramp	27,778	27,538	-240	-0.9%
Total	**72,695,000**	**72,588,118**	**-106,882**	**-0.1%**

Note: Daily VMT values were added for a select set of model links with traffic counts

TABLE 33: DAILY VEHICLE MILES TRAVELED (VMT) SHIFTS BY JURISDICTION – BASELINE VS. INCREASED DC TELECOMMUTE

Jurisdiction	Baseline	Increased DC Telecommute	Difference	% Difference
0 District of Columbia	8,941,362	8,783,482	-157,880	-1.8%
1 Montgomery County	20,328,674	20,219,296	-109,378	-0.5%
2 Prince George's County	22,858,203	22,625,604	-232,599	-1.0%
3 Arlington County	4,115,028	4,073,309	-41,719	-1.0%
4 City of Alexandria	2,276,859	2,255,418	-21,441	-0.9%
5 Fairfax County	26,522,312	26,426,176	-96,136	-0.4%
6 Loudoun County	7,681,832	7,676,754	-5,078	-0.1%
7 Prince William County	9,353,674	9,339,198	-14,476	-0.2%
9 Frederick County	7,864,143	7,837,212	-26,931	-0.3%
10 Howard County	11,213,399	11,174,348	-39,051	-0.3%
11 Anne Arundel County	15,570,936	15,507,167	-63,769	-0.4%
12 Charles County	3,101,885	3,084,707	-17,178	-0.6%
14 Carrol County	4,113,457	4,103,293	-10,164	-0.2%
15 Calvert County	1,465,150	1,460,309	-4,841	-0.3%
16 St. Mary's County	1,894,029	1,877,587	-16,442	-0.9%
17 King George County	660,149	652,680	-7,469	-1.1%
18 City of Fredericksburg	809,963	808,729	-1,234	-0.2%
19 Stafford County	3,575,635	3,562,548	-13,087	-0.4%
20 Spotsylvania County	2,339,762	2,338,231	-1,531	-0.1%
21 Fauquier County	3,206,525	3,204,562	-1,963	-0.1%
22 Clarke County	1,029,370	1,027,745	-1,625	-0.2%
23 Jefferson County	1,380,098	1,376,769	-3,329	-0.2%
Total	160,302,445	159,415,124	-887,321	-0.6%
TPB Planning Area	113,043,972	112,321,156	-722,816	-0.6%
Non-TPB Member Area	47,258,473	47,093,968	-164,505	-0.3%
Air Quality Nonattainment Area (8-Hour Ozone)	**114,509,122**	**113,781,465**	**-727,657**	**-0.6%**

Note: Daily VMT values were added for all HPMS links in the model

Transit Ridership Shifts

Transit network level travel demand shifts due to the increase in DC telecommuting are summarized in several tables, listed below:

- Transit boardings by mode (**TABLE 34**)
- Transit boardings by operator (**TABLE 35**)
- Metrorail Station entries by station group (**TABLE 36**)

Overall, these transit comparison tables reveal a small reduction in transit ridership, by around 5.2% or over 85,930 fewer daily boardings across all transit modes, due to the increase in telecommuting to DC.

As expected, the ridership of Metrorail is impacted the most, with 58,135 fewer boardings, or roughly a 6.1% drop (**TABLE 35**). Among the various Metrorail lines, the Red Line stations in the DC core show the highest drop in boardings, 7.4%, and the Orange/Blue Line stations in the Virginia/DC core show the second highest drop in boardings, 7.6%. (**TABLE 36**).

The ridership of Amtrak/VRE commuter rail is predicted to also drop by 777 boardings, 5.2%. Also, MARC commuter trains show a small decrease of 1,809 riders. Additionally, the local DC area buses operated by Arlington Transit ART, Alexandria DASH, Fairfax Connector, Prince George's County TheBus, Montgomery County RideOn, and WMATA are predicted to have around 17,843 fewer riders when all combined.

TABLE 34: TRANSIT BOARDINGS BY MODE – BASELINE VS. INCREASED DC TELECOMMUTE

Transit Mode	Baseline	Increased DC Telecommute	Difference	% Difference
Local Metrobus	336,825	322,211	-14,614	-4.3%
Express Metrobus	39,306	36,901	-2,405	-6.1%
Metrorail	948,667	890,532	-58,135	-6.1%
Commuter Rail	59,906	57,320	-2,586	-4.3%
Other Local Bus in the WMATA Area	161,473	158,145	-3,328	-2.1%
Other Express Bus in the WMATA Area	5,629	5,491	-138	-2.5%
Other Local Bus beyond the WMATA Area	25,341	25,226	-115	-0.5%
Other Express Bus beyond the WMATA Area	61,643	57,217	-4,426	-7.2%
Bus Rapid Transit (BRT) and Streetcar	4,603	4,421	-182	-4.0%
All Bus	630,217	605,190	-25,027	-4.0%
Total	**1,643,393**	**1,557,463**	**-85,930**	**-5.2%**

TABLE 35: TRANSIT BOARDINGS BY OPERATOR/SERVICE – BASELINE VS. INCREASED DC TELECOMMUTE

Transit Operator/Service	Baseline	Increased DC Telecommute	Difference	% Difference
WMATA Metrorail	948,667	890,532	-58,135	-6.1%
AMTRAK / VRE commuter rail	14,974	14,196	-777	-5.2%
MARC commuter rail	44,932	43,123	-1,809	-4.0%
Arlington Transit ART / Alexandria DASH / Fairfax Connector / Prince George's County TheBus / Montgomery County RideOn / WMATA bus	497,675	479,832	-17,843	-3.6%
Alexandria DASH / Fairfax Connector / WMATA bus	58,539	55,022	-3,517	-6.0%
DC Circulator bus	6,876	6,597	-279	-4.1%
Annapolis Transit / Calvert County CCPT / Carroll County / Fairfax City Bus / GMU Shuttle / Loudoun County Local / Saint Mary's County STS / Frederick County TransIT / Charles County VanGO bus	22,350	22,264	-86	-0.4%
Washington Flyer Coach / Loudoun County Commuter Bus / MARTZ Bus / Maryland Commuter Bus	48,039	44,586	-3,453	-7.2%
DC OKLAH	1,341	1,309	-31	-2.3%
Total	**1,643,393**	**1,557,463**	**-85,930**	**-5.2%**

TABLE 36: METRORAIL STATION ENTRIES BY STATION GROUP – BASELINE VS. INCREASED DC TELECOMMUTE

Station Group	Baseline	Increased DC Telecommute	Difference	% Difference
Red Line - "A" route MD outside Beltway	28,862	27,584	-1,278	-4.4%
Red Line - "A" route MD inside Beltway	28,721	27,554	-1,167	-4.1%
Red Line - "A" route DC non-core	25,769	24,265	-1,504	-5.8%
Red Line - DC core	145,497	134,690	-10,808	-7.4%
Red Line - "B" route DC non-core	28,248	26,568	-1,680	-5.9%
Red Line - "B" route MD	29,514	27,760	-1,754	-5.9%
Green Line - "E" route MD	15,993	15,280	-714	-4.5%
Green Line - "E" route DC non-core	18,992	17,817	-1,176	-6.2%
Green Line - DC core	41,296	37,834	-3,461	-8.4%
Green Line - "F" route DC non-core	24,857	23,307	-1,550	-6.2%
Green Line - "F" route MD	15,841	14,674	-1,166	-7.4%
Blue/Yellow Line - VA Fairfax	18,809	17,481	-1,328	-7.1%
Blue/Yellow Line - VA Alexandria	15,505	15,043	-462	-3.0%
Blue/Yellow Line - VA Core	32,966	31,504	-1,462	-4.4%
Orange Line - VA Fairfax	11,148	10,491	-657	-5.9%
Orange/Silver Line - VA Arlington non-core	41,425	39,654	-1,771	-4.3%
Orange/Blue/Silver Line - VA/DC core	114,078	105,435	-8,644	-7.6%
Orange/Blue/Silver Line - DC non-core	16,624	15,832	-792	-4.8%
Orange Line - DC/MD	16,576	15,783	-793	-4.8%
Blue/Silver Line - DC/MD	20,296	18,945	-1,350	-6.7%
Silver Line - Phase I & Phase 2	20,784	20,152	-632	-3.0%
Total	**711,801**	**667,652**	**-44,150**	**-6.2%**

Trip Flow Shifts

The comparison of trip origin-destination flow changes due to an increase in telecommuting to DC is summarized in several tables, listed below:

- Intra-jurisdictional work trips using the Single-Occupant Vehicle (SOV) mode (**TABLE 37**)
- Inter-jurisdictional work trip origins using the SOV mode (**TABLE 38**)
- Inter-jurisdictional work trip destinations using the SOV mode (**TABLE 39**)
- Intra-jurisdictional shopping trips using the SOV mode (**TABLE 40**)
- Inter-jurisdictional shopping trip origins using the SOV mode (**TABLE 41**)
- Inter-jurisdictional shopping trip destinations using the SOV mode (**TABLE 42**)

Intra-jurisdictional work trips using the SOV mode (**TABLE 37**) show a decrease, as expected, for a majority of the jurisdictions in the modeled area including DC, which had the highest decrease of 17,356 trips. This decrease in local work trips using the SOV mode accounted for an overall 1.4% decrease against the backdrop of 3.05 million local work trips using the SOV mode in year 2018 travel conditions.

In parallel, the inter-jurisdictional work trip origins using the SOV mode (**TABLE 38**) also shows a decrease, as expected, in trips, due to the increase in telecommuting to DC. Overall, these reductions total 42,656 trips, or a 2.0% decrease from the 2.2 million trips in the Baseline scenario. The same trend of SOV trip reductions was also evident when the inter-jurisdictional work trip destinations using the SOV mode were compared (**TABLE 39**) between the Baseline and Increased Telecommuting to DC scenario.

The intra-jurisdictional shopping trips using the SOV mode (**TABLE 40**) shows an increase, as expected, for all of the jurisdictions in the modeled area including DC, which had an increase of 801 trips. This increase in shopping trips using the SOV mode accounted for an overall 0.5% increase against the backdrop of 1.36 million local shopping trips using the SOV mode in year 2018 travel conditions.

Similarly, inter-jurisdictional shopping trip origins using the SOV mode (Table 41) shows a small increase, as expected, due to an increase in telecommuting to DC. Overall, these increases total 1,804 trips, or 0.7% increase from the 0.25 million trips in the Baseline scenario. The same trend of SOV trip increases was also evident when the inter-jurisdictional shopping trip destinations using the SOV mode were compared (**TABLE 42**) between the Baseline and Increased Telecommuting to DC scenario.

TABLE 37: INTRA-JURISDICTIONAL WORK TRIPS USING SOV MODE – BASELINE VS. INCREASED DC TELECOMMUTE

Jurisdiction	Baseline	Increased DC Telecommute	Difference	% Difference
0 District of Columbia	217,906	200,550	-17,356	-8.0%
1 Montgomery County	483,071	477,699	-5,372	-1.1%
2 Prince George's County	311,826	307,750	-4,076	-1.3%
3 Arlington County	55,779	55,038	-741	-1.3%
4 City of Alexandria	35,566	35,057	-509	-1.4%
5 Fairfax County	587,547	582,407	-5,140	-0.9%
6 Loudoun County	174,788	173,182	-1,606	-0.9%
7 Prince William County	212,768	210,824	-1,944	-0.9%
9 Frederick County	122,371	121,442	-929	-0.8%
10 Howard County	148,366	147,481	-885	-0.6%
11 Anne Arundel County	324,645	322,431	-2,214	-0.7%
12 Charles County	60,270	59,718	-552	-0.9%
14 Carrol County	77,155	76,539	-616	-0.8%
15 Calvert County	32,992	32,825	-167	-0.5%
16 St. Mary's County	72,816	71,973	-843	-1.2%
17 King George County	7,423	7,364	-59	-0.8%
18 City of Fredericksburg	11,387	11,328	-59	-0.5%
19 Stafford County	41,088	40,716	-372	-0.9%
20 Spotsylvania County	32,328	32,077	-251	-0.8%
21 Fauquier County	19,710	19,505	-205	-1.0%
22 Clarke County	2,287	2,250	-37	-1.6%
23 Jefferson County	18,337	18,132	-205	-1.1%
Total	**3,050,426**	**3,006,288**	**-44,138**	**-1.4%**

TABLE 38: INTER-JURISDICTIONAL WORK TRIP ORIGINS USING SOV MODE – BASELINE VS. INCREASED DC TELECOMMUTE

Jurisdiction	Baseline	Increased DC Telecommute	Difference	% Difference
0 District of Columbia	274,515	259,472	-15,043	-5.5%
1 Montgomery County	242,131	237,433	-4,698	-1.9%
2 Prince George's County	277,633	270,864	-6,769	-2.4%
3 Arlington County	139,994	137,970	-2,024	-1.4%
4 City of Alexandria	101,398	99,943	-1,455	-1.4%
5 Fairfax County	359,870	355,458	-4,412	-1.2%
6 Loudoun County	116,078	115,783	-295	-0.3%
7 Prince William County	129,497	128,363	-1,134	-0.9%
9 Frederick County	54,737	54,166	-571	-1.0%
10 Howard County	103,205	101,729	-1,476	-1.4%
11 Anne Arundel County	105,200	103,176	-2,024	-1.9%
12 Charles County	42,205	41,574	-631	-1.5%
14 Carrol County	32,737	32,262	-475	-1.5%
15 Calvert County	22,562	22,276	-286	-1.3%
16 St. Mary's County	17,290	17,061	-229	-1.3%
17 King George County	7,724	7,613	-111	-1.4%
18 City of Fredericksburg	21,947	21,771	-176	-0.8%
19 Stafford County	41,832	41,352	-480	-1.1%
20 Spotsylvania County	25,929	25,782	-147	-0.6%
21 Fauquier County	17,496	17,373	-123	-0.7%
22 Clarke County	4,379	4,342	-37	-0.8%
23 Jefferson County	12,689	12,629	-60	-0.5%
Total	**2,151,048**	**2,108,392**	**-42,656**	**-2.0%**

TABLE 39: INTER-JURISDICTIONAL WORK TRIP DESTINATIONS USING SOV MODE – BASELINE VS. INCREASED DC TELECOMMUTE

Jurisdiction	Baseline	Increased DC Telecommute	Difference	% Difference
0 District of Columbia	274,252	259,217	-15,035	-5.5%
1 Montgomery County	242,050	237,462	-4,588	-1.9%
2 Prince George's County	277,663	270,803	-6,860	-2.5%
3 Arlington County	139,955	137,923	-2,032	-1.5%
4 City of Alexandria	101,317	99,718	-1,599	-1.6%
5 Fairfax County	359,336	355,206	-4,130	-1.1%
6 Loudoun County	116,074	115,740	-334	-0.3%
7 Prince William County	130,208	129,049	-1,159	-0.9%
9 Frederick County	54,623	54,094	-529	-1.0%
10 Howard County	103,081	101,630	-1,451	-1.4%
11 Anne Arundel County	105,128	103,161	-1,967	-1.9%
12 Charles County	42,165	41,562	-603	-1.4%
14 Carrol County	32,777	32,274	-503	-1.5%
15 Calvert County	22,605	22,311	-294	-1.3%
16 St. Mary's County	17,358	17,061	-297	-1.7%
17 King George County	7,762	7,673	-89	-1.1%
18 City of Fredericksburg	22,060	21,869	-191	-0.9%
19 Stafford County	42,150	41,578	-572	-1.4%
20 Spotsylvania County	25,977	25,812	-165	-0.6%
21 Fauquier County	17,477	17,327	-150	-0.9%
22 Clarke County	4,349	4,301	-48	-1.1%
23 Jefferson County	12,681	12,621	-60	-0.5%
Total	**2,151,048**	**2,108,392**	**-42,656**	**-2.0%**

TABLE 40: INTRA-JURISDICTIONAL SHOPPING TRIPS USING SOV MODE – BASELINE VS. INCREASED DC TELECOMMUTE

Jurisdiction	Baseline	Increased DC Telecommute	Difference	% Difference
0 District of Columbia	67,405	68,206	801	1.2%
1 Montgomery County	211,334	211,881	547	0.3%
2 Prince George's County	161,501	162,167	666	0.4%
3 Arlington County	30,137	30,367	230	0.8%
4 City of Alexandria	22,063	22,360	297	1.3%
5 Fairfax County	234,154	235,585	1,431	0.6%
6 Loudoun County	66,251	66,276	25	0.0%
7 Prince William County	103,107	103,820	713	0.7%
9 Frederick County	58,799	59,015	216	0.4%
10 Howard County	68,564	69,093	529	0.8%
11 Anne Arundel County	135,723	136,289	566	0.4%
12 Charles County	32,405	32,770	365	1.1%
14 Carrol County	39,890	39,971	81	0.2%
15 Calvert County	19,038	19,106	68	0.4%
16 St. Mary's County	25,808	25,928	120	0.5%
17 King George County	4,491	4,488	-3	-0.1%
18 City of Fredericksburg	5,997	6,019	22	0.4%
19 Stafford County	23,635	23,741	106	0.4%
20 Spotsylvania County	17,902	18,004	102	0.6%
21 Fauquier County	13,634	13,657	23	0.2%
22 Clarke County	3,039	3,059	20	0.7%
23 Jefferson County	13,889	13,842	-47	-0.3%
Total	**1,358,766**	**1,365,644**	**6,878**	**0.5%**

TABLE 41: INTER-JURISDICTIONAL SHOPPING TRIP ORIGINS USING SOV MODE – BASELINE VS. INCREASED DC TELECOMMUTE

Jurisdiction	Baseline	Increased DC Telecommute	Difference	% Difference
0 District of Columbia	22,706	22,990	284	1.3%
1 Montgomery County	26,523	26,877	354	1.3%
2 Prince George's County	36,961	37,343	382	1.0%
3 Arlington County	22,389	22,565	176	0.8%
4 City of Alexandria	20,820	20,929	109	0.5%
5 Fairfax County	43,638	43,877	239	0.5%
6 Loudoun County	10,920	10,987	67	0.6%
7 Prince William County	10,045	10,100	55	0.5%
9 Frederick County	3,348	3,325	-23	-0.7%
10 Howard County	10,335	10,421	86	0.8%
11 Anne Arundel County	9,903	9,937	34	0.3%
12 Charles County	4,431	4,476	45	1.0%
14 Carrol County	2,765	2,757	-8	-0.3%
15 Calvert County	1,899	1,910	11	0.6%
16 St. Mary's County	1,564	1,544	-20	-1.3%
17 King George County	584	602	18	3.1%
18 City of Fredericksburg	6,445	6,456	11	0.2%
19 Stafford County	5,824	5,808	-16	-0.3%
20 Spotsylvania County	5,174	5,167	-7	-0.1%
21 Fauquier County	2,025	2,045	20	1.0%
22 Clarke County	510	499	-11	-2.2%
23 Jefferson County	629	627	-2	-0.3%
Total	249,438	251,242	1,804	0.7%

TABLE 42: INTER-JURISDICTIONAL SHOPPING TRIP DESTINATIONS USING SOV MODE– BASELINE VS. INCREASED DC TELECOMMUTE

Jurisdiction	Baseline	Increased DC Telecommute	Difference	% Difference
0 District of Columbia	22,767	22,910	143	0.6%
1 Montgomery County	26,480	26,858	378	1.4%
2 Prince George's County	37,032	37,459	427	1.2%
3 Arlington County	22,328	22,540	212	0.9%
4 City of Alexandria	20,954	21,051	97	0.5%
5 Fairfax County	43,614	43,898	284	0.7%
6 Loudoun County	10,824	10,878	54	0.5%
7 Prince William County	10,033	10,100	67	0.7%
9 Frederick County	3,338	3,313	-25	-0.7%
10 Howard County	10,232	10,338	106	1.0%
11 Anne Arundel County	9,979	9,991	12	0.1%
12 Charles County	4,421	4,472	51	1.2%
14 Carrol County	2,806	2,801	-5	-0.2%
15 Calvert County	1,901	1,904	3	0.2%
16 St. Mary's County	1,554	1,540	-14	-0.9%
17 King George County	595	607	12	2.0%
18 City of Fredericksburg	6,484	6,509	25	0.4%
19 Stafford County	5,798	5,767	-31	-0.5%
20 Spotsylvania County	5,162	5,170	8	0.2%
21 Fauquier County	2,005	2,016	11	0.5%
22 Clarke County	504	497	-7	-1.4%
23 Jefferson County	627	623	-4	-0.6%
Total	**249,438**	**251,242**	**1,804**	**0.7%**

4.0 ARLINGTON MEMORIAL BRIDGE CLOSED TO AUTO AND TRUCK TRAFFIC

This chapter describes the results of the Arlington Memorial Bridge Closure scenario, where the Arlington Memorial Bridge across Potomac River was closed to auto and truck traffic but public transit vehicles were allowed.

4.1 DESCRIPTION

This scenario is to test the model's sensitivity to roadway capacity reductions.[11] Specifically, Arlington Memorial Bridge, known colloquially as "Memorial Bridge," was closed to autos and trucks, but the transit service on the bridge was kept intact. In this model run, three "limit code" variables (AMLIMIT, PMLIMIT, OPLIMIT) for two Arlington Memorial Bridge links (20294-20925, 20925-20294) were changed from "4" (all vehicles allowed, other than trucks) to 9 (transit only) in the "link.dbf" file.[12] The Baseline scenario was compared to the Memorial Bridge Closure Scenario, which is labeled as "Bridge Closure" in the subsequent summary tables. The location of the Arlington Memorial Bridge (in red) and other major Potomac River crossings are shown in **FIGURE 4**.

[11] Depending on whether we would like to examine short-term or long-term effects, there could be two different approaches to model a bridge closure scenario. To simulate the short-term effects of a bridge closure, one may run the travel model for assignment only with no speed feedback, which essentially freezes the trip tables. This would be a reasonable approach if the bridge closure is temporary. To examine the model's sensitivity in the long term, on the other hand, one may run the model with speed feedback, which would allow travelers to change their travel destinations (such as work/school locations or shopping destinations), departure times, travel modes, etc. in response to a permanent closure of a bridge. This scenario analysis adopts the second approach with the assumption of a permanent bridge closure.

[12] In its normal configuration, Arlington Memorial Bridge is closed to truck traffic, allowing only light-duty vehicles and transit (buses).

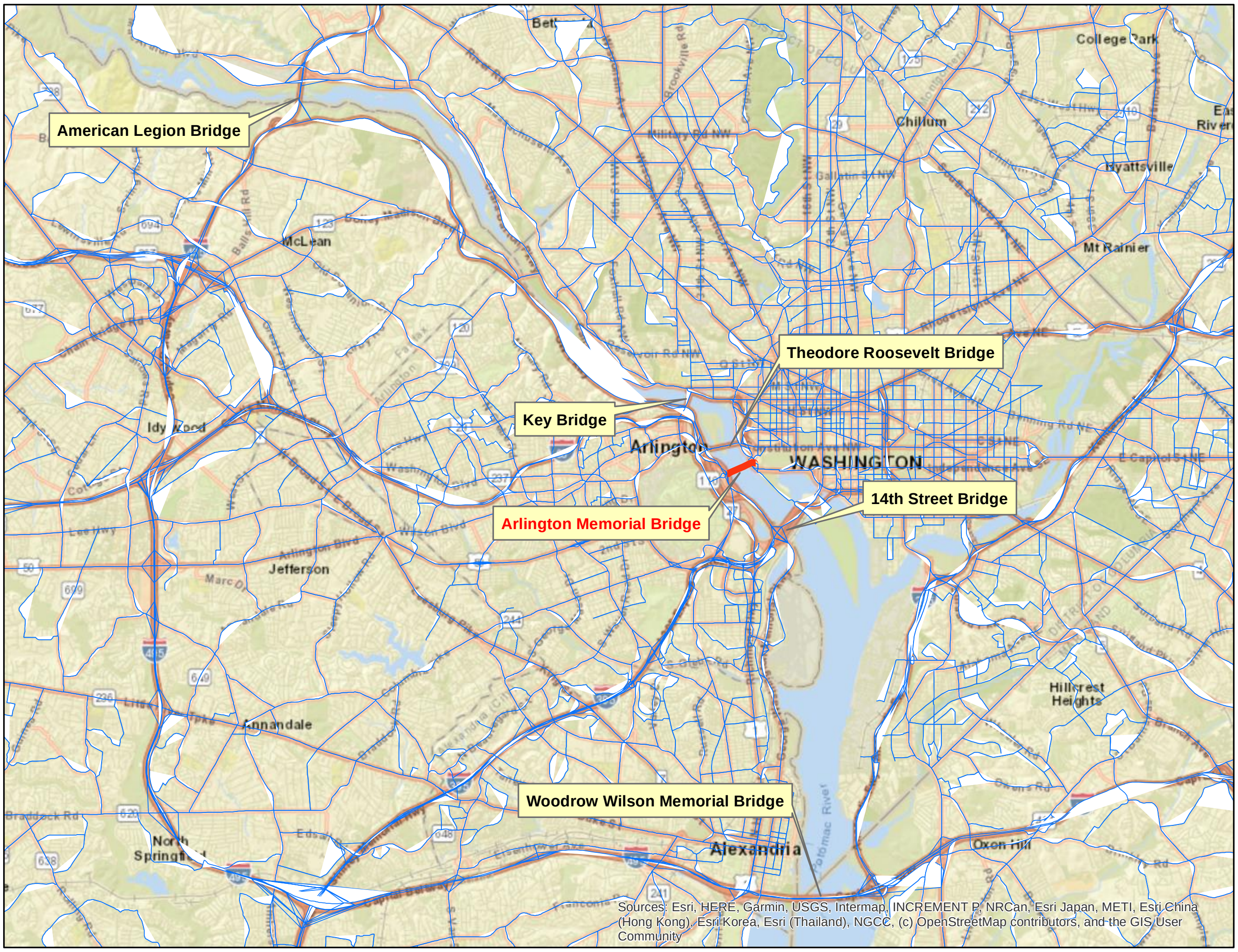

FIGURE 4: ARLINGTON MEMORIAL BRIDGE AND OTHER NEARBY BRIDGE ALTERNATIVES

4.2 EXPECTED OUTCOMES

We expect:

- A decrease in the county-to-county flows of workers, particularly between counties that may require the use of the Memorial Bridge to cross the Potomac River.
- Overall, slightly shorter trip lengths as some people forgo crossing the Potomac River due to the bridge closure, while the trip lengths between DC and some suburban Virginia jurisdictions may become longer due to the detour to alternative bridges.
- No noticeable change in time-of-day choice due to the bridge closure for all periods.
- More traffic using other bridges crossing the Potomac River, such as Theodore Roosevelt Bridge and 14th Street Bridge.

- More congestion and lower vehicle travel speeds, particularly in the regional core (DC, City of Alexandria and Arlington County).
- A decrease in total travel measured by Vehicle Miles of Travel (VMT) or Vehicle Hours of Travel (VHT), and an increase in Vehicle Hours of Delay (VHD).
- A shift from auto to transit modes, such as Metrorail, bus, and VRE, because we retain transit over the bridge. The tour mode choice will likely show some reductions in auto tours between Virginia and DC.

4.3 ACTUAL OUTCOMES

At the regional level, **TABLE 43** shows negligible changes in the total number of tours, trips, and stops, as expected. The bridge closure resulted in 102,000 less VMT (0.089% decrease than the Baseline scenario) as reported by the visualizer (the actual assigned VMT decreases by 475k, which is more accurate).

TABLE 43: REGIONAL TRAVEL MEASURES - BASELINE VS. BRIDGE CLOSURE

	Baseline	Bridge Closure	Difference	% Difference
Total population	7,250,066	7,250,066	0	0.000%
Total households	2,790,357	2,790,357	0	0.000%
Total tours	9,245,201	9,245,053	-148	-0.002%
Total trips	23,917,718	23,917,747	29	0.000%
Total stops	5,427,316	5,427,641	325	0.006%
Total VMT	114,940,412	114,838,576	-101,836	-0.089%

Because of the marginal differences in total tours, stops, and trips, there are indistinguishable changes to travel measures as well, such as tours per person and trips per household, as indicated in **FIGURE 5**.

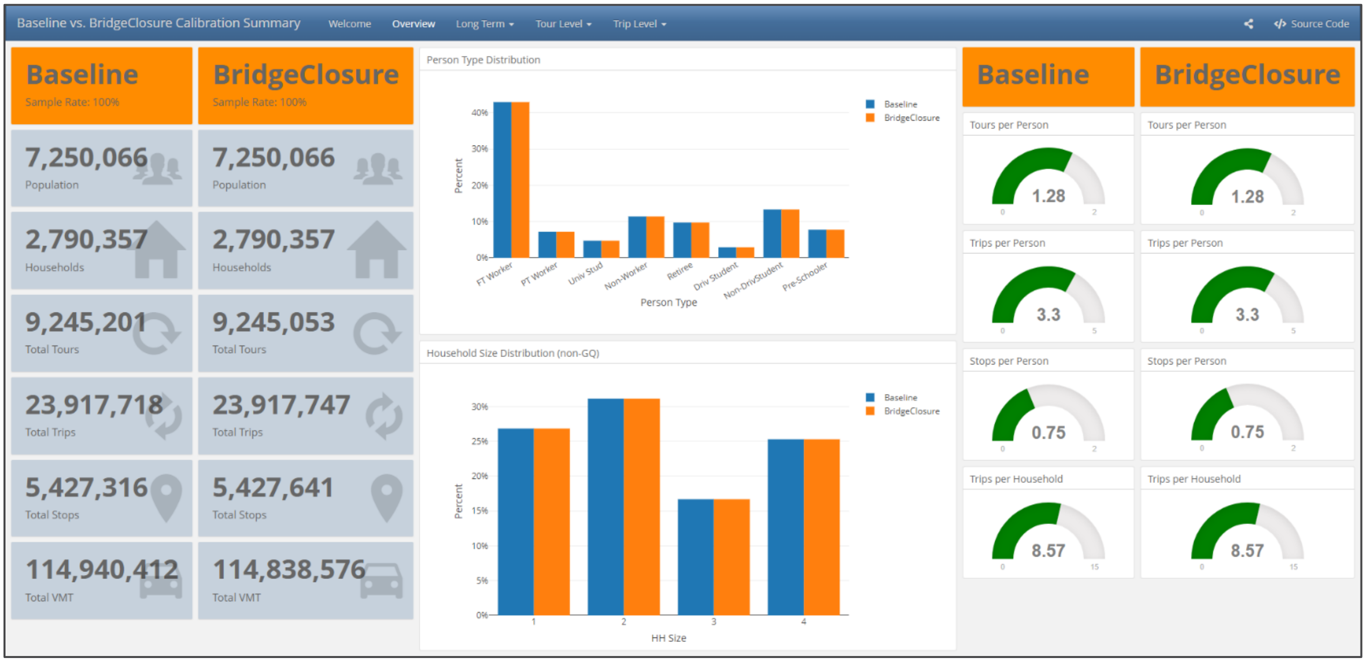

FIGURE 5: VISUALIZER SUMMARY - BASELINE VS. BRIDGE CLOSURE:

The commuting flow tables show jurisdiction-to-jurisdiction flows of workers. It should be mentioned that all the trip flow tables presented in this report are in Origin-Destination (O-D) format. As expected, worker flows traveling from suburban jurisdictions (e.g., Fairfax County) to the urban core (e.g., DC or Alexandria) changed, as shown in **TABLE 44** and **TABLE 45**. Most jurisdiction-to-jurisdiction interchanges that would likely use the Arlington Memorial Bridge when it is open show a decrease in worker flows in the Memorial Bridge Closure Scenario. For example, the flows from Fairfax County to DC and from DC to Fairfax County both dropped by 1.1% and by 2.7%, respectively. However, there are also decreases in worker flows between jurisdictions located on different sides of the Potomac River, even though the predominant commuting routes would tend to favor other bridges to cross the river. For example, the Montgomery to Alexandria worker flow, which would likely use the American Legion Memorial Bridge, fell by 3%. On the other hand, commuting flows traveling on the same side of the bridge show a small increase, such as a 0.6% increase in the Fairfax to Arlington flow, as the closure of Memorial Bridge shifts some of the workplace locations from across the river to the same side of the river. Overall, 379 (or 0.05%) fewer workers would work in DC. Similar to the result from the telecommute frequency test, the Phase 2 models predict much greater stability in the number of workers who choose to work in each TAZ than the Phase 1 models, due to the use of the simulation constraint mechanism versus the shadow pricing mechanism. Some of the differences cannot be explained by the bridge closure and are due to Monte Carlo variation used to select alternatives in destination choice.

TABLE 44: CHANGES IN COUNTY-TO-COUNTY WORKER FLOWS – BASELINE VS. BRIDGE CLOSURE

Jurisdiction	Alexandria	Anne Arundel	Arlington	Calvert	Carroll	Charles	Clarke	DC	Fairfax	Fauquier	Frederick	Fredericksburg	Howard	Jefferson	King George	Loudoun	Montgomery	Prince George's	Prince William	Spotsylvania	St. Mary's	Stafford	Total
Alexandria	128	-8	4	5	1	2	n.a.	-319	-21	4	2	1	-1	0	4	11	75	34	61	1	8	1	-7
Anne Arundel	-53	-3	-37	17	-2	33	-1	-168	-74	3	-40	-1	384	0	17	-31	264	-328	5	0	26	1	12
Arlington	79	-12	262	-1	1	-8	n.a.	-565	169	3	9	1	-23	n.a.	3	69	63	-122	49	-2	4	-5	-26
Calvert	31	77	-65	121	-1	13	n.a.	-130	-28	1	0	2	-2	n.a.	5	-19	-48	11	10	0	22	0	0
Carroll	-15	22	-19	4	181	-5	-3	47	-3	2	-35	0	-114	-4	1	-119	30	27	6	0	-3	0	0
Charles	-26	-60	-55	-25	2	87	n.a.	243	-17	2	-2	0	19	n.a.	1	-7	-17	-114	-20	0	-2	-10	-1
Clarke	1	-3	1	-1	-1	-2	8	-21	2	-1	4	-4	5	14	n.a.	-15	-5	4	6	0	n.a.	7	0
DC	-150	-46	-331	-10	1	13	n.a.	641	-429	0	-4	1	30	1	-4	37	57	210	-2	0	9	-4	20
Fairfax	-147	-56	303	4	-3	9	-3	-985	665	15	-1	2	-31	0	-3	255	-35	-58	61	2	-3	-2	-11
Fauquier	-12	-2	-4	3	-3	2	1	-11	78	-103	9	21	-4	3	8	-4	1	1	-2	23	-2	-4	-1
Frederick	9	-8	8	-5	15	-5	-4	63	17	-1	3	-2	-82	-1	-2	96	-47	-46	0	-1	-4	-1	2
Fredericksburg	9	0	-16	-2	n.a.	16	n.a.	1	8	3	n.a.	-19	3	n.a.	15	3	4	4	-19	-12	4	-4	0
Howard	-51	-66	-109	24	-8	-12	-2	-328	213	-2	-13	-1	409	0	-10	-88	250	-192	6	-1	-27	3	-5
Jefferson	-18	23	-30	0	-12	-1	55	9	-94	-11	54	3	23	24	n.a.	-113	53	15	27	-2	-1	-5	0
King George	2	11	9	-3	n.a.	0	n.a.	6	-7	0	-2	13	-5	n.a.	9	-1	7	-9	11	5	-17	-30	0
Loudoun	-26	-2	-2	6	6	-3	0	138	-118	6	48	-3	-7	-8	-2	-99	-34	17	83	2	3	4	9
Montgomery	-155	-423	-77	7	3	1	0	621	10	-1	-93	1	-64	3	-1	-75	278	84	-121	3	3	1	5
Prince George's	-106	-297	-299	-63	15	98	n.a.	844	-391	3	6	3	-107	-2	18	-103	165	246	-10	-2	7	-4	22
Prince William	50	-31	-11	10	-1	-19	0	-330	223	16	-15	-22	9	-1	6	-5	24	30	47	10	-7	15	-2
Spotsylvania	8	3	-22	-15	0	6	n.a.	-31	43	-12	3	32	4	0	-49	-1	-5	-4	26	36	11	-33	0
St. Mary's	-24	7	11	-24	0	-27	n.a.	-18	-18	-1	-4	4	-7	n.a.	-10	-4	8	-39	1	4	137	3	-1
Stafford	19	7	-27	1	4	-15	-1	-86	122	-23	8	-2	-11	-1	4	17	-16	10	-49	-39	4	73	-1

Total	**-447**	**-867**	**-506**	**53**	**199**	**183**	**51**	**-379**	**350**	**-97**	**-61**	**30**	**428**	**28**	**12**	**-196**	**1,072**	**-219**	**176**	**27**	**172**	**6**	**15**

TABLE 45: PERCENT CHANGE IN COUNTY-TO-COUNTY WORKER FLOWS – BASELINE VS. BRIDGE CLOSURE

Jurisdiction	Alexandria	Anne Arundel	Arlington	Calvert	Carroll	Charles	Clarke	DC	Fairfax	Fauquier	Frederick	Fredericksburg	Howard	Jefferson	King George	Loudoun	Montgomery	Prince George's	Prince William	Spotsylvania	St. Mary's	Stafford	Total
Alexandria	0.7	-2.5	0.0	13.5	16.7	0.8		-1.3	-0.1	23.5	5.9	6.7	-0.5	0.0	40.0	1.6	1.9	0.8	6.3	8.3	29.6	1.6	-0.01
Anne Arundel	-3.3	0.0	-0.9	1.0	-0.6	4.2	-100.0	-0.9	-1.6	20.0	-13.7	-50.0	1.7	0.0	27.4	-6.4	2.1	-1.0	1.6	0.0	9.0	7.1	0.00
Arlington	1.0	-3.1	0.7	-4.0	11.1	-5.2		-1.2	0.5	18.8	18.0	14.3	-7.8		33.3	6.2	0.9	-3.0	6.2	-18.2	19.0	-10.9	-0.02
Calvert	5.0	2.6	-6.1	0.7	-14.3	1.1		-2.0	-1.9	50.0	0.0	22.2	-0.8		7.7	-25.3	-4.0	0.2	11.0	0.0	0.4	0.0	0.00
Carroll	-7.7	0.8	-3.1	14.3	0.4	-19.2	-18.8	1.3	-0.2	8.7	-0.5	0.0	-1.1	-7.0	16.7	-9.7	0.3	1.6	3.3	0.0	-13.6	0.0	0.00
Charles	-0.8	-4.1	-1.5	-1.6	40.0	0.3		1.9	-0.3	28.6	-10.0	0.0	5.1		0.1	-2.8	-0.7	-0.9	-4.9	0.0	-0.1	-7.2	0.00
Clarke	2.2	-15.8	0.9	-100.0	-6.3	-40.0	0.9	-7.1	0.1	-0.8	1.6	-100.0	25.0	2.4		-0.8	-2.3	11.4	1.5	0.0		100.0	0.00
DC	-2.4	-1.7	-1.7	-8.4	2.3	3.2		0.2	-2.7	0.0	-3.6	14.3	1.3	50.0	-13.8	3.5	0.2	1.0	-0.3	0.0	16.4	-10.3	0.01
Fairfax	-0.5	-3.9	0.6	3.0	-4.4	1.1	-20.0	-1.1	0.2	2.5	-0.2	1.3	-2.5	0.0	-10.0	1.0	-0.2	-0.4	0.3	1.6	-2.3	-0.3	0.00
Fauquier	-4.8	-5.9	-0.6	300.0	-42.9	9.5	7.7	-0.6	1.2	-1.0	13.4	4.8	-13.8	14.3	24.2	-0.2	0.2	0.5	0.0	6.0	-25.0	-0.3	0.00
Frederick	2.8	-0.7	0.7	-29.4	0.3	-20.8	-7.4	1.0	0.4	-1.0	0.0	-40.0	-2.1	-0.2	-40.0	1.4	-0.2	-3.4	0.0	-33.3	-50.0	-7.7	0.00
Fredericksburg	7.5	0.0	-9.6	-25.0		50.0		0.2	1.2	3.6		-0.4	100.0		4.4	6.0	5.6	7.8	-2.6	-0.5	22.2	-0.2	0.00
Howard	-8.1	-0.3	-4.7	31.2	-0.4	-9.8	-66.7	-2.5	6.2	-10.0	-1.0	-100.0	0.6	0.0	-47.6	-11.6	1.0	-1.1	2.2	-25.0	-40.9	33.3	0.00
Jefferson	-12.9	28.0	-7.0	0.0	-6.9	-50.0	7.8	1.0	-2.8	-10.0	1.4	300.0	9.2	0.3		-2.0	2.9	13.2	5.5	-66.7	-100.0	-35.7	0.00
King George	1.6	14.9	5.8	-3.7		0.0		0.7	-1.2	0.0	-100.0	1.1	-29.4		0.2	-3.3	5.0	-2.0	2.3	0.5	-4.7	-2.2	0.00
Loudoun	-1.5	-0.7	0.0	66.7	5.6	-4.8	0.0	1.1	-0.2	1.2	2.0	-12.5	-1.9	-1.7	-66.7	-0.1	-1.2	1.2	1.3	15.4	33.3	4.0	0.00
Montgomery	-3.0	-5.7	-0.4	3.8	0.2	0.3	0.0	0.6	0.0	-1.2	-1.7	7.7	-0.7	9.4	-3.2	-1.4	0.1	0.3	-7.4	21.4	3.5	1.7	0.00
Prince George's	-0.8	-1.9	-1.5	-4.2	11.2	2.0		0.6	-1.5	8.3	2.2	11.5	-0.9	-33.3	10.3	-6.2	0.4	0.1	-0.7	-7.1	1.0	-4.7	0.00
Prince William	0.6	-6.7	-0.1	31.3	-4.5	-6.8	0.0	-1.5	0.3	0.7	-8.7	-2.8	2.9	-3.8	8.3	0.0	0.4	0.8	0.0	1.7	-15.6	0.4	0.00
Spotsylvania	1.6	8.3	-3.4	-40.5	0.0	3.4		-1.6	1.4	-3.0	50.0	0.3	23.5	0.0	-3.8	-0.4	-1.3	-1.4	0.9	0.2	9.2	-0.4	0.00
St. Mary's	-5.8	1.6	1.8	-0.8	0.0	-0.8		-0.5	-1.8	-50.0	-44.4	6.2	-7.2		-2.1	-8.9	1.5	-1.6	1.6	7.8	0.3	3.9	0.00

Stafford	1.3	6.3	-1.4	4.3	200.0	-9.3	-33.3	-1.5	1.2	-2.6	80.0	0.0	-14.1	-20.0	0.4	2.6	-1.6	1.3	-0.4	-0.8	4.4	0.4	0.00
Total	**-0.4**	**-0.4**	**-0.3**	**0.2**	**0.4**	**0.4**	**2.8**	**0.0**	**0.1**	**-0.6**	**-0.1**	**0.1**	**0.3**	**0.3**	**0.1**	**-0.1**	**0.2**	**-0.1**	**0.1**	**0.1**	**0.3**	**0.0**	**0.00**

The closure of Arlington Memorial Bridge had very small impacts on mandatory and non-mandatory tour lengths, as shown in **TABLE 46** and **TABLE 47**. As expected, Table 46 shows slightly shorter average lengths of work tours originating from some jurisdictions while other jurisdictions show slightly longer distances. For example, the work tour length is 0.57% longer for Arlington and 0.32% shorter for Carroll County. Similarly, Table 47 indicates a slightly shorter average non-mandatory tour length in the Memorial Bridge Closure Scenario. These changes indicate that more people would travel to the same side of the Potomac River or find alternate routes when the Memorial Bridge is closed for autos and trucks.

FIGURE 6 showed that the Memorial Bridge Closure Scenario had no visible changes (compared to the Baseline) on the distributions of tour arrival and departure times, and tour durations, as expected.

FIGURE 7 indicates virtually no shifting in work tour mode choice at the regional scale. This is a bit surprising given that Arlington Memorial Bridge is one of the key bridges connecting Virginia and DC. A further check of total tours by mode, presented in **TABLE 48** and **TABLE 49:**, indicates that there were indeed some changes in modal splits, but those changes were too small to be discerned in the Visualizer charts. Despite the small changes, the shifts from auto modes to non-motorized and transit modes are as expected. **TABLE 49:** shows that walk, walk-transit, park-and-ride transit, and kiss-and-ride transit tours in the Memorial Bridge Closure Scenario increased by 0.06%, 0.03%, 0.88%, and 0.39%, respectively. Auto tours slightly decreased (less than 0.06%). A similar pattern can be found in the trip mode choice comparison in **TABLE 50**. It is unclear why bike tours for 0-Auto households increased by 2.07% as shown on Table 48. In Phase 1 sensitivity testing, we observed a small drive-alone share of tours and trips made by 0-auto households in the modeling results that reflected situations when members of 0-auto households rent or borrow automobiles. However, the Phase 2 Model is not reflecting that pattern anymore.

TABLE 46: MANDATORY TOUR LENGTH COMPARISON - BASELINE VS. BRIDGE CLOSURE:

Jurisdiction	Baseline			Bridge Closure			Difference			% Difference		
	Work	University	K-12	Work	University	K-12	Work	University	K-12	Work	University	K-12
Alexandria	8.48	4.63	3.47	8.56	4.45	3.47	0.08	-0.17	-0.01	0.96%	-3.70%	-0.19%
Anne Arundel	15.18	14.89	5.32	15.22	15.14	5.42	0.04	0.25	0.10	0.24%	1.65%	1.93%
Arlington	7.17	3.85	3.60	7.21	3.79	3.59	0.04	-0.06	-0.01	0.57%	-1.58%	-0.38%
Calvert	23.38	43.15	7.18	23.39	42.59	7.10	0.01	-0.55	-0.08	0.02%	-1.29%	-1.13%
Carroll	22.05	23.12	6.53	21.98	22.85	6.28	-0.07	-0.27	-0.25	-0.32%	-1.17%	-3.77%
Charles	21.02	20.72	7.29	20.99	20.34	8.08	-0.03	-0.38	0.78	-0.13%	-1.82%	10.74%
Clarke	33.84	41.67	7.24	33.83	41.99	7.19	-0.01	0.31	-0.04	-0.03%	0.75%	-0.61%
DC	5.42	3.94	4.42	5.41	3.46	4.31	-0.01	-0.48	-0.11	-0.13%	-12.12%	-2.41%
Fairfax	11.08	6.44	4.15	11.08	6.00	4.14	0.00	-0.44	-0.01	0.00%	-6.90%	-0.31%
Fauquier	24.41	16.97	7.22	24.50	17.05	7.16	0.10	0.09	-0.06	0.39%	0.52%	-0.89%
Frederick	20.71	16.89	6.88	20.70	16.90	7.10	-0.02	0.01	0.22	-0.09%	0.09%	3.16%
Fredericksburg	12.69	2.48	5.97	12.79	2.46	5.99	0.11	-0.02	0.02	0.84%	-0.69%	0.28%
Howard	14.58	19.00	5.13	14.57	19.40	5.00	-0.01	0.40	-0.13	-0.04%	2.13%	-2.50%
Jefferson	29.42	14.71	7.94	29.53	14.90	7.99	0.11	0.20	0.05	0.38%	1.35%	0.67%
King George	27.00	31.98	8.51	26.95	31.94	8.48	-0.05	-0.04	-0.03	-0.19%	-0.13%	-0.35%
Loudoun	15.06	10.57	4.43	15.09	10.64	4.41	0.03	0.07	-0.02	0.17%	0.68%	-0.41%
Montgomery	11.51	11.28	4.69	11.50	11.10	4.52	0.00	-0.18	-0.17	-0.02%	-1.56%	-3.60%
Prince George's	12.61	9.22	5.39	12.61	8.76	5.44	-0.01	-0.46	0.05	-0.06%	-4.97%	0.90%
Prince William	16.84	6.44	3.92	16.83	6.48	4.02	-0.01	0.04	0.10	-0.07%	0.62%	2.54%
Spotsylvania	18.23	6.14	5.80	18.18	6.11	5.81	-0.05	-0.03	0.01	-0.28%	-0.48%	0.14%
St. Mary's	17.33	40.35	9.81	17.25	39.91	9.75	-0.08	-0.44	-0.07	-0.47%	-1.08%	-0.68%
Stafford	22.02	17.66	5.38	22.01	17.70	5.36	-0.01	0.04	-0.03	-0.04%	0.24%	-0.47%
Total	**13.35**	**10.32**	**5.01**	**13.35**	**10.09**	**5.01**	**0.00**	**-0.23**	**0.00**	**0.01%**	**-2.25%**	**-0.05%**

TABLE 47: NON-MANDATORY TOUR LENGTH COMPARISON - BASELINE VS. BRIDGE CLOSURE:

	Baseline	Bridge Closure	Difference	% Difference
Escorting	4.40	4.40	0.00	-0.02%
Individual Maintenance	5.27	5.27	0.00	-0.07%
Individual Discretionary	6.29	6.29	0.01	0.09%
Joint Maintenance	6.09	6.09	0.00	-0.06%
Joint Discretionary	6.86	6.84	-0.02	-0.27%
At-Work	5.07	5.06	-0.01	-0.10%
Total	**5.65**	**5.65**	**0.00**	**-0.03%**

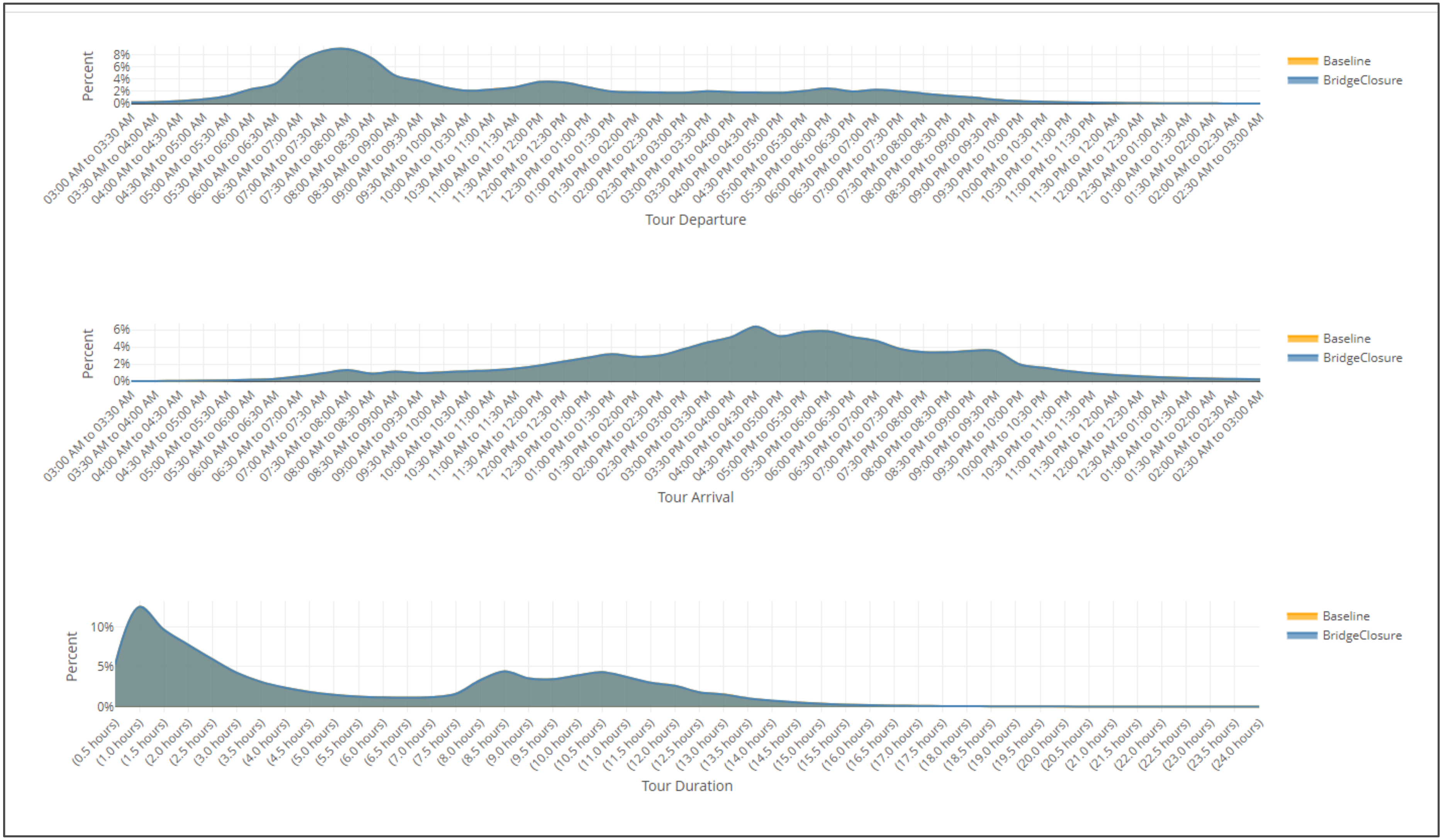

FIGURE 6: TOUR DEPARTURE, ARRIVAL, AND DURATION - BASELINE VS. BRIDGE CLOSURE

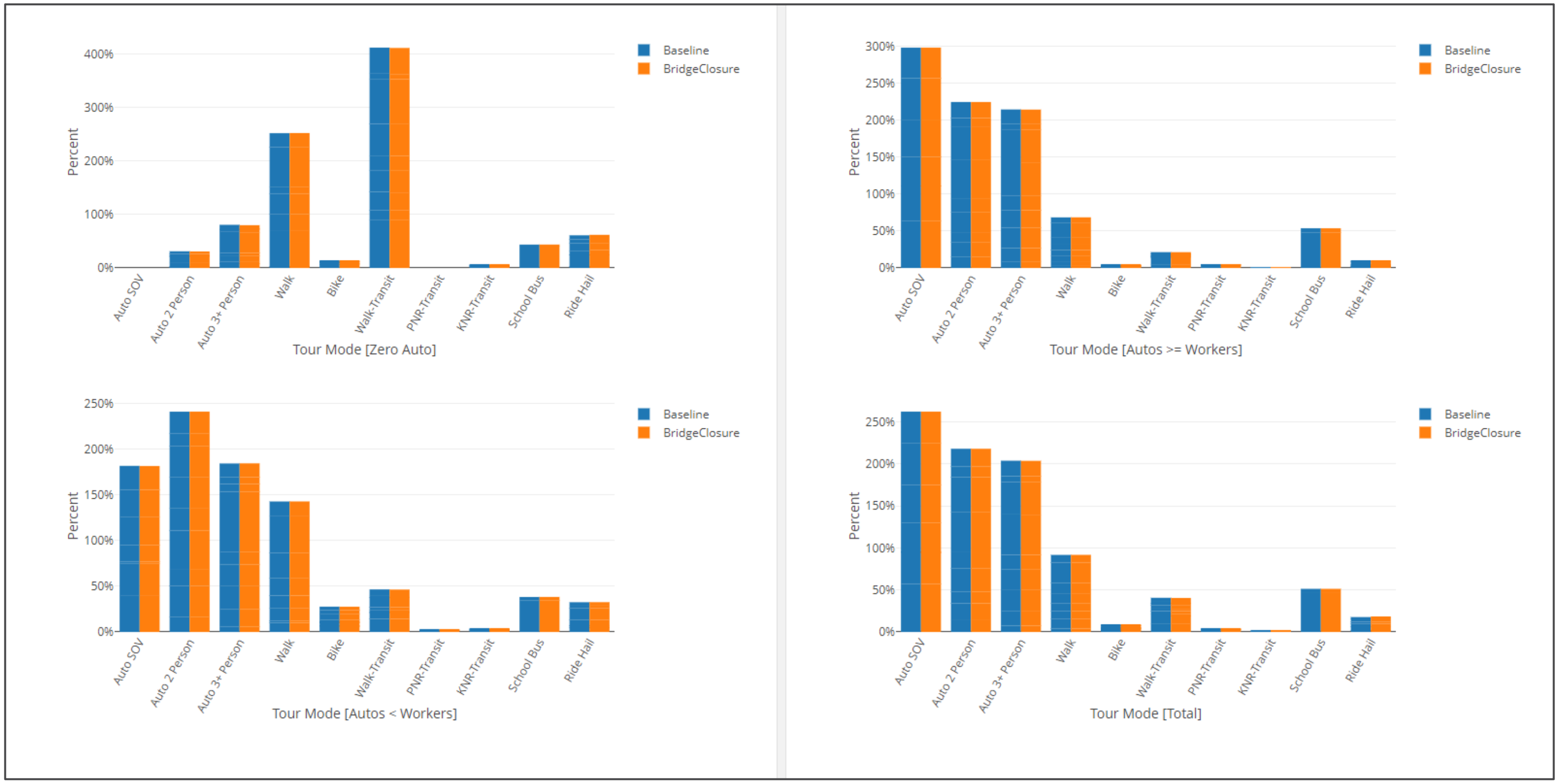

FIGURE 7: DISTRIBUTION OF WORK TOURS BY MODE – BASELINE VS. BRIDGE CLOSURE

TABLE 48: TOTAL TOURS BY TOUR MODE AND AUTO SUFFICIENCY - BASELINE VS. BRIDGE CLOSURE

Tour Mode	Baseline				Bridge Closure			
	0 Auto	Autos < Workers	Autos >= Workers	Total	0 Auto	Autos < Workers	Autos >= Workers	Total
Drive-Alone	0	337,979	3,105,480	3,443,459	0	337,635	3,104,820	3,442,455
Shared 2	19,496	307,394	1,632,434	1,959,324	19463	307,285	1,632,174	1,958,922
Shared 3+	27,710	197,536	1,485,124	1,710,370	27523	197,637	1,484,176	1,709,336
Walk	106,956	201,221	528,815	836,992	106885	201,281	529,314	837,480
Bike	7,727	48,219	47,950	103,896	7887	48,189	48,182	104,258
Walk-Transit	202,459	93,904	151,093	447,456	202394	93,899	151,276	447,569
PNR-Transit	0	8,209	85,061	93,270	0	8,257	85,830	94,087
KNR-Transit	4,654	10,393	15,388	30,435	4666	10,376	15,511	30,553
School Bus	14,322	46,180	411,438	471,940	14330	46,229	411,482	472,041
Ride Hail	31,247	50,012	66,800	148,059	31469	50,170	66,713	148,352
Total	**414,571**	**1,301,047**	**7,529,583**	**9,245,201**	**414,617**	**1,300,958**	**7,529,478**	**9,245,053**

TABLE 49: CHANGES IN TOTAL TOURS BY TOUR MODE AND AUTO SUFFICIENCY – BASELINE VS. BRIDGE CLOSURE

Tour Mode	Difference				% Difference			
	0 Auto	Autos < Workers	Autos >= Workers	Total	0 Auto	Autos < Workers	Autos >= Workers	Total
Drive-Alone	0	-344	-660	-1,004		-0.10%	-0.02%	-0.03%
Shared 2	-33	-109	-260	-402	-0.17%	-0.04%	-0.02%	-0.02%
Shared 3+	-187	101	-948	-1,034	-0.67%	0.05%	-0.06%	-0.06%
Walk	-71	60	499	488	-0.07%	0.03%	0.09%	0.06%
Bike	160	-30	232	362	2.07%	-0.06%	0.48%	0.35%
Walk-Transit	-65	-5	183	113	-0.03%	-0.01%	0.12%	0.03%
PNR-Transit	0	48	769	817		0.58%	0.90%	0.88%
KNR-Transit	12	-17	123	118	0.26%	-0.16%	0.80%	0.39%
School Bus	8	49	44	101	0.06%	0.11%	0.01%	0.02%
Ride Hail	222	158	-87	293	0.71%	0.32%	-0.13%	0.20%
Total	**46**	**-89**	**-105**	**-148**	**0.01%**	**-0.01%**	**0.00%**	**0.00%**

TABLE 50: CHANGES IN TRIPS BY TRIP MODE - BASELINE VS. BRIDGE CLOSURE:

Trip Mode	Baseline	Bridge Closure	Difference	% Difference
Auto SOV	11,312,502	11,309,891	-2,611	-0.02%
Auto 2 Person	5,234,366	5,233,396	-970	-0.02%
Auto 3+ Person	3,491,106	3,490,029	-1,077	-0.03%
Walk	1,762,665	1,763,107	442	0.03%
Bike	219,064	220,150	1,086	0.50%
Walk-Transit	778,747	779,642	895	0.11%
PNR-Transit	186,540	188,174	1,634	0.88%
KNR-Transit	60,870	61,106	236	0.39%
School bus	471,878	471,978	100	0.02%
Ride-hail	399,980	400,274	294	0.07%
Total	**23,917,718**	**23,917,747**	**29**	**0.00%**

Highway Traffic Shifts

To provide the context for this analysis, below is a list of major Potomac River Bridges, ranked by their observed Annual Average Daily Traffic (AADT) in 2018:

- American Legion Bridge: 251k AADT
- 14th Street Bridge: 249k AADT
- Woodrow Wilson Bridge: 238 AADT
- Theodore Roosevelt Bridge: 95k AADT
- Arlington Memorial Bridge: 62k AADT
- Key Bridge: 52k AADT
- Chain Bridge: 21k AADT

The difference in loaded daily traffic volumes between the Memorial Bridge Closure scenario and the Baseline scenario is shown in **FIGURE 8** and **FIGURE 9**.

As expected, the Memorial Bridge closure results in a reasonable displacement pattern of vehicles shifting to other Potomac River crossing bridges (Theodore Roosevelt, 14th Street, Key, and the Woodrow Wilson Bridge). As shown in **FIGURE 9**, there are volume drops on roadway links that lead to both ends of the Memorial Bridge. These findings are consistent with past findings using the Gen2

Travel Model, which is trip based (see, for example, slide 11 of Milone and Moran. "TPB Version 2.3 Travel Model on the 3,722-TAZ Area System: Status Report and Sensitivity Tests." Presented to the COG/TPB Travel Forecasting Subcommittee, July 22, 2011).

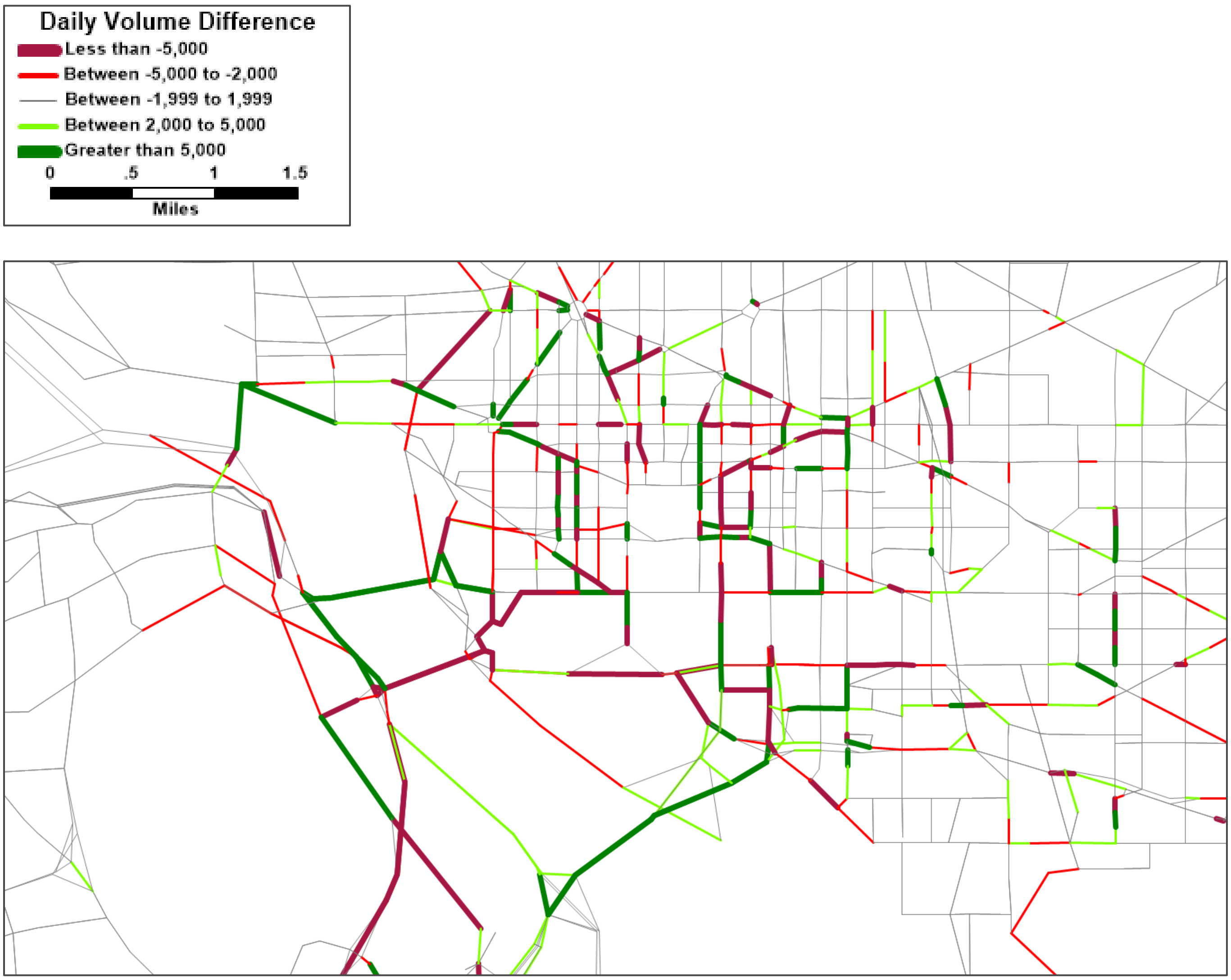

FIGURE 8: DAILY TRAFFIC VOLUME SHIFTS IN DC – BASELINE VS. BRIDGE CLOSURE

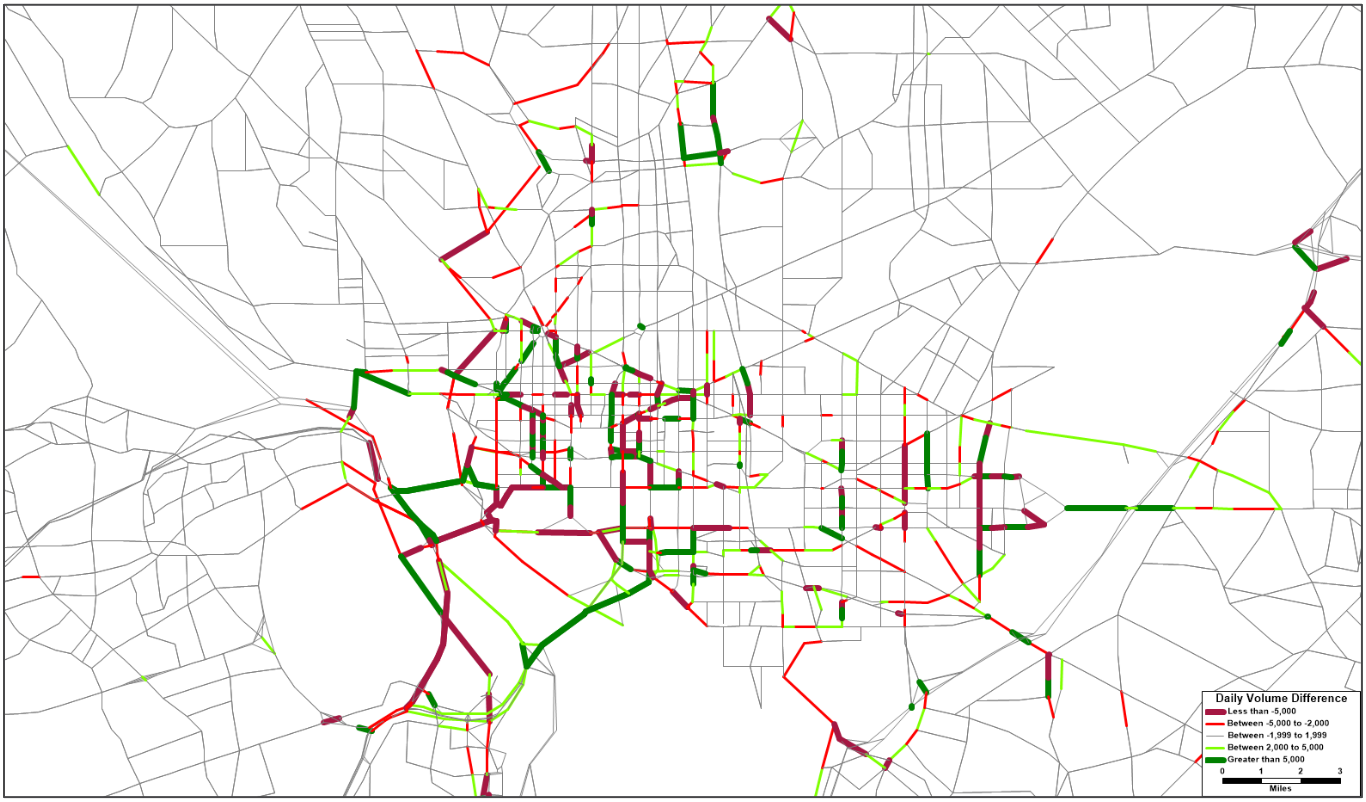

FIGURE 9: DAILY TRAFFIC VOLUME SHIFTS IN DC SUBURBS – BASELINE VS. BRIDGE CLOSURE

As shown in **TABLE 51**, this Memorial Bridge Closure test resulted in a VMT drop of 475,217 or 0.27%, a small decrease in total VHT (0.21%) and a small decrease in VHD by 0.08%. Note that the directionality and magnitude of the VHT and VMT shifts may be different than what is shown here if focused on just the Memorial Bridge corridor.

TABLE 51: DAILY VMT, VHT, AND VHD - BASELINE VS. BRIDGE CLOSURE:

	Baseline	Bridge Closure	Difference	% Difference
Total Daily Vehicle Miles Traveled (VMT)	178,004,086	177,528,869	-475,217	-0.27%
Total Daily Vehicle Hours Traveled (VHT)	5,185,711	5,174,633	-11,078	-0.21%
Total Daily Vehicle Hours of Delay (VHD)	1,891,840	1,890,380	-1,460	-0.08%

Transit Ridership Shifts

Average weekday transit ridership by transit sub-mode is shown in **TABLE 52**. Total transit ridership increased by 4,849 or 0.3%. Metrorail ridership increased by 0.2%, commuter rail by 0.7%, and all bus increased by 0.4%. The ridership increase was 1.4% for VRE and 0.5% for MARC.

TABLE 52: TRANSIT BOARDINGS BY MODE - BASELINE VS. BRIDGE CLOSURE

Transit Mode	Baseline	Bridge Closure	Difference	% Difference
Local Metrobus	336,825	337,706	881	0.3%
Express Metrobus	39,306	39,891	585	1.5%
Metrorail	948,667	950,553	1,886	0.2%
Commuter Rail	59,906	60,327	421	0.7%
▪ MARC	44,932	45,150	218	0.5%
▪ VRE	14,974	15,176	203	1.4%
Other Local Bus in the WMATA Area	161,473	161,869	395	0.2%
Other Express Bus in the WMATA Area	5,629	5,701	72	1.3%
Other Local Bus beyond the WMATA Area	25,341	25,606	265	1.0%
Other Express Bus beyond the WMATA Area	61,643	61,920	277	0.4%
Bus Rapid Transit and Street Car	4,603	4,670	67	1.4%
All Bus	630,217	632,693	2,475	0.4%
Total	**1,643,393**	**1,648,242**	**4,849**	**0.3%**

The above result is consistent with the expectation that when the Memorial Bridge is closed, drivers from Virginia will choose destinations that minimize the need to cross a bridge into DC or will use transit to reach their destinations in DC instead of driving.

Trip Flow Shifts

Similar to the change in worker commuting flows, the hypothetical closure of Arlington Memorial Bridge led to modest decreases in overall trip flows between DC and Virginia jurisdictions, particularly those close to the bridge, such as Arlington, Alexandria, and Fairfax. At the same time, there was an increase in intra-jurisdictional travel in a majority of the jurisdictions in the modeled area. The total changes and percent changes in jurisdiction-to-jurisdiction daily trip flows are presented in **TABLE 53** and **TABLE 54**, respectively.

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TABLE 53: ORIGIN-DESTINATION CHANGES IN DAILY TOTAL TRIP FLOWS - BASELINE VS. BRIDGE CLOSURE

Jurisdiction	DC	Montgomery	Prince George's	Arlington	Alexandria	Fairfax	Loudoun	Prince William	Frederick	Howard	Anne Arundel	Charles	Carrol	Calvert	St. Mary's	King George	Fredericksburg	Stafford	Spotsylvania	Fauquier	Clarke	Jefferson	Total
DC	1,460	1,420	1,563	-2,948	-1,133	-2,705	-27	-549	102	-155	-107	291	-24	-22	-34	17	26	-41	-22	31	-15	-6	-2,878
Montgomery County	1,428	2,832	702	-221	-181	245	-226	-646	-252	417	-154	-48	-61	-33	17	-5	2	-1	11	-13	1	77	3,891
Prince George's County	1,872	515	915	-525	-277	-768	29	-39	-18	-182	-619	9	48	-168	-18	-3	-1	10	-2	47	6	14	845
Arlington County	-2,786	-137	-659	1,409	308	663	-63	-50	-24	-114	-46	-40	-33	-61	-19	12	-1	14	-8	-2	-7	-34	-1,678
City of Alexandria	-978	-128	-335	315	962	-186	15	-165	8	-55	-71	23	9	35	-15	8	-2	4	13	-7	4	4	-542
Fairfax County	-2,761	3	-776	826	-44	5,501	-112	-526	47	255	-128	-40	6	-40	15	-2	14	71	26	115	7	-56	2,401
Loudoun County	-57	-175	56	-35	-54	-263	-1,182	-2	314	-92	-5	-17	-34	-9	-5	5	-6	34	3	117	-34	-178	-1,619
Prince William County	-565	-583	5	-8	24	-741	-106	-1,763	38	-65	-33	2	-43	4	-32	-15	-37	-117	74	905	22	-5	-3,039
Frederick County	23	-214	-2	5	14	67	380	19	-380	-354	-36	-2	16	-2	1	-6	0	-2	4	76	4	59	-330
Howard County	-335	211	-137	-118	-89	375	-109	-161	-258	1,057	480	17	156	15	-17	1	1	8	-3	1	-12	-2	1,081
Anne Arundel County	-324	167	-422	-117	-111	-122	19	17	-78	195	-930	0	19	41	72	14	3	17	-1	12	1	1	-1,527
Charles County	314	-7	-75	-76	-1	-48	-11	51	0	41	-42	142	-1	-20	45	41	1	-19	146	22	0	-2	501
Carrol County	21	-1	66	-12	-3	-22	-76	-81	24	141	7	-2	403	6	-1	-2	-2	-1	1	-3	3	-1	465
Calvert County	-81	-47	-71	-66	31	9	-17	-10	3	6	48	-49	1	745	-17	-5	-1	3	-11	1	n.a.	-1	471
St. Mary's County	-35	6	-64	-2	-32	42	-5	-50	-1	-13	52	85	7	-3	220	-24	5	-3	-19	-5	0	1	162
King George County	-5	14	35	2	5	3	-3	9	-6	-5	14	6	-2	-4	-32	-46	-6	14	6	-4	1	0	-4
City of Fredericksburg	24	-6	6	-6	7	32	6	-27	3	3	1	25	-2	3	2	9	77	-14	-6	30	-2	2	167
Stafford County	-97	-17	-5	-44	19	129	31	-72	4	2	16	-24	1	-3	1	-4	24	188	-111	-11	10	-1	36
Spotsylvania County	-10	16	-10	-11	12	41	1	38	2	1	0	111	1	-14	-16	-2	42	-90	-38	11	-1	-1	83
Fauquier County	26	-8	28	-16	13	183	95	926	58	-12	17	17	0	2	-6	1	26	-41	21	-499	1	-9	823
Clarke County	-22	0	2	4	2	18	-63	20	-3	-4	3	-2	6	-1	0	1	-3	6	-1	12	23	91	89
Jefferson County	10	30	23	-34	-14	-52	-195	22	87	14	6	-3	-8	0	1	1	5	-4	0	-13	77	693	646
Total	**-2,878**	**3,891**	**845**	**-1,678**	**-542**	**2,401**	**-1,619**	**-3,039**	**-330**	**1,081**	**-1,527**	**501**	**465**	**471**	**162**	**-4**	**167**	**36**	**83**	**823**	**89**	**646**	**44**

TABLE 54: CHANGES IN DAILY TOTAL TRIP FLOWS - BASELINE VS. BRIDGE CLOSURE

Jurisdiction	Intra-Jurisdictional Change in Trips	Intra-Jurisdictional % Change in Trips	Regional Change in Trip Origins or Destinations	Regional % Change in Trip Origins or Destinations
DC	1,460	0.1%	-4,338	-0.5%
Montgomery County	2,832	0.1%	1,059	0.2%
Prince George's County	915	0.1%	-70	0.0%
Arlington County	1,409	0.3%	-3,087	-0.7%
City of Alexandria	962	0.4%	-1,504	-0.5%
Fairfax County	5,501	0.2%	-3,100	-0.3%
Loudoun County	-1,182	-0.1%	-437	-0.2%
Prince William County	-1,763	-0.1%	-1,276	-0.4%
Frederick County	-380	-0.1%	50	0.0%
Howard County	1,057	0.1%	24	0.0%
Anne Arundel County	-930	-0.1%	-597	-0.2%
Charles County	142	0.0%	359	0.4%
Carrol County	403	0.1%	62	0.1%
Calvert County	745	0.4%	-274	-0.5%
St. Mary's County	220	0.1%	-58	-0.1%
King George County	-46	-0.1%	42	0.2%
City of Fredericksburg	77	0.1%	90	0.1%
Stafford County	188	0.1%	-152	-0.1%
Spotsylvania County	-38	0.0%	121	0.2%
Fauquier County	-499	-0.4%	1,322	3.0%
Clarke County	23	0.1%	66	0.6%
Jefferson County	693	0.6%	-47	-0.2%
Total	**11,789**	**0.1%**	**-11,745**	**-0.2%**

Auto drivers to DC from all jurisdictions decreased by 4,088 trips (from 1,528,995 to 1,524,907) or 0.3%. The trip flow of total auto drivers between DC and Northern Virginia declined by 3.6%. As shown in **Table 55**, there is decline in auto drivers **to** DC from the other parts of the regional core (Alexandria, by 3.7%, and Arlington, by 3.9%), from the inner suburbs (Fairfax, by 3.3%), and from the outer suburbs (Loudoun, by 1.3% and Prince William. by 4.8%). Similarly, there is also a decline in auto drivers **from** DC to the other parts of the regional core (Alexandria. by 4.3%, and Arlington, by 4.1%), to the inner suburbs (Fairfax, by 3.3%), and to the outer suburbs (Loudoun and Prince William, by 1.0% and 4.1%, respectively).

TABLE 55: CHANGES IN DAILY AUTO TRIP FLOWS TO/FROM DC - BASELINE VS. BRIDGE CLOSURE

Jurisdiction	Change in Trips to DC	% Change in Trips to DC	Change in Trips from DC	% Change in Trips from DC
DC	711	0.1%	711	0.1%
Montgomery County	949	0.6%	856	0.5%
Prince George's County	1,630	0.7%	1378	0.6%
Arlington County	-2,441	-3.9%	-2579	-4.1%
City of Alexandria	-970	-3.7%	-1157	-4.3%
Fairfax County	-2,713	-3.3%	-2596	-3.3%
Loudoun County	-127	-1.3%	-74	-1.0%
Prince William County	-667	-4.8%	-464	-4.1%
Frederick County	2	0.0%	67	2.0%
Howard County	-340	-2.7%	-140	-1.2%
Anne Arundel County	-264	-1.4%	-98	-0.6%
Charles County	316	2.6%	276	2.3%
Carrol County	30	1.1%	-19	-0.9%
Calvert County	-37	-0.7%	12	0.2%
St. Mary's County	-25	-0.8%	-32	-1.1%
King George County	-2	-0.4%	20	4.5%
City of Fredericksburg	2	0.5%	-4	-1.5%
Stafford County	-116	-3.3%	-61	-2.4%
Spotsylvania County	-33	-3.6%	-43	-6.2%
Fauquier County	21	1.9%	13	1.6%
Clarke County	-26	-13.8%	-19	-15.1%
Jefferson County	12	2.9%	-5	-2.0%
Total	**-4,088**	**-0.3%**	**-3958**	**-0.3%**

5.0 FREQUENCY OF ALL HIGH-CAPACITY TRANSIT SERVICES DOUBLED

This chapter describes the results of a scenario test where all High-Capacity Transit (HCT) service frequency was doubled in the base year model.

5.1 DESCRIPTION

The goal of this scenario was to examine how the model responds to a change in transit service frequency. The frequency of all High-Capacity Transit (HCT) services was doubled for all four time-of-day periods. As noted, HCT includes Metrorail, commuter rail, light rail, streetcar, and Bus Rapid Transit (BRT). This scenario was modeled by cutting the HEADWAY[1] value in half for each line in the MODE3**.LIN files (for Metrorail), MODE4**.LIN files (for commuter rail), MODE5**.LIN files (for light rail transit), and MODE10**.LIN files (for BRT and Streetcar) across all four time-of-day periods (AM, MD, PM, and NT). Note that the light rail transit line files (MODE5**.LIN) are blank in both the Baseline and this sensitivity test scenario, since the MTA Purple Line service had not yet begun to operate in the model year of 2018. This scenario is called the Doubling of the HCT Frequency Scenario and is labeled as “Double HCT Freq.” in the subsequent summary tables.

5.2 EXPECTED OUTCOMES

We expect to see:

- Decreases in auto ownership due to increased transit accessibility, particularly for jurisdictions that are well connected by HCT services.
- A decrease of VMT, VHT, and VHD due to the shift from auto travel to HCT.
- More transit boardings across Metrorail and commuter rail lines and fewer bus boardings and auto trips as HCT becomes more attractive.
- Increases in both walk-access and drive-access transit trip flows between jurisdictions that are well connected by HCT services.

5.3 ACTUAL OUTCOMES

At the regional level, TABLE 56, shows marginal decreases in total numbers of tours, trips, and stops in the Double HCT Frequency Scenario. This scenario generated 1,788 fewer tours (0.02% decrease), 20,030 fewer trips (0.08% decrease), and 16,454 fewer stops (0.3% decrease). Total tours decreased slightly, probably because of the decrease in autos owned; households with fewer vehicles tend to make fewer tours. The drop in number of stops might be because of the shifting from auto and bus modes to HCT, as transit tours tend to make fewer intermediate stops than auto tours.

TABLE 56: REGIONAL TRAVEL MEASURES - BASELINE VS. DOUBLE HCT FREQUENCY

	Baseline	Double HCT Frequency	Difference	% Difference
Total population	7,250,066	7,250,066	0	0.000%
Total households	2,790,357	2,790,357	0	0.000%
Total tours	9,245,201	9,243,413	-1,788	-0.019%
Total trips	23,917,718	23,897,688	-20,030	-0.084%
Total stops	5,427,316	5,410,862	-16,454	-0.303%
Total VMT	**114,940,412**	**114,466,113**	**-474,300**	**-0.413%**

Because of the marginal differences in total tours, stops, and trips, there are indistinguishable changes to travel rate measures, such as tours per person or trips per household, as indicated in **FIGURE 10**.

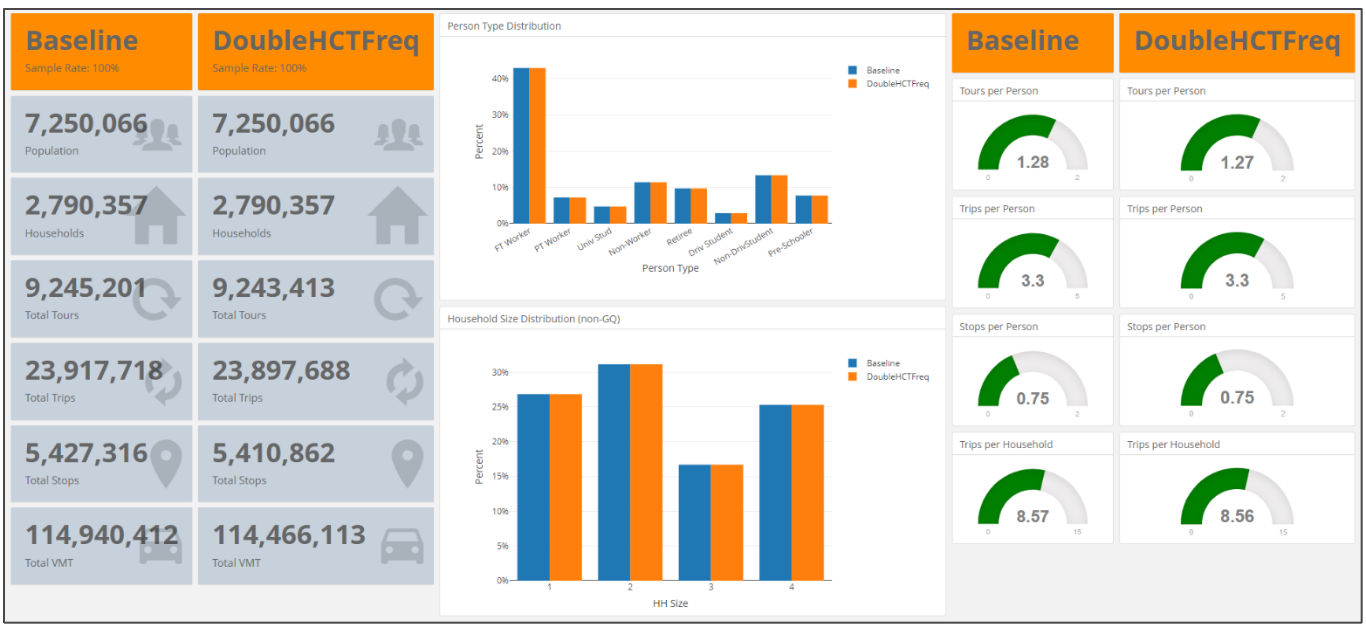


FIGURE 10: VISUALIZER SUMMARY - BASELINE VS. DOUBLE HCT FREQUENCY

TABLE 57 shows the total and percentage changes in auto ownership by jurisdiction. As expected, there were fewer households owning at least one vehicle in the Double HCT Frequency Scenario. Larger losses in vehicle ownership were seen in jurisdictions that are better connected with HCT services, such as DC, Prince George's County, Alexandria, and Arlington. For example, there were 2,770 (or 1.35%) fewer households in DC and 1,143 (or 0.37%) fewer households in Prince George's County owning at least one vehicle.

TABLE 57: CHANGES IN AUTO OWNERSHIP BY JURISDICTION - BASELINE VS. DOUBLE HCT FREQUENCY

	Baseline		Double HCT Freq.		Difference		% Difference	
Jurisdiction	HH with 0 Veh	HH with 1+ Veh	HH with 0 Veh	HH with 1+ Veh	HH with 0 Veh	HH with 1+ Veh	HH with 0 Veh	HH with 1+ Veh
Alexandria	7,710	67,072	7,925	66,857	215	-215	2.79%	-0.32%
Anne Arundel	5,794	210,445	5,826	210,413	32	-32	0.55%	-0.02%
Arlington	15,747	94,967	15,909	94,805	162	-162	1.03%	-0.17%
Calvert	549	32,667	549	32,667	0	0	0.00%	0.00%
Carroll	1,790	61,733	1,790	61,733	0	0	0.00%	0.00%
Charles	1,317	56,730	1,317	56,730	0	0	0.00%	0.00%
Clarke	177	5,517	177	5,517	0	0	0.00%	0.00%
DC	143,871	205,045	146,641	202,275	2,770	-2,770	1.93%	-1.35%
Fairfax	9,329	423,652	9,363	423,618	34	-34	0.36%	-0.01%
Fauquier	540	25,241	540	25,241	0	0	0.00%	0.00%
Frederick	2,779	94,956	2,783	94,952	4	-4	0.14%	0.00%
Fredericksburg	496	10,240	499	10,237	3	-3	0.60%	-0.03%
Howard	2,233	115,871	2,261	115,843	28	-28	1.25%	-0.02%
Jefferson	902	22,993	902	22,993	0	0	0.00%	0.00%
King George	160	8,530	160	8,530	0	0	0.00%	0.00%
Loudoun	1,808	130,229	1,803	130,234	-5	5	-0.28%	0.00%
Montgomery	29,232	358,117	29,392	357,957	160	-160	0.55%	-0.04%
Prince George's	37,405	307,731	38,548	306,588	1,143	-1,143	3.06%	-0.37%
Prince William	3,224	167,375	3,279	167,320	55	-55	1.71%	-0.03%
Spotsylvania	738	33,459	738	33,459	0	0	0.00%	0.00%
St. Mary's	1,498	42,918	1,497	42,919	-1	1	-0.07%	0.00%
Stafford	705	46,865	706	46,864	1	-1	0.14%	0.00%
Total	**268,004**	**2,522,353**	**272,605**	**2,517,752**	**4,601**	**-4,601**	**1.72%**	**-0.18%**

At the regional level, the total average tour lengths for the mandatory and non-mandatory tours were marginally higher when doubling the frequency of HCT services, as presented in **TABLE 58** and **TABLE 59**. Work and university tour lengths increased by 0.58% and 1.17%, respectively, while the K-12 tour lengths increased by 0.2%. This makes sense as most work tours are typically longer and more likely to use HCT services, while K-12 tours tend to be shorter and are less likely to be affected by changes in HCT services. While most jurisdictions show some increases in work tour lengths, those increases are higher percentage wise in outer suburban jurisdictions. This is expected as better HCT services would tend to lead to longer commutes from these jurisdictions to job centers such as downtown DC. As shown on Table 58, among non-mandatory tour purposes, “Individual Discretionary” tour length increased the most, by 0.58%.

TABLE 58: MANDATORY TOUR LENGTH - BASELINE VS. DOUBLE HCT FREQUENCY

	Baseline			Double HCT Freq.			Difference			% Difference		
Jurisdiction	Work	University	K-12	Work	University	K-12	Work	University	K-12	Work	University	K-12
Alexandria	8.48	4.63	3.47	8.61	4.50	3.41	0.13	-0.13	-0.06	1.55%	-2.75%	-1.70%
Anne Arundel	15.18	14.89	5.32	15.27	15.31	5.37	0.09	0.42	0.05	0.59%	2.81%	0.99%
Arlington	7.17	3.85	3.60	7.28	4.01	3.63	0.10	0.16	0.02	1.41%	4.22%	0.63%
Calvert	23.38	43.15	7.18	23.38	43.04	7.16	0.00	-0.11	-0.02	-0.01%	-0.25%	-0.29%
Carroll	22.05	23.12	6.53	22.07	22.84	6.55	0.03	-0.28	0.03	0.12%	-1.22%	0.40%
Charles	21.02	20.72	7.29	21.02	20.45	7.41	0.00	-0.26	0.11	0.02%	-1.27%	1.56%
Clarke	33.84	41.67	7.24	33.89	42.23	7.22	0.06	0.55	-0.01	0.17%	1.32%	-0.19%
DC	5.42	3.94	4.42	5.58	4.58	4.62	0.16	0.64	0.20	3.03%	16.26%	4.55%
Fairfax	11.08	6.44	4.15	11.10	6.16	4.15	0.02	-0.29	0.00	0.20%	-4.47%	-0.04%
Fauquier	24.41	16.97	7.22	24.49	17.08	7.17	0.08	0.11	-0.05	0.34%	0.64%	-0.69%
Frederick	20.71	16.89	6.88	20.76	16.94	6.98	0.04	0.05	0.10	0.22%	0.31%	1.44%
Fredericksburg	12.69	2.48	5.97	12.69	2.46	5.95	0.00	-0.02	-0.02	0.03%	-0.88%	-0.35%
Howard	14.58	19.00	5.13	14.76	19.43	5.08	0.19	0.43	-0.05	1.28%	2.28%	-0.92%
Jefferson	29.42	14.71	7.94	29.72	14.97	7.93	0.30	0.27	-0.01	1.02%	1.83%	-0.19%
King George	27.00	31.98	8.51	27.06	31.92	8.53	0.06	-0.07	0.02	0.21%	-0.21%	0.19%
Loudoun	15.06	10.57	4.43	15.11	10.64	4.40	0.05	0.07	-0.03	0.33%	0.69%	-0.58%
Montgomery	11.51	11.28	4.69	11.59	11.29	4.52	0.09	0.01	-0.17	0.74%	0.10%	-3.54%
Prince George's	12.61	9.22	5.39	12.74	9.34	5.51	0.13	0.12	0.12	1.02%	1.31%	2.21%
Prince William	16.84	6.44	3.92	16.87	6.48	3.92	0.03	0.04	-0.01	0.18%	0.60%	-0.13%
Spotsylvania	18.23	6.14	5.80	18.11	6.10	5.77	-0.12	-0.04	-0.03	-0.64%	-0.67%	-0.46%
St. Mary's	17.33	40.35	9.81	17.23	40.09	9.86	-0.10	-0.26	0.05	-0.59%	-0.65%	0.50%
Stafford	22.02	17.66	5.38	22.04	17.72	5.38	0.01	0.06	0.00	0.06%	0.34%	-0.08%
Total	**13.35**	**10.32**	**5.01**	**13.43**	**10.44**	**5.02**	**0.08**	**0.12**	**0.01**	**0.58%**	**1.17%**	**0.20%**

TABLE 59: NON–MANDATORY TOUR LENGTH - BASELINE VS. DOUBLE HCT FREQUENCY

	Baseline	Double HCT Freq.	Difference	% Difference
Escorting	4.40	4.42	0.02	0.46%
Individual Maintenance	5.27	5.28	0.01	0.13%
Individual Discretionary	6.29	6.33	0.04	0.58%
Joint Maintenance	6.09	6.09	0.00	0.03%
Joint Discretionary	6.86	6.86	0.01	0.08%
At-Work	5.07	5.08	0.01	0.26%
Total	**5.65**	**5.67**	**0.02**	**0.31%**

We expected to see a small shift from off-peak to peak periods as the improved HCT services would mitigate peak spreading. However, it is difficult to tell from the visualizer graphics whether this reverse peak spreading phenomenon has occurred. There are indeed some marginal changes in the tour aggregate departure, as indicated in **Table 60**, but the result is mixed. Specifically, the total tours departing from home and other locations during the AM-peak period increased by 7,002 tours (or 0.2%), while the tours departing during the PM-peak period unexpectedly decreased by 329 (or 0.02%). Similarly, the tours departing during the MD and NT periods decreased by 6,452 (or 0.24%) and 2,063 (or 0.02%), respectively. In contrast, the total tours arriving at home and other locations decreased by 0.16% for the AM period, by 0.20% for the MD period, by 0.13% for the NT period, and slightly increased by 0.17% for the PM period.

TABLE 60: TOUR DEPARTURES AND ARRIVALS BY TIME-OF-DAY - BASELINE VS. DOUBLE HCT FREQUENCY

Time of Day	Baseline	Double HCT Freq.	Difference	% Difference
Number of Tour Departures				
AM (6 am - 9 am)	3,457,560	3,464,562	7,002	0.20%
MD (9 am – 3 pm)	2,675,153	2,668,701	-6,452	-0.24%
NT (3 am - 6 am, 7 pm – 3 am)	1,151,063	1,149,000	-2,063	-0.18%
PM (3 pm – 7 pm)	1,419,231	1,418,902	-329	-0.02%
Total Departures	**8,703,007**	**8,701,165**	**-1,842**	**-0.02%**
Number of Tour Arrivals				

AM (6 am - 9 am)	442445	441759	-686	-0.16%
MD (9 am – 3 pm)	2225815	2221311	-4,504	-0.20%
NT (3 am - 6 am, 7 pm – 3 am)	2,309,335	2,306,377	-2,958	-0.13%
PM (3 pm – 7 pm)	3,725,412	3,731,718	6,306	0.17%
Total Arrivals	**8,703,007**	**8,701,165**	**-1,842**	**-0.02%**

As expected, the Double HCT Frequency Scenario resulted in a shift from other modes (auto, walk, bike, etc.) to transit modes, as shown in and **Table 61** Specifically, park-and-ride transit tours increased by 17.6%, followed by the 6.29% increase in kiss-and-ride access transit tours and the 2.72% increase in walk-access transit tours. For households with at least one vehicle per worker, the park-and-ride transit tours increased by 17.01%. For households with fewer than one vehicle per worker, the park-and-ride transit tours had a higher increase (23.62%), which is consistent with our expectation. Compared with the Memorial Bridge Closure Scenario, this scenario had greater impacts on the mode shifts as expected.

TABLE 61: TOTAL TOURS BY TOUR MODE AND AUTO SUFFICIENCY - BASELINE VS. DOUBLE HCT FREQUENCY

	Baseline				Double HCT Freq.			
Tour Mode	**0 Auto**	**Autos < Workers**	**Autos >= Workers**	**Total**	**0 Auto**	**Autos < Workers**	**Autos >= Workers**	**Total**
Drive-Alone	0	337,979	3,105,480	3,443,459	0	337,267	3,088,356	3,425,623
Shared 2	19,496	307,394	1,632,434	1,959,324	19,632	307,212	1,628,104	1,954,948
Shared 3+	27,710	197,536	1,485,124	1,710,370	28,250	197,163	1,479,536	1,704,949
Walk	106,956	201,221	528,815	836,992	108,786	200,370	524,867	834,023
Bike	7,727	48,219	47,950	103,896	7,843	47,702	47,510	103,055
Walk-Transit	202,459	93,904	151,093	447,456	209,439	97,231	152,965	459,635
PNR-Transit	0	8,209	85,061	93,270	0	10,148	99,533	109,681
KNR-Transit	4,654	10,393	15,388	30,435	4,988	11,050	16,311	32,349
Ride Hail	14,322	46,180	411,438	471,940	14,577	46,265	410,739	471,581
School Bus	31,247	50,012	66,800	148,059	31,529	49,752	66,288	147,569
Total	**414,571**	**1,301,047**	**7,529,583**	**9,245,201**	**425,044**	**1,304,160**	**7,514,209**	**9,243,413**

TABLE 62: CHANGES IN TOTAL TOURS BY TOUR MODE AND AUTO SUFFICIENCY - BASELINE VS. DOUBLE HCT FREQUENCY:

	Difference (Double HCT Freq. – Baseline)				% Difference (Double HCT Freq. – Baseline)			
Tour Mode	0 Auto	Autos < Workers	Autos >= Workers	Total	0 Auto	Autos < Workers	Autos >= Workers	Total
Drive-Alone	0	-712	-17,124	-17,836		-0.21%	-0.55%	-0.52%
Shared 2	136	-182	-4,330	-4,376	0.70%	-0.06%	-0.27%	-0.22%
Shared 3+	540	-373	-5,588	-5,421	1.95%	-0.19%	-0.38%	-0.32%
Walk	1,830	-851	-3,948	-2,969	1.71%	-0.42%	-0.75%	-0.35%
Bike	116	-517	-440	-841	1.50%	-1.07%	-0.92%	-0.81%
Walk-Transit	6,980	3,327	1,872	12,179	3.45%	3.54%	1.24%	2.72%
PNR-Transit	0	1,939	14,472	16,411		23.62%	17.01%	17.60%
KNR-Transit	334	657	923	1,914	7.18%	6.32%	6.00%	6.29%
Ride Hail	255	85	-699	-359	1.78%	0.18%	-0.17%	-0.08%
School Bus	282	-260	-512	-490	0.90%	-0.52%	-0.77%	-0.33%
Total	**10,473**	**3,113**	**-15,374**	**-1,788**	**2.53%**	**0.24%**	**-0.20%**	**-0.02%**

A similar pattern for the changes in trips by trip mode can be observed in **TABLE 63**. Auto, ride-hail, and school bus trips decreased while all the transit-related trips increased. These changes are reasonable due to the increased attractiveness of HCT services.Bike trips decreased by 1,772 or 0.81%, and walk trips decreased by 6,806 or 0.39%.

TABLE 63: CHANGES IN TRIPS –BY TRIP MODE - BASELINE VS. DOUBLE HCT FREQUENCY

Trip Mode	Baseline	Double HCT Freq.	Difference	% Difference
Drive-Alone	11,312,502	11,252,151	-60,351	-0.53%
Shared 2	5,234,366	5,224,463	-9,903	-0.19%
Shared 3+	3,491,106	3,483,392	-7,714	-0.22%
Walk	1,762,665	1,755,859	-6,806	-0.39%
Bike	219,064	217,292	-1,772	-0.81%
Walk-Transit	778,747	809,574	30,827	3.96%
PNR-Transit	186,540	219,362	32,822	17.60%
KNR-Transit	60,870	64,698	3,828	6.29%
School Bus	471,878	471,514	-364	-0.08%
Ride Hail	399,980	399,383	-597	-0.15%
Total	**23,917,718**	**23,897,688**	**-20,030**	**-0.08%**

Highway Traffic Shifts

Daily volume differences between the Baseline and Double HCT Frequency scenarios are displayed in **FIGURE 11**. It should be noted that the normal range for the gray color, which indicates a minimum volume difference at the link level, is a daily link volume difference of +/- 100 vehicles. **FIGURE 11** displays link volume differences in colors throughout the region, including both volume increases in green and volume decreases in red, greater magnitude changes are shown as thicker lines. These changes suggest that the change in the frequency of HCT services has marginal impact on the highway traffic.

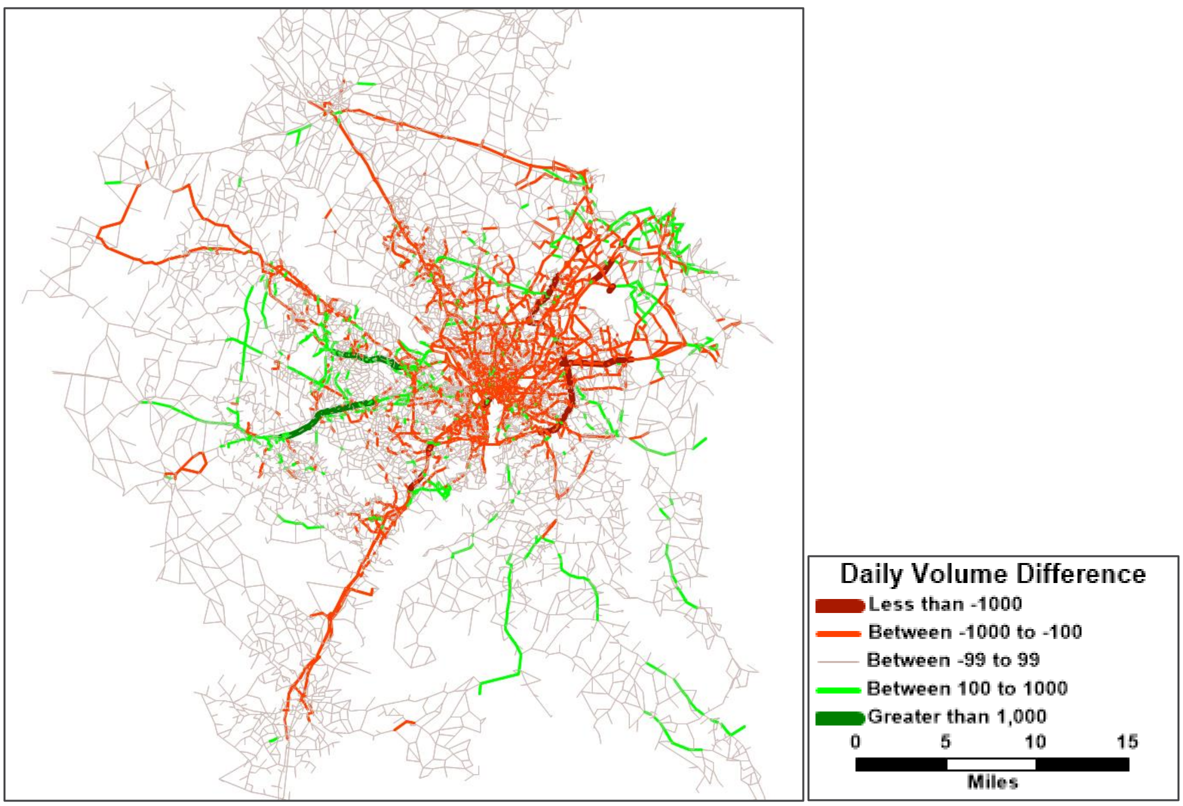


FIGURE 11: DAILY TRAFFIC VOLUME DIFFERENCE - DOUBLE HCT FREQUENCY MINUS BASELINE

As shown in **TABLE 64**, total regional daily VMT slightly declined by 625,061, or 0.35%.

Similarly, total VHT and total VHD declined by 0.89% and 1.78%, respectively. The direction of change is reasonable and meets expectations. Consistent with the findings from prior TPB studies,[13] the relatively small magnitude of changes in region-level auto travel suggests that even an extremely aggressive change in transit service, like this, would not be sufficient to reduce auto travel or roadway congestion in a significant way.

TABLE 64: DAILY VMT, VHT, AND VHD - BASELINE VS. DOUBLE HCT FREQUENCY:

	Baseline	Double HCT Freq.	Difference	% Difference
Total Daily Vehicle Miles Traveled (VMT)	178,004,086	177,379,025	-625,061	-0.35%
Total Daily Vehicle Hours Traveled (VHT)	5,185,711	5,139,780	-45,931	-0.89%
Total Daily Vehicle Hours of Delay (VHD)	1,891,840	1,858,140	-33,700	-1.78%

Transit Ridership Shifts

As shown in **Table 65**, Metrorail ridership increased by 103,119 (10.9%) and commuter rail ridership increased by 38,858 (64.9%). Since there was no change to the frequency of buses, All Bus ridership has slightly increased by 3,030 or 0.5%. The directionality and magnitude of these changes resulting from the increase in HCT services are consistent with the expectation and seem reasonable.

TABLE 65: WEEKDAY TRANSIT RIDERSHIP BY MODE - BASELINE VS. DOUBLE HCT FREQUENCY

Transit Mode	Baseline	Double HCT Freq.	Difference	% Difference
Local Metrobus	336,825	336,646	-179	-0.1%
Express Metrobus	39,306	39,133	-173	-0.4%
Metrorail	948,667	1,051,786	103,119	10.9%
Commuter Rail	59,906	98,764	38,858	64.9%
▪ MARC	44,932	70,677	25,744	57.3%
▪ VRE	14,974	28,087	13,114	87.6%
Other Local Bus in the WMATA Area	161,473	164,038	2,565	1.6%
Other Express Bus in the WMATA Area	5,629	5,861	232	4.1%

[13] For example, refer to Sanghyeon Ko and Feng Xie to Mark Moran, "Analysis of Fare-Free Scenarios for the Metropolitan Washington Region", COG/TPB Memorandum, January 18, 2022.

Other Local Bus beyond the WMATA Area	25,341	27,328	1,987	7.8%
Other Express Bus beyond the WMATA Area	61,643	60,241	-1,402	-2.3%
Bus Rapid Transit and Street Car	4,603	10,321	5,719	124.2%
All Bus	630,217	633,248	3,030	0.5%
Total	**1,643,393**	**1,794,119**	**150,726**	**9.2%**

Daily transit ridership for major HCT lines (distinguished by transit route names coded in the COG/TPB's network database[14]) for both Baseline and Double HCT Frequency scenario is shown in **TABLE 66**. Please note that, different from the Metrorail ridership data summarized in **TABLE 65**, the ridership for Metrorail routes in **TABLE 66** includes transfers from other Metrorail routes. **FIGURE 12** and **FIGURE 13**show Metrorail routes and commuter rail routes respectively.

Doubling the frequency of HCT services resulted in a significant increase in daily Metrorail ridership on the Orange Line (WMORNA: Vienna - New Carrollton), by 54% and on the Red Line (WMREDA: Shady Grove - Glenmont), by 44%; followed by the Yellow Line (Mt. Vernon SQ/7th St. Convention Center - Huntington Avenue), by 27%.However, the decrease in transit ridership on the Blue (WMBLUA: Franconia/Springfield- Largo TWN CTR), Redline B (WMREDB: Silver Spring – Grosvenor) and Silver lines (Wiehle – Largo) despite their frequency increases appears to be counterintuitive. One possible explanation is that the ridership on some of those lines could have shifted to their competitor routes that largely run in parallel (e.g., “WMREDB” to “WMREDA” and "WMSILV" to "WMORNA"). Commuter rail daily ridership shows a significant increase on the Brunswick Line by 112% and VRE Manassas Line by 113 %. (Consider referencing the Metro and Commuter Rail maps included below Table 65)

Overall, the directionality and magnitude of the resultant changes in HCT ridership by route from doubling HCT services (**TABLE 66**) seem reasonable for most HCT routes and match expectations. Maps for Metrorail lines and commuter rail lines are shown in **FIGURE 12** and **FIGURE 13** respectively.

TABLE 66: DAILY TRANSIT RIDERSHIP BY TRANSIT ROUTE - BASELINE VS. DOUBLE HCT FREQUENCY:

Transit Route Name	Mode No.	Baseline	Double HCT Freq.	Difference	% Difference
WMBUA	3	103,928	92,017	-11,911	-11%
WMGRNA	3	115,891	127,609	11,718	10%
WMORNA	3	110,920	170,295	59,375	54%
WMREDA	3	156,268	225,362	69,094	44%
WMREDB	3	98,851	43,834	-55,017	-56%
WMSILV	3	77,874	43,832	-34,042	-44%
WMYELA	3	56,583	72,102	15,519	27%
MARC – Brunswick Line	4	6,596	13,993	7,397	112%

[14] Page 70, Highway and Transit Networks Used in the Air Quality Conformity Analysis of the 2020 Amendment to Visualize 2045 and the FY 2021-2024 TIP (Ver. 2.3.78 Travel Model), April 10, 2020

MARC – Camden Line	4	8,715	18,932	10,217	117%
MARC – Penn Line	4	29,622	37,752	8,130	27%
VRE – Manassas Line	4	4,497	9,557	5,060	113%
VRE – Fredericksburg Line	4	10,477	18,530	8,053	77%

FIGURE 12: METRORAIL LINES

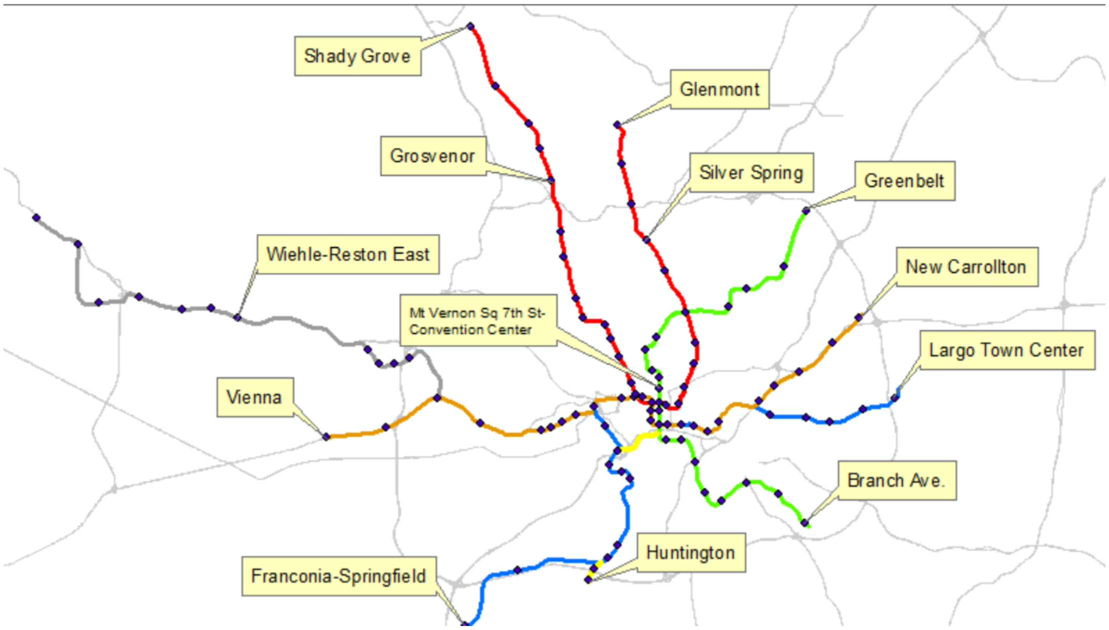
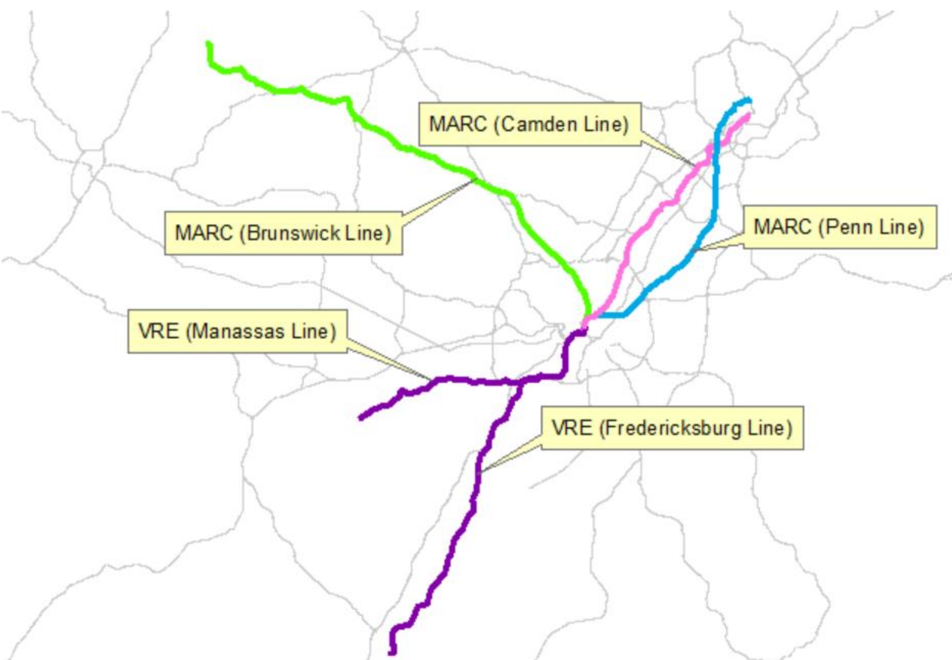


FIGURE 13: COMMUTER RAIL ROUTES



Trip Flow Shifts

As expected, the Double HCT Frequency Scenario increased walk-access and drive-access transit trip flows throughout the region (Table 67 and **TABLE 68**). For walk-access transit, there was an increase of 30,639 trips regionwide, particularly for trip flows between DC, Montgomery County, Prince George's County, Arlington County, City of Alexandria, and Fairfax County in the Metrorail "catchment" area. For park-and-ride (PNR) access transit (Table 68), the results show an increase of 32,822 trips across the region with increases concentrated on trip flows between DC and suburban jurisdictions (e.g., Prince George's County, Montgomery County, Fairfax County, Howard County, Prince William County, Anne Arundel County) in major commuter rail corridors. There were far fewer kiss-and-ride (KNR) access transit trips in the region and thus they are not discussed here.

TABLE 67: CHANGES IN DAILY WALK-ACCESS TRANSIT TRIP FLOWS - BASELINE VS. DOUBLE HCT FREQUENCY

Jurisdiction	DC	Montgomery	Prince George's	Arlington	Alexandria	Fairfax	Loudoun	Prince William	Frederick	Howard	Anne Arundel	Charles	Carrol	Calvert	St. Mary's	King George	Fredericksburg	Stafford	Spotsylvania	Fauquier	Clarke	Jefferson	Total
DC	5,731	647	2,124	1,092	1,141	633	10	371	-4	182	479	-29		6	-4		210	15	19				12,623
Montgomery County	660	1,992	335	275	80	235	24	12	20	15	6	4		0			1					0	3,659
Prince George's County	2,160	426	1,462	277	172	163	-2	2		58	33	-2		4	-1		3						4,755
Arlington County	1,195	213	220	849	144	551	14	7	0	-3	8	3		4	-2		-1	-3					3,199
City of Alexandria	1,088	87	211	154	373	284	7	14		2	0	-4		-1	1		2	2					2,220
Fairfax County	684	227	148	492	317	689	38	13	0	4	3	6		0			5	3					2,630
Loudoun County	10	25	2	12	5	20	-11																67
Prince William County	308	19	16	4	19	38	-2	59									3	0	-1				464
Frederick County	7	16	0	2	0	3			31														59
Howard County	209	20	45	4	5	6				-58	4												235
Anne Arundel County	443	2	37	7	8	8				-7	-9												489
Charles County	-22	2	-1	1	0	5	-1					4			-1								-13
Carrol County													-6										-6
Calvert County	6	-2	6	1	1	-3						0		0									9
St. Mary's County	-2		-2	-1	0							-2			6								-1
King George County																							
City of Fredericksburg	198	2		-1	7	4		3									0	-1	2				220

Stafford County	14	0		1	0	0		0									1	1	0				17
Spotsylvania County	10	0															1	0	1				12
Fauquier County																							
Clarke County																							
Jefferson County		0	0																				1
Total	**12,699**	**3,676**	**4,609**	**3,170**	**2,272**	**2,636**	**77**	**484**	**47**	**195**	**524**	**-20**	**-6**	**13**	**0**		**225**	**17**	**21**			**0**	**30,639**

TABLE 68: CHANGES IN DAILY PNR-ACCESS TRANSIT TRIP FLOWS - BASELINE VS. DOUBLE HCT FREQUENCY

Jurisdiction	DC	Montgomery	Prince George's	Arlington	Alexandria	Fairfax	Loudoun	Prince William	Frederick	Howard	Anne Arundel	Charles	Carrol	Calvert	St. Mary's	King George	Fredericksburg	Stafford	Spotsylvania	Fauquier	Clarke	Jefferson	Total
DC	196	1,525	2,884	53	94	1,514	146	1,103	382	1,429	885	47	43	23	0	25	23	399	151	52	15	102	11,091
Montgomery County	1,525	1,320	343	86	33	104	19	116	181	55	122	4	6	3	4	2	-1	28	7	4	4	89	4,054
Prince George's County	2,884	343	206	289	47	178	2	52	6	99	88	2	3	3	-2			4	3			11	4,225
Arlington County	53	86	289	76	10	378	37	246	25	188	144	50	-1	-2	-4	5	-1	67	30	14	1	15	1,706
City of Alexandria	94	33	47	10	30	239	-5	143	7	19	9	5		-3	-1	2	2	45	22	4	-1	-1	702
Fairfax County	1,514	104	178	378	239	562	49	132	47	72	54	5	0	-3	3	-5	1	57	35	6	-1	11	3,438
Loudoun County	146	19	2	37	-5	49	40	3		0	-1	0		-1									291
Prince William County	1,103	116	52	246	143	132	3	52		2	0					7	6	24	30	1			1,917
Frederick County	382	181	6	25	7	47			2													0	652
Howard County	1,429	55	99	188	19	72	0	2		18	10												1,896
Anne Arundel County	885	122	88	144	9	54	-1	0		10	24												1,340
Charles County	47	4	2	50	5	5	0					-22			3								96
Carrol County	43	6	3	-1		0																	54
Calvert County	23	3	3	-2	-3	-3	-1							0	0								23
St. Mary's County	0	4	-2	-4	-1	3						3		0	4								7
King George County	25	2		5	2	-5		7															36
City of Fredericksburg	23	-1		-1	2	1		6									0	4	8				45
Stafford County	399	28	4	67	45	57		24									4	2	-2				629
Spotsylvania County	151	7	3	30	22	35		30									8	-2	2				288
Fauquier County	52	4		14	4	6		1															84
Clarke County	15	4		1	-1	-1																	21
Jefferson County	102	89	11	15	-1	11			0														227
Total	**11,091**	**4,054**	**4,225**	**1,706**	**702**	**3,438**	**291**	**1,917**	**652**	**1,896**	**1,340**	**96**	**54**	**23**	**7**	**36**	**45**	**629**	**288**	**84**	**21**	**227**	**32,822**

6.0 HYPOTHETICAL AUTONOMOUS VEHICLE MARKET SHARE IN THE HORIZON YEAR

This chapter describes the results of a scenario test where 20% of households in the metropolitan Washington region own at least one Autonomous Vehicle in the horizon year of 2045.

6.1 DESCRIPTION

As part of the Gen3, Phase 2, development, RSG extended the ActivitySim vehicle type choice/vehicle allocation models for autonomous vehicles (AVs) and revised the AV ownership model, the auto ownership model, the tour mode choice model, and the trip mode choice model in the pipeline of ActivitySim models to improve the ability of the Gen3 Model to evaluate AV related scenarios.[15] Using an interim version of the developmental Gen3, Phase 2, Model (Last commit date: July 12, 2023) that incorporated the above AV-related enhancements, COG staff conducted a hypothetical scenario analysis that examined the impact of having an overall 20% market share of AVs in the metropolitan Washington region in the horizon year of 2045. The initial analysis was conducted in September 2023, and the findings and recommendations were documented in a technical memorandum dated September 8, 2023.[16] To address issues found in the September analysis, mainly regarding the extension of vehicle type data for forecast years, RSG made updates to the model, and COG staff subsequently reran the test and documented the updated findings in a second memorandum dated October 17.[17] After RSG fixed discrepancies that COG staff noticed in the October analysis regarding the simulation of AVs in the vehicle type choice model, COG staff ran the test the third time and documented the findings in a memo dated December 15, 2023.[18] In April 2024, COG staff extended the December analysis in consideration of trips made by unoccupied autonomous vehicles, or so called AV “deadheading” trips. COG staff conducted additional scenarios that simulate AV deadheading trips and documented the findings in a memo dated May 16, 2024.[19] This chapter reports the findings from both the December analysis and the extended scenario analysis in April 2024.

The detailed setup of the Baseline and Build scenarios for this sensitivity test can be found in the December 15, 2023 memo. It should be noted that the assumption of an overall 20% AV

[15] From Andrew Rohne, RSG to Mark Moran, Feng Xie, Ray Ngo, MWCOG, “MWCOG Gen3 Model AV Updates”, Technical Memorandum, July 7, 2023.
[16] Feng Xie to Mark Moran, “Modeling Autonomous Vehicles (AVs) in the Gen3, Phase 2, Travel Model: A Scenario Analysis,” Memorandum, September 8, 2023.
[17] Feng Xie to Mark Moran, “Modeling Autonomous Vehicles (AVs) in the Gen3, Phase 2, Travel Model: A Scenario Analysis, Updated Findings” Memorandum, October 17, 2023.
[18] Feng Xie to Mark Moran, “Modeling Autonomous Vehicles (AVs) in the Gen3, Phase 2, Travel Model: A Scenario Analysis, Further Updated Findings” Memorandum, December 15, 2023.
[19] Feng Xie to Mark Moran, “Modeling Autonomous Vehicles (AVs) in the Gen3, Phase 2, Travel Model: A Scenario Analysis, Further Updated Findings” Memorandum, May 16, 2024.

market share in 2045 was made based on the AV deployment predictions developed by the Victoria Transport Policy Institute.[20] Starting with the target AV market shares by income segment used in the Northern Virginia Transportation Authority (NVTA) TransAction Model,[21] COG staff slightly adjusted the NVTA targets such that the target share of AV-owning households for all income segments combined exactly matched 20% in the Gen3 Model. The final target shares by household income segment used for the Build scenario are shown in **Table 69**.

TABLE 69: TARGET SHARES OF AV-OWNING HOUSEHOLDS BY INCOME SEGMENT FOR 2045

Income Segment	Household Income	Target Share
1	0-50k	5%
2	50k-100k	16%
3	100k-150k	25%
4	150k+	33%
Total		20%

On top of the 2045 Build Scenario, COG staff conducted two additional scenarios in April 2024, using post-processing, to examine the effects of AV deadheading trips: The first scenario ("Build + AV Deadheading 50%") assumes that 50% of AVs return to tour origins after dropping off passengers at primary tour destinations while the other 50% park nearby; The second scenario ("Build + AV Deadheading 100%") assumes 100% of AVs returning to tour origins. The detailed setup of the two scenarios can be found in the May 16, 2024 memo.

6.2 EXPECTED OUTCOMES

ActivitySim does not model autonomous vehicles (AVs) in its default setting. Before discussing the expected outcomes of this scenario test, it is helpful to describe the AV specification that RSG implemented in the Gen3 Model, which contains five sequential components in the ActivitySim model pipeline:[22]

- Autonomous Vehicle (AV) Ownership Model – This is a binary logit model that predicts whether a household will own an AV. By default, this model uses a constant in the utility equation set to -999 to disable owning an AV. For application purposes requiring the AV

[20] Todd Litman, "Autonomous Vehicle Implementation Predictions: Implications for Transport Planning", Victoria Transport Policy Institute, January 25, 2023, Page 29-30, https://www.vtpi.org/avip.pdf
[21] Cambridge Systematics, Inc. and Arizona State University, "Hybrid Travel Demand Modeling in Northern Virginia - An Integrated Macro-mesoscopic Demand and Simulation Framework", NVTA Modeling Workshop, March 10, 2023.
[22] For more details, refer to RSG, BMG and MWCOG, Draft Gen3 Model User's Guide, Section 5.4 "Model Calibration and Validation", Section 6.5 "ACTIVITYSIM Resident Travel Model", and Section 7.2 "Using the Gen3 Model for AV Ownership", August 22, 2023, https://app.box.com/file/1122272139151?s=ummvzd4t6xaqwow4oywnnx5wn9bcncwa

model, that constant will need to be disabled or set to 0 and the AV ownership Model will need to be calibrated to match the target AV market shares.[23]

- Auto Ownership Model – This is a multinomial logit model that selects the number of automobiles (0, 1, 2, 3 or 4+) owned by each household in the simulation. In the case that a household owns an AV, auto ownership constants are adjusted to disable the 0 auto and 4+ auto alternatives and reduce the utilities of the 2-auto and 3-auto alternatives, since AV-owning households would likely have a lower propensity to own multiple vehicles. The adjusted model constants that are currently implemented in the Gen3 Model are documented in the RSG memo dated July 7, 2023 (see **TABLE 70** below, which is Table 2 in the RSG memo).
- Vehicle Type Choice Model – This model selects a vehicle type for each household vehicle. It is a multinomial logit model that simulates simultaneous choice of the body type, age, and fuel type of each vehicle. The model was estimated using data from 2017 National Household Travel Survey (NHTS), supplemented with the U.S. Environmental Protection Agency's (EPA's) fuel economy testing database. As such, this model, by default, considers only vehicle types available up until 2017. For future-year scenarios that consider AVs, the vehicle type data file used in this model must be extended to include vehicle type data after 2017. At least one vehicle in an AV-owning household must be simulated as an AV in the vehicle type choice model. RSG updated the configuration[24] to force AV to be the first choice for AV-owning households. RSG also updated the configuration to prevent AV from being selected for any non-AV-owning household. The updated configuration would force the vehicle type choice model to fail if an AV-owning household has none of its household vehicles simulated as an AV.[25]
- Vehicle Allocation Model – This multinomial logit model selects a vehicle that will be used for each tour by each auto occupancy level (Driving Alone, Shared Ride 2, Shared Ride 3+). In an AV scenario, an AV-owning household may choose an AV or a non-AV (if available) for a given tour and occupancy level. Again, the vehicle type data file used in this model must first be extended to include AVs.
- Tour/Trip Mode Choice Models – The tour mode choice model assigns to each tour the "primary" travel mode that is used to get from the origin to the primary destination, while the trip mode choice model assigns a travel mode for each trip on a given tour. If an AV

[23] See the RSG guidelines on AV Ownership Model calibration in RSG, "MWCOG Gen3 Travel Demand Forecasting Model AV Model Training", March 30, 2023, https://app.box.com/s/gldb8umlmgkhbhtpj74humqsqpo7uchm
See also, RSG, BMG and MWCOG, Draft Gen3 Model User's Guide, Section 5.4 "Model Calibration and Validation", August 22, 2023, https://app.box.com/file/1122272139151?s=ummvzd4t6xaqwow4oywnnx5wn9bcncwa

[24] Specifically, the configuration in "source/configs/activitysim/configs/vehicle_type_choice_op4.csv" and "source/configs/activitysim/configs/vehicle_type_choice_op4_coefficients.csv" were updated.

[25] For more details, refer to Andrew Rohne, "RE: A quick question on AV", Email to Feng Xie (Cc: Mark Moran, Ray Ngo, Joel Freedman", November 16, 2023 11:14 AM.

is selected as the vehicle to be used on a tour/trip, a set of “modifier” parameters will be turned on in the preprocessor of the mode choice models to reflect the reduced burdens or the lowered minimum driving age requirements associated with the use of AV (see **Error! Reference source not found.** below, which is Table 1 in the RSG memo).

TABLE 70: AV-OWNING HOUSEHOLD AUTO OWNERSHIP CONSTANTS

Coefficient Description	Constant Name	Constant Value
AV Households - Zero Autos	coef_av0	-999
AV Households - One Auto	coef_av1	0
AV Households - Two Autos	coef_av2	-0.69
AV Households - Three Autos	coef_av3	-1.39
AV Households - Four+ Autos	coef_av4	-999

TABLE 71: AV MODE CHOICE ADJUSTMENT DEFAULTS

Item	Constant Name (Used in constants.yaml)	Adjustment Default
In-Vehicle Time Multiplier	autoIVTFactorAV	0.75
Parking Cost Multiplier	autoParkingCostFactorAV	0.5
Terminal Time Multiplier	autoTerminalTimeFactorAV	0.65
Minimum Driving Age (years old)	minAgeDriveAloneAV	13

For example, in **TABLE 71** we can see that parking costs for AV trips are cut in half (factor = 0.5). In reality, an AV would face the same parking cost as a non-AV. However, to simulate the fact that an AV could drop someone off at work site or transit center and return to home, without incurring a parking charge, the model is set up such that an AV traveler experiences a reduced parking cost, making it more likely that an AV would be used for a trip involving paid parking than a non-AV.

Despite all the above AV-related treatments, the AV specification that was implemented as of December 2023 had its limitations. Joel Freedman, the RSG manager of the Gen3 Model Development Project, noted in an email sent to COG staff in May 2023[26] that the proposed AV implementation in the Gen3 Model did not account for certain effects, such as the “VMT impacts of empty vehicle repositioning trips (known as ‘deadheading), implications of curbside parking for pickups/drop-offs, potential capacity/speed effects of vehicle platooning, [and] signal optimization.” As such, the AV functionality in the current model is “limited to just mode choice and upstream model effects through the mode choice logsum.” In this regard, an AV behaves more like a regular household car with some privileges in terms of reduced in-vehicle time disutility, reduced parking cost/terminal time and a younger minimum driving age, rather than an

[26] Joel Freedman, “RE: Proposed methodologies for AV and equity related analyses using the Gen3, Phase 2, Model”, Email to Feng Xie and Andrew Rohne, May 5, 2023.

AV with more autonomous and intelligent behaviors (e.g., trip chaining, pickups/drop-offs at curbsides or transit stations, deadheading, self-parking, AV ride-sharing, etc.), which is more likely to become a reality in the future. When presenting on the AV implementation at the September 2023 Travel Forecasting Subcommittee meeting,[27] Joel further enumerated the limitations on both demand and supply sides of the model. On the demand side, he noted that, "ActivitySim only simulates person travel", and travel decisions in relation to those sophisticated AV functionalities such as AV repositioning are not represented; On the supply side, he added, network models are not set up for AVs – There are no congestion effects of unoccupied AVs, and there is no consideration of the capacity or speed effects of AVs (e.g., AV platooning, signal optimization/Vehicle-to-infrastructure connectivity, exclusive lanes), either. Based on these considerations, COG staff expected to see only moderate AV effects with a limited AV representation in the Gen3 Model. This expectation was confirmed by the observation of very marginal increases in vehicle miles of travel (VMT) in the scenario analysis, which will be discussed in the next sections.

AV deadheading is identified as one of the missing elements that would significantly impact VMT. To enhance the AV representation in the Gen3 Model, MWCOG staff extended the AV specification by simulating AV deadheading trips based on simplified assumptions. Specifically, AV deadheading trips are simulated in a post-processing procedure consisting of the following two steps:

First, AV deadheading trips are **generated** with the following assumptions:

- It is assumed that each tour that uses an AV, regardless of the number of tour participants, is served by one AV.
- It is assumed that, after dropping off their passengers(s) at primary tour destinations, a certain portion of AVs will return empty to tour origins to serve other household members and will come back later to pick up the passenger(s) dropped off at tour destinations. In other words, each of the tours that use AV will generate two AV deadheading trips, one inbound trip from tour destination to tour origin, and one outbound trip from tour origin to tour destination. It is assumed that the inbound (returning) trip occurs at the same time-of-day period as tour departure, while the outbound (pickup) trip occurs at the same period as tour arrival.
- It is assumed that the rest of AVs find parking nearby after dropping off their passenger(s) at tour destinations. It is also assumed that the parking locations are so close that the AV deadheading trips between tour destinations and parking locations can be ignored, as they do not add much VMT to the system.

[27] Joel Freedman, "Status Report on the COG/TPB Developmental, Disaggregate, Activity-based Travel Demand Forecasting Model, Known as the Gen3 Travel Model", Presentation at the Travel Forecasting Subcommittee, September 22, 2023, https://www.mwcog.org/file.aspx?&A=2KUxoXg7RmhNA0IxJOCiQdKu1nRDbxMcx5hl4AsIe%2b4%3d

Second, AV deadheading trips are then **assigned** to the highway network with the following assumptions:

- AV deadheading trips are assigned to the highway network as a separate vehicle type along with existing vehicle types such as single-occupancy vehicles (SOV), high-occupancy vehicles for two persons (HOV2), high-occupancy vehicles for three or more persons (HOV3+), commercial vehicles, and trucks.
- It is assumed that the same toll charged to an SOV will be charged to a deadheading AV. The value of time, also known as the value of travel time savings, for empty AVs should be lower than other vehicle types. For simplicity, it is assumed that the value of time for a deadheading AV is half of that of an SOV.
- It should be noted that this post-processing assignment procedure does not consider speed feedback. Thus, tolls and roadway congestion do not affect the generation or distribution of the AV deadheading trips, just their routing choices.

This approach simplifies AV repositioning behaviors as AVs may go to a different location than tour origin to serve other household members (trip chaining), or park at a location farther away from tour destination to reduce parking cost. Furthermore, the one-off generation and assignment of AV deadheading trips does not consider speed feedback effects as introducing those additional trips to the system may substantially increase roadway congestion and tolls. Nevertheless, this extension enables the Gen3 Model to better account for the VMT impacts of AV deadheading trips, and thus improves the realism of the AV specification in the model.

With the extended AV specification that considers AV deadheading trips, COG staff expected to see a much more pronounced system effect of AV in the two additional scenarios, which assume 50% and 100% of AV returning to tour origins after dropping off passengers at primary tour destinations, respectively. The latter provides a “bookend” scenario where AV deadheading trips could result in a maximum possible VMT increase.

6.3 ACTUAL OUTCOMES

INITIAL FINDINGS

COG staff created and examined a range of model summaries that compared the Build scenario to the Baseline, including the ABM Visualizer,[28] the View-from-Space (VFS) summary,[29] daily volume difference plots, and others. Very marginal differences in regional travel statistics were observed between the Baseline and Build scenarios. For example, on the demand side, the total number of tours decreased by 0.13% from 9,091,932 in the Baseline to 9,079,712 in the Build, the total number of trips fell by 0.05% from 23,467,774 to 23,454,961, and the total number of stops increased by 0.22% from 5,283,910 to 5,295,537. On the supply side, total Vehicle Hours of Travel (VHT) increased by 1.54%, total Vehicle Hours of Delay (VHD) increased by 2.85%,

[28] Box link to the ABM Visualizer summary file: https://app.box.com/s/d52q6pr2zckjh0oxw1muhamyoscmr4b0
[29] Box link to the VFS summary file: https://app.box.com/s/haoe5lhakp7bwn6c3vwnun0tahucpl10

Vehicle Miles of Travel (VMT) increased by 0.66%, and total transit boardings decreased by 8.40%. The daily average speed (VMT divided by VHT) decreased from 32.66 mph to 32.38 mph by 0.86%. While the directionality of some of these changes seems to be consistent with prior studies, the magnitude of AV effects appears to be much smaller than our expectations. For example, using twelve production-use regional models in the U.S., Fehr & Peers evaluated autonomous vehicle (AV) effects with a focus on vehicle travel and transit ridership when responding to “commonly accepted AV input effects such as lowering parking costs and increasing freeway capacity” and confirmed that “making vehicle travel more convenient has the potential to significantly increase vehicle use and reduce transit ridership.”[30] If we focus on activity-based models, the Fehr & Peers study found VMT increases ranging between 5% and 40% and decreases in transit trips between 30% and 60%. As discussed earlier in this document, the moderate AV effects observed in this test can mainly be attributed to the lack of consideration of more intelligent AV behaviors and AV-related network treatments in the current Gen3 Model.

INVESTIGATIONS

To further analyze the AV testing results, COG staff conducted the following four additional comparisons:

1. Comparison of the same group of households (“Group 2”) that do not own an AV in the Baseline but do own an AV in Build, in Baseline vs. Build
2. Comparison of the same group of households (“Group 1”) that never own an AV, either in Baseline or Build, in Baseline vs. Build
3. Comparison of Group 1 vs. Group 2 households in Build
4. Comparison of Group 1 vs. Group 2 households in Baseline

Using an R script that summarizes the ActivitySim outputs for a subset of population, COG staff generated four sets of ActivitySim summary statistics in csv format for Group 1 and Group 2 households in the Baseline and Build scenarios, respectively. Staff then ran the VFS script four times to make each of the above four comparisons.

The following is what COG staff found in this investigation:

The first comparison focuses on the same group of households (Group 2 households) that do not own an AV in the Baseline scenario but own an AV in the Build scenario. This group of households is of most interest because one can compare, “apples to apples,” to examine changes in household travel behaviors before and after the use of AVs. The screenshot in The second comparison looks at the group of households who never own AVs (Group 1) in Baseline

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[30] See Fehr & Peers, 2023, https://www.fehrandpeers.com/autonomous-vehicle-research/;
See also: Ronald T. Milam, Adrita Islam, et al., “Using Current Practice Regional Models To Test Autonomous Vehicle Effects On Travel Demand And Public Agency Policy Responses”, Presented at the 99th TRB Annual Meeting, January 12-16, 2020, in Washington, D.C., https://www.fehrandpeers.com/wp-content/uploads/2020/01/Milam_Islam_Johnson_Fong_Donkor_Xu_AV-Modeling_TRB_2020.pdf

vs. Build. Again, the screenshot in **FIGURE 15** below includes only select statistics. As can be seen, the number of tours (#5) and trips (#6) made by Group 1 households were about the same, but total VMT decreased by 3.1% (#8) going from the Baseline to the Build scenario, suggesting that they made slightly shorter tours/trips. This is consistent with the observation of shorter average mandatory tour lengths (Items 78-81) and non-mandatory tour lengths (Items 130-137, except for #136). The auto ownership of Group 1 households did not change between the two scenarios. They made shorter tours/trips and generated slightly less VMT, probably because of the increased roadway congestion in the Build Scenario. Likely for the same reason, Group 1 households also made slightly fewer stops (#7) and traveled shorter out-of-direction distances to reach stop destinations. No significant changes in trip mode choice are observed (Items 300-310), as AV is unavailable to this group of households.

below includes only select statistics from this comparison (full summaries can be accessed through the Box link provided at the bottom).

As can be seen in Item #8, Group 2 households generated slightly more VMT (+6.3%) after owning AV, but they also made fewer tours (#5), suggesting that Group 2 households traveled in slightly greater tour lengths after they owned AVs. This is consistent with Items #79 and #80, which show larger work/university tour lengths in the Build scenario. On the other hand, the AV-owning households made slightly more stops (#7) and traveled to destinations with longer out-of-direction distances (#265-275).

But why were AV-owning households making fewer tours? The cause could be multifaceted. For example, this could be related to the change in total cars owned by Group 2 households. As shown in Items 53-57, the numbers of 1-car and 2-car households increased in the Build scenario, the number of 3-car households decreased, and the numbers of 0-car and 4-plus-car households dropped to zero, due to the changes to the auto ownership constants described in Table 1. Assuming the households with 4+ cars on average own 4.5 cars per household, COG staff did a back-of-the-envelope calculation on total number of household cars based on Items 53-57. It was found that Group 2 households owned in total about 1,720,000 regular cars in Baseline, while they owned only 1,360,000 cars in Build, including both regular cars and AVs, which translates into a 21% loss of total passenger cars owned. As a result, although Group 2 households can travel farther and generate more VMT with AVs, they also had to reduce the number of tours due to the overall loss of auto ownership (As explained earlier, it does not help that the current Gen3 Model does not simulate AV repositioning trips). Another possible cause to the decrease of total tours could be longer tour distances for higher-priority purposes, which lead to less time leftover to generate non-mandatory tours. Evidence for this can be found in the time-of-day shifts of tour departures/ arrivals – For example, COG staff observed a slight increase in the number of tour departures in the early morning and night periods (NT1 and NT2, Items #139, 143), likely to accommodate the longer tours in the Build scenario.

The decrease in auto ownership could lead to problematic results in some of the downstream models, as their model constants that are estimated based on number of autos owned do not account for increased mobility provided by an autonomous vehicle. For example, as shown in

Items 68-72, Group 2 households switched to teleworking probably to compensate for the loss of auto mobility in the Build scenario. This movement, however, is somewhat counterintuitive as AVs are supposed to make commuting more attractive.

In the meantime, AV-owning households also switched away from transit, making overall 29% fewer transit trips (items #306-308), particularly, 40% fewer PNR transit trips (Item #307). These transit trips were likely replaced by AV auto trips that saw much reduced burdens in terms of travel time and parking cost. PNR/KNR transit trips were also negatively affected by the increased roadway congestion and hence increased drive access time in the Build scenario.

A further analysis of disaggregate ActivitySim outputs[31] indicates that, out of 712,079 AV-owning households, 607,510 (85.3%) of them owned one AV, 100,941 (14.2%) of them owned two AVs and 3,628 (0.5%) of them owned three AVs in the Build scenario. Out of the 2,655,489 tours[32] that were made by this group of households, 1,602,239, or 60.3% of them used AV.

[31] For internal reference, "Z:\team_mem\fxie\PyCharm_Projects\Summarize_AV_ownership_and_allocation_to_tours\output_2045_AV.txt"

[32] This total figure (2,655,489) is different from the total shown in Figure 12 (2,887,448) because in the former case, a joint tour made by multiple household members was counted as one tour while in the latter case, it was counted as multiple tours, one for each household member on the joint tour.

FIGURE 14: COMPARISON OF GROUP 2 HOUSEHOLDS IN BASELINE VS. BUILD: SELECTED TRAVEL STATISTICS

	Item	Group 2: HHs_before_owning_AV_2045	Group 2: HHs_after_owning_AV_2045	Diff.	% Diff.
0	scenario	2045_baseline	2045_AV		
2	I. Overview				
3	total population	2,694,761	2,694,761	0	0.0%
4	total households	712,079	712,079	0	0.0%
5	total tours	2,897,668	2,887,448	-10220	-0.4%
6	total trips	7,397,808	7,401,365	3557	0.0%
7	total person stops	1,602,472	1,626,469	23997	1.5%
8	total vmt	54,268,604	57,667,020	3398416	6.3%
51	II. Long-Term Model Summaries				
52	Households by car ownership				
53	0 car	14,580	0	-14580	-100.0%
54	1 car	110,323	198,891	88568	80.3%
55	2 cars	313,922	378,516	64594	20.6%
56	3 cars	164,562	134,672	-29890	-18.2%
57	4+ cars	108,692	0	-108692	-100.0%
68	Telecommute Frequency				
69	1 day a week	174,817	191,781	16964	9.7%
70	2 to 3 days a week	140,219	154,022	13803	9.8%
71	4 days a week	52,467	51,265	-1202	-2.3%
72	No telecommute	1,309,915	1,280,206	-29709	-2.3%
73	total out-of-home workers	1,677,418	1,677,274	-144	0.0%
78	Average mandatory tour lengths in miles				
79	work tour length	20.49	21.25	0.76	3.7%
80	university tour length	13.77	13.82	0.05	0.4%
81	school tour length	6.24	6.16	-0.08	-1.3%
130	Average Non-Mandatory tour lengths (Miles)				
131	Escorting	4.63	4.57	-0.06	-1.3%
132	Indi-Maintenance	5.97	5.97	0	0.0%
133	Indi-Discretionary	6.79	6.66	-0.13	-1.9%
134	Joint-Maintenance	6.66	6.7	0.04	0.6%
135	Joint-Discretionary	7.06	7.02	-0.04	-0.6%
136	At-Work	4.77	4.37	-0.4	-8.4%
137	All Tours	5.93	5.77	-0.16	-2.7%
138	Tour departures by TOD				
139	NT1	266,203	277,886	11683	4.4%
140	AM	1,272,253	1,251,792	-20461	-1.6%
141	MD	822,073	818,923	-3150	-0.4%
142	PM	209,470	206,298	-3172	-1.5%
143	NT2	100,309	100,590	281	0.3%
265	Aver. out-of-direction dist. by tour purpose				
266	Work	2.81	2.97	0.16	5.7%
267	University	4.68	5.38	0.7	15.0%
268	School	3.98	4.13	0.15	3.8%
269	Escorting	3.06	3.24	0.18	5.9%
270	Indi-Maintenance	3.42	3.69	0.27	7.9%
271	Indi-Discretionary	2.76	2.91	0.15	5.4%
272	Joint-Maintenance	3.22	3.43	0.21	6.5%
273	Joint-Discretionary	2.82	2.93	0.11	3.9%
274	At-Work	2.1	2.17	0.07	3.3%
275	total average distance	2.92	3.09	0.17	5.8%
300	Trips by trip mode				
301	Auto SOV	3,512,933	3,600,059	87126	2.5%
302	Auto HOV2	1,474,366	1,517,139	42773	2.9%
303	Auto HOV3+	1,209,541	1,209,243	-298	0.0%
304	Walk	465,679	464,206	-1473	-0.3%
305	Bike	87,677	99,372	11695	13.3%
306	Walk-Transit	185,183	142,981	-42202	-22.8%
307	PNR-Transit	126,292	75,668	-50624	-40.1%
308	KNR-Transit	34,774	26,994	-7780	-22.4%
309	School Bus	200,788	174,449	-26339	-13.1%
310	Ride Hail	100,575	91,254	-9321	-9.3%
311	total trips	7,397,808	7,401,365	3557	0.0%

Note: Full spreadsheet summary table can be accessed through https://app.box.com/s/gbpggfbao3q9pd30lfnbgvczoucqzu33

The second comparison looks at the group of households who never own AVs (Group 1) in Baseline vs. Build. Again, the screenshot in **FIGURE 15** below includes only select statistics. As can be seen, the number of tours (#5) and trips (#6) made by Group 1 households were about the same, but total VMT decreased by 3.1% (#8) going from the Baseline to the Build scenario, suggesting that they made slightly shorter tours/trips. This is consistent with the observation of shorter average mandatory tour lengths (Items 78-81) and non-mandatory tour lengths (Items 130-137, except for #136). The auto ownership of Group 1 households did not change between the two scenarios. They made shorter tours/trips and generated slightly less VMT, probably because of the increased roadway congestion in the Build Scenario. Likely for the same reason, Group 1 households also made slightly fewer stops (#7) and traveled shorter out-of-direction distances to reach stop destinations. No significant changes in trip mode choice are observed (Items 300-310), as AV is unavailable to this group of households.

FIGURE 16: COMPARISON OF GROUP 1 HOUSEHOLDS IN BASELINE VS. BUILD: SELECTED TRAVEL STATISTICS

	Item	Group 1: HHs_never_owning_AV_2045_baseline	Group 1: HHs_never_owning_AV_2045_AV	Diff.	% Diff.
0	scenario	2045_baseline	2045_AV		
2	I. Overview				
3	total population	6,323,134	6,323,134	0	0.0%
4	total households	2,843,145	2,843,145	0	0.0%
5	total tours	6,194,264	6,192,264	-2000	0.0%
6	total trips	16,069,966	16,053,596	-16370	-0.1%
7	total person stops	3,681,438	3,669,068	-12370	-0.3%
8	total vmt	63,157,664	61,170,984	-1986680	-3.1%
78	Average mandatory tour lengths in miles				
79	work tour length	9.27	8.81	-0.46	-5.0%
80	university tour length	9.9	9.86	-0.04	-0.4%
81	school tour length	5.68	5.6	-0.08	-1.4%
130	Average Non-Mandatory tour lengths (Miles)				
131	Escorting	4.2	4.16	-0.04	-1.0%
132	Indi-Maintenance	4.84	4.84	0	0.0%
133	Indi-Discretionary	5.68	5.66	-0.02	-0.4%
134	Joint-Maintenance	5.67	5.67	0	0.0%
135	Joint-Discretionary	6.32	6.32	0	0.0%
136	At-Work	4.65	4.66	0.01	0.2%
137	All Tours	5.26	5.25	-0.01	-0.2%
265	Aver. out-of-direction dist. by tour purpose				
266	Work	2.65	2.65	0	0.0%
267	University	3.5	3.48	-0.02	-0.6%
268	School	3.67	3.67	0	0.0%
269	Escorting	2.82	2.81	-0.01	-0.4%
270	Indi-Maintenance	3.09	3.09	0	0.0%
271	Indi-Discretionary	2.51	2.5	-0.01	-0.4%
272	Joint-Maintenance	3.08	3.09	0.01	0.3%
273	Joint-Discretionary	2.62	2.61	-0.01	-0.4%
274	At-Work	1.98	1.99	0.01	0.5%
275	total average distance	2.77	2.77	0	0.0%
300	Trips by trip mode				
301	Auto SOV	7,472,995	7,447,428	-25567	-0.3%
302	Auto HOV2	3,091,370	3,084,947	-6423	-0.2%
303	Auto HOV3+	2,038,777	2,035,844	-2933	-0.1%
304	Walk	1,619,746	1,625,478	5732	0.4%
305	Bike	185,103	188,590	3487	1.9%
306	Walk-Transit	755,647	762,786	7139	0.9%
307	PNR-Transit	156,842	158,628	1786	1.1%
308	KNR-Transit	63,422	63,478	56	0.1%
309	School Bus	391,376	391,963	587	0.1%
310	Ride Hail	294,688	294,454	-234	-0.1%
311	total trips	16,069,966	16,053,596	-16370	-0.1%

Note: Full spreadsheet summary table can be accessed through https://app.box.com/s/8nxqf5hv54dhpalqjak3x3el7hkeya5o

The third comparison looks at Group 1 vs. Group 2 households in the Build scenario. In appearance, the comparison summary (THE FOURTH comparison looks at Group 1 vs. Group 2 in the Baseline scenario. Neither Group 1 nor Group 2 households owned an AV in Baseline, but Group 2 still generated significantly more tours/trips/VMT per capita (

Figure 18). As discussed above, this difference could be attributed to the difference in household income distributions between the two groups.

) shows vast differences between Group 1 and Group 2: Relative to Group 1, Group 2 households made 9% more tours (#9) and 8% more trips per person (#10), traveled a 141% longer distance on work tours (#79), and generated 276% more VMT per household (bottom row)! Initially, COG staff thought these differences were due to AV ownership and were puzzled about why these prominent AV effects did not show up in the first comparison. Then COG staff realized that target AV market shares differ by income segment, and households with higher income have higher AV ownership. As a result, households who do not own AV (Group 1) and households who own AV (Group 2) have very different demographic profiles in terms of income - Group 2 has a larger portion of high-income households who tend to generate more travel. Thus, the difference in travel statistics shown below, in Figure 3, is mostly attributable to the difference in travel patterns between households of different income levels rather than the ownership of an AV. This is also evidenced in the fourth comparison, which will be discussed below. Please note that the total households for Group 2 is exactly 75% fewer than that for Group 1 (#4). That is because, by design, there are exactly 20% of total households who own AV and 80% of them that do not in the Build scenario.

FIGURE 17: COMPARISON OF GROUP 1 VS. GROUP 2 HOUSEHOLDS IN BUILD: SELECTED TRAVEL STATISTICS

	Item	Group 1: HHs_wo_AV	Group 2: HHs_w_AV	Diff.	% Diff.
0	scenario	2045_AV	2045_AV		
2	I. Overview				
3	total population	6,323,134	2,694,761	-3628373	-57%
4	total households	2,843,145	712,079	-2131066	-75%
5	total tours	6,192,264	2,887,448	-3304816	-53%
6	total trips	16,053,596	7,401,365	-8652231	-54%
7	total person stops	3,669,068	1,626,469	-2042599	-56%
8	total vmt	61,170,984	57,667,020	-3503964	-6%
9	tours per person	0.98	1.07	0.09	9%
10	trips per person	2.54	2.75	0.21	8%
11	stops per person	0.58	0.6	0.02	3%
12	trips per household	5.65	10.39	4.74	84%
78	Average mandatory tour lengths in miles				
79	work tour length	8.81	21.25	12.44	141%
80	university tour length	9.86	13.82	3.96	40%
81	school tour length	5.6	6.16	0.56	10%
130	Average Non-Mandatory tour lengths (Miles)				
131	Escorting	4.16	4.57	0.41	10%
132	Indi-Maintenance	4.84	5.97	1.13	23%
133	Indi-Discretionary	5.66	6.66	1	18%
134	Joint-Maintenance	5.67	6.7	1.03	18%
135	Joint-Discretionary	6.32	7.02	0.7	11%
136	At-Work	4.66	4.37	-0.29	-6%
137	All Tours	5.25	5.77	0.52	10%
	Resident VMT per Capita	9.67	21.40	11.73	121%
	Resident VMT per household	21.52	80.98	59.47	276%

Note: Full spreadsheet summary table can be accessed through https://app.box.com/s/xghti6qnwqvpmcpcnag5pv021v1c688w

The fourth comparison looks at Group 1 vs. Group 2 in the Baseline scenario. Neither Group 1 nor Group 2 households owned an AV in Baseline, but Group 2 still generated significantly more tours/trips/VMT per capita (

FIGURE 18). As discussed above, this difference could be attributed to the difference in household income distributions between the two groups.

FIGURE 18: COMPARISON OF GROUP 1 VS. GROUP 2 HOUSEHOLDS IN BASELINE: SELECTED TRAVEL STATISTICS

	Item	Group 1: HHs_never_own_AV	Group 2: HHs_own_AV_in_Build	Diff.	% Diff.
0	scenario	2045_Baseline	2045_Baseline		
2	I. Overview				
3	total population	6,323,134	2,694,761	-3628373	-57.4%
4	total households	2,843,145	712,079	-2131066	-75.0%
5	total tours	6,194,264	2,897,668	-3296596	-53.2%
6	total trips	16,069,966	7,397,808	-8672158	-54.0%
7	total person stops	3,681,438	1,602,472	-2078966	-56.5%
8	total vmt	63,157,664	54,268,604	-8889060	-14.1%
9	tours per person	0.98	1.08	0.1	10.2%
10	trips per person	2.54	2.75	0.21	8.3%
11	stops per person	0.58	0.59	0.01	1.7%
12	trips per household	5.65	10.39	4.74	83.9%
78	Average mandatory tour lengths in miles				
79	work tour length	9.27	20.49	11.22	121.0%
80	university tour length	9.9	13.77	3.87	39.1%
81	school tour length	5.68	6.24	0.56	9.9%
130	Average Non-Mandatory tour lengths (Miles)				
131	Escorting	4.2	4.63	0.43	10.2%
132	Indi-Maintenance	4.84	5.97	1.13	23.3%
133	Indi-Discretionary	5.68	6.79	1.11	19.5%
134	Joint-Maintenance	5.67	6.66	0.99	17.5%
135	Joint-Discretionary	6.32	7.06	0.74	11.7%
136	At-Work	4.65	4.77	0.12	2.6%
137	All Tours	5.26	5.93	0.67	12.7%
	Resident VMT per Capita (#8/#3)	9.99	20.14	10.15	102%
	Resident VMT per household (#8/#4)	22.21	76.21	54.00	243%

Note: Full spreadsheet summary table can be accessed through https://app.box.com/s/wdwa3eiayiy9duohzk91yti1c36lg6k5

ADDITIONAL FINDINGS

The impact of AV deadheading trips was examined in the two additional scenarios created on top of the 2045 Build Scenario. Both scenarios resulted in substantial increases in total travel. As shown in Table 72, total VMT increased by 13%, total VHT increased by 26% and total VHD increased by 46% going from Scenario 1 (Baseline) to Scenario 3 (“2045 Build + AV Deadheading” with 50% of AV returning to tour origins)”, while total VMT increased by 26%, total VHT increased by 62% and total VHD increased by 115% in Scenario 4 (“2045 Build + AV Deadheading” with 100% of AV returning to tour origins)” relative to the Baseline. The percent VMT changes in both scenarios are in line with the findings from the Fehr and Peers study. As noted earlier, Scenario 3 and Scenario 4 did not consider the speed feedback effects and thus tended to over-simulate the VMT, but they (especially Scenario 4) provided a bookend estimation of maximum possible VMT impacts of AV when AV deadheading is considered.

As shown in Table 73, Scenario 3 introduced about 1.6 million AV deadheading trips and 23.9 million AV deadheading VMT to the system, while Scenario 4 added about 3.2 million AV deadheading trips and 48.0 million AV deadheading VMT. As compared to Scenario 2 (2045 Build with no deadheading), households owning AVs made about 41% more VMT in Scenario 3 and about 83% VMT in Scenario 4 due to AV deadheading trips. In a presentation made to the European Transport Conference (ETC) on September 7,[33] RSG mentioned of a Java-based AV household trip allocation model developed for SANDAG. It was noted that the SANDAG model “Simulates AV car sharing and vehicle repositioning for trips made by members of an AV-owning household” and “Predicts approximately 63% more VMT per household on average for owning an AV due to vehicle repositioning”. Findings from our extended AV scenario analysis (in terms of percent increase in VMT made by AV-owning households due to AV deadheading) seem to be in line with the SANDAG model.

TABLE 72: INCREASED TRAVEL IN 2045 BUILD SCENARIOS CONSIDERING AV DEADHEADING

SCENARIO	1	2	3	4	% DIFFERENCE		
	2045 BASELINE	2045 BUILD	2045 BUILD + AV DEADHEADING		2 MINU 1	3 MINUS 1	4 MINUS 1
			50% AV RETURN	100% AV RETURN			
TOTAL VMT	198,063,812	199,366,922	223,839,121	248,756,764	1%	13%	26%
TOTAL VHT	6,064,648	6,157,982	7,661,293	9,795,008	2%	26%	62%
TOTAL VHD	2,397,504	2,465,843	3,502,529	5,156,751	3%	46%	115%

TABLE 73: INCREASED TRAVEL IN 2045 BUILD SCENARIOS CONSIDERING AV DEADHEADING

SCENARIO	2	3	4	% DIFFERENCE	
	2045 BUILD	2045 BUILD + AV DEADHEADING		3 MINUS 2	4 MINUS 2
		50% AV RETURN	100% AV RETURN		
AV DEADHEADING TRIPS	0	1,602,240	3,204,480	N.A.	
VMT BY HOUSEHOLDS OWNING AV					
AUTODRIVER VMT	57,667,020	57,667,020	57,667,020	0%	0%
AV DEADHEADING VMT	0	23,854,084	47,999,877	N.A.	N.A.
TOTAL VMT	57,667,020	81,521,104	105,666,897	41%	83%

[33] Joel Freedman and David Hensle, “Modeling Vehicle Type with Autonomous Vehicle Extension in an Activity-Based Framework”, Presented to European Transport Conference, September 7, 2023.

CONCLUDING REMARKS

The AV specification of the Gen3 Model is a critical addition to TPB's regional travel models in terms of their ability to evaluate the impact of this emerging technology. The December 2023 scenario analysis confirmed some success in the AV model implementation in terms of capturing the increased auto travel and reduced transit ridership for the AV-owning households due to the reduced travel burdens associated with their use of AVs. However, it also revealed some of the limitations:

- The AV implementation as of December 2023 did not account for some of the more advanced AV dynamics such as repositioning ("deadheading") trips, curbside pickups/drop-offs, and AV ridesharing; It also did not consider the AV effects on the supply side.
- In addition, the auto ownership model constants that are adjusted as part of the current AV specification seem to have reduced the overall auto ownership/mobility for AV-owning households, thus resulting in fewer tours and trips being made. Those constants were borrowed from SANDAG with values either asserted or informed from stated preference (SP) surveys. Whether these values are realistic remains to be seen when the empirical data becomes available.
- The decrease in auto ownership also led to somewhat counterintuitive results in the downstream models, as the downstream model constants that are estimated based on number of cars owned do not account for increased mobility provided by an autonomous vehicle. In an email sent on December 5, 2023,[34] RSG staff suggested that "a vehicle availability model would change many of these constants from being household-based to being person-based, which would solve the problem."

Overall, the Gen3 Model, with the AV specification as of December 2023, predicted a slight net increase in total auto travel and a moderate decrease in transit boardings if 20% of the households in this region own AVs in the horizon year of 2045. Although the directionality of these changes is consistent with our expectation, the magnitude of these AV effects was not as significant as what had been revealed in prior studies. This can mainly be attributed to the lack of treatments for more intelligent AV behaviors AV repositioning (deadheading). If SANDAG's AV household trip allocation model that simulates AV car sharing and vehicle repositioning represents the state of art in AV modeling, the significant VMT impact predicted by the SANDAG model (specifically, "approximately 63% more VMT per household on average for owning an AV due to vehicle repositioning") suggested that there was still room to improve the realism of the AV representation in the Gen3 Model.

[34] Joel Freedman, "RE: Memo on MWCOG's Autonomous Vehicle (AV) scenario analysis", Email to Feng Xie and Andrew Rohne, December 5, 2023.

To address this limitation, MWCOG extended the AV specification in the Gen3 Model in April 2024 to simulate AV deadheading trips based on simplified assumptions. The addition of AV deadheading trips in a post-processing procedure substantially increased total travel in the system, and the resulting VMT changes in the extended scenario analysis were consistent with prior studies. Although this simplified approach does not fully capture the sophisticated AV dynamics, it provides a reasonable bookend estimation of the VMT impacts of AV at a regional scale. While COG staff currently does not recommend the use of the Gen3 Model for AV-related policy analysis, the Gen3 Model with this extended AV specification could be used for exploratory scenario analysis or strategic planning related to autonomous vehicles.

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