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Metropolitan Washington Council of Governments

GEN3 MODEL PHASE 1 SENSITIVITY TESTING RESULTS

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PREPARED FOR:

METROPOLITAN WASHINGTON COUNCIL OF GOVERNMENTS

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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, 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, to be known as the Generation 3, or Gen3, Model.

The model is being implemented in two phases. Phase 1 is to be a prototype model that can be tested by the COG/TPB staff. Phase 2 is to be 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. The 2018 traffic counts and transit boarding counts that are used for Phase 1 model validation were provided by MWCOG staff and were documented separately. Thus, the preparation of the count data is not covered in this report. The following models were calibrated to RTS/MTS data (see Figure 1):

[1] Gen3 Phase 1 Data Development Report, December 29, 2021 (https://app.box.com/s/xe5vb28daox1aqtw895iy2r5ocy584w8)

- Auto ownership
- Coordinated daily activity pattern (CDAP)
- Tour mode choice
- Trip mode choice
- Individual non-mandatory tour frequency
- Stop frequency
- Tour destination choice
- Stop location choice

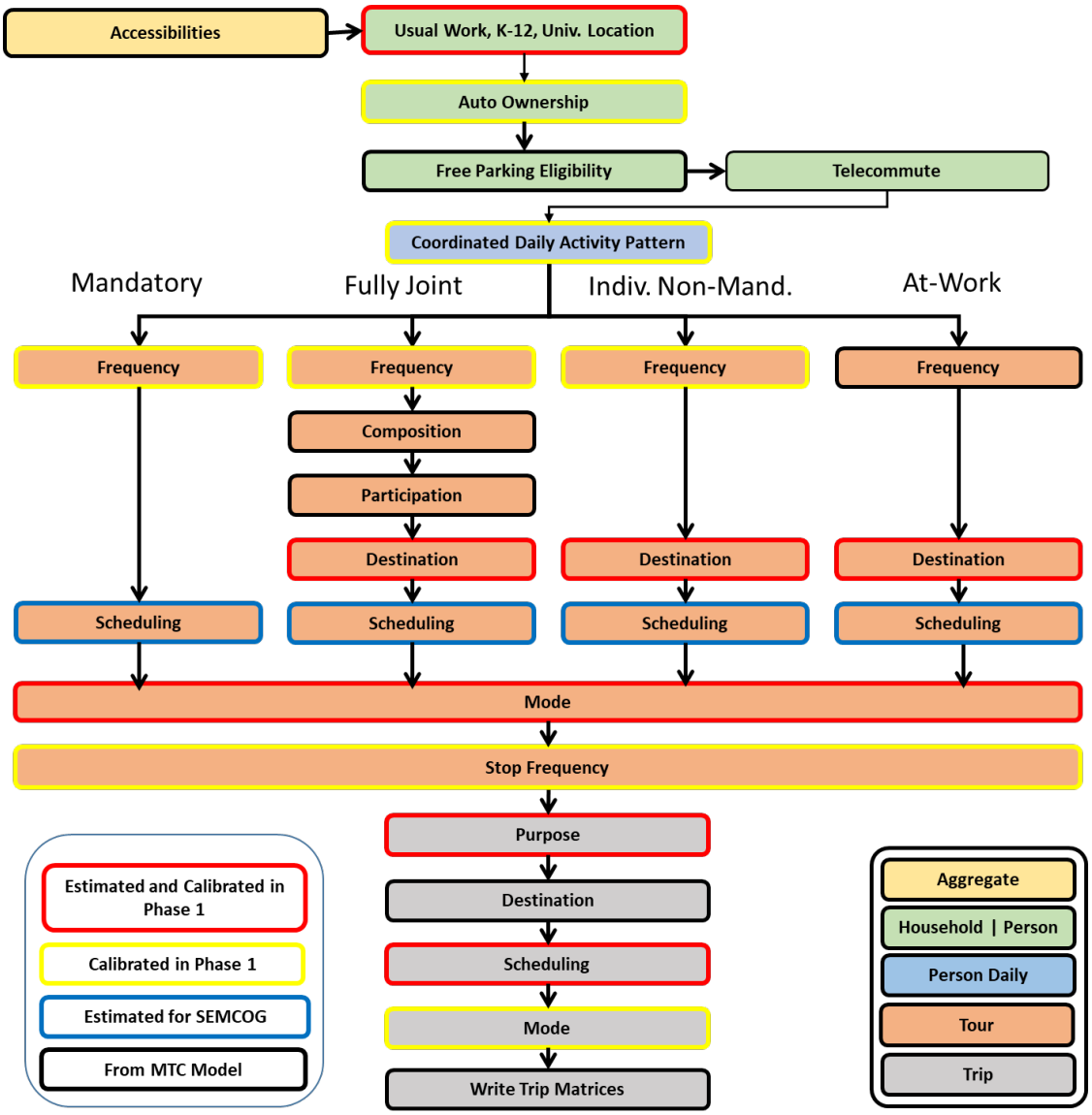

FIGURE 1: GEN3 PHASE 1 MODEL STRUCTURE

This report describes Gen3 Phase 1 sensitivity testing results. The following sensitivity tests were run in Phase 1:

- An auto operating cost test, in which auto operating cost was increased by 10 cents per mile to reflect a vehicle tax or increase in fuel cost. RSG ran this sensitivity test.
- 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. RSG ran this sensitivity test.

- A highway capacity reduction test, in which the Arlington Memorial Bridge was closed to auto use. MWCOG ran this sensitivity test.
- 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). MWCOG ran this sensitivity test.
- A test where toll rates on variably priced tolling facilities during peak hours were increased by 50%. MWCOG ran this sensitivity test.

Each test is described in a separate chapter of the 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 tests. However, the Baseline scenarios differ slightly between the sensitivity tests run by RSG versus the tests run by COG staff. When running the auto operating cost scenario, RSG discovered that the auto operating cost used for trip mode choice was 1 cent per mile less than the auto operating cost used for tour mode choice. This was corrected to use the same auto operating cost for both tour and trip mode choice (19.26 cents per mile). In order to correct this issue from occurring in future model runs, the auto operating cost parameter was moved from the tour_mode_choice.yaml and trip_mode_choice.yaml files to constants.yaml. The COG Baseline model run still has this inconsistency. However, this should not affect the reasonableness of the results for the COG sensitivity tests. In addition, the Baseline scenario in the variable toll test is slightly different from those in the other two COG tests as the Baseline toll rates were re-estimated for the purpose of this test.

Note that the results presented in this report are the result of a baseline versus build scenario in which both scenarios use the same random number seed, in order to reduce Monte Carlo simulation variance[2] 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 build alternative is different for a subset of households, people in those households may generate different numbers of tours, with different destinations, modes,

[2] 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.

etc. To some extent these changes are consistent with the change in auto ownership, but the overall outcome may not be immediately obvious.

Furthermore, the 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 higher than the noise (Monte Carlo simulation variance) 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 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 RTS/MTS data. 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. However, 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 highway and transit assignment results.

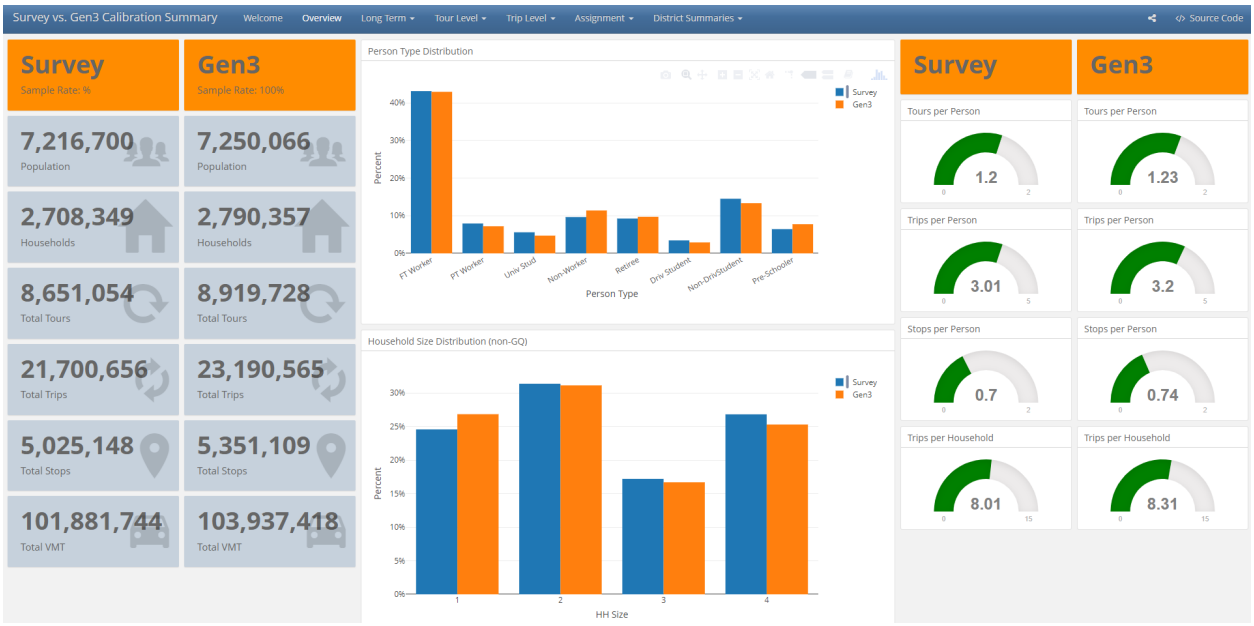

FIGURE 2: ABM VISUALIZER OVERVIEW PAGE

2.0 AUTO OPERATING COST SCENARIO

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 to 29.26 cents per mile, in order to emulate a vehicle-mile tax policy scenario. This was implemented by changing line 61 in the tour_mode_choice.yaml file and line 62 in the trip_mode_choice.yaml file, from `costPerMile: 19.26` to `costPerMile: 29.26`. When testing this scenario, we discovered that the costPerMile setting in the trip_mode_choice.yaml file in the base scenario was set incorrectly to 18.29 cents per mile. The auto operating cost used in the model is based on a report by the American Automobile Association, entitled " Your Driving Costs: How Much Are You Really Paying to Drive?" for 2018[3]. The auto operating cost used in the model includes the cost of fuel, maintenance, repair, and tires and is averaged across all vehicle types. In order to compare the AOC scenario to a consistent base scenario, the cost per mile was corrected to 29.26 cents per mile and the base scenario was re-run with the corrected value. This Baseline model run was also used for comparison to the District of Columbia Telecommute Scenario described below.

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 auto ownership utility equations or in the accessibility terms currently used in the auto ownership model.
- We may 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 increased cost of auto which will affect tour and trip mode choice logsums
- We do not expect significant changes to time-of-day since the increased auto operating cost is not differentiated by time of day
- We expect mode shifts from auto to non-motorized and transit modes

[3] https://exchange.aaa.com/wp-content/uploads/2018/09/18-0090_2018-Your-Driving-Costs-Brochure_FNL-Lo-5-2.pdf, accessed March 14, 2022.

- We expect somewhat fewer stops generated per tour as tour lengths decrease
- We expect decreased vehicle miles of travel 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 ActivitySim results between the scenarios from the activity-based model visualizer tool. BaselineIn order to keep the discussion concise, we only show visualizer outputs for model components that exhibit some noticeable change between the Baseline and build scenarios. The full visualizer file is available on Box for those interested in further investigating differences.

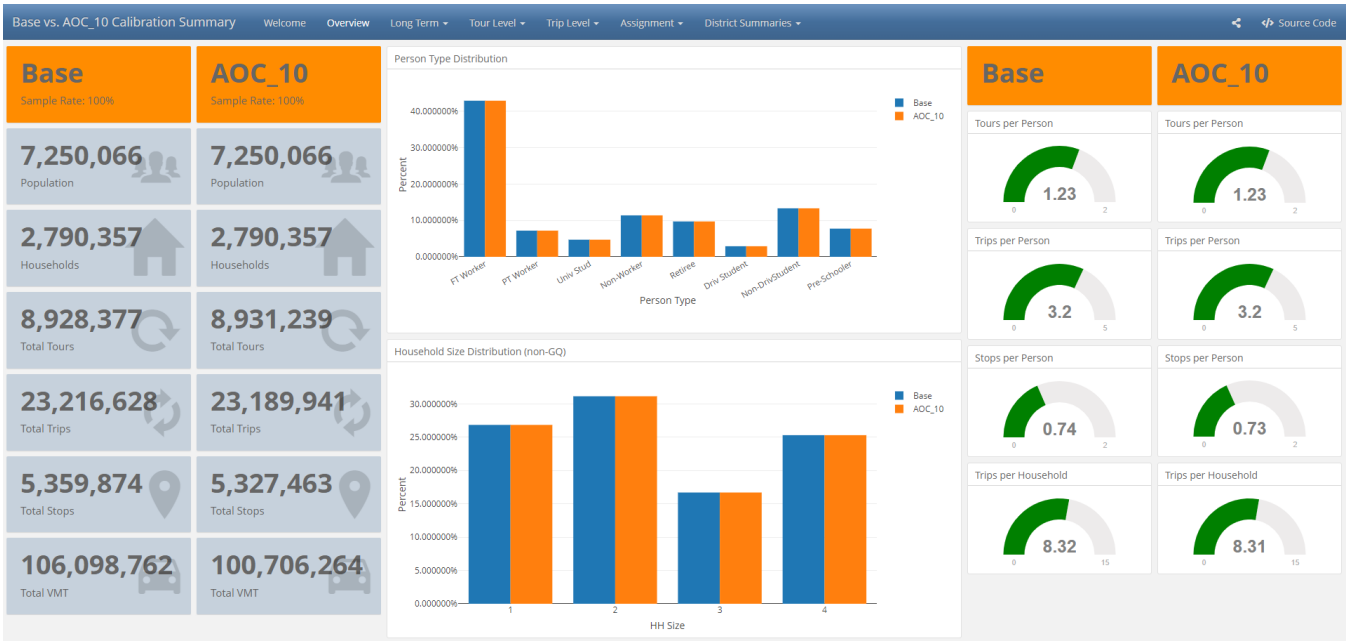

FIGURE 3: AOC VERSUS BASELINE VISUALIZER SUMMARY

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 2,862 more tours in the AOC scenario, which is a 0.03%

increase over the Baseline. This is likely due to simulation variance in the results. There are 32,411 fewer stops generated in the AOC scenario compared to the Baseline scenario, a decrease of 0.6%. This is consistent with our a priori expectations for decreased stop generation, due to shorter auto tour lengths. This leads to a decrease of 26,687 total trips generated, which is a decrease of 0.1%.

Vehicle miles of travel (VMT) generated by households decreases by 5,392,498 miles or 5.1% 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 1.3% for work location choice, 2.5% for university location choice, and 1.8% for school 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 0.4 miles or 7.5%. 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 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 bBaseline scenario and the AOC scenario. As expected, the Gen3 Phase 1 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 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 with better transit accessibility than auto-owning households. Walk mode tours increase by 3.2% and bike mode tours increase by 5.1% in the AOC scenario. Walk-transit tours increase by 3.4%, park-and-ride transit tours increase by 12.0%, and kiss-and-ride transit tours increase by 7.4%. School bus tours increase by 3.2% and ride-hail tours increase by 6.4% in the AOC scenario. Note that the cost of ride-hailing services was not increased as part of this scenario. In reality some portion of a mileage-based tax would likely be passed on to customers.

TABLE 1: BASELINE VERSUS AOC MANDATORY TOUR LENGTH COMPARISON

	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	5.5	1.9	2.9	5.4	1.9	2.8	-0.1	0.0	0.0	-1.5%	-0.5%	-0.7%
Montgomery County	11.9	7.4	3.7	11.8	7.3	3.6	-0.1	-0.1	-0.1	-1.0%	-1.1%	-1.6%
Prince George's County	12.7	5.0	4.2	12.5	4.9	4.2	-0.2	-0.1	-0.1	-1.2%	-1.4%	-1.4%
Arlington County	6.8	2.6	3.3	6.7	2.5	3.2	-0.1	0.0	0.0	-1.3%	-0.8%	-1.5%
City of Alexandria	8.5	3.5	3.1	8.4	3.5	3.1	-0.1	0.0	-0.1	-0.9%	-0.6%	-1.9%
Fairfax County	11.5	5.1	3.8	11.4	5.0	3.8	-0.1	-0.1	-0.1	-1.0%	-1.2%	-1.6%
Loudoun County	16.2	9.2	3.9	16.0	9.0	3.8	-0.2	-0.2	-0.1	-1.2%	-2.5%	-1.8%
Prince William County	16.7	6.3	3.5	16.5	6.3	3.5	-0.2	-0.1	-0.1	-1.0%	-1.0%	-1.7%
Frederick County	16.4	8.6	4.3	16.1	8.3	4.2	-0.3	-0.3	-0.1	-2.0%	-3.0%	-1.6%
Howard County	13.2	7.4	4.0	13.0	7.2	3.9	-0.1	-0.2	-0.1	-0.8%	-2.4%	-2.0%
Anne Arundel County	13.8	10.1	4.2	13.7	9.7	4.1	-0.1	-0.4	-0.1	-1.0%	-3.8%	-1.7%
Charles County	22.5	13.3	5.3	22.2	12.7	5.2	-0.3	-0.6	-0.1	-1.3%	-4.2%	-1.9%
Carrol County	17.0	11.7	5.2	16.6	11.1	5.1	-0.4	-0.6	-0.1	-2.5%	-4.9%	-1.4%
Calvert County	24.6	34.8	5.0	24.2	33.5	4.9	-0.4	-1.3	-0.1	-1.7%	-3.8%	-1.8%
St. Mary's County	17.5	10.7	5.8	17.1	10.1	5.7	-0.5	-0.6	-0.1	-2.8%	-5.8%	-1.4%
King George County	26.3	30.6	7.4	25.8	28.8	7.3	-0.5	-1.8	-0.1	-1.9%	-5.7%	-1.6%
City of Fredericksburg	10.5	1.7	3.3	10.2	1.6	3.3	-0.3	0.0	0.0	-2.8%	-2.4%	-0.9%
Stafford County	19.8	15.8	4.3	19.4	14.9	4.3	-0.4	-0.9	-0.1	-1.8%	-5.4%	-1.4%
Spotsylvania County	15.2	6.1	4.0	14.8	5.9	4.0	-0.4	-0.2	0.0	-2.6%	-3.0%	-1.0%
Fauquier County	25.7	16.9	7.2	25.4	16.4	7.0	-0.3	-0.6	-0.1	-1.2%	-3.3%	-2.1%
Clarke County	29.9	40.5	7.0	29.3	40.3	6.9	-0.6	-0.2	-0.1	-1.9%	-0.6%	-1.0%
Jefferson County	24.2	14.7	5.9	23.5	13.8	5.8	-0.7	-0.9	-0.1	-2.8%	-6.5%	-1.5%
Total	**13.0**	**6.5**	**4.0**	**12.8**	**6.3**	**3.9**	**-0.2**	**-0.2**	**-0.1**	**-1.3%**	**-2.5%**	**-1.8%**

TABLE 2:BASELINE VERSUS AOC NON-MANDATORY TOUR LENGTH COMPARISON

Purpose	Baseline Scenario	AOC Scenario	Difference	Percent Difference
Escorting	4.3	4.0	-0.3	-6.1%
Individual Maintenance	5.7	5.3	-0.4	-6.5%
Individual Discretionary	6.2	5.7	-0.5	-8.7%
Joint Maintenance	7.2	6.6	-0.6	-7.8%
Joint Discretionary	7.3	6.5	-0.8	-10.3%
At-Work	5.0	4.9	-0.2	-3.0%
Total	5.9	5.5	-0.4	-7.5%

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

	Baseline				AOC			
Tour Mode	0 Auto	Autos < Workers	Autos >= Workers	Total	0 Auto	Autos < Workers	Autos >= Workers	Total
Drive-Alone	5,195	220,573	3,120,296	3,346,064	4,814	216,273	3,101,399	3,322,486
Shared 2	13,775	211,033	1,754,551	1,979,359	13,084	207,134	1,740,922	1,961,140
Shared 3+	22,094	150,047	1,508,016	1,680,157	20,869	144,893	1,482,914	1,648,676
Walk	94,438	157,870	567,280	819,588	95,431	161,930	588,200	845,561
Bike	10,146	35,107	54,840	100,093	10,405	36,524	58,252	105,181
Walk-Transit	121,541	87,331	120,545	329,417	123,943	90,009	126,605	340,557
PNR-Transit	-	13,706	68,567	82,273	-	14,985	77,136	92,121
KNR-Transit	2,300	10,001	13,955	26,256	2,439	10,715	15,033	28,187
School Bus	9,128	24,445	398,767	432,340	9,177	25,532	411,254	445,963
Ride Hail	31,053	37,065	64,712	132,830	32,221	39,864	69,282	141,367
Total	305,737	1,143,306	10,393,058	11,842,101	308,020	1,138,600	10,361,142	11,807,762

TABLE 4: DIFFERENCE AND PERCENT DIFFERENCE BETWEEN BASELINE AND AOC TOTAL TOURS BY TOUR MODE AND AUTO SUFFICIENCY

Tour Mode	Difference				Percent Difference			
	0 Auto	Autos < Workers	Autos >= Workers	Total	0 Auto	Autos < Workers	Autos >= Workers	Total
Drive-Alone	-381	-4,300	-18,897	-23,578	-7.3%	-1.9%	-0.6%	-0.7%
Shared 2	-691	-3,899	-13,629	-18,219	-5.0%	-1.8%	-0.8%	-0.9%
Shared 3+	-1,225	-5,154	-25,102	-31,481	-5.5%	-3.4%	-1.7%	-1.9%
Walk	993	4,060	20,920	25,973	1.1%	2.6%	3.7%	3.2%
Bike	259	1,417	3,412	5,088	2.6%	4.0%	6.2%	5.1%
Walk-Transit	2,402	2,678	6,060	11,140	2.0%	3.1%	5.0%	3.4%
PNR-Transit		1,279	8,569	9,848	0.0%	9.3%	12.5%	12.0%
KNR-Transit	139	714	1,078	1,931	6.0%	7.1%	7.7%	7.4%
School Bus	49	1,087	12,487	13,623	0.5%	4.4%	3.1%	3.2%
Ride Hail	1,168	2,799	4,570	8,537	3.8%	7.6%	7.1%	6.4%
Total	2,283	-4,706	-31,916	-34,339	0.7%	-0.4%	-0.3%	-0.3%

Table 5 compares the intermediate stop out-of-direction distance by tour purpose between the Baseline scenario and the AOC scenario. The stop distance decreases by between 0.2 and 0.4 miles for each purpose, which is a decrease of between 9.4% and 12.2% over the Baseline scenario. This decrease is consistent with expectations and is due to the increased cost of auto travel due to the increase in AOC.

TABLE 5: BASELINE VERSUS AOC INTERMEDIATE STOP OUT-OF-DIRECTION DISTANCE BY TOUR PURPOSE COMPARISON

Tour_Purpose	Baseline Scenario (mi)	AOC Scenario (mi)	Difference (mi)	Percent Difference
Work	3.5	3.2	-0.3	-9.4%
University	3.7	3.3	-0.4	-10.8%
School	3.6	3.2	-0.4	-12.2%
Escorting	3.6	3.2	-0.4	-9.7%
Individual Maintenance	3.5	3.2	-0.3	-9.3%
Individual Discretionary	3.6	3.2	-0.4	-9.7%
Joint Maintenance	3.7	3.3	-0.4	-10.4%
Joint Discretionary	3.6	3.2	-0.4	-10.1%
At-Work	2.2	2.0	-0.2	-9.4%
Total	3.5	3.2	-0.3	-9.7%

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: BASELINE VERSUS AOC TRIPS BY TRIP MODE COMPARISON

Trip Mode	Baseline Scenario	AOC Scenario	Difference	Percent Difference
Drive-Alone	10,701,979	10,615,807	-86,172	-0.8%
Shared 2	4,923,995	4,873,273	-50,722	-1.0%
Shared 3+	3,680,954	3,620,599	-60,355	-1.6%
Walk	2,114,195	2,188,407	74,212	3.5%
Bike	223,827	235,146	11,319	5.1%
Walk-Transit	634,180	662,302	28,122	4.4%
PNR-Transit	157,809	176,891	19,082	12.1%
KNR-Transit	49,240	52,754	3,514	7.1%
School Bus	432,340	445,963	13,623	3.2%
Ride Hail	298,109	318,799	20,690	6.9%
Total	23,216,628	23,189,941	-26,687	-0.1%

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% due to the increase in auto operating cost, with somewhat higher reductions in low-density population and employment centers, along collector streets, in the suburbs of the DC region (most notably in 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 5.8 million vehicle-miles traveled, or by 3.3%, from a Baseline VMT of 175.3 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 5.1% 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 8). 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. It appears that the Gen3 Model’s mode choice component is more sensitive to AOC for mid-day and night time periods for the shared-ride modes.

The AOC scenario run also shows truck trips slightly increased (Table 8), 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. In the Phase 2 Gen3 Model deployment, any AOC increase will likely need to be reflected through all downstream and auxiliary models, including the truck model.

TABLE 7: DAILY TRAFFIC VOLUME SHIFTS BY SCREENLINE– AOC

Screenline	Baseline	AOC	Absolute Difference	Percent Difference
1	797,997	767,026	-30,971	-3.9%
2	1,270,973	1,240,829	-30,144	-2.4%
3	927,778	890,395	-37,383	-4.0%
4	1,307,374	1,266,347	-41,027	-3.1%
5	1,223,023	1,173,549	-49,474	-4.0%
6	1,824,797	1,759,458	-65,339	-3.6%
7	1,244,567	1,192,979	-51,588	-4.1%
8	1,949,638	1,884,418	-65,220	-3.3%
9	1,117,196	1,068,621	-48,575	-4.3%
10	642,721	619,810	-22,911	-3.6%
11	373,883	362,278	-11,605	-3.1%
12	654,263	633,652	-20,611	-3.2%
13	571,545	551,164	-20,381	-3.6%
14	306,708	294,024	-12,684	-4.1%
15	350,548	338,722	-11,826	-3.4%
16	227,512	218,047	-9,465	-4.2%
17	535,628	510,741	-24,887	-4.6%
18	762,343	732,974	-29,369	-3.9%
19	737,380	710,716	-26,664	-3.6%
20	1,310,273	1,262,705	-47,568	-3.6%
22	1,895,631	1,818,493	-77,138	-4.1%
23	254,063	244,908	-9,155	-3.6%
24	505,107	483,838	-21,269	-4.2%
25	168,118	161,739	-6,379	-3.8%
26	574,812	562,567	-12,245	-2.1%
27	472,053	460,393	-11,660	-2.5%
28	217,637	210,101	-7,536	-3.5%
31	197,088	191,518	-5,570	-2.8%
32	139,949	136,739	-3,210	-2.3%
33	357,706	345,799	-11,907	-3.3%
34	164,697	157,119	-7,578	-4.6%
35	963,133	951,995	-11,138	-1.2%
36	101,744	98,008	-3,736	-3.7%
37	58,237	55,890	-2,347	-4.0%
38	264,642	256,268	-8,374	-3.2%
Total	24,470,764	23,613,830	-856,934	-3.5%

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

TABLE 8: VMT SHIFTS BY TIME PERIOD– AOC

Time Period and Mode	Baseline	AOC	Absolute Difference	Percent Difference
AM-Total	38,157,789	37,404,0284	-753,761	-2.0%
MD-Total	51,109,127	49,618,390	-1,490,738	-2.9%
PM-Total	55,473,142	53,988,942	-1,484,200	-2.7%
NT-Total	48,009,312	45,693,277	-2,316,035	-4.8%
DAILY-Total	192,749,373	186,704,640	-6,044,733	-3.1%

Note:

- VMT values were added for all modeled links.

TABLE 9: DAILY VEHICLE MILES TRAVELED (VMT) SHIFTS BY AREA TYPE– AOC

Area Type	Baseline	AOC	Absolute Difference	Percent Difference
1	2,616,411	2,535,311	-81,100	-3.1%
2	12,195,807	11,771,523	-424,284	-3.5%
3	16,550,246	16,057,200	-493,046	-3.0%
4	10,766,815	10,400,097	-366,718	-3.4%
5	18,355,769	17,780,717	-575,052	-3.1%
6	19,457,795	18,863,445	-594,350	-3.1%
Total	79,942,843	77,408,293	-2,534,550	-3.2%

Notes:

- 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.
- Daily VMT values were added for a select set of model links with traffic counts

TABLE 10: DAILY VEHICLE MILES TRAVELED (VMT) SHIFTS BY FACILITY TYPE– AOC

Facility Type	Baseline	AOC	Absolute Difference	Percent Difference
Freeway	37,551,952	36,371,226	-1,180,726	-3.1%
Major Arterial	18,579,108	18,026,306	-552,802	-3.0%
Minor Arterial	15,180,574	14,663,258	-517,316	-3.4%
Collector	2,700,782	2,585,109	-115,673	-4.3%
Expressway	5,903,769	5,736,793	-166,976	-2.8%
Ramp	26,658	25,601	-1,057	-4.0%
Total	79,942,843	77,408,293	-2,534,550	-3.2%

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

TABLE 11: DAILY VEHICLE MILES TRAVELED (VMT) SHIFTS BY JURISDICTIONS– AOC

Jurisdiction	Baseline	AOC	Absolute Difference	Percent Difference
0 District of Columbia	10,534,165	10,202,591	-331,574	-3.1%
1 Montgomery County	22,708,899	21,860,176	-848,723	-3.7%
2 Prince George's County	25,252,656	24,327,455	-925,201	-3.7%
3 Arlington County	4,389,339	4,217,451	-171,888	-3.9%
4 City of Alexandria	2,381,787	2,291,886	-89,901	-3.8%
5 Fairfax County	27,808,689	26,676,367	-1,132,322	-4.1%
6 Loudoun County	8,432,319	8,109,409	-322,910	-3.8%
7 Prince William County	10,193,430	9,828,698	-364,732	-3.6%
9 Frederick County	9,131,626	8,849,948	-281,678	-3.1%
10 Howard County	12,155,900	11,870,710	-285,190	-2.3%
11 Anne Arundel County	16,198,213	15,814,836	-383,377	-2.4%
12 Charles County	3,272,051	3,150,731	-121,320	-3.7%
14 Carrol County	4,482,867	4,400,006	-82,861	-1.8%
15 Calvert County	1,688,563	1,624,413	-64,150	-3.8%
16 St. Mary's County	2,078,011	2,004,393	-73,618	-3.5%
17 King George County	783,166	763,517	-19,649	-2.5%
18 City of Fredericksburg	921,063	900,242	-20,821	-2.3%
19 Stafford County	4,299,966	4,165,090	-134,876	-3.1%
20 Spotsylvania County	2,450,792	2,417,805	-32,987	-1.3%
21 Fauquier County	3,620,716	3,535,416	-85,300	-2.4%
22 Clarke County	1,077,106	1,057,399	-19,707	-1.8%
23 Jefferson County	1,454,222	1,424,138	-30,084	-2.1%
Total	175,315,546	169,492,677	-5,822,869	-3.3%

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

Transit Ridership Shifts

A comparison of transit network travel demand shifts due to the AOC increase is 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 modest increase of transit ridership, by around 6.4% or over 84,000 new riders, due to the increase in auto operating cost, with somewhat higher percent increases (in the range of 7 to 18%) for local bus within and beyond the WMATA service area.

The ridership of Metrorail is increased by over 5%, or over 37,000 new riders due to the AOC increase, which is expected (Table 12). Among the various Metrorail lines, the Silver Line shows the highest percent increase of 10.5% for around 1,300 new daily riders, and the Orange/Blue/ Silver 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, each over 3,600 new riders, but only reflecting percent increases in the 3-4% range (Table 14).

The ridership of Amtrak/VRE commuter rail is predicted to go up by 2,200 new daily riders, or a 17% increase (Table 13). In contrast, MARC commuter trains only show an increase of 1,500 new riders, an increase by 5%.

TABLE 12: TRANSIT BOARDINGS BY MODE– AOC

Transit Mode	Baseline	AOC	Absolute Difference	Percent Difference
Local Metrobus	310,247	331,210	20,963	6.8%
Express Metrobus	19,872	21,669	1,797	9.0%
Metrorail	739,021	776,651	37,630	5.1%
Commuter Rail	42,927	46,676	3,749	8.7%
Other Local Bus in the WMATA Area	150,645	163,902	13,257	8.8%
Other Express Bus in the WMATA Area	1,799	1,907	108	6.0%
Other Local Bus beyond the WMATA Area	26,743	29,905	3,162	11.8%
Other Express Bus beyond the WMATA Area	20,201	23,734	3,533	17.5%
All Bus	529,507	572,327	42,820	8.1%
Total	1,311,455	1,395,654	84,199	6.4%

TABLE 13: TRANSIT BOARDINGS BY OPERATOR/SERVICE– AOC

Transit Operator/Service	Baseline	AOC	Absolute Difference	Percent Difference
WMATA Metrorail	739,021	776,651	37,630	5.1%
AMTRAK/ VRE commuter rail	12,949	15,198	2,249	17.4%
MARC commuter rail	29,978	31,478	1,500	5.0%
ART/ DASH/ FFx Con./ PG/ Ride On/ WMATA bus	456,556	491,107	34,551	7.6%
DASH/ FFx Con./ WMATA bus	29,463	32,558	3,094	10.5%
DC Circulato bus	7,593	7,921	328	4.3%
Annapolis/ Calvert County/ Carroll County/ FFx City Bus/ GMU Shuttle/ Loudoun County Local/ Saint Mary's/ TransIT/ VANGO bus	23,486	25,989	2,503	10.7%
Flyer/ Loudoun County Commuter/ MARTZ/ Maryland Commuter bus	12,409	14,752	2,344	18.9%
Total	1,311,455	1,395,654	84,199	6.4%

TABLE 14: METRORAIL STATION ENTRIES BY STATION GROUP– AOC

Station Group	Baseline	AOC	Absolute Difference	Percent Difference
Red Line - "A" route MD outside Beltway	19,571	21,264	1,693	8.7%
Red Line - "A" route MD inside Beltway	22,442	23,696	1,254	5.6%
Red Line - "A" route DC non-core	18,765	19,571	806	4.3%
Red Line - DC core	114,905	118,510	3,605	3.1%
Red Line - "B" route DC non-core	16,350	16,984	634	3.9%
Red Line - "B" route MD	21,673	23,190	1,517	7.0%
Green Line - "E" route MD	13,717	14,495	778	5.7%
Green Line - "E" route DC non-core	15,279	15,581	302	2.0%
Green Line - DC core	34,017	35,263	1,246	3.7%
Green Line - "F" route DC non-core	15,617	16,246	629	4.0%
Green Line - "F" route MD	12,637	13,742	1,105	8.7%
Blue/Yellow Line - VA Fairfax	12,735	13,915	1,180	9.3%
Blue/Yellow Line - VA Alexandria	11,817	12,710	893	7.6%
Blue/Yellow Line - VA Core	28,698	30,023	1,325	4.6%
Orange Line - VA Fairfax	7,279	8,014	735	10.1%
Orange/Silver Line - VA Arlington non-core	36,678	38,387	1,709	4.7%
Orange/Blue/Silver Line - VA/DC core	92,014	95,754	3,740	4.1%
Orange/Blue/Silver Line - DC non-core	9,596	9,908	312	3.3%
Orange Line - DC/MD	11,078	11,863	785	7.1%
Blue /SilverLine - DC/MD	13,740	14,807	1,067	7.8%
Silver Line - Phase I & Phase 2	12,161	13,443	1,282	10.5%
Total	540,769	567,366	26,597	4.9%

Trip Flow Shifts

A comparison of trip origin-destination flow changes due to the AOC increase is 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 an increase for a majority of the jurisdictions in the model area including the DC area, which had the highest increase of 2,800 trips. The exceptions to this trend are three jurisdictions, namely Fairfax, Montgomery, and Prince George's counties. This increase in local work trips using the SOV mode accounted for an overall 0.4% increase against the backdrop of 2.64 million local work trips using the SOV mode in year 2018 travel conditions.

In contrast, the inter-jurisdictional work trip origins using the SOV mode (Table 16) shows a decrease, which meets expectations, 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 53,000 trips, or 2.5% 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) shows an increase for all of the jurisdictions in the model area including the Fairfax County and Prince George’s County, which had the highest two increases of nearly 2,800 trips. This increase in intra-jurisdictional shopping trips using the SOV mode accounted for an overall 1.4% increase against the backdrop of 1.34 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) shows 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, DC, and Montgomery County. Overall, these reductions add to nearly 26,000 trips, or 8.6% decrease from the 0.3 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 scenario.

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

Jurisdiction	Baseline	AOC	Absolute Difference	Percent Difference
Alexandria	26,923	27,770	847	3.1%
Anne Arundel	281,729	282,492	763	0.3%
Arlington	45,698	46,295	597	1.3%
Calvert	22,802	23,117	315	1.4%
Carroll	72,622	73,605	983	1.4%
Charles	41,693	42,077	384	0.9%
Clarke	2,270	2,370	100	4.4%
DC	251,747	254,548	2,801	1.1%
Fairfax	498,300	498,261	-39	0.0%
Fauquier	13,091	13,294	203	1.6%
Frederick	124,727	125,266	539	0.4%
Fredericksburg	9,239	9,554	315	3.4%
Howard	133,971	134,791	820	0.6%
Jefferson	19,301	19,868	567	2.9%
King George	5,255	5,385	130	2.5%
Loudoun	135,033	135,542	509	0.4%
Montgomery	405,893	405,381	-512	-0.1%
Prince George's	249,242	248,432	-810	-0.3%
Prince William	175,102	176,310	1,208	0.7%
Spotsylvania	28,010	28,363	353	1.3%
St. Mary's	56,822	57,285	463	0.8%
Stafford	36,055	36,919	864	2.4%
Total	2,635,525	2,646,925	11,400	0.4%

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

Jurisdiction	Baseline	AOC	Absolute Difference	Percent Difference
Alexandria	95,433	93,819	-1,614	-1.7%
Anne Arundel	103,964	101,587	-2,377	-2.3%
Arlington	137,030	134,719	-2,311	-1.7%
Calvert	19,534	19,102	-432	-2.2%
Carroll	23,818	23,060	-758	-3.2%
Charles	39,193	38,241	-952	-2.4%
Clarke	3,556	3,496	-60	-1.7%

DC	325,742	319,314	-6,428	-2.0%
Fairfax	346,864	337,374	-9,490	-2.7%
Fauquier	16,428	16,014	-414	-2.5%
Frederick	41,090	39,755	-1,335	-3.2%
Fredericksburg	21,232	20,899	-333	-1.6%
Howard	101,351	98,717	-2,634	-2.6%
Jefferson	9,520	9,154	-366	-3.8%
King George	5,591	5,429	-162	-2.9%
Loudoun	105,878	102,522	-3,356	-3.2%
Montgomery	245,727	238,878	-6,849	-2.8%
Prince George's	281,965	274,738	-7,227	-2.6%
Prince William	119,681	116,255	-3,426	-2.9%
Spotsylvania	22,660	21,808	-852	-3.8%
St. Mary's	14,091	13,670	-421	-3.0%
Stafford	37,490	36,473	-1,017	-2.7%
Total	2,117,838	2,065,024	-52,814	-2.5%

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

Jurisdiction	Baseline	AOC	Absolute Difference	Percent Difference
Alexandria	95,503	93,784	-1,719	-1.8%
Anne Arundel	103,675	101,237	-2,438	-2.4%
Arlington	137,420	135,148	-2,272	-1.7%
Calvert	19,565	19,081	-484	-2.5%
Carroll	23,682	22,965	-717	-3.0%
Charles	38,964	38,005	-959	-2.5%
Clarke	3,538	3,474	-64	-1.8%
DC	329,445	322,988	-6,457	-2.0%
Fairfax	345,764	336,522	-9,242	-2.7%
Fauquier	16,366	15,940	-426	-2.6%
Frederick	41,122	39,803	-1,319	-3.2%
Fredericksburg	21,137	20,814	-323	-1.5%
Howard	101,102	98,540	-2,562	-2.5%
Jefferson	9,425	9,096	-329	-3.5%
King George	5,660	5,484	-176	-3.1%
Loudoun	105,961	102,581	-3,380	-3.2%
Montgomery	245,642	238,461	-7,181	-2.9%
Prince George's	280,473	273,399	-7,074	-2.5%
Prince William	119,223	115,872	-3,351	-2.8%
Spotsylvania	22,674	21,854	-820	-3.6%
St. Mary's	14,082	13,657	-425	-3.0%
Stafford	37,415	36,319	-1,096	-2.9%
Total	2,117,838	2,065,024	-52,814	-2.5%

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

Jurisdiction	Baseline	AOC	Absolute Difference	Percent Difference
Alexandria	16,938	17,616	678	4.0%
Anne Arundel	135,704	137,111	1,407	1.0%
Arlington	22,660	23,075	415	1.8%
Calvert	20,215	20,746	531	2.6%
Carroll	43,196	43,913	717	1.7%
Charles	32,481	33,462	981	3.0%
Clarke	3,368	3,478	110	3.3%
DC	110,536	110,804	268	0.2%
Fairfax	218,553	221,313	2,760	1.3%
Fauquier	14,263	14,830	567	4.0%
Frederick	60,220	60,496	276	0.5%
Fredericksburg	5,506	5,658	152	2.8%
Howard	68,875	69,839	964	1.4%
Jefferson	15,151	15,473	322	2.1%
King George	5,122	5,210	88	1.7%
Loudoun	67,550	68,500	950	1.4%
Montgomery	193,084	194,703	1,619	0.8%
Prince George's	134,426	137,198	2,772	2.1%
Prince William	100,833	102,121	1,288	1.3%
Spotsylvania	18,808	19,252	444	2.4%
St. Mary's	27,821	28,144	323	1.2%
Stafford	24,243	24,985	742	3.1%
Total	1,339,553	1,357,927	18,374	1.4%

TABLE 19: REGIONAL INTER-JURISDICTIONAL SHOPPING TRIP ORIGINS USING SOV MODE– AOC

Jurisdiction	Baseline	AOC	Absolute Difference	Percent Difference
Alexandria	19,821	18,504	-1,317	-6.6%
Anne Arundel	10,529	9,181	-1,348	-12.8%
Arlington	22,960	21,384	-1,576	-6.9%
Calvert	2,164	1,844	-320	-14.8%
Carroll	2,907	2,671	-236	-8.1%
Charles	4,725	4,287	-438	-9.3%
Clarke	540	470	-70	-13.0%
DC	54,312	50,464	-3,848	-7.1%
Fairfax	43,860	39,604	-4,256	-9.7%
Fauquier	2,046	1,841	-205	-10.0%
Frederick	3,517	3,138	-379	-10.8%
Fredericksburg	6,860	6,404	-456	-6.6%
Howard	10,367	9,245	-1,122	-10.8%
Jefferson	666	556	-110	-16.5%
King George	607	551	-56	-9.2%
Loudoun	11,649	10,431	-1,218	-10.5%
Montgomery	30,614	27,882	-2,732	-8.9%
Prince George's	51,772	47,903	-3,869	-7.5%
Prince William	10,120	8,777	-1,343	-13.3%
Spotsylvania	5,394	4,877	-517	-9.6%
St. Mary's	1,738	1,524	-214	-12.3%
Stafford	5,916	5,428	-488	-8.2%
Total	303,084	276,966	-26,118	-8.6%

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

Jurisdiction	Baseline	AOC	Absolute Difference	Percent Difference
Alexandria	19,907	18,619	-1,288	-6.5%
Anne Arundel	10,545	9,209	-1,336	-12.7%
Arlington	23,071	21,408	-1,663	-7.2%
Calvert	2,172	1,839	-333	-15.3%
Carroll	2,889	2,657	-232	-8.0%
Charles	4,684	4,236	-448	-9.6%
Clarke	534	458	-76	-14.2%
DC	55,006	51,091	-3,915	-7.1%
Fairfax	43,765	39,572	-4,193	-9.6%
Fauquier	2,008	1,813	-195	-9.7%
Frederick	3,560	3,156	-404	-11.3%
Fredericksburg	6,834	6,386	-448	-6.6%
Howard	10,363	9,218	-1,145	-11.0%
Jefferson	667	575	-92	-13.8%
King George	617	559	-58	-9.4%
Loudoun	11,577	10,299	-1,278	-11.0%
Montgomery	30,453	27,774	-2,679	-8.8%
Prince George's	51,239	47,444	-3,795	-7.4%
Prince William	10,099	8,792	-1,307	-12.9%
Spotsylvania	5,386	4,873	-513	-9.5%
St. Mary's	1,743	1,525	-218	-12.5%
Stafford	5,965	5,463	-502	-8.4%
Total	303,084	276,966	-26,118	-8.6%

3.0 INCREASED TELECOMMUTING TO D.C. 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.[4] "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.[5] Explanatory variables include employment type of the worker (Services, Sales/Office, Resource/Construction, or Transportation/Materials), number of adults in the household,

[4] 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.

[5] 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.

household income, number of household vehicles, whether there are children in the household, whether 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 as follows:

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 calculated as follows:

1) We assumed a distribution of telecommute frequency for workers with a work TAZ in DC based on their employment type for purposes of the scenario test, as shown in Table 21. The distribution assumes that Office workers have the highest likelihood of telecommuting, followed by Industrial workers and Other workers, and that Retail workers have the lowest likelihood of telecommuting.
2) We multiplied the telecommute frequency percentages by the distribution of jobs by employment type, and summed across employment types, for each Jurisdiction. The result of this calculation is a weighted average telecommute frequency target by Jurisdiction. Based on the Round 9.1a Cooperative Forecasts for 2018, the distribution of employment by type in DC is 4% Industrial employment, 10% Retail employment, 79% Office employment, and 6% Other employment. The initial and target telecommute frequency percentages for workers with a TAZ in DC are shown in Table 22.

3) We calibrate the telecommute frequency alternative-specific constants for workers with a work TAZ in DC to match the target distribution. The final shares are also shown in Table 22. The target shares decrease the percent of workers who telecommute less than one day per week by 61%, and workers who telecommute just 1 day per week by 63%. The share of DC workers who telecommute 2-3 days per week are increased by 143%, and the share of DC workers who telecommute 4 or more days per week are increased by 16-fold.

TABLE 21: ASSUMED DISTRIBUTION OF TELECOMMUTE FREQUENCY BY EMPLOYMENT TYPE FOR INCREASED TELECOMMUTING TO DC SCENARIO

Employment Type	1-day	2-3 days	4 days
Industrial	20%	10%	5%
Retail	10%	0%	0%
Office	0%	20%	60%
Other	20%	10%	5%

TABLE 22: TARGET TELECOMMUTE FREQUENCY SHARES, INITIAL SHARES, AND FINAL SHARES FOR WORKERS WITH A WORK TAZ IN DC FOR THE INCREASED TELECOMMUTING TO DC SCENARIO

Telecommute Frequency	Initial Share	Target Share	Final Share
Less than 1 day per week	82%	32%	34%
1 day per week	8%	3%	3%
2-3 days per week	7%	17%	16%
4+ days per week	3%	48%	47%
Total	100%	100%	100%

After the model was calibrated, the entire scenario was run with four complete speed feedback iterations and the results were summarized.

3.2 EXPECTED OUTCOMES

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

- 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 23 and Table 24 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 survey, 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.

An interesting finding from these tables is that the number of workers who work in DC increases in the telecommute scenario. This is likely due to the increased accessibility of downtown due to decreased congestion because of the higher share of telecommuters. In total there are 13,514 more workers with a work TAZ in DC in the Increased DC Telecommute scenario than in the Baseline scenario, which is an increase of 1.6%. It is difficult to say whether such an effect is likely; probably in the case of a non-COVID scenario, decreases in congestion might lead to more workers choosing to work in D.C.

However, the shadow pricing mechanism[6], if run enough iterations, would account for this phenomenon. The ActivitySim consortium is funding further enhancement of the shadow pricing mechanism that is expecting to improve the match of workers to jobs by TAZ.

TABLE 23: BASELINE SCENARIO VERSUS INCREASED DC TELECOMMUTE SCENARIO WORKERS BY WORK STATUS AND DAILY ACTIVITY PATTERN

	Baseline Scenario				Increased DC Telecommute Scenario			
Person Type	Mandatory	Non-Mandatory	Home	Total	Mandatory	Non-Mandatory	Home	Total
Full-time worker	510,414	115,425	93,916	719,755	389,375	194,971	147,328	731,674
Part-time worker	40,058	40,460	22,935	103,453	22,648	53,551	28,849	105,048
Total	550,472	155,885	116,851	823,208	412,023	248,522	176,177	836,722

TABLE 24: DIFFERENCE AND PERCENT DIFFERENCE IN BASELINE SCENARIO VERSUS INCREASED DC TELECOMMUTE SCENARIO WORKERS BY WORK STATUS AND DAILY ACTIVITY PATTERN

	Baseline Scenario				Increased DC Telecommute Scenario			
Person Type	Mandatory	Non-Mandatory	Home	Total	Mandatory	Non-Mandatory	Home	Total
Full-time worker	(121,039)	79,546	53,412	11,919	-23.7%	68.9%	56.9%	1.7%
Part-time worker	(17,410)	13,091	5,914	1,595	-43.5%	32.4%	25.8%	1.5%
Total	(138,449)	92,637	59,326	13,514	-25.2%	59.4%	50.8%	1.6%

Table 25 and Table 26 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 similarly from the Baseline alternative, and that work tour shares decrease more for part-time workers than for full-time workers. There are no

[6] Shadow pricing is a procedure that attempts to constrain the proportion of workers who select a work TAZ with the proportion of employment in that TAZ input to the model.

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 24.

TABLE 25: BASELINE SCENARIO VERSUS INCREASED DC TELECOMMUTE SCENARIO WORKERS BY WORK STATUS AND TOTAL WORK TOURS

	Baseline Scenario			Increased DC Telecommute Scenario		
Person Type	1 Work Tour	2 Work Tours	Total	1 Work Tour	2 Work Tours	Total
Full-time worker	494,208	16,206	510,414	377,068	12,307	389,375
Part-time worker	38,383	1,675	40,058	21,714	934	22,648
Total	532,591	17,881	550,472	398,782	13,241	412,023

TABLE 26: DIFFERENCE AND PERCENT DIFFERENCE IN BASELINE SCENARIO VERSUS INCREASED DC TELECOMMUTE SCENARIO WORKERS BY WORK STATUS AND TOTAL WORK TOURS

	Baseline Scenario			Increased DC Telecommute Scenario		
Person Type	1 Work Tour	2 Work Tours	Total	1 Work Tour	2 Work Tours	Total
Full-time worker	(117,140)	(3,899)	(121,039)	-23.7%	-24.1%	-23.7%
Part-time worker	(16,669)	(741)	(17,410)	-43.4%	-44.2%	-43.5%
Total	(133,809)	(4,640)	(138,449)	-25.1%	-25.9%	-25.2%

Table 27 and Table 28 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 0 non-mandatory tours decreases by 30,068 in the Increased DC Telecommute scenario, or 6.0%. The share of workers with 1 non-mandatory tour increases by 11% and the share of workers with 2 or more non-mandatory tours increases by 18.5% in the Increased DC Telecommute scenario. These findings are consistent with expectations.

TABLE 27: BASELINE SCENARIO VERSUS INCREASED DC TELECOMMUTE SCENARIO WORKERS BY WORK STATUS AND TOTAL NON-MANDATORY TOURS

	Baseline Scenario				Increased DC Telecommute Scenario			
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	453,180	203,050	49,041	705,271	429,194	224,723	58,229	712,146
Part-time worker	51,969	32,920	13,350	98,239	45,887	37,180	15,676	98,743
Total	505,149	235,970	62,391	803,510	475,081	261,903	73,905	810,889

TABLE 28: DIFFERENCE AND PERCENT DIFFERENCE IN BASELINE SCENARIO VERSUS INCREASED DC TELECOMMUTE SCENARIO WORKERS BY WORK STATUS AND TOTAL NON-MANDATORY TOURS

	Baseline Scenario				Increased DC Telecommute Scenario			
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	(23,986)	21,673	9,188	6,875	-5.3%	10.7%	18.7%	1.0%
Part-time worker	(6,082)	4,260	2,326	504	-11.7%	12.9%	17.4%	0.5%
Total	(30,068)	25,933	11,514	7,379	-6.0%	11.0%	18.5%	0.9%

Highway Traffic Shifts

A comparison of highway network level travel demand shifts due to the telecommuting increase to DC is 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 one percent due to the increase in telecommuting to DC, with relatively 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.

Overall, the Gen3 Model is predicting a reduction of VMT by 1.83 million vehicle-miles traveled, or by 1.0%, from a Baseline VMT of 175.3 million in the region in year 2018 conditions due to an increase in telecommuting to DC (Table 33).

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. Also, the Gen3 Model shows relatively higher percent reductions during the AM and Night time periods than the PM and MD peak periods, likely due to the increase in non-mandatory travel for telecommuting workers (Table 30).

The telecommuting scenario run also shows truck trips slightly increased, despite the fact that truck trips are actually not directly impacted by the telecommuting scenario 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.

TABLE 29: DAILY TRAFFIC VOLUME SHIFTS BY SCREENLINE– TELECOMMUTE

Screenline	Baseline	Telecommute to DC	Absolute Difference	Percent Difference
1	797,997	783,861	-14,136	-1.8%
2	1,270,973	1,227,448	-43,525	-3.4%
3	927,778	907,492	-20,286	-2.2%
4	1,307,374	1,265,386	-41,988	-3.2%
5	1,223,023	1,200,214	-22,809	-1.9%
6	1,824,797	1,790,335	-34,462	-1.9%
7	1,244,567	1,232,756	-11,811	-0.9%
8	1,949,638	1,928,823	-20,815	-1.1%
9	1,117,196	1,106,063	-11,133	-1.0%
10	642,721	638,574	-4,147	-0.6%
11	373,883	371,185	-2,698	-0.7%
12	654,263	647,772	-6,491	-1.0%
13	571,545	565,557	-5,988	-1.0%
14	306,708	303,648	-3,060	-1.0%
15	350,548	346,167	-4,381	-1.2%
16	227,512	222,322	-5,190	-2.3%
17	535,628	530,278	-5,350	-1.0%
18	762,343	757,249	-5,094	-0.7%
19	737,380	731,471	-5,909	-0.8%
20	1,310,273	1,281,065	-29,208	-2.2%
22	1,895,631	1,871,360	-24,271	-1.3%
23	254,063	252,434	-1,629	-0.6%
24	505,107	498,642	-6,465	-1.3%
25	168,118	166,951	-1,167	-0.7%
26	574,812	571,694	-3,118	-0.5%
27	472,053	469,092	-2,961	-0.6%
28	217,637	214,415	-3,222	-1.5%
31	197,088	196,637	-451	-0.2%
32	139,949	139,514	-435	-0.3%
33	357,706	356,276	-1,430	-0.4%
34	164,697	162,628	-2,069	-1.3%
35	963,133	965,381	2,248	0.2%
36	101,744	100,860	-884	-0.9%
37	58,237	57,775	-462	-0.8%
38	264,642	264,299	-343	-0.1%
Total	24,470,764	24,125,624	-345,140	-1.4%

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

TABLE 30: DAILY TRAFFIC VOLUME SHIFTS BY TIME PERIOD AND TRAVEL MODE– TELECOMMUTE

Time Period and Mode	Baseline	Telecommute to DC	Absolute Difference	Percent Difference
AM-Total	38,157,789	37,594,093	-563,696	-1.5%
MD-Total	51,109,127	51,205,347	96,219	0.2%
PM-Total	55,473,142	54,994,436	-478,706	-0.9%
NT-Total	48,009,312	47,023,139	-986,174	-2.1%
DAILY-Total	192,749,373	190,817,016	-1,932,357	-1.0%

Note:

- VMT values were added for modeled network links

TABLE 31: DAILY VEHICLE MILES TRAVELED (VMT) SHIFTS BY AREA TYPE– TELECOMMUTE

Area Type	Baseline	Telecommute to DC	Absolute Difference	Percent Difference
1	2,616,411	2,538,442	-77,969	-3.0%
2	12,195,807	12,022,637	-173,170	-1.4%
3	16,550,246	16,437,940	-112,306	-0.7%
4	10,766,815	10,666,322	-100,493	-0.9%
5	18,355,769	18,210,601	-145,168	-0.8%
6	19,457,795	19,323,996	-133,799	-0.7%
Total	79,942,843	79,199,938	-742,905	-0.9%

Notes:

- 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.
- 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– TELECOMMUTE

Facility Type	Baseline	Telecommute to DC	Absolute Difference	Percent Difference

Freeway	37,551,952	37,252,214	-299,738	-0.8%
Major Arterial	18,579,108	18,407,938	-171,170	-0.9%
Minor Arterial	15,180,574	15,025,039	-155,535	-1.0%
Collector	2,700,782	2,649,735	-51,047	-1.9%
Expressway	5,903,769	5,838,238	-65,531	-1.1%
Ramp	26,658	26,774	116	0.4%
Total	79,942,843	79,199,938	-742,905	-0.9%

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– TELECOMMUTE

Jurisdiction	Baseline	Telecommute to DC	Absolute Difference	Percent Difference
0 District of Columbia	10,534,165	10,174,609	-359,556	-3.4%
1 Montgomery County	22,708,899	22,452,421	-256,478	-1.1%
2 Prince George's County	25,252,656	24,857,314	-395,342	-1.6%
3 Arlington County	4,389,339	4,297,881	-91,458	-2.1%
4 City of Alexandria	2,381,787	2,336,065	-45,722	-1.9%
5 Fairfax County	27,808,689	27,521,605	-287,084	-1.0%
6 Loudoun County	8,432,319	8,348,268	-84,051	-1.0%
7 Prince William County	10,193,430	10,153,244	-40,186	-0.4%
9 Frederick County	9,131,626	9,092,107	-39,519	-0.4%
10 Howard County	12,155,900	12,116,988	-38,912	-0.3%
11 Anne Arundel County	16,198,213	16,132,394	-65,819	-0.4%
12 Charles County	3,272,051	3,233,990	-38,061	-1.2%
14 Carrol County	4,482,867	4,477,242	-5,625	-0.1%
15 Calvert County	1,688,563	1,670,876	-17,687	-1.0%
16 St. Mary's County	2,078,011	2,069,618	-8,393	-0.4%
17 King George County	783,166	777,375	-5,791	-0.7%
18 City of Fredericksburg	921,063	919,731	-1,332	-0.1%
19 Stafford County	4,299,966	4,282,104	-17,862	-0.4%
20 Spotsylvania County	2,450,792	2,448,867	-1,925	-0.1%
21 Fauquier County	3,620,716	3,599,150	-21,566	-0.6%
22 Clarke County	1,077,106	1,071,941	-5,165	-0.5%
23 Jefferson County	1,454,222	1,451,047	-3,175	-0.2%
Total	175,315,546	173,484,837	-1,830,709	-1.0%

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

Transit Ridership Shifts

A comparison of transit network level travel demand shifts due to the increase in DC telecommuting is 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 fair reduction in transit ridership, by around 13.9% or over 181,000 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 126,000 fewer boardings, or roughly a 17% drop (Table 35). Among the various Metrorail lines, the Red Line stations in the DC core show the highest drop in boardings, 19.7%, and the Orange/Blue/Silver Line stations in the Virginia/DC core show the second highest drop in boardings, 19.8 %. (Table 36).

The ridership of Amtrak/VRE commuter rail is predicted to drop by 2,200 boardings, 17%. Similarly, MARC commuter trains also show a decrease of 1,300 riders, a decrease of 4.4%.

TABLE 34: TRANSIT BOARDINGS BY MODE– TELECOMMUTE

Transit Mode	Baseline	Telecommute to DC	Absolute Difference	Percent Difference
Local Metrobus	310,247	278,107	-32,141	-10.4%
Express Metrobus	19,872	15,695	-4,177	-21.0%
Metrorail	739,021	612,531	-126,490	-17.1%
Commuter Rail	42,927	39,429	-3,498	-8.1%
Other Local Bus in the WMATA Area	150,645	142,809	-7,836	-5.2%
Other Express Bus in the WMATA Area	1,799	1,462	-337	-18.7%
Other Local Bus beyond the WMATA Area	26,743	25,149	-1,594	-6.0%
Other Express Bus beyond the WMATA Area	20,201	14,546	-5,655	-28.0%
All Bus	529,507	477,768	-51,739	-9.8%
Total	1,311,455	1,129,727	-181,727	-13.9%

TABLE 35: TRANSIT BOARDINGS BY OPERATOR/SERVICE– TELECOMMUTE

Transit Operator	Baseline	Telecommute to DC	Absolute Difference	Percent Difference
WMATA Metrorail	739,021	612,531	-126,490	-17.1%
AMTRAK/ VRE commuter rail	12,949	10,761	-2,188	-16.9%
MARC commuter rail	29,978	28,668	-1,310	-4.4%
ART/ DASH/ FFx Con./ PG/ Ride On/ WMATA bus	456,556	416,236	-40,320	-8.8%
DASH/ FFx Con./ WMATA bus	29,463	23,074	-6,389	-21.7%
DC Circulato bus	7,593	7,280	-313	-4.1%
Annapolis/ Calvert County/ Carroll County/ FFx City Bus/ GMU Shuttle/ Loudoun County Local/ Saint Mary's/ TransIT/ VANGO	23,486	22,548	-938	-4.0%
Flyer/ Loudoun County Commuter/ MARTZ/ Maryland Commuter	12,409	8,629	-3,780	-30.5%
Total	1,311,455	1,129,727	-181,727	-13.9%

TABLE 36: METRORAIL STATION ENTRIES BY STATION GROUP– TELECOMMUTE

Station Group	Baseline	Telecommute to DC	Absolute Difference	Percent Difference
Red Line - "A" route MD outside Beltway	19,571	17,092	-2,479	-12.7%
Red Line - "A" route MD inside Beltway	22,442	20,428	-2,014	-9.0%
Red Line - "A" route DC non-core	18,765	16,062	-2,703	-14.4%
Red Line - DC core	114,905	92,295	-22,610	-19.7%
Red Line - "B" route DC non-core	16,350	13,673	-2,677	-16.4%
Red Line - "B" route MD	21,673	17,634	-4,039	-18.6%
Green Line - "E" route MD	13,717	11,377	-2,340	-17.1%
Green Line - "E" route DC non-core	15,279	12,877	-2,402	-15.7%
Green Line - DC core	34,017	26,745	-7,272	-21.4%
Green Line - "F" route DC non-core	15,617	12,956	-2,661	-17.0%
Green Line - "F" route MD	12,637	9,850	-2,787	-22.1%
Blue/Yellow Line - VA Fairfax	12,735	10,003	-2,732	-21.5%
Blue/Yellow Line - VA Alexandria	11,817	10,319	-1,498	-12.7%
Blue/Yellow Line - VA Core	28,698	25,296	-3,402	-11.9%
Orange Line - VA Fairfax	7,279	5,909	-1,370	-18.8%
Orange/Silver Line - VA Arlington non-core	36,678	31,954	-4,724	-12.9%
Orange/Blue/Silver Line - VA/DC core	92,014	73,801	-18,213	-19.8%
Orange/Blue/Silver Line - DC non-core	9,596	7,754	-1,842	-19.2%
Orange Line - DC/MD	11,078	8,987	-2,091	-18.9%
Blue/Silver Line - DC/MD	13,740	10,993	-2,747	-20.0%
Silver Line - Phase I & Phase 2	12,161	10,972	-1,189	-9.8%
Total	540,769	446,977	-93,792	-17.3%

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: 53,000 trips. This decrease in local work trips using the SOV mode accounted for an overall 3.7% decrease against the backdrop of 2.64 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 nearly 113,000 trips, or a 5.4% 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 AOC 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 the highest increase: nearly 6,300 trips. This increase in shopping trips using the SOV mode accounted for an overall 5.6% increase against the backdrop of 1.34 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 an increase, as expected, in trips, due to an increase in telecommuting to DC. Overall, these increases total nearly 7,500 trips, or 2.5% increase from the 0.3 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 AOC scenario.

TABLE 37: INTRA-JURISDICTIONAL WORK TRIPS USING SOV MODE– TELECOMMUTE

Jurisdiction	Baseline	Telecommute to DC	Absolute Difference	Percent Difference
Alexandria	26,923	25,954	-969	-3.6%
Anne Arundel	281,729	279,707	-2,022	-0.7%
Arlington	45,698	44,201	-1,497	-3.3%
Calvert	22,802	22,068	-734	-3.2%
Carroll	72,622	72,450	-172	-0.2%
Charles	41,693	39,493	-2,200	-5.3%
Clarke	2,270	2,307	37	1.6%
DC	251,747	198,507	-53,240	-21.1%
Fairfax	498,300	489,474	-8,826	-1.8%
Fauquier	13,091	12,984	-107	-0.8%
Frederick	124,727	123,979	-748	-0.6%
Fredericksburg	9,239	9,231	-8	-0.1%
Howard	133,971	132,418	-1,553	-1.2%
Jefferson	19,301	19,411	110	0.6%
King George	5,255	5,174	-81	-1.5%
Loudoun	135,033	133,203	-1,830	-1.4%
Montgomery	405,893	396,825	-9,068	-2.2%
Prince George's	249,242	237,026	-12,216	-4.9%
Prince William	175,102	172,698	-2,404	-1.4%
Spotsylvania	28,010	27,871	-139	-0.5%
St. Mary's	56,822	56,216	-606	-1.1%
Stafford	36,055	35,811	-244	-0.7%
Total	2,635,525	2,537,008	-98,517	-3.7%

TABLE 38: INTER-JURISDICTIONAL WORK TRIP ORIGINS USING SOV MODE– TELECOMMUTE

Jurisdiction	Baseline	Telecommute to DC	Absolute Difference	Percent Difference
Alexandria	95,433	92,157	-3,276	-3.4%
Anne Arundel	103,964	101,185	-2,779	-2.7%
Arlington	137,030	133,117	-3,913	-2.9%
Calvert	19,534	18,623	-911	-4.7%
Carroll	23,818	23,580	-238	-1.0%
Charles	39,193	36,758	-2,435	-6.2%
Clarke	3,556	3,511	-45	-1.3%
DC	325,742	276,459	-49,283	-15.1%
Fairfax	346,864	336,156	-10,708	-3.1%
Fauquier	16,428	16,205	-223	-1.4%
Frederick	41,090	40,765	-325	-0.8%
Fredericksburg	21,232	21,065	-167	-0.8%
Howard	101,351	99,349	-2,002	-2.0%
Jefferson	9,520	9,377	-143	-1.5%
King George	5,591	5,480	-111	-2.0%
Loudoun	105,878	103,834	-2,044	-1.9%
Montgomery	245,727	235,025	-10,702	-4.4%
Prince George's	281,965	261,000	-20,965	-7.4%
Prince William	119,681	117,451	-2,230	-1.9%
Spotsylvania	22,660	22,462	-198	-0.9%
St. Mary's	14,091	13,647	-444	-3.2%
Stafford	37,490	36,886	-604	-1.6%
Total	2,117,838	2,004,092	-113,746	-5.4%

TABLE 39: INTER-JURISDICTIONAL WORK TRIP DESTINATIONS USING SOV MODE– TELECOMMUTE

Jurisdiction	Baseline	Telecommute to DC	Absolute Difference	Percent Difference
Alexandria	95,503	92,158	-3,345	-3.5%
Anne Arundel	103,675	100,856	-2,819	-2.7%
Arlington	137,420	133,495	-3,925	-2.9%
Calvert	19,565	18,651	-914	-4.7%
Carroll	23,682	23,446	-236	-1.0%
Charles	38,964	36,525	-2,439	-6.3%
Clarke	3,538	3,492	-46	-1.3%
DC	329,445	279,589	-49,856	-15.1%
Fairfax	345,764	335,317	-10,447	-3.0%
Fauquier	16,366	16,181	-185	-1.1%
Frederick	41,122	40,839	-283	-0.7%
Fredericksburg	21,137	20,966	-171	-0.8%
Howard	101,102	99,259	-1,843	-1.8%
Jefferson	9,425	9,308	-117	-1.2%
King George	5,660	5,541	-119	-2.1%
Loudoun	105,961	103,886	-2,075	-2.0%
Montgomery	245,642	234,735	-10,907	-4.4%
Prince George's	280,473	259,901	-20,572	-7.3%
Prince William	119,223	116,979	-2,244	-1.9%
Spotsylvania	22,674	22,467	-207	-0.9%
St. Mary's	14,082	13,617	-465	-3.3%
Stafford	37,415	36,884	-531	-1.4%
Total	2,117,838	2,004,092	-113,746	-5.4%

TABLE 40: INTRA-JURISDICTIONAL SHOPPING TRIPS USING SOV MODE– TELECOMMUTE

Jurisdiction	Baseline	Telecommute to DC	Absolute Difference	Percent Difference
Alexandria	16,938	17,167	229	1.4%
Anne Arundel	135,704	136,646	942	0.7%
Arlington	22,660	23,344	684	3.0%
Calvert	20,215	20,602	387	1.9%
Carroll	43,196	43,378	182	0.4%
Charles	32,481	33,173	692	2.1%
Clarke	3,368	3,389	21	0.6%
DC	110,536	116,781	6,245	5.6%
Fairfax	218,553	221,666	3,113	1.4%
Fauquier	14,263	14,418	155	1.1%
Frederick	60,220	60,264	44	0.1%
Fredericksburg	5,506	5,530	24	0.4%
Howard	68,875	69,463	588	0.9%
Jefferson	15,151	15,283	132	0.9%
King George	5,122	5,087	-35	-0.7%
Loudoun	67,550	67,847	297	0.4%
Montgomery	193,084	195,623	2,539	1.3%
Prince George's	134,426	136,732	2,306	1.7%
Prince William	100,833	101,954	1,121	1.1%
Spotsylvania	18,808	18,865	57	0.3%
St. Mary's	27,821	28,016	195	0.7%
Stafford	24,243	24,362	119	0.5%
Total	1,339,553	1,359,590	20,037	1.5%

TABLE 41: INTER-JURISDICTIONAL SHOPPING TRIP ORIGINS USING SOV MODE– TELECOMMUTE

Jurisdiction	Baseline	Telecommute to DC	Absolute Difference	Percent Difference
Alexandria	19,821	20,415	594	3.0%
Anne Arundel	10,529	10,517	-12	-0.1%
Arlington	22,960	23,741	781	3.4%
Calvert	2,164	2,190	26	1.2%
Carroll	2,907	2,897	-10	-0.3%
Charles	4,725	4,912	187	4.0%
Clarke	540	528	-12	-2.2%
DC	54,312	56,813	2,501	4.6%
Fairfax	43,860	44,531	671	1.5%
Fauquier	2,046	2,062	16	0.8%
Frederick	3,517	3,527	10	0.3%
Fredericksburg	6,860	6,898	38	0.6%
Howard	10,367	10,431	64	0.6%
Jefferson	666	664	-2	-0.3%
King George	607	612	5	0.8%
Loudoun	11,649	11,725	76	0.7%
Montgomery	30,614	31,504	890	2.9%
Prince George's	51,772	53,351	1,579	3.0%
Prince William	10,120	10,087	-33	-0.3%
Spotsylvania	5,394	5,434	40	0.7%
St. Mary's	1,738	1,743	5	0.3%
Stafford	5,916	5,954	38	0.6%
Total	303,084	310,536	7,452	2.5%

TABLE 42: INTER-JURISDICTIONAL SHOPPING TRIP DESTINATIONS USING SOV MODE– TELECOMMUTE

Jurisdiction	Baseline	Telecommute to DC	Absolute Difference	Percent Difference
Alexandria	19,907	20,504	597	3.0%
Anne Arundel	10,545	10,558	13	0.1%
Arlington	23,071	23,767	696	3.0%
Calvert	2,172	2,188	16	0.7%
Carroll	2,889	2,872	-17	-0.6%
Charles	4,684	4,867	183	3.9%
Clarke	534	523	-11	-2.1%
DC	55,006	57,458	2,452	4.5%
Fairfax	43,765	44,476	711	1.6%
Fauquier	2,008	2,028	20	1.0%
Frederick	3,560	3,570	10	0.3%
Fredericksburg	6,834	6,881	47	0.7%
Howard	10,363	10,449	86	0.8%
Jefferson	667	675	8	1.2%
King George	617	616	-1	-0.2%
Loudoun	11,577	11,611	34	0.3%
Montgomery	30,453	31,417	964	3.2%
Prince George's	51,239	52,835	1,596	3.1%
Prince William	10,099	10,067	-32	-0.3%
Spotsylvania	5,386	5,418	32	0.6%
St. Mary's	1,743	1,749	6	0.3%
Stafford	5,965	6,007	42	0.7%
Total	303,084	310,536	7,452	2.5%

4.0 ARLINGTON MEMORIAL BRIDGE CLOSED TO AUTO AND TRUCK TRAFFIC

4.1 DESCRIPTION

This scenario is to test the model's sensitivity to roadway capacity reductions.[7] 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.[8] The Baseline scenario was compared to the Memorial Bridge Closure Scenario, which is labeled as "noMemBr" 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

[7] 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.

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

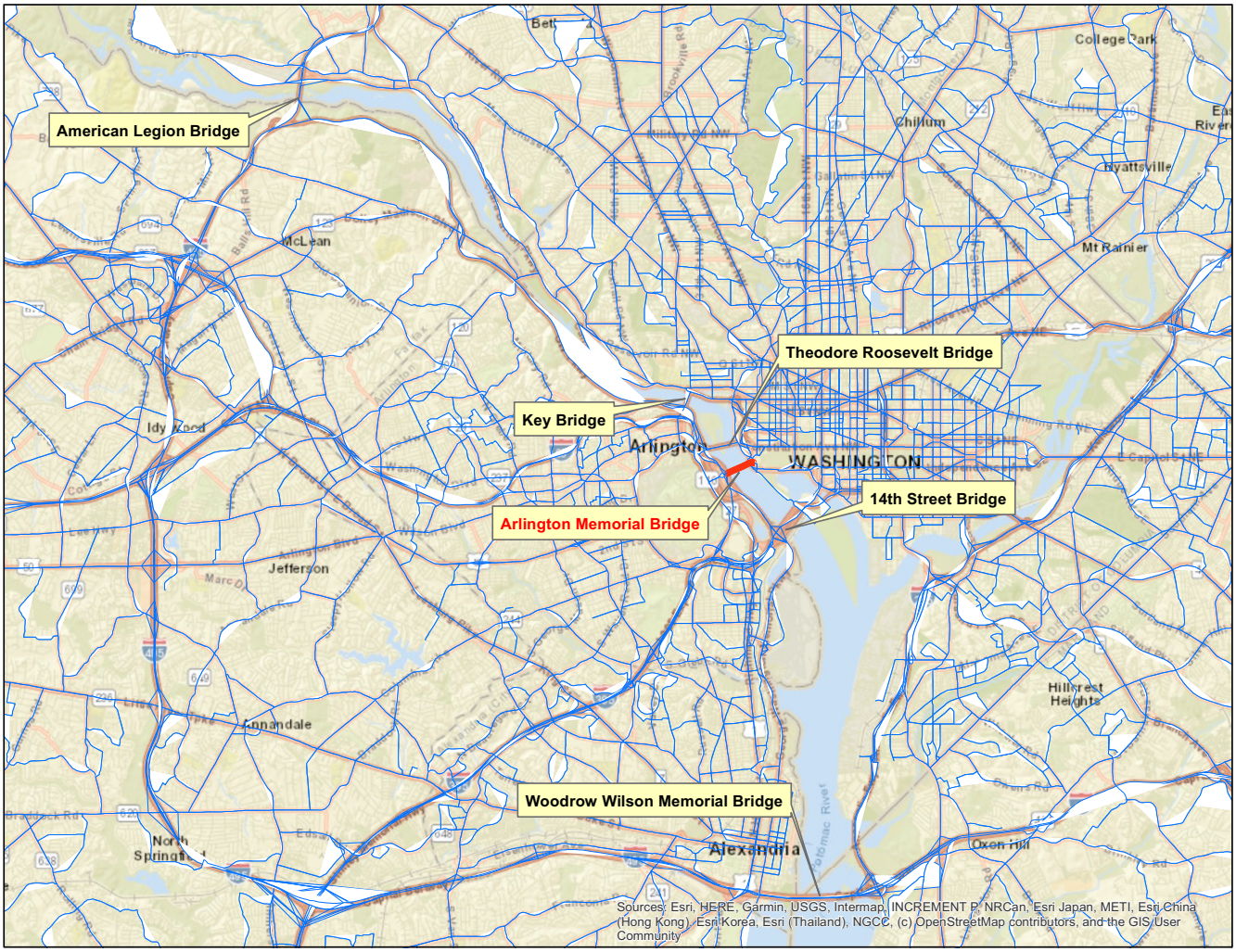

FIGURE 4: ARLINGTON MEMORIAL BRIDGE AND OTHER NEARBY BRIDGE ALTERNATIVES

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 75 more tours (0.00% increase), 904 fewer trips (0.00% decrease), and 1,056 fewer stops (0.02% decrease) than the Baseline scenario. As these changes are so small at the regional level, it is difficult to differentiate meaningful model responses with model noises. In that sense, model summaries for a more focused study area surrounding the Memorial Bridge would shed more light on the model sensitivity. Due to the time constraints, however, this sensitivity analysis is focused on high-level model statistics. More in-depth analyses could be explored in Phase 2 sensitivity testing.

TABLE 43: BASELINE VS. MEMORIAL BRIDGE CLOSURE: REGIONAL TOTAL COMPARISON

	Base	noMemBr	Diff (noMemBr - Base)	% Diff (noMemBr - Base)
Total population	7,250,066	7,250,066	-	0.00%
Total households	2,790,357	2,790,357	-	0.00%
Total tours	8,938,145	8,938,220	75	0.00%
Total trips	23,242,205	23,241,301	-904	-0.00%
Total stops	5,365,915	5,364,859	-1,056	-0.02%

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

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

The commuting flow tables show jurisdiction-to-jurisdiction flows of workers. Please note that all the trip flow tables presented in this report are in Origin-Destination (O-D) format. As expected, changes in worker flows traveling from suburban jurisdictions (e.g., Fairfax) to the core (e.g., DC or Arlington) are visible, shown in Table 45. Most jurisdiction-to-jurisdiction interchanges that would likely use the Memorial Bridge when it is open show a decrease in worker flows in the Memorial Bridge Closure Scenario. For example, the flows from Fairfax to DC and from DC to Fairfax both dropped by 2%. 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 7%. On the other hand, commuting flows traveling on the same side of the bridge show a small increase, such as a 1% 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, 1,440 (or 0.2%) fewer workers would work in DC. The directions of these changes appear reasonable.

TABLE 44: BASELINE VS. MEMORIAL BRIDGE CLOSURE: CHANGES IN COUNTY – COUNTY FLOWS OF WORKERS

	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	181	8	157	1	-1	-5	0	-446	221	2	6	0	-8	0	0	18	-162	17	9	-2	0	4	0
Anne Arundel	-12	18	-170	5	-23	-2	-1	92	-7	-1	-29	1	236	-1	-1	-8	-104	-5	10	0	2	0	0
Arlington	34	-30	390	1	0	1	0	-387	174	0	2	1	-23	0	0	16	-21	-168	12	1	-4	1	0
Calvert	-5	15	-26	-3	0	10	0	57	-47	0	4	-1	-11	0	1	9	-14	19	-2	0	-6	0	0
Carroll	-7	26	-14	0	41	3	0	12	-19	0	33	0	-36	-2	1	-1	-7	-35	6	0	-1	0	0
Charles	69	45	-112	22	0	67	0	-171	30	0	1	2	-17	0	0	-14	83	8	-15	3	5	-6	0
Clarke	-5	1	1	0	6	0	16	-8	14	-5	-10	0	6	-7	-1	-11	4	-6	10	-2	-1	-2	0
DC	-60	-50	-221	1	-3	2	0	643	-285	1	-20	-1	-8	0	1	6	18	-10	-12	-1	-4	3	0
Fairfax	388	24	317	-5	1	-15	1	-1,572	1,116	2	14	-3	-26	0	-5	78	-38	-362	69	-2	7	11	0
Fauquier	-6	7	10	3	-1	0	0	-14	29	7	2	-5	-8	1	3	28	-8	-20	-24	-5	1	0	0
Frederick	-10	-16	50	2	-4	-1	-1	46	-35	1	-45	0	10	4	0	-5	18	-16	3	-1	0	0	0
Fredericksburg	7	3	-16	0	2	4	0	-1	8	0	0	-9	0	0	6	4	-1	1	-14	3	0	3	0
Howard	15	-108	-44	0	-12	-11	0	42	-66	0	3	0	189	1	0	-20	-21	44	-13	0	1	0	0
Jefferson	7	6	-17	-1	5	2	-10	2	-11	2	35	1	-12	3	0	-32	14	5	2	-2	0	1	0
King George	-15	0	1	-8	-1	-3	0	-15	20	-1	1	6	-7	0	12	5	5	-4	1	0	7	-4	0
Loudoun	26	1	-238	3	-4	0	-5	-362	382	16	45	2	-24	7	1	297	-208	56	3	-2	2	2	0
Montgomery	-288	108	-282	-1	18	-19	0	907	-417	1	-30	-2	122	0	-1	14	-76	-16	-38	0	-2	2	0
Prince George's	-72	100	-312	10	7	-45	1	428	-253	0	15	-1	-191	0	0	8	253	35	11	1	0	5	0
Prince William	54	19	155	-7	5	6	0	-523	235	-4	-8	-20	-9	0	4	145	-32	-166	117	9	5	15	0
Spotsylvania	-2	15	15	-7	3	-17	0	-19	19	0	-1	10	0	0	4	-12	-23	7	-11	32	-2	-11	0
St. Mary's	-1	20	-28	-62	4	25	0	13	-17	0	-1	0	19	0	1	-8	3	33	-4	1	-1	3	0
Stafford	43	-5	-35	0	1	12	0	-164	81	6	0	-34	-7	0	8	-3	1	-20	26	6	7	77	0
Total	341	207	-419	-46	44	14	1	-1,440	1,172	27	17	-53	195	6	34	514	-316	-603	146	39	16	104	0

TABLE 45: BASELINE VS. MEMORIAL BRIDGE CLOSURE: PERCENTAGE CHANGES IN COUNTY – COUNTY FLOWS OF WORKERS

	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	1%		1%					-2%	1%								-4%	0%	1%				0.0%
Anne Arundel		0%	-7%	0%				0%	0%				1%				-1%	0%					0.0%
Arlington	0%		1%					-1%	1%							1%	0%	-4%					0.0%
Calvert		0%		0%		1%		1%	-3%								-1%	0%			0%		0.0%
Carroll		1%			0%			1%			0%		0%				0%	-3%					0.0%
Charles	2%	3%	-3%	2%		0%		-1%	1%								4%	0%			0%		0.0%
Clarke							1%		1%					-1%		-1%							0.0%
DC	-1%	-2%	-1%					0%	-2%				0%				0%	0%					0.0%
Fairfax	1%	2%	1%					-2%	0%				-2%			0%	0%	-2%	0%				0.0%
Fauquier								-1%	0%	0%						1%			0%			0%	0.0%
Frederick		-1%			0%			1%	-1%		0%		0%	0%		0%	0%	-1%					0.0%
Fredericksburg												0%								0%		0%	0.0%
Howard		0%	-3%		0%			0%	-3%		0%		0%				0%	0%					0.0%
Jefferson									-1%		1%			0%		-1%	1%						0.0%
King George												0%			0%					0%		0%	0.0%
Loudoun	1%		-4%					-3%	0%		1%			1%		0%	-2%	3%	0%				0.0%
Montgomery	-7%	1%	-2%		1%			1%	-1%		0%		1%			0%	0%	0%	-3%				0.0%
Prince George's	-1%	0%	-1%			-1%		0%	-1%				-1%				1%	0%	1%				0.0%
Prince William	1%		1%					-2%	0%	0%						1%	-1%	-5%	0%			0%	0.0%
Spotsylvania								-1%	1%			0%							0%	0%		0%	0.0%
St. Mary's				-2%		1%		0%	-2%									1%			0%		0.0%
Stafford	3%		-2%					-3%	1%			0%							0%	0%		0%	0.0%
Total	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0.0%

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 in Virginia, for example the work tour length is 0.2% shorter for Arlington and 0.2% shorter for Fairfax. 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 when the Memorial Bridge is closed for autos and trucks.

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

	Base			noMemBr			Diff (noMemBr - Base)			% Diff (noMemBr - Base)		
Jurisdiction	**Work**	**University**	**K-12**	**Work**	**University**	**K-12**	**Work**	**University**	**K-12**	**Work**	**University**	**K-12**
Alexandria	8.5	3.6	3.1	8.5	3.5	3.1	0.0	0.0	0.0	0.4%	-0.6%	-0.1%
Anne Arundel	13.9	10.1	4.2	13.9	10.1	4.2	0.0	0.0	0.0	-0.3%	0.5%	0.1%
Arlington	6.8	2.6	3.3	6.8	2.6	3.3	0.0	0.0	0.0	-0.2%	-0.8%	-0.1%
Calvert	24.6	34.9	5.0	24.6	34.8	5.0	0.0	-0.1	0.0	-0.1%	-0.2%	-0.1%
Carroll	17.0	11.6	5.2	17.0	11.6	5.2	0.0	0.0	0.0	0.0%	0.0%	0.1%
Charles	22.4	13.2	5.3	22.5	13.2	5.3	0.0	0.0	0.0	0.1%	0.1%	0.2%
Clarke	29.8	40.7	7.0	29.9	41.3	7.0	0.0	0.6	0.0	0.1%	1.5%	0.0%
DC	5.5	1.9	2.9	5.4	1.9	2.9	0.0	0.0	0.0	-0.1%	0.4%	0.1%
Fairfax	11.5	5.1	3.8	11.5	5.1	3.8	0.0	0.0	0.0	-0.2%	-0.1%	-0.1%
Fauquier	25.7	17.0	7.2	25.7	17.0	7.2	0.0	0.0	0.0	-0.1%	0.1%	-0.1%
Frederick	16.4	8.6	4.3	16.4	8.6	4.3	0.0	0.0	0.0	-0.1%	-0.1%	0.0%
Fredericksburg	10.4	1.7	3.3	10.5	1.7	3.3	0.0	0.0	0.0	0.2%	-0.1%	0.2%
Howard	13.2	7.4	4.0	13.2	7.4	4.0	0.0	0.0	0.0	0.0%	0.3%	-0.1%
Jefferson	24.0	14.4	5.9	24.1	14.4	5.9	0.0	0.0	0.0	0.1%	0.0%	0.1%
King George	26.3	31.1	7.4	26.3	31.2	7.4	0.0	0.1	0.0	0.0%	0.2%	0.1%
Loudoun	16.2	9.2	3.9	16.2	9.2	3.9	0.0	0.0	0.0	0.0%	0.2%	0.0%
Montgomery	11.9	7.4	3.7	11.9	7.4	3.7	0.0	0.0	0.0	-0.2%	0.0%	-0.1%
Prince George's	12.6	4.9	4.2	12.6	4.9	4.2	0.0	0.0	0.0	0.0%	0.0%	-0.2%
Prince William	16.7	6.3	3.5	16.7	6.3	3.5	0.0	0.0	0.0	-0.2%	0.4%	0.1%
Spotsylvania	15.2	6.0	4.0	15.1	6.0	4.0	0.0	-0.1	0.0	-0.3%	-0.9%	-0.5%
St. Mary's	17.5	10.7	5.8	17.6	10.8	5.8	0.0	0.0	0.0	0.1%	0.2%	0.1%
Stafford	19.8	15.7	4.3	19.7	15.6	4.3	-0.1	-0.1	0.0	-0.4%	-0.5%	0.1%
Total	**13.0**	**6.5**	**4.0**	**13.0**	**6.5**	**4.0**	**0.0**	**0.0**	**0.0**	**-0.1%**	**0.1%**	**0.0%**

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

	Base	noMemBr	Diff (noMemBr - Base)	% Diff (noMemBr - Base)
Escorting	4.3	4.3	0.0	-0.14%
Individual Maintenance	5.6	5.6	0.0	-0.06%
Individual Discretionary	6.2	6.2	0.0	-0.16%
Joint Maintenance	7.1	7.1	0.0	-0.18%
Joint Discretionary	7.3	7.3	0.0	-0.10%
At-Work	5.0	5.0	0.0	-0.03%
Total	**5.9**	**5.9**	**0.0**	**-0.11%**

- Compared with the Baseline, the Memorial Bridge Closure Scenario had no visible changes on the distributions of tour arrival and departure times (hence tour durations), as expected.

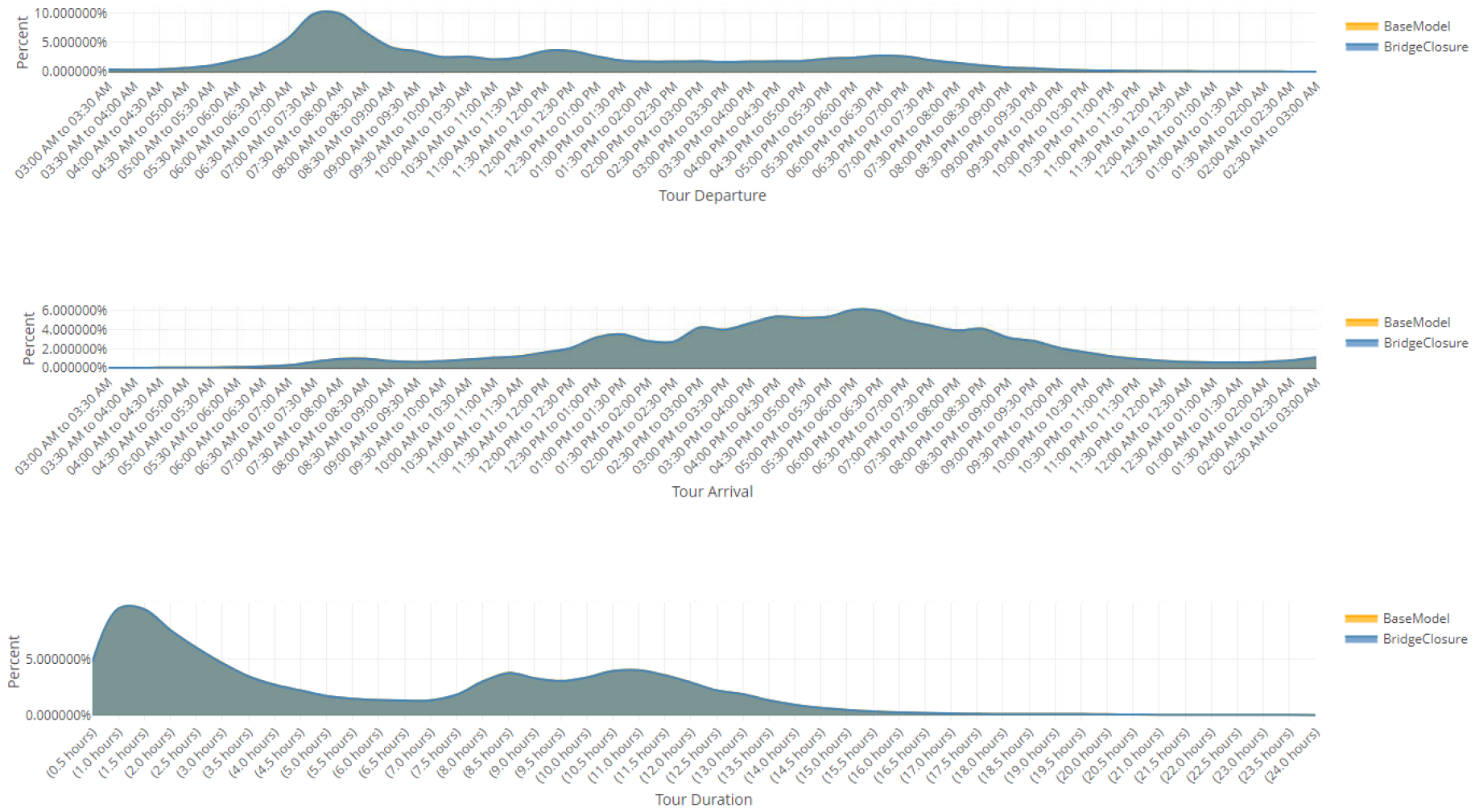

FIGURE 6: BASELINE VS. MEMORIAL BRIDGE CLOSURE: TOUR DEPARTURE, ARRIVAL, AND DURATION

There was no discernible change in the tour mode shares for all purposes, which is a little bit surprising given that Arlington Memorial Bridge is one of the key bridges connecting Virginia and DC. Figure 7 indicates virtually no shifting in work tour mode choice.

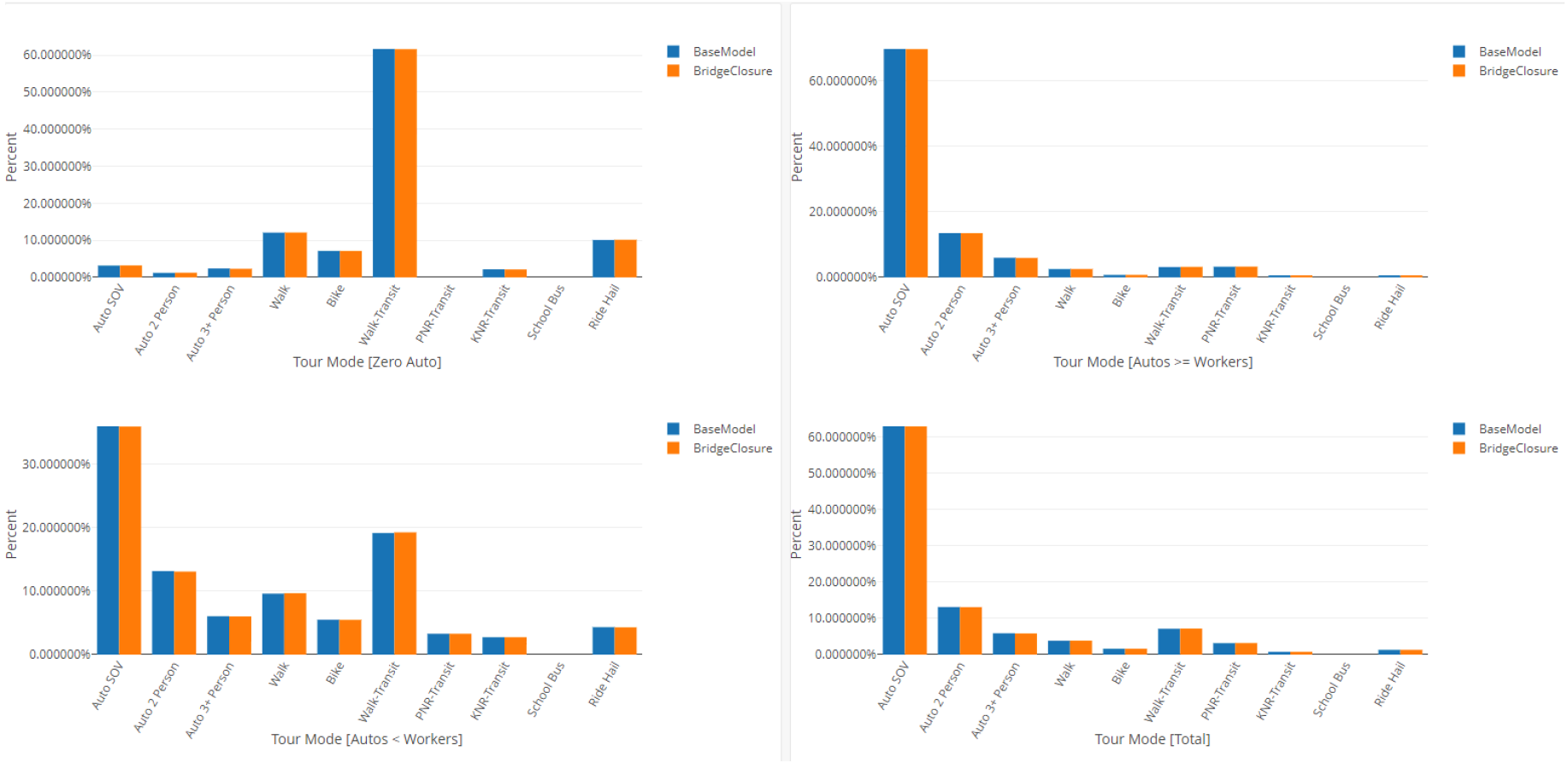

FIGURE 7: BASELINE VS. MEMORIAL BRIDGE CLOSURE: DISTRIBUTION OF WORK TOURS BY MODE

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 to non-motorized and transit modes are in the correct direction. 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 0.12%, 0.41%, 0.65%, and 0.94%, 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 the drive-alone tours and bike tours for 0-Auto households increased by 1.15% and decreased by 0.34%, respectively[9].

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

	Baseline				noMemBr			
Tour Mode	0 Auto	Autos < Workers	Autos >= Workers	Total	0 Auto	Autos < Workers	Autos >= Workers	Total
Drive-Alone	5,151	220,650	3,123,641	3,349,442	5,210	220,616	3,122,528	3,348,354
Shared 2	13,866	211,436	1,756,595	1,981,897	13,843	211,105	1,755,717	1,980,665
Shared 3+	22,001	150,455	1,509,932	1,682,388	22,002	150,490	1,509,227	1,681,719
Walk	94,322	158,100	567,636	820,058	94,456	158,229	568,361	821,046
Bike	10,304	35,322	55,024	100,650	10,269	35,306	55,066	100,641
Walk-Transit	121,606	87,390	120,762	329,758	121,608	87,850	121,651	331,109
PNR-Transit	0	13,574	68,842	82,416	0	13,529	69,425	82,954
KNR-Transit	2,332	10,078	13,915	26,325	2,303	10,104	14,165	26,572
Ride Hail	9,120	24,452	398,820	432,392	9,127	24,439	398,852	432,418
School Bus	30,990	37,012	64,817	132,819	30,971	36,724	65,047	132,742
Total	**309,692**	**948,469**	**7,679,984**	**8,938,145**	**309,789**	**948,392**	**7,680,039**	**8,938,220**

[9] Note that we observe a small drive-alone share of tours and trips made by 0-auto households in the survey data. This occurs when members of 0-auto households rent or borrow automobiles.

Table 49: Baseline vs. Memorial Bridge Closure: CHANGES IN TOTAL TOURS BY TOUR MODE AND AUTO SUFFICIENCY

	Diff (noMemBr - Base)				% Diff (noMemBr - Base)			
Tour Mode	0 Auto	Autos < Workers	Autos >= Workers	Total	0 Auto	Autos < Workers	Autos >= Workers	Total
Drive-Alone	59	-34	-1,113	-1,088	1.15%	-0.02%	-0.04%	-0.03%
Shared 2	-23	-331	-878	-1,232	-0.17%	-0.16%	-0.05%	-0.06%
Shared 3+	1	35	-705	-669	0.00%	0.02%	-0.05%	-0.04%
Walk	134	129	725	988	0.14%	0.08%	0.13%	0.12%
Bike	-35	-16	42	-9	-0.34%	-0.05%	0.08%	-0.01%
Walk-Transit	2	460	889	1,351	0.00%	0.53%	0.74%	0.41%
PNR-Transit	0	-45	583	538		-0.33%	0.85%	0.65%
KNR-Transit	-29	26	250	247	-1.24%	0.26%	1.80%	0.94%
Ride Hail	7	-13	32	26	0.08%	-0.05%	0.01%	0.01%
School Bus	-19	-288	230	-77	-0.06%	-0.78%	0.35%	-0.06%
Total	**97**	**-77**	**55**	**75**	**0.03%**	**-0.01%**	**0.00%**	**0.00%**

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

trip_mode	Gen3 Base	Gen3 noMemBr	Diff (noMemBr - Base)	% Diff (noMemBr - Base)
Auto SOV	10,714,451	10,712,379	-2,072	-0.02%
Auto 2 Person	4,930,823	4,926,509	-4,314	-0.09%
Auto 3+ Person	3,685,543	3,684,401	-1,142	-0.03%
Walk	2,114,407	2,116,851	2,444	0.12%
Bike	224,986	224,890	-96	-0.04%
Walk-Transit	634,305	636,936	2,631	0.41%
PNR-Transit	158,082	159,292	1,210	0.77%
KNR-Transit	49,422	49,900	478	0.97%
Ride-hail	432,392	432,418	26	0.01%
School bus	297,794	297,725	-69	-0.02%
Total	**23,242,205**	**23,241,301**	**-904**	**0.00%**

Highway Traffic Shifts

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

- American Legion Bridge: 251k AADT
- 14th Street Bridge: 249k AADT
- Woodrow Wilson Bridge: 238 AADT
- Theodor 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).

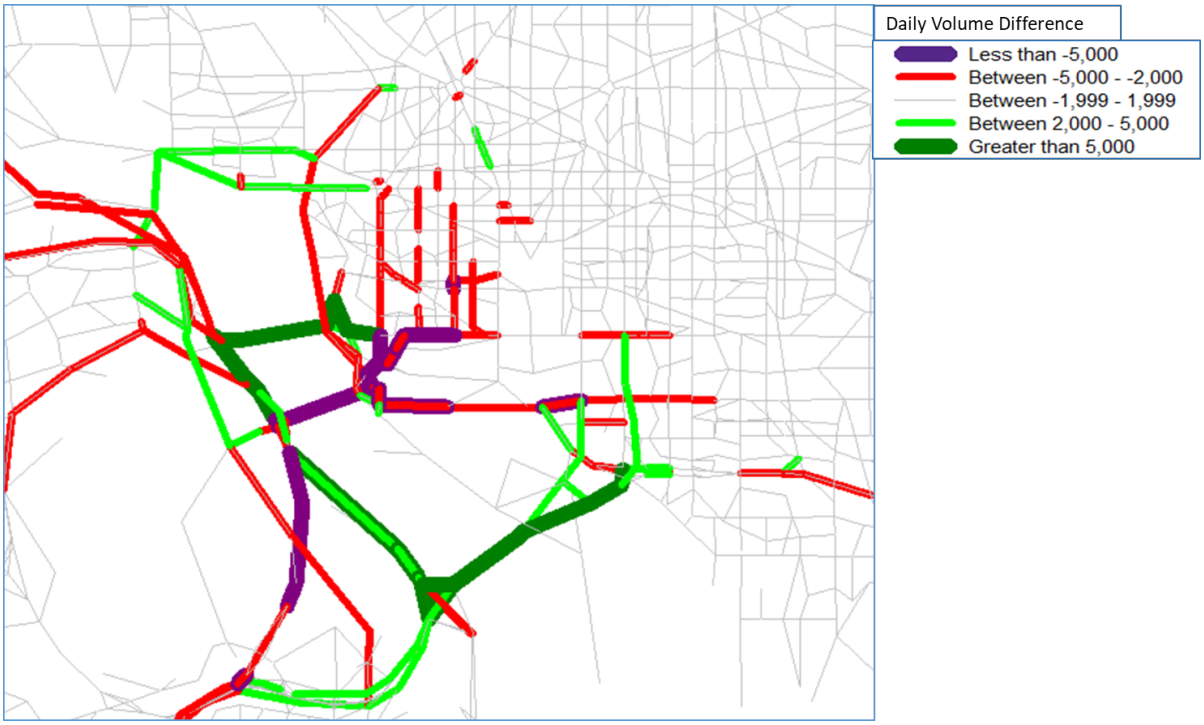

FIGURE 8: DAILY VOLUME DIFFERENCE (IN 000S): MEMORIAL BRIDGE CLOSURE MINUS BASELINE (IMMEDIATE VICINITY)

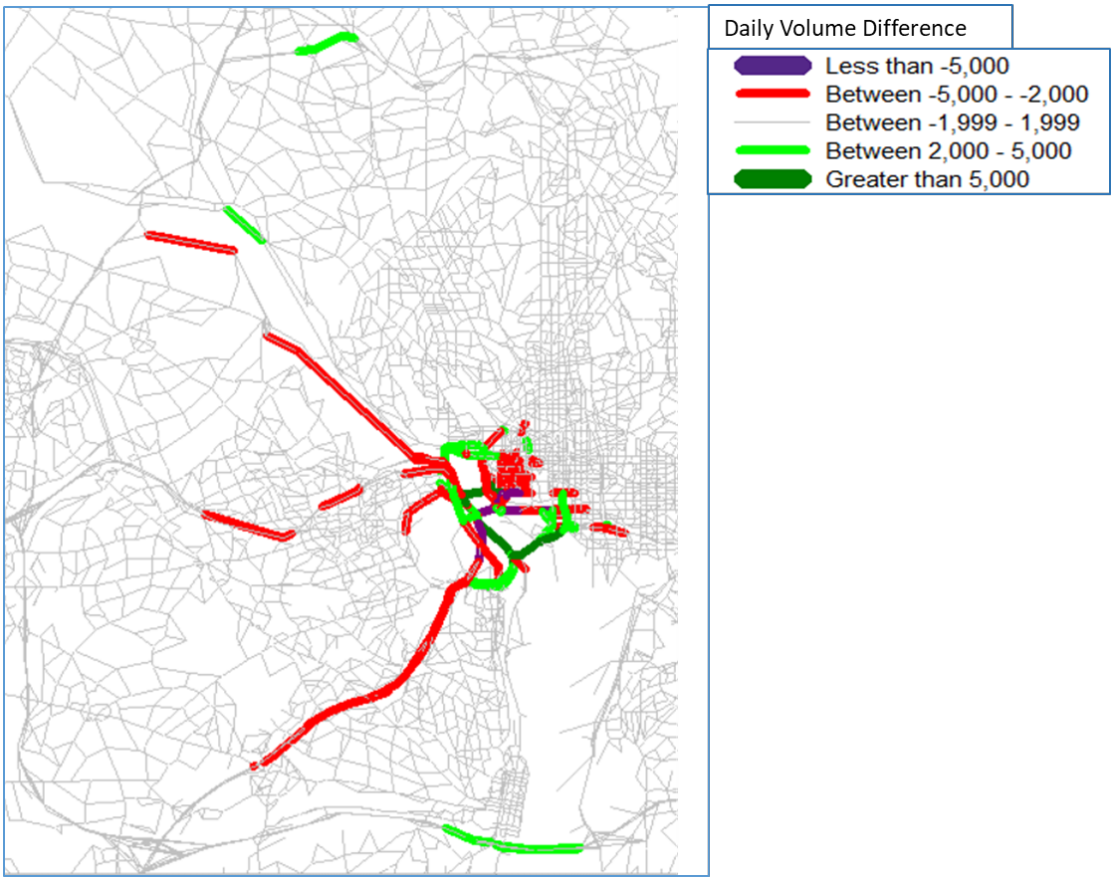

FIGURE 9: DAILY VOLUME DIFFERENCE (IN 000S): MEMORIAL BRIDGE CLOSURE MINUS BASELINE (LARGER AREA)

As expected and shown in Table 51, this Memorial Bridge Closure test resulted in a VMT drop of 118,122 or 0.07%, a marginal decrease in total VHT (0.01%) and a slight increase in VHD by 0.12%.

TABLE 51: BASELINE VS. MEMORIAL BRIDGE CLOSURE: DAILY VMT BY FACILITY TYPE, TOTAL VEHICLE HOURS TRAVEL (VHT), AND TOTAL VEHICLE-HOURS OF DELAY (VHD) COMPARISON

	Gen3 Base	NoMemBr	Diff (noMemBr - Base)	% Diff
Total VMT	175,617,095	175,498,973	-118,122	-0.07%
Total VHT	5,116,172	5,115,465	-707	-0.01%
Total VHD	1,866,470	1,868,765	2,295	0.12%

Transit Ridership Shifts

Average weekday transit ridership by transit sub-mode is shown in Table 52. Total transit ridership increased by 5,251 or 0.47%. Metrorail ridership increased by 0.5%, commuter rail by 0.29%, and all bus increased by 0.46%. The slight decline of the ridership for VRE lines, which mainly serve the commuters from Virginia to DC, could be related to changes in destination choice, as DC destinations become generally less attractive to commuters in Virginia with the closure of the bridge.

TABLE 52: BASELINE VS. MEMORIAL BRIDGE CLOSURE: AVERAGE WEEKDAY TRANSIT RIDERSHIP BY MODE

	Gen3 Base	Gen3 noMemBr	Diff (noMemBr - Base)	% Diff
Metrorail	535,695	538,374	2,679	**0.50%**
Commuter Rail	43,030	43,155	125	**0.29%**
MARC	30,121	30,362	241	0.80%
VRE	12,909	12,793	-116	-0.90%
All Bus	528,868	531,315	2,447	**0.46%**
Total	***1,107,593***	***1,112,844***	***5,251***	***0.47%***
Notes:	MARC stations include external dummy stations (9200-9202) used for modeling external commuter rail boardings			

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 relatively large decreases in overall trip flows between DC and Virginian 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 all these jurisdictions. 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: BASELINE VS. MEMORIAL BRIDGE CLOSURE: TOTAL CHANGES IN TOTAL DAILY TRIP FLOWS

	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	1,277	6	461	37	-2	37	-6	-1,266	297	-3	-13	8	-31	3	-1	-33	-317	85	126	8	0	17	690
Anne Arundel	24	-164	-159	-53	-25	3	2	-30	-60	-2	-56	2	382	-18	-3	-3	-6	177	13	5	7	-8	28
Arlington	664	-205	2,408	-8	-11	-120	-5	-2,872	394	2	-28	6	-48	-14	0	-97	-374	-1,073	-57	4	-8	17	-1,425
Calvert	6	-31	-25	52	2	31	0	48	10	2	-2	-2	-18	0	-5	10	-24	-25	-22	-3	35	3	42
Carroll	-1	3	-16	3	35	-2	-6	29	-12	0	17	0	-1	18	0	-3	-34	2	2	0	0	1	35
Charles	45	39	-78	54	3	-1	2	-107	-33	0	4	3	-26	1	-26	-5	27	-63	31	-7	-18	12	-143
Clarke	-6	1	-8	0	1	2	18	-12	11	3	-6	1	1	-12	-1	-37	17	-6	16	0	0	-3	-20
DC	-1,593	-197	-3,210	29	17	-24	-5	3,119	-2,727	-24	-9	0	15	8	2	-169	1,247	714	-460	-25	15	-85	-3,362
Fairfax	592	-26	578	-22	0	-23	-16	-3,112	4,139	50	-47	-1	-25	27	4	386	-298	-324	207	1	4	17	2,111
Fauquier	-13	2	14	4	3	1	5	-23	25	40	8	-12	-6	-8	-2	73	6	-20	-26	5	2	34	112
Frederick	6	-18	-11	4	-22	13	6	44	-64	0	-324	1	17	23	-1	42	-3	51	-9	0	-2	2	-245
Fredericksburg	-8	2	0	-3	3	11	1	-18	35	0	2	-83	0	-2	19	9	-8	3	-13	40	3	-45	-52
Howard	-42	273	-30	-10	19	-35	0	-3	-19	-6	34	-2	-260	-23	3	7	269	-37	-9	-3	-2	1	125
Jefferson	-4	-9	-9	-1	33	2	-29	10	-3	0	-1	0	-16	78	1	-24	-4	5	21	0	1	2	53
King George	-10	0	-12	1	0	-25	-1	-3	22	3	0	-23	0	2	-7	-3	0	8	0	2	-3	25	-24
Loudoun	-69	-4	-177	7	-7	14	-1	-262	641	117	38	3	-6	-55	-2	957	-248	7	147	-1	-3	-1	1,095
Montgomery	-408	91	-479	-59	10	14	4	1,341	-422	8	158	3	192	7	-1	-184	-1,597	404	-72	-9	9	-14	-1,004
Prince George's	103	255	-699	-14	-29	-18	-8	308	-463	-15	-11	7	-65	-5	10	-5	426	1,513	-66	-2	7	-26	1,203
Prince William	111	-3	44	-1	4	15	21	-457	258	-65	-9	-44	2	20	0	179	-62	-227	-168	34	5	89	-254
Spotsylvania	-13	7	5	-3	2	-10	0	-14	20	2	-1	59	-2	3	4	0	-10	5	-24	231	-3	6	264
St. Mary's	-5	9	-17	23	0	-31	-1	28	-7	4	-2	10	12	1	0	-5	-3	45	-4	1	45	-1	102
Stafford	34	-3	-5	2	-1	3	-1	-110	69	-4	3	12	8	-1	-18	0	-8	-41	113	-17	8	375	418
Total	690	28	-1,425	42	35	-143	-20	-3,362	2,111	112	-245	-52	125	53	-24	1,095	-1,004	1,203	-254	264	102	418	-251

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

	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	1%	1%	1%	10%	-5%	1%	-24%	-3%	0%	-1%	-10%	9%	-10%	8%	-2%	-2%	-5%	0%	2%	3%	0%	1%	0%
Anne Arundel	2%	0%	-7%	-1%	-2%	0%	40%	0%	-2%	-10%	-6%	33%	0%	-32%	-8%	-1%	0%	0%	5%	28%	2%	-18%	0%
Arlington	1%	-11%	1%	-1%	-10%	-5%	-10%	-2%	0%	0%	-6%	6%	-5%	-10%	0%	-2%	-1%	-4%	-1%	1%	-3%	1%	0%
Calvert	1%	0%	-3%	0%	29%	1%		1%	1%	100%	-17%	-11%	-6%		-6%	24%	-2%	0%	-18%	-17%	0%	12%	0%
Carroll	-2%	0%	-8%	75%	0%	-18%	-40%	2%	-2%	0%	0%		0%	13%		-1%	0%	0%	4%	0%	0%	33%	0%
Charles	1%	2%	-3%	1%	30%	0%	200%	-1%	-1%	0%	14%	3%	-8%	100%	-1%	-3%	2%	0%	6%	-4%	0%	6%	0%
Clarke	-21%	17%	-14%		8%	200%	0%	-9%	1%	1%	-2%	50%	6%	0%	-100%	-1%	16%	-23%	3%	0%		-27%	0%
DC	-3%	-1%	-2%	1%	2%	0%	-5%	0%	-2%	-3%	0%	0%	0%	3%	0%	-2%	1%	0%	-3%	-3%	1%	-4%	0%
Fairfax	0%	-1%	0%	-3%	0%	0%	-2%	-3%	0%	1%	-3%	0%	-1%	2%	1%	0%	0%	-1%	0%	0%	1%	0%	0%
Fauquier	-6%	9%	3%	133%	43%	6%	1%	-2%	0%	0%	7%	-1%	-19%	-7%	-3%	2%	1%	-11%	0%	1%	20%	1%	0%
Frederick	4%	-1%	-2%	50%	0%	76%	2%	1%	-3%	0%	0%	25%	0%	0%	-100%	0%	0%	4%	-3%	0%	-20%	13%	0%
Fredericksburg	-7%	17%	0%	-21%		10%		-5%	5%	0%	100%	0%	0%	-50%	1%	24%	-9%	5%	-1%	0%	4%	0%	0%
Howard	-11%	0%	-3%	-5%	0%	-15%	0%	0%	-1%	-29%	1%	-67%	0%	-11%	50%	2%	1%	0%	-6%	-50%	-3%	8%	0%
Jefferson	-7%	-11%	-5%	-100%	19%	200%	-1%	2%	0%	0%	0%	0%	-7%	0%		0%	0%	5%	8%	0%	100%	33%	0%
King George	-14%	0%	-14%	1%		-1%	-100%	-1%	6%	4%	0%	-1%	0%		0%	-14%	0%	2%	0%	0%	0%	1%	0%
Loudoun	-3%	-1%	-3%	23%	-2%	12%	0%	-2%	0%	3%	0%	10%	-1%	-1%	-11%	0%	-2%	0%	1%	-1%	-9%	0%	0%
Montgomery	-6%	0%	-2%	-7%	0%	1%	5%	1%	-1%	2%	0%	8%	0%	1%	-2%	-2%	0%	0%	-2%	-8%	4%	-4%	0%
Prince George's	0%	0%	-3%	0%	-3%	0%	-32%	0%	-1%	-11%	-1%	19%	0%	-8%	2%	0%	0%	0%	-2%	-2%	0%	-6%	0%
Prince William	1%	-1%	0%	-1%	12%	3%	5%	-2%	0%	0%	-3%	-2%	1%	9%	0%	1%	-1%	-6%	0%	1%	6%	0%	0%
Spotsylvania	-5%	30%	1%	-15%	100%	-6%	0%	-1%	1%	0%	-14%	0%	-20%	300%	0%	0%	-6%	3%	-1%	0%	-4%	0%	0%
St. Mary's	-1%	2%	-5%	0%	0%	0%	-100%	1%	-1%	50%	-14%	15%	15%	100%	0%	-11%	-1%	1%	-4%	1%	0%	-1%	0%
Stafford	3%	-4%	0%	10%	-14%	1%	-9%	-3%	1%	0%	18%	0%	30%	-14%	-1%	0%	-1%	-7%	0%	0%	9%	0%	0%
Total	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Auto drivers to DC from all jurisdictions decreased by 2,511 (from 1,207,516 to 1,205,005) or 0.21%.

The trip flow of total auto drivers between DC and Northern Virginia declined by 3.5%. As shown in Table 55, there is decline in auto drivers **to** DC from the other parts of the regional core (Alexandria, by 3.0%, and Arlington, by 3.7%), from the inner suburbs (Fairfax, by 3.6%), and from the outer suburbs (Loudoun, by 3.5% and Prince William. by 2.9%). Similarly, there is also a decline in auto drivers **from** DC to the other parts of the regional core (Alexandria. by 3.9%, and Arlington, by 4.2%), to the inner suburbs (Fairfax, by 3.1%), and to the outer suburbs (Loudoun and Prince William, by 1.7% and 3.3%, respectively).

TABLE 55: BASELINE VS. MEMORIAL BRIDGE CLOSURE: AUTO DRIVERS TRIP FLOW BETWEEN NORTHERN VIRGINIA AND DC COMPARISON

Auto drivers to DC from Northern Virginia

Jurisdiction	Gen 3 Base (a)	Memorial Bridge Closure (b)	Diff. (b-a)	Pct. Diff (b-a)/a
Arlington	60,514	58,261	-2,253	-3.7%
City of Alexandria	23,903	23,179	-724	-3.0%
Fairfax	68,267	65,825	-2,442	-3.6%
Loudoun	6,880	6,641	-239	-3.5%
Prince William	9,822	9,540	-282	-2.9%
Stafford	1,815	1,758	-57	-3.1%
Total	**171,201**	**165,204**	**-5,997**	**-3.50%**

Auto drivers from Dc to Northern Virginia

Jurisdiction	Gen 3 Base (a)	Memorial Bridge Closure (b)	Diff. (b-a)	Pct. Diff (b-a)/a
Arlington	62,129	59,536	-2,593	-4.2%
City of Alexan	25,056	24,088	-968	-3.9%
Fairfax	67,887	65,784	-2,103	-3.1%
Loudoun	5,095	5,009	-86	-1.7%
Prince Willian	7,374	7,128	-246	-3.3%
Stafford	992	993	-85	-8.6%
Total	**168,533**	**162,538**	**-5,995**	**-3.56%**

5.0 FREQUENCY OF ALL HIGH-CAPACITY TRANSIT SERVICES DOUBLED

5.1 DESCRIPTION

The goal of this scenario was to examine how the model responds to a change in transit capacity. 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). We modeled this scenario by cutting the HEADWAY[1] value in half for each line in the MODE3**.LIN, MODE4**.LIN, MODE5**.LIN, and MODE10**.LIN files for all four time-of-day periods. 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 has not yet begun to operate. In addition, we found that no transit volumes were loaded on Mode 10 (streetcar/BRT) links due to a glitch associated with the Non-Transit (NT) leg generation for Mode 10 stations in the Gen3, Phase 1, Model. As a result, this sensitivity test was not able to capture the change in streetcar/BRT ridership associated with the frequency increase. This scenario is called the HCT Capacity Increase Scenario and is labeled as "DblHCTFreq" in the subsequent summary tables.

5.2 EXPECTED OUTCOMES

We expect:

- 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 HCT Capacity Increase Scenario. This scenario generated 1,170 fewer tours (0.01% decrease), 10,633 fewer trips (0.05% decrease), and 8,293 fewer stops (0.15% decrease). 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 less intermediate stops than auto tours.

TABLE 56: BASELINE VS. HCT CAPACITY INCREASE: REGIONAL TOTAL COMPARISON

	Base	DblHCTFreq	Diff (DblHCTFreq - Base)	% Diff (DblHCTFreq - Base)
Total population	7,250,066	7,250,066		0.00%
Total households	2,790,357	2,790,357		0.00%
Total tours	8,938,145	8,936,975	-1,170	-0.01%
Total trips	23,242,205	23,231,572	-10,633	-0.05%
Total stops	5,365,915	5,357,622	-8,293	-0.15%

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

FIGURE 10: BASELINE VS. HCT CAPACITY INCREASE: VISUALIZER SUMMARY

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 HCT Capacity Increase Scenario. Larger losses in vehicle ownership were seen in jurisdictions that are better connected with HCT services, such as DC, Montgomery, and Arlington. For example, there were 1,654 (or 0.68%) fewer households in DC and 883 (or 0.25%) fewer households in Montgomery owning at least one vehicle.

TABLE 57: BASELINE VS. HCT CAPACITY INCREASE: CHANGES IN AUTO OWNERSHIP BY JURISDICTION

	Baseline		DblHCTFreq		Diff (DblHCTFreq - Base)		% Diff (DblHCTFreq - Base)	
	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	10,241	64,541	10,560	64,222	319	-319	3.11%	-0.49%
Anne Arundel	4,059	212,180	4,068	212,171	9	-9	0.22%	0.00%
Arlington	19,193	91,521	19,761	90,953	568	-568	2.96%	-0.62%
Calvert	224	32,992	225	32,991	1	-1	0.45%	0.00%
Carroll	825	62,698	826	62,697	1	-1	0.12%	0.00%
Charles	921	57,126	922	57,125	1	-1	0.11%	0.00%
Clarke	73	5,621	73	5,621	0	0	0.00%	0.00%
DC	106,380	242,536	108,034	240,882	1,654	-1,654	1.55%	-0.68%
Fairfax	25,235	407,746	25,621	407,360	386	-386	1.53%	-0.09%
Fauquier	281	25,500	282	25,499	1	-1	0.36%	0.00%
Frederick	2,464	95,271	2,464	95,271	0	0	0.00%	0.00%
Fredericksburg	499	10,237	497	10,239	-2	2	-0.40%	0.02%
Howard	1,887	116,217	1,897	116,207	10	-10	0.53%	-0.01%
Jefferson	323	23,572	323	23,572	0	0	0.00%	0.00%
King George	57	8,633	57	8,633	0	0	0.00%	0.00%
Loudoun	1,781	130,256	1,781	130,256	0	0	0.00%	0.00%
Montgomery	31,152	356,197	32,035	355,314	883	-883	2.83%	-0.25%
Prince George's	27,531	317,605	28,385	316,751	854	-854	3.10%	-0.27%
Prince William	3,405	167,194	3,434	167,165	29	-29	0.85%	-0.02%
Spotsylvania	471	33,726	471	33,726	0	0	0.00%	0.00%
St. Mary's	720	43,696	718	43,698	-2	2	-0.28%	0.00%
Stafford	422	47,148	420	47,150	-2	2	-0.47%	0.00%
Total	**238,144**	**2,552,223**	**242,854**	**2,547,513**	**4,710**	**-4,710**	**1.98%**	**-0.18%**

At the regional level, the total average tour lengths for the mandatory and non-mandatory tours were marginally higher when increasing the frequency of HCT services, as presented in Table 58 and Table 59. Work and university tour lengths increased by 0.5% and 0.2%, respectively, while the K-12 tour lengths barely changed. 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. The only

exception is Arlington, where the work tour length decreased by 0.2%. The reason for this is unclear. Among non-mandatory tour purposes, “Individual Discretionary” tour length increased the most, by 0.23%.

TABLE 58: BASELINE VS. HCT CAPACITY INCREASE: MANDATORY TOUR LENGTH COMPARISON

	Base			DblHCTFreq			Diff (DblHCTFreq - Base)			% Diff (DblHCTFreq - Base)		
Jurisdiction	**Work**	**University**	**K-12**	**Work**	**University**	**K-12**	**Work**	**University**	**K-12**	**Work**	**University**	**K-12**
Alexandria	8.5	3.6	3.1	8.5	3.6	3.1	0.0	0.0	0.0	0.1%	0.4%	0.5%
Anne Arundel	13.9	10.1	4.2	13.9	10.2	4.2	0.0	0.1	0.0	0.0%	0.9%	-0.1%
Arlington	6.8	2.6	3.3	6.8	2.5	3.3	0.0	0.0	0.0	-0.2%	-1.1%	0.2%
Calvert	24.6	34.9	5.0	24.6	34.9	5.0	0.0	0.0	0.0	0.1%	0.1%	-0.1%
Carroll	17.0	11.6	5.2	17.0	11.7	5.2	0.0	0.0	0.0	0.1%	0.2%	0.0%
Charles	22.4	13.2	5.3	22.5	13.3	5.3	0.0	0.0	0.0	0.2%	0.4%	0.2%
Clarke	29.8	40.7	7.0	30.2	41.1	7.0	0.3	0.3	0.0	1.0%	0.8%	0.0%
DC	5.5	1.9	2.9	5.5	1.9	2.9	0.0	0.0	0.0	0.5%	0.5%	0.1%
Fairfax	11.5	5.1	3.8	11.5	5.1	3.8	0.0	0.0	0.0	0.3%	-0.1%	0.1%
Fauquier	25.7	17.0	7.2	25.9	17.0	7.2	0.2	0.0	0.0	0.7%	-0.3%	0.1%
Frederick	16.4	8.6	4.3	16.6	8.6	4.3	0.1	0.0	0.0	0.9%	0.3%	0.0%
Fredericksburg	10.4	1.7	3.3	10.6	1.7	3.3	0.2	0.0	0.0	1.8%	-0.1%	0.1%
Howard	13.2	7.4	4.0	13.3	7.4	4.0	0.1	0.0	0.0	0.8%	-0.1%	0.0%
Jefferson	24.0	14.4	5.9	24.5	14.5	5.9	0.5	0.1	0.0	2.2%	0.7%	0.0%
King George	26.3	31.1	7.4	26.4	30.7	7.4	0.1	-0.5	0.0	0.4%	-1.5%	0.2%
Loudoun	16.2	9.2	3.9	16.3	9.2	3.9	0.0	0.0	0.0	0.2%	0.1%	0.0%
Montgomery	11.9	7.4	3.7	11.9	7.4	3.7	0.1	0.0	0.0	0.5%	0.1%	0.0%
Prince George's	12.6	4.9	4.2	12.7	4.9	4.2	0.0	0.0	0.0	0.3%	0.0%	0.0%
Prince William	16.7	6.3	3.5	16.9	6.3	3.5	0.2	0.0	0.0	1.0%	0.3%	0.2%
Spotsylvania	15.2	6.0	4.0	15.4	6.1	4.0	0.2	0.0	0.0	1.2%	0.4%	-0.5%
St. Mary's	17.5	10.7	5.8	17.6	10.7	5.8	0.0	0.0	0.0	0.2%	0.0%	-0.1%
Stafford	19.8	15.7	4.3	20.1	15.7	4.3	0.3	0.0	0.0	1.6%	0.1%	0.0%
Total	**13.0**	**6.5**	**4.0**	**13.1**	**6.5**	**4.0**	**0.1**	**0.0**	**0.0**	**0.5%**	**0.2%**	**0.0%**

TABLE 59: BASELINE VS. HCT CAPACITY INCREASE: NON – MANDATORY TOUR LENGTH COMPARISON

	Base	DblHCTFreq	Diff (DblHCTFreq - Base)	% Diff (DblHCTFreq - Base)
Escorting	4.3	4.3	0.0	0.15%
Individual Maintenance	5.6	5.6	0.0	0.07%
Individual Discretionary	6.2	6.2	0.0	0.23%
Joint Maintenance	7.1	7.1	0.0	-0.06%
Joint Discretionary	7.3	7.3	0.0	-0.02%
At-Work	5.0	5.0	0.0	-0.39%
Total	**5.9**	**5.9**	**0.0**	**0.04%**

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 during the AM-peak period increased by merely 1,136 (or 0.0%), while the tours departing during the PM-peak period unexpectedly decreased by 840 (or 0.0%). Similarly, the tours departing during the MD and NT periods marginally decreased by 3,702 (or 0.1%) and unexpectedly increased by 2,288 (or 0.1%), respectively.

TABLE 60: BASELINE VS. HCT CAPACITY INCREASE: TOUR DEPARTURE BY TIME-OF-DAY COMPARISON

	Base	DblHCTFreq	Diff (DblHCTFreq - Base)	% Diff (DblHCTFreq - Base)
AM	6,544,630	6,545,766	1,136	0.0%
MD	4,983,414	4,979,712	-3,702	-0.1%
NT	2,061,356	2,063,644	2,288	0.1%
PM	2,844,936	2,844,096	-840	-0.0%

As expected, the HCT Capacity Increase Scenario resulted in a shift from other modes (auto, walk, bike, etc.) to transit modes, as shown in Table 61. Specifically, park-and-ride transit tours increased by 11.8%, followed by the 6.3% increase in kiss-and-ride access transit tours and the 4.5% increase in walk-access transit tours. For households with at least one vehicle per worker, the park-and-ride transit tours increased by 12.2%. For households with fewer than one vehicle per worker, the park-and-ride transit tours had a smaller increase (9.6%), 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: BASELINE VS. HCT CAPACITY INCREASE: TOTAL TOURS BY TOUR MODE AND AUTO SUFFICIENCY

	Baseline				DblHCTFreq			
Tour Mode	0 Auto	Autos < Workers	Autos >= Workers	Total	0 Auto	Autos < Workers	Autos >= Workers	Total
Drive-Alone	5,151	220,650	3,123,641	3,349,442	5,178	218,081	3,108,113	3,331,372
Shared 2	13,866	211,436	1,756,595	1,981,897	14,018	210,333	1,754,264	1,978,615
Shared 3+	22,001	150,455	1,509,932	1,682,388	22,224	149,533	1,506,902	1,678,659
Walk	94,322	158,100	567,636	820,058	95,256	157,496	567,072	819,824
Bike	10,304	35,322	55,024	100,650	10,196	34,445	54,663	99,304
Walk-Transit	121,606	87,390	120,762	329,758	127,149	90,717	126,853	344,719
PNR-Transit	0	13,574	68,842	82,416	0	14,878	77,249	92,127
KNR-Transit	2,332	10,078	13,915	26,325	2,411	10,815	14,757	27,983
Ride Hail	9,120	24,452	398,820	432,392	9,203	24,428	398,353	431,984
School Bus	30,990	37,012	64,817	132,819	31,067	36,528	64,793	132,388
Total	**309,692**	**948,469**	**7,679,984**	**8,938,145**	**316,702**	**947,254**	**7,673,019**	**8,936,975**

TABLE 62: BASELINE VS. HCT CAPACITY INCREASE: CHANGES IN TOTAL TOURS BY TOUR MODE AND AUTO SUFFICIENCY

	Diff (DblHCTFreq - Base)				% Diff (DblHCTFreq - Base)			
Tour Mode	0 Auto	Autos < Workers	Autos >= Workers	Total	0 Auto	Autos < Workers	Autos >= Workers	Total
Drive-Alone	27	-2,569	-15,528	-18,070	0.52%	-1.16%	-0.50%	-0.54%
Shared 2	152	-1,103	-2,331	-3,282	1.10%	-0.52%	-0.13%	-0.17%
Shared 3+	223	-922	-3,030	-3,729	1.01%	-0.61%	-0.20%	-0.22%
Walk	934	-604	-564	-234	0.99%	-0.38%	-0.10%	-0.03%
Bike	-108	-877	-361	-1,346	-1.05%	-2.48%	-0.66%	-1.34%
Walk-Transit	5,543	3,327	6,091	14,961	4.56%	3.81%	5.04%	4.54%
PNR-Transit	0	1,304	8,407	9,711		9.61%	12.21%	11.78%
KNR-Transit	79	737	842	1,658	3.39%	7.31%	6.05%	6.30%
Ride Hail	83	-24	-467	-408	0.91%	-0.10%	-0.12%	-0.09%
School Bus	77	-484	-24	-431	0.25%	-1.31%	-0.04%	-0.32%
Total	**7,010**	**-1,215**	**-6,965**	**-1,170**	**2.26%**	**-0.13%**	**-0.09%**	**-0.01%**

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. Interestingly, bike trips decreased by 3,069 or 1.4%, but walk trips increased by 3,018 or 0.1%. It could be because walk trips are complimentary to transit tours, for intermediate stops, whereas bike tour and trip mode competes with transit.

TABLE 63: BASELINE VS. HCT CAPACITY INCREASE: CHANGES IN TRIP-BY-TRIP MODE

trip_mode	Base	DblHCTFreq	Diff (DblHCTFreq - Base)	% Diff (DblHCTFreq - Base)
Drive-Alone	10,714,451	10,663,273	-51,178	-0.48%
Shared 2	4,930,823	4,923,249	-7,574	-0.15%
Shared 3+	3,685,543	3,678,260	-7,283	-0.20%
Walk	2,114,407	2,117,425	3,018	0.14%
Bike	224,986	221,917	-3,069	-1.36%
Walk-Transit	634,305	668,299	33,994	5.36%
PNR-Transit	158,082	177,254	19,172	12.13%
KNR-Transit	49,422	52,741	3,319	6.72%
School Bus	432,392	431,984	-408	-0.09%
Ride Hail	297,794	297,170	-624	-0.21%
Total	***23,242,205***	***23,231,572***	***-10,633***	***-0.05%***

Highway Traffic Shifts

Daily volume differences between the Baseline and alternative (Increase HCT Capacity) 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 +/- 2,000 vehicles (tvoldiff=-1.99-1.99). We had to change the minimum difference range to +/- 1,000 vehicles (tvoldiff=-0.99-0.99) in Figure 11 because everything was grayed out when we used the normal range, meaning that no link volume difference was found to be larger than +/- 2,000 in the Increase HCT Capacity Scenario. With the revised minimum difference range of +/- 1,000 vehicles, the plot in Figure 11 displays link volume differences in colors throughout the region, including both volume increases in green and volume decreases in red. Based on our prior experiences with volume difference plots for Gen2 Models, however, it is very difficult to differentiate the volume differences caused by the HCT frequency increase and those resulting from the imperfect model convengence with this revised range of +/- 1,000 vehicles. OBJOBJ. The fact that everything was grayed out with the normal range of +/-2,000 vehicles suggests that the change in the frequency of HCT services has very marginal impact on the highway traffic.

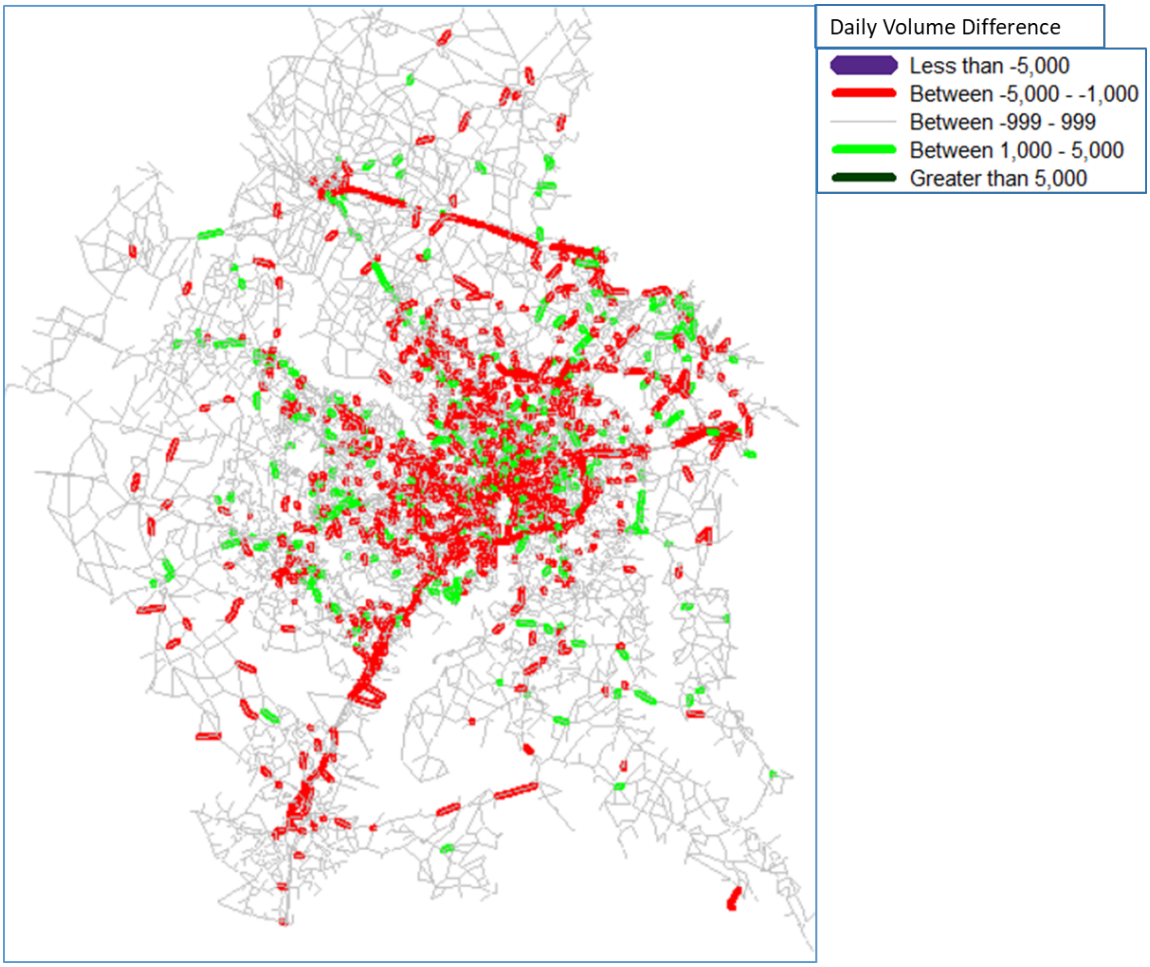

FIGURE 11: DAILY VOLUME DIFFERENCE (IN 000S): HCT CAPACITY INCREASE MINUS BASELINE

As shown in the table below, total regional daily VMT slightly declined by 495,661, or 0.3%.

Similarly, total VHT and total VHD declined by 0.82% and 1.71%, respectively. The direction of change is reasonable and meets expectations. Consistent with the findings from prior TPB studies,[10] 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.

[10] 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.

TABLE 64: BASELINE VS. HCT CAPACITY INCREASE: DAILY VMT, TOTAL VHT, AND TOTAL VHD

	Gen3 Base	Double HCT Frequency	Difference (dblHCTfreq - Base)	Pct. Diff
Total VMT	175,617,095	175,121,434	-495,661	-0.28%
Total VHT	5,116,172	5,074,363	-41,809	-0.82%
Total VHD	1,866,470	1,834,490	-31,980	-1.71%

Transit Ridership Shifts

As shown in Table 65, Metrorail ridership increased by 54,963 (10.3%) and commuter rail ridership increased by 21,368 (49.7%). Since there was no change to the frequency of buses, All Bus ridership has declined by 10,398 or 2.0%. The directionality and magnitude of these changes resulting from the increase in HCT services are consistent with the expectation and seem reasonable.

TABLE 65: BASELINE VS. HCT CAPACITY INCREASE: AVERAGE WEEKDAY TRANSIT RIDERSHIP BY MODE IN THE MODELED AREA

	Gen3 Base	dblHCTfreq	Diff (dblHCTfreq - Base)	% Diff
Metrorail	535,695	590,658	54,963	10.3%
Commuter Rail	43,030	64,398	21,368	49.7%
MARC	30,121	40,964	10,843	36.0%
VRE	12,909	23,434	10,525	81.5%
All Bus	528,868	518,470	-10,398	-2.0%
Total	*1,107,593*	*1,173,526*	*65,933*	*6.0%*
Notes:	MARC stations include external dummy stations (9200-9202) used for modeling external commuter rail boardings			

Daily transit ridership for HCT lines (distinguished by transit route names coded in the COG/TPB's network database[11]) for both Baseline and Build 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.

Doubling the frequency of HCT services resulted in a significant increase in daily Metrorail ridership on the Orange Line (WMORNA: Vienna - New Carrollton), by 60% and on the Red Line (WMREDA: Shady Grove - Glenmont), by 54%; followed by the Yellow Line (Mt. Vernon SQ/7th St. Convention Center - Huntington Avenue), by 29%.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

[11] 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

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 87.5% and VRE Manassas Line by 99.8 %.

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 our expectations.

TABLE 66: BASELINE VS. HCT CAPACITY INCREASE: DAILY TRANSIT RIDERSHIP BY TRANSIT ROUTE

Transit Route Name	Mode No.	Baseline Ridership	Build Scenario Ridership	Difference	Percent Difference
WMBLUA	3	98,226	89,048	-9,178	-9.3%
WMGRNA	3	115,507	133,174	17,667	15.3%
WMORNA	3	110,350	176,417	66,067	59.9%
WMREDA	3	159,812	246,793	86,982	54.4%
WMREDB	3	106,496	43,801	-62,695	-58.9%
WMSILV	3	80,539	42,735	-37,804	-46.9%
WMYELA	3	69,975	90,361	20,386	29.1%
MARC BRUNSWICK LINE	4	6,438	12,070	5,632	87.5%
MARC CAMDEN LINE	4	4,026	7,158	3,132	77.8%
MARC PENN LINE	4	19,657	21,736	2,079	10.6%
VRE MANASSAS LINE	4	4,344	8,678	4,334	99.8%
VRE FREDERICKSBURG LINE	4	5,079	8,980	3,901	76.8%

Trip Flow Shifts

As expected, the HCT Capacity Increase Scenario increased walk-access and drive-access transit trip flows throughout the region (Table 67). For walk-access transit, there was an increase of 33,393 trips regionwide, particularly for interchanges between DC, Montgomery, Prince George's, Arlington, Alexandria, and Fairfax in the Metrorail "catchment” area. For park-and-ride (PNR) access transit (Table 68), we saw an increase of 19,188 trips across the region with increases concentrated on interchanges between DC and suburban jurisdictions (e.g., Montgomery, Howard, Anne Arundel, Fairfax, Prince William) 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: BASELINE VS. HCT CAPACITY INCREASE: CHANGES IN DAILY WALK-ACCESS TRANSIT TRIP FLOWS

	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	258	5	237	0	0	1	0	874	219	0	1	-1	0	0	0	-3	100	89	2	0	0	0	1,782
Anne Arundel	2	-43	-2	0	0	0	0	22	-3	0	0	0	2	0	0	0	-3	21	0	0	0	0	-4
Arlington	269	-2	1,071	0	0	10	0	2,320	552	0	-4	0	4	0	0	10	432	353	-21	0	0	1	4,995
Calvert	-1	0	-1	-4	0	0	0	3	1	0	0	0	0	0	0	0	-1	-1	0	0	0	0	-4
Carroll	0	0	0	0	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-2
Charles	0	0	4	0	0	3	0	-3	-1	0	0	0	0	0	0	0	1	0	0	0	0	0	4
Clarke	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DC	908	21	2,287	-1	0	-2	0	8,923	765	0	1	6	0	0	0	13	1,357	1,729	23	0	-1	1	16,030
Fairfax	232	-4	431	-1	0	-1	0	768	774	0	1	3	-2	0	0	20	222	123	39	0	0	-1	2,604
Fauquier	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Frederick	1	0	-4	0	0	0	0	3	0	0	-7	0	0	0	0	0	13	-2	0	0	0	0	4
Fredericksburg	-1	0	1	0	0	0	0	2	5	0	0	-16	0	0	0	0	0	0	1	2	0	3	-3
Howard	0	4	2	0	0	0	0	1	1	0	0	0	-13	0	0	0	4	15	0	0	0	0	14
Jefferson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	2
King George	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Loudoun	0	0	-1	0	0	0	0	22	26	0	0	0	0	0	0	-10	0	-2	0	0	0	0	35
Montgomery	75	1	455	-1	0	0	0	1,304	221	0	12	1	2	2	0	7	2,579	217	4	0	0	0	4,879
Prince George's	82	12	405	-1	0	1	0	1,588	129	0	-1	0	13	0	0	-1	257	573	-5	0	0	0	3,052
Prince William	3	0	-11	0	0	0	0	11	50	0	0	2	0	0	0	0	2	-3	-55	1	0	2	2
Spotsylvania	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
St. Mary's	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	-2
Stafford	-1	0	2	0	0	0	0	0	-2	0	0	2	0	0	0	0	0	0	1	0	0	2	4
Total	1,827	-6	4,876	-8	-2	12	0	15,837	2,737	0	3	-3	6	2	0	36	4,964	3,113	-11	4	-2	8	33,393

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

	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	1	-34	0	0	4	0	-63	191	5	0	6	3	0	0	3	-7	31	174	11	0	49	374
Anne Arundel	1	104	12	2	0	3	0	507	-3	0	0	0	25	0	0	0	31	252	0	0	0	0	934
Arlington	-24	5	-83	7	-1	22	0	-110	14	12	7	13	4	-3	3	-18	57	184	253	33	1	78	454
Calvert	0	2	7	-2	0	0	0	5	-1	0	0	0	0	0	0	0	4	2	0	0	0	0	17
Carroll	0	0	-1	0	0	0	0	12	0	0	0	0	0	0	0	0	14	0	0	0	0	0	25
Charles	3	3	22	0	0	-16	0	2	5	0	0	0	0	0	0	0	4	9	0	0	0	0	32
Clarke	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
DC	-62	510	-109	5	13	3	1	-69	1,422	52	88	27	503	3	36	79	899	480	1,038	155	1	389	5,464
Fairfax	179	-3	23	-1	0	6	0	1,433	124	11	5	2	-2	5	5	43	78	95	176	27	0	55	2,261
Fauquier	5	0	11	0	0	0	0	53	12	0	0	2	0	0	0	0	0	0	0	0	0	0	83
Frederick	0	0	8	0	1	0	0	89	5	0	10	0	0	4	0	-1	223	7	0	0	0	0	346
Fredericksburg	5	0	14	0	0	0	0	27	2	2	0	24	0	0	1	0	5	0	17	54	0	11	162
Howard	3	26	5	0	0	0	0	505	-2	0	0	0	8	0	0	0	84	200	0	0	0	0	829
Jefferson	0	0	-3	0	0	0	0	3	4	0	5	0	0	0	0	0	31	0	0	0	0	0	40
King George	0	0	3	0	0	0	0	37	4	0	0	1	0	0	0	0	2	1	1	0	0	0	49
Loudoun	2	0	-16	0	0	0	0	79	41	0	-1	0	0	0	0	11	37	0	2	-1	0	0	154
Montgomery	-5	30	56	4	12	3	0	909	82	0	220	5	79	32	2	35	1,504	169	89	13	0	12	3,251
Prince George's	35	243	182	1	0	8	0	467	95	0	7	0	190	0	1	0	163	299	35	4	2	3	1,735
Prince William	181	0	252	0	0	0	0	1,043	183	0	0	17	0	0	1	2	88	34	93	25	0	54	1,973
Spotsylvania	11	0	33	0	0	0	0	155	27	0	0	53	0	0	0	-1	13	4	25	1	0	7	328
St. Mary's	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	3	0	7
Stafford	49	0	79	0	0	0	0	390	51	0	0	9	0	0	0	0	12	3	57	7	0	12	669
Total	383	921	462	16	25	33	1	5,476	2,256	82	341	159	810	41	49	153	3,242	1,772	1,960	329	7	670	19,188

6.0 PEAK-PERIOD TOLL RATES INCREASED BY 50%

6.1 DESCRIPTION

This test was to examine the multi-dimensional impacts of toll rate changes to various model components, such as mode choice, time-of-day choice, route choice, and possibly destination choice and trip length. The per mile toll rates for all the variably priced toll facilities in the region were increased by 50% in AM and PM Peak Periods for this sensitivity test. These facilities are shown in red in Figure 12. We implemented this scenario by increasing the "AM_TFTR" and "PM_TFTR" values from the base scenario by 50% for tollgrp>2 in the "toll_esc.dbf" file.[12] This scenario is called the Increased Toll Scenario and is labeled as "1.5Tolls" in the subsequent summary tables. Note that the variable toll rates for the Baseline scenario were re-estimated using the same iterative toll searching algorithm that has been adopted in the Gen2/Ver. 2.3 and Gen2/Ver. 2.4 Model. This resulted in a slightly different Baseline scenario as compared to the Baseline scenario used for the Memorial Bridge Closure and the HCT Frequency Increase sensitivity tests.

[12] Toll group codes: "1" = flat toll; "2" = toll that varies by time of day; "3" and greater = tolls that change dynamically based on congestion level. See p. 132 of "User's Guide for the COG/TPB Gen2/Version 2.4 Travel Demand Forecasting Model." Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, March 15, 2021.

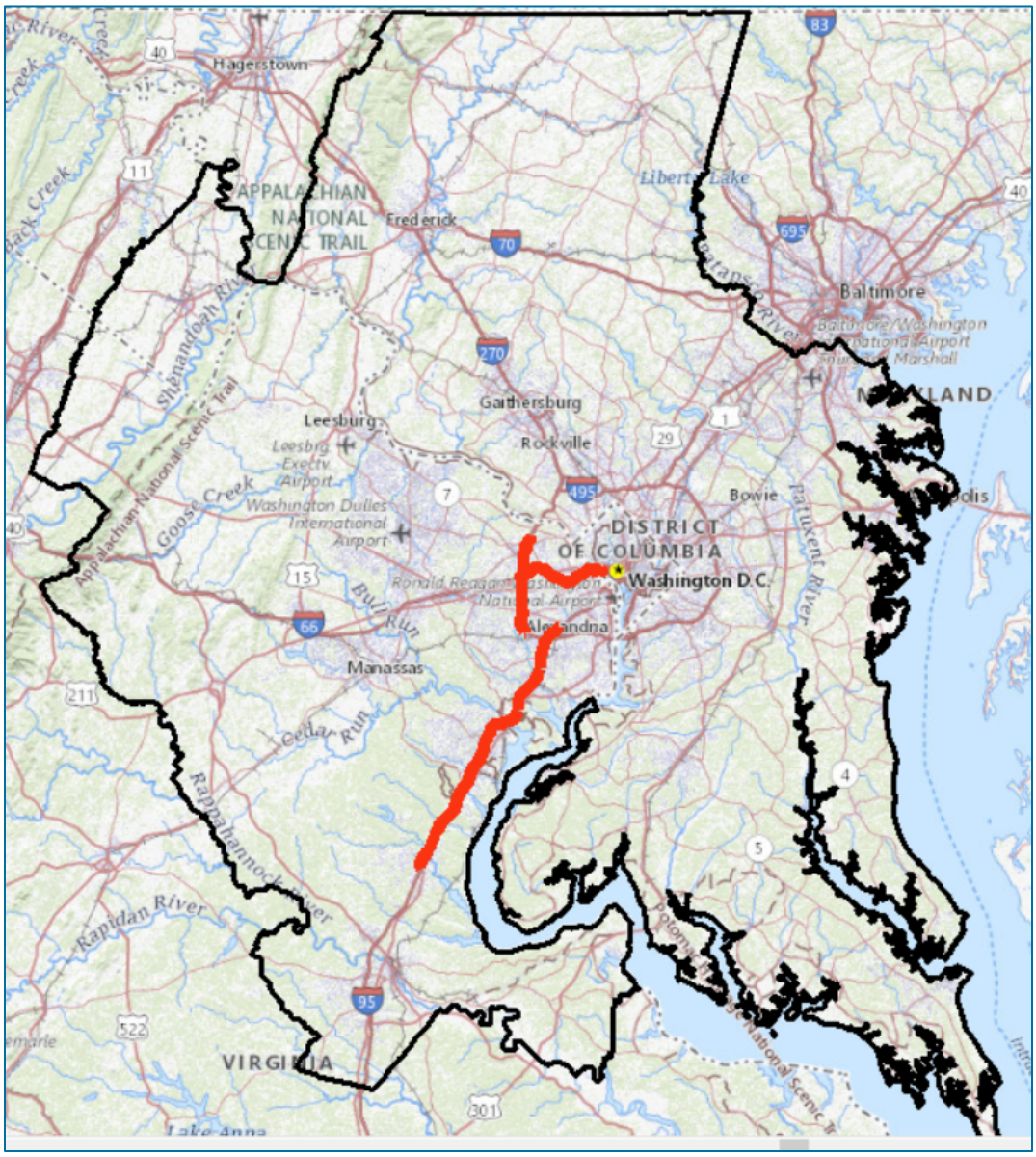

FIGURE 12: VARIABLE TOLLING FACILITIES, WHERE TOLL RATES WERE INCREASED BY 50%

6.2 EXPECTED OUTCOMES

We expect:

- Shifts in traffic from peak to off-peak periods to avoid the increased tolls.
- Decreases in auto SOV trips and increases in auto 3+ person trips.
- Shifts in traffic from HOT lanes to parallel highways and local roads.

- Increases in transit trips that offset decreases in auto trips.

6.3 ACTUAL OUTCOMES

A comparison between the Increased Toll Scenario and the 2018 toll Baseline was made. At the regional level, Table 69 shows merely 1,601 (0.01%) more trips, 1,695 (0.03%) more stops, and 48 (0.00%) fewer tours.

TABLE 69: BASELINE VS. INCREASED TOLLS: REGIONAL TOTAL COMPARISON

	Base	1.5Tolls	Diff (1.5Tolls - Base)	% Diff (1.5Tolls - Base)
Total population	7,250,066	7,250,066	0	0.00%
Total households	2,790,357	2,790,357	0	0.00%
Total tours	8,939,184	8,939,136	-48	0.00%
Total trips	23,244,307	23,245,908	1,601	0.01%
Total stops	5,365,939	5,367,634	1,695	0.03%

FIGURE 13: BASELINE VS. INCREASED TOLLS: VISUALIZER SUMMARY

At the regional level, the Increased Toll Scenario had minimal effect on auto ownership, which is in line with expectations. For example, the 0-vehicle households slightly decreased by 0.04%, and the 3-vehicle households marginally increased by 0.01%. The 1-vehicle and 2-vehicle household groups each increased by 0.01%, while households with 4+ vehicles barely changed.

TABLE 70: BASELINE VS. INCREASED TOLLS: LEVEL CHANGES IN AUTO OWNERSHIP

	Baseline (Households)					1.5Tolls				
	0Veh	1Veh	2Veh	3Veh	4Plus Veh	0Veh	1Veh	2Veh	3Veh	4Plus Veh
Alexandria	10,241	38,341	21,948	2,962	1,290	10,244	38,340	21,943	2,965	1,290
Anne Arundel	4,059	67,796	89,686	37,267	17,431	4,076	67,779	89,680	37,277	17,427
Arlington	19,193	40,431	40,358	7,424	3,308	19,200	40,419	40,364	7,420	3,311
Calvert	224	7,499	14,118	7,704	3,671	225	7,499	14,117	7,703	3,672
Carroll	825	16,829	25,448	14,059	6,362	825	16,826	25,450	14,062	6,360
Charles	921	15,801	22,173	12,889	6,263	923	15,801	22,168	12,891	6,264
Clarke	73	1,734	2,245	1,134	508	74	1,733	2,245	1,134	508
DC	106,380	136,773	85,724	13,326	6,713	106,377	136,763	85,742	13,335	6,699
Fairfax	25,235	121,312	178,798	71,954	35,682	25,194	121,340	178,811	71,953	35,683
Fauquier	281	6,401	10,586	5,831	2,682	281	6,401	10,585	5,832	2,682
Frederick	2,464	27,960	39,968	18,839	8,504	2,462	27,962	39,968	18,840	8,503
Fredericksburg	499	4,800	3,769	1,116	552	497	4,802	3,770	1,115	552
Howard	1,887	32,470	51,797	22,021	9,929	1,883	32,478	51,793	22,017	9,933
Jefferson	323	7,089	9,505	4,918	2,060	322	7,090	9,505	4,918	2,060
King George	57	1,960	3,635	2,110	928	57	1,959	3,636	2,110	928
Loudoun	1,781	28,592	62,078	26,383	13,203	1,772	28,603	62,081	26,379	13,202
Montgomery	31,152	114,628	154,260	58,209	29,100	31,137	114,654	154,244	58,215	29,099
Prince George's	27,531	112,841	120,198	55,412	29,154	27,513	112,864	120,171	55,427	29,161
Prince William	3,405	43,337	71,408	34,515	17,934	3,386	43,355	71,405	34,520	17,933
Spotsylvania	471	8,312	13,928	7,713	3,773	471	8,311	13,928	7,714	3,773
St. Mary's	720	13,556	17,414	8,851	3,875	720	13,554	17,417	8,850	3,875
Stafford	422	10,047	20,502	11,020	5,579	418	10,048	20,505	11,020	5,579
Total	**238,144**	**858,509**	**1,059,546**	**425,657**	**208,501**	**238,057**	**858,581**	**1,059,528**	**425,697**	**208,494**

TABLE 71: BASELINE VS. INCREASED TOLLS: TOTAL AND PERCENTAGE CHANGES IN AUTO OWNERSHIP

	Diff (1.5Tolls - Base)					% Diff (1.5Tolls - Base)				
	0Veh	1Veh	2Veh	3Veh	4Plus Veh	0Veh	1Veh	2Veh	3Veh	4Plus Veh
Alexandria	3	-1	-5	3	0	0.03%	0.00%	-0.02%	0.10%	0.00%
Anne Arundel	17	-17	-6	10	-4	0.42%	-0.03%	-0.01%	0.03%	-0.02%
Arlington	7	-12	6	-4	3	0.04%	-0.03%	0.01%	-0.05%	0.09%
Calvert	1	0	-1	-1	1	0.45%	0.00%	-0.01%	-0.01%	0.03%
Carroll	0	-3	2	3	-2	0.00%	-0.02%	0.01%	0.02%	-0.03%
Charles	2	0	-5	2	1	0.22%	0.00%	-0.02%	0.02%	0.02%
Clarke	1	-1	0	0	0	1.37%	-0.06%	0.00%	0.00%	0.00%
DC	-3	-10	18	9	-14	0.00%	-0.01%	0.02%	0.07%	-0.21%
Fairfax	-41	28	13	-1	1	-0.16%	0.02%	0.01%	0.00%	0.00%
Fauquier	0	0	-1	1	0	0.00%	0.00%	-0.01%	0.02%	0.00%
Frederick	-2	2	0	1	-1	-0.08%	0.01%	0.00%	0.01%	-0.01%
Fredericksburg	-2	2	1	-1	0	-0.40%	0.04%	0.03%	-0.09%	0.00%
Howard	-4	8	-4	-4	4	-0.21%	0.02%	-0.01%	-0.02%	0.04%
Jefferson	-1	1	0	0	0	-0.31%	0.01%	0.00%	0.00%	0.00%
King George	0	-1	1	0	0	0.00%	-0.05%	0.03%	0.00%	0.00%
Loudoun	-9	11	3	-4	-1	-0.51%	0.04%	0.00%	-0.02%	-0.01%
Montgomery	-15	26	-16	6	-1	-0.05%	0.02%	-0.01%	0.01%	0.00%
Prince George's	-18	23	-27	15	7	-0.07%	0.02%	-0.02%	0.03%	0.02%
Prince William	-19	18	-3	5	-1	-0.56%	0.04%	0.00%	0.01%	-0.01%
Spotsylvania	0	-1	0	1	0	0.00%	-0.01%	0.00%	0.01%	0.00%
St. Mary's	0	-2	3	-1	0	0.00%	-0.01%	0.02%	-0.01%	0.00%
Stafford	-4	1	3	0	0	-0.95%	0.01%	0.01%	0.00%	0.00%
Total	**-87**	**72**	**-18**	**40**	**-7**	**-0.04%**	**0.01%**	**0.00%**	**0.01%**	**0.00%**

The shifts in tour departure/arrival times from peak to off-peak periods are expected.. Unfortunately, similar to the HCT Capacity Increase Scenario, the changes in the tour aggregate departure, shown in

Table 72, are marginal and indicate some unexpected results. For example, the total tours departing during the PM-and NT periods marginally decreased by 976 (or 0.0%) and increased by 1,228 (or 0.1%), respectively. Generally, no discernible shift in the distributions of tour arrival time, departure time, or tour durations are shown in Figure 14 or Figure 15. This finding suggests that the time-of-day model may not be sufficiently sensitive to the toll rate change.

TABLE 72: BASELINE VS. INCREASED TOLLS: TOUR DEPARTURE BY TIME-OF-DAY COMPARISON

	Base	1.5Tolls	Diff (1.5Tolls - Base)	% Diff (1.5Tolls - Base)
AM	6,545,058	6,544,240	-818	0.0%
MD	4,984,882	4,985,458	576	0.0%
NT	2,061,058	2,059,830	-1,228	-0.1%
PM	2,845,354	2,846,330	976	0.0%

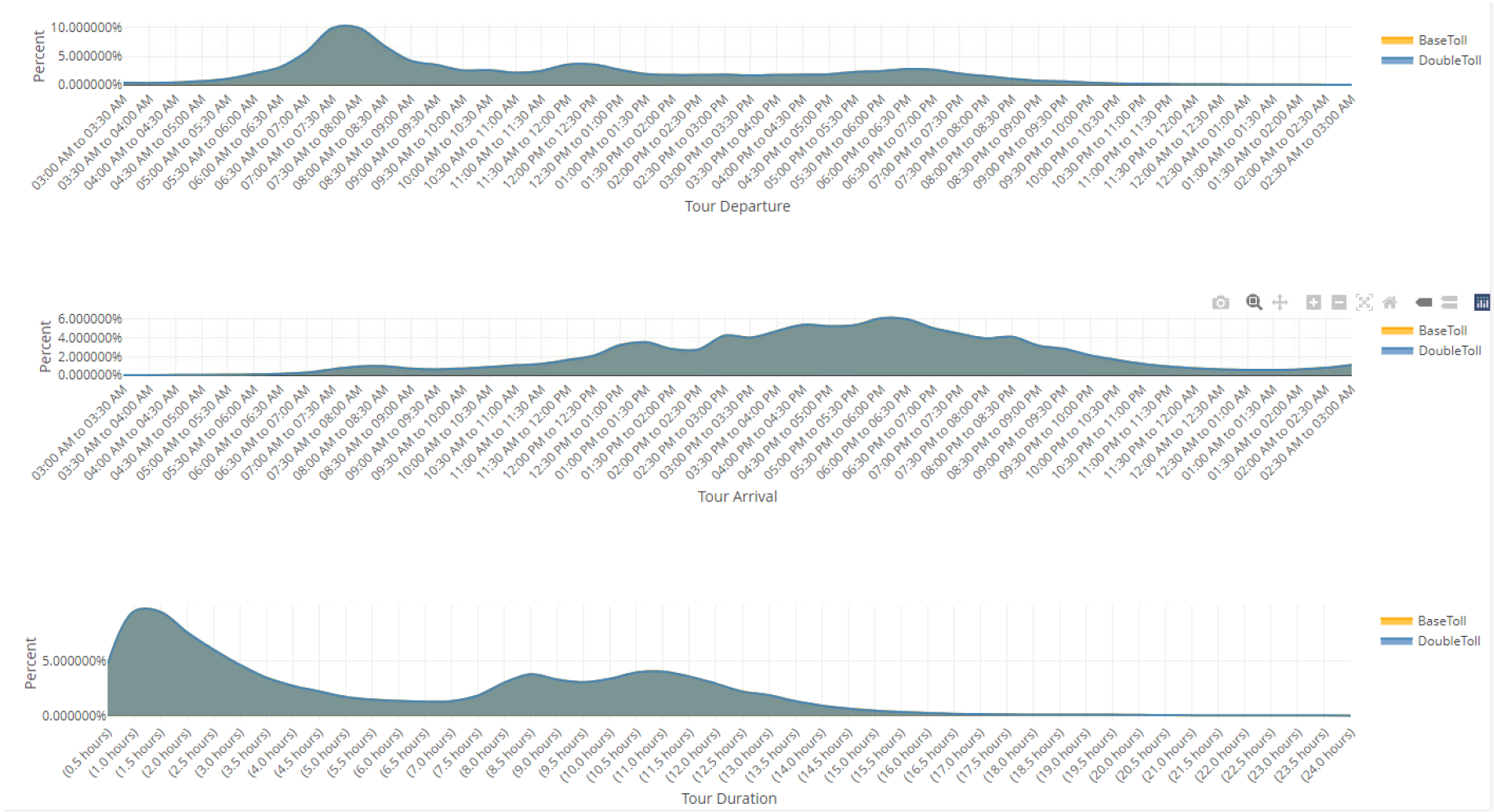

FIGURE 14: BASELINE VS. INCREASED TOLLS: TOUR DEPARTURE, ARRIVAL, AND DURATION

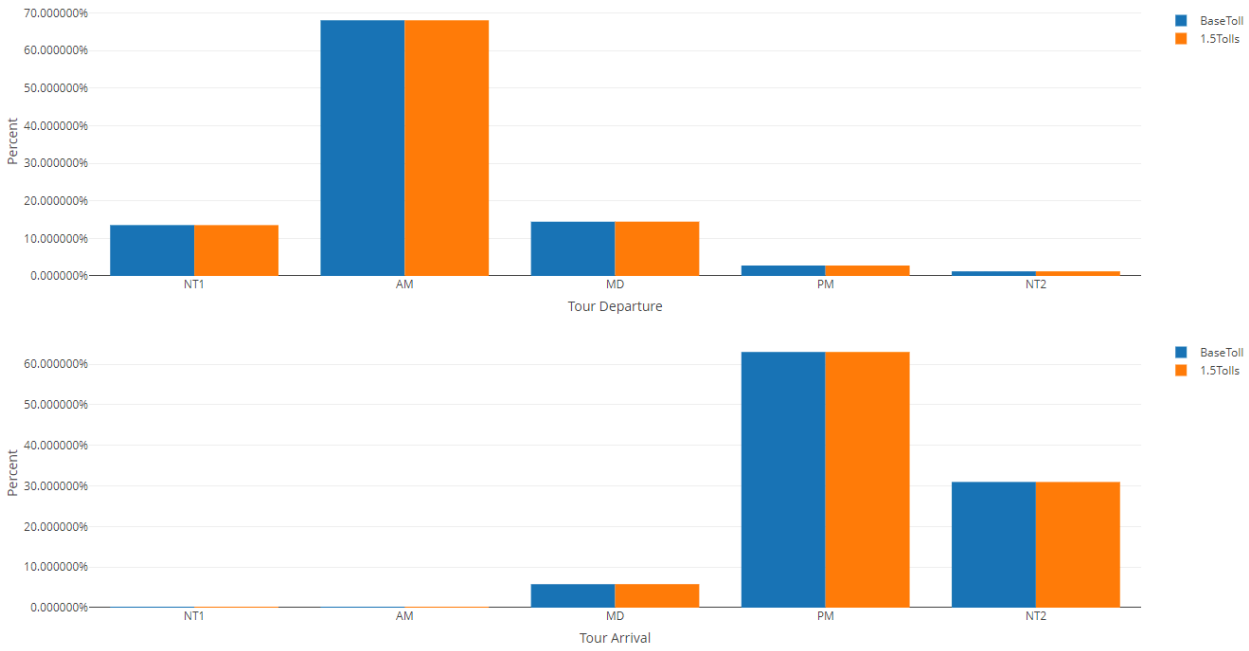

FIGURE 15: BASELINE VS. INCREASED TOLLS: AGGREGATE TOUR DEPARTURE AND ARRIVAL FOR WORK TOURS

Table 73 and Table 74 indicate some small shifts from auto SOV, HOV2, and ride hail tours to HOV3+ and PNR transit tours. For example, auto SOV tours decreased by 0.01% and HOV3+ tours increased by 0.07%. The directionality of these shifts is expected because the higher tolls apply only to vehicles with fewer than three occupants when traveling in the peak period and peak direction. An exception is for I-66 Inside the Beltway where 2+-person carpool tours can use the facility for free, while auto SOV tours must pay the toll. It is unclear why walk-access transit tours decreased (by 0.05%) and whether the model is sufficiently sensitive to the large increase in toll rates (by 50%).

TABLE 73: BASELINE VS. INCREASED TOLLS: TOTAL TOURS BY TOUR MODE AND AUTO SUFFICIENCY

	Baseline				1.5Tolls			
Tour Mode	0 Auto	Autos < Workers	Autos >= Workers	Total	0 Auto	Autos < Workers	Autos >= Workers	Total
Drive-Alone	5,186	221,026	3,123,541	3,349,753	5,194	220,955	3,123,294	3,349,443
Shared 2	13,890	211,446	1,756,479	1,981,815	13,875	210,998	1,756,051	1,980,924
Shared 3+	22,115	150,544	1,510,228	1,682,887	21,985	150,626	1,511,398	1,684,009
Walk	94,293	158,038	568,275	820,606	94,359	158,143	568,278	820,780
Bike	10,253	35,204	54,948	100,405	10,228	35,205	55,096	100,529
Walk-Transit	121,485	87,444	121,114	330,043	121,401	87,537	120,946	329,884
PNR-Transit	0	13,557	68,676	82,233	0	13,612	68,655	82,267
KNR-Transit	2,312	10,026	14,128	26,466	2,341	10,023	13,999	26,363
Ride Hail	9,121	24,483	398,772	432,376	9,099	24,465	398,640	432,204
School Bus	31,017	36,884	64,699	132,600	30,930	36,921	64,882	132,733
Total	**309,672**	**948,652**	**7,680,860**	**8,939,184**	**309,412**	**948,485**	**7,681,239**	**8,939,136**

TABLE 74: BASELINE VS. INCREASED TOLLS: CHANGES IN TOTAL TOURS BY TOUR MODE AND AUTO SUFFICIENCY

	Diff (1.5Tolls - Base)				% Diff (1.5Tolls - Base)			
Tour Mode	0 Auto	Autos < Workers	Autos >= Workers	Total	0 Auto	Autos < Workers	Autos >= Workers	Total
Drive-Alone	8	-71	-247	-310	0.15%	-0.03%	-0.01%	-0.01%
Shared 2	-15	-448	-428	-891	-0.11%	-0.21%	-0.02%	-0.04%
Shared 3+	-130	82	1,170	1,122	-0.59%	0.05%	0.08%	0.07%
Walk	66	105	3	174	0.07%	0.07%	0.00%	0.02%
Bike	-25	1	148	124	-0.24%	0.00%	0.27%	0.12%
Walk-Transit	-84	93	-168	-159	-0.07%	0.11%	-0.14%	-0.05%
PNR-Transit	0	55	-21	34		0.41%	-0.03%	0.04%
KNR-Transit	29	-3	-129	-103	1.25%	-0.03%	-0.91%	-0.39%
Ride Hail	-22	-18	-132	-172	-0.24%	-0.07%	-0.03%	-0.04%
School Bus	-87	37	183	133	-0.28%	0.10%	0.28%	0.10%
Total	**-260**	**-167**	**379**	**-48**	**-0.08%**	**-0.02%**	**0.00%**	**0.00%**

Highway Traffic Shifts

Comparison of the estimated AM peak and PM peak 2018 toll rates from the Gen3 Model and the Version 2.4 Model (where there is difference) are shown in Table 75 and Table 76, respectively.

In general, the estimated 2018 toll rates from the Gen3 Model are slightly lower than those from the Ver. 2.4 Model, but most are comparable for the Gen3, Phase 1, Model currently adopts the same highway assignment and toll setting processes as Gen2 Model.

As shown in Table 75, estimated AM toll rates from Gen3 Model for Toll Groups # 208, #209 and #210 are significantly higher than those from Ver. 2.4 Model. The three toll groups are on I-66 EB leading to the Roosevelt Bridge. The toll overestimation could be related to the DC VMT overestimation and screenline volume overestimation (especially the Potomac River crossing screenline) in Gen3, Phase 1, Model.

TABLE 75: THE GEN3 MODEL VERSUS THE VER. 2.4 MODEL: ESTIMATED 2018 AM PEAK TOLL RATES

TOLLGRP	Gen 2.4			Gen 3			Diff. (Gen 3 - Gen 2.4)			% Difference		
	AM T	PM T	OP T	AM T	PM T	OP T	AM T	PM T	OP T	AM T	PM T	OP T
1	0	0	0	0	0	0	0	0	0	-	-	-
11	20	20	15	30	20	15	10	0	0	50.0%	0.0%	0.0%
13	130	30	15	170	20	15	40	-10	0	30.8%	-33.3%	0.0%
19	60	20	15	50	20	15	-10	0	0	-16.7%	0.0%	0.0%
21	30	20	15	20	20	15	-10	0	0	-33.3%	0.0%	0.0%
77	70	20	15	40	20	15	-30	0	0	-42.9%	0.0%	0.0%
85	90	20	15	80	20	15	-10	0	0	-11.1%	0.0%	0.0%
87	450	20	15	430	20	15	-20	0	0	-4.4%	0.0%	0.0%
89	50	20	15	40	20	15	-10	0	0	-20.0%	0.0%	0.0%
93	100	20	15	90	20	15	-10	0	0	-10.0%	0.0%	0.0%
95	100	20	15	90	20	15	-10	0	0	-10.0%	0.0%	0.0%
97	100	20	15	90	20	15	-10	0	0	-10.0%	0.0%	0.0%
99	110	20	15	100	20	15	-10	0	0	-9.1%	0.0%	0.0%
103	30	20	15	20	20	15	-10	0	0	-33.3%	0.0%	0.0%
107	130	20	15	140	20	15	10	0	0	7.7%	0.0%	0.0%
109	150	20	15	160	20	15	10	0	0	6.7%	0.0%	0.0%
111	400	20	15	510	20	15	110	0	0	27.5%	0.0%	0.0%
117	70	20	15	40	20	15	-30	0	0	-42.9%	0.0%	0.0%
119	70	20	15	40	20	15	-30	0	0	-42.9%	0.0%	0.0%
202	30	20	15	40	20	15	10	0	0	33.3%	0.0%	0.0%
203	210	20	15	250	20	15	40	0	0	19.0%	0.0%	0.0%
208	90	20	15	190	20	15	100	0	0	111.1%	0.0%	0.0%
209	80	20	15	150	20	15	70	0	0	87.5%	0.0%	0.0%
210	30	20	15	80	20	15	50	0	0	166.7%	0.0%	0.0%

As shown in Table 76, Toll Groups # 84 and #86 PM toll rates from Gen3 Model are significantly under-estimated as compared to those from Ver. 2.4 Model. These toll groups are on I-95 SB immediately south of the I-495 & I-95 interchange. The cause of this toll rate underestimation may be discernible due to the many differences in Gen2 and Gen3 Models (e.g., destination choice, time-of-day choice).

TABLE 76: THE GEN3 MODEL VERSUS THE VER. 2.4 MODEL: ESTIMATED 2018 PM PEAK TOLL RATES

TOLLGRP	Gen 2.4			Gen 3			Diff. (Gen 3 - Gen 2.4)			% Difference		
	AM T	PM T	OP T	AM T	PM T	OP T	AM T	PM T	OP T	AM T	PM T	OP T
1	0	0	0	0	0	0	0	0	0	-	-	-
13	130	30	15	170	20	15	40	-10	0	30.8%	-33.3%	0.0%
24	20	70	15	20	50	15	0	-20	0	0.0%	-28.6%	0.0%
30	20	90	15	20	70	15	0	-20	0	0.0%	-22.2%	0.0%
82	20	410	15	20	460	15	0	50	0	0.0%	12.2%	0.0%
84	20	160	15	20	60	15	0	-100	0	0.0%	-62.5%	0.0%
86	20	70	15	20	20	15	0	-50	0	0.0%	-71.4%	0.0%
94	20	30	15	20	20	15	0	-10	0	0.0%	-33.3%	0.0%
96	20	30	15	20	20	15	0	-10	0	0.0%	-33.3%	0.0%
98	20	30	15	20	20	15	0	-10	0	0.0%	-33.3%	0.0%
100	20	30	15	20	20	15	0	-10	0	0.0%	-33.3%	0.0%
102	20	30	15	20	20	15	0	-10	0	0.0%	-33.3%	0.0%
106	20	40	15	20	20	15	0	-20	0	0.0%	-50.0%	0.0%
108	20	60	15	20	40	15	0	-20	0	0.0%	-33.3%	0.0%
112	20	50	15	20	20	15	0	-30	0	0.0%	-60.0%	0.0%
220	20	30	15	20	40	15	0	10	0	0.0%	33.3%	0.0%
225	20	1000	15	20	650	15	0	-350	0	0.0%	-35.0%	0.0%
226	20	210	15	20	130	15	0	-80	0	0.0%	-38.1%	0.0%
229	20	240	15	20	150	15	0	-90	0	0.0%	-37.5%	0.0%

As shown in Figure 16, there is a decrease in traffic volumes on variable tolling facilities on the Capital Beltway and I-95 in Virginia (shown in red) and volume increases (shown in green) on the parallel general purpose lanes. There are no significant volume changes in the other parts of the region (with the exception of a few green links between Baltimore and DC, probably due to model converging noise).The result indicates that although increasing variable tolls has a localized impact on the use of the tolling facilities and parallel facilities, it does not seem to have a significant impact on regional traffic patterns.

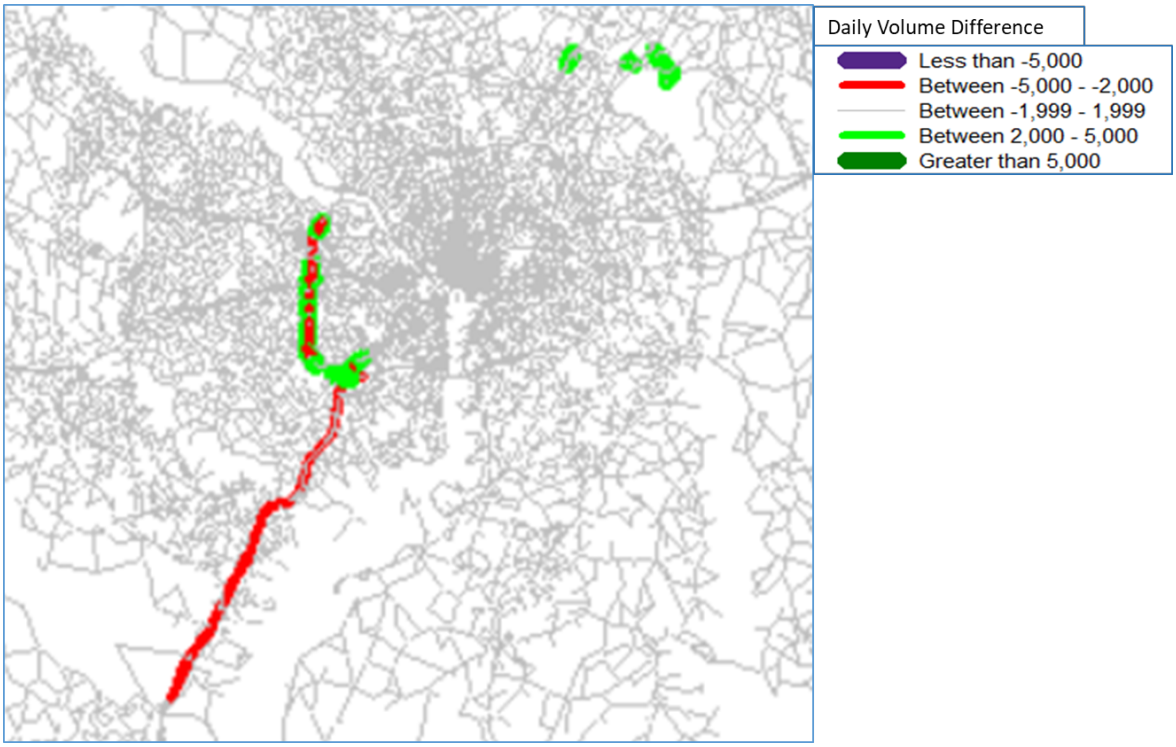

FIGURE 16: DAILY VOLUME DIFFERENCE (IN 000S): INCREASED TOLLS MINUS BASELINE

As shown in Table 77, total VMT, VHT and VHD have declined marginally.

TABLE 77: BASELINE VS. INCREASED TOLLS: DAILY VMT, TOTAL VHT, AND TOTAL VHD

	Gen3 Base	Increase VarToll by 50%	Difference (IncVarToll- Base)	Pct. Diff
Total_VMT	175,617,095	175,484,144	-132,951	-0.08%
Total_VHT	5,116,172	5,113,909	-2,263	-0.04%
Total_VHD	1,866,470	1,865,817	-653	-0.03%

As shown in Table 78, average weekday total transit ridership has increased slightly by 0.1%. Metrorail ridership has decreased by 0.4%. Commuter Rail and All Bus ridership have increased marginally.

Transit Ridership Shifts

While the increase in overall transit ridership is expected, the decrease in Metrorail ridership resulting from this sensitivity test is counter intuitive and does not meet our expectation that Metrorail ridership will increase as the result of mode shift from auto trips.

TABLE 78: BASELINE VS. INCREASED TOLLS: AVERAGE WEEKDAY TRANSIT RIDERSHIP BY MODE IN MODELED AREA

	Gen3 Base	IncVarTOll	Diff (IncVarToll - Base)	% Diff
Metrorail	535,695	533,611	-2,084	-0.4%
Commuter Rail	43,030	43,165	135	**0.3%**
MARC	30,121	30,138	17	0.1%
VRE	12,909	13,027	118	0.9%
All Bus	528,868	531,834	2,966	0.6%
Total	***1,107,593***	***1,108,610***	***1,017***	***0.1%***
Notes:	MARC stations include external dummy stations (9200-9202) use			
	for modeling external commuter rail boardings			

Trip Flow Shifts

Table 79, Table 80, and Table 81 show the changes in trip flows for all modes, SOV, and HOV3+, respectively, throughout the region. In general, we expected to see increases in transit trips and HOV3+ auto trips (In 2018, HOV2 and HOV3+ auto trips can use the tolling facilities on I-66 inside the Beltway for free while HOV3+ trips can use the tolling facilities on I-95 and Capital Beltway for free) due to the increase of variable tolls that is mostly targeted for SOV trips. As expected, increasing the toll rates reduced auto trips to DC (by 7,095), most of which were auto SOV trips (3,421). However, there were unexpected drops in trips to DC from Virginia jurisdictions by non-SOV modes, such as decreases in HOV3+ and transit-related trips. Similarly, the considerable drops in HOV3+ trips from DC to Prince George's, and from Spotsylvania to DC, as well as a decrease of 324 walk-access transit trips, mostly to DC, contradicted our expectations. It is also unclear why this sensitivity test shows some large changes in intra-jurisdictional trip flows, such as a decrease of 3,810 trips in DC and an increase of 5,496 trips in Prince George's County. These unexpected changes in trips by mode could be related to changes in destination choice.

TABLE 79: BASELINE VS. INCREASED TOLLS: CHANGES IN OVERALL DAILY TRIP FLOWS

	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	628	64	-7	8	9	-36	-4	-297	154	-11	-11	-3	8	3	-10	-25	-11	152	-95	-8	-1	9	516
Anne Arundel	0	1,328	-11	-154	23	66	-5	177	101	5	25	-2	347	3	1	53	546	1,368	10	1	-20	-6	3,856
Arlington	-218	18	127	16	-16	38	7	-852	-17	14	-10	5	35	4	12	20	-40	-439	37	14	45	-15	-1,215
Calvert	-42	-102	21	208	2	46	0	-210	50	-1	-3	-1	-34	-1	-6	-8	17	14	29	1	-9	0	-29
Carroll	17	117	4	3	-743	-9	2	-2	-11	1	-42	1	156	9	2	-5	-128	-25	-3	-1	0	1	-656
Charles	-48	55	66	39	-3	855	0	-305	19	-1	-7	-10	5	0	-23	-8	27	121	-2	-1	32	-32	779
Clarke	-8	-2	8	-1	3	1	-52	-2	-3	18	15	-2	-3	25	-1	22	4	1	-18	1	1	4	11
DC	110	131	-1,298	-121	38	-257	1	-3,810	-387	11	10	6	-132	-8	-1	-41	-154	-1,170	45	0	-13	-55	-7,095
Fairfax	83	107	477	46	-19	-79	24	-430	87	-70	-7	7	1	59	-10	254	-32	-133	-229	-25	17	-8	120
Fauquier	4	9	-14	-4	-1	-7	13	15	-3	176	5	5	-4	-8	-4	-52	-2	-2	48	7	0	-17	164
Frederick	-6	32	-20	-3	-14	-6	-3	-4	29	6	-201	-1	62	-43	0	87	-156	32	-9	1	1	0	-216
Fredericksburg	3	2	7	4	1	-11	-1	8	8	25	0	33	3	-1	19	-5	-9	5	7	110	-2	-24	182
Howard	3	2	36	-7	148	-21	-2	-73	9	-4	56	4	176	18	-1	-16	238	-342	-18	-1	8	5	218
Jefferson	2	1	6	-2	10	2	18	-8	63	1	-60	-1	-6	-841	1	159	17	-7	-10	-3	1	2	-655
King George	-13	0	-9	-4	2	-14	-1	2	-6	-5	2	13	-2	2	7	1	4	10	20	16	16	-16	25
Loudoun	10	22	121	3	-20	-6	21	81	66	-25	61	-3	1	152	-3	-142	66	-17	-67	9	4	-14	320
Montgomery	-90	451	-290	19	-49	1	5	3	67	-15	-59	-6	164	-13	6	93	-1,194	-17	-47	-2	-4	-5	-982
Prince George's	175	1,621	-476	-80	-34	175	-5	-1,204	173	3	4	4	-544	-10	1	-22	-131	5,496	-25	11	-39	6	5,099
Prince William	-65	18	55	13	7	20	-9	-29	-196	67	7	80	-26	-4	9	-58	-43	26	15	-18	9	-183	-305
Spotsylvania	-2	7	1	7	-1	-2	0	-7	-23	-3	0	106	0	0	-12	5	-6	7	-15	-82	-12	-29	-61
St. Mary's	-30	-6	15	-12	-2	37	0	-59	47	3	0	5	8	2	0	2	1	27	0	-7	324	-13	342
Stafford	3	-19	-34	-7	3	-14	2	-89	-107	-31	-1	-58	3	-3	38	6	4	-8	22	-84	-16	798	408
Total	516	3,856	-1,215	-29	-656	779	11	-7,095	120	164	-216	182	218	-655	25	320	-982	5,099	-305	-61	342	408	826

TABLE 80: BASELINE VS. INCREASED TOLLS: CHANGES IN DAILY AUTO SOV TRIP FLOWS

	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	513	61	-5	30	10	14	2	-137	-87	-7	-10	-2	23	-6	-8	-18	33	92	-158	-5	-11	-26	298
Anne Arundel	-19	607	-37	-128	24	79	-4	136	90	2	25	-2	379	3	4	44	424	811	9	-2	-32	-13	2,400
Arlington	-171	-16	-204	3	-11	-40	-3	-419	-348	3	-11	3	28	1	10	21	31	-237	-151	2	24	-40	-1,525
Calvert	-32	-58	34	121	2	35	0	-121	38	1	-3	-2	-29	-1	-3	-11	13	-2	21	0	12	-3	12
Carroll	18	99	8	-2	-550	-8	1	-8	-7	-1	20	1	128	9	1	-5	-94	-8	4	-1	0	0	-395
Charles	23	22	3	38	-2	692	0	-190	6	-2	-5	-13	8	0	-12	-9	20	156	-11	7	55	-22	764
Clarke	-5	-2	7	-1	2	1	-119	3	-19	18	10	-2	2	3	-1	8	10	1	-11	1	1	3	-90
DC	117	86	-665	-30	23	-123	1	-1,574	-486	12	13	2	-95	-8	-2	-56	268	-290	-202	-2	5	-55	-3,061
Fairfax	-276	118	64	56	-16	-75	10	-395	177	-59	-15	-16	-14	42	2	127	-105	-133	-726	-42	30	-182	-1,428
Fauquier	7	1	-12	-1	-2	-3	17	8	1	189	2	-8	-2	-9	-1	-42	-4	-3	65	6	0	6	215
Frederick	-10	42	-6	-1	30	-3	-5	-12	48	-3	-308	0	104	-52	1	74	-92	32	-12	1	2	0	-170
Fredericksburg	-2	1	-5	4	1	-11	-1	-2	-30	18	2	46	1	-1	-16	2	-4	1	-5	56	5	-54	6
Howard	-3	28	35	-21	86	-11	1	-25	-7	-2	85	2	135	16	-3	-20	171	-222	-10	1	3	0	239
Jefferson	-2	-1	7	-2	-2	3	16	-7	39	1	-34	-1	-10	-482	0	139	18	-1	-16	-2	0	1	-336
King George	-7	7	-2	-2	0	-23	-1	-4	3	-1	2	-3	-3	1	0	1	-3	7	22	12	15	5	26
Loudoun	-3	20	68	-5	-18	-1	24	28	-28	-11	23	1	-2	139	0	-98	76	-51	5	10	5	-19	163
Montgomery	-20	330	-92	11	-5	22	8	130	2	-10	-4	-4	103	-3	5	25	-71	58	-52	-6	3	4	434
Prince George's	64	1,035	-361	-30	-20	39	-1	-319	114	2	21	2	-364	-10	-6	-25	-273	3,042	-30	3	-27	1	2,857
Prince William	-148	34	-177	7	8	6	-13	-341	-675	49	6	58	-18	-5	6	-21	-65	24	-446	-21	7	-227	-1,952
Spotsylvania	-22	1	-4	7	-1	1	0	-9	-65	-3	1	18	0	1	-17	4	-11	2	-26	-109	-9	-19	-260
St. Mary's	-20	-7	5	-9	-2	90	0	-33	28	1	1	6	2	0	0	5	2	16	-2	-5	218	-12	284
Stafford	-55	-22	-109	-9	1	-12	3	-121	-406	-11	-2	-20	-1	3	57	-4	-3	-7	-32	-93	-12	498	-357
Total	-53	2,386	-1,448	36	-442	672	-64	-3,412	-1,612	186	-181	66	375	-359	17	141	341	3,288	-1,764	-189	294	-154	-1,876

TABLE 81: BASELINE VS. INCREASED TOLLS: CHANGES IN DAILY AUTO HOV3+ TRIP FLOWS

	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	69	-5	-26	7	-2	-13	-2	18	194	-1	0	-1	-10	5	4	-9	1	80	71	4	2	41	427
Anne Arundel	9	33	6	-9	11	16	0	48	-10	1	2	0	95	0	3	6	30	180	0	1	7	2	431
Arlington	-50	-6	-125	-7	2	13	5	-91	237	-5	-9	4	10	2	1	-12	-10	-80	147	5	7	20	58
Calvert	0	1	-11	78	0	5	0	-30	12	-2	1	1	-3	0	2	5	4	-17	2	-1	4	2	53
Carroll	1	28	-12	1	-125	-2	-1	5	8	0	-51	0	1	-1	1	-1	14	-10	-3	0	0	1	-146
Charles	-17	17	4	4	-1	-195	0	-24	11	1	-4	3	8	0	-12	1	11	-85	-3	-4	-13	-2	-300
Clarke	-2	0	1	0	0	0	25	1	-9	-1	-2	0	0	16	0	-2	0	0	-5	0	0	-1	21
DC	3	62	-34	-30	9	-30	3	-64	31	2	8	1	10	-1	-1	-5	-84	-212	123	5	-22	27	-199
Fairfax	205	-10	76	7	9	12	3	-60	229	-1	15	15	13	-1	4	23	87	-26	396	40	1	168	1,205
Fauquier	-7	2	-8	-2	1	-1	-3	7	18	-1	3	5	-3	0	-3	-7	0	4	-42	0	0	-11	-48
Frederick	7	8	-16	-1	-38	-2	-1	16	7	6	-141	0	-11	0	-1	-8	14	8	-7	0	2	-1	-159
Fredericksburg	2	1	6	0	0	0	0	0	34	6	-1	2	1	0	13	-5	-2	2	7	-5	-4	14	71
Howard	0	49	4	0	9	4	-3	3	-6	-2	-27	0	149	6	0	-1	38	33	0	-1	1	2	258
Jefferson	0	0	1	0	6	0	-9	-3	3	0	8	1	-4	-170	0	24	0	-1	5	0	0	1	-138
King George	6	0	-2	5	1	2	0	5	5	-3	0	18	-2	0	-18	0	6	-3	-1	0	6	2	27
Loudoun	-6	11	30	3	-2	-4	6	13	42	-7	21	-2	-7	13	0	23	-24	-4	-49	-3	-2	-8	44
Montgomery	-22	12	-27	-2	4	-4	-1	-73	33	-3	-31	-1	78	-7	3	36	-500	56	16	2	3	6	-422
Prince George's	72	166	-64	-1	-4	14	-3	-65	32	2	9	2	-40	0	4	7	84	660	27	5	6	-2	911
Prince William	36	3	176	-1	0	5	-8	193	454	5	-3	9	-1	5	6	-27	3	53	242	-2	1	19	1,168
Spotsylvania	14	4	8	0	1	-4	0	-8	19	-1	0	25	-1	0	14	-2	5	3	5	-85	-3	14	8
St. Mary's	-8	2	5	-7	0	-24	0	-15	18	0	0	-1	-4	0	1	-3	2	-5	-2	-2	-31	4	-70
Stafford	39	2	54	0	1	-4	0	35	242	-10	-1	-10	0	-1	-7	5	14	4	34	17	0	89	503
Total	351	380	46	45	-118	-212	11	-89	1,604	-14	-203	71	279	-134	14	48	-307	640	963	-24	-35	387	3,703

7.0 CONCLUSIONS

Overall, the sensitivity testing results indicate that the Gen3 Phase 1 model is appropriately sensitive to inputs. The key findings are summarized below by sensitivity test, according to expectations for each test, followed by unexpected findings. We also make suggestions for Phase 2 model improvements and sensitivity testing.

Increased Auto Operating Cost Scenario

As expected, the magnitude and scheduling of tours did not change as a result of this test. Tour lengths and stop out-of-direction distance decreased significantly due to the increased cost of the auto mode, and we observed expected changes in tour and trip mode choice from auto to non-auto modes. The number of intermediate stops decreased due to the decreased tour lengths. Assignment results moved in the expected direction, with decreased VMT and increased transit boardings.

One unexpected change is that the percent decrease in shared-ride modes was greater than the percent decrease in drive-alone. This is explained by the direct elasticity[13] formula derived from a logit model:

Direct Elasticity = Parameter * Variable * (1 – Probability)

Parameter is the coefficient on the variable for which elasticity is being measured, Variable is the value of the variable in the baseline scenario, and Probability is the probability of the alternative whose attribute is changing. Since direct elasticity is inversely proportional to the probability of the alternative, it is reasonable that shared-ride would change by a greater percentage than drive-alone modes with respect to a change in auto operating cost. However, some models consider cost sharing in the treatment of auto operating cost. In such models, auto operating cost is divided by occupancy (or a factor somewhat less than occupancy to account for non-linear effects). In the Gen3 Phase 1 tour and trip mode choice models, parking cost and tolls is divided by occupancy but not auto operating cost. If auto operating cost were divided by occupancy, the mode choice models would calculate higher shared-ride probabilities for longer tours, all else being equal, in which case the output would be longer shared-ride tours than drive-alone tours. We will investigate tour length by mode in Gen3 Phase 2 to better understand this relationship.

We also note that increased auto operating cost only affected resident travel in this sensitivity test. We recommend that auto operating cost be introduced into the auto generalized cost equation used in traffic assignment, so that route choice is affected. We also recommend that

[13] Direct elasticity measures the percentage change in the probability for an alternative for a 1% change in one of the variables considered in the utility equation of that alternative.

auto operating cost be added to the impedance matrix used for truck trip distribution. However this would require re-calibration of truck trip length frequency distributions due to the additional impedance.

Increased Telecommuting to DC Scenario

As expected, the model results include a decreased share of workers who work in DC with a mandatory activity pattern, and a corresponding decrease in work travel for those workers. The model also demonstrated 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. There was a decrease in total trips to DC, vehicle miles of travel, and transit boardings as a results of increased telecommuting. Express transit services (which tend serve DC workers) were more heavily impacted than other transit services.

One unexpected outcome of this scenario was the 'bounce-back' effect of increased workers who choose to work in DC, due to decreased congestion into, out of, and within DC because of the reduced number of workers traveling. This caused increased accessibilities to DC, and the work location choice model shadow pricing mechanism did not fully compensate for the increased accessibilities. RSG will be working on an enhancement to the shadow pricing mechanism that should result in a better match to input employment data. The updated ActivitySim software should be available within the Gen3 Phase 2 development timeline and will be transferred to MWCOG when it is available.

Arlington Memorial Bridge Closed To Auto And Truck Traffic

As expected, the model responded to the Arlington Memorial Bridge closure to auto and truck traffic by reducing the number of tours between zone-pairs that could use the bridge. There were small decreases in tour and trip lengths due to the bridge closure but we suspect that the changes were more concentrated for households and persons that crossed the bridge in the baseline scenario. We also noted reasonable changes in tour and trip mode, as auto tours and trips decreased, and transit tours and trips increased. We noticed no significant changes in time-of-day choice. We observed reasonable changes with respect to highway and transit assignment; volumes and congestion increased on other competitive bridges such as the Theodore Roosevelt Bridge and the 14th Street Bridge. Total VMT decreased and VHD increased as a result of the closure.

We did not see any unexpected outcomes in this scenario test.

Frequency Of All High-Capacity Transit Services Doubled

As expected, household auto ownership decreased as a result of improving transit headways for high capacity transit services in jurisdictions with access to high capacity transit. There were very minimal changes to the magnitude and scheduling of travel. We observe mode shifts from auto, non-motorized, and bus modes to high capacity transit, and commensurate decreases in VMT, VHT, and VHD, with increases in high capacity transit boardings.

Although the outcomes were expected, we believe that re-estimation of the auto ownership and trip mode choice models in Phase 2, along with better calibration of the mode choice models (particularly with respect to high capacity transit modes such as Metro and commuter rail) may improve the model's sensitivity to this scenario.

Peak-Period Toll Rates Increased By 50%

The model demonstrated reasonable, if small, changes in terms of tour and trip mode choice; since the tolls only apply to vehicles with less than three occupants, the model predicted a switch from drive-alone and shared-2 modes to shared 3+ and transit. However, these changes were very small at a regional level. The model did not indicate any significant changes in the magnitude or scheduling of travel. The highway assignment model responded as expected to the increased toll rates; traffic volumes on variable tolling facilities on the Capital Beltway and I-95 in Virginia decreased and volumes increased on the parallel general purpose lanes.

It is possible that the demand models did not change significantly if the increase in the toll cost was offset by a decrease in toll travel time. We suggest plotting the toll cost and auto travel time changes between the baseline and build alternatives for zone-pairs to investigate the effects of this change on skims. We also suggest creating a few summaries specifically for travelers in the toll corridor to determine whether the effects were more localized.

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