National Capital Region
Transportation Planning Board

MEMORANDUM

TO: Feng Xie, Manager, Model Development Group, COG/TPB

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SUBJECT: Year-2018 Validation of TPB Version 2.4 Travel Model

DATE: August 17, 2021

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1 INTRODUCTION

The National Capital Region Transportation Planning Board (TPB) Version 2.4 Travel Model is a trip-based, "four-step" travel demand model that belongs to the Version 2 family of travel models, which, more recently, has also be referred to as the Generation 2, or Gen2 family of travel models. The Version 2.4 Travel Model was derived from the Version 2.3 Travel Model. Currently there are two production-use versions of the TPB regional travel demand forecasting model: Gen2/Ver. 2.3.78 and Gen2/Ver. 2.4. The Ver. 2.3.78 Model has been adopted by the TPB, but the Ver. 2.4 Model has not been used for an air quality conformity (AQC) analysis and thus has not been adopted by the TPB yet. The Ver. 2.4 Model will be used in the upcoming AQC analysis of the 2022 Update of the Long-Range Transportation Plan (LRTP), known as Visualize 2045, which the TPB will review, and possibly adopt, in spring 2022. The Version 2.3 Travel Model was calibrated and validated to year-2007 conditions.[1] It was later re-validated to both year-2010[2] and year-2014[3] conditions. The most recent validation, to year-2014 conditions, was conducted using the Ver. 2.4 Model in 2020.[4]

Compared to the Ver. 2.3.78 Model, the Ver. 2.4 Model incorporates major updates, described in more detail in a prior technical memorandum[5] and in the Version 2.4 Travel Model User's Guide.[6] The need for the 2018 model validation arose when RSG, the consultant on the TPB's next-generation travel model, known as Generation 3, or Gen3 Model, requested to use the 2018 validation statistics from the Gen2/Ver. 2.4 Model as benchmarks for the Gen3 Model, which will be developed based on the 2018 data and will be validated to 2018 conditions.

[1] Ronald Milone et al., "Calibration Report for the TPB Travel Forecasting Model, Version 2.3, on the 3,722-Zone Area System," Final Report (Washington, D.C.: Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, January 20, 2012), https://www.mwcog.org/transportation/data-and-tools/modeling/model-documentation/.
[2] Ronald Milone to Files, "2010 Validation of the Version 2.3 Travel Demand Model," Memorandum, June 30, 2013, https://www.mwcog.org/transportation/data-and-tools/modeling/model-documentation/.
[3] Feng Xie to Dusan Vuksan and Mark Moran, TPB staff, "Year-2014 Validation of TPB's Version 2.3 Travel Demand Model," Memorandum, March 12, 2019.
[4] Meseret Seifu to Feng Xie, "Year-2014 Validation of TPB Version 2.4 Travel Model," Memorandum, October 29, 2020.
[5] Ibid, October 29, 2020.
[6] Ray Ngo, Feng Xie, and Mark S. Moran, "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), https://www.mwcog.org/transportation/data-and-tools/modeling/model-documentation/.

This memorandum documents the year-2018 validation performance of the Ver. 2.4 Model. Specifically, the following summary results of the Ver. 2.4 Model are included: 1) A condensed summary of global modeling results in 2018; and 2) selected highway modeling performance summaries pertaining to year 2018; and 3) year-2018 transit ridership validation statistics. Since the latest Ver. 2.4 Model validation was conducted for year 2014, the 2014 modeling and validation results are also included in these summaries to provide a point of comparison.

2 VER. 2.4 MODEL PERFORMANCE

Summary tables providing year-2014 and year-2018 global travel modeling results of the Version 2.4 Model (Table A-1) and highway validation performance results (Tables A-2 - A-5) can be found in Appendix A at the end of this memorandum. Summary tables providing year-2014 and year-2018 annual average weekday transit ridership by mode and average weekday Metrorail ridership by station group validation results of the Version 2.4 Model (Tables B-1 – B-2) can be found in Appendix B at the end of this memorandum. The sources of observed transit ridership data, for years 2014 and 2018, are described in detail in Appendix B (Pages B-4 – B-6) at the end of this memorandum.

Reviewing the 2014 and 2018 global modeling results, highway validation results and transit validation results from the Ver. 2.4 Model for both 2014 and 2018, staff made the following observations.

2.1 Global Modeling Results

- Table A-1 compares the global travel modeling results of the 2014 and 2018 model validations of the Ver. 2.4 Model. Compared to 2014, the estimated 2018 total transit person trips have increased by 2.7% (line 58). Similarly, there were increases in both the total vehicle miles traveled (VMT, 4.4%, line 107) and vehicle-hours of delay (VHD, 13.4%).
- Since the same Ver. 2.4 Model generated both 2014 and 2018 estimates, the increases in transit and auto travel between 2014 and 2018 is largely driven by the demographic growth. As shown in Table A-1, the Round 9.1a Cooperative Forecasts of Land Use, show a 4.6% increase in households, a 3.2% increase in jobs and a 4.5% increase in population.

2.2 Highway Validation Results

- Compared to year-2014, the 2018 VMT validation performance for TPB member jurisdictions is mostly improved or remained the same as shown in Table A-2. The 2014 VMT over-estimation for Frederick County (12%) had been investigated, but no model-related problems have been identified thus far. The over-estimation is perhaps attributed to land use problems (e.g., interpolated land activity for 2014) which is not something that can be easily fixed.[7] In 2018, the Estimated-to-Observed Ratio (E/O) for City of Alexandria substantially increased from 1.02 in 2014 to 1.16 in 2018. As shown in Table 1, this could largely be attributed to the year-to-year fluctuation of observed VMT that occurs on major roads (known as non-local VMT) in the City of Alexandria, where the observed VMT dropped by 8 percent between 2014 and 2018 (from 2,016,133 to 1,851,663) and bounced back in 2019.

[7] Meseret Seifu to Feng Xie, "Year-2014 Validation of TPB Version 2.4 Travel Model", Memorandum, October 29, 2020

Table 1: City of Alexandria Observed Total VMT on Major ("Non-Local") Roads (Years 2014-2019)

City of Alexandria	
Year	Total Non-Local VMT
2014	2,016,133
2015	2,003,610
2016	1,846,739
2017	1,875,434
2018	1,851,663
2019	2,161,333

As shown in Table A-2, the underestimation for Spotsylvania Co. (E/O=0.67 in 2014 and 0.63 in 2018) is mainly attributed to a mismatch in geographic coverage, i.e., observed data represents the entire county while the estimated VMT represent only the northern portion of the county that is included in the TPB Modeled Area. The VMT overestimation trend in Clarke County remains the same as the 2014 validation. The significant increase in the E/O ratio for Jefferson County (from 1.23 in 2014 to 1.41 in 2018) is attributed to the reduction in the observed data, by 9% (from 1,177,470 to 1,069,310), as well as the increase in estimated VMT by 4% (from 1,445,730 to 1,505,291). Staff had investigated the reasons for the drop in observed VMT for the county, between 2014 and 2018, and suspected that this was related to permanent counting stations.[8]

- As shown in Table A-3, the estimated-to-observed (E/O) ratios for daily VMT by facility type are based on a sample of 6,688 directional daily link volumes in the 2014 and 7,887 in 2018. The ratios for 2014 (1.05) and 2018 (1.03) appear quite comparable and closely meet the "acceptable" standard cited in Florida DOT (FDOT), FHWA, and Virginia DOT (VDOT) manuals.[9]
- As shown in Table A-4, in 2018 many screenlines located in the inner suburbs validate well (also shown in green in Figure A-1). There are many improvements in terms of the screenline volume validation between 2014 and 2018. The 2018 improvement in the screenline validation performance was likely due to the increased availability of link counts on the regional screenlines, rather than the improvements made to the Ver. 2.4 Travel Model. In 2018, 97% of all links crossing regional screenlines are coded with traffic counts, [10] as compared to 37% in 2014.[11] The screenlines shown in Table 2 are all good examples of improvements in terms of the daily screenline crossings performance for the additional counts that became available: screenlines near Baltimore (#26, #27), in other parts of Maryland (#13, #23) and in Virginia (#1, #5, #9, and #18).

[8] Martha Kile July 12, 2021 email response, "The reported VMT in Jefferson County has been declining over the past several years. VMT is estimated based on mileage and traffic counts. Jefferson County was counted in 2014 and 2017. I assume that fluctuations outside of those years are based on factors developed from permanent counting stations in other counties. The one permanent counting station in Jefferson County has not been operational in a few years".

[9] See, for example, the appendices of Cambridge Systematics, Inc., "FSUTMS-Cube Framework Phase II: Model Calibration and Validation Standards: Final Report" (Tallahassee, Florida: Florida Department of Transportation, Systems Planning Office, October 2, 2008), http://www.fsutmsonline.net/images/uploads/reports/FR2_FDOT_Model_CalVal_Standards_Final_Report_10.2.08.pdf.

[10] Meseret Seifu to Feng Xie,"2018 Daily and Hourly Traffic Counts", Memorandum, June 22, 2021

[11] Meseret Seifu to Ron Milone. "2014 Daily and Hourly Traffic Counts". Memorandum, May 22, 2017.

Table 2: Screenlines with improved Validation performance

	Est/Obs ratio		Pct Links w/Counts	
Screenline	**2014**	**2018**	**2014**	**2018**
1	0.74	0.96	36%	96%
5	0.86	0.99	26%	91%
9	0.77	1.03	30%	90%
18	0.89	0.91	32%	88%
13	1.13	1.09	30%	100%
23	1.27	0.93	19%	94%
26	1.68	0.91	38%	96%
27	1.30	1.05	38%	88%

Note: *cells are color coded according to their daily volume E/O ratios (used in Figure A-1)*

- In Figure A-1, screenlines are color coded according to their daily volume E/O ratios. In 2018 many screenlines located in the regional core and inner suburbs validate well (shown in green). Screenlines near external stations, especially those in Maryland, are over-estimated (shown in red or orange), though Screenline #35, near Baltimore, is well validated (shown in green on the map). The less satisfactory validation results of these outer screenlines, in both 2014 and 2018, could be attributed to the many missing observed counts associated with those screenlines, as well as the suboptimal forecasting accuracy associated with large zone sizes in the outer areas. In 2014, there was no traffic count on screenline #11 in Virginia (shown in grey) but in 2018, there are counts assigned to these links.
- As shown in the inset map (Figure A-2), Screenline #20 (Potomac River Screenline) validates fairly well in both 2014 and 2018 (shown in green). As shown in Table A-4, the percent difference of observed and estimated volumes on this screenline met the standard (+/- 20%) in both 2014 and 2018, but the validation in 2018 had become slightly worse (the E/O ratio changed from 0.99 in 2014 to 0.91 in 2018).[12] In order to analyze the reduction in the E/O ratio, the observed and estimated volumes on each bridge across Screenline #20 for both years 2014 and 2018 were summarized in Table 3. As shown in Table 3, the estimated volumes on the Potomac River-crossings did increase between 2014 and 2018, but the rate of increase could not keep up with that of the observed traffic counts. Overall, the observed counts on this screenline increased by 11% (from 905,074 to 1,007,056) but the estimated volumes increased by only 3% (from 891,909 to 920,725). If we look at the Potomac River crossings individually, the Woodrow Wilson Bridge and the 14th St. Bridge were both underestimated in 2018. The Woodrow Wilson Bridge was almost right on in 2014 and was underestimated by 12% in 2018, while the 14th St. Bridge was underestimated by 25% in 2014 and became significantly underestimated by 30% in 2018. For Chain Bridge, the significant increase in the E/O ratio (from 1.19 to 1.66) was mainly attributed to the reduction in the observed data, by 26% (from 29,312 to 21,676), as well as the increase in estimated volume by 3% (from 34,877 to 36,011). The validation performance for the other four bridges, on the other hand, either remained the same (i.e., Memorial Bridge, Roosevelt Bridge, and Key Bridge) or were much improved (i.e., American Legion Bridge). Since the Potomac River is an important screenline for this region, staff will continue to monitor the performance of traffic volume validation on this screenline over time. It remains to be seen if

[12] An observed count coding error was detected on Woodrow Wilson Bridge, which was subsequently fixed by staff for both the 2014 and 2018 validations. As a result, the 2014 observed count and E/O ratio for Screenline #20 are different than those documented in Meseret Seifu to Feng Xie, "Year-2014 Validation of TPB Version 2.4 Travel Model", Memorandum, October 29, 2020

the slight worsening of validation performance on this screenline between 2014 and 2018 is a temporary phenomenon.

Table 3: Years 2014 and 2018 Potomac River Bridge crossings

		2014			2018		
	Facility	Obs	Est	E/O	Obs	Est	E/O
1	Woodrow Wilson Bridge	209,270	207,483	0.99	244,422	214,133	0.88
2	14th Street Bridge	237,414	178,151	0.75	260,988	182,996	0.70
3	Memorial Bridge	53,924	57,184	1.06	65,036	59,612	0.92
4	Roosevelt Bridge	95,232	102,062	1.07	99,502	105,806	1.06
5	Key Bridge	53,466	52,331	0.98	54,192	53,723	0.99
6	Chain Bridge	29,312	34,877	1.19	21,676	36,011	1.66
7	American Legion Bridge	226,456	259,821	1.15	261,240	268,445	1.03
	Total	**905,074**	**891,909**	**0.99**	**1,007,056**	**920,725**	**0.91**

- In Table A-5, the RMSE values were developed from the E/O link volumes for a sample of approximately 6,700 network links in 2014 and 7,900 network links in 2018. Historically, the percent RMSE statistics for TPB models have been observed to be around 20% for freeways and around 40% for all sampled links. Overall, the percent RMSE values for 2014 and 2018 by facility type and by volume group are found largely comparable. The RMSE benchmarks (labeled "Standard" in the table) were derived from a 2014 VDOT report.[13]

2.3 Transit Validation Results

- For the transit validation of the Version 2.4 Travel Model, two validation tests were performed: daily transit ridership by transit sub-mode and daily Metrorail ridership by station group. Transit ridership validation results by sub-mode for years 2014 and 2018 can be found in Appendix B (Table B-1) at the end of this memorandum. The regional transit ridership validates reasonably well for 2014, with an Estimated-to-Observed (E/O) ratio of 1.04, but is significantly overestimated for 2018, with a ratio of 1.24. Specifically, the Metrorail ridership is overestimated by 30% and bus ridership by 20%. This validation result was expected. As shown in the charts below (Figure 1 and Figure 2), there was a significant drop in Metrorail and bus ridership between 2014 and 2018. The daily Metrorail ridership dropped from 694k in 2014 to 606k in 2018 (or 13%, Figure 1) and the Metrobus ridership dropped from 0.44M to 0.36M (or 18%, Figure 2). The regional bus ridership data indicate the same trend. As shown in Table B-1, the observed bus boarding counts decreased from 648,083 to 575,642 (or 11%) regionally between 2014 and 2018. The estimated transit ridership from the Ver. 2.4 Model, on the other hand, continues to increase driven by the steady demographic growth in the region. As shown in Table B-1, the estimated Metrorail boarding counts increased from 744,835 in 2014 to 787,671 in 2018 (or 6%) while the estimated bus boarding counts slightly decreased from 705,146 to 689,496 (or 2%).
- Recently, observed Metrorail ridership started to diverge (downward) from the TPB's Metrorail ridership estimates, which generally trend upward over time. The divergence has occurred because the long-range model does not account for real, short-term service factors

[13] Cambridge Systematics, Inc., "Travel Demand Modeling Policies and Procedures, Ver. 2.00" (Virginia Department of Transportation, June 2014), http://www.virginiadot.org/projects/resources/vtm/vtm_policy_manual.pdf.

(operational disruptions and reliability issues) that have influenced market demand in recent years.[14] Pre COVID-19, the decline in Metrorail ridership can be partially attributed to all the safety and maintenance work, such as SafeTrack. With the bulk of the safety and maintenance work having come to an end, the recovery of Metrorail ridership in 2019 indicates that the decline of Metrorail ridership between 2014 and 2018 might be temporary. For example, average weekday Metrorail ridership increased from 606,000 in 2018 to 626,000 in 2019 (or 3%). The decline in bus ridership in recent years, on the other hand, is a national phenomenon.[15] COVID-19 significantly disrupted the transit ridership and made the long-term forecasting of transit ridership much more challenging. It remains unclear to what extent the transit ridership of this region can recover during the post-COVID era. While the Version 2.4 Model failed to capture the decline in transit ridership between 2014 and 2018, TPB staff will continue to monitor the transit validation performance of the model post COVID-19.

- The validation performance of commuter rail in 2014 and 2018 remained the same (0.76). The validation for MARC is much improved while that for VRE ridership worsens.

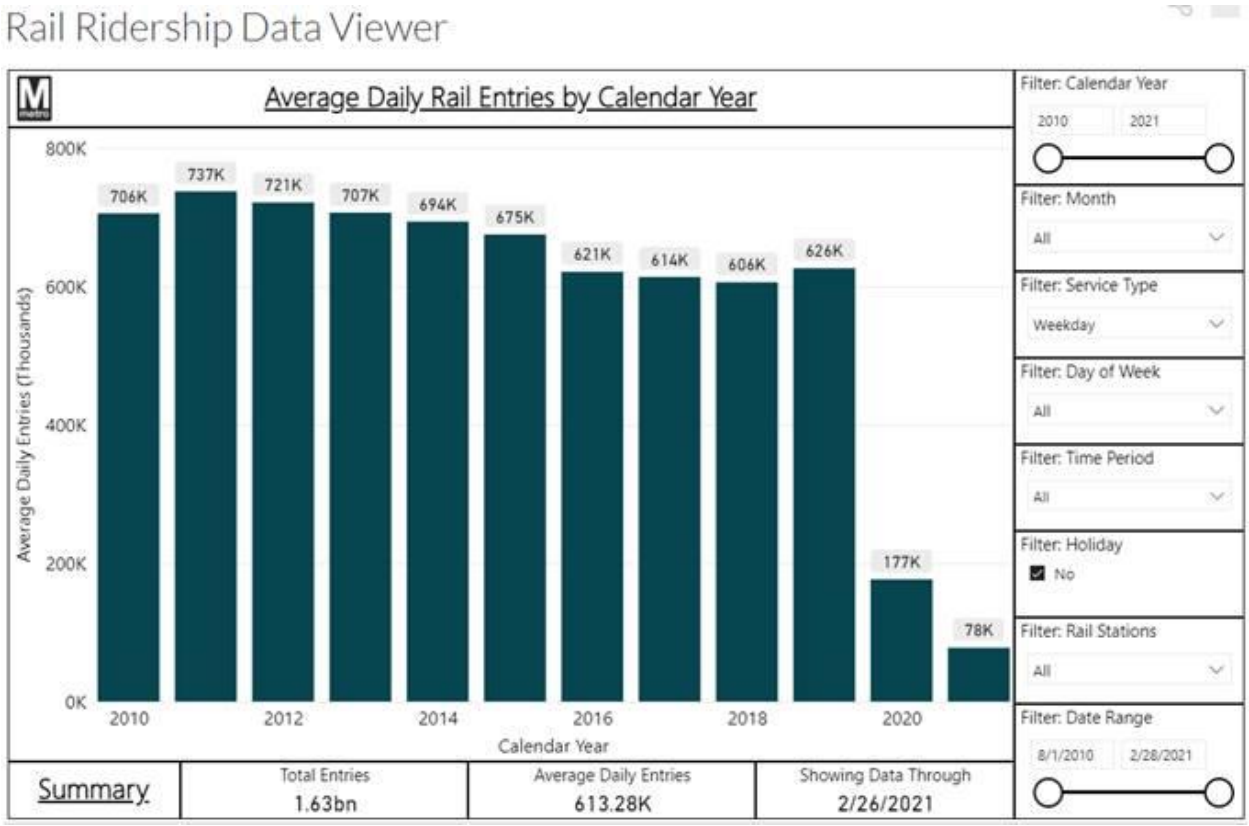


Figure 1 Average daily Metrorail ridership by year

[14] Ron Milone and Meseret Seifu to Allison Davis (WMATA), "Observed and Estimated Metrorail Trips: Period 2012-2016", Memorandum August 28, 2018.

[15] Catherine Vanderwaart, "Washington Region Bus Ridership Trends", Washington Metropolitan Area Transit Authority, March 8, 2018, https://www.mwcog.org/assets/1/28/03082018_-_Item_10_-_Bus_Ridership_Trends.pdf

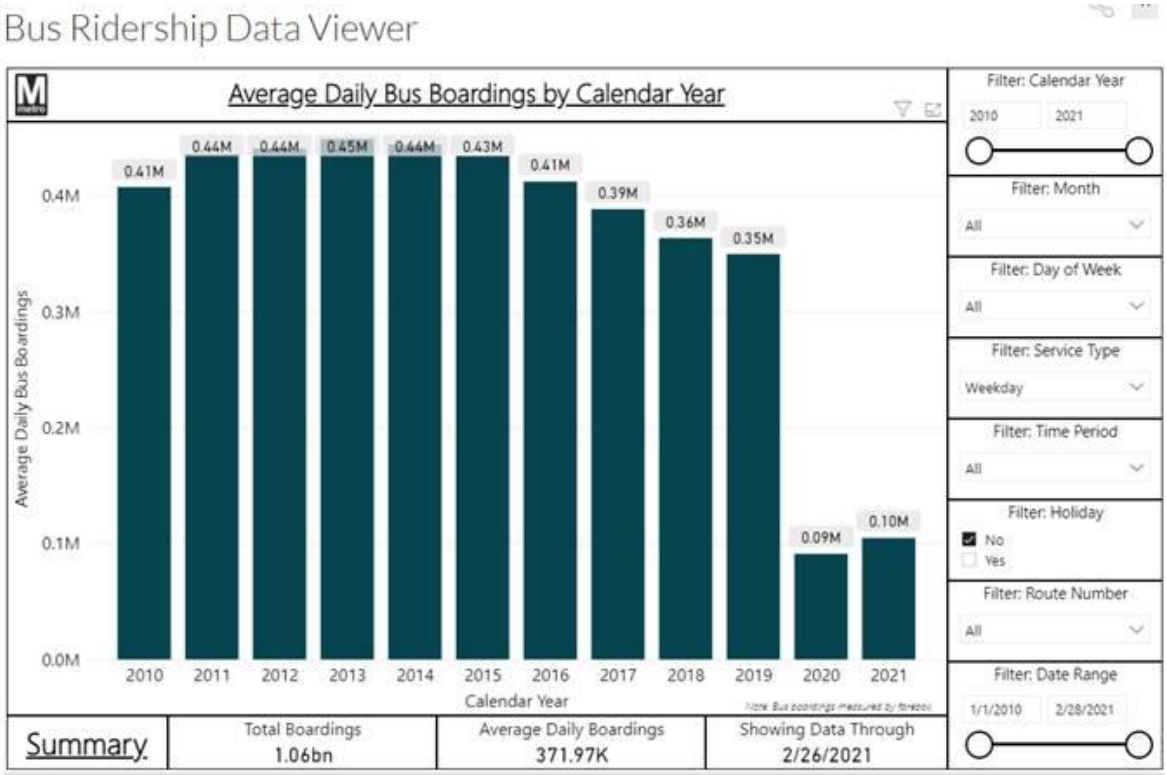


Figure 2 Average daily Metrobus ridership by year

Source: WMATA data portal

- Table B-2 shows year 2014 and 2018 Metrorail ridership by station group. The table indicates that 2014 Metrorail ridership by station group validates well, with 14 out of 21 station groups meeting the standards (table cells shown with yellow shade).[16] However, in 2018 **only** three station groups (#4, #14, and # 19) meet the standards (table cells shown with green shade). Among them only two station groups, specifically Red Line - DC core (0.93) and Blue/Yellow Line - VA Core (1.04), show a good fit. Map B1 displays the geographical locations of the station groups.[17] Map B-2 displays Metro stations groups colored according to Metrorail ridership E/O ratios by station group. In 2014 among the four station groups that didn't meet the standards (#5, #16, #18 and #21), Orange Line – VA Arlington non-Core (1.88) and Silver Line Phase 1 (2.29) are the two being most over-estimated. When Silver Line Phase 2 opens in February 2022,[18] both the simulated and the observed ridership for the Silver Line Phase 1 group are expected to change. The significant over-estimation of the Metrorail station-group ridership in 2018 is consistent with the over-estimation of 2018 Metrorail ridership observed in the transit ridership by mode summary.

[16] As a regional planning model, the Version 2.3. model was calibrated and validated for Metrorail station groups but not for individual stations. Thus, the Metrorail ridership validation was not examined at the station level in this re-validation.
[17] Page B-2, Feng Xie, "Year-2014 Validation of TPB's Version 2.3 Travel Demand Model", MWCOG/TPB Memorandum, March 12, 2019.
[18] Source: https://en.wikipedia.org/wiki/Silver_Line_(Washington_Metro)

3 CONCLUSIONS

The 2018 highway validation results of the Ver. 2.4 Model are reasonable. The 2018 validation statistics from the Version 2.4 Travel model are comparable to 2014 and largely met federal or state standards.

However, year-2018 transit ridership by mode as well as the Metrorail station-group validation results of the Version 2.4 Travel Model show significant overestimation for Metrorail and bus ridership. The Version 2.4 Travel Model, which was estimated and calibrated to year 2007 conditions, was not able to capture the decline of Metrorail and bus ridership between 2014 and 2018. The results indicate that the 2018 transit validation statistics from the Version 2.4 Model are not good benchmarks for the Gen3 Model. While staff will continue to monitor the transit validation performance of the Ver. 2.4 Model to more recent conditions, it is recommended that RSG use the 2014 validation statistics from the Ver. 2.4 Model as benchmarks for the Gen3 Model development.

Since the Version 2.4 Model has been validated to year 2014 conditions, the federal regulations allow the model to be used for AQC analyses through 2024 (10 years from the latest validation year), which is around the time when the development of the Gen3 Model should be completed. If Gen3 Model is not ready for production use by then, however, staff will need to validate the Ver. 2.4 Model or its successor to conditions more recent than 2014. Ideally, the 2018 validation documented in this memo would allow the Ver. 2.4 Model to be used for the AQC analyses up to 2028. The model, however, is shown to have a substandard performance in terms of 2018 transit ridership validation. If the decline in transit ridership between 2014 and 2018 turns out be temporary, the model may be able to validate better to conditions more recent than 2018. If that is not the case, then staff may consider re-estimating and re-calibrating the model to more recent household survey data (i.e., 2017/2018 Regional Travel Survey) in order to improve its validation performance.

For internal reference, the locations of the 2014 and 2018 validation work may be found at the following LAN locations:

- Z:\ModelRuns\fy21\CGV2_4_2020_Amendment_Visualize2045_Xmittal\2018_Final\Summary\Highway_2018_Rev
- Z:\ModelRuns\fy21\CGV2_4_2020_Amendment_Visualize2045_Xmittal\2018_Final\Summary\Highway_2018_Rev\transit\2018_Transit_Validation_v08.xlsx
- Z:\ModelRuns\fy21\CGV2_4_2020_Amendment_Visualize2045_Xmittal\2018_Final\Summary\Highway_2018_Rev\Sta_Grp_EOBuffer_Map\Map_Validation_Results_by_Metrorail_StationGrps.mxd
- L:\modelRuns\fy19\Ver2.3.75_Visualize2045_CLRP_Xmittal_Model_Validation\Validation\2014_Validation_Transit\Metrorail_Ridership_by_Station_Group\Map_Validation_Results_by_Metrorail_StationGrps.mxd
- Z:\ModelRuns\fy21\CGV2_4_2020_Amendment_Visualize2045_Xmittal\2018_Final\Summary\2018_Bus_Ridership\ Transit_Ridership_RTDC_FY2018.xlsx

Note about drive mappings: L: (\\tms6\ateam); Z: (\\tms8\F)

Appendix A:

Table A-1 Control Totals 2014 and 2018 Demographic and Travel Statistics A-1
Table A-2 Estimated and Observed Year 2014 Daily VMT by Jurisdiction A-4
Table A-3 Estimated and Observed Year 2014 and 2018 Daily VMT by Facility Type A-4
Table A-4 Estimated and Observed 2014 Daily Vehicular Screenline Crossings A-5
Table A-5 Daily Directional 2014 Volume percent RMSE by Facility Type and Volume Group A-8

Figure A-1 Screenline crossing performance (Est./Obs. ratios) Map, 2014 .....A-6
Figure A-2 Screenline crossing performance (Est./Obs. ratios) Map, 2014 (Inset Maps) A-7

Table A-1 Control Totals 2014 and 2018 Demographic and Travel Statistics

		2014	2018	Difference	% Diff.
1	Households	2,584,936	2,704,396	119,460	4.6%
2	Jobs	3,982,930	4,112,001	129,071	3.2%
3	HH Population	6,851,243	7,165,132	313,889	4.6%
4	HH & GQ Population	6,983,525	7,298,214	314,689	4.5%
5	HH_Inc1	709,974	745,801	35,827	5.0%
6	HH_Inc2	800,949	838,366	37,417	4.7%
7	HH_Inc3	531,816	555,933	24,117	4.5%
8	HH_Inc4	542,228	564,326	22,098	4.1%
9	HH_All_Incs	2,584,966	2,704,426	119,460	4.6%
10	HH_Siz1	650,926	683,423	32,497	5.0%
11	HH_Siz2	780,830	816,600	35,770	4.6%
12	HH_Siz3	452,946	473,053	20,107	4.4%
13	HH_Siz4	700,265	731,350	31,085	4.4%
14	HH_ALL_Sizs	2,584,966	2,704,426	119,460	4.6%
15	HH_VA0	233,255	248,477	15,222	6.5%
16	HH_VA1	783,784	822,390	38,606	4.9%
17	HH_VA2	985,234	1,029,166	43,932	4.5%
18	HH_VA3+	582,692	604,394	21,702	3.7%
19	HH_All_VAs	2,584,966	2,704,426	119,460	4.6%
20	HBWAutoPsnXI	302,152	320,819	18,667	6.2%
21	HBSAutoPsnXI	67,719	72,065	4,346	6.4%
22	HBOAutoPsnXI	228,528	242,911	14,383	6.3%
23	NHWAutoPsnXI	31,158	32,782	1,624	5.2%
24	NHOAutoPsnXI	60,590	63,748	3,158	5.2%
25	AutoPsnXI	690,146	732,324	42,178	6.1%
26	HBWAutoPsnIX	190,556	200,882	10,326	5.4%
27	HBSAutoPsnIX	68,958	73,592	4,634	6.7%
28	HBOAutoPsnIX	323,821	344,000	20,179	6.2%
29	NHWAutoPsnIX	31,153	32,776	1,623	5.2%
30	NHOAutoPsnIX	60,582	63,738	3,156	5.2%
31	AutoPsnIX	675,070	714,988	39,918	5.9%
32	NonMotr_HBW Trips	150,650	166,425	15,775	10.5%
33	NonMotr_HBS_Trips	320,722	358,920	38,198	11.9%
34	NonMotr_HBO_Trips	909,301	988,759	79,458	8.7%
35	NonMotr_NHW_Trips	476,505	499,994	23,489	4.9%
36	NonMotr_NHO_Trips	371,157	389,501	18,344	4.9%
37	NonMotr_ALL_Trips	2,228,335	2,403,599	175,264	7.9%

Table A-1: Continued

		2014	2018	Difference	% Diff.
38	Ext_HBWAdr	428,438	453,642	25,204	5.9%
39	Ext_HBSAdr	83,152	88,635	5,483	6.6%
40	Ext_HBOAdr	342,858	364,331	21,473	6.3%
41	Ext_NHWAdr	48,548	51,085	2,537	5.2%
42	Ext_NHOAdr	94,569	99,501	4,932	5.2%
43	Ext_ALLAdr	997,566	1,057,194	59,628	6.0%
44	Ext_ComVeh	78,407	83,606	5,199	6.6%
45	Ext_Medium_Trk	23,733	25,021	1,288	5.4%
46	Ext_Heavy_Trk	28,541	30,178	1,637	5.7%
47	MC_HBWPsn	3,916,186	4,092,322	176,136	4.5%
48	MC_HBSPsn	3,117,483	3,219,914	102,431	3.3%
49	MC_HBOPsn	7,221,594	7,503,810	282,216	3.9%
50	MC_NHWPsn	1,632,901	1,691,969	59,068	3.6%
51	MC_NHOPsn	3,288,896	3,413,638	124,742	3.8%
52	MC_ALLPsn	19,177,060	19,921,654	744,594	3.9%
53	MC_HBW_Trn	779,694	809,944	30,250	3.9%
54	MC_HBS_Trn	26,427	26,120	-307	-1.2%
55	MC_HBO_Trn	205,178	212,269	7,091	3.5%
56	MC_NHW_Trn	90,163	88,068	-2,095	-2.3%
57	MC_NHO_Trn	36,002	32,264	-3,738	-10.4%
58	**MC_All_Trn**	**1,137,465**	**1,168,664**	**31,199**	**2.7%**
59	HBW_TransitPct	19.9	19.8	-0.1	-0.6%
60	HBS_TransitPct	0.9	0.8	0.0	-4.7%
61	HBO_TransitPct	2.8	2.8	0.0	-0.4%
62	NHW_TransitPct	5.5	5.2	-0.3	-5.6%
63	NHO_TransitPct	1.1	1.0	-0.1	-12.8%
64	ALL_TransitPct	5.9	5.9	-0.1	-1.0%
65	MC_HBW_AutoPsn	3,136,492	3,282,379	145,887	4.7%
66	MC_HBS_AutoPsn	3,091,056	3,193,794	102,738	3.3%
67	MC_HBO_AutoPsn	7,016,416	7,291,542	275,126	3.9%
68	MC_NHW_AutoPsn	1,542,737	1,603,902	61,165	4.0%
69	MC_NHO_AutoPsn	3,252,893	3,381,374	128,481	3.9%
70	MC_ALL_AutoPsn	18,039,595	18,752,990	713,395	4.0%
71	Int_HBWAutoDrv	2,860,228	2,989,036	128,808	4.5%
72	Int_HBSAutoDrv	2,038,839	2,102,876	64,037	3.1%
73	Int_HBOAutoDrv	4,469,372	4,639,509	170,137	3.8%
74	Int_NHWAutoDrv	1,291,272	1,333,820	42,548	3.3%
75	Int_NHOAutoDrv	2,184,483	2,257,076	72,593	3.3%
76	Int_ALLAutoDrv	12,844,193	13,322,316	478,123	3.7%

Table A-1: Continued

		2014	2018	Difference	% Diff.
77	HBW_OCC	1.1	1.1	0.0	0.0%
78	HBS_OCC	1.5	1.5	0.0	0.0%
79	HBO_OCC	1.6	1.6	0.0	0.0%
80	NHW_OCC	1.2	1.2	0.0	0.8%
81	NHO_OCC	1.5	1.5	0.0	0.7%
82	ALL_OCC	1.4	1.4	0.0	0.7%
83	Int_CommVeh	1,092,089	1,129,972	37,883	3.5%
84	Int_Med_Truck	448,746	464,206	15,460	3.4%
85	Int_Hvy_Truck	106,298	109,055	2,757	2.6%
86	ALL_HBWAdr	3,288,666	3,442,678	154,012	4.7%
87	ALL_HBSAdr	2,121,991	2,191,511	69,520	3.3%
88	ALL_HBOAdr	4,812,230	5,003,840	191,610	4.0%
89	ALL_NHWAdr	1,339,820	1,384,905	45,085	3.4%
90	ALL_NHOAdr	2,279,052	2,356,577	77,525	3.4%
91	ALL_ALLAdr_MC	13,841,759	14,379,510	537,751	3.9%
92	ALL_CV	1,170,496	1,213,578	43,082	3.7%
93	ALL_Mtk	472,480	489,227	16,747	3.5%
94	ALL_Htk	134,838	139,233	4,395	3.3%
95	THRU_Truck	34,149	36,545	2,396	7.0%
96	THRU_Auto&CV	43,198	45,819	2,621	6.1%
97	Taxi_AutoDrv	129,676	133,877	4,201	3.2%
98	Visitor/Tourist Adr	263,707	272,272	8,565	3.2%
99	School AutroDrv	303,248	317,298	14,050	4.6%
100	Final_Medium_Truck	525,397	539,968	14,571	2.8%
101	Final_Heavy_Truck	145,344	148,232	2,888	2.0%
102	AirPax_AutoDrv	67,597	72,217	4,620	6.8%
103	Final_Comm_Veh	1,362,066	1,401,309	39,243	2.9%
104	All_Veh_Trips_MC	16,716,141	17,347,047	630,906	3.8%
105	TRIPS_per_HH	7.43	7.38	-0.05	-0.7%
106	TRIPS_per_Pop	2.75	2.73	-0.02	-0.7%
107	**Total_VMT**	**159,691,204**	**166,758,801**	**7,067,597**	**4.4%**
108	VMTperCapita	22.87	22.85	-0.02	-0.1%
109	VMTperHH	61.78	61.66	-0.12	-0.2%
110	VMTperTrip	9.55	9.61	0.06	0.6%
111	**Total_VHD**	**1,046,550**	**1,186,577**	**140,027**	**13.4%**

Table A-2 Estimated and Observed Year 2014 and 2018 Daily VMT by Jurisdiction

Jur	*Observed*		*Est. Version 2.4*		*Est/Obs ratio*	
	2014	**2018**	**2014**	**2018**	**2014**	**2018**
District of Columbia	7,922,357	8,410,547	7,910,374	8,160,132	1.00	0.97
Montgomery County	19,757,260	20,844,658	20,053,933	20,794,263	1.02	1.00
Prince George's County	23,646,575	25,320,822	21,816,275	22,659,440	0.92	0.89
Arlington County	4,046,638	4,115,600	4,004,099	4,109,213	0.99	1.00
City of Alexandria	2,016,133	1,851,663	2,050,969	2,140,652	1.02	1.16
Fairfax County	26,663,007	28,284,350	26,910,009	28,111,768	1.01	0.99
Loudoun County	6,623,699	7,342,782	6,681,249	7,449,610	1.01	1.01
Prince William County	9,425,332	10,300,396	9,443,949	10,162,646	1.00	0.99
Frederick County	7,798,767	8,391,370	8,716,957	9,066,689	1.12	1.08
Charles County	3,276,575	3,426,164	3,065,323	3,237,058	0.94	0.94
TPB Planning Area	***111,176,343***	***118,288,351***	***110,653,137***	***115,891,471***	***1.00***	***0.98***
Stafford County	4,006,798	4,358,421	4,472,254	4,716,562	1.12	1.08
Calvert County	1,987,808	2,019,452	1,637,084	1,652,935	0.82	0.82
Howard County	10,546,027	11,526,986	10,963,782	11,426,554	1.04	0.99
Anne Arundel County	15,493,973	16,518,082	15,653,162	16,058,594	1.01	0.97
Carrol County	3,290,959	3,408,904	4,114,971	4,381,657	1.25	1.29
St. Mary's County	2,246,712	2,367,534	2,156,753	2,134,630	0.96	0.90
King George County	871,306	932,207	794,934	835,846	0.91	0.90
City of Fredericksburg	929,927	990,749	857,116	894,269	0.92	0.90
Spotsylvania County ŧ	3,442,058	3,774,287	2,296,448	2,376,420	0.67	0.63
Fauquier County ‡	3,439,861	3,686,566	3,620,994	3,802,460	1.05	1.03
Clarke County	810,485	827,733	1,024,839	1,082,114	1.26	1.31
Jefferson County	1,177,470	1,069,310	1,445,730	1,505,291	1.23	1.41
Non-TPB Member Area	***48,243,384***	***51,480,231***	***49,038,067***	***50,867,332***	***1.02***	***0.99***
Modeled Area Total:	***159,419,727***	***169,768,582***	***159,691,204***	***166,758,803***	***1.00***	***0.98***

Notes:

* The observed VMT data is from HPMS.

ŧ Observed VMT is for the entire Spotsylvania County while Estimated is for northern portion of county only.

‡ Fauquier County urbanized area is part of TPB Planning Area. Fauquier is not included as a TPB member in this summary as the HPMS VMT data is only available for the whole county.

§ **FDOT standard** for estimated-over-observed VMT Areawide is ±5% (acceptable) and ±2% (preferable).

Table A-3 Estimated and Observed Year 2014 and 2018 Daily VMT by Facility Type

	E/O Ratio		**Standard ŧ**	
FTYPE	**2014**	**2018**	**Acceptable**	**Preferable**
Freeway	1.06	1.05	±7%	±6%
Major Arterial	1.08	1.07	±15%	±10%
Minor Arterial	1.10	1.09	±15%	±10%
Collector	0.74	0.74	±25%	±20%
Expressway	0.91	0.89	±15%	±10%
Total	**1.05**	**1.03**	***±5%***	***±2%***

* Based on 6,688 directional links with daily traffic counts in 2014

* Based on 7, 889 directional links with daily traffic counts in 2018

ŧ **FDOT standards** for VMT by facility type, which are also cited in the FHWA and VDOT manuals

Table A-4 Estimated and Observed 2014 and 2018 Daily Vehicular Screenline Crossings

	Observed		*Est. Version 2.4*		*Est/Obs ratio*		
Screenline	**2014**	**2018**	**2014**	**2018**	**2014**	**2018**	**Standard ***
1	189,600	735,984	139,704	708,101	0.74	0.96	±10%
2	363,864	806,349	431,647	920,454	1.19	1.14	±10%
3	242,200	882,990	221,378	861,443	0.91	0.98	±10%
4	562,162	814,206	655,504	1,035,244	1.17	1.27	±10%
5	454,700	1,155,304	391,099	1,149,003	0.86	0.99	±10%
6	1,207,388	1,814,934	1,214,572	1,733,978	1.01	0.96	±10%
7	561,400	1,306,634	545,257	1,229,064	0.97	0.94	±10%
8	1,053,952	1,819,850	1,087,083	1,808,035	1.03	0.99	±10%
9	328,000	988,678	253,129	1,022,366	0.77	1.03	±10%
10	125,000	560,808	117,685	568,891	0.94	1.01	±10%
11	N/A	365,044	N/A	325,871	N/A	0.89	±10%
12	399,264	556,200	374,359	590,432	0.94	1.06	±10%
13	271,530	476,770	306,667	518,282	1.13	1.09	±10%
14	242,602	349,176	253,854	305,742	1.05	0.88	±10%
15	323,004	391,476	269,751	316,926	0.84	0.81	±10%
16	157,428	255,272	127,015	193,340	0.81	0.76	±10%
17	133,300	562,714	126,491	575,447	0.95	1.02	±10%
18	438,500	756,980	389,893	690,224	0.89	0.91	±10%
19	346,150	781,184	269,700	647,331	0.78	0.83	±10%
20	**905,074**	**1,007,058**	**891,909**	**920,725**	**0.99**	**0.91**	**±10%**
22	826,658	1,958,201	813,702	1,689,163	0.98	0.86	±10%
23	38,446	245,118	48,943	227,861	1.27	0.93	±20%
24	359,688	545,712	313,126	473,524	0.87	0.87	±10%
25	100,842	122,120	123,985	161,966	1.23	1.33	±10%
26	38,998	383,406	65,700	349,397	1.68	0.91	±20%
27	137,466	372,748	178,893	389,825	1.30	1.05	±10%
28	214,260	239,356	164,995	204,263	0.77	0.85	±10%
31	64,798	87,040	141,007	187,487	2.18	2.15	±10%
32	37,000	83,000	76,390	145,524	2.06	1.75	±20%
33	47,000	288,500	49,301	345,841	1.05	1.20	±20%
34	101,990	129,264	114,430	158,312	1.12	1.22	±10%
35	725,446	1,028,266	730,602	979,480	1.01	0.95	±10%
36	25,412	52,256	41,194	92,598	1.62	1.77	±20%
37	23,500	30,182	45,295	54,442	1.93	1.80	±20%
38	163,600	339,218	117,899	255,188	0.72	0.75	±10%
Total:	**11,210,222**	**22,291,998**	**11,092,159**	**21,835,768**	**0.99**	**0.98**	**N/A**

Note:

* FDOT standard for screenline volumes is used (±10% for screenline volumes larger than 50k and ±20% for screenline volumes smaller than 50k). VDOT standard is much more stringent.

Figure A-1 Screenline crossing performance (Est./Obs. ratios) Map, Years 2014 and 2018

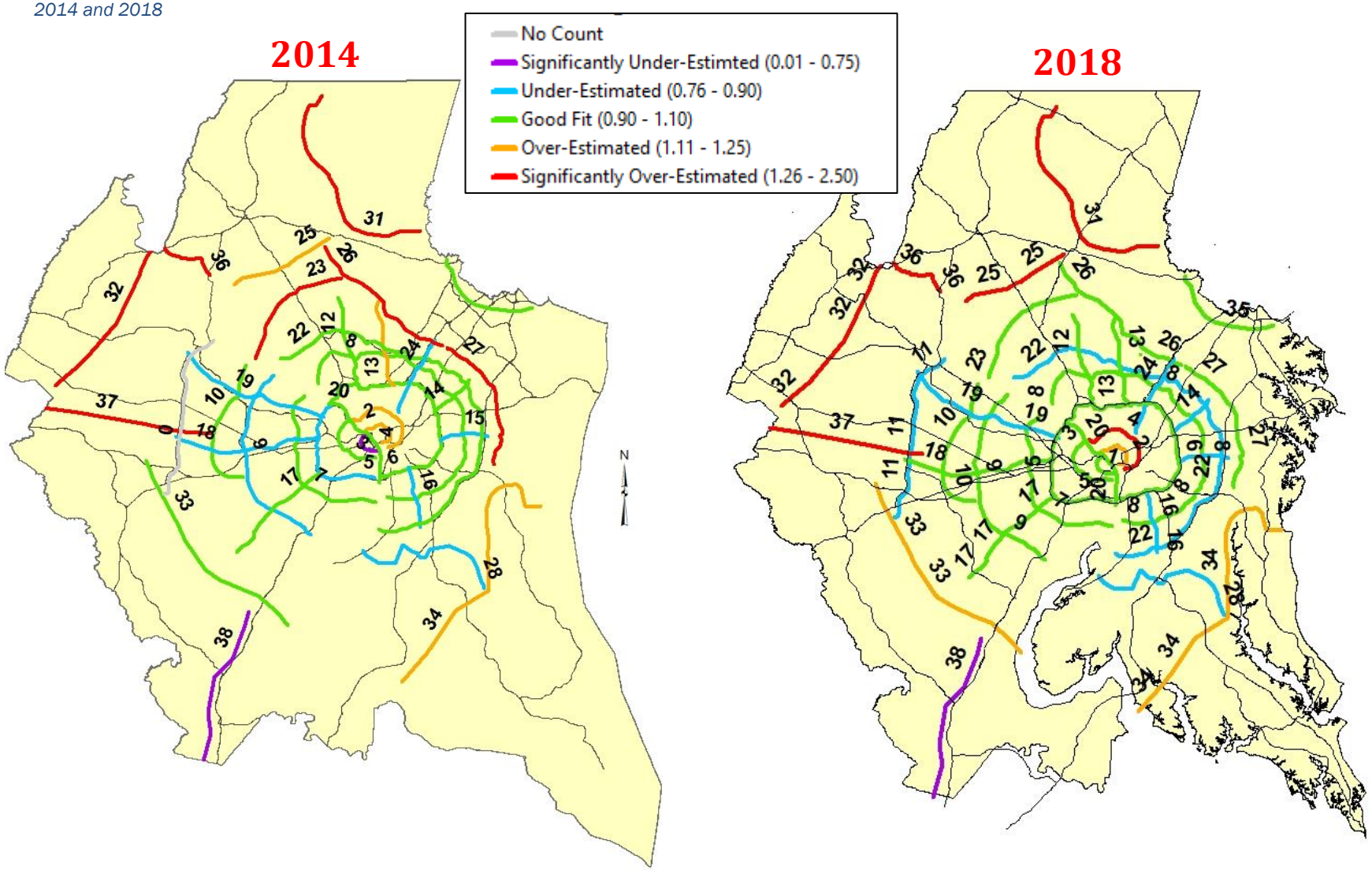
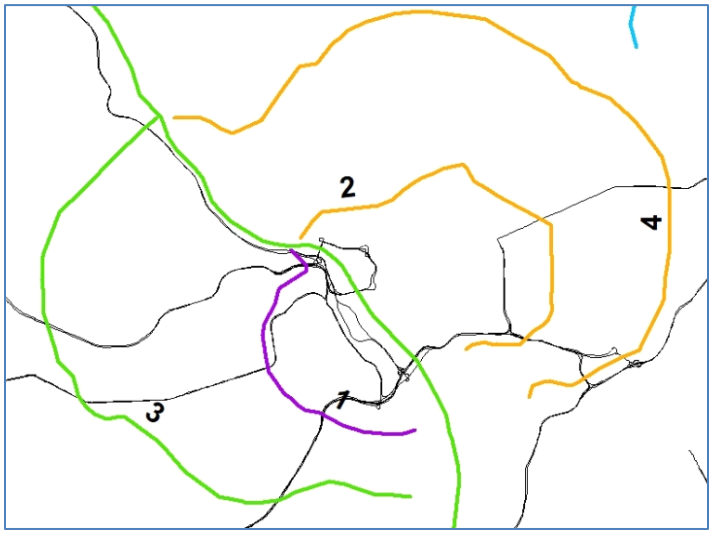


Figure A-2 Screenline crossing performance (Est./Obs. ratios) Map, Years 2014 and 2018 (Inset Maps)

2014



2018

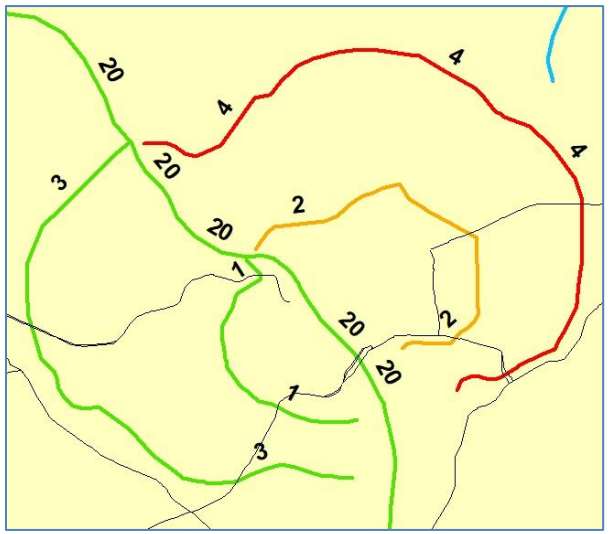


Table A-5 Daily Directional 2014 and 2018 Volume percent RMSE by Facility Type and Volume Group

	2014		2018	
Facility Type	**Links w/ Counts**	**% RMSE**	**Links w/ Counts**	**% RMSE**
Freeway	517	22.17%	689	24.38%
Major Arterial	1,867	36.94%	2,067	38.96%
Minor Arterial	2,939	49.05%	3,337	48.52%
Collector	1,139	74.81%	1,549	76.67%
Expressway	224	34.12%	245	36.14%
Ramp	2	11.58%	2	4.11%
Total:	**6,688**	**42.01%**	**7,889**	**44.22%**

Daily Directional Volume % RMSE by Volume Group*

	2014		2018		
Volume Range	**Links w/ Counts**	**% RMSE**	**Links w/ Counts**	**% RMSE**	**Standard ǂ**
Less than 5,000	2,045	103.72%	2,460	112.67%	100%
5,000-9,999	1,699	53.03%	1,947	58.28%	45%
10,000-14,999	1,049	42.65%	1,166	42.31%	35%
15,000-19,999	583	33.96%	743	33.53%	30%
20,000-29,999	622	29.49%	734	31.06%	27%
30,000-49,999	329	27.11%	392	27.92%	25%
50,000-59,999	94	20.58%	116	22.71%	20%
Greater than 60,000	267	19.57%	331	21.28%	19%
Total:	**6,688**	**42.01%**	**7,889**	**44.22%**	**40%**

Notes:

* Based on 7, 887 directional links with daily traffic counts

ǂ VDOT standard for percent RMSE areawide; FDOT areawide standard is

ǂ VDOT standard for percent RMSE by volume group

Appendix B:

Table B-1 2014 and 2018 Observed and Estimated Average Weekday Transit Ridership by Mode in Modeled Area B-1

Table B-2 2014 and 2018 Observed and Simulated Annual Average Weekday Metrorail Ridership by Station Group B-1

Table B-3 2018 Bus Ridership by operator – Annual Average Weekday Ridership B-5

Figure B-1 MWCOG / TPB Definition of Metrorail Station Groups B-2

Figure B-2 2018 Metrorail ridership E/O ratio by Station Groups B-3

Figure B-3 Annual Unlinked Trips by Local BUS/STREECAR OPEATORS B-4

Table B-1 2014 and 2018 Observed and Estimated Average Weekday Transit Ridership by Mode in Modeled Area

	2014			2018		
	Observed ("O")	**Estimated ("E")**	**E/O ratio**	**Observed ("O")**	**Estimated ("E")**	**E/O ratio**
Metrorail	737,679	744,835	1.01	605,909	787,671	1.30
Commuter Rail	36,482	27,779	0.76	36,836	28,111	0.76
MARC	20,171	17,298	0.86	19,306	18,666	0.97
VRE	16,311	10,481	0.64	17,530	9,445	0.54
All Bus*	648,083	705,146	1.09	575,642	689,496	1.20
Total:	**1,422,244**	**1,477,759**	**1.04**	**1,218,387**	**1,505,278**	1.24

** The observed bus ridership includes I-X and X-I bus trips made by residents/non-residents of the TPB modeled area while the Ver. 2.4 Model simulates only resident I-I trips. However, as shown in the Table B-3, 2018 Bus ridership by operator, the I-X and X-I bus trips, which likely use commuter buses, accounted for only a very small fraction of total bus ridership (0.63 %).*

Table B- 2 2014 and 2018 Observed and Simulated Annual Average Weekday Metrorail Ridership by Station Group

Station Group	Year 2014			Year 2018			Standard*
	Obs	Est	Ratio (E/O)	Obs	Est	Ratio (E/O)	
1. Red Line - "A" route MD outside Beltway	32,231	33,833	1.05	26,664	38,887	1.46	±20%
2. Red Line - "A" route MD inside Beltway	26,483	32,511	1.23	21,583	33,900	1.57	±20%
3. Red Line - "A" route DC non-core	24,995	24,664	0.99	20,577	26,053	1.27	±20%
4. Red Line - DC core	149,787	111,204	0.74	127,659	118,124	0.93	±20%
5. Red Line - "B" route DC non-core	26,532	36,348	1.37	21,519	33,957	1.58	±20%
6. Red Line - "B" route MD	26,134	23,179	0.89	21,244	34,506	1.62	±20%
7. Green Line - "E" route MD	20,273	19,858	0.98	16,020	20,235	1.26	±20%
8. Green Line - "E" route DC non-core	27,131	21,054	0.78	21,396	28,261	1.32	±20%
9. Green Line - DC core	38,906	44,634	1.15	36,365	48,212	1.33	±20%
10. Green Line - "F" route DC non-core	24,526	27,717	1.13	21,840	31,034	1.42	±20%
11. Green Line - "F" route MD	20,518	17,743	0.86	16,184	21,463	1.33	±20%
12. Blue/Yellow Line - VA Fairfax	19,863	20,615	1.04	14,964	22,610	1.51	±25%
13. Blue/Yellow Line - VA Alexandria	15,720	13,566	0.86	12,592	16,667	1.32	±25%
14. Blue/Yellow Line - VA Core	51,911	59,401	1.14	42,396	44,286	1.04	±20%
15. Orange Line - VA Fairfax	28,891	14,617	0.51	14,855	21,331	1.44	±20%
16. Orange Line - VA Arlington non-core	31,877	59,784	1.88	27,054	51,606	1.91	±20%
17. Orange/Blue Line - VA/DC core	109,967	102,391	0.93	92,125	120,648	1.31	±20%
18. Orange/Blue Line - DC non-core	13,117	12,532	0.96	10,774	16,086	1.49	±25%
19. Orange Line - DC/MD	17,347	15,278	0.88	12,275	14,955	1.22	±25%
20. Blue Line - DC/MD	15,595	17,582	1.13	12,604	18,556	1.47	±25%
21. Silver Line - Phase I & Phase 2	15,875	36,328	2.29	15,219	26,300	1.73	±25%
Total	737,679	744,835	1.01	605,909	787,671	1.30	N/A

Note: * FDOT Standard for transit ridership >20,000 passengers per day is ±20% (acceptable) and ±15% (preferable), and is ±25% (acceptable) and ±20% (preferable) for 10k-20k passengers per day

Figure B- 3 MWCOG / TPB Definition of Metrorail Station Groups

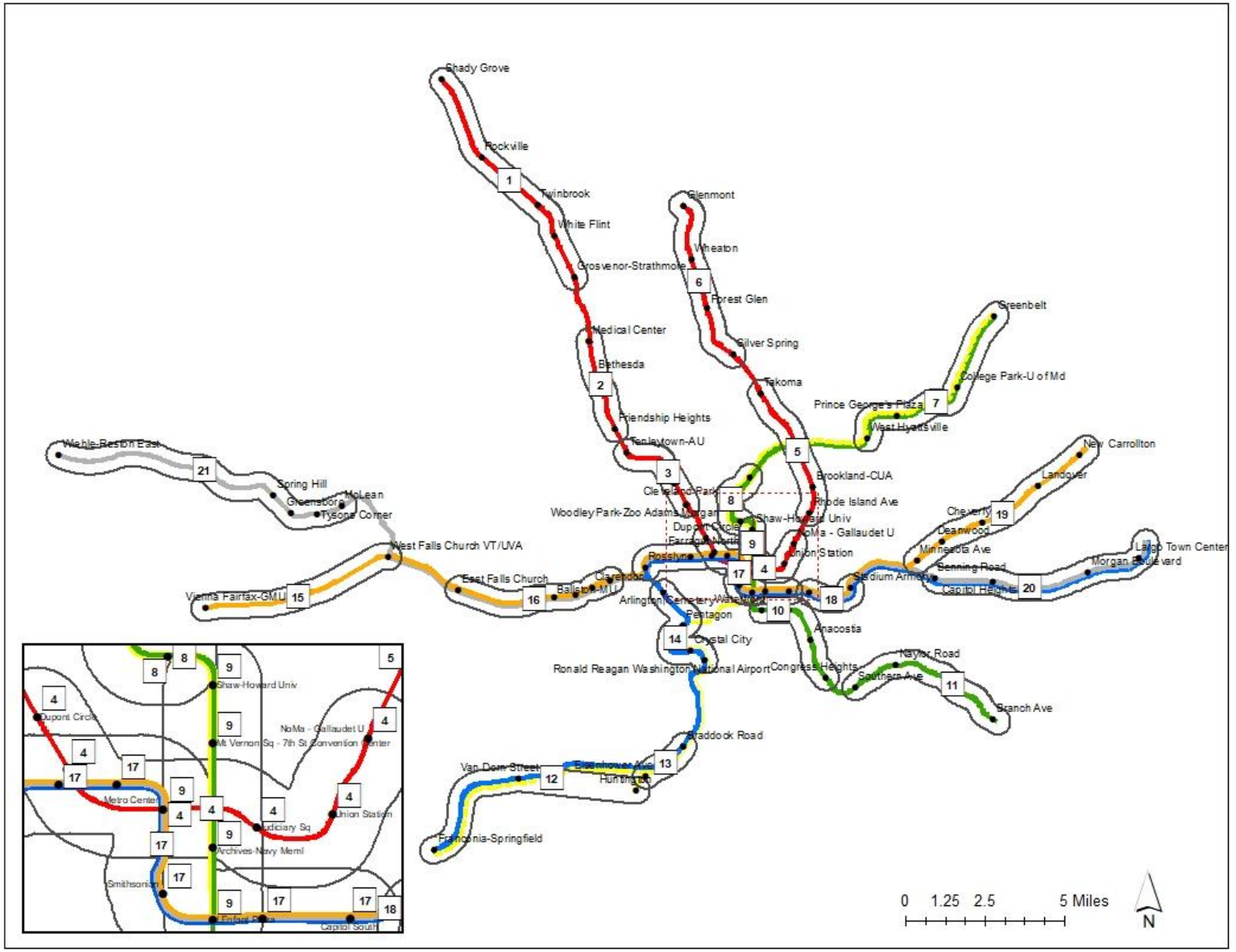
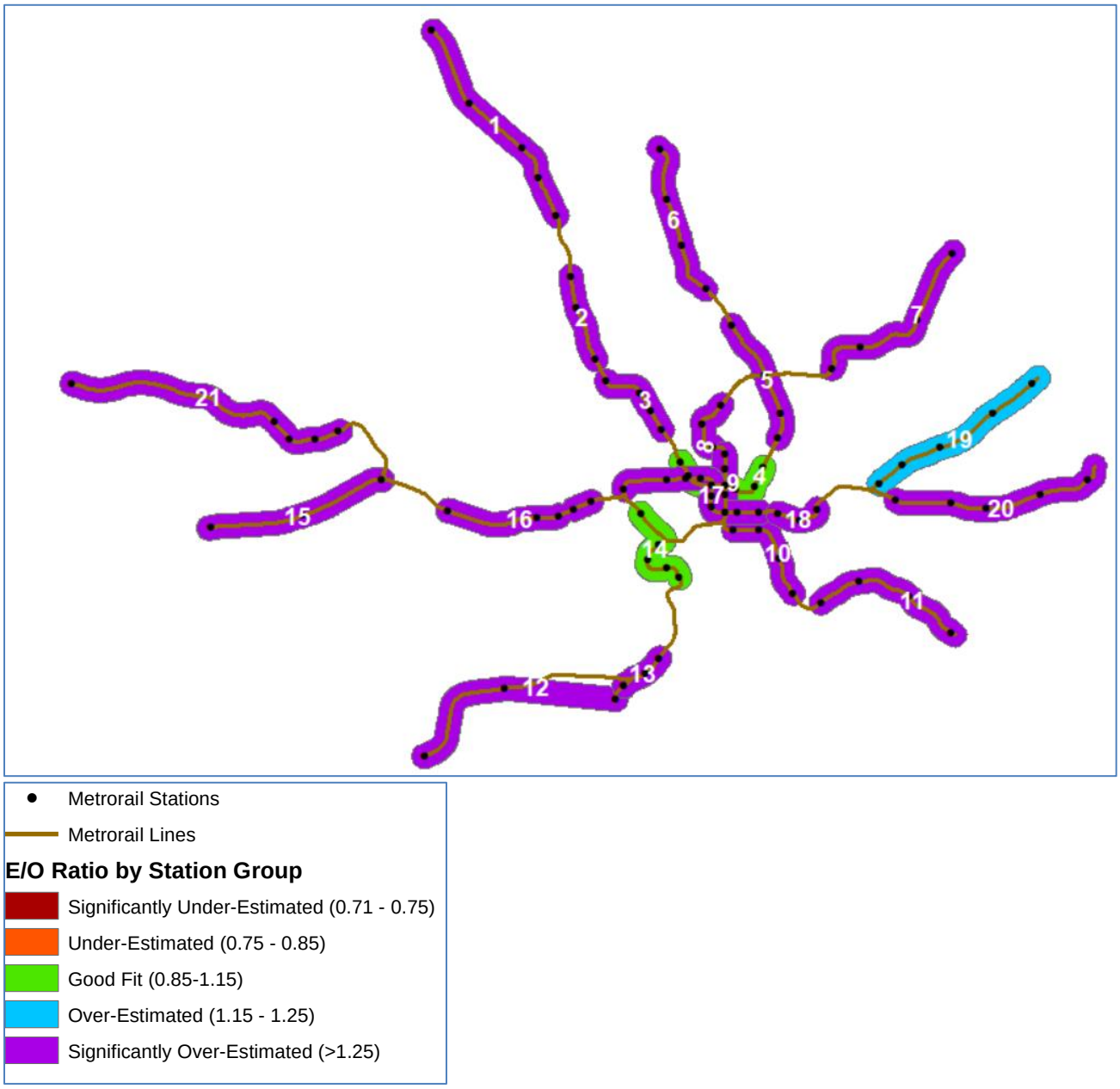


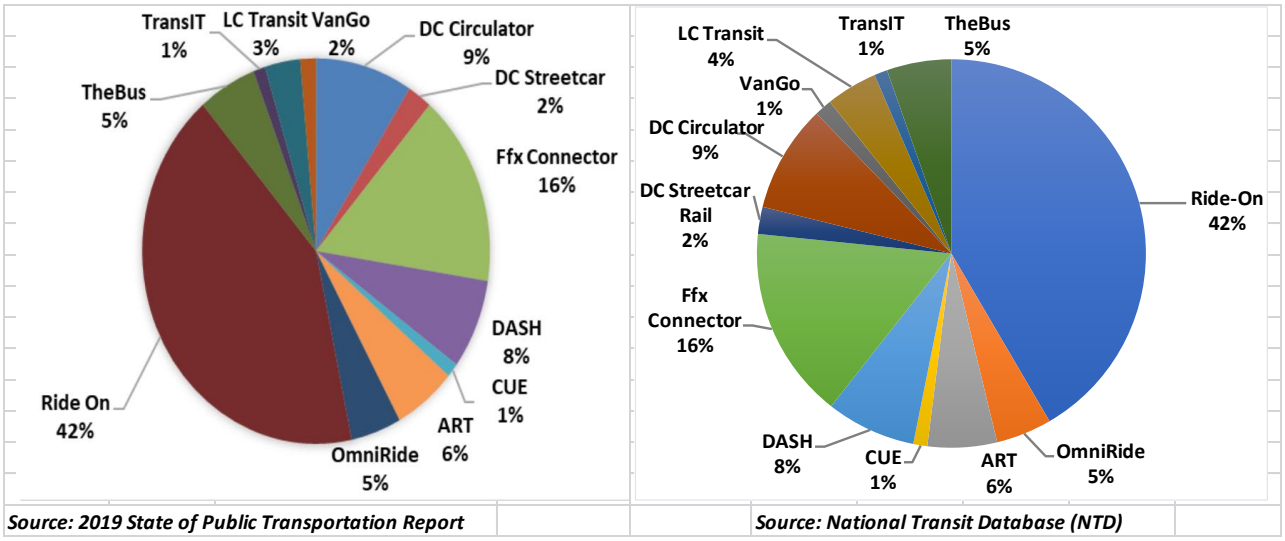
Figure B-4 2018 Metrorail ridership E/O ratio by Station Groups



Year 2014 and 2018 Observed Transit Ridership Data Sources

- Year 2014 Metrorail ridership came from WMATA Crystal Reports System (with adjustments made to Silver Line stations). For 2014 , the 2015 Silver Line station counts were used for the Silver Line was opened in July 2014. More discussions on the year 2014 MARC and VRE ridership targets can be found in a prior technical memorandum.[19] The 2014 regional bus ridership data was from the data that Cambridge Systematics developed in support of the Ver. 2.5 Model development.[20]
- The 2018 Internal-to-Internal (I-I) Metrorail/VRE/MARC boardings are developed by BMG from the Transit On-Board Survey (TOBS data). [21]
- Year 2018 observed bus ridership data was developed using the National Transit Database (NTD). The following procedures were used to develop and compare the 2018 bus ridership data with other independent sources:
    - ➢ Collected the 2018 average weekday bus unlinked trips and annual unlinked trips from the NTD;
    - ➢ Created a pie chart that breaks down local bus/streetcar trips by operator, using the 2018 annual unlinked trips data from NTD;
    - ➢ Replicated the pie chart that was developed for the State of Public Transportation Report [22], as shown in Figure B-3.

Figure B-5 ANNUAL Unlinked Trips by Local BUS/STREECAR OPEATORS



Source: 2019 State of Public Transportation Report | *Source: National Transit Database (NTD)*

- ➢ Developed the 2018 annual average weekday bus ridership data by operator independently from the Regional Transportation Data Clearinghouse (RTDC);

[19] Feng Xie to Files, "Updating the Calibration and Validation Targets for Commuter Rail in TPB's Version 2.3 Travel Demand Model", Memorandum, October 21, 2019.
[20] Cambridge Systematics with Gallop Corporation, "FY17 Task Orders Final Report", June 2017
[21] The observed data for Metrorail/MARC/VRE may be subject to change as BMG has not finalized their results yet.
[22] Eric Randall, "2019 State of Public Transportation Report", TPB Technical Committee, July 10, 2020. https://www.mwcog.org/assets/1/28/07102020_-_Item_8_-_Presentation_-_2019_State_of_Public_Transportation_Report.pdf

- Compared the bus ridership data from the RTDC with the data from the NTD, as shown in Table B-3, the data compared well with each other (e.g., the regional totals are 593,521 vs 575,642, with 3% difference. In Table B-3, cells are color-coded based on their sources and descriptions shown at the bottom of the Table.

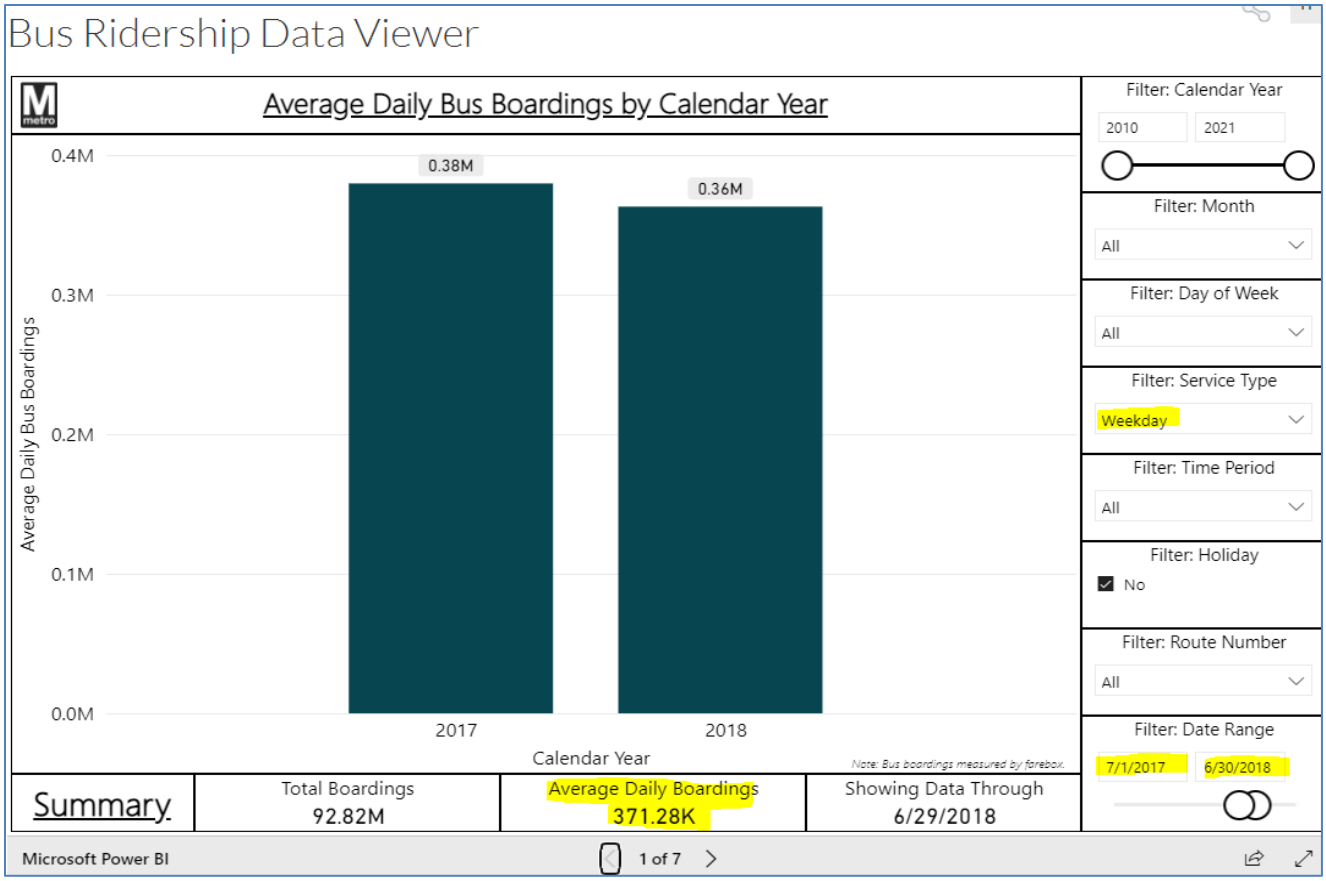
Table B- 3 2018 Bus Ridership by operator – Annual Average Weekday Ridership

	RTDC	NTD	Ratio
Operator	**Ann_Avg_Weekday**	**Ann_Avg_weekday**	**NTD/RTDC)**
ART Bus	11,131	10,379	0.93
Dash	13,162	12,806	0.97
DC Circulator	16,885	17,945	1.06
Fairfax City Bus	1,208	2,161	1.79
Fairfax Connector	28,751	28,250	0.98
Loudoun County Commuter Bus	9,234	6,672	0.63
Loudoun County Local Bus	1,433		
Metro Bus	403,458	371,280	0.92
MTA	16,050	23,761	1.48
Omni-Ride	5,128	11,419	2.23
PG TheBus	10,804	14,640	1.36
Ride On Bus	71,832	71,432	0.99
TransIT	1,971	2,180	1.11
VANGO	2,474	2,717	1.10
Grand Total	**593,521**	**575,642**	**0.97**

Source: https://www.wmata.com/initiatives/ridership-portal/Bus-Data-Portal.cfm (Screenshot shown below)

Source: https://www.mwcog.org/assets/1/28/07102020_-_Item_8_-_Presentation_-_2019_State_of_Public_Transportation_Report.pdf (23,761=6,011,495/253)
This is not an apple-to-apple comparison as 23,761 includes all commuter bus trips, not just MTA commuter bus.

Source:FY 2019 VANGO bus ridership from RTDC is used for data is NOT available for FY 2018.


Bus Ridership Data Viewer
Average Daily Bus Boardings by Calendar Year
0.4M
0.3M
0.2M
0.1M
0.0M
Average Daily Bus Boardings
0.38M
0.36M
2017
2018
Calendar Year
Note: Bus boardings measured by farebox.
Summary
Total Boardings
92.82M
Average Daily Boardings
371.28K
Showing Data Through
6/29/2018
Filter: Calendar Year
2010
2021
Filter: Month
All
Filter: Day of Week
All
Filter: Service Type
Weekday
Filter: Time Period
All
Filter: Holiday
No
Filter: Route Number
All
Filter: Date Range
7/1/2017
6/30/2018
Microsoft Power BI
1 of 7