Michael Baker INTERNATIONAL

We Make a Difference

Technical Memorandum

To: File

From: Michael Baker International

Date: November 9, 2018

Re: Hampton Roads Transportation Planning Organization (HRTPO) Regional Connectors Study

Task 2 FINAL Memo – Evaluate Regional Travel Demand Model

Current Hampton Roads Modeling Process

The Hampton Roads regional travel demand model represents an advanced practice four-step forecasting model to support air quality analysis and project planning in the Hampton Roads region.[1] Michael Baker International (MBI) gathered available files, data, and documentation describing the Hampton Roads model. Files and data describing the travel model were obtained from the Virginia Department of Transportation (VDOT) and directly from HRTPO. Documentation was obtained from VDOT's website and includes the following issued from the Transportation & Mobility Planning Division:

- Hampton Roads Model Methodology Report (Ver. 1.0), December 2013
- Hampton Roads Model User's Guide (Ver. 1.0), August 2013
- Hampton Roads Model Release Notes (Ver. 1.2), September 2014

MBI initially submitted a formal request to VDOT's Transportation & Mobility Planning Division for the most contemporary Hampton Roads model sets and supporting data. VDOT responded to the request and provided two (2) model sets; one representing 2009 (base year) and the other year 2040. The current model version release by the Virginia Department of Transportation (VDOT) is '1.2'. Version 1.0 was released in December 2013 and was subsequently updated in June 2014 to reflect revisions to toll facility coding for future year networks, capacity and free flow speed on some links, and changes to the external travel model. Version 1.2, released in September 2014, incorporates these revisions; but reflects the elimination of the Route 460 expressway in future year networks.

MODEL STRUCTURE/PROCEDURES

[1] Hampton Roads Model Methodology Report (Ver. 1.0), AECOM, December 2013.

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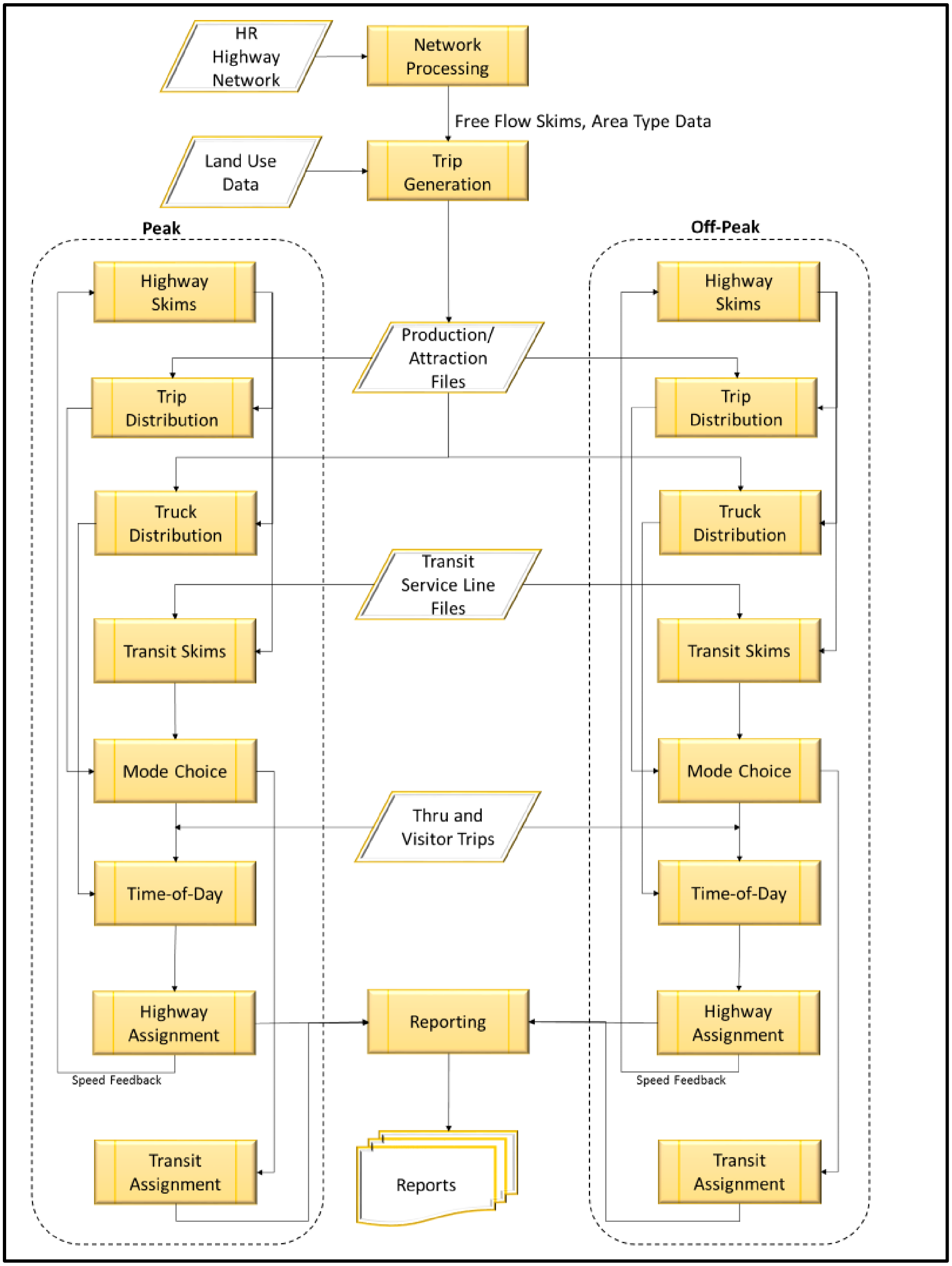
MBI has acquired all HRTPO travel model files and available documentation and below summarizes the model structure, modeling procedures, software, and data flows associated with the model. The HRTPO travel model estimates automobile (single-occupant, carpool) and heavy truck trips to the highway network and bus, light rail, and fringe parking trips to the transit network producing time-of-day estimates of average weekday travel in the Hampton Roads region. Travel estimation for the thirteen jurisdiction HRTPO travel model region is based on a "four-step", trip-based, transportation model formulation developed by using CUBE/Voyager as the development platform[2]. The four steps include trip generation, trip distribution, mode choice and trip assignment. Time-of-day estimation in the HRTPO model manifests itself through two (2) separate components for passenger vehicles and light trucks: one for "peak" and one for "off-peak" travel – determining trip distribution and mode choice. Highway trip assignment is further divided into two (2) periods for the peak component, 6-9AM and 3-6PM; and two (2) periods for the off-peak component, 9AM-3PM and 6PM-6AM. A separate four-step model estimates heavy trucks using the same time-of-day partitioning as the previously described passenger vehicle and light truck model. Figure 1 below illustrates the relationship between these steps and the associated data flows.

The HRTPO travel model provides estimates for 2009 and 2040 based on 2009 household and employment data and 2040 land use forecasts provided by HRTPO. The model was validated to 2009 data. The CUBE Catalog and Application environment facilitates model execution and maintenance. A brief overview of the modeling process follows. Reference documentation cited above provide a more in-depth discussion.

<u>Trip generation</u> estimates person trip productions and attractions for six (6) travel purposes: home-based work (HBW), home-based shopping (HBS), home-based social/recreation (HBSR), home-based other (HBO), non-home-based work (NHBW), and non-home-based other (NHBO). These purposes are then combined into four (4) purposes moving forward to the next steps in the model: HBW, HBS, HBO (HBO+HBSR), and NHB (NHBW+NHBO). The person trip productions are estimated by applying household trip rates to the number of households in a traffic analysis zone (TAZ) stratified by household size and auto ownership. Person trip attractions are estimated based on a linear relationship which is a function of employment (retail, non-retail) and number of households in a TAZ; and the accessibility of any given TAZ[3]. The magnitude of heavy truck trips is estimated separately and are based on a linear relationship which is a function of employment (industrial, retail, office) and number of households in a TAZ as well as development density. Another available adjustment to the magnitude of truck trips generated is through the designation of "truck zones". TAZs with this designation have their trip ends factored to account for truck generation rates likely to be higher than the regional average. Resulting productions and attractions for persons and trucks are then separated into "peak" and "off-peak" for input into the two separate time-of-day components of the model.

[2] Citilabs software, version 5.1.3.
[3] Accessibility variable used for calculation of HBW attractions only.

Figure 1: HRTPO Modeling Process



Trip distribution employs gravity models calibrated to distribute person trips and heavy truck trips by time-of-day. Impedances used by the gravity models are a weighted sum of highway travel time and tolls to reflect out of-pocket trip cost. Travel time includes running time, terminal time, and penalties for major river crossings. Toll costs are included for all non-work trips and included optionally for work related trips. A speed feedback process updates the time component of impedance based on the change in travel speeds in response to congestion, as a result of highway trip assignment towards the end of the modeling process. Each person trip purpose and heavy trucks use separate gravity models to distribute trips.

There is also a separate gravity model calibrated for distributing internal/external vehicle trips (trips with one end inside and one end outside the region). Relationships were initially developed between internal person trip ends and external stations using a Monte Carlo simulation process based on locations of origin and destination zones[4] and traffic counts at each external station.

A nested logit model determines mode choice for HBW and non-work trips (HBS, HBO, and NHB) for the available modes: auto, transit, and fringe parking[5]. In addition to these main modes, the choice model estimates three levels of auto occupancy (drive alone, two-person carpools, three plus-person carpools), two types of transit access (walk and drive), and three types of fringe parking egress (walk, shuttle bus, and transit). The impedances of competing highway and transit services and household automobile ownership determine the mode shares for any given TAZ-to-TAZ volume of person trips. There are separate models for peak and off-peak time periods, and for each trip purpose by auto ownership.

Four (4) travel impedance components for the transit modes provide input to the HRTPO mode choice model. These are run time (total in-vehicle time), "excess" time (total out-of-vehicle time), number of transfers, and walk time. These components are weighted based on parameters used for previous forecasts[6] in the region and are consistent with FTA national experience. The impedances are based on restrained highway travel times and available transit service for the respective times-of-day. Calculation of “best path” transit impedances differentiate walk to transit and drive to transit paths for both peak and off-peak periods as well as fringe parking paths for the peak period.

An estimate of through trips (vehicle trips with both ends outside the region) is the final component of trips needed for the regional trip matrices. The HRTPO model uses a synthesized external-external trip table. The trip table was developed based on external station volumes and identification and weighting of likely station-to-station movements.

Highway trip assignment assigns vehicle trips to the highway networks with a multi-iteration user-equilibrium assignment process which includes capacity restraint[7] after each iteration. The highway

[4] NHTS data.
[5] Available only to HBW peak period trips.
[6] Norfolk LRT Project Final Design Patronage Forecasting Report, 2007.
[7] Conical functions by facility type based on research by the Virginia Modeling, Analysis and Simulation Center.

assignment procedure is a multi-class and is sensitive to the presence of high-occupancy vehicle (HOV) facilities in the highway network and permits only HOV trips to use HOV facilities. The impedances used for capacity restraint are highway-based costs, specifically the sum of highway travel time and tolls. The assignment procedure accommodates different toll values for autos and trucks, and accounts for their different values-of-time. Trucks and passenger vehicles are assigned together. The highway assignment procedure provides time-of-day roadway volume estimates for AM peak (6-9AM), Midday (9AM-3PM), PM peak (3PM-6PM), and Night (6PM-6AM).

Transit assignment uses output from the mode choice procedure in the last feedback iteration to assign trips to peak and off-peak periods. Within each period there are separate assignments for each transit access mode (walk and drive). There are also separate assignments for each fringe parking egress mode for the peak period (walk, shuttle, transit).

Free-flow highway speeds and link capacities are selected from a look-up table that is stratified by roadway facility type and area type. In general, free-flow speed and capacity decreases with increasing development density. There is an area type model that provides an automated procedure for updating area type codes in the network based on changes in existing and future development densities.

REVIEW OF MODEL PERFORMANCE

The MBI team executed the model sets received from VDOT based on the request submitted in July 2018. MBI verified documented highway assignment performance of the 2009 model set as detailed on pages 3-4 in the Hampton Roads Model, Ver 1.2, Release Notes (September 2014). Tables 1-3 below compare the validation as documented with results calculated from the executed model set received from VDOT. Validation reflects daily estimated model volumes as compared to counts.

Table 1: Model Validation Comparison by Volume Group

Roadway Volume Range	Number of Records	Root Mean Square Error (%)		Volume-to-Count Ratio	
		Documented	Calculated	Documented	Calculated
1 - 5,000	1,599	72.16	72.16	1.15	1.15
5,000 - 10,000	754	42.70	42.57	1.06	1.06
10,000 - 20,000	639	28.32	29.00	1.01	1.00
20,000 - 30,000	172	25.60	25.70	0.94	0.94
30,000 - 40,000	55	19.03	19.27	1.00	1.01
40,000 - 50,000	45	14.22	15.87	0.97	0.99
50,000 - 60,000	19	21.65	21.93	0.96	0.96
60,000 - 70,000	3	22.19	22.22	0.90	0.90
70,000 - 80,000	3	13.47	13.90	0.88	0.87
All	**3,289**	**39.45**	**40.05**	**1.02**	**1.02**

Table 2: Model Validation Comparison by Facility Type

Roadway Volume Range	Number of Records	Root Mean Square Error (%)		Volume-to-Count Ratio	
		Documented	Calculated	Documented	Calculated
Interstate	150	19.30	20.74	1.03	1.03
Minor Freeway	72	26.70	26.73	0.98	0.98
Principal Art	394	29.96	30.00	1.05	1.05
Major Art	180	38.20	38.31	0.96	0.97
Minor Art	1,248	40.54	40.48	1.01	1.01
Major Collector	228	75.94	76.19	0.96	0.96
Minor Collector	974	60.72	60.69	1.03	1.02
Local	36	65.30	65.18	1.08	1.08
High Speed Ramp	1	17.84	14.20	0.82	0.86
Low Speed Ramp	6	56.66	56.82	0.98	0.98
All	**3,289**	**39.44**	**39.93**	**1.02**	**1.02**

Table 3: Model Validation Comparison by Area Type

Roadway Volume Range	Number of Records	Root Mean Square Error (%)		Volume-to-Count Ratio	
		Documented	Calculated	Documented	Calculated
CBD	10	65.91	66.21	0.51	0.51
OBD	525	36.87	38.99	1.01	1.01
Urban	702	35.93	36.47	1.01	1.01
Sub Urban	781	39.57	39.67	0.99	0.99
Rural	1,271	41.58	41.46	1.07	1.07
All	3,289	39.45	40.05	1.02	1.02

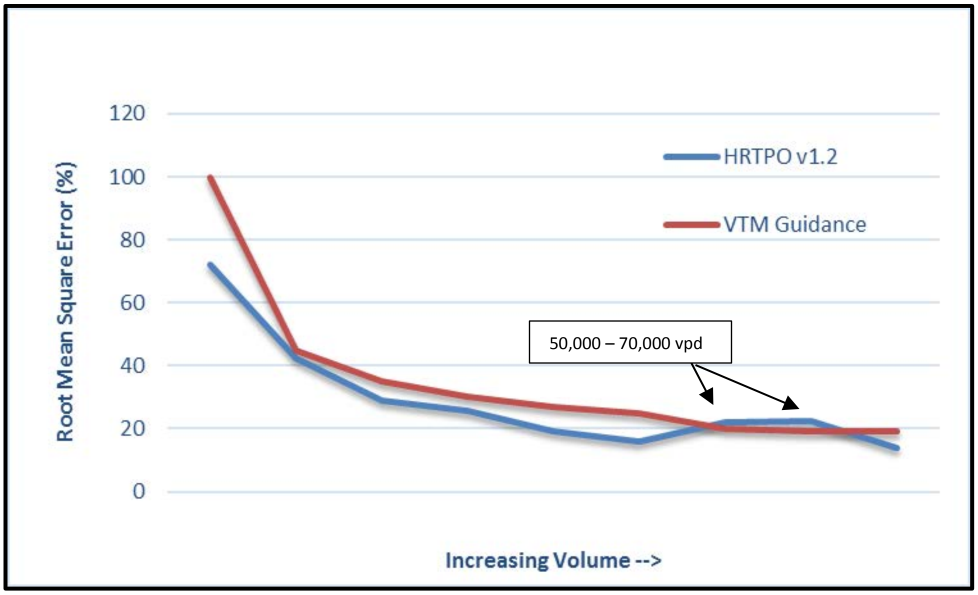
Tables 1-3 show that the results calculated from the 2009 model set received from VDOT almost identically match highway assignment validation results documented. Differences may be attributed to execution of the model using a different version of CUBE/Voyager[8] from that used by VDOT.

MBI also compared highway assignment performance of the HRTPO model with guidelines specified in the VTM Policies and Procedures Manual (version 2.0). Figure 2 below indicates that highway assignment accuracy is generally within VTM guidelines. The exceptions are a few relatively high-

[8] HRTPO Model user's guide specifies use of version 5.1.3. Model obtained from VDOT was executed by MBI using version 6.1.2, which is consistent with the version HRTPO uses.

volume roadway segments[9] carrying 50,000 to 70,000 vehicles per day (vpd). The accuracy of assignment to these segments is slightly less than recommended by VTM guidance.

Figure 2: Accuracy of Regional Daily Roadway Segment Assignments



There are 28 screen lines defined in the HRTPO Model for the region. Figure 3 below shows the locations of these screen lines.[10] Figure 4 below shows the accuracy of estimated daily assigned volumes vs. observed volumes for the individual screen lines. While the model estimated volumes over all screen lines is within 3.1% of the observed volume, there are a considerable number of screen lines that exceed the recommended deviation of VTM guidance.

[9] I-64 between Mallory St and Woodland Rd; I-64 between I-264 and Indian River Rd; I-64 between Oak Grove Connector and Battlefield Blvd; and Berkley Bridge over the Elizabeth River.
[10] p. 106, Hampton Roads Model Methodology Report (Ver. 1.0), December 2013

Figure 3: Locations of Regional Screen lines

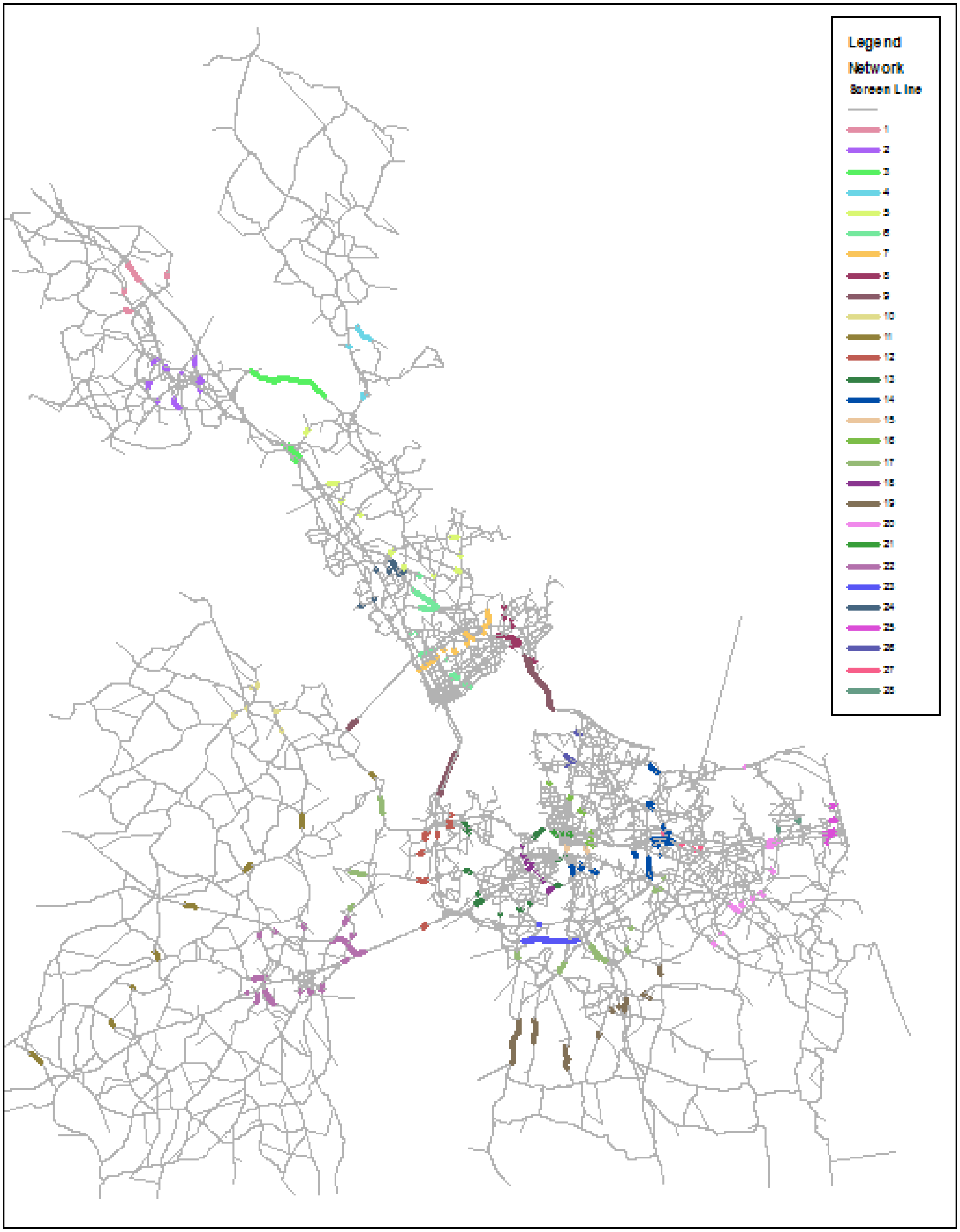
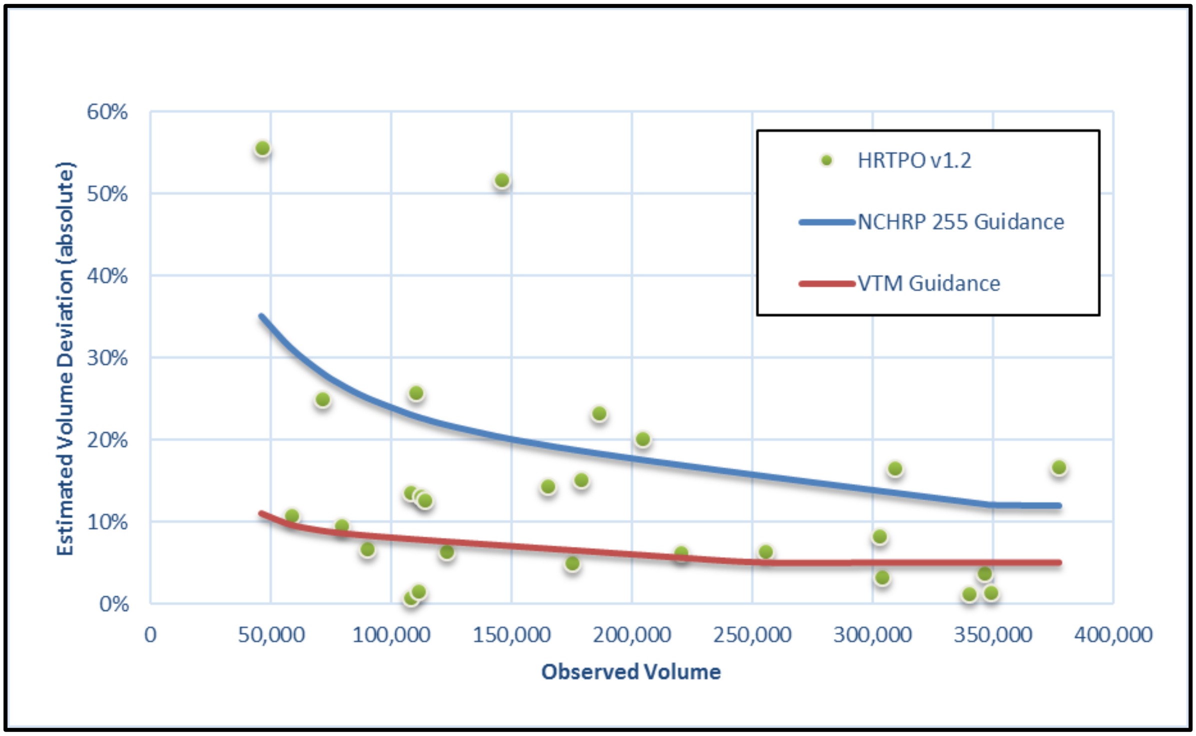


Figure 4: Accuracy of Daily Screen Line Assignments



Nearly half of the screen lines meet or are very close to the accuracy requirements specified by VTM guidance. Of the remaining screen lines that do not meet VTM guidance, about half do not meet the less stringent NCHRP 255[11] criteria for volume deviation. While the accuracy of regional link assignments may generally meet VTM guidelines, the model may not explain well the travel patterns and associated magnitudes captured by some screen lines. Although in aggregate trip generation and distribution perform reasonably on a regional basis, as indicated in the methodology report, this accuracy may need examination on a finer geographic level.

RECOMMENDATIONS

One of the centerpieces of the Regional Connectors Study is the measurement of transportation benefits associated with the inclusion of several major roadway segments not included in the HRCS SEIS Preferred Alternative. The HRTPO model will need to display a sensitivity to congestion, travel time reliability, and accessibility in the context of scenario planning. The model will also need to assess the reaction of travelers of different income levels to specific scenarios; enabling the evaluation of social and economic justice, and in part economic impacts. Considering these needs, a review of national best practices, model enhancements in other regions, and discussions with the Citilabs software vendor; MBI has developed a list of potential enhancements to the modeling process that will address the needs of

[11] Highway Traffic Data for Urbanized Area Project Planning and Design, Transportation Research Board, December 1982.

the Study, as well as broaden the model's analysis capabilities. Table 4 below lists candidate actions for improving the current HRTPO model for use in this Study, as well as addressing future planning challenges.

Some of these recommendations overlap with HRTPO model modifications currently underway by VDOT and its consultants, including a base year update to Year 2015 - accommodating HRTPO's long range planning process. MBI is actively coordinating with VDOT and their consultants to incorporate recommendations that MBI deems critical to the Regional Connectors Study in this model update (highlighted in bold type in the table below). Determination as to whether a recommended action is "critical" balances the gain in analytical capability due to implementing the action versus time added to the schedule for the VDOT updates underway. Notes below the table explain the rationale for the critical recommendations.

Table 4: Candidate Recommended Actions

Model Component	Description of Action
General	• Expand segmentation of non home-based trip purposes. • Accommodate sensitivity to the presence of connected/autonomous vehicles. • Accommodate sensitivity to new modes enabled by technology (ride hailing…). • Account for induced demand due to added roadway capacity. • **Evaluate travel patterns associated with major facilities and harbor crossings with information from GPS origin-destination (O-D) data including Streetlight and Airsage.[1]**
Trip Generation	• Assess need for special generator representation using available surveys and cell phone/GPS data ("big data"). • **Evaluate and update external travel (XX, XI, IX) based on information from the Virginia Statewide travel demand model and/or information from GPS origin-destination (O-D) data including Streetlight and Airsage.[2]**
Truck Trip Generation/ Distribution	• **Assess need for special generator representation using available surveys and cell phone/GPS data ("big data").[3]**

Model Component	Description of Action
Trip Distribution	• Implement income stratification. • Revisit impedance/generalized cost functions (sensitivity to traveler values-of-time by trip purpose, treatment of transit captives…). • Evaluate integration of "matrix estimation" or "adaptable assignment" routines to revise trip tables to better match validation traffic counts.
Auto/Truck Trip Assignment	• Develop/implement standardized assignment validation/performance summary reporting. • **Assign trips by purpose and income accounting for different values-of-time.**[4] • **Incorporate a toll choice model.**[5] • Account for travel time reliability in route choice.

Notes

1- As indicated by the discussion on page 8 of this memo regarding screen line assignment accuracy, travel patterns and magnitudes estimated by the model will need further investigation. With respect to this study, it will be particularly important to understand and have the model represent well the travel markets that use the Harbor crossings.

2- The methodology report (p.44) indicates a need for survey or other data for estimating external-external travel apart from the synthetic approach currently used. The associated GPS data could also aid in estimating the other external travel components. Moreover, this data can increase understanding of how prevalent external travel is in the markets served by the Harbor crossings and major facilities in the region.

3- This data will provide additional information to validate trip generation and distribution to/from ports and truck terminals in the region. Refining the truck model may improve truck trip assignment performance and yield additional insight into future demand.

4- This refinement will facilitate environmental justice and economic impact analysis and improve sensitivity of the model to congestion. Route choice will be sensitive to travelers' values-of-time in response to congestion. This refinement will also allow tabulation of assignments by income groups, providing a clearer understanding of benefits.

5- The model's current method of accounting for travelers' reactions to tolls is not adequate for forecasting the use of express (HOT) lanes, which will be a prevalent feature of the regional highway network into the future. Income/trip purpose stratification described in Note 4 will complement the toll choice model.