GEN2/VER. 2.3 MODEL DEVELOPMENT

Recent Calibration of Nested-Logit Mode Choice Model

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Introduction

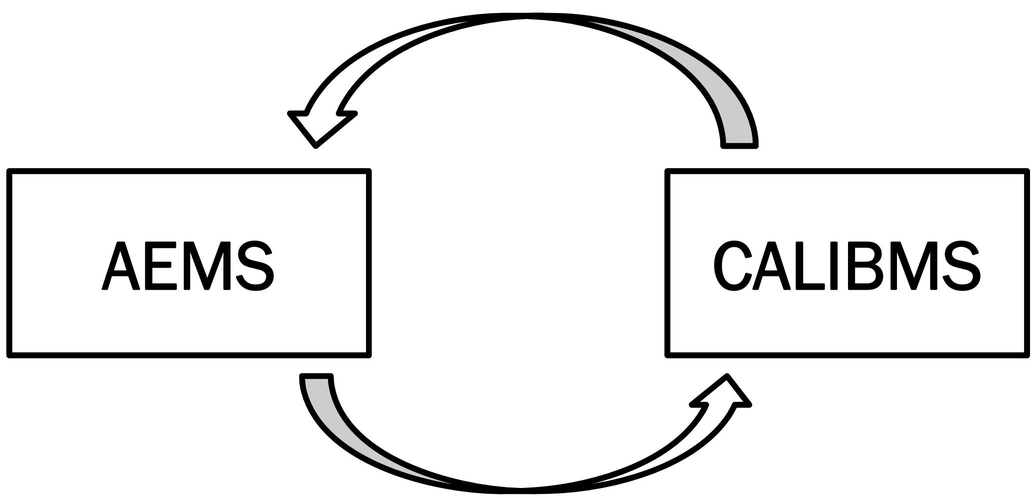
- Calibrating the Nested-Logit Mode Choice (NLMC) model entails finding a set of nesting constants for the utility functions that allow the model to most closely replicate observed market shares known as "targets".
- This is the fifth time that the NLMC model of TPB Gen2/Version 2.3 Travel Demand Model has been calibrated by TPB staff.
- In all five calibration efforts, the model was calibrated to year-2007 targets:
  - Auto person trip targets were developed based on the COG/TPB 2007/2008 Household Travel Survey (HTS) data and adjusted (since the fourth calibration) based on the 2000 Census Transportation Planning Products (CTPP) data. With the exception of the first calibration, auto targets were extracted from simulated trip tables.
  - Transit person trip targets were derived from a series of Transit On-Board Surveys (TOSs) conducted during 2005 and 2008.

Introduction (Cont'd)

- The fifth calibration was warranted by the following model development activities that TPB staff conducted in the past year:
  - TPB staff updated transit person trip calibration targets associated with commuter rail following corrections to the 2005 VRE Passenger Survey data (presented to the TFS on 9/20/2019).
  - In a parallel modeling effort, TPB staff implemented model refinements to improve the simulation of external auto person trips in Version 2.3.82, which had noticeable effects on simulated auto person trip patterns and thus on auto calibration targets (the implementation of main external-trip-related model changes in the Ver. 2.5 Model was presented to the TFS on 5/18/2018).
  - Through sensitivity testing, TPB staff also made adjustments to model parameters related to commuter rail path-building to improve the simulation of commuter rail ridership **(this sensitivity testing work will be the focus of this presentation).**

CALIBMS Based Calibration Process

- Calibration of COG/TPB's NLMC model is performed by a Fortran program named "CALIBMS" in an automated routine.
- CALIBMS, as well as AEMS that implements the NLMC model, are iteratively executed in tandem until convergence, or until a maximum number of iterations (typically 20) is reached.
- The calibration process generates a series of AEMS control files that contain re-estimated nesting constants for the NLMC model.



Streamlined Calibration Process

- The calibration process, previously implemented through a series of automated, semi-automated and manual procedures, was streamlined and further automated for this calibration work.
- The streamlined process includes five consecutive steps, each being automated in a Cube Voyager, SAS or Windows batch file script:
  - Step 1. Develop Auto Targets
  - Step 2. Update CALIBMS Goal Files
  - Step 3. Set Up and Execute CALIBMS Run
  - Step 4. Create Summaries of CALIBMS Outputs for QA/QC
  - Step 5. Copy Resulting CALIBMS Nesting Constants
- Streamlining and additional automation significantly reduced time and labor needed for preparing, executing and summarizing a calibration run.

Sensitivity Testing: Investigation

- In order to improve the simulation of commuter rail ridership, TPB staff conducted an in-depth investigation into the modeling of commuter rail trips in the current model.
- It is widely acknowledged that the unique characteristics of commuter rail provide additional amenities (utilities) for commuter rail travel:
  - Commuter rail service is schedule-based;
  - Commuter rail trains usually provide a seat to every passenger;
  - Commuter rail ride is usually fast and comfortable, etc.
- The investigation indicates that the underestimation of commuter rail ridership in the current model may partially be attributed to a lack of preferential treatment, in the model, towards commuter rail travel.

Sensitivity Testing: Methodologies

- A study conducted for Federal Railroad Administration (FRA) implemented a range of model changes to provide preferential treatment to commuter rail and to improve the travel forecasting for VRE:
  - Changes to model parameters related to commuter rail path building;
  - Changes to model/network inputs, such as overriding HBW trip tables, station-specific exit/transfer times and shadow prices.
- TPB staff adopted a more incremental approach to make sure changes to the regional model would be <u>minimal</u> and <u>defensible</u>:
  - Avoided post-processing trip tables or making station-specific adjustments, and focused on adjustments to path-building parameters;
  - Evaluated a variety of path-building parameters in preliminary testing and selected three for further consideration;
  - Evaluated different combinations of the selected parameters and different adjusted values in sensitivity tests.

Sensitivity Testing: Preliminary Testing

Table 2. Path-Building Model Parameters Considered in Preliminary Testing

Parameter*	Description	Propsed Change	Inclusion/Exclusion in Further Testing
MODEFAC[4]	weight of in-vehicle travel time	From 1.0 to 0.8	Included as it provides a 20% discount of perceived IVTT to reflect the amenities of a commuter rail ride associated with guaranteed seating, comfortableness, being able to read, nap or surf the Internet (sometimes with free Wi-Fi access).
MODEFAC[11]	weight of drive access time	From 1.5 to 1.0	Excluded as it resulted in a marginal change in commuter rail ridership.
IWAITFAC[4]	weight of initial waiting times	From 2.5 to 0.5	Included as it reflected the ability of commuter rail riders to minimize their initial waiting times according to fixed train schedule.
XWAITFAC[4]	weight of transfer waiting times	From 2.5 to 0.5	Excluded as the ability of commuter rail riders to minimize their transfer times is limited if the "transfer-to" transit does not provide fixed schedules.
COMBINE	headway combining threshold	PK: 5 to 30 OP: 10 to 60	Excluded as it resulted in a marginal change in commuter rail ridership.
IWAITMAX[4]	maximum initial waiting time	From 60 to 10	Included as it reflected the ability of commuter rail riders to minimize their initial waiting times according to fixed train schedule.

Sensitivity Testing: Selected Parameters

- MODEFAC[4] is discounted to reflect the amenities of a commuter rail ride.
  - Changing the value from 1.0 to 0.8 provides a 20% discount of the <u>perceived</u> in-vehicle travel time.
- Both IWAITFAC[4] and IWAITMAX[4] are related to commuter rail initial waiting time, but they affect the model in different ways.
  - IWAITFAC[4] weights the <u>perceived</u> initial waiting time. Lowering the value from 2.5 to 0.5, for example, reduces the perceived time corresponding to an actual 10-minute initial waiting time from 25 minutes to 5 minutes.
  - IWAITMAX[4] caps the <u>actual</u> initial waiting time. A value of 10 minutes, for instance, assumes maximum average waiting time to be 10 minutes and maximum waiting time of an individual rider to be 20 minutes. (Cube uses a “half-the-headway” approach to calculate average initial waiting times, assuming waiting times of individual riders are evenly distributed between 0 and the headway).

Sensitivity Testing: Procedures

- TPB staff then conducted sensitivity tests following a seven-step process which:
  1) took the Version 2.3.82 Model as the starting point;
  2) adjusted selected path-building parameters in a specific combination;
  3) executed corresponding year-2007 travel demand model run;
  4) extracted auto targets from the respective 2007 modeling outputs;
  5) performed NLMC model calibration in a CALIBMS run (Runs #4 - #7);
     - Three preceding calibration runs (Runs #1 - #3), conducted with updated transit/auto person trip calibration targets, did not alter path-building parameters.
  6) executed a year-2014 run using the re-calibrated travel model; and
  7) evaluated corresponding 2007 calibration and 2014 validation results.
     - CALIBMS Run #3 based on Version 2.3.82 represents a baseline for assessing the calibration results of each sensitivity test.

Sensitivity Testing: Calibration Results

Baseline (Run #3)

Run #4: IWAITFAC[4]: 2.5=>0.5, MODEFAC[4]: 1.0=>0.8

Run #5: IWAITMAX[4]: 60=>10, MODEFAC[4]: 1.0=>0.8

Run #6: IWAITMAX[4]: 60=>7.5, IWAITFAC[4]: 2.5=>1.5, MODEFAC[4]: 1.0=>0.8

Run #7: IWAITMAX[4]: 60=>7.5, MODEFAC[4]: 1.0=>0.8

Table 4. Year-2007 Observed and Estimated Daily Commuter Rail Person Trips by Market Segment

MKT SEG	Production Area	Attraction Area	Observed	Estimated (E/O Ratio) from CALIBMS Runs: Run #3	Run #4	Run #5	Run #6	Run #7
1	DC	DC core	58	20 (0.35)	126 (2.18)	20 (0.35)	126 (2.18)	39 (0.67)
2	DC	VA core	3	3 (1.00)	58 (19.45)	33 (11.03)	81 (27.15)	52 (17.17)
3	DC	Urban DC, MD, VA	5	201 (40.17)	437 (87.41)	293 (58.52)	484 (96.83)	337 (67.45)
4	DC	Suburban MD, VA	662	833 (1.26)	1,187 (1.79)	1,139 (1.72)	1,346 (2.03)	1,241 (1.87)
5	MD urban	DC core	0	90 (N/A)	237 (N/A)	109 (N/A)	195 (N/A)	167 (N/A)
6	MD urban	VA core	0	16 (N/A)	34 (N/A)	21 (N/A)	28 (N/A)	26 (N/A)
7	MD urban	Urban DC, MD, VA	1	34 (33.78)	110 (110.31)	75 (74.95)	102 (102.29)	92 (92.26)
8	MD urban	Suburban MD, VA	48	76 (1.59)	90 (1.87)	229 (4.77)	309 (6.44)	294 (6.12)
9	VA core/urban	DC core	27	6 (0.21)	141 (5.23)	72 (2.65)	145 (5.38)	109 (4.05)
10	VA core/urban	VA core	0	0 (N/A)	6 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)
11	VA core/urban	Urban DC, MD, VA	16	8 (0.52)	39 (2.46)	12 (0.74)	48 (2.97)	20 (1.25)
12	VA core/urban	Suburban MD, VA	67	53 (0.79)	105 (1.56)	65 (0.97)	88 (1.32)	70 (1.04)
13	MD suburban	DC core	9,820	9,896 (1.01)	9,940 (1.01)	10,115 (1.03)	10,183 (1.04)	10,164 (1.04)
14	MD suburban	VA core	420	502 (1.20)	501 (1.19)	548 (1.31)	561 (1.34)	560 (1.33)
15	MD suburban	Urban DC, MD, VA	2,528	2,605 (1.03)	2,666 (1.05)	2,767 (1.09)	2,913 (1.15)	2,874 (1.14)
16	MD suburban	Suburban MD, VA	1,110	1,173 (1.06)	1,189 (1.07)	1,400 (1.26)	1,482 (1.33)	1,467 (1.32)
17	VA suburban	DC core	3,356	3,536 (1.05)	3,538 (1.05)	3,856 (1.15)	3,922 (1.17)	3,922 (1.17)
18	VA suburban	VA core	1,513	1,516 (1.00)	1,516 (1.00)	1,532 (1.01)	1,537 (1.02)	1,537 (1.02)
19	VA suburban	Urban DC, MD, VA	5,939	6,017 (1.01)	6,017 (1.01)	6,119 (1.03)	6,142 (1.03)	6,141 (1.03)
20	VA suburban	Suburban MD, VA	977	1,105 (1.13)	1,147 (1.17)	1,408 (1.44)	1,496 (1.53)	1,472 (1.51)
		Total:	**26,550**	**27,691 (1.04)**	**29,085 (1.10)**	**29,813 (1.12)**	**31,189 (1.17)**	**30,584 (1.15)**

Sensitivity Testing: Validation Results

Baseline

IWAITFAC[4]: 2.5=>0.5
MODEFAC[4]: 1.0=>0.8

IWAITMAX[4]: 60=>10
MODEFAC[4]: 1.0=>0.8

IWAITMAX[4]: 60=>7.5
IWAITFAC[4]: 2.5=>1.5
MODEFAC[4]: 1.0=>0.8

IWAITMAX[4]: 60=>7.5
MODEFAC[4]: 1.0=>0.8

Table B2. Year-2014 Validation of Average Weekday Transit Ridership by Mode in Modeled Area: Observed vs. Simulated in Scenarios (A)-(G)

	2014 Observed ("O")		Scenario (A) 2014 Val. (Original)		Scenario (B) 2014 (NLMC Model Re-Calibrated in CALIBMS Run #1 with Only Updt. Transit Targets)		Scenario (C) 2014 (NLMC Model Re-Calibrated in CALIBMS Run #3 with Updt. Transit Targets and Updt. Auto Targets from Ver.2.3.82)		Scenario (D) 2014 (NLMC Model Re-Calibrated in CALIBMS Run #4 with Updt. Transit Targets and Updt. Auto Targets from Ver.2.3.82 + Weight of CR Initial Wait Time 2.5=>0.5 + Weight of IVTT 1.0=>0.8		Scenario (E) 2014 (NLMC Model Re-Calibrated in CALIBMS Run #5 with Updt. Transit Targets and Updt. Auto Targets from Ver.2.3.82 + CR Initial Wait Max. Time 60=>10 + Weight of IVTT 1.0=>0.8		Scenario (F) 2014 (NLMC Model Re-Calibrated in CALIBMS Run #6 with Updt. Transit Targets and Updt. Auto Targets from Ver.2.3.82 + CR Initial Wait Max. Time 60=>7.5 + Weight of CR Initial Wait Time 2.5=>1.5 + Weight of IVTT 1.0=>0.8		Scenario (G) 2014 (NLMC Model Re-Calibrated in CALIBMS Run #7 with Updt. Transit Targets and Updt. Auto Targets from Ver.2.3.82 + CR Initial Wait Max. Time 60=>7.5 + Weight of IVTT 1.0=>0.8	
	Outdated	Updated	Estim. ("E")	E/O	Estim. ("E")	E/O	Estim. ("E")	E/O	Estim. ("E")	E/O	Estim. ("E")	E/O	Estim. ("E")	E/O	Estim. ("E")	E/O
Metrorail	737,679	737,679	746,541	1.01	747,781	1.01	744,623	1.01	744,393	1.01	744,443	1.01	744,209	1.01	744,189	1.01
Commuter Rail	54,217	36,483	32,275	0.60	35,688	0.98	24,665	0.68	26,048	0.71	27,771	0.76	29,863	0.82	28,812	0.79
MARC	36,051	20,171	28,200	0.78	27,810	1.38	15,444	0.77	15,884	0.79	17,304	0.86	17,829	0.88	17,688	0.88
VRE	18,166	16,311	4,075	0.22	7,878	0.48	9,221	0.57	10,165	0.62	10,468	0.64	12,035	0.74	11,124	0.68
All Bus	648,083	648,083	715,273	1.10	714,893	1.10	706,245	1.09	705,125	1.09	704,713	1.09	704,612	1.09	705,031	1.09
Total:	***1,439,979***	***1,422,245***	***1,494,089***	***1.04***	***1,498,362***	***1.05***	***1,475,532***	***1.04***	***1,475,566***	***1.04***	***1,476,926***	***1.04***	***1,478,684***	***1.04***	***1,478,031***	***1.04***

Sensitivity Testing: Ridership by Station

Baseline

IWAITFAC[4]: 2.5=>0.5
MODEFAC[4]: 1.0=>0.8

IWAITMAX[4]: 60=>10
MODEFAC[4]: 1.0=>0.8

IWAITMAX[4]: 60=>7.5
IWAITFAC[4]: 2.5=>1.5
MODEFAC[4]: 1.0=>0.8

IWAITMAX[4]: 60=>7.5
MODEFAC[4]: 1.0=>0.8

Table B3. VRE Simulated (2014) Boardings by Station

		Simulated 2014 Boardings (including internal trips only)														
		Scenario (C) 2014 (NLMC Model Re-Calibrated in CALIBMS Run #3 with Updt. Transit Targets and Updt. Auto Targets from Ver.2.3.82)			Scenario (D) 2014 (NLMC Model Re-Calibrated in CALIBMS Run #4 with Updt. Transit Targets and Updt. Auto Targets from Ver.2.3.82 + Weight of CR Initial Wait Time 2.5=>0.5 + Weight of IVTT 1.0=>0.8			Scenario (E) 2014 (NLMC Model Re-Calibrated in CALIBMS Run #5 with Updt. Transit Targets and Updt. Auto Targets from Ver.2.3.82 + CR Initial Wait Max. Time 60=>10 + Weight of IVTT 1.0=>0.8			Scenario (F) 2014 (NLMC Model Re-Calibrated in CALIBMS Run #6 with Updt. Transit Targets and Updt. Auto Targets from Ver.2.3.82 + CR Initial Wait Max. Time 60=>7.5 + Weight of CR Initial Wait Time 2.5=>1.5 + Weight of IVTT 1.0=>0.8			Scenario (G) 2014 (NLMC Model Re-Calibrated in CALIBMS Run #7 with Updt. Transit Targets and Updt. Auto Targets from Ver.2.3.82 + CR Initial Wait Max. Time 60=>7.5 + Weight of IVTT 1.0=>0.8		
Station Group	**Station**	**Peak**	**Off-Peak**	**Total**	**Peak**	**Off-Peak**	**Total**	**Peak**	**Off-Peak**	**Total**	**Peak**	**Off-Peak**	**Total**	**Peak**	**Off-Peak**	**Total**
VRE Terminal Zone	Union Station	879	269	1,148	777	609	1,386	922	385	1,307	951	763	1,714	933	515	1,448
	L'Enfant	1,783	22	1,805	1,861	270	2,131	1,837	201	2,038	1,879	617	2,496	1,868	313	2,181
	Crystal City	398	2	399	531	89	619	527	59	586	531	156	687	533	86	619
	Alexandria	831	154	985	723	465	1,188	734	209	943	754	544	1,298	744	337	1,081
	Subtotal	***3,891***	***446***	***4,337***	***3,892***	***1,433***	***5,324***	***4,019***	***853***	***4,872***	***4,114***	***2,080***	***6,194***	***4,077***	***1,251***	***5,328***
Manassas Line	Backlick Road	452	13	464	464	26	489	485	78	563	488	85	573	488	89	577
	Rolling Road	335	9	344	371	9	379	393	36	429	388	44	432	390	43	433
	Burke Centre	433	127	560	479	118	596	493	259	751	499	315	814	505	313	817
	Manassas Park	294	17	310	314	35	349	319	103	422	321	123	444	321	116	437
	Manassas	733	59	791	771	74	844	788	157	944	787	182	969	796	175	970
	Broad Run/Airport	247	5	251	273	6	278	281	17	297	281	19	299	282	19	301
	Subtotal	***2,492***	***228***	***2,719***	***2,669***	***266***	***2,935***	***2,757***	***649***	***3,406***	***2,763***	***767***	***3,530***	***2,780***	***754***	***3,534***
Fredericksburg Line	Franconia/Springfield	160	7	167	213	22	235	166	61	227	195	79	273	171	70	240
	Lorton	223	27	250	256	26	281	263	71	334	258	78	336	264	80	343
	Woodbridge	975	16	991	577	14	591	489	33	522	533	43	575	454	41	495
	Rippon	143	13	156	443	14	456	430	46	476	403	58	460	449	56	505
	Quantico	53	12	65	33	12	44	46	22	68	45	25	70	48	26	74
	Brooke	50	0	50	67	0	67	60	0	60	60	0	60	61	0	61
	Leeland Road	30	2	32	82	3	85	45	5	50	43	6	49	44	6	50
	Fredericksburg	444	12	456	138	11	149	429	24	453	465	25	490	471	26	497
	Subtotal	***2,077***	***89***	***2,166***	***1,806***	***100***	***1,906***	***1,927***	***262***	***2,188***	***2,000***	***312***	***2,311***	***1,960***	***304***	***2,263***
	Total	**8,459**	**762**	**9,221**	**8,367**	**1,798**	**10,165**	**8,703**	**1,763**	**10,466**	**8,876**	**3,159**	**12,035**	**8,817**	**2,308**	**11,124**

Note: * Data Source: AECOM, Inc. "VRE Forecasting Deep Dive", January 26, 2015.

Final Calibration

- Version 2.3.83 implemented proposed parameter adjustments associated with CALIBMS Run #5 on top of Version 2.3.82.
  - CALIBMS Runs #6 and #7 were excluded for consideration as they resulted in more pronounced over-estimations (all sensitivity tests resulted in an overestimation of commuter rail person trips, but a moderate level of overestimation was viewed as acceptable, since VRE Passenger Survey did not account for off-peak trips).
  - CALIBMS Run #4 was also dropped from consideration because that 1) adjustment to IWAITFAC[4] led to a localized change to VRE ridership (concentrated at Terminal Zone stations in off-peak periods), and that 2) changing the IWAITFAC[4] value to 0.5 is less defensible as it discounts actual initial waiting time by half.
- Version 2.3.84 incorporated the re-estimated nesting constants resulting from a final calibration run based on Version 2.3.83.
  - As expected, results of final calibration replicated those of Run #5.

Final Validations

- Using the re-calibrated Version 2.3.84 Model, TPB staff conducted both year-2007 and year-2014 validations with a focus on transit ridership.
- 2007 commuter rail ridership validated very well to observed data, which were derived from independent data sources not used in 2007 calibration.
- 2014 commuter rail ridership is underestimated by 24% (MARC by 14% and VRE by 36%), which is nonetheless a significant improvement compared to the validation statistics based on the Version 2.3.75 Model, which showed a 40% underestimation on Slide 12 (presented to the TFS on 3/15/19).

Table 11. Year-2007 Average Weekday Transit Ridership by Sub-Mode

	Observed ("O")	Estimated ("E")	Ratio (E/O)
Metrorail	726,013 *	712,103	0.98
Commuter Rail	29,664	27,901	0.94
MARC	17,080 **	15,813	0.93
VRE	12,584 ł	12,089	0.96
All Bus	N/A	674,858	N/A
Rail Total:	***755,677***	***740,004***	***0.98***

Notes: * Data Source: WMATA historical ridership computed by Crystal ReportsSystem
** Data Source: MARC Growth and Investment Plan in 2007
ł Data Source: Chronology of the Virginia Railway Express

Table 12. Year-2014 Average Weekday Transit Ridership by Sub-Mode

	Observed ("O")	Estimated ("E")	Ratio (E/O)
Metrorail	737,679 *	744,443	1.01
Commuter Rail	36,483	27,771	0.76
MARC	20,171 **	17,304	0.86
VRE	16,311 **	10,468	0.64
All Bus	648,083 **	704,713	1.09
Transit Total:	***1,422,245***	***1,476,926***	***1.04***

Notes: * Data Source: WMATA Crystal ReportsSystem (with adjustments related to Silver Line stations)
** Data Source: Version 2.5 Model Development Report

Discussions

- In 2014, commuter rail accounted for only about 4% of all transit trips and 0.2% of all motorized person trips, which has two implications:
  - The 24% underestimation of 2014 commuter rail ridership should not affect the validity of modeling data in support of regional planning activities such as the Long Range Transportation Plan (LRTP) Update and Air Quality Conformity (AQC) Determination.
  - Relatively small market share of commuter rail made it very challenging to match corresponding validation targets.
- Different validation results in 2007 and 2014 indicated <u>inconsistencies</u> between 2007 and 2014 model forecasts, which may arise from:
  - <u>Land use forecasting,</u> which is not fully integrated with travel forecasting;
  - <u>Trip distribution</u>, but TPB staff have limited means to adjust trip distribution outputs for certain market segments as staff seek to minimize the use of K-factors.

Discussions (Cont'd)

- The modeling of commuter rail ridership could be further improved in the following areas:
  - Inconsistencies between 2007 and 2014 forecasts could be avoided by conducting model calibration and validation in the same year of 2014;
  - A destination choice model in place of the gravity-based trip distribution model would provide more explanatory powers in the utility function.
  - More recent information on non-work-related and external commuter rail trips may help improve model calibration/validation.
- For sub-regional modeling practices/planning studies, model could be further improved through post-processing and/or *ad hoc* enhancements, such as:
  - Post-processing person trip tables,
  - Making adjustments to station-specific variables,
  - Making additional adjustments to transit path-building parameters, and
  - Implementing other sub-regional model/network enhancements.

Conclusions

- The Nested Logit Mode Choice (NLMC) model of TPB Gen2/Version 2.3 Travel Demand Model was calibrated for the fifth time following:
  - Recent updates to commuter rail calibration targets,
  - Model refinements related to external auto person trips, and
  - Adjustments to path-building parameters that help the model reflect the premium attributes of commuter rail travel.
- 2007 validation was a large improvement over Ver. 2.3.75 Model.
- Although the resulting Version 2.3.84 Model still underestimates the 2014 commuter rail ridership at the regional level, the validation statistics have significantly improved.
- As the next step, TPB staff assessed the performance of the Version 2.3.84 Model through a comprehensive model re-validation to year-2014 conditions that included both highway and transit targets.

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