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MEMORANDUM

Date: July 24, 2015

Project #: 188850

To: Keith Norberg, Karen Fink
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From: Franklin Cai, TE, Jim Damkowitch

Subject: TRPA Model Review

FINDING SUMMARY

Kittelson & Associates performed a peer review of both static and dynamic model validation performance of the Tahoe Regional Planning Agency/Tahoe Metropolitan Planning Organization's (TRPA/TMPO) Tour Based Travel Demand Model. Based on this analysis, the TRPA/TMPO travel demand model was determined to meet all static and dynamic validation tests with the exception of one – which was more a function of an inadequate sample size for testing than a model accuracy issue.

INTRODUCTION

To evaluate the veracity of the TRPA/TMPO travel demand model to accurately predict travel behavior, TRPA/TMPO's 2014 baseline model results were evaluated relative to several key validation criteria pursuant to the following related travel demand model publications:

- Caltrans 2010 Regional Transportation Plan Guidelines;
- Travel Forecasting Guidelines, (California Department Transportation, 1992); and,
- Nevada Department of Transportation (NDOT) Traffic Forecasting Guidelines (May, 2012)

To facilitate the peer review, TRPA/TMPO provided the following 2014 baseline model files:

- Loaded base year model networks for four land-use alternatives.
- Geographic files of centroids
- Geographic files of the basin outline
- Geographic files of TAZ boundaries
- Excel summary file of static validation statistics

In addition, the following model background materials were also provided:

- Technical Memorandum (Fehr & Peers, June, 2010): Final TRPA PTOD Areas Mixed Use Trip Generation Estimate
- Technical Memorandum (Fehr & Peers, September 20, 2011): Validation of TRPA Base Year 2010 Travel Demand Model
- VMT Indicator Summary (TRPA)
- Draft Technical Memorandum (Fehr & Peers, August 9, 2011): TRPA Travel Demand Model Sensitivity Evaluation
- Technical Memorandum (TRPA, February 27, 2015): 2014 Model Calibration

Although not entirely relevant to this peer review, KAI also summarized all model validation criteria from the following state/federal documents as a potential future resource for TRPA/TMPO to consider during future baseline model updates. This summary is provided in Attachment A of this memorandum.

- Travel Forecasting Guidelines, California Department Transportation (1992)
- Travel Forecasting Guidelines, Nevada Department of Transportation (May 2012)
- Travel Model Validation and Reasonableness Checking Manual Second Edition
- Travel Model Improvement Program Travel Model Validation and Reasonableness Checking Manual Second Edition (September 24, 2010)
- 2010 California Regional Transportation Plan Guidelines (April 7, 2010)
- A Manual of Regional Transportation Modeling Practice for Air Quality Analysis
- Transportation-Air Quality Planning: Issues & Analysis Needs
- EPA Section 187 VMT Forecasting and Tracking Guidance (March 1992)
- Guidance for the Use of Latest Planning Assumptions in Transportation Conformity Determinations (March 2001)

VALIDATION CRITERIA:

Based on the review of the aforementioned documents and previous TRPA/TMPO modeling validation efforts, the following static criteria were selected for this evaluation.

Primary Static Criteria and Thresholds

Validation Item	Criteria for Acceptance
Percent of Links with volume-to-count ratios within Caltrans deviation allowance	At Least 75%
Correlation Coefficient	At Least 0.88
Percent Root Mean Squared Error (RMSE)	Below 40%

In order to determine if the TRPA/TMPO model “behaves” appropriately to changes in model parameters or inputs, the following dynamic land use sensitivity tests were also examined:

- Add 100 households to a TAZ
- Add 100 employees to a TAZ
- Subtract 100 households from a TAZ
- Subtracts 100 employees from a TAZ

Based on the static nature of the transportation system, model sensitivity to network changes was not considered necessary.

ASSESSMENT OF VALIDATION RESULTS

Static Validation

Based on the existing sample of roadway locations historically tracked by TRPA/TMPO for model validation purposes, the link level static validation results for state highways in the Tahoe Region are provided in **Table 1** and also shown graphically in **Figure 1**. As shown, the model generally over-estimates daily volumes on SR-28, SR-431 and SR-267 and both under- and over-estimates, depending on location, daily traffic on US-50. Of the 24 locations reported, 15 (or 63%) are within the "Maximum Deviation". To increase the representativeness of the validation sample, nine local roadways with available count data were added to the analysis (**Table 2**). The resulting percentage of validation links meeting criteria increased to 70%. For future validation assessments, it is recommended that TRPA/TMPO expand its' model validation sample. This would likely yield an overall percentage of locations that meet the target criteria of 75% (see Recommendation Section of this technical memorandum).

As shown in **Figure 2**, the correlation coefficient between the TRPA/TMPO baseline model volumes and traffic counts is .8949 - which meets established criteria. Another statistic for identifying the consistency between the model outputs and the base year counts is the Percent Root Mean Square Error (RMSE). The percent RMSE for the TRPA/TMPO baseline model is 25.79% which is well below the maximum acceptable range of 40%. Given that acceptable RMSE limits vary by AADT range, **Table 3** shows the TRPA/TMPO model RMSE by ADT volume range relative to NDOT's RMSE error tolerance criteria. All ADT volume range groups meet established criteria.

Table 4 summarizes the static validation results for the TRPA/TMPO 2014 baseline model. As shown, two of the three tests meet criteria for validation of travel demand models.

Although not listed as Primary Static Criteria, given the importance of accurately estimating VMT in the Tahoe Region particularly in the context of TRPA/TMPO's VMT Threshold, a VMT validation metric is desired. Given that Tahoe Region specific HPMS VMT estimates are not developed or reported jointly by Caltrans and NDOT, compliance with Section 187 of the Clean Air Act – VMT tracking and baseline VMT percent deviation criteria is not possible. However, the 1990 Clean Air Act (November 15, 1990) Section 187 VMT model validation criteria was applied based on the traffic count information in **Table 2**. The sum of daily traffic counts at the 24 count locations was multiplied by the TRPA/TMPO VMT adjustment factor 3.42 to yield daily VMT specific to the Principal Arterial functional classification. This estimate was then compared to the TRPA/TMPO travel demand model 2014 VMT estimate for principal arterials. This comparison was within the proscribed 3% tolerance established by Section 187 of the CAAA (**Table 5**).

Table 2. Tahoe Region Traffic Count Station Calibration (State Highways Only)

2014 Base Count Station Location	Cross Street	Status	2014 Traffic Count	2014 Model	Model-Count Difference	Model-Count % Difference	Deviation	Maximum Deviation	Within Deviation
US 50 mp 70.62	SR 89	Trend	17,600	14,794	2,806	84.06%	0.1594	0.30	Yes
US 50 mp 71.48	Pioneer	Trend	17,200	20,151	(2,951)	117.2%	(0.1716)	0.30	Yes
US 50 mp 75.45	Wye	Trend	39,500	29,525	9,975	74.7%	0.2525	0.23	No
US 50 mp 76.41	Keys	Trend	37,500	35,916	1,584	95.8%	0.0422	0.24	Yes
US 50 mp 77.33	Al Tahoe	Trend	39,000	39,128	(128)	100.3%	(0.0033)	0.23	Yes
US 50 mp 80.14	Park	Continuous	36,500	29,166	7,334	79.9%	0.2009	0.24	Yes
US 50 ATR 0521109	Parkway	Continuous	33,738	39,960	(6,222)	118.4%	(0.1844)	0.24	Yes
US 50 sta 0041	Kingsbury	Trend	25,980	25,013	967	96.3%	0.0372	0.26	Yes
SR 28 sta 0035	Spooner	Trend	6,805	9,842	(3,037)	144.6%	(0.4463)	0.42	No
SR 28 ATR 3122409	W.Lakeshore	Continuous	16,494	23,741	(7,247)	143.9%	(0.4394)	0.30	No
SR 28 mp 11.00	Stateline	Continuous	17,900	24,198	(6,298)	135.2%	(0.3518)	0.30	No
SR 28 mp 9.34	SR 267	Continuous	21,500	21,256	244	98.9%	0.0113	0.27	Yes
SR 28 mp 1.85	Lake Forest	Trend	13,700	20,718	(7,018)	151.2%	(0.5123)	0.32	No
SR 89 mp 19.54	Bliss Park	Trend	6,000	4,314	1,686	71.9%	0.2810	0.44	Yes
SR 89 mp 11.69	Fallen Leaf	Trend	6,400	5,938	462	92.8%	0.0722	0.44	Yes
SR 89 mp 8.67	TC Wye	Trend	18,200	13,514	4,686	74.3%	0.2575	0.31	Yes
SR 267 mp 9.28	North Avenue	Trend	13,100	15,957	(2,857)	121.8%	(0.2181)	0.32	Yes
SR 89 MP 0.00 Alpine-El Dorado	Luther	Trend	3,400	4,240	(840)	124.7%	(0.2471)	0.60	Yes
US 50 MP 65.62 Echo Lake Road	Echo	Trend	15,100	12,276	2,824	81.3%	0.1870	0.31	Yes
SR 207 ATR 0531509- sta 0024	Kingsbury	Continuous	13,153	17,431	(4,278)	132.5%	(0.3252)	0.31	No
US 50 ATR 252125	Spooner	Continuous	14,349	18,785	(4,436)	130.9%	(0.3092)	0.31	Yes
SR 431 sta 770	Mt. Rose	Trend	6,700	11,053	(4,353)	165.0%	(0.6497)	0.43	No
SR 267 MP 6.23 Martis Peak Rd	SR 267	Trend	10,600	16,435	(5,835)	155.0%	(0.5505)	0.36	No
SR 89 MP 13.72 Squaw Valley Rd	SR 89	Continuous	16,600	19,830	(3,230)	119.5%	(0.1946)	0.32	No
		Total	447,019	473,181	(26,162)	**0.9447**			

Table 3. Tahoe Region Traffic Count Station Calibration (Includes Local Roadways)

2014 Base Count Station Location	Cross Street	Status	2014 Traffic Count	2014 Model	Model-Count Difference	Model-Count % Difference	Deviation	Maximum Deviation	Within Deviation
US 50 mp 70.62	SR 89	Trend	17,600	14,794	2,806	84.06%	0.1594	0.30	Yes
US 50 mp 71.48	Pioneer	Trend	17,200	20,151	(2,951)	117.2%	(0.1716)	0.30	Yes
US 50 mp 75.45	Wye	Trend	39,500	29,525	9,975	74.7%	0.2525	0.23	No
US 50 mp 76.41	Keys	Trend	37,500	35,916	1,584	95.8%	0.0422	0.24	Yes
US 50 mp 77.33	Al Tahoe	Trend	39,000	39,128	(128)	100.3%	(0.0033)	0.23	Yes
US 50 mp 80.14	Park	Continuous	36,500	29,166	7,334	79.9%	0.2009	0.24	Yes
US 50 ATR 0521109	Parkway	Continuous	33,738	39,960	(6,222)	118.4%	(0.1844)	0.24	Yes
US 50 sta 0041	Kingsbury	Trend	25,980	25,013	967	96.3%	0.0372	0.26	Yes
SR 28 sta 0035	Spooner	Trend	6,805	9,842	(3,037)	144.6%	(0.4463)	0.42	No
SR 28 ATR 3122409	W.Lakeshore	Continuous	16,494	23,741	(7,247)	143.9%	(0.4394)	0.30	No
SR 28 mp 11.00	Stateline	Continuous	17,900	24,198	(6,298)	135.2%	(0.3518)	0.30	No
SR 28 mp 9.34	SR 267	Continuous	21,500	21,256	244	98.9%	0.0113	0.27	Yes
SR 28 mp 1.85	Lake Forest	Trend	13,700	20,718	(7,018)	151.2%	(0.5123)	0.32	No
SR 89 mp 19.54	Bliss Park	Trend	6,000	4,314	1,686	71.9%	0.2810	0.44	Yes
SR 89 mp 11.69	Fallen Leaf	Trend	6,400	5,938	462	92.8%	0.0722	0.44	Yes
SR 89 mp 8.67	TC Wye	Trend	18,200	13,514	4,686	74.3%	0.2575	0.31	Yes
SR 267 mp 9.28	North Avenue	Trend	13,100	15,957	(2,857)	121.8%	(0.2181)	0.32	Yes
SR 89 MP 0.00 Alpine-El Dorado	Luther	Trend	3,400	4,240	(840)	124.7%	(0.2471)	0.60	Yes
US 50 MP 65.62 Echo Lake Road	Echo	Trend	15,100	12,276	2,824	81.3%	0.1870	0.31	Yes
SR 207 ATR 0531509- sta 0024	Kingsbury	Continuous	13,153	17,431	(4,278)	132.5%	(0.3252)	0.31	No
US 50 ATR 252125	Spooner	Continuous	14,349	18,785	(4,436)	130.9%	(0.3092)	0.31	Yes
SR 431 sta 770	Mt. Rose	Trend	6,700	11,053	(4,353)	165.0%	(0.6497)	0.43	No
SR 267 MP 6.23 Martis Peak Rd	SR 267	Trend	10,600	16,435	(5,835)	155.0%	(0.5505)	0.36	No
SR 89 MP 13.72 Squaw Valley Rd	SR 89	Continuous	16,600	19,830	(3,230)	119.5%	(0.1946)	0.32	No
Barbara Avenue	Martin	Local Cnt	3,370	2,834	536	84.1%	0.1591	0.49	**Yes**
Black Bart	Pioneer	Local Cnt	4,360	5,113	(753)	117.3%	(0.1727)	0.47	**Yes**
Lake Tahoe Blvd.	N Upper Truckee	Local Cnt	2,104	3,221	(1,117)	153.1%	(0.5309)	0.53	**No**
Lake Tahoe Blvd.	Sawmill	Local Cnt	4,512	4,034	478	89.4%	0.1059	0.46	**Yes**
North Upper Truckee Road	Mt. Rainer Drive	Local Cnt	7,749	5,443	2,306	70.2%	0.2976	0.41	**Yes**
North Upper Truckee Road	US 50	Local Cnt	5,750	6,239	(489)	108.5%	(0.0850)	0.43	**Yes**
Pioneer Trail	US 50	Local Cnt	6,450	6,777	(327)	105.1%	(0.0507)	0.44	**Yes**
Pioneer Trail	Golden Bear	Local Cnt	7,988	9,125	(1,137)	114.2%	(0.1423)	0.40	**Yes**
Pioneer Trail	City Limits	Local Cnt	11,757	10,448	1,309	88.9%	0.1113	0.33	**Yes**
		Total	501,059	526,415	(25,356)	**0.9518**			

Figure 1. Tahoe Region Traffic Count Station Calibration

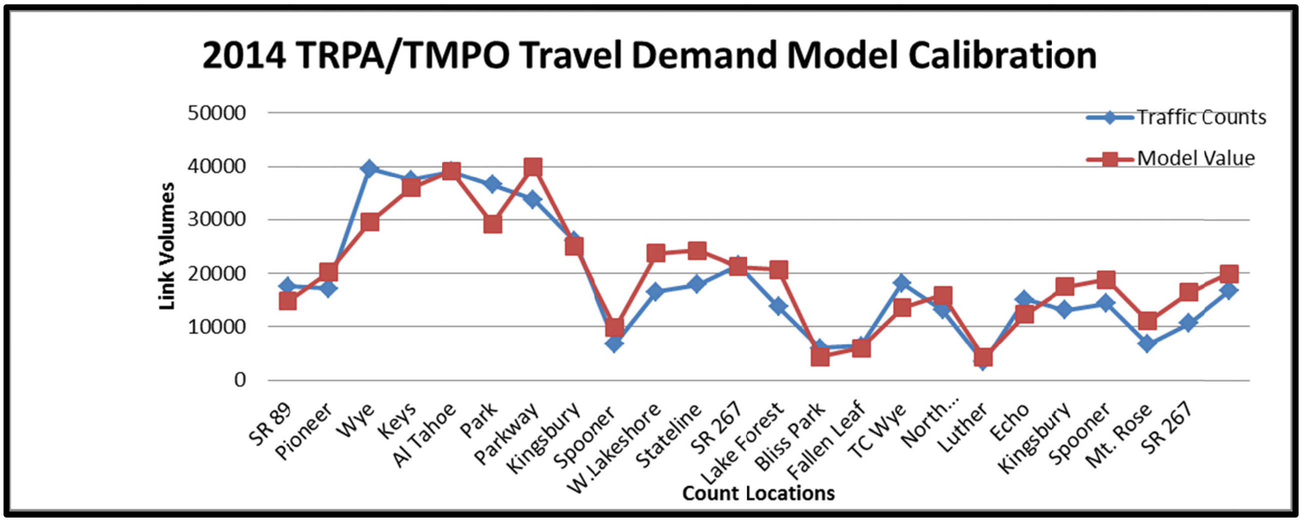


Figure 2. 2014 Model Coefficient of Determination (State Highways Only)

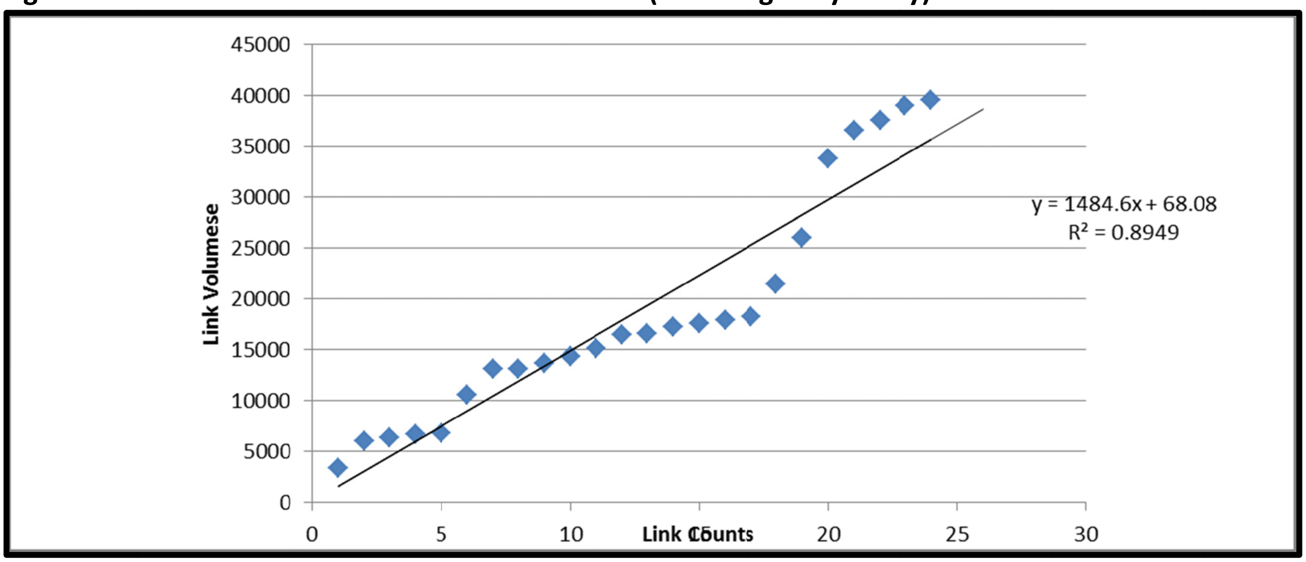


Table 3. Percent Root Mean Square Error by ADT Range

AADT Range	Max RMSE	Model RMSE	Within Max	Observations
< 5,000	100%	21.96%	Yes	5
5,000 – 9,999	45%	32.46%	Yes	8
10,000 – 14,999	35%	30.49%	Yes	6
15,000 – 19,999	30%	27.13%	Yes	7
20,000 – 49,999	25%	15.83%	Yes	7
> 50,000	20%	n/a	n/a	0

Table 4 Static Validation Results

Validation Item	Criteria for Acceptance	TRPA/TMPO Model Result
Percent of Links within allowable deviation	At Least 75%	70%
Correlation Coefficient	At Least 0.88	.89
Percent Root Mean Squared Error (RMSE)	Below 40%	25.79%

Table 5 CAA Section 187 VMT Tracking – Principal Arterials Only

2014 Base TRPA/TMPO Model	2014 Count Based PA VMT[1]	2014 Model PA VMT	Model-Count Difference	Model-Count % Difference	Deviation	Section 187 Max VMT Deviation	Within Deviation
Principal Arterial VMT Check	1,528,805	1,539,037	-10,232	1.006692809	-1.3585364	3%	Yes

1. Daily VMT from a peak travel day (2nd weekend in August) multiplied times a constant of 3.42 that accounts for other VMT model inputs (e.g., average distance traveled, average vehicle occupancy). The constant was derived by dividing the 1981 VMT estimate (1,649,000) by the 1981 peak August traffic volume (482,106).

Dynamic Validation

The following dynamic land use sensitivity tests were examined to test the sensitivity of the TRPA/TMPO to parameter changes. **Figure 3** provides the approximate locations of each of the TAZs used as part of this analysis.

- Scenario 1 Add 100 households to TAZ 90
- Scenario 2 Add 100 employees to TAZ 297
- Scenario 3 Subtract 100 households from TAZ 137
- Scenario 4 Subtracts 100 employees from TAZ 212

Table 6 provides the VMT changes that resulted from each of these scenarios relative to the 2014 baseline model run. As shown, the model behaved correctly in terms of direction of change (positive or negative) in each case. For evaluating the reasonableness of the magnitude of VMT change, additional information such as the number of trips reduced is needed. In lieu of this information, average trip length in miles was estimated taking the weighted average (using % of VMT as the weight) of model based average trip lengths by type of trip (**Table 7**). Applying the average trip length to the total VMT change in Scenario 1 and Scenario 3 results in an average number of vehicle trips per household (added or reduced) of 15.82 and 9.7 daily vehicle trips per household respectively. Based on the ITE Trip Generation Manual 9th Edition, the trip generation for a single-family detached housing unit (ITE Land Use Code 210) is 9.52 trips per weekday (9.81 per weekend day). Based on this comparison – the magnitude of VMT change for Scenario 3 is reasonable. The higher 15.82 vehicle trip per household for Scenario 1 also appears reasonable when considering that the location of TAZ 90 is nearly outside the Basin and would necessitate considerably longer trip lengths to meet basic OD pairs.

The magnitude of change in VMT resulting from the addition and subtraction of employment is also reasonable when considering the locations of TAZ 212 relative to TAZ 297. The relative change in attractiveness in TAZ 212 would result in expectedly less VMT change given the greater intensity of development and population in TAZ 212 resulting in shorter trip lengths and therefore VMT change relative to TAZ 297.

Based on these findings, the dynamic validation results of the TRPA/TMPO travel demand model appear reasonable.

Table 6 Dynamic Validation Results

Scenario	Description	Daily VMT	Delta of Baseline	VMT/HH Baseline	VMT/Emp Baseline
Scenario 0	Baseline	1,891,180	n/a		
Scenario 1	Add 100 HH TAZ 90	1,917,910	26,730	267.3	
Scenario 2	Add 100 Emp TAZ 297	1,924,577	33,397		333.97
Scenario 3	Sub 100 HH TAZ 137	1,874,734	-16,446	-164.46	
Scenario 4	Sub 100 Emp TAZ 212	1,885,239	-5,941		-59.41

Table 7 Tahoe Region Average Trip Length (Weighted Average)

Trip Type	2014 Trip Length	% of Total VMT	VMT % Weighted Trip Length
Day Visitor	32.2	33.50%	10.8
External Worker	21.76	7.60%	1.7
Overnight Worker	7.2	10.10%	0.7
Resident	4.53	38.30%	1.7
Seasonal	13.64	7.60%	1.0
Through	32.79	2.90%	1.0
Weighted Average Trip Length			**16.9**

Figure 3. Dynamic Validation Test Locations

RECOMMENDATIONS FOR FUTURE VALIDATION REPORTING

According to California Department of Transportation's Forecasting Guidelines, "the regional agency should strive to obtain traffic counts on ten percent or more of the region wide highway segments (i.e., model links) being analyzed... this ten percent goal applies also to the distribution of counts in each functional classification (freeways and principal arterials, at a minimum)." The TRPA/TMPO model validation uses counts from just 24 (expanded to 33 locations herein) for validation purposes. Expansion of the number of count locations is recommended for future validation assessments. Systematic data collection of traffic counts on roadways that are not on the state system should be considered. Count locations should be strategically considered during the establishment of screenline locations (see following recommendation).

As part of the calibration/validation process, a screen line analysis was not performed - but due to the "circular" nature of the model's network, screen lines may not be necessary given that the count locations are on the state highways which already serve as the only means of getting in and out of the Tahoe Region. Nonetheless, given that screenline assessments help validate model trip distribution results, TRPA/TMPO should consider establishing model screenlines for future model validation exercises.

Multiple guidelines (including California DOT's) ask for the calibration and validation of the transit model. Documenting the calibration/validation of the mode split module to actual transit ridership is recommended. This can be performed as a region-wide holistic check by summing up total model ridership and comparing to total actual transit ridership. More detailed line specific transit ridership validation tests is problematic given the historical variability in transit ridership by line in the Tahoe Region.

Given that Tahoe Region specific HPMS VMT estimates are not developed or reported jointly by Caltrans and NDOT, compliance with Section 187 of the Clean Air Act – VMT tracking and baseline VMT percent deviation criteria is not possible. For this analysis, the TRPA/TMPO VMT adjustment factor 3.42 was used to yield a "ground truth" daily VMT of the principal arterial system which was then compared to model VMT by functional classification output. It is recommended that a secondary alternative principal arterial VMT estimate be developed via: Segment Length (in miles) x AADT. This can be annually calculated using Excel using published information by Caltrans and NDOT.

4-D Utility Discussion – Dynamic Validation

To ensure that the travel and vehicle emission benefits of Smart Growth land use strategies are reasonably quantified by TRPA/TMPO's travel demand model, it is recommended that future dynamic validation exercises include a with and with-out 4D post processing comparison. The comparison should specifically focus on the number of vehicle trip reductions and the average trip length of these eliminated trips as well changes in mode split resulting from 4-D processor. Logically, the average trip length of reduced trips resulting from the 4D process should be less than the model average trip length for most if not all trip purposes. This expected outcome is premised on the understanding that Smart Growth strategies do not eliminate person trips – but facilitates shorter trip lengths and/or promotes choices to use alternatives to the single occupant vehicle.

If such testing reveals that the 4D process as currently applied by TRPA/TMPO (i.e., factoring the vehicle trip OD matrix) does not yield logical results, TRPA/TMPO should consider modifications within a model's trip distribution and mode split estimates.

Original statistical research used as the basis for the Ds methods as well as newer research and techniques to improve on the Ds process so that travel models do not just reduce vehicle trips but actually estimate shifts to shorter trips and alternative modes has been applied as "Urban Form Adjustment" techniques. These techniques were tested in Fresno County during the San Joaquin Valley Blueprint process and are currently being implemented in other models. The Urban Form Adjustment process mostly uses lists of TAZs with easy-to-use rating scales (0 to 3) to identify locations with urban forms which help to promote lower vehicle trips. The process uses simple identification of the following inputs:

- TAZs with supportive urban design features (such as high density right next to an arterial with bus service), and rate the TAZ by how much of the TAZ land use includes the newer development types
- Districts of TAZs with supportive urban design features (such as a dense retail development across the street from a dense residential development in a different TAZ)
- Corridors of TAZs with improved transit service or improved bicycle/pedestrian paths

However, even more sophisticated models can have difficulty in evaluating smart growth issues if the land uses are aggregated into medium or large TAZs. With the aggregation to TAZs, the specific accessibility of individual land uses within each TAZ cannot be distinguished and separately evaluated. In addition, a 3-Step or 4-Step model does not automatically account for changes in the travel environments such as pedestrian and bicycle amenities, or development architecture that encourages the use of alternative modes.

It should also be noted that the D process is most appropriate for models that have little sensitivity to smart growth factors. These would include models with large TAZs, vehicle trip generation as opposed to person trip generation, poor representation of short trips, and few land use categories for trip generation estimates. It may be that the TRPA/TMPO model exhibits some of these characteristics.

ATTACHMENT A.

SUMMARY OF STATE AND FEDERAL CRITERIA FOR THE VALIDATION OF TRAVEL DEMAND MODELS:

Forecasting Guidelines, California Department of Transportation

- The regional agency should strive to obtain traffic counts on ten percent or more of the region wide highway segments being analyzed, if resources allow. This ten percent goal applies also to the distribution of counts in each functional classification (freeways and principal arterials, at a minimum). Validation for groups of links in a screenline should include all highway segments crossing the screenline.

- Calibration and validation of the transit assignment model follows the same procedures as the highway assignment model, except that transit ridership counts would replace traffic counts. Inaccurate estimates can imply incorrect assumptions used in path-building or mode choice.

- A test of the percent error by functional classification will provide insight into whether the assignment model is loading trips onto the functionally classified systems in a reasonable manner. The percent error by functional classification is the total assigned traffic volumes divided by the total counted traffic volumes (ground counts) for all links that have counted volumes, disaggregated by functional classification. Suggested error limits are:

  Suggested and Region-wide Validation Criteria Functional Classification Percent Error:

Freeways	Less than 7 percent
Principal Arterials	Less than 10 percent
Minor Arterials	Less than 15 percent
Collectors	Less than 25 percent
Frontage Roads	Less than 25 percent

  Source: FHWA Calibration & Adjustment of System Planning Models; December 1990

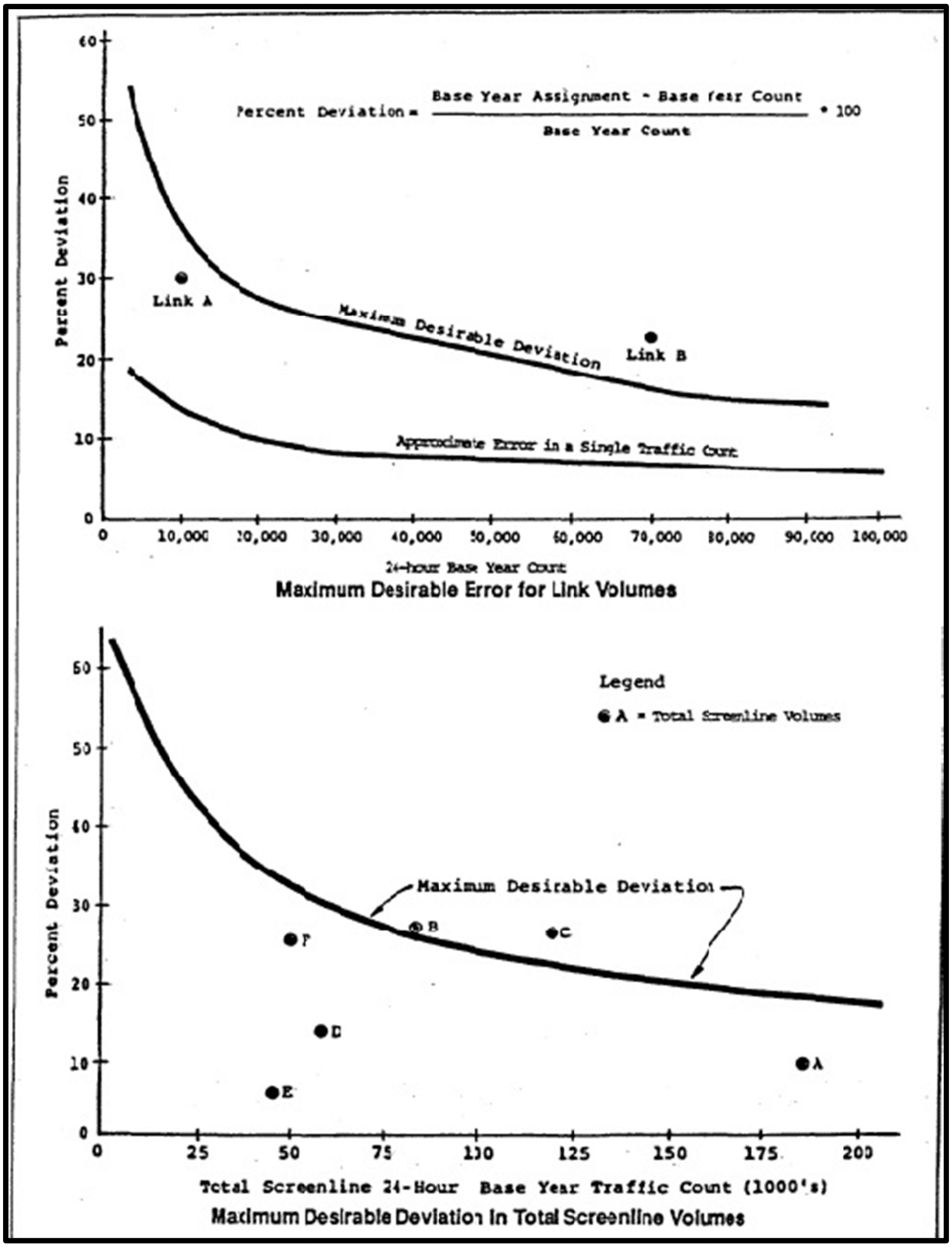
- The correlation coefficient estimates the correlation between the actual ground counts and the estimated traffic volumes and is produced by most software packages.

- Suggested Region wide Correlation Coefficient > 0.88.

- The vehicle-miles-traveled is a significant factor for emission inventories and should be compared to available data sources, such as the Highway Performance Management System (HPNIS). HPMS and other estimates of regional estimates of VMT are also subject to estimation error and are reasonable only as verification of consistency and do not provide a useful measure of the accuracy of the model system.

- The validation process should also include the comparison of ground counts to estimated volumes on individual freeway and principal arterial links, as well as screenlines defined to capture the travel demand from one area to another.

- The suggested link-specific validation criteria are that 75% of freeway and principal arterials and all screenlines meet the maximum desirable deviation in the figure below.



Travel Forecasting Guidelines, Nevada Department of Transportation

- The review of the base year model is performed to ensure the ability of the model to replicate base year conditions and as an extension, the design year conditions in the project vicinity. The validation of the base year model is performed by comparing base year counts to the modeled volumes. It is important to establish the output of the model in comparison with the field data available. The output from most models is the Average Weekday Traffic (AWDT); some models may also output other quantities (AADT, etc.). Since models can vary significantly, the agency responsible for developing and maintaining the model should be contacted to establish the exact model output. Any modifications made to the model output and the calculation of the modification factors (also known as Model Output Conversion Factors (MOCF)) should be well documented in the traffic forecasting report.

- In the evaluation of the model for base year conditions, if the model outputs are found to vary from the field count data, base year refinements need to be made to ensure that the model better reflects the actual conditions in the project vicinity. The following is a series of refinements which are commonly used:

  - The network should be updated to ensure proper representation of roadway facilities through the inclusion of parallel roadway links, collector, and other secondary roads within the project area of influence. Acceptable refinements include changes in facility type, area type, and the number of lanes.

  - The Traffic Analysis Zone (TAZ) centroid connectors and their location should be examined and adjusted if necessary.

  - The socio-economic base year data in the TAZs should be reviewed within the project area of influence. Trips generated by prominent activity generators should also be compared to actual traffic counts. If discrepancies are found from observed conditions, then coordination with the regional planning agency needs to occur to obtain consent and approval to make TAZ socio-economic modifications.

- The base year land use data should be analyzed within the project area of influence for its accuracy and consistency with local comprehensive plans. Local planning agencies and MPOs should be contacted to verify the socio-economic land use data within the project area of influence. Within the project area of influence, all existing Traffic Analysis Zones (TAZs) should be analyzed based on their size and the number of trips they generate. Trip end summaries for zones of interest in the project area of influence should be evaluated for reasonableness. It may be necessary in the project area of influence to refine the existing TAZ structure to obtain a better assignment. Special care must be taken to correctly code the new centroid connectors. It is noted that population, employment and other totals for the entire model cannot be changed. These totals must continue to reflect the adopted RTP totals.

- The model base year network within the project area of influence should also be evaluated to see if all of the major roadways are coded appropriately. Additional roadways might need to be added to the network to provide better loading points for newly created TAZs/centroid connectors, and to allow for an improved path building process. The coding of all roadways within the area of influence should be checked with regards to their facility type and number of lanes.

- An analysis should be conducted to identify whether a sufficient amount of count data is available within the project area of influence. If critical links are missing counts then additional counts should be obtained. If any roadways have been added to the network, the availability of counts should be checked for these added roadways. An analysis should be conducted to add cutlines, which might require additional counts, within the project area of influence to create the ability to quickly analyze the accuracy of the distribution patterns. These additional counts would have to be adjusted to the base year of the study as well as to the units the model uses (axle adjustments, AADT, ADT, AWDT, etc.). Note that this may be a costly endeavor, and not always feasible or desirable, based on the production schedule of certain projects.

- After refining the model to improve its ability to reflect base year conditions, the model outputs should be tested against consistency thresholds. If it meets the consistency thresholds, then the model can be applied for the future year conditions.

- Base year (model) runs should be compared with the base year ground counts along cutlines and the project corridor on a link by link basis. This comparison will indicate where specific network coding changes may be required. Traffic volumes assigned to a link in the project area of influence that significantly vary from the ground counts.

- Maximum Allowable Percent Deviation Comparison Scale for Planning Projects Environmental Analysis of Volume-Count Difference for All links at Cutlines:

  - ± 20% (< 50,000 AADT)
  - ± 15% (≥ 50,000 AADT & < 250,000 AADT)
  - ± 10% (≥ 250,000 AADT)
  - ± 10% (< 50,000 AADT)
  - ± 7.5% (≥ 50,000 AADT & < 250,000 AADT)
  - ± 5% (≥ 250,000 AADT)

Travel Model Validation and Reasonableness Checking Manual Second Edition

- Comparisons of base year model results to observations might be considered "traditional" validation. The comparisons might be of model results to disaggregate data such as data from a supplementary survey not used for model estimation or to aggregate data such as traffic counts or transit boardings. Comparing base year model results to different aggregations of the data used to estimate or calibrate a model is not as sound of a validation practice as comparing to independent data. However, for some validation tests, the data used for model estimation or calibration are the only data available.

- Temporal validation is an important aspect of model validation since, by definition, it implies comparing model results to data not used in model estimation. Both backcasts and forecasts may be used for model validation. For example, if a model is estimated using 2007 survey data, the model could be used to backcast to 2000 conditions, and compared to year 2000 traffic counts, transit boardings, Census Transportation Planning Package (CTPP) data, or other historical data. Likewise, if a model was estimated or calibrated using 2005 survey data, a "forecast" validation could be performed against 2008 data.

- Model sensitivity testing includes several important types of checks including both disaggregate and aggregate checks. Disaggregate checks, such as the determination of model elasticity, are performed during model estimation. Aggregate sensitivity testing results from temporal validation. Sensitivity testing can also include model application using alternative demographic, socioeconomic, transportation supply, or policy assumptions to determine the reasonableness of the resulting travel forecasts.

- Reasonableness and logic checks include the types of checks that might be made under model sensitivity testing. These checks also include the comparison of estimated (or calibrated) model parameters against those estimated in other regions with similar models. Reasonableness and logic checks may also include "components of change" analyses and an evaluation of whether or not the models "tell a coherent story" as recommended by the FTA for New Starts analysis.

2010 California Regional Transportation Plan Guidelines

Validation testing for a travel demand forecasting (TDF) model should include both static and dynamic tests. Static validation tests compare the model's base year traffic volume estimates to traffic counts using the statistical measures listed below and the threshold criteria contained in the table below as specified in the Travel Forecasting Guidelines, Caltrans, 1992. Below is a list of possible validation measures and thresholds.

- Volume-to-count ratio – is computed by dividing the volume assigned by the model and the actual traffic count for individual roadways model-wide. This value provides a general context for the relationship (i.e., high or low) between model volumes and counts.

- Percent of Links Within Caltrans Deviation Allowance – the deviation is the difference between the model volume and the actual count divided by the actual count. The Caltrans deviation thresholds recognize that allowances shrink as the count increases (i.e., lower tolerance for differences between the model volume estimates and counts).

- Correlation Coefficient – estimates the correlation (strength and direction of the linear relationship) between the actual traffic counts and the estimated traffic volumes from the model.

- Percent Root Mean Square Error (RMSE) – is the square root of the model volume minus the actual count squared divided by the number of counts. It is a measure similar to standard deviation in that it assesses the accuracy of the entire model.

  Static Validation Criteria and Thresholds:

  - Percent of links with volume-to-count ratios within Caltrans deviation allowance: At Least 75%
  - Correlation Coefficient: At Least 0.88
  - Percent Root Mean Squared Error (RMSE): Below 40%

Dynamic validation determines the model's sensitivity to changes in land uses and/or the transportation system. These types of tests are recommended in the Model Validation and Reasonableness Checking Manual (Travel Model Improvement Program, FHWA, 1997). The results of dynamic validation tests are inspected for reasonableness in the direction and magnitude of the changes. Dynamic validation can include the following model sensitivity tests, as appropriate given the type of regional model and alternatives under evaluation.

- Add lanes to a link
- Add a link

- Delete a link
- Change link speeds
- Change link capacities
- Add 100 households to a TAZ
- Add 1,000 households to a TAZ
- Add 5,000 households to a TAZ
- Add 10,000 households to a TAZ
- Increase/Decrease toll rates
- Increase/Decrease transit fares
- Increase transit speeds

Review of the dynamic validation tests should indicate that changes to the model volumes occurred in the appropriate direction and magnitude before the model is used in policy analysis or planning.

The list below specifies possible transit assignment validation criteria that can be applied to transportation models:

- Difference between actual counts to model results for a given year by route group (i.e., Local Bus, Express Bus, etc.): +/- 20%
- Difference between actual counts to model results for a given year by Transit Mode (i.e., Light Rail, Bus, etc.): +/- 10%

Key model validation statistics should be documented, showing the correspondence of the model prediction for a validation year to empirical data.

Model Sensitivity Testing Recommendations:

- Models should be tested for sensitivity to changes in inputs, parameter values, and policies. Elasticities for several variables should be calculated and compared to theory and those generated by other models.

- As part of the model development process, all models should, as applicable to the region, be sensitive to the following items, or acknowledge the model limitations:

  a. Price sensitivity, such as in tolling or congestion-pricing applications

  b. Destination-proximity: accessibility of an area to other activities

  c. Density, or clustered development

  d. Diversity, or mixture of land uses

  e. Distance to transit

  f. Design and layout of an area's transportation facilities

  g. Evaluation of development in known industrial areas

  h. Equity and environmental justice sensitivities, such as effects of transportation and development scenarios on low-income, minority and transit-dependent households

i. Sensitivity to different types of transportation options, including transit (broken down by mode), walking and bicycling

j. Sensitivity to different economic/income growth rates

- Experimental sensitivity tests, wherein a single factor or variable is adjusted higher and lower from its baseline value, should be run to determine the corresponding changes in model output variables. Results should be documented. Minimally, the outputs shown would be: total VMT; light-duty vehicle VMT total and per capita; light-duty vehicle greenhouse gas total and per capita; total person trips; person trips by automobile modes; person trips by transit modes; and person trips by bike and walk modes.

- Results of planning scenario tests, wherein the modeled results of planning scenarios are tabulated and correlated to show the overall sensitivity of the travel demand model to a combination of factors and policies included in the planning scenario should be documented.

- The documentation of the sensitivity tests should identify the range of reasonable sensitivity based on research literature, and account for where in this range the travel demand model sensitivity falls.

- Where results of planning scenario tests are reported, the MPO should show a correspondence between the planning scenario test results and the experimental, single factor sensitivity testing. Part of this documentation should assess the degree of interaction of factors and policies (i.e. the difference between the sum of all scenario variables taken individually, and the total change in modeled results).

- Model assessment and documentation should identify areas where the model lacks capacity for analysis of a factor or policy, and any factors or policy for which the model sensitivities fall outside the range of results documented in research literature.

A Manual of Regional Transportation Modeling Practice for Air Quality Analysis

- Models should feed back travel times resulting from the traffic assignment step to the mode choice and trip distribution (and possibly, to the trip generation) steps, and should be run to an approximate equilibrium. Model systems which omit such feedback loops in most cases should be upgraded.

- In addition, individual models should be upgraded, where necessary, to incorporate key variables that are widely agreed to be strong determinants of travel behavior and that are needed to analyze key policy options. For example, common shortcomings of models in current use include: (1) no trip generation variables beyond auto ownership and income (e.g., household composition: workers per household); (2) inadequate representation of trip attractions; (3) trip distribution models which omit transit and walking accessibility (needed in areas where transit and walk modes are important); (4) lack of peaking information on trips by type and market segment; (5) simplistic representation of socioeconomic variables affecting travel behavior; and (6) simplistic characterization and modeling of non-work travel.80 Improvements to address these shortcomings would be in order.

- Among the variables that some areas have omitted from their models, and should add as soon as possible, are: (1) household income (a key variable that should appear wherever cost appears); (2) parking charges and auto operating costs (without which analyses of parking pricing strategies, congestion pricing, toll roads, etc. can only be done off-line); and (3) the number of workers in the household (a key variable affecting ridesharing).

Transportation-Air Quality Planning: Issues & Analysis Needs

- The basic goal of RTP conformity analyses is to determine whether a region's adopted long range transportation plan is consistent with attainment and maintenance of national ambient latest planning assumptions and emissions models, and must show timely implementation of TCMs from the applicable State Implementation Plan (SIP). In addition the analysis must include all regionally significant transportation facilities and operations expected to be in place by the target years of the analysis(interim milestone years and attainment and horizon years)

EPA Section 187 VMT Forecasting and Tracking Guidance

The model needs to accurate and confident that:

- The travel demand forecasting model is validated with the most recent calendar year ground counts according to generally accepted modeling procedures;
- The methods and measures used to validate the model and the results of that validation;
- The extent to which the traffic assignment matched the base year ground count for groups of links ranked by average daily traffic volume;
- That the travel demand forecasting model method uses a constrained equilibrium approach to allocating trips among links;
- That a distinction is made between peak versus off-peak trip volumes and travel times;
- That model outputs on zone-to-zone travel times are recycled as inputs until a self-consistent equilibrium trip assignment among zones is achieved and that this recycling is done until a self-consistent equilibrium trip assignment is achieved among modes as well ,if transit trips make up a significant portion of historical or expected future travel on the network;
- That no link is loaded beyond its responsible capacity;
- That the travel demand forecasting model forecasts of future year VMT are based upon the future demographic and land-use assumptions of the agency responsible for making such forecasts for transportation planning purposes and upon the future highway and transit network, and that the demographic land-use assumptions for future years are reasonable in light of the planned highway and transit network, local land-use policy ,and other relevant influences on public and private development and location decisions.
- That the highway and transit network assumptions are consistent with the attainment strategy and demonstration through the attainment date, and (if a model scenario year falls after the attainment date) that beyond the attainment date the network assumptions are based on reasonable expectations.

Federal Conformity Regulation Latest Planning Assumptions (Section 93.110)

Pursuant to Section 93.122(b)(1) of the transportation conformity regulation, the following network modeling assumptions must be documented. Once modeling capabilities have been established to address these assumptions, any future “backsliding” (i.e., reducing model capability and functionality) is not acceptable and can provide the basis for a non-conformance finding.

i. Network Model Validation
ii. Land Use, Population, and Employment
iii. Consistency of Land Development and Use with Future Transportation System Alternatives
iv. Capacity Sensitive Assignment
v. Zone-to-zone Travel Impedances between Trip Distribution and Trip Assignment
vi. Model Sensitivity to Time(s), Cost(s) and Other Factors Affecting Travel Choices

Pursuant to Section 93.122(b)(2) – Reasonable Methods to estimate traffic speeds and delay

Pursuant to Section 93.122(b)(3) – HPMS Estimates of Regional VMT (see Section 187, Section 93.110)

Guidance for the Use of Latest Planning Assumptions in Transportation Conformity Determinations (January 2001)

- Using the "latest" planning assumptions means that the conformity determination is based on the most current information that is available to state and local planners (e.g., the MPO or other agency can obtain the information from another agency, the information is appropriate for the current conformity determination, the information is readily transferable for use in transportation and/or emissions modeling, etc.).

- Latest planning assumptions must be derived from the population, employment, travel, and congestion estimates that have been most recently developed by the MPO (or other agency authorized to make such estimates), and approved by the MPO. Once approved, these estimates must be used for determining the latest planning assumptions. In areas using network-based travel models, scenarios of land development and use must be consistent with the future transportation system for which emissions are being estimated, and the distribution of employment and residences for the transportation system must be reasonable. The

- The interagency consultation process must be used to determine which planning assumptions are considered the latest and best assumptions for conformity determinations. The conformity rule specifically requires that the interagency consultation process be used to evaluate and choose assumptions to be used in conformity analyses.

- The consultation process should be used to evaluate assumptions for quality and accuracy as needed prior to use in conformity. Whenever

Highway Performance Monitoring System (HPMS) data is used for current and future years in conformity analyses, the most recently available HPMS estimates of vehicle miles traveled (VMT) must be used. Historical trends and other factors should be considered as a primary source of information from which planning assumptions should be evaluated (e.g., population, employment). If assumptions are used that contradict historical trends, the conformity determination should include an explanation regarding why the assumptions are appropriate. This explanation should be included when the conformity determination is provided for public comment. The consultation process should not be used to unduly delay or exclude the use of new information or to selectively employ it for the convenience of the conformity process.

- Areas that rely on the U.S. Census for certain planning assumptions must use the most recent estimates available from the Census Bureau. Areas that are using assumptions based on data collected through local or state surveys or other mechanisms should use the consultation process to determine whether older state or local