2022 Transportation Conformity

Appendix 12.7:
Travel Model Validation and TAFT

North Central Texas Council of Governments

Transportation Analytical Forecasting Tool (TAFT)

Model Validation Report

TAFT Transportation Analytical Forecasting Tool

Model and Data Development

Transportation Department

North Central Texas Council of Governments

Contents

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Chapter 1. Introduction

1.1. Background of TAFT

This document describes the roadway network model and the roadway validation performance measures. The TAFT is acronym of Transportation Analytical Forecasting Tool. It is the official travel demand model developed by North Central Texas Council of Governments (NCTCOG) to model North Texas area. TAFT is a four-step trip-based travel demand model and is developed based on the following surveys.

- 2009 National Household Travel Survey (NHTS)
- 2012 Workplace Survey
- 2014 Transit Onboard Survey
- 2015 Airport Survey
- 2016 External Trip Survey
- 2014 American Community Survey (ACS)
- 2014 Traffic Count Data

The input of TAFT includes the following: demographic data, roadway network, transit network and route system, and airport and external stations forecasts. It produces traffic volumes on roadways and transit usage data on the transit system.

This report focuses on the roadway model and is organized as follows: Chapter 1 introduces TAFT's background and model structure. In Chapter 2, we discuss in detail the roadway network components specified in TAFT. In Chapter 3, we discuss traffic counts, including the source of the counts, count conversion process, and the finalized counts in usage. In Chapter 4, we do intensive comparisons between modelled travel volume and the observed travel counts in a variety of perspectives. We compare performance measures by functional class, by time-of-day, by area type, by volume, and by county. These performance measures gauge the model quality of TAFT for the base year of 2014. Finally, Chapter 5 concludes this report.

1.2. Model Structure of TAFT

The model flow chart is illustrated in Exhibit 1-1. It reads demographic data and the zone layer to create market segments, and then develops home-based trip generation and distribution. It then develops non-home-based trip generation and distribution. Note that non-home-based trips are developed after and based on home-based trips development, so the origin of non-home-based trips can connect to destination of home-based trips. The model then reads transit skims to do the mode choice, and forecasts drive alone and share ride person trips. The person trips are converted to auto trips by time-of-day, then combined with truck trips, feeding to the roadway assignment procedure and produce roadway skims. In the roadway assignment, the relative gap is specified as 10^{-4}. If travel time is converged, it then performs transit assignment and then stops. Otherwise the produced skims are fed back into trip distribution, and the process repeats until travel time has converged, or the maximum iteration of feedback loop is reached. The maximum iteration of feedback loop is 5, because experiments show that with 5 feedback loops the skims are typically converged.

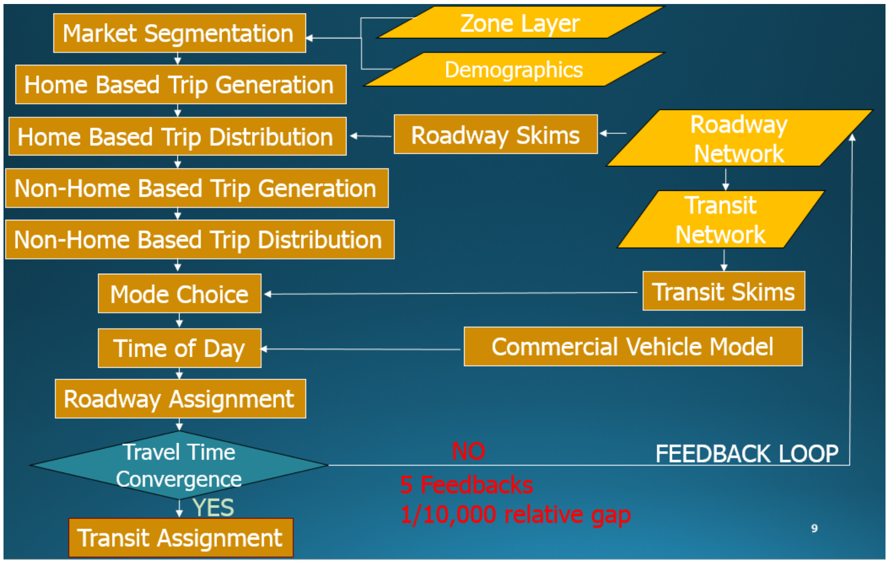

Exhibit 1-1. Model structure in TAFT

Chapter 2. Roadway Network Model in TAFT

2.1. Traffic Analysis Zones

The modeling area of TAFT includes the following 13 full counties: Collin, Dallas, Denton, Ellis, Hill, Hood, Hunt, Johnson, Kaufman, Parker, Rockwall, Tarrant, and Wise.

The modeling area is divided into 5,352 traffic analysis zones. This includes 5,303 internal zones, and 49 external zones.

2.2. Functional Class

There are 9 types of functional classes associated for each roadway links, they are tabulated in Exhibit 2-1.

Exhibit 2-1 Functional Class in TAFT

Funcl Class	**1**	**2**	**3**	**4**	**6**	**7**	**8**	**9**
Description	Freeway	Principal Arterial	Minor Arterial	Collector	Freeway Ramp	Frontage Road	HOV	Rail

2.3. Time of Day

There are three time-of-day periods:

AM: the a.m. peak period from 6:30 a.m. to 8:59 a.m.;

PM: the p.m. peak period from 3:00 p.m. to 6:29 p.m.;

OP: the off-peak from 9:00 a.m. to 2:59 p.m. and from 6:30 p.m. to 6:29 a.m.

2.4. Capacity

Freeway hourly capacity is defined based on free flow speed and is listed in Exhibit 2-3. Hourly capacities for HOVs are 1600 regardless of area type. Hourly capacities on other functional classes are defined based on Area Type and separated by divided and undivided. Divided hourly capacities are listed in Exhibit 2-3 and undivided hourly capacities are listed in Exhibit 2-4. Hourly capacity then is converted to period capacity by timing a conversion factor, which is shown in Exhibit 2-5.

Exhibit 2-2. Freeway Hourly Capacities Per Lane Based on Free Flow Speed (vehicle per lane per hour).

Free flow speed	**>=75**	**>=70 and <75**	**>=65 and <70**	**>=60 and <65**	**>=55 and <60**	**>=50 and <55**	**>=45 and <50**	**>=40 and <45**	**>=35 and <40**	**>=30 and <35**
Capacity	2100	2050	2000	1950	1900	1800	1750	1700	1600	1500

Exhibit 2-3. Arterial Hourly Capacities per Lane (Divided)

Area Type	Functional Class						
	Freeway	**Principal Arterial**	**Minor Arterial**	**Collector**	**Freeway Ramp**	**Frontage Road**	**HOV**
CBD	N/A	725	725	475	1250	725	1600
Outer Business District	N/A	775	775	500	1375	775	1600
Urban Residential	N/A	850	825	525	1425	850	1600
Suburban Residential	N/A	925	900	575	1600	900	1600
Rural	N/A	1025	975	600	1725	975	1600

Exhibit 2-4. Arterial Hourly Capacities per Lane (Undivided) (vehicle per lane per hour)

Area Type	Functional Class						
	Freeway	**Principal Arterial**	**Minor Arterial**	**Collector**	**Freeway Ramp**	**Frontage Road**	**HOV**
CBD	N/A	650	650	425	1250	650	N/A
Outer Business District	N/A	725	725	450	1375	725	N/A
Urban Residential	N/A	775	750	475	1425	750	N/A
Suburban Residential	N/A	875	825	525	1600	825	N/A
Rural	N/A	925	875	550	1725	875	N/A

Exhibit 2-5. Capacity Conversion of Factors from Hourly to Time Periods

Area Type	Functional Class						
	Freeway	Principal Arterial	Minor Arterial	Collector	Freeway Ramp	Frontage Road	HOV
AM	2.3	2.1	2.1	2.1	2.3	2.1	2.3
PM	3.2	2.9	2.9	2.9	3.2	2.9	3.2
OP	10.0	9.2	9.2	9.2	10.0	9.2	10.0

2.5. Trip Purposes

Travel behavior depends on the purpose of the activities being performed. TAFT focuses on three trips purposes: home-based-work trips (HBW), home-non-work trips (HNW), nonhome-based trips (NHB). In addition, the model distinguishes travel behavior for two demographic groups: low- and middle-income (income group 1, 2, and 3) versus high income (income group 4). Two types of travel modes—drive alone and share ride—are considered. Note that truck travel is treated separately from the trip purposes for personal travel. In total, there are 10 classes/trip purposes in the roadway assignment. They are:

- HBWDAINC123 – home-based-work trips drive alone income groups 1, 2 and 3;
- HBWDAINC4andNHBDAWRK – home-based-work trips drive alone income group 4 and non-home-based drive alone work related trips;
- HBWSRINC123 – home-based-work trips share ride income groups 1, 2 and 3;
- HBWSRINC4andNHBSRWRK - home-based-work trips share ride income group 4 and non-home-based share ride work related trips;
- HNWDAINC123 – home-non-work trips drive alone income groups 1, 2 and 3;
- HNWDAINC4andNHBDANONWRK – home-non-work trips drive alone income group 4 and non-home-based drive alone non-work related trips;
- HNWSRINC123 – home-non-work trips share ride income groups 1, 2 and 3;
- HNWSRINC4andNHBSRNONWRK – home-non-work trips share ride income group 4 and non-home-based share ride non-work related trips;
- MedTruck – medium trucks;
- HvyTruck – heavy trucks.

2.6. Value of Time

The relationship between value of time and income is developed based on USDOT (2015) [USDOT (2015). The Value of Travel Time Savings: Departmental Guidance for Conducting Economic Evaluations Revision 2 (2015 Update). Office of the Secretary of Transportation, USDOT]. [https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-valuation-travel-time-economic]. In USDOT (2015), the value of time is developed as a percentage of average hourly earnings. Particularly the value of time ($ per person hour) is recommended as 100% for business type of trips, and 50% for personal type of trips. TAFT adopts the similar concept, but is adjusted with local data.

In TAFT, the value of time is developed as a percentage of the average hourly rate, the latter is further developed from the annual median household income in each income category divided by 2,080 hours per year.

The median income for income group 1, 2, 3, and 4 are in Table 2-6.

Exhibit 2-6 Annual median income at income groups

Income level	Annual Income	Median Annual Income	Average hourly rate ($/hr)
1	0-35k	22,499	$10.8
2	35k-50k	42,499	$20.43
3	50k-75k	67,499	$32.45
4	>75k	112,499	$54.08
All		54,999	$26.44

In TAFT, value of time (VOT) is different for the AM, PM, and OP periods. The value of time of PM is used as the base. Value of time for the AM period is approximately twice as the PM, and OP is approximately 70% of the PM. The value of time in TAFT is developed as follows.

- For HBW trips, the value (PM) is 100% of the hourly rate of median income;
- For HNW trips, the value (PM) is 50% of the hourly rate of median income;
- For NHB Work-Related trips, the value (PM) is 100% of the hourly rate of median Income of Income Group 4; and
- For NHB Non-Work Related trips, the value (PM) is 50% of the hourly rate of median income of Income Group 4.

The value of time for commercial and external vehicles are determined based on the calibration of truck volumes to counts while maintaining a reasonable relationship with the VOTs determined for other trip purposes as described below:

- For commercial auto trips, the value of time is equal to the highest value of time of auto trips, which corresponds to the vehicle class HBWDAINC4.
- For commercial medium and heavy truck trips, the value of time is determined based on the calibration of the model versus counts.
- For external auto trips, the value of time is equal to the highest value of time of auto trips, which corresponds to the vehicle class HBWDAINC4.
- For external medium and heavy truck trips, the value of time is determined based on the calibration of the model versus counts.

Exhibit 2-7. Value of time in the traffic assignment of TAFT

Row	Vehicle Class	Description	Value of Travel Time Savings (AM,PM,OP) ($/person-hr)
1	HBWDAINC123	Home-Based Work Drive Alone Income group 123, Income<75,000	48, 21, 15
2	HBWDAINC4	Home-Based Work Drive Alone Income group 4, Income >=75,000	102, 54, 36
3	HBWSRINC123	Home-Based Work Shared Ride Income group 123, Income <75,000	48, 21, 15
4	HBWSRINC4	Home-Based Work Shared Ride Income group 4, Income>=75,000	102, 54, 36
5	HNWDAINC123	Home-Non-Work Drive Alone Income group 123, Income<75,000	30, 10.5, 7.8
6	HNWDAINC4	Home-Non-Work Drive Alone Income group 4, Income>=75,000	60, 27, 19.2
7	HNWSRINC123	Home-Non-Work Shared Ride Income group 123, Income<75,000	30, 10.5, 7.8
8	HNWSRINC4	Home-Non-Work Shared Ride Income group 4, Income>=75,000	60, 27, 19.2
9	NHBDAWRK	Non-Home-Based Drive Alone Work Related	102, 54, 36
10	NHBSRWRK	Non-Home-Based Shared Ride Work Related	102, 54, 36
11	NHBDANONWRK	Non-Home-Based Drive Alone Non-Work Related	60, 27, 19.2
12	NHBSRNONWRK	Non-Home-Based Shared Ride Non-Work Related	60, 27, 19.2
13	CV -Auto	Commercial Vehicle - Auto	102, 54, 36
14	CV-Med-Truck	Commercial Vehicle –Medium Truck	90, 60, 60
15	CV-Hvy-Truck	Commercial Vehicle –Heavy Truck	90, 60, 60
16	Ext-Auto	External – Auto	102, 54, 36
16	Ext -Med-Truck	External – Medium Truck	90, 60, 60

Row	Vehicle Class	Description	Value of Travel Time Savings (AM,PM,OP) ($/person-hr)
17	Ext- Hvy-Truck	External - Heavy Truck	90, 60, 60

2.7. Volume-Delay Function (VDF)

The VDF function includes four types of travel times, free flow travel time, conical congestion delay, signal delay and un-signalized delay. The general form of the VDF is in Equation 2-1.

$$T = T_0 + C_d + S_d + U_d \tag{2-1}$$

where:

T: loaded travel time;

T_0: free flow travel time;

C_d: Conical congestion delay;

S_d: Signal delay;

U_d: Un-signalized traffic control delay.

Conical delay:

Conical delay1 is in the following form as in Equation 2-2.

$$C_d = [1 + \sqrt{\alpha^2(1-x+\varepsilon)^2 + \beta^2} - \alpha(1-x+\varepsilon) - \beta - h] \times T_0 \tag{2-2}$$

where:

x: volume capacity ratio

$\beta = \frac{2\alpha - 1}{2\alpha - 2}$

$h = 1 + \sqrt{\alpha^2(1-0+\varepsilon)^2 + \beta^2} - \alpha(1-0+\varepsilon) - \beta$

ε: VDF shift

α: estimated parameters of the model

Signal delay:

Signal delay is developed based on Webster's delay function, but only consider the first term – uniform delay.

$$S_d = \frac{1}{60} \times \frac{r^2}{2C[\max\left(1 - \frac{v}{s}, 0.1\right)]} = \frac{SPar}{\max\left(1 - \frac{v}{s}, 0.1\right)} \tag{2-3}$$

where:

r: red time;

C: cycle length;

v: volume;

s: adjusted saturation flow rate,

SPar, signalized parameter, it equals $\frac{1}{60} \times \frac{r^2}{2C}$.

Calculation of signal delay requires the red time and cycle length of the signal. These items are generally unknown, so they are estimated by formula.

The basic form of signal delay is not differentiable due to the "max" term. To make the delay function satisfy the mathematical property (continuously increasing function, and continuously differentiable), it is modified as follows.

$$S_d = \frac{1}{60} \times \frac{r^2}{2C(1 - \frac{v}{s})} = \frac{SPar}{(1 - \frac{v}{s})} \qquad \text{if } \frac{v}{s} \leq 0.875 \tag{2-4}$$

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1 See Spiess, Heinz, Technical Note—Conical Volume-Delay Functions, in Transportation Science 1990 24:2, 153- 158; https://pubsonline.informs.org/doi/abs/10.1287/trsc.24.2.153

$$S_d = \frac{1}{60} \times \frac{r^2}{2C * 0.1} = \frac{SPar}{0.1} \qquad \text{if } \frac{v}{s} \geq 0.925 \qquad (2\text{-}5)$$

Interpolated by a polynomial function such that it is continuously increasing and continuously differentiable. The interpolation is as follows: if $0.875 < \frac{v}{s} < 0.925$ (2-6)

$$S_d = CA \times (\frac{v}{s})^3 + CB \times (\frac{v}{s})^2 + CC \times \left(\frac{v}{s}\right) + CD$$

Un-signalized control delay:

$$U_d = \text{min\_delay} + UPar * \frac{v}{c} \qquad (2\text{-}7)$$

$UPar = \frac{3}{60} \times (\frac{nk-w}{2})$ for yield sign and four-way stop sign;

$UPar = \frac{3}{60} \times 2 \times (\frac{nk-w}{2})$ for two-way stop sign.

where:

n: number of inbound links;

k: number of outbound links;

w: number of two-way links;

c: capacity,

Min_delay is set equal to 10/60. (i.e., 10 seconds)

2.8. Feedback Loop

The feedback procedure involves feeding the travel time after assignment back into the trip distribution process to assure travel time consistency. In a well-defined feedback process, the values of the input variables and output variables should converge. The selection of appropriate convergence criteria is necessary to inform modelers when the iterative application of the feedback loop can be entered, and the final assignment result can be used. In TAFT, experiments show that after 5 iterations the travel times in assignment and trip distribution converge. Therefore, the feedback loop in TAFT is specified as 5 iterations.

2.9. Inputs and Outputs of the Model

For the roadway model, the input files include roadway network, vehicle trip matrices by time-of-day, and demographic data. TAFT adopts a generalized cost method for multi-modal multi-class roadway assignment. The generalized cost component considers path choice by a combined measure of roadway operating cost, toll cost, and travel time. The generalized cost function is in Equation (2-8). Different vehicle classes may access different roadway networks and may have different value-of-time parameters. The output is time-of-day traffic volume for each class on the links.

$$gc_{OD}^{m} = \sum_{a \in A_{OD}^{m}} \left\{ VOT^{m} VDF\left(t_a, c_a, \sum_{m} x_a \right) \right\} + \sum_{i \in M_{OD}^{m}} MT_m^i + \sum_{i \in M_{OD}^{m}} MO_m^i \tag{2-8}$$

gc_{OD}^{m}: Generalized cost between origin O and destination D for mode m;

m: Mode;

a: Link;

OD: Origin-Destination;

A_{OD}^{m}: Set of links from O to D for mode m;

VOT^{m}: Value of time for mode m;

VDF: Volume delay function;

t_a: Free flow travel time on link a;

c_a: Capacity on link a;

x_a: Total volume on link a;

MT_m^i: Toll value on link i for mode m;

MO_m^i: Operating cost on link i for mode m.

Chapter 3. Traffic Counts and Observed Travel Time Data

3.1. Traffic Counts

The majority of the traffic counts used in the calibration of the travel demand model were collected by the Texas Department of Transportation (TxDOT) as part of the Saturation Count program. These counts were complemented by those collected by cities and other local agencies.

For the large majority of the locations, the traffic count data was available for one weekday per direction of travel at 15-minute intervals during a continuous 24-hour period. In general, the traffic counts were collected during the months when regular school activities occur, such as the months of February, March, April, May, September, and October.

The traffic count data was originally stored as a point layer referenced by the coordinates of the location where each count was collected. Later, in order to transfer the traffic count data to the roadway network, all the points were assigned to links of the network. Currently, the traffic count data is stored in the roadway network at 30-minutes intervals and by direction.

Imputation of Traffic Counts on Freeways

For the 2014 traffic count, originally, there were traffic counts on only 302 links. Because counts were available at almost 3000 ramps, it was possible to impute traffic counts for additional 1873 freeway links just by adding and subtracting the counts on successive exits and entries along large segments of freeways, after or before a location in the main lanes where a traffic count was collected. This imputation process was performed for each 30-minute interval.

Classification counts

Detailed classification counts were available for 590 links. These counts were incorporated into the roadway network considering the following basic classes:

- Light vehicles (passenger cars and motorcycles)
- Buses
- Medium Trucks (Less than 3 axles)
- Heavy trucks (Any truck with 3 axles or more)

Coverage of traffic count

The TxDOT traffic counts were collected for year 2010, 2014 and 2019, and the counts for all the three years will be compared to the model results in the following chapters. For year 2010, daily counts are much more than the time-of-day counts, and thus we only compare daily traffic for year 2010. For year 2019, one may notice that the freeway count is limited, only has 215 locations. Therefore, we include side fire device traffic count on freeway for year 2019, which has 1,108 locations. The number of observations of traffic counts for different years are summarized in Exhibit 3-1. Note that number of observations is different from count locations. At the same count location, there might be two observations, one is for AB direction and the other one is for BA direction. In such a case, it is counted as two observations.

Exhibit 3-1. Traffic count coverage for different years

Functional class	2010 TxDOT Counts (#Obs)	2014 TxDOT Counts (#Obs)	2019 TxDOT Counts (#Obs)
1	926	2,174	215
2	1,246	3,244	2,391
3	2,199	6,436	4,497
4	1,369	5,719	2,055
6	1,321	2,937	318
7	377	866	475
All Funcl	7,439	21,376	9,951

3.2. National Performance Management Research Data Set (NPMRDS)

The source of the travel time data was the National Performance Management Research Data Set (NPMRDS). These travel time data were collected by the company HERE using mobile and GPS devices for year 2014. For year 2019 the provider has been changed and the data is collected by INRIX. These data were made available by FHWA for all the roads that are part of the National Highway Systems, which includes all freeways, almost all major arterials and half of the frontage roads. FHWA provided these data at 5 minutes intervals for all days of the year.

For the purposes of the travel model calibration, the data was averaged at 30-minute intervals for the following days of the week: Tuesday, Wednesday and Thursday. Only the data for the months of February, March, April, May, September and October were considered.

The data was transferred from the speed segments of NPMRDS, defined as Traffic Message Channels (TMCs), to the model roadway network using a conflation process. Because TMCs and the roadway segments are not geographically similar, only the speed data was transferred and the travel times for each link of the roadway network was recalculated based on the length of the link.

The coverage of the travel time data is shown below.

Exhibit 3-2. The coverage of travel time

Functional Class	**Links**	**Centerline, miles**
1	3,420	1,725.6
2	3,357	1,164.7
3	1,164	393.7
4	172	31.6
6	411	139.0
7	1,894	491.9

8	1	0.6
All	10,419	3,946.9

Chapter 4. Performance Measures, Year 2014 Validation

This section compares the traffic count and model volume in base year 2014. The applied statistics includes %Error (percent error), R^2(coefficient of determination), %RMSE (percent root mean square error), and MAE (mean absolute error). They are defined as follows.

Type of Check	Specification
percent error (%Error)	$\%Error = \frac{\sum_i Model_i - \sum_i Count_i}{\sum_i Count_i} \times 100\%$
coefficient of determination (R^2)	$R = \frac{N \times \left[\sum_{i=1}^{N}(Count_i \times Model_i)\right] - \left(\sum_{i=1}^{N} Count_i\right) \times \left(\sum_{i=1}^{N} Model_i\right)}{\sqrt{\left[\left(N \times \sum_{i=1}^{N} Count_i^2\right) - \left(\sum_{i=1}^{N} Count_i\right)^2\right] \times \left[\left(N \times \sum_{i=1}^{N} Model_i^2\right) - \left(\sum_{i=1}^{N} Model_i\right)^2\right]}}$ $R^2 = R \times R$
percent root mean square error (%RMSE)	$\%RMSE = \frac{\sqrt{\frac{\sum_i (Model_i - Count_i)^2}{Number\ of\ counts}}}{\frac{\sum_i Count_i}{Number\ of\ counts}} \times 100\%$
mean absolute error (MAE)	$MAE = \frac{\sum_i \frac{Absolute(Model_i - Count_i)}{Count_i}}{Number\ of\ counts} \times 100\%$

%Error measures the difference between modeled traffic volume and traffic count, as a percentage of the traffic count. It is a useful tool for determining the precision of the modeled volume. A percentage close to zero means the modeled volume is close to the targeted value, i.e., traffic count.

Pearson's product-moment correlation coefficient (R) is a standard statistical measure. R is a dimensionless index ranging between -1.0 to 1.0 which reflects the extent of a linear relationship between modeled traffic volume and traffic count. R^2, which is also called coefficient of determination, is typically interpreted as the proportion of the variance in a dependent variable that is predictable from the independent variables. As pointed out in Cambridge Systematics (2008), "*this traditional interpretation does not hold for traffic assignment validation since the modeled traffic assignment is not dependent on the traffic count, or vice versa…In effect, R squared has been assumed to be a measure of the amount of variation in traffic counts "explained" by the model.*"

%RMSE is a measure of accuracy of the traffic assignment measuring the average error between the observed traffic count and modeled traffic volumes. For comparison purpose, %RMSE should be aggregated by functional class or by link volume group, or by geographical region. In Cambridge

Systematics (2008), there are standard of %RMSE aggregated by volume group, which is compared against the modeled traffic volume in TAFT.

Mean absolute error (MAE), or sometimes also known as mean absolute percentage error, or mean absolute percentage deviation, is a measure of accuracy of the traffic volume forecasted by the assignment method. It measures the size of the error in percentage terms. It is calculated as the average of the unsigned percentage error. MAE should not be used when traffic count value is small, since traffic count is in the denominator of the equation, the MAE will often take on extreme high value when count is close to zero. This scale sensitivity renders the MAE close to worthless as an error measure for low-volume data.

4.1 Volume over Count, by Functional Class and Time-of-Day

The model comparisons by functional class for daily traffic is tabulated in Exhibit 4-1. In Cambridge Systematics, Inc. (2008), it gave a benchmark of volume-over-count percent error, as shown in Exhibit 4-2. %Error for freeway and principal arterial is 0.61% and -0.86% respectively, which is fairly good for a regional model compared with the standard, which is +/- 7% for freeway and +/- 10% for principal arterial in Exhibit 4-2. Minor arterial %Error is 7.03%, and collector is -14.02%. They beat the standard which is +/- 15% and +/- 25% respectively. This tells the minor arterial and collectors with low volumes are hard to match, particularly for collectors. It is usually believed that a regional model should not be of concern for collectors, whose traffic volumes in the model are easily changed significantly with change of locations and connectivity of centroid connectors. In a summary, the performance measures are fairly well for freeway and arterials, and become worse on collectors. %RMSE is a measure of dispersion and tends to normalize model error better than volume-over-count ratios (%Error) that allow for high ratios to offset low ratios. For overall %RMSE, most documents focusing on the US applications recommend values of 30 and 40 (Cambridge Systematics, Inc., 2018). Several cases accept as high as 50 percent areawide %RMSE. In TAFT, for daily traffic, %RMSE is 19.95% for freeway, and is 47.94% for all functional classes. Only freeway satisfies this standard. For freeway ramps, %Error is 2.82% and %RMSE is 72.92%; for frontage road, %Error is -12.18% and %RMSE is 78.02%. The accuracy of freeway ramp is fairly good, and of frontage road becomes worse in the model.

Exhibit 4-1. Model comparisons by functional class

Funcl	**2014 Day**				
	#obs	**%Error**	**R^2**	**%RMSE**	**MAE(%)**
1	2,174	0.61	0.88	19.95%	16.32%
2	3,244	-0.86	0.43	46.39%	45.50%
3	6,436	7.03	0.44	62.35%	58.20%
4	5,719	-14.20	0.32	87.75%	90.32%
6	2,937	2.82	0.57	72.92%	69.47%
7	866	-12.18	0.51	78.02%	110.58%

Funcl	2014 Day				
	#obs	%Error	R^2	%RMSE	MAE(%)
All	21,376	0.46	0.89	47.94%	64.28%

Exhibit 4-2. Standards of volume-over-count percent error

Standards	Statistic Acceptable	Preferable
Freeway volume over count	+/- 7%	+/-6%
Principal arterial volume over count	+/- 10%	+/-10%
Minor arterial volume-over-count	+/- 15%	+/-10%
Collector volume-over-count	+/- 25%	+/-20%
Frontage Road volume-over-count	+/- 25%	+/-20%

Model comparison by functional class for time of day is summarized in Exhibit 4-2 to 4-4. The results by time of day are similar to that of daily. From percent error (%Error) standpoint, the model has a fairly good match to traffic counts for freeway and principal arterials. Although the error for minor arterials and collectors is larger, the PM and OP time periods meet the preferable standard of +/- 10% and +/- 20%. AM minor arterial meets accepted standard of +/- 15%, and AM collector meets preferable standard of +/- 20%. The freeway ramp is fairly well within the range of 5%. On frontage roads, the percent error is within the range of +/- 15%, which meets the standard of +/- 25%.

From %RMSE standpoint, freeway has the best result, about 25%. It is followed by principal arterial, about 50%. On minor arterials, %RMSE is about 60% to 75%. On collectors, %RMSE is about 85% - 100%. On the high-volume links, %RMSE is small, and on the low volume links, %RMSE becomes large. Thus, it is more desirable to match traffic volume on high volume links than on low volume links.

Exhibit 4-3. Model comparison by functional class AM

Funcl	2014 AM				
	#obs	%Error	R^2	%RMSE	MAE(%)
1	2,175	-2.16%	0.84	24.51%	21.63%
2	2,074	2.36%	0.53	54.65%	59.24%
3	4,109	14.35%	0.54	75.23%	70.53%

Funcl	2014 AM				
	#obs	%Error	R^2	%RMSE	MAE(%)
4	4,572	-9.71%	0.35	91.01%	102.63%
6	2,948	4.74%	0.53	81.27%	89.58%
7	871	-5.17%	0.54	85.05%	194.25%
All	16,776	2.18%	0.85	56.65%	80.16%

Exhibit 4-4. Model comparison by functional class PM

Funcl	2014 PM				
	#obs	%Error	R^2	%RMSE	MAE(%)
1	2,174	2.11%	0.84	22.64%	18.59%
2	2,073	-1.66%	0.46	46.12%	56.31%
3	4,111	2.75%	0.47	60.51%	59.78%
4	4,595	-19.36%	0.32	86.41%	94.25%
6	2,956	3.69%	0.51	76.96%	81.57%
7	876	-11.45%	0.50	79.05%	130.18%
All	16,785	-0.44%	0.87	50.16%	70.28%

Exhibit 4-5. Model comparison by functional class OP

Funcl	2014 OP				
	#obs	%Error	R^2	%RMSE	MAE(%)
1	2,174	0.78%	0.84	24.69%	19.55%
2	2,074	-1.37%	0.36	53.68%	66.81%
3	4,115	7.09%	0.36	74.11%	67.89%
4	4,699	-12.34%	0.29	101.99%	108.31%
6	2,976	2.05%	0.54	82.36%	79.85%
7	881	-13.83%	0.46	89.87%	228.45%
All	16,919	0.47%	0.86	56.93%	82.11%

Scatterplots of modeled traffic volumes versus the observed traffic counts are useful validation tools. The scatter plots for all links and functional class for daily and time of day are plotted in Exhibit 4-6 to 4-33. The plots variations between the modeled traffic and counts. Overall, they exhibit the similar trend as analyzed before. It has a good match with traffic counts for all links, freeway, and principal arterials. The variation in the scatter plots becomes large on those low-volume counts, including minor arterials, collectors, freeway ramps and frontage road.

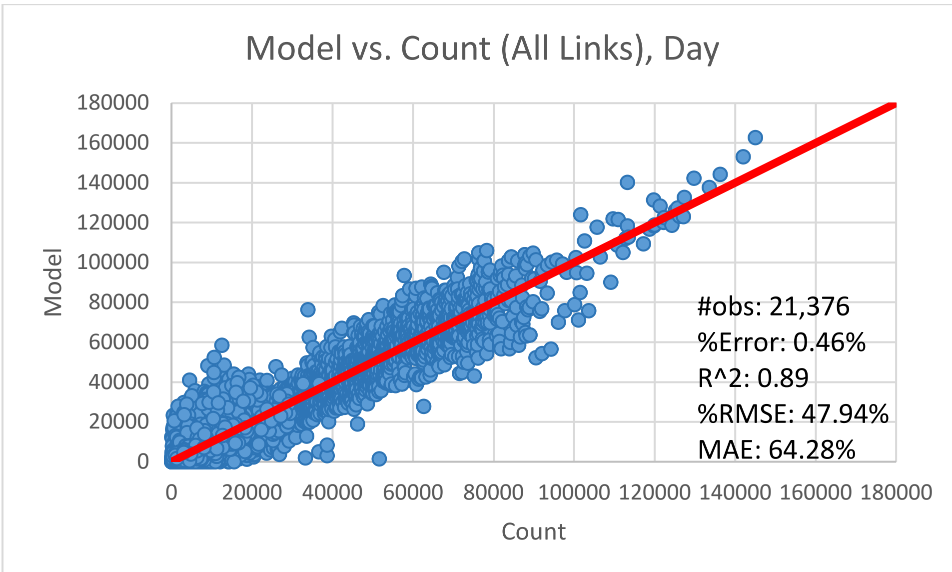

Exhibit 4-6. Scatter plot for all links, day

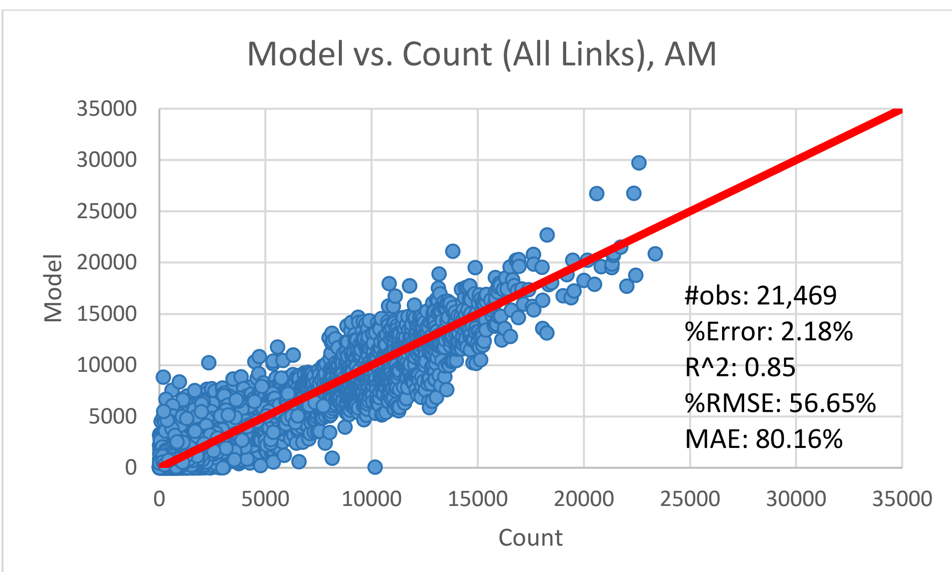

Exhibit 4-7. Scatter plot for all links, AM

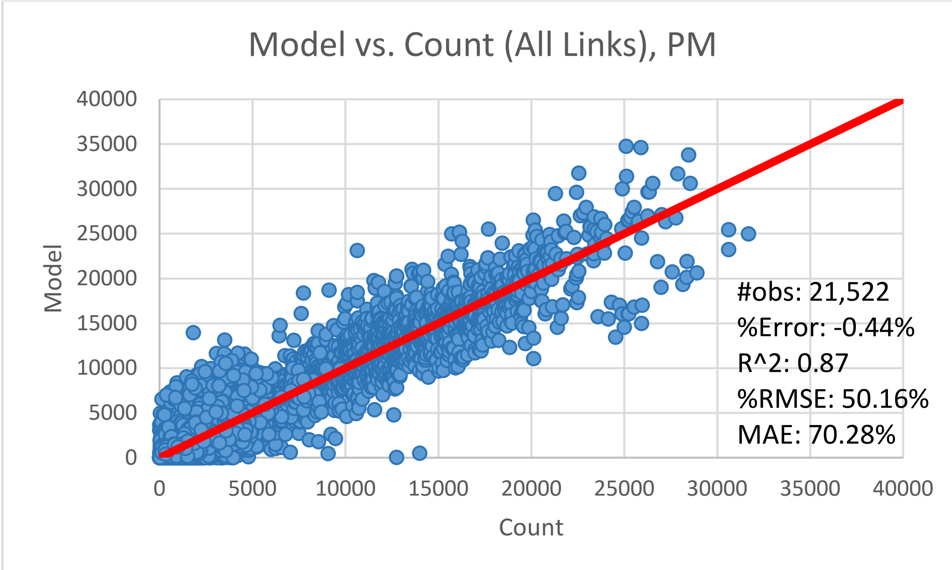

Exhibit 4-8. Scatter plot for all links, PM

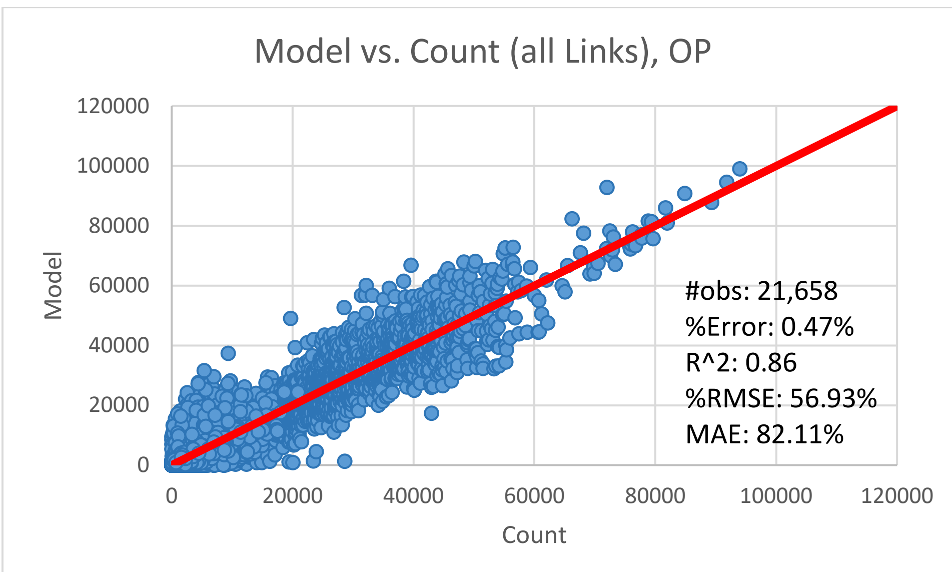

Exhibit 4-9. Scatter plot for all links, OP

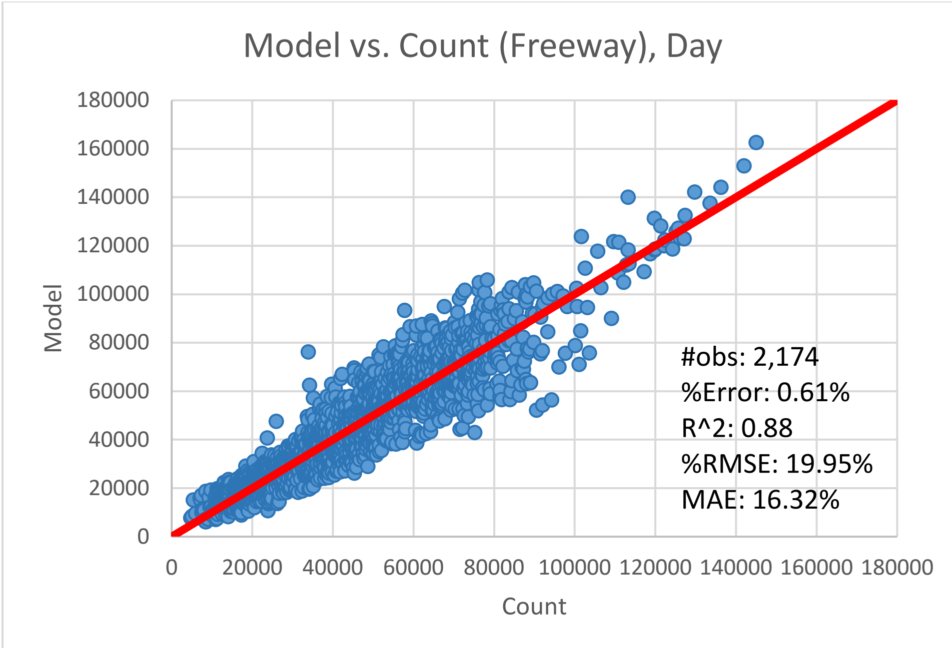

Exhibit 4-10. Scatter plot for freeway, day

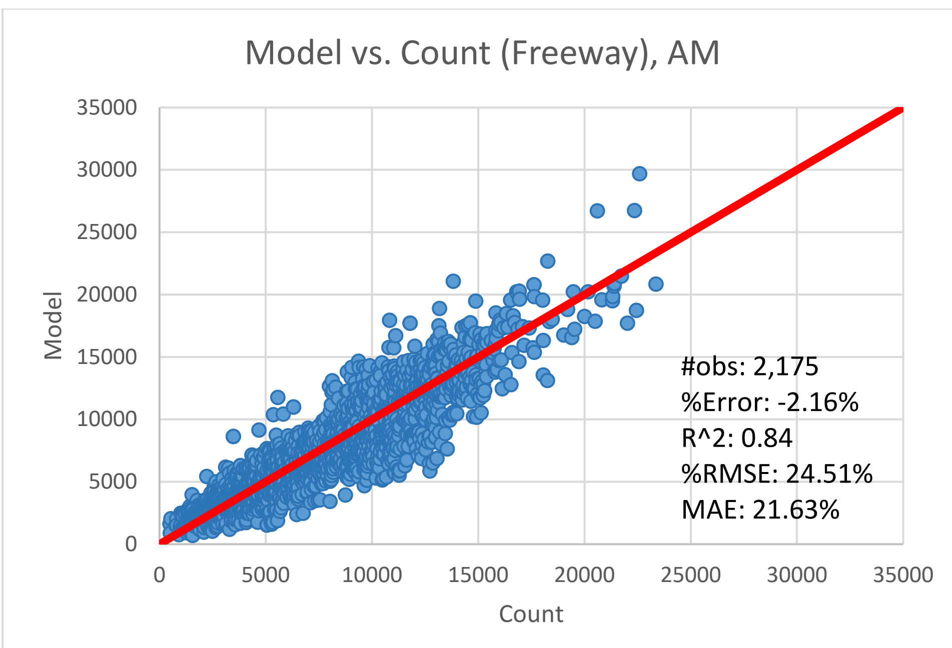

Exhibit 4-11. Scatter plot for freeway, AM

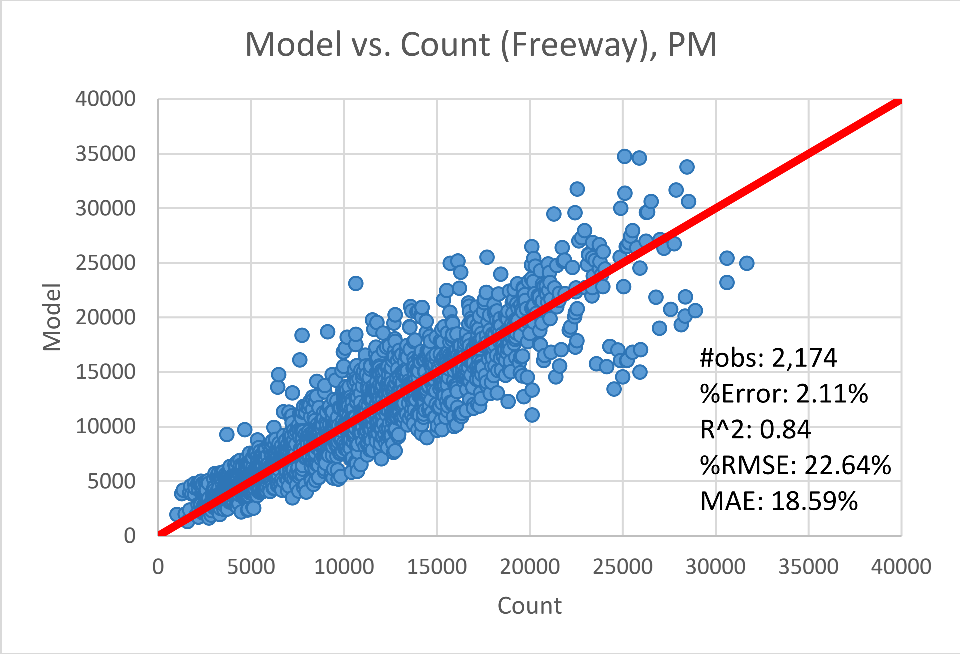

Exhibit 4-12. Scatter plot for freeway, PM

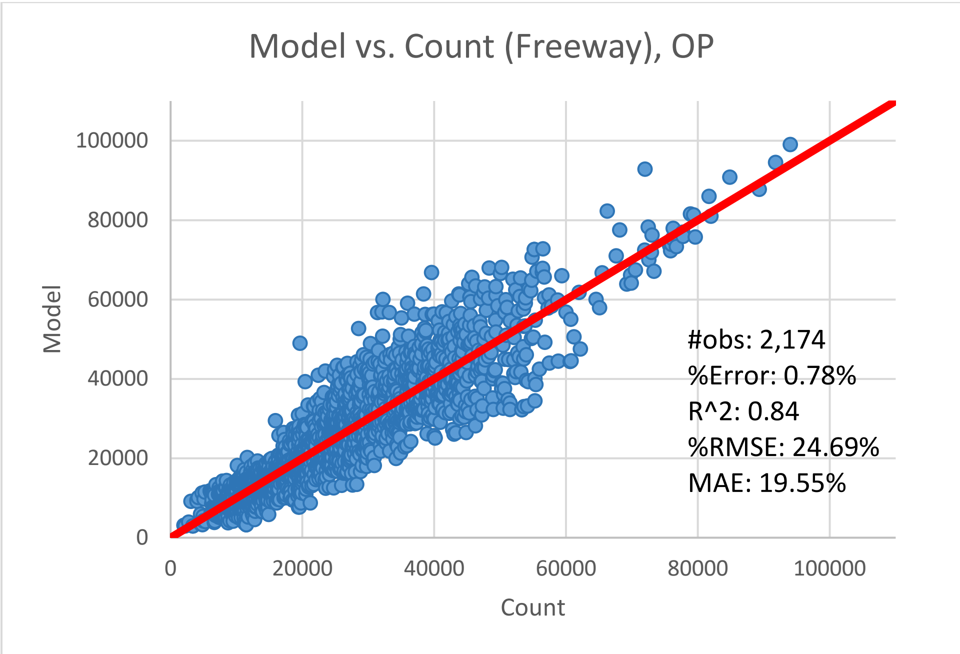

Exhibit 4-13. Scatter plot for freeway, OP

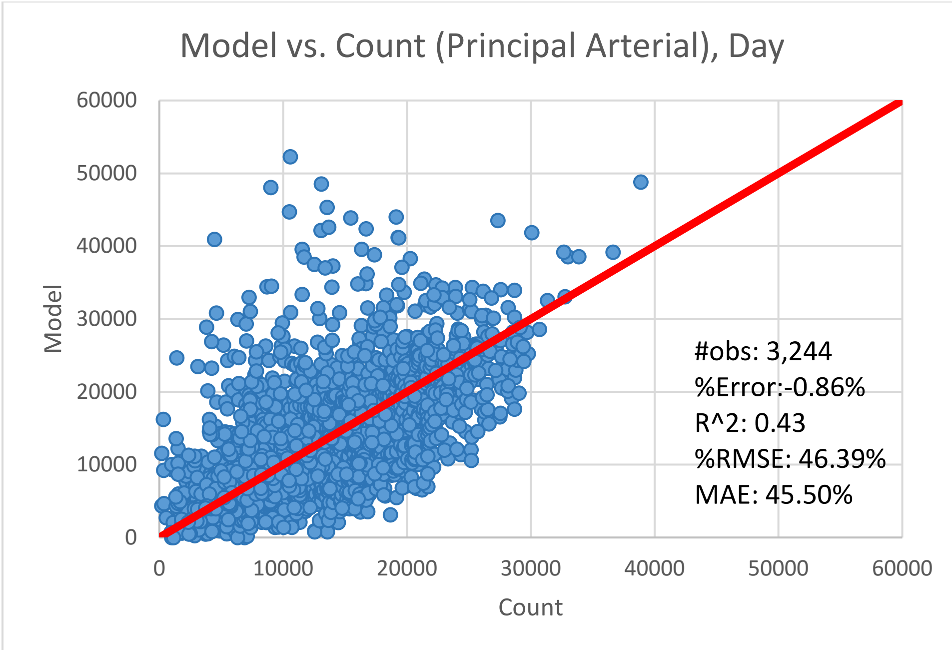

Exhibit 4-14. Scatter plot for principal arterial, day

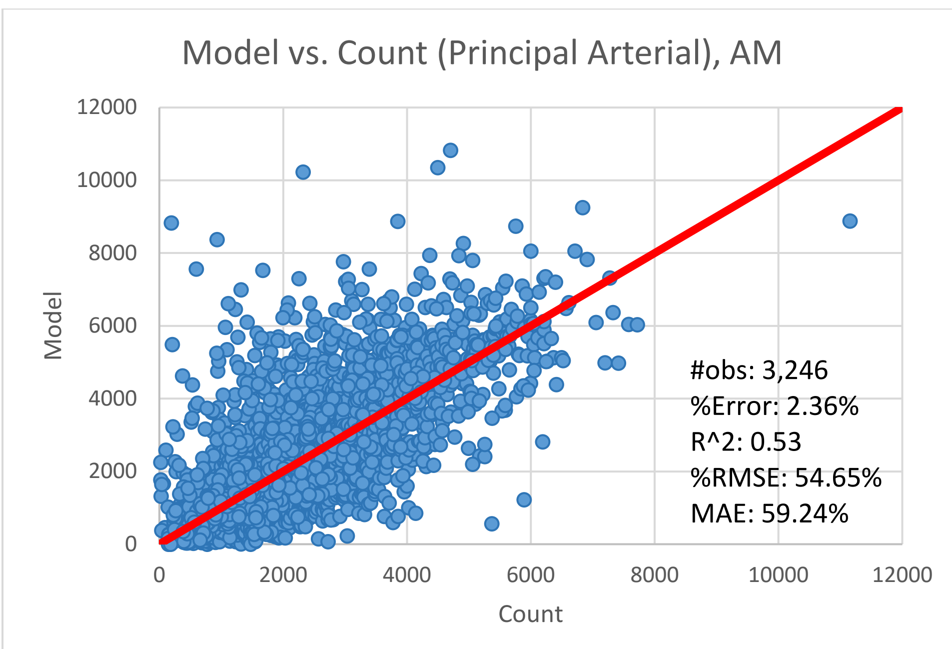

Exhibit 4-15. Scatter plot for principal arterial, AM

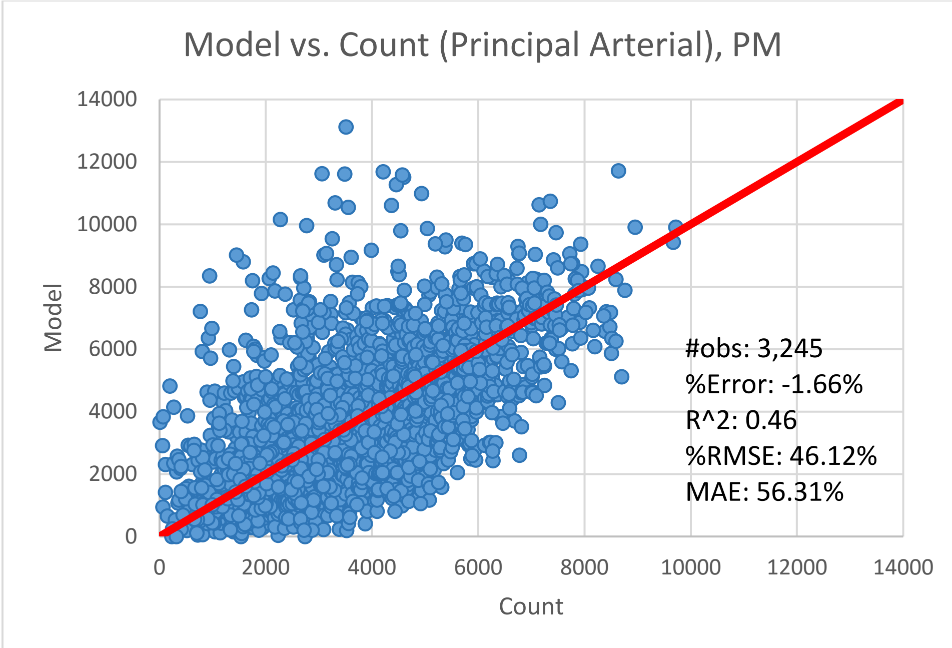

Exhibit 4-16. Scatter plot for principal arterial, PM

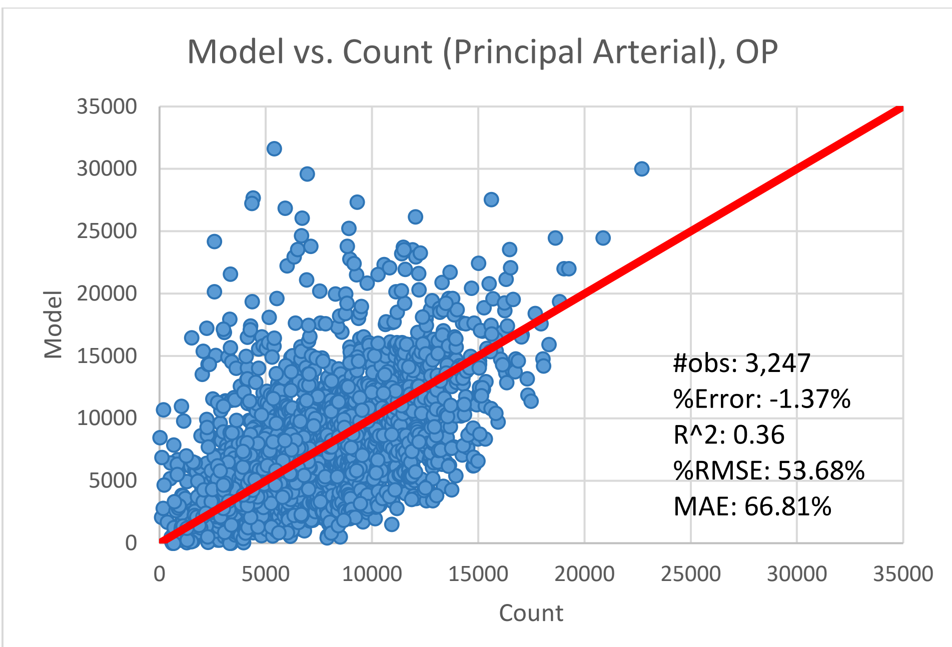

Exhibit 4-17. Scatter plot for principal arterial, OP

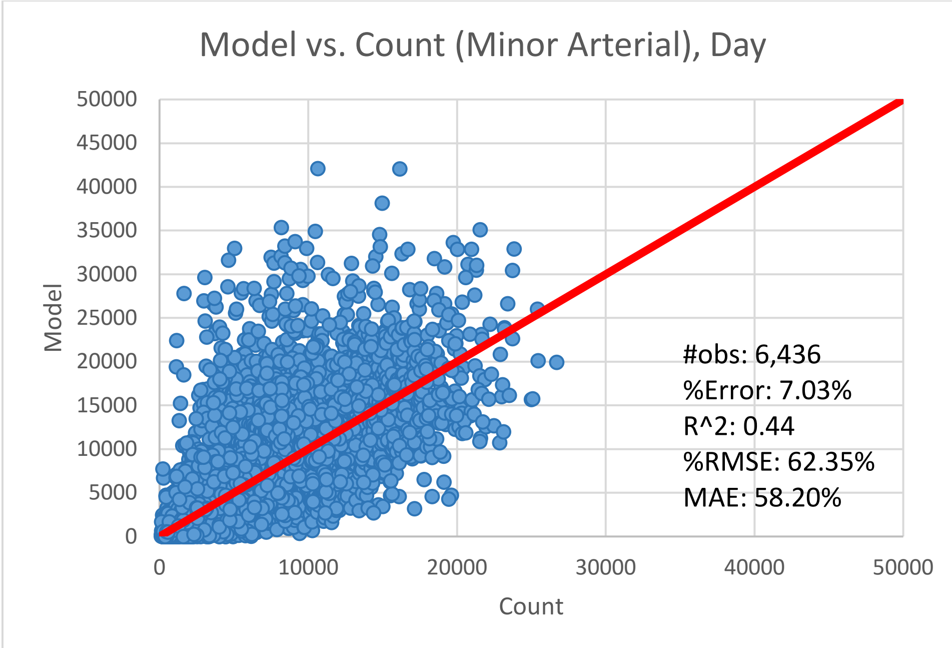

Exhibit 4-18. Scatter plot for minor arterial, day

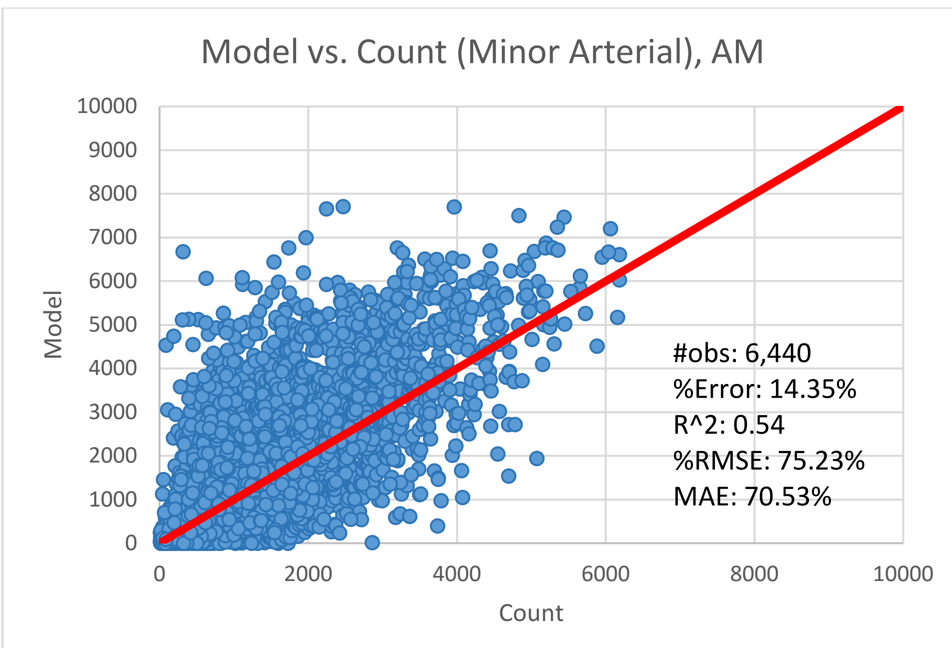

Exhibit 4-19. Scatter plot for minor arterial, AM

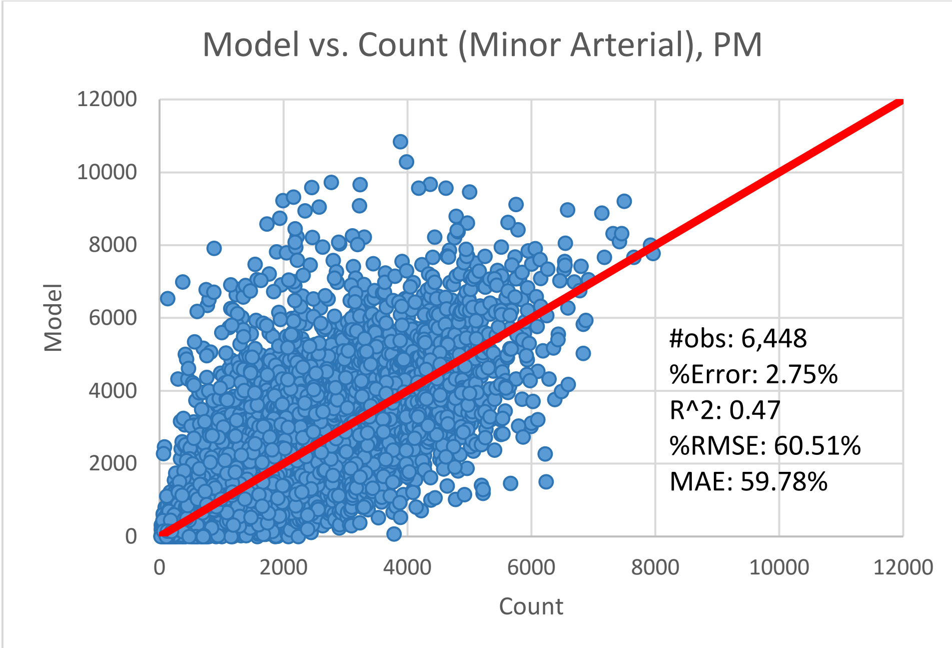

Exhibit 4-20. Scatter plot for minor arterial, PM

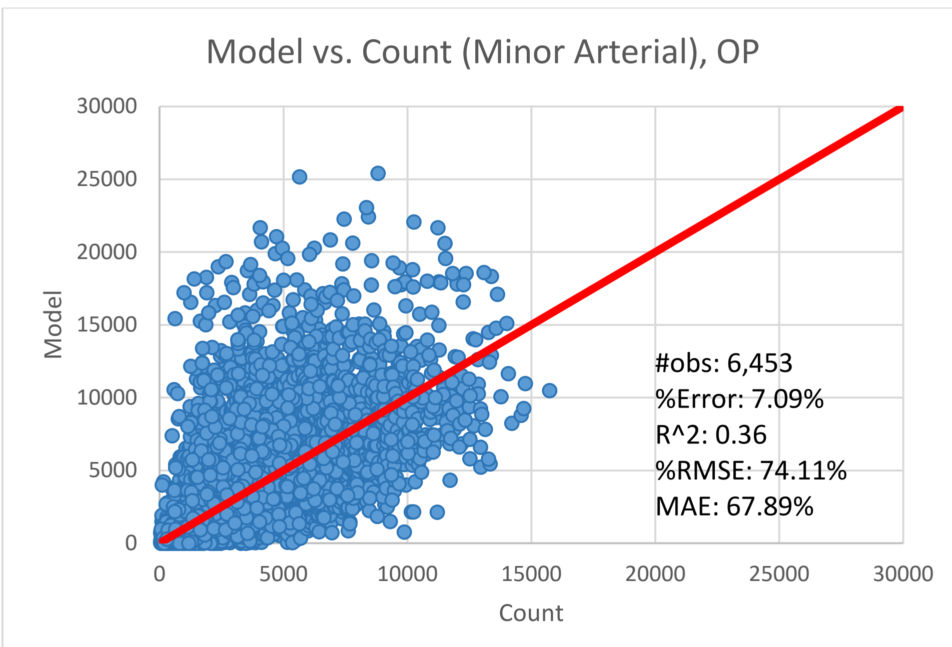

Exhibit 4-21. Scatter plot for minor arterial, OP

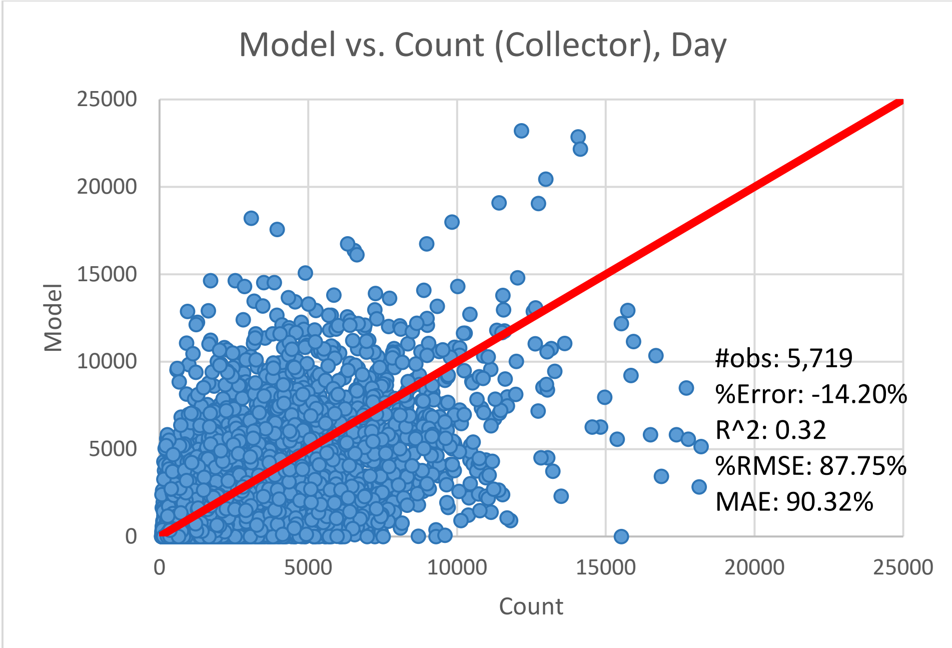

Exhibit 4-22. Scatter plot for collector, day

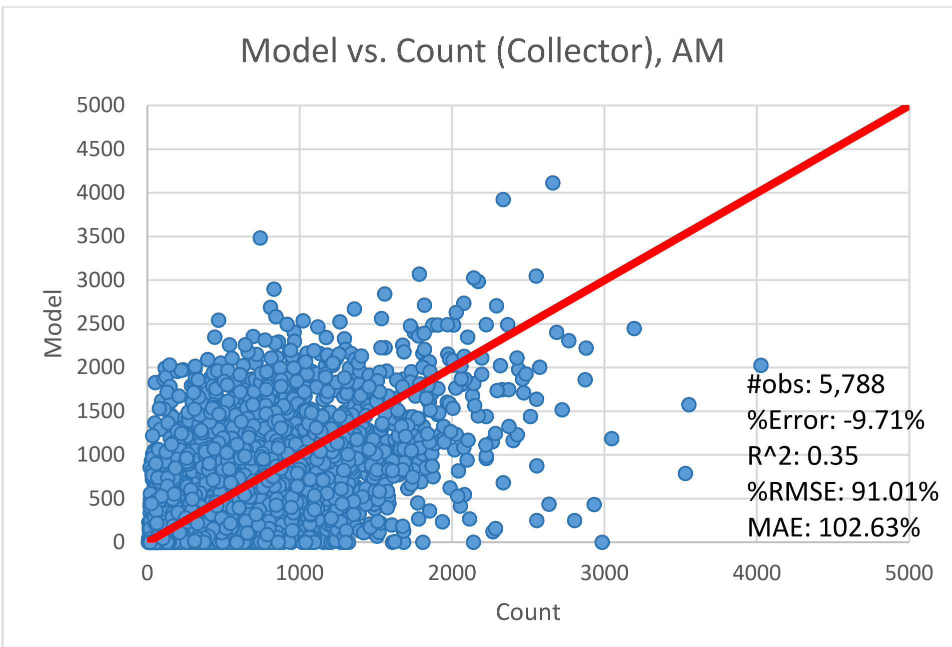

Exhibit 4-23. Scatter plot for collector, AM

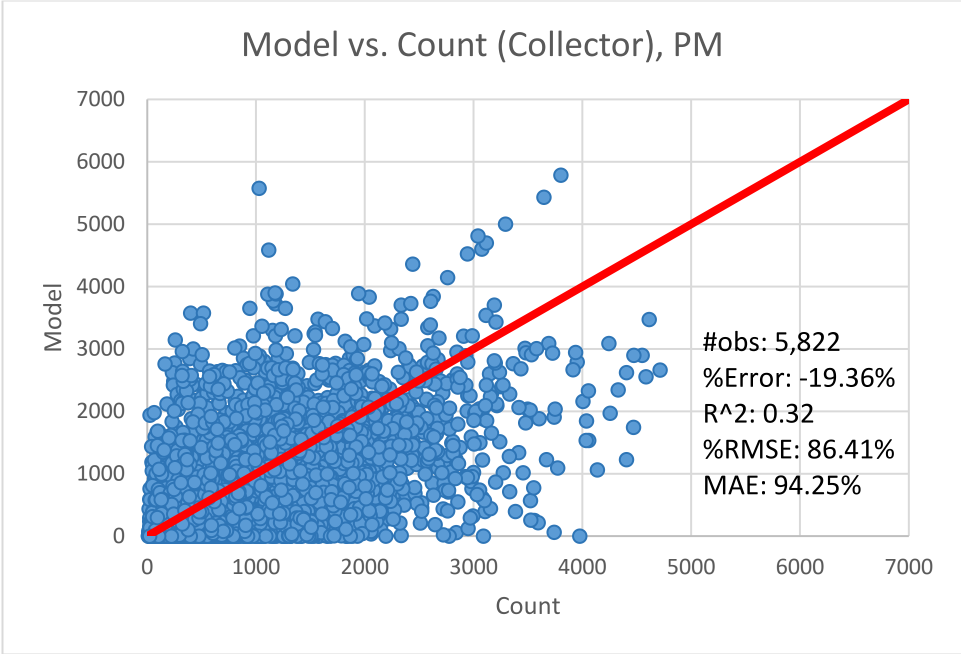

Exhibit 4-24. Scatter plot for collector, PM

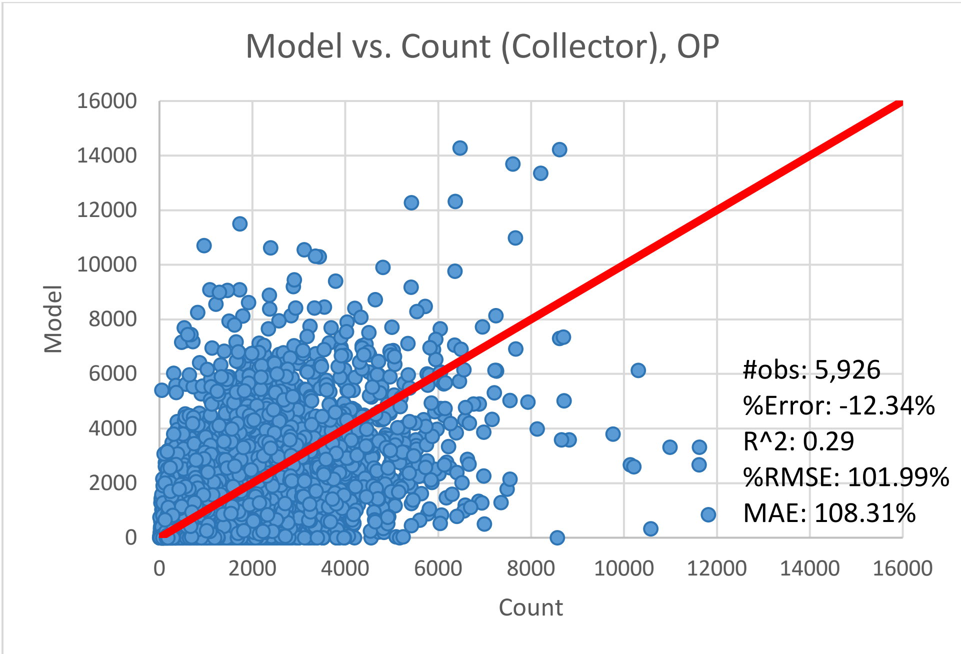

Exhibit 4-25. Scatter plot for collector, OP

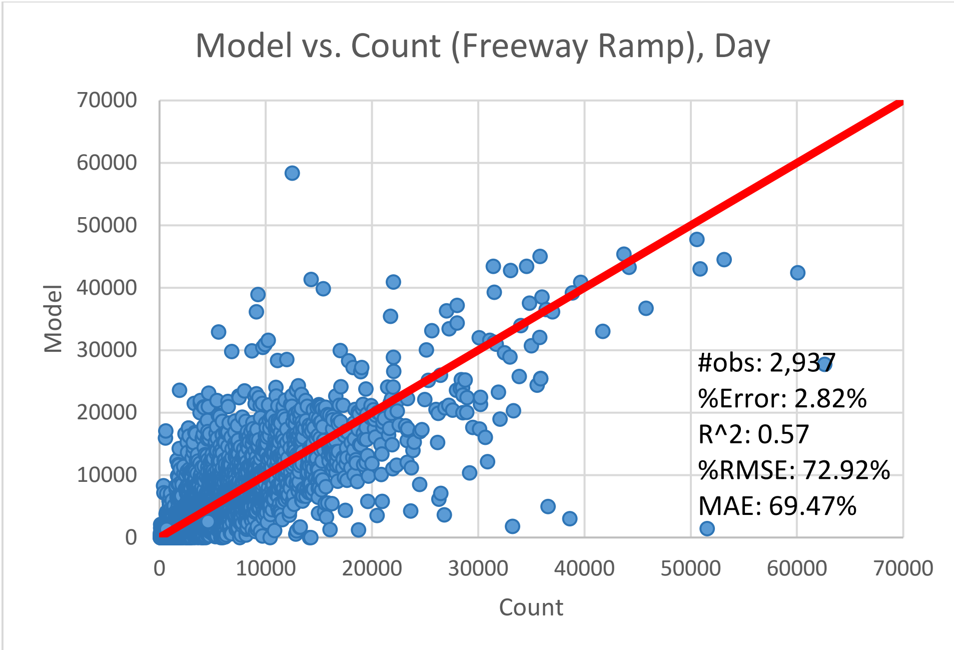

Exhibit 4-26. Scatter plot for freeway ramp, day

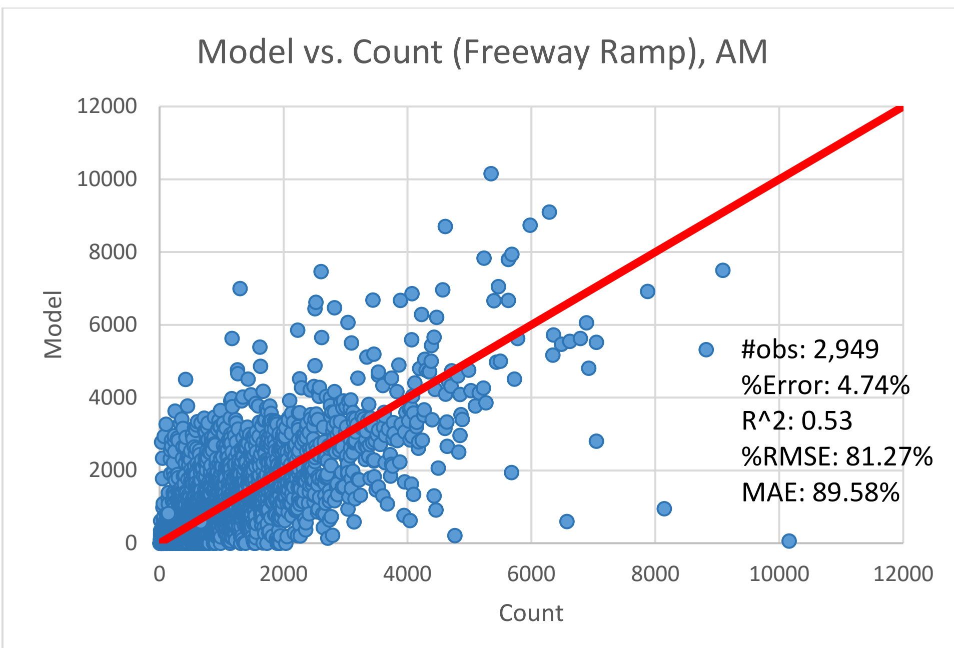

Exhibit 4-27. Scatter plot for freeway ramp, AM

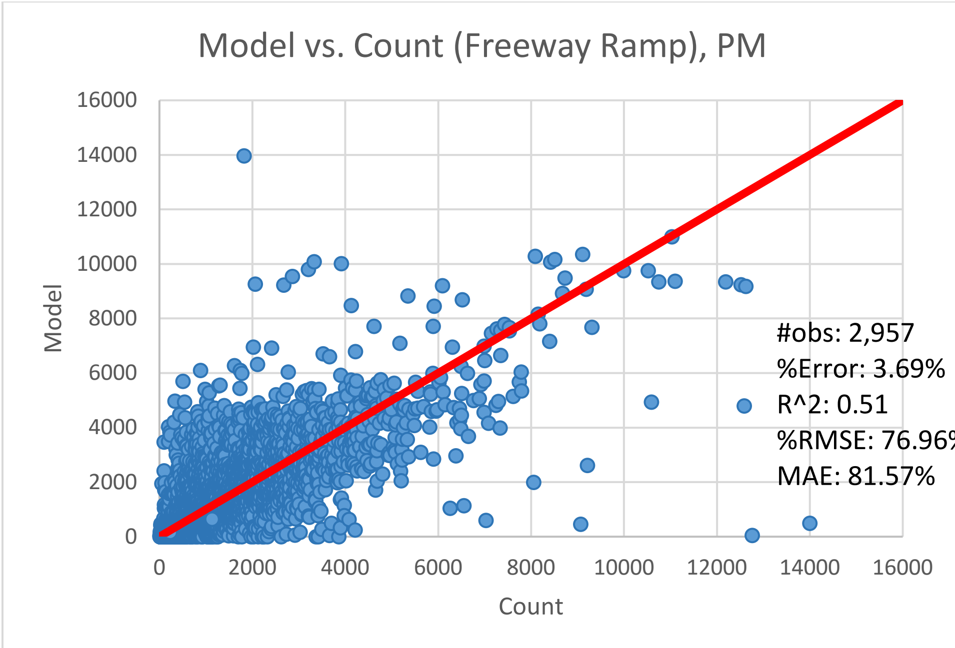

Exhibit 4-28. Scatter plot for freeway ramp, PM

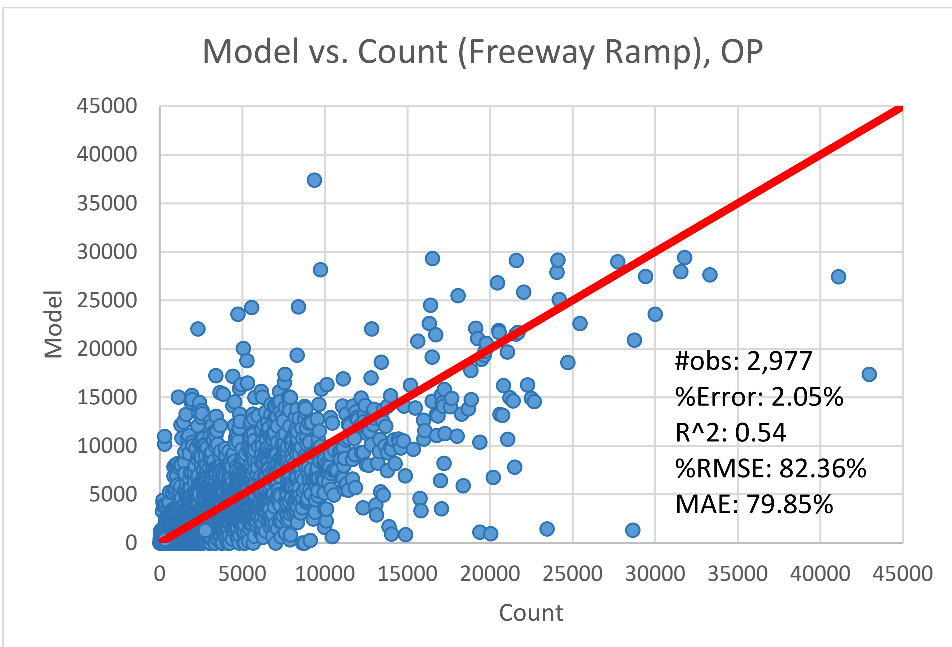

Exhibit 4-29. Scatter plot for freeway ramp, OP

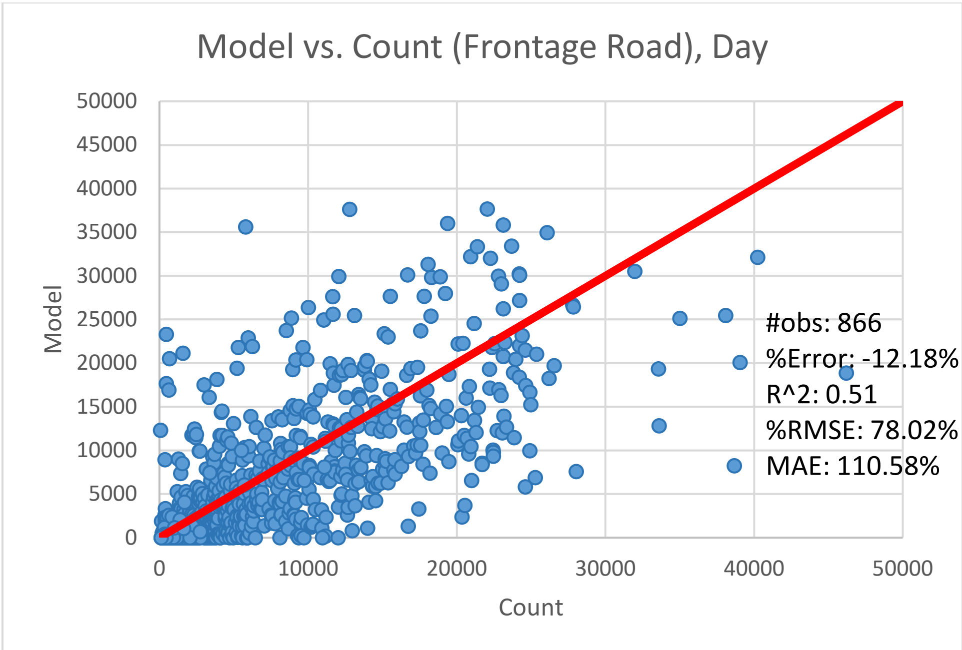

Exhibit 4-30. Scatter plot for frontage road, day

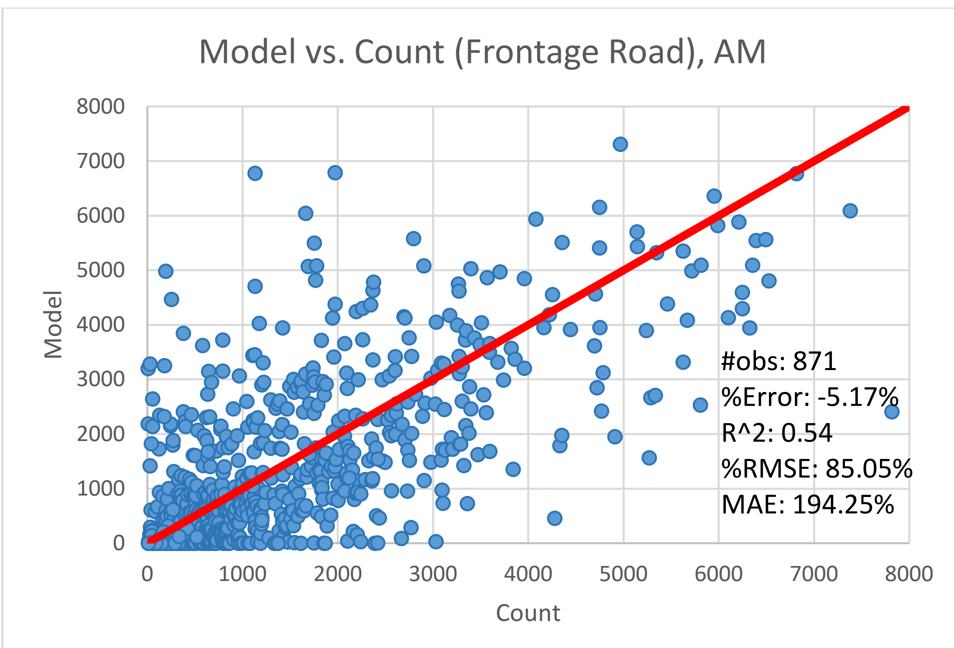

Exhibit 4-31. Scatter plot for frontage road, AM

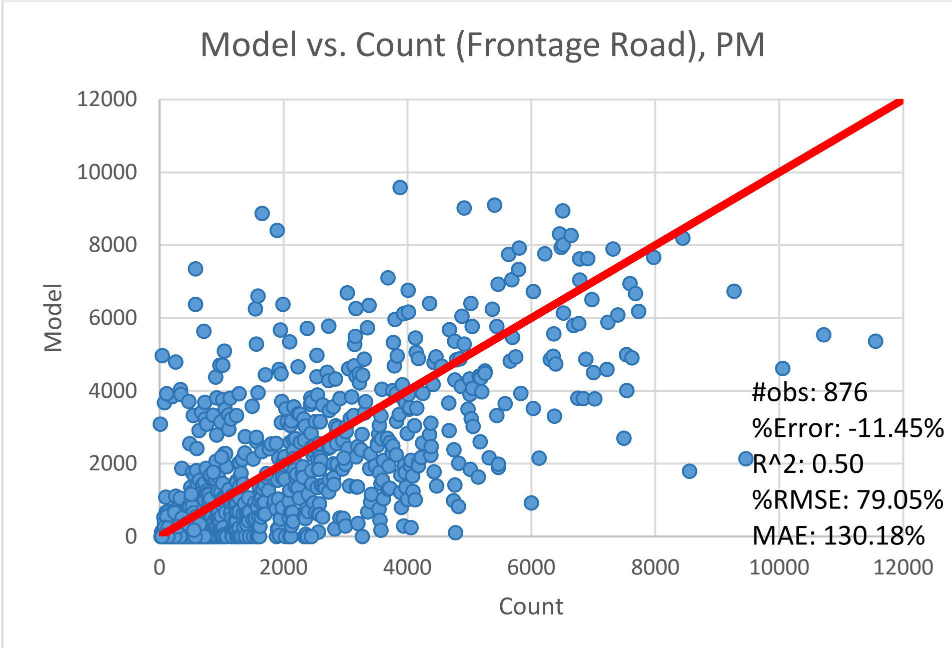

Exhibit 4-32. Scatter plot for frontage road, PM

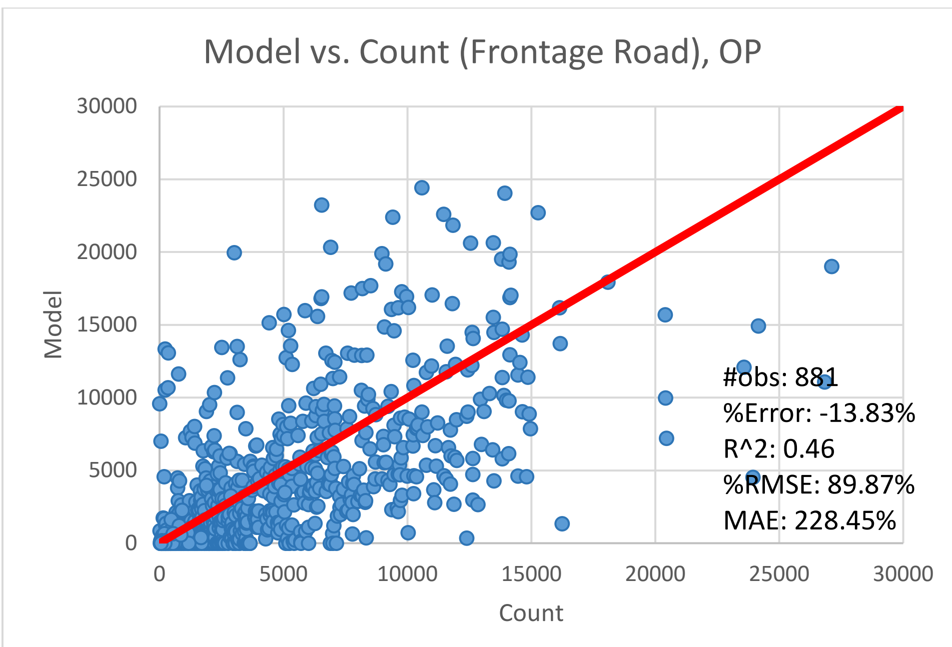

Exhibit 4-33. Scatter plot for frontage road, OP

4.2 %Error vs. %Link

This section examines the relationship between cumulative percentage link and absolute error for daily volume on two types of roads—freeway and principal arterial. The cumulative percentage link vs absolute percentage error for daily volume on freeway is in Exhibit 4-34. It shows 40% freeway links are with error +/-10%; 70% links have error +/-20%; and 85% links have error +/-30%.

The percentage link vs absolute percentage error for daily volume on freeway is in Exhibit 4-35. Compared with Exhibit 4-34, this figure plots %link vs each absolute %error interval. It shows 20% freeway links are with error +/-5%; and 20% links have error -10% to -5% and 5% to 10%. There are 18% links have error -15% to -10% and 10% to 15%; 12% links have error -20% to -15% and 15% to 20%.

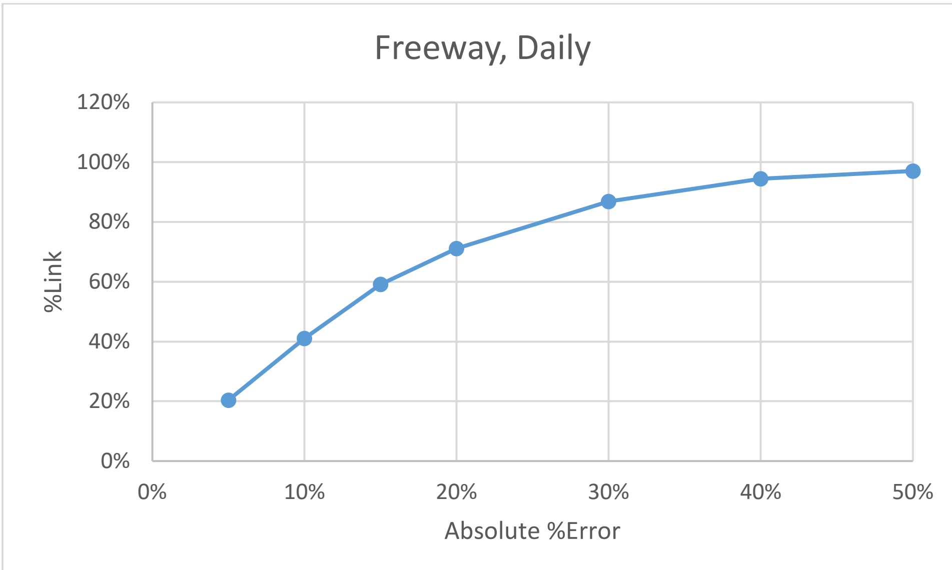

Exhibit 4-34. Cumulative Percentage Link vs. Absolute %Error, Freeway, Daily

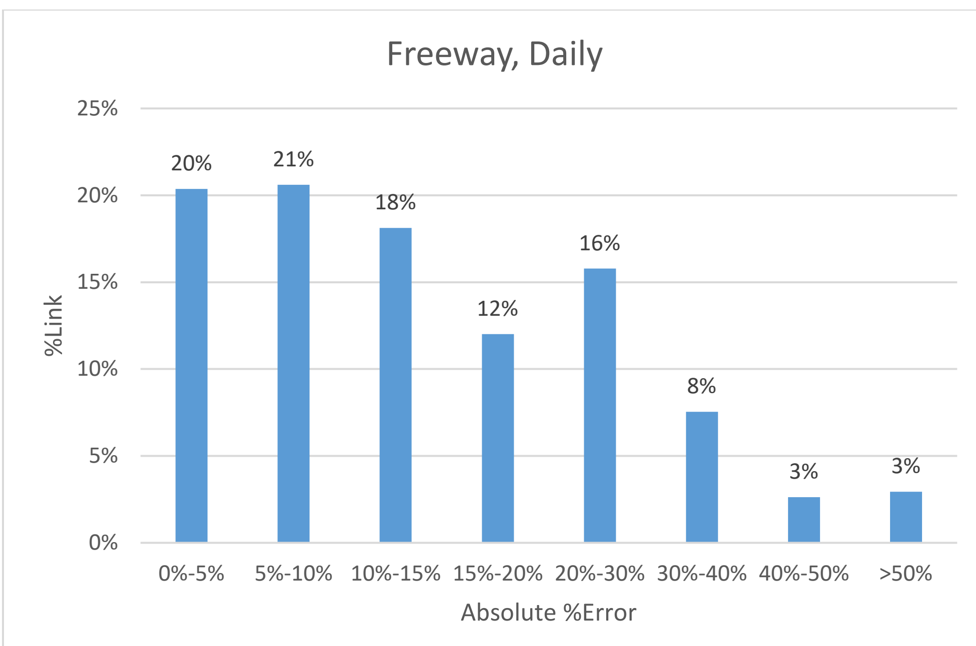

Exhibit 4-35. Percentage Link vs. Absolute %Error, Freeway, Daily

On principal arterials, the cumulative percentage of links vs absolute percentage error for daily volume is in Exhibit 4-36. It shows 40% arterial links are with error +/-20%; 55% links have error +/-30%; and 77% links have error +/-50%.

The percentage link vs absolute percentage error for daily volume on principal arterial is in Exhibit 4-37. It shows 10% links are with error +/-5%; and another 10% links have error -10% to -5% and 5% to 10%. There are 9% links have error -15% to -10% and 10% to 15%; and another 9% links have error -20% to -15% and 15% to 20%.

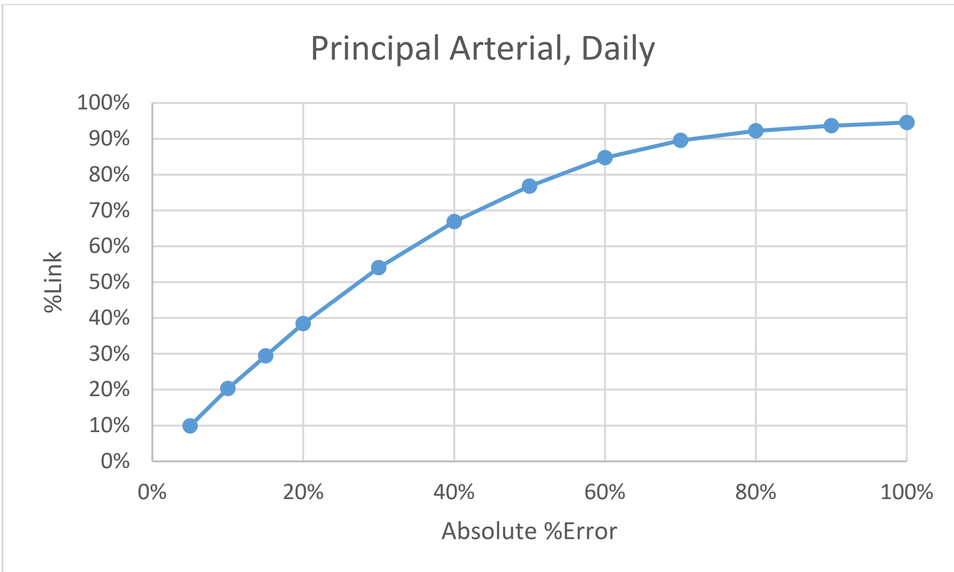

Exhibit 4-36. Cumulative Percentage Link vs. Absolute %Error, Principal Arterial, Daily

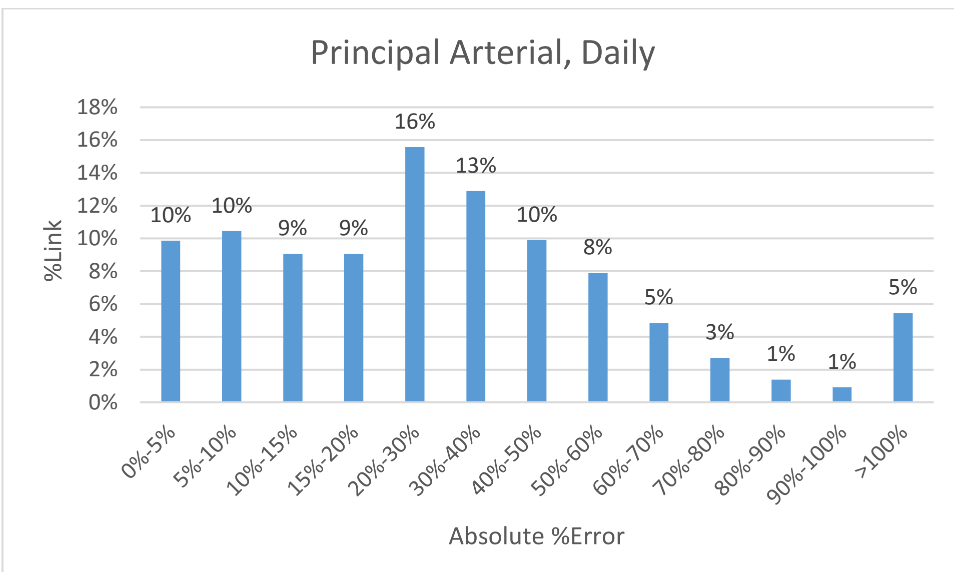

Exhibit 4-37. Percentage Link vs. Absolute %Error, Principal Arterial, Daily

4.3 Toll Roads

The comparison of the four key performance measures for toll roads is tabulated in Exhibit 4-38. A series of scatter plots between the modeled traffic volumes and the observed traffic counts for toll roads are in Exhibit 4-39 -4-42. Exhibit 4-39 is for daily traffic and Exhibits 4-40-4-42are by time of day. There are 358 observations on roads operated by the North Texas Tollway Authority (NTTA). The %error daily is -0.85%; AM is -1.83%; PM is -1.73%; and OP is -0.03%. Overall %error is within the range of +/- 2%. R^2 daily is 0.85; AM is 0.78; PM is 0.84; and OP is 0.77. Overall R^2 for daily and time of day are greater than 0.75. The %RMSE for daily is 17%; AM is 21%; PM is 16%; and OP is 25%. Overall %RMSE are within the range of +/- 30%. The MAE for daily is 15%, AM is 21%, PM is 15%, and OP is 22%. Overall MAE are within the range of +/- 25%. In general, the statistics for daily is best, PM is slightly worse, the next is AM, then OP.

Exhibit 4-38. Model comparison for toll road by time of day and day

Toll Road	AM	PM	OP	Day
#obs	358	358	358	358
%Error	-1.83%	-1.73%	-0.03%	-0.85%
R^2	0.78	0.84	0.77	0.85
%RMSE	21.04%	15.71%	25.42%	16.52%
MAE (%)	20.81%	14.88%	22.47%	15.28%

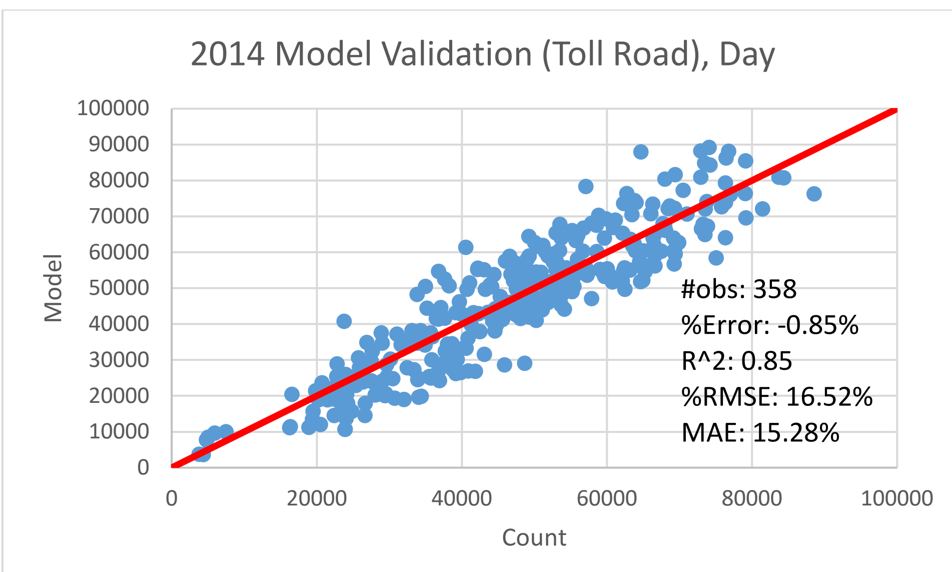

Exhibit 4-39. Scatter plot for toll road, day

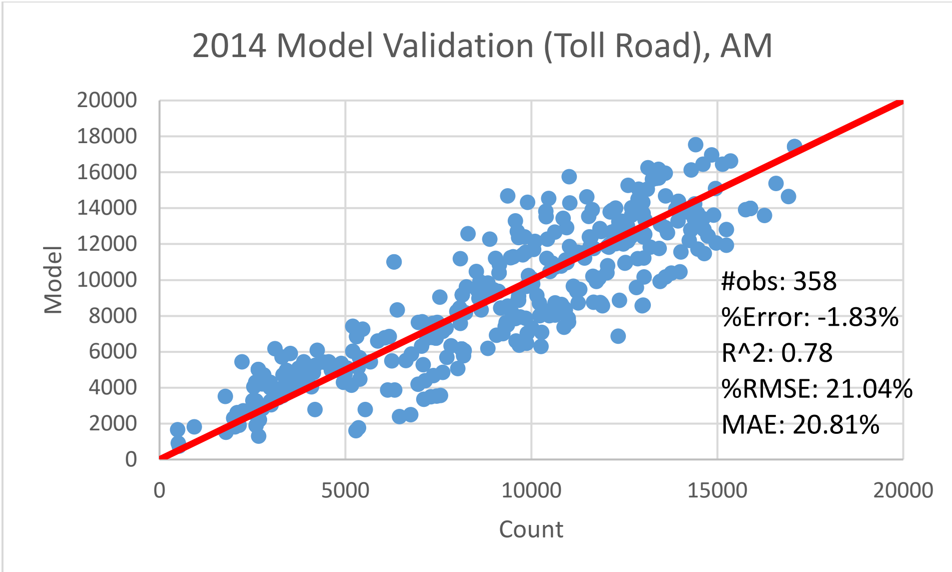

Exhibit 4-40. Scatter plot for toll road, AM

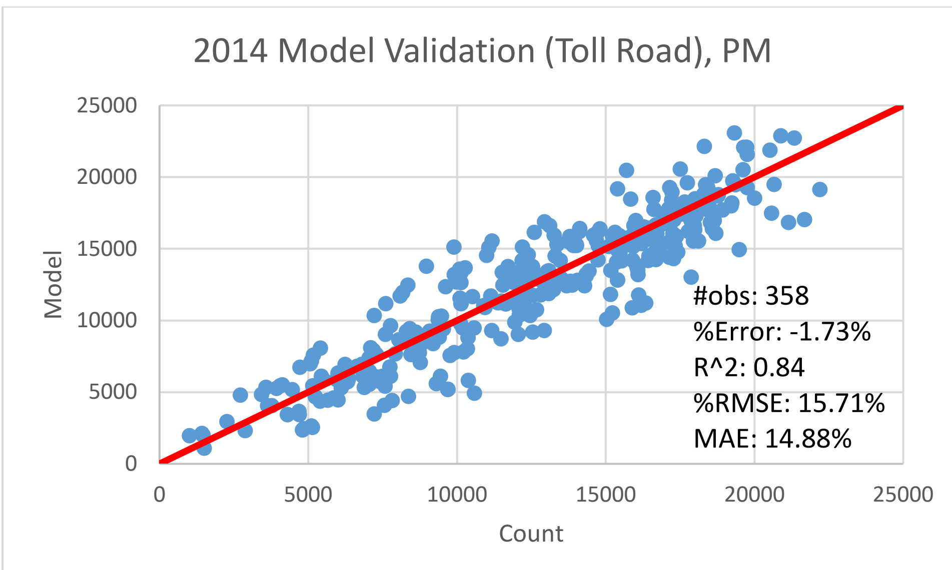

Exhibit 4-41. Scatter plot for toll road, PM

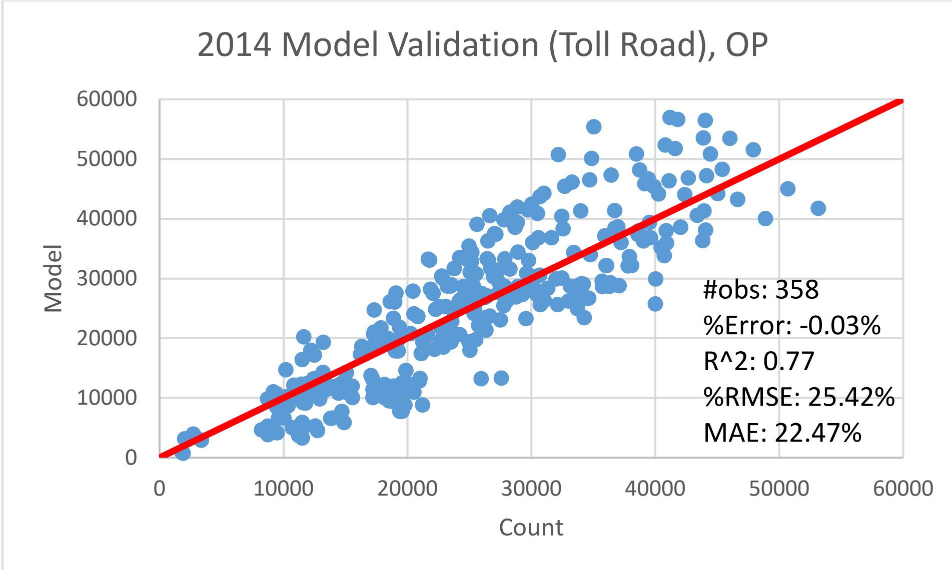

Exhibit 4-42. Scatter plot for toll road, OP

4.4 Model Comparison by Area Type

In TAFT, trip attraction model is a cross-classification model by area type and employment type. The area type is defined in Exhibit 4-43 and its geographic region is show in Exhibit 4-44.

Exhibit 4-43. Area type definition

Area Type	Description
1	Central Business District
2	Outer Business District
3	Urban Residential
4	Suburban Residential
5	Rural

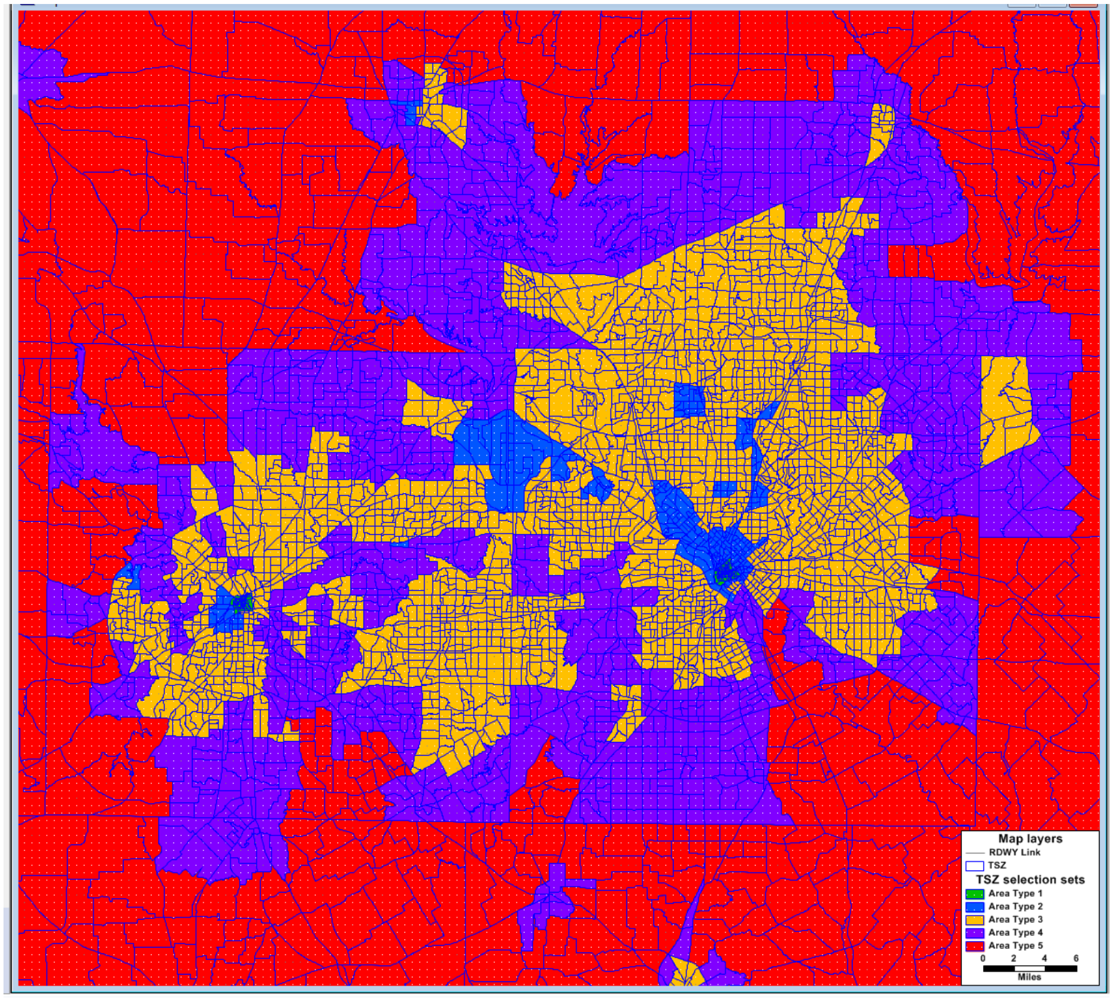

Exhibit 4-44. Area type map

The model comparison by area type for daily traffic is shown in Exhibit 4-45. The statistics, including %error, %RMSE and MAE are all high in Area Type 1; this indicating the model may have internal issues at the trip level. This is suspicious and deserves further investigation. For Area Type 2, %error is 30%, %RMSE is 56%, and MAE is 97%. Those statistics are in the normal range. MAE is much higher than %RMSE indicates that low-volume data is volatile. Most counts are located in Area Type 3, 4 and 5, and the performance measures are better than Area Type 1 and 2. For Area Type 3, 4 and 5, %error is within +/- 8%; %RMSE is around 40%-50%, and MAE is about 50% - 80%.

Exhibit 4-45. Model comparison by area type, day

Area Type	2014 Day				
	#obs	%Error	R^2	%RMSE	MAE
1	162	126.51%	0.67	170.09%	222.52%
2	1,084	29.96%	0.94	56.39%	96.70%

Area Type	2014 Day				
	#obs	%Error	R^2	%RMSE	MAE
3	9,641	-0.07%	0.95	42.32%	55.80%
4	5,611	-7.85%	0.94	44.87%	55.03%
5	4,878	-3.65%	0.94	48.79%	79.22%

The %error is compared by area type and by functional class in Exhibit 4-46. In Area Type 1, all functional classes are high. Freeway is 22% high; with even higher errors on arterials. Again it indicates the model may contain internal issue in the trip table for Area Type 1, which deserve further investigation. For Area Type 2, the %error is also high, not as high as in Area Type 1 but still significant. The daily traffic is overestimated in Area Type 2. For Area Type 3, 4 and 5, %error is within +/-10% on freeway and arterials. On collectors, %error is around 20%. On frontage road, %error is around 35%.

Exhibit 4-46. %Error comparison by area type by functional class, day

Functional Classes		Area Type				
		1	2	3	4	5
1	Freeway	22.66	8.58	0.51	-2.27	1.48
2	Principal Arterial	143.86	39.77	-3.25	-7.88	-7.09
3	Minor Arterial	202.84	69.00	5.18	-8.66	-0.23
4	Collector	90.24	40.43	-14.93	-21.27	-20.62
6	Freeway Ramp	60.85	38.25	2.35	-11.36	-11.57
7	Frontage Road	126.96	16.61	-3.32	-33.16	-35.30

The %RMSE is compared by area type and by functional class for daily traffic in Exhibit 4-47. On freeway all area type is about 20%, which indicates that freeway volume is controlled within range. For Area Type 1 the %RMSE is more than 100% on arterials, collectors and frontage roads. Again, it indicates that the model may have error in Area Type 1. For Area Type 2, the %RMSE is close to 100% on minor arterials and collectors. On major arterial, %RMSE is 63%. On ramps it is 81%, and on frontage road, it is 56%. For Area Type 3, 4 and 5, %RMSE is in the range of 40% - 80%, except freeway and few outliers (e.g., collectors in Area Type 5 is 138%). The comparison shows that Area Type 3,4 and 5 is better modeled than Area Type 1 and 2.

Exhibit 4-47. %RMSE comparison by area type by functional class, day

Funcl\Area Type	%RMSE, Day				
	1	2	3	4	5
1	22.72	17.82	17.53	22.32	19.89
2	181.10	63.70	40.55	38.49	43.32
3	245.86	105.65	50.29	53.61	71.67
4	239.76	107.52	75.97	79.49	138.45
6	94.13	81.66	61.61	65.24	82.48
7	194.35	55.97	74.88	65.18	118.22

The MAE is compared by area type and by functional class for daily traffic in Exhibit 4-48. The trend is similar to that of %RMSE. On freeway all area types are within a range of 15% - 25%. In Area Type 1 and 2, Functional classes 2 – 7 are much high. In Area Type 3, 4, 5, MAE are generally in a normal range.

Exhibit 4-48. MAE comparison by area type by functional class, day

Funcl\Area Type	**MAE(%), Day**				
	1	**2**	**3**	**4**	**5**
1	23.69	17.98	14.42	17.18	17.73
2	185.70	72.57	41.07	38.10	47.13
3	270.47	120.48	46.42	48.78	71.79
4	313.87	129.58	75.19	80.56	121.68
6	156.21	94.39	59.00	60.36	87.77
7	139.61	61.73	138.53	65.56	120.59

4.5 Model Comparison by Volume

Exhibit 4-49 depicts a range of accepted and preferable accuracy ranges for daily traffic for six volume groups (Cambridge Systematics, Inc., 2008.). It also compares the modeled percent error in different volume groups. In general, volume is low, the standard of percent error is high; and when volume is high, it accepts low percent error. Preferable percent error is more stringent than accepted percent error. As shown in the table, the modeled percent error fits the preferable standard. When volume is low (<30000), the modeled percent error is around 5%, which is far less than the preferable standard of 20% - 25%. When volume is high (>30000), the modeled percent error is around 1%, which is much less than the preferable standard of 10% - 25%. Overall, the percent error in the model outperforms the standard in all different volume groups significantly.

Exhibit 4-49. Standard and model %Error by link volume, day

Volume (vehicle per day)	**%Error, Acceptable**	**%Error, preferable**	**%Error, model**
<10,000	50	25	5.67
10,000-30,000	30	20	-4.18
30,000-50,000	25	15	1.20
50,000-65,000	20	10	5.04
65,000-75,000	15	5	0.91
75,000+	10	5	-0.06

Source: Cambridge Systematics, Inc., (2008.)

Exhibit 4-50 depicts a range of accepted %RMSE in eight volume groups. For overall RMSE, there is a wide variation in acceptability throughout the U.S. with most documents recommending values of 30 to 40, and several accepting as high as 50 percent areawide RMSE. When volume is low, the data is more volatile, therefore the standard %RMSE is high. Standard %RMSE decreases as volume grows. The preferable %RMSE is more stringent than the acceptable standard. The modeled %RMSE for different volume group is tabulated in Exhibit 4-51. When volume is low (<20000), the modeled %RMSE misses the acceptable standard. When volume is high (>20000), it meets the acceptable standard. This result indicates that the modeled volume is more confident in high volume than low volume. As in all other regional travel demand model, the accuracy in low volume groups is less confident in TAFT.

Exhibit 4-50. Standard %RMSE by link volume

Volume (vehicle per day)	**%RMSE**	
	Acceptable	**Preferable**
<5,000	100	45
5,000-9,999	45	35
10,000-14,999	35	27
15,000-19,999	30	25
20,000-29,999	27	15
30,000-49,999	25	15
50,000-59,999	20	10
60,000+	19	10
RMSE Areawide	45%	35

Source: Cambridge Systematics, Inc., (2008.)

Exhibit 4-51. Model comparison by volume, day

Volume (vehicle per day)	**#obs**	**%Error**	**R^2**	**%RMSE**	**MAE**
<5,000	9,270	12.80	0.20	126.30	99.65
5,000-9,999	5,336	1.84	0.08	64.81	47.91
10,000-14,999	2,884	-2.39	0.05	46.02	34.75
15,000-19,999	1,495	-5.11	0.07	32.86	25.00
20,000-29,999	941	-5.93	0.16	26.86	21.54
30,000-49,999	659	1.20	0.37	21.37	16.21
50,000-59,999	269	6.23	0.19	19.13	14.60
60,000+	522	0.80	0.59	15.86	12.79

Volume (vehicle per day)	#obs	%Error	R^2	%RMSE	MAE
All	21,376	0.46	0.89	47.94	64.28

Absolute %Error by different daily volume categories is plotted in Exhibit 4-52. When volume is small (x<5000), absolute %error is 12%; this number drops to 1.84% for volume categories of [5000, 10000) and 2.39% for volume category [10000, 15000). As volume increases, absolute %error increase to 5.11% for volume category [15000, 20000), and 5.93% for volume category [20000, 30000). When volume is large (x>60000), the absolute %error diminishes; it becomes 0.8%.

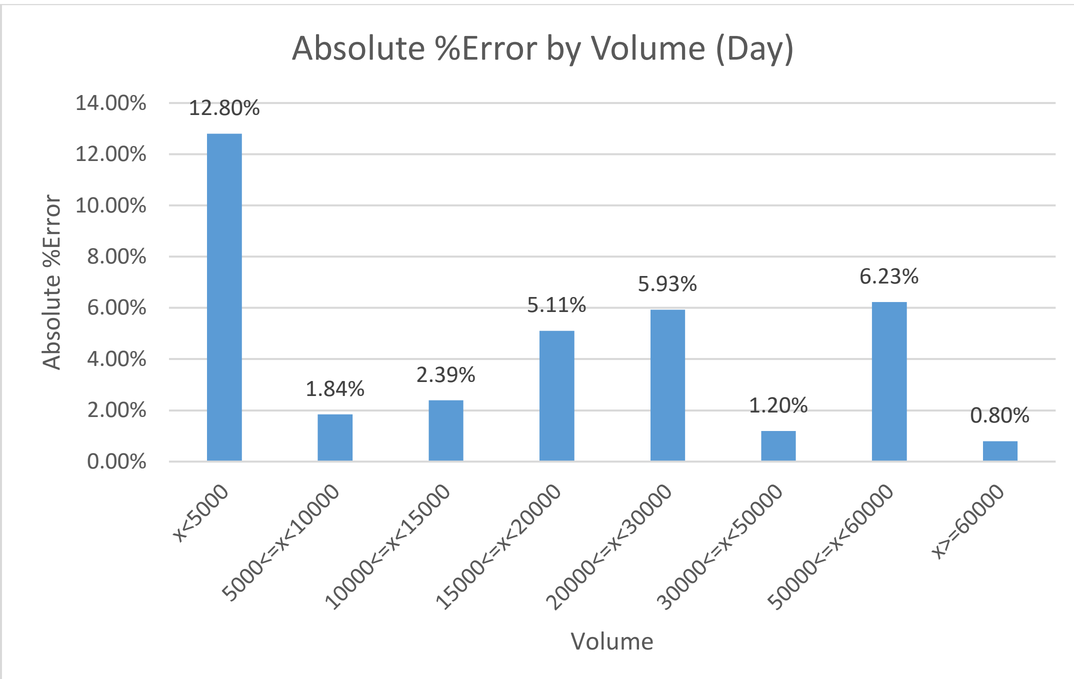

Exhibit 4-52. Absolute %Error by Volume (Day)

The model comparison for different volume group for time of day is tabulated in Exhibit 4-53 – 4-55. Note that the %RMSE standard in Exhibit 4-43 is for daily traffic, but here what is compared is time of day. It is noticed that R^2 diminishes as volume going high, which means there is weak strength of the linear relationship between the assigned volumes and traffic counts.

Exhibit 4-53. Model comparison by volume, AM

Traffic Count, AM	#obs	%Error	R^2	%RMSE	MAE
X<5,000	19,892	6.28	0.60	73.42	84.85
5,000<=X<10,000	979	-4.30	0.40	24.53	19.43
10,000<=X<15,000	499	-5.41	0.28	20.62	16.74

Traffic Count, AM	#obs	%Error	R^2	%RMSE	MAE
15,000<=X<20,000	85	-1.86	0.27	13.15	11.18
20,000<=X<30,000	14	-0.05	0.07	15.88	12.04
30,000<=X<50,000	-	-	-	-	-
50,000<=X<60,000	-	-	-	-	-
60,000<=X	-	-	-	-	-
All	21,469	2.13	0.86	56.36	79.94

Exhibit 4-54. Model comparison by volume, PM

Traffic Count, PM	#obs	%Error	R^2	%RMSE	MAE
X<5,000	18,910	-0.66	0.52	68.18	77.21
5,000<=X<10,000	1,510	-1.84	0.41	27.42	21.12
10,000<=X<15,000	590	3.81	0.17	22.58	17.28
15,000<=X<20,000	378	-0.41	0.23	14.60	11.33
20,000<=X<30,000	131	-1.23	0.08	19.75	14.98
30,000<=X<50,000	3	-20.82	0.14	20.94	20.82
50,000<=X<60,000	-	-	-	-	-
60,000<=X	-	-	-	-	-
All	21,522	-0.34	0.87	49.81	70.08

Exhibit 4-55. Model comparison by volume, OP

Traffic Count, OP	#obs	%Error	R^2	%RMSE	MAE
X<5,000	14,108	7.51	0.28	110.34	106.13
5,000<=X<10,000	4,541	-4.44	0.10	51.90	40.42
10,000<=X<15,000	1,325	-8.51	0.08	33.95	26.74
15,000<=X<20,000	404	-2.73	0.11	26.68	19.35
20,000<=X<30,000	577	4.85	0.22	27.08	20.26
30,000<=X<50,000	582	5.24	0.25	21.60	16.77

Traffic Count, OP	#obs	%Error	R^2	%RMSE	MAE
50,000<=X<60,000	77	-1.72	0.10	20.08	17.77
60,000<=X	40	0.85	0.75	9.60	7.17
All	21,658	0.78	0.87	56.48	80.68

4.6 Truck Comparison

Daily truck comparison is shown in Exhibit 4-57 – 4-59. Exhibit 4-57 is for medium truck; Exhibit 4-58 is for heavy truck, and Exhibit 4-59 is for all trucks, including both medium and heavy trucks. In NCTCOG classification, 2-axle 6-tire is medium truck, more axles and/or more tires are heavy truck.

The truck comparison results are summarized in Exhibit 4-56. It specifies statistics by truck type, including medium truck, heavy truck and truck (medium + heavy), by daily and by time of day. Overall the %Error shows that the model is less than count for both medium and heavy trucks. Medium truck is more volatile, with daily %RMSE of 106%. Statistics of Heavy truck is better than that of medium truck. For heavy truck, daily %RMSE is 64%. For all trucks, the daily %Error is within 20%, and the daily %RMSE is 60%.

Exhibit 4-56. Model comparison for truck

Time period	Type	#Obs	%Error	R^2	%RMSE	MAE
AM	Medium Truck	383	-33.6%	0.54	103.7%	98.6%
	Heavy Truck	374	-17.4%	0.81	68.1%	181.6%
	Truck	390	-22.8%	0.80	67.0%	118.4%
PM	Medium Truck	387	-28.3%	0.47	109.3%	87.4%
	Heavy Truck	379	-10.1%	0.81	68.0%	184.4%
	Truck	390	-16.1%	0.80	65.9%	83.5%
OP	Medium Truck	391	-28.5%	0.48	108.1%	80.0%
	Heavy Truck	392	-17.0%	0.87	65.0%	163.2%
	Truck	392	-20.2%	0.86	60.6%	78.3%
Day	Medium Truck	393	-29.1%	0.48	105.9%	79.9%
	Heavy Truck	393	-15.8%	0.87	63.6%	163.9%
	Truck	393	-19.8%	0.85	60.3%	83.2%

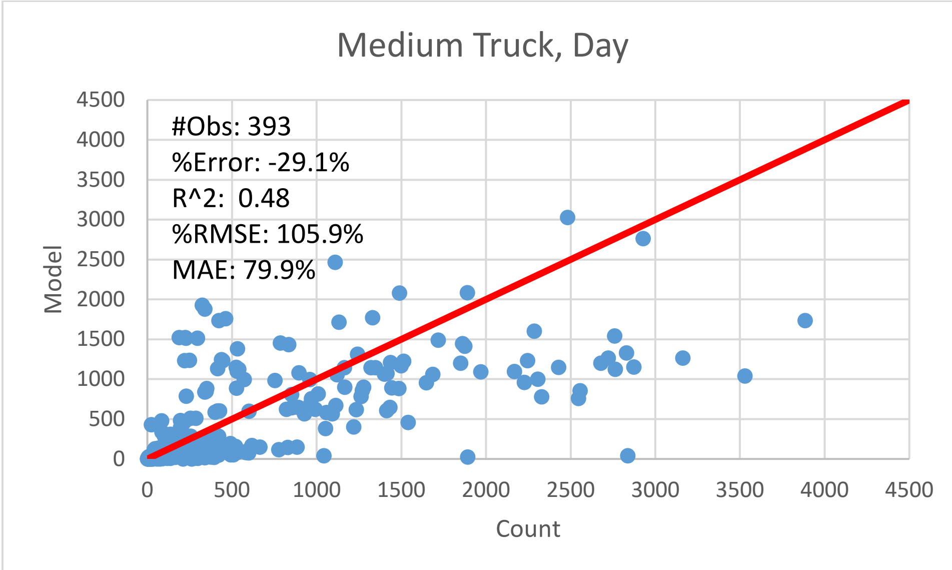

Exhibit 4-57. Model comparison for medium truck, daily

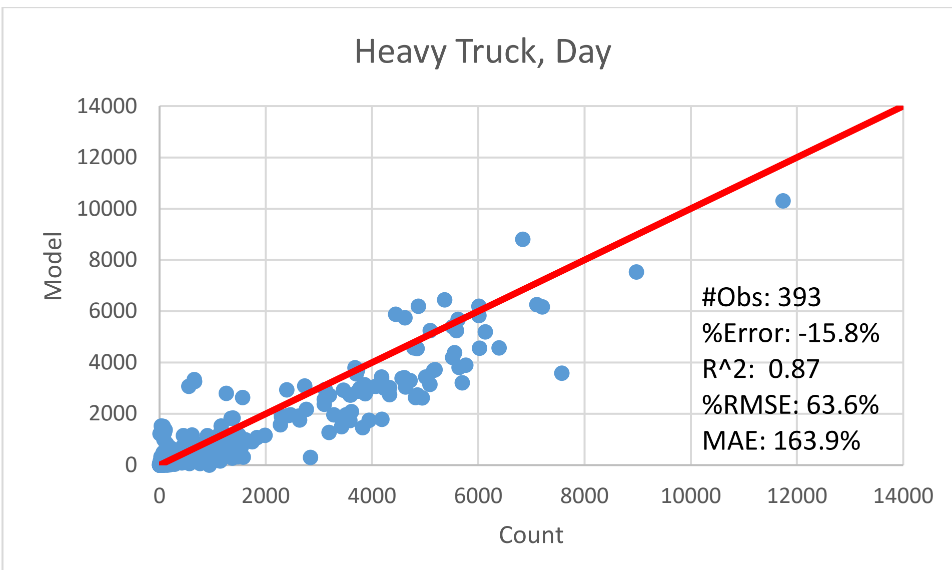

Exhibit 4-58. Model comparison for heavy truck, daily

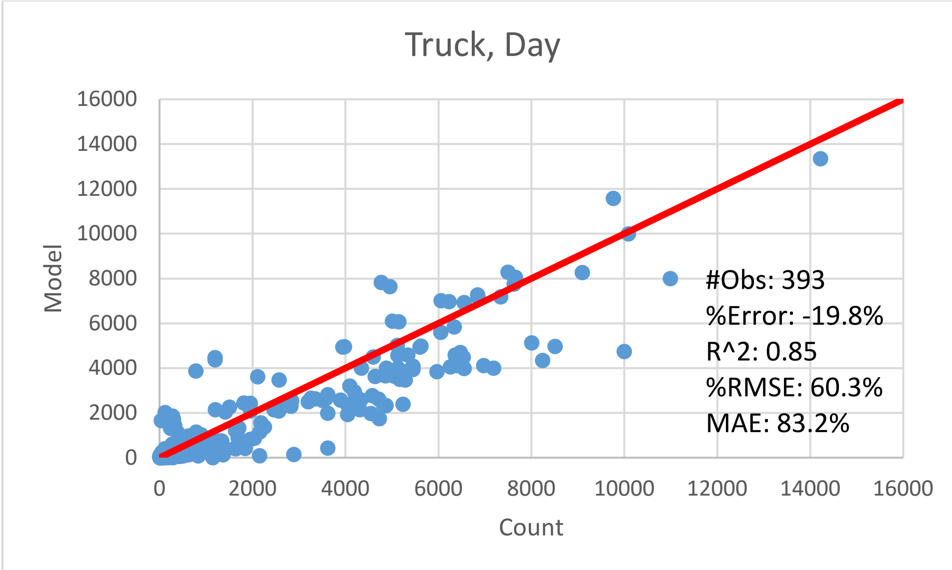

Exhibit 4-59. Model comparison for tuck (medium+heavy), daily

The time of day comparison of trucks are compared in Exhibit 4-60 – 4-68. In time of day, the %error is generally negative, meaning the model is less than the counts. For all trucks, time of day %error is between -22% and -16%; %RMSE is around 60% - 65%. Among medium and heavy trucks, time of day statistics of heavy truck is better than that of medium truck. For heavy truck, time of day %error is between -17% and -10%; %RMSE is around 68%. For medium truck, time of day %error is between -36% and -28%; %RMSE is around 100% to 110%.

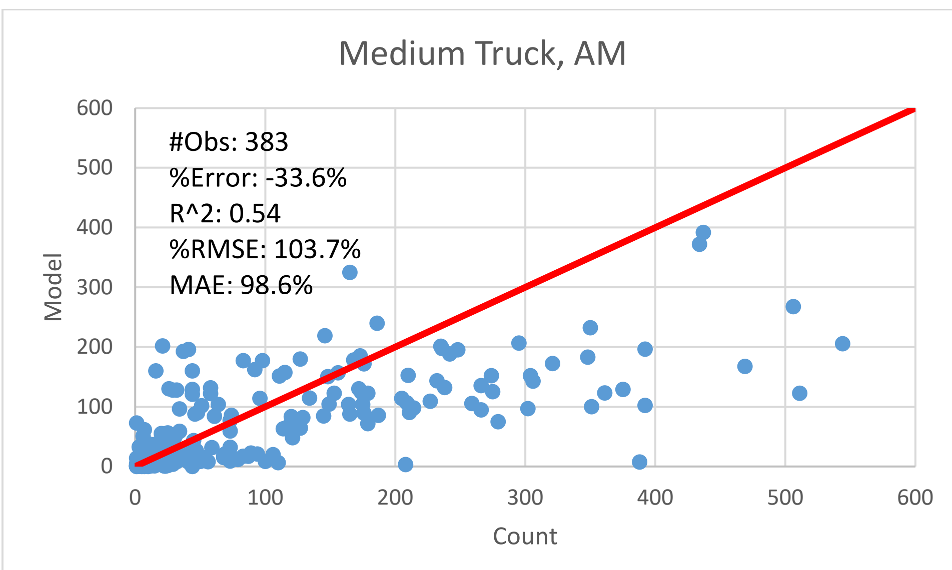

Exhibit 4-60. Model comparison for medium truck, AM

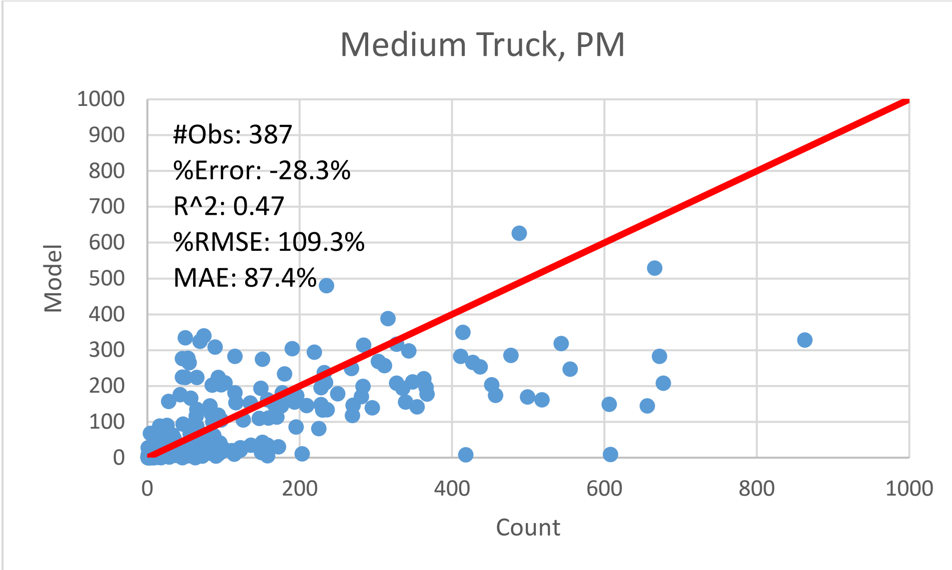

Exhibit 4-61. Model comparison for medium truck, PM

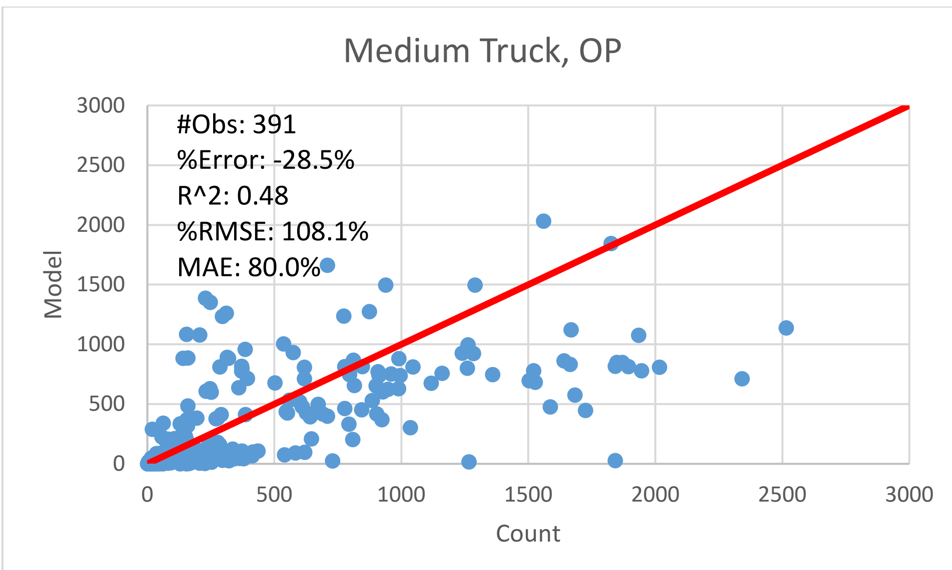

Exhibit 4-62. Model comparison for medium truck, OP

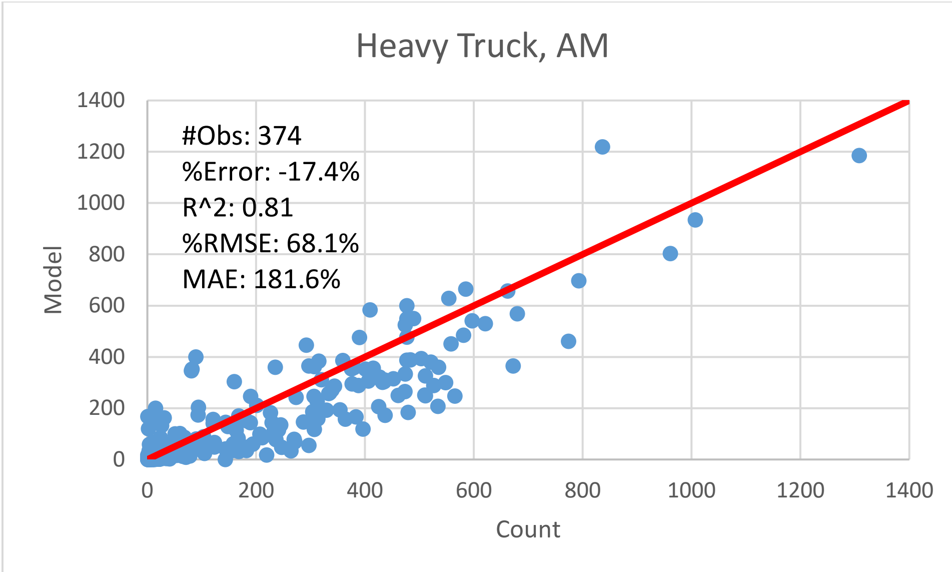

Exhibit 4-63. Model comparison for heavy truck, AM

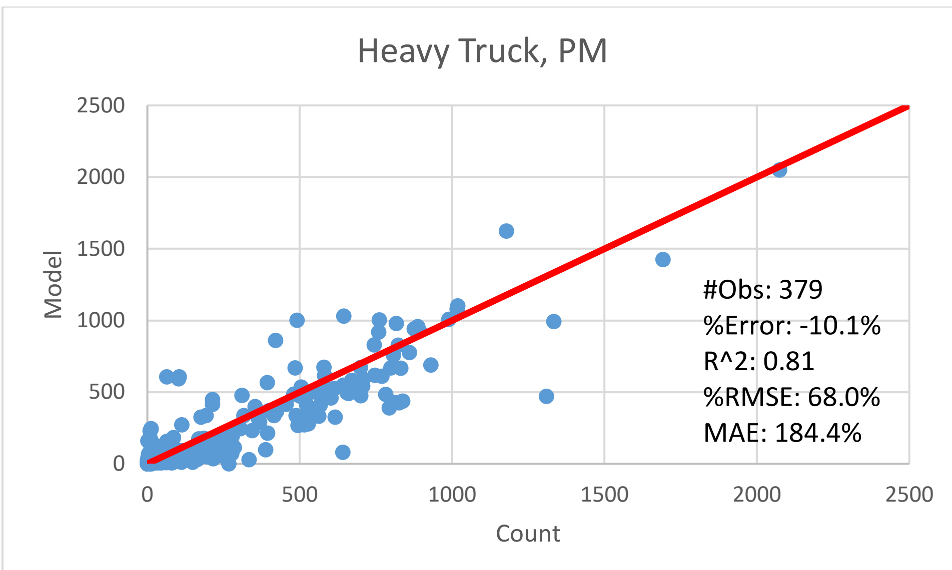

Exhibit 4-64. Model comparison for heavy truck, PM

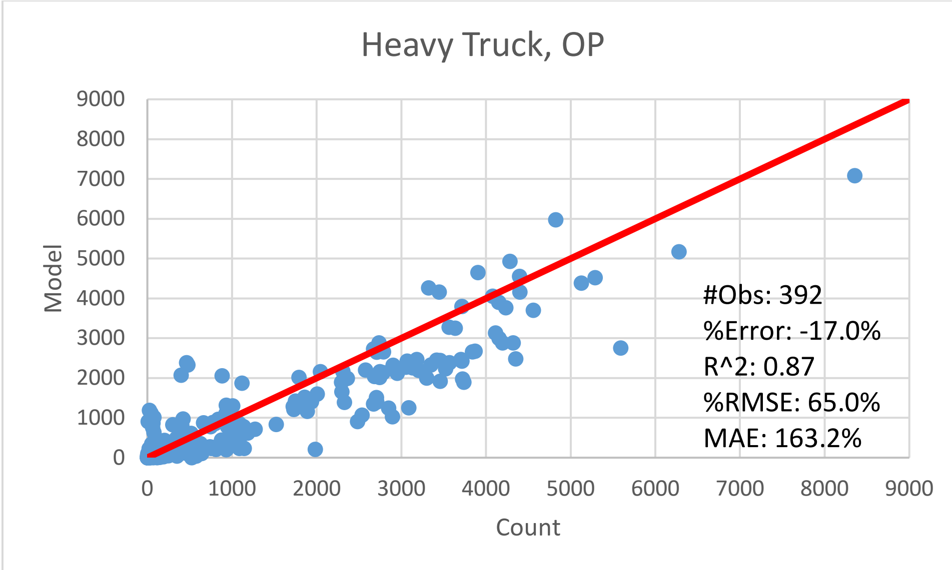

Exhibit 4-65. Model comparison for heavy truck, OP

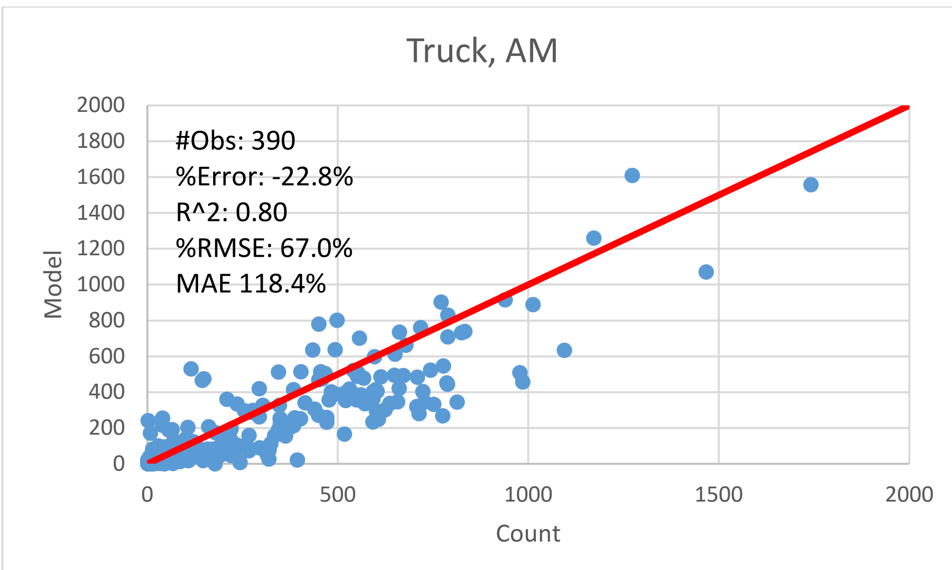

Exhibit 4-66. Model comparison for all truck, AM

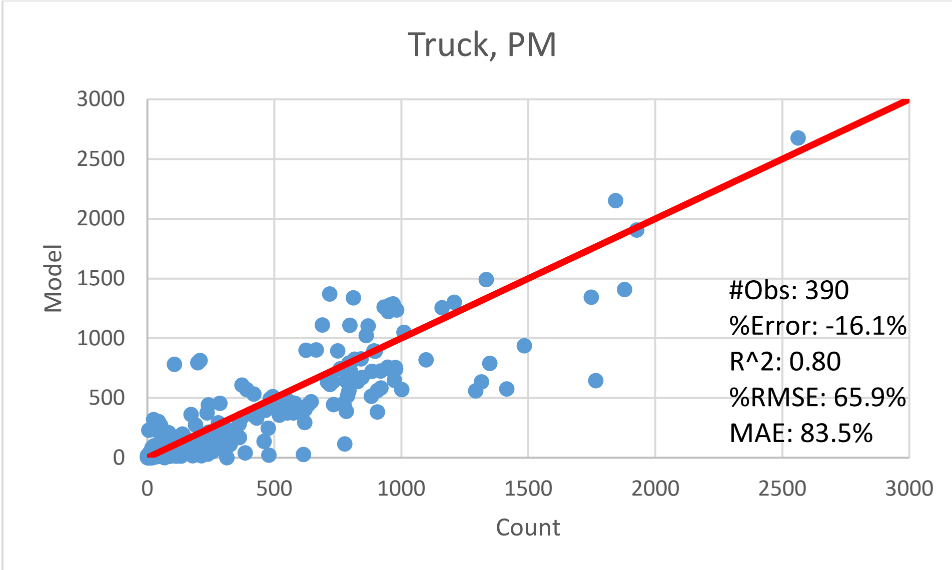

Exhibit 4-67. Model comparison for all truck, PM

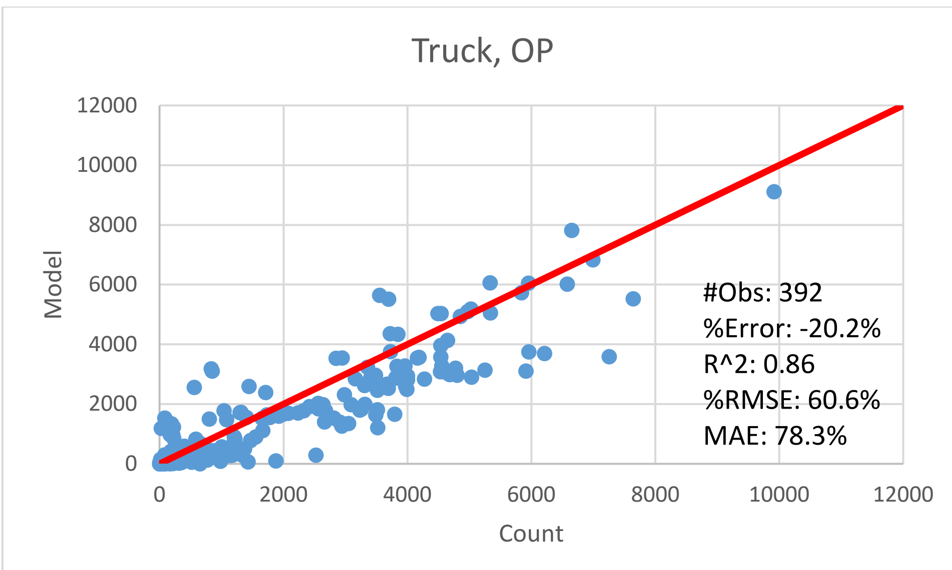

Exhibit 4-68. Model comparison for all truck, OP

4.7 Screenline Analysis

There are 24 screenlines produced in this section. Screenlines 1-5 are vertical lines separating the study area into two parts; screenlines 6-11 are horizontal lines separating the study area into two parts; screenlines 12-18 are polygons that enclose an area of interest. Screenlines 19-24 are smaller-segment of screenlines randomly selected. Screenline analysis provides a method of comparing the traffic assignment results against traffic count data. This is facilitated by comparing the directional (or bi-directional) sum of assigned traffic volumes across a screenline with the directional (or bi-directional) total of the traffic count volumes across the same screenline. According to Cambridge Systematics (2008), the standard of desirable deviation of volume to count ratio is +/-20%, depending on the screenline volume.

The screenlines 1-5 are shown in Exhibit 4-69. Among them, screenlines 1 cuts across rural area; screenlines 2 and 3 go across the Dallas downtown following US75 and US67 respectively. Screenline 4 cut across Arlington and airport. Screenline 5 cuts across Fort Worth downtown following I-35 West.

Screenline analysis results for daily traffic are summarized in Exhibit 4-70. On screenline 1, the number of observations and total count is small because it is in the rural area. Percent error is -8% and %RMSE is 51%. Screenlines 2,3,4 have enough observations and total counts are more than 1 million, percent error is -10%, -4% and 3% respectively. %RMSEs are between 50% - 60%. Screenline 5 percent error is -3% and %RMSE is 78%. Overall percent errors for screenlines 1-5 are within +/-10%, meeting the standard.

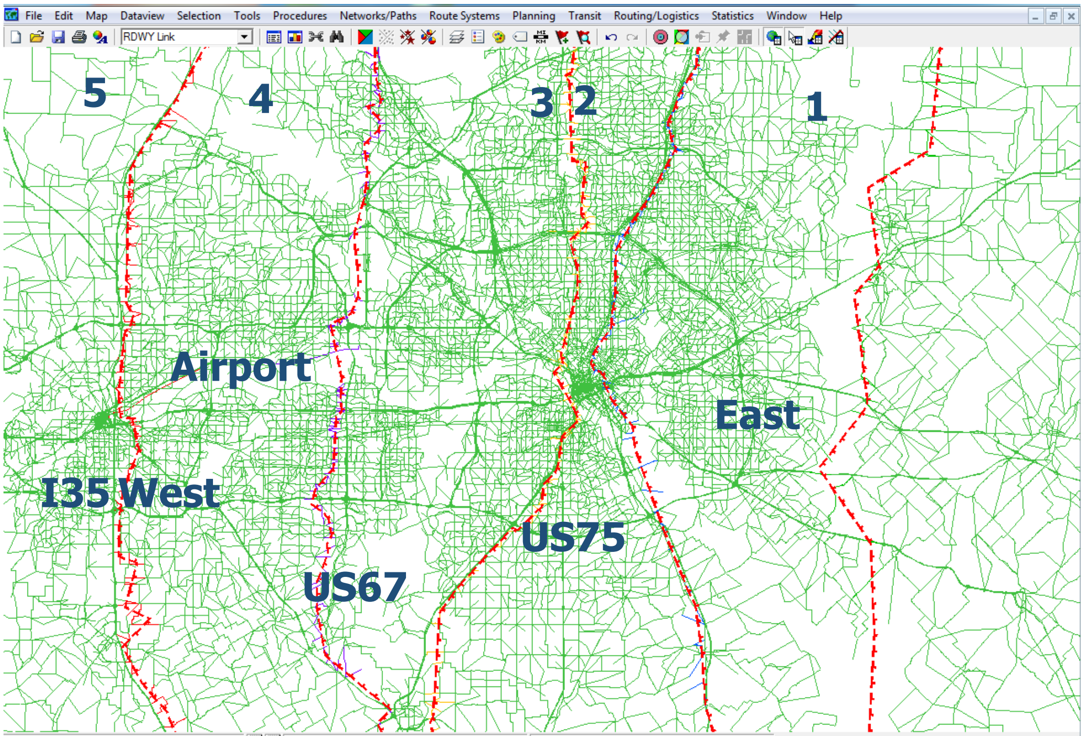

Exhibit 4-69. Screen line (1-5)

Exhibit 4-70. Screen line analysis (1-5), day

Screen Line	#obs	Total flow	Total Count	%Error	%RMSE
1	21	240,990	261,276	-7.76	51.26
2	66	1,261,585	1,394,717	-9.55	55.71
3	85	2,126,480	2,208,309	-3.71	50.35
4	57	1,097,531	1,064,022	3.15	62.54
5	57	766,577	792,074	-3.22	77.50

The screenlines 6-11 are shown in Exhibit 4-71. Among them, screenlines 6, 10, and 11 cut across rural area. Screenlines 7 and 8 go across the suburban area. Screenline 9 cuts across Dallas and Fort Worth downtown.

Screenline analysis results for daily traffic are summarized in Exhibit 4-72. Screenlines 6-10 have total counts more than 1 million, percent errors are generally within +/-10%, except screenline 10, the percent error is -11%. The %RMSEs are generally between 40% - 70%.

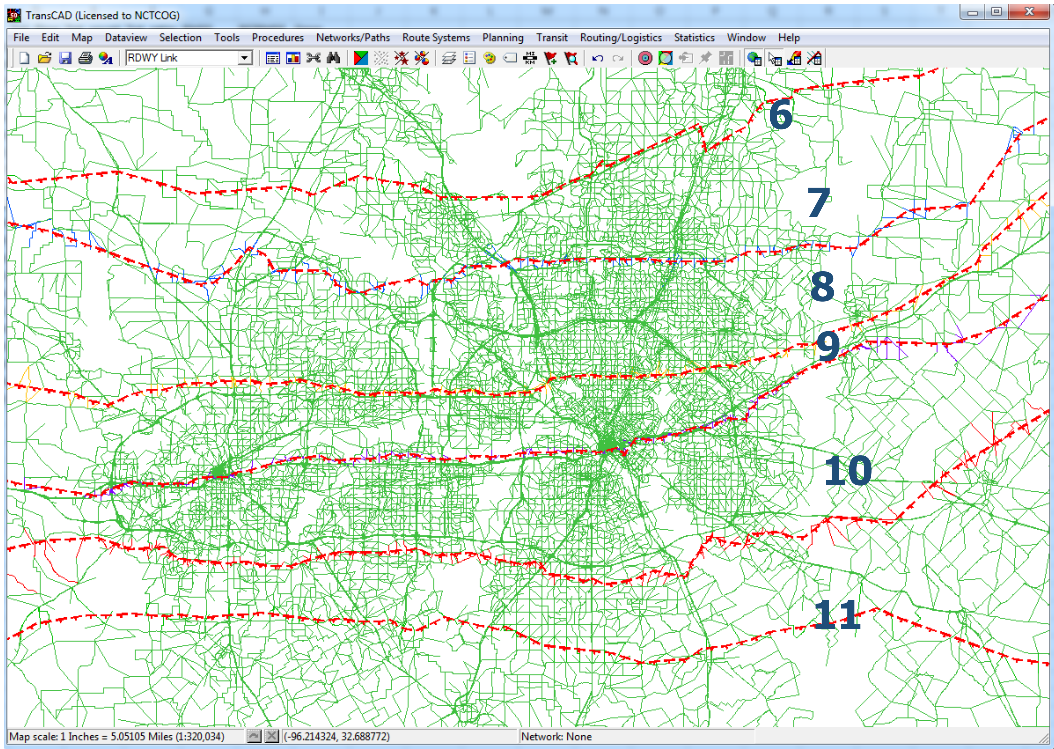

Exhibit 4-71. Screen line (6-11)

Exhibit 4-72. Screen line analysis (6-11), day

Screen Line	#obs	Total flow	Total Count	%Error	%RMSE
6	57	1,051,410	1,138,270	-7.63	48.14
7	70	1,608,731	1,558,958	3.19	40.34
8	90	1,861,257	1,908,822	-2.49	47.13
9	131	2,547,721	2,357,532	8.07	67.88
10	79	1,135,786	1,275,573	-10.96	54.84
11	48	648,881	674,083	-3.74	41.99

Screenlines 12-18 (Exhibit 4-73) are polygons. Screenline 12 circles around I-635 and I-20, producing an outer loop of Dallas. Screenline 13 circles around inner boundary of Dallas downtown. Screenline 14 circles around I-20 and I-820, producing an outer loop of Fort Worth. Screenline 15 circles around inner boundary of Fort Worth downtown. Screenline 16 circles around Denton; screenline 17 circles around McKinney; and screenline 18 circles around DFW airport.

Screenline analysis results for daily traffic are summarized in Exhibit 4-74. Screenline 13 (Dallas downtown) and screenline 15 (Fort Worth downtown) are overestimated. Percent errors are 44% and 34% respectively. It indicates that downtown may have too many trips and thus the model may overestimate the volume. Other screenlines are generally within +/-20%, meeting the standard. As for the %RMSE, the two overestimated screenlines (13 and 15) around downtowns are 82%, other screenlines are with %RMSE ranging between 40% and 60%.

It is concluded that downtown Dallas and downtown Fort Worth volume are overestimated in the model, which deserve further investigation.

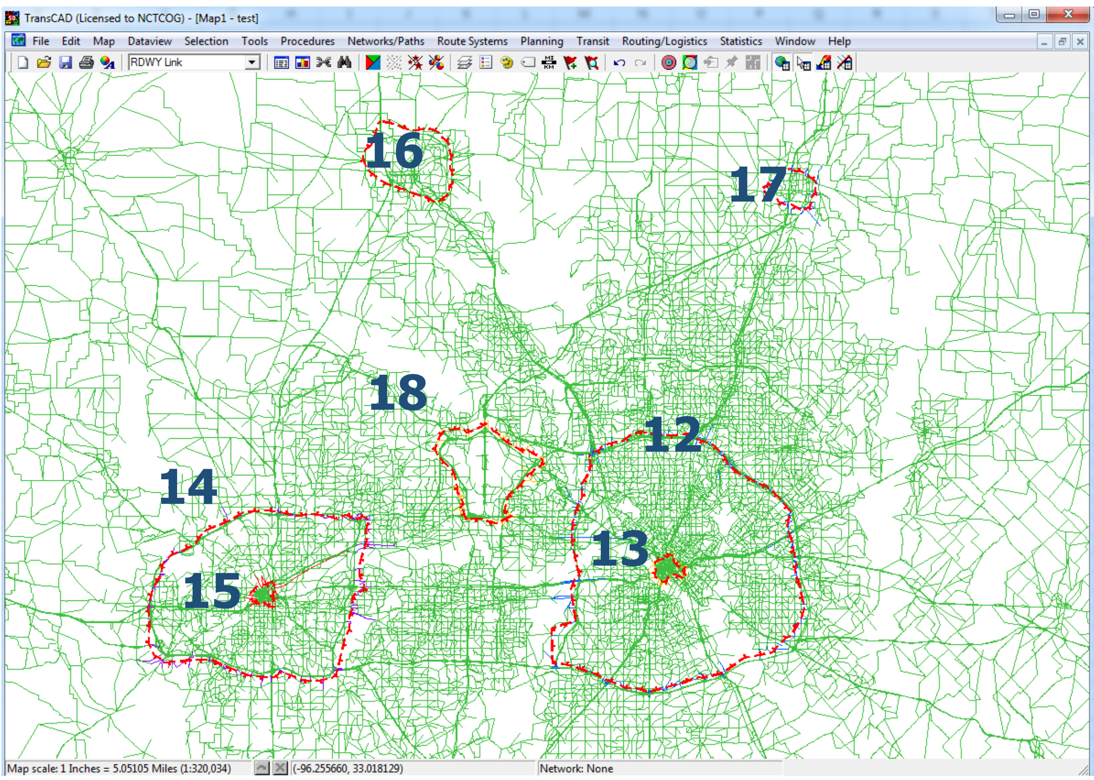

Exhibit 4-73. Screen line (12-18)

Exhibit 4-74. Screen line analysis (12-18), day

Screen Line	#obs	Total flow	Total Count	%Error	%RMSE
12	98	2,378,784	2,150,623	10.61	50.07
13	44	1,201,110	833,749	44.06	81.89
14	53	953,394	1,105,000	-13.72	41.93

Screen Line	#obs	Total flow	Total Count	%Error	%RMSE
15	25	435,291	324,735	34.04	81.86
16	17	305,376	357,771	-14.64	54.83
17	7	248,958	208,841	19.21	58.88
18	36	1,130,198	953,611	18.52	54.22

Screenlines 19-24 (Exhibit 4-75) are smaller-segment screenlines compared to 1-18. They cut only partial of the region rather than the entire region in a random manner. Overall the percent error meet the standard of +/-20%. The %RMSE ranges between 40% and 65%. Screenline 23, which cuts I-35E in the northwest side of downtown, has the worst performance. Percent error is 15% and %RMSE is 64%. It indicates that the model overestimates around this area. This is consistent with the result of screenline 13 that in downtown area the model overestimates, particularly on freeway.

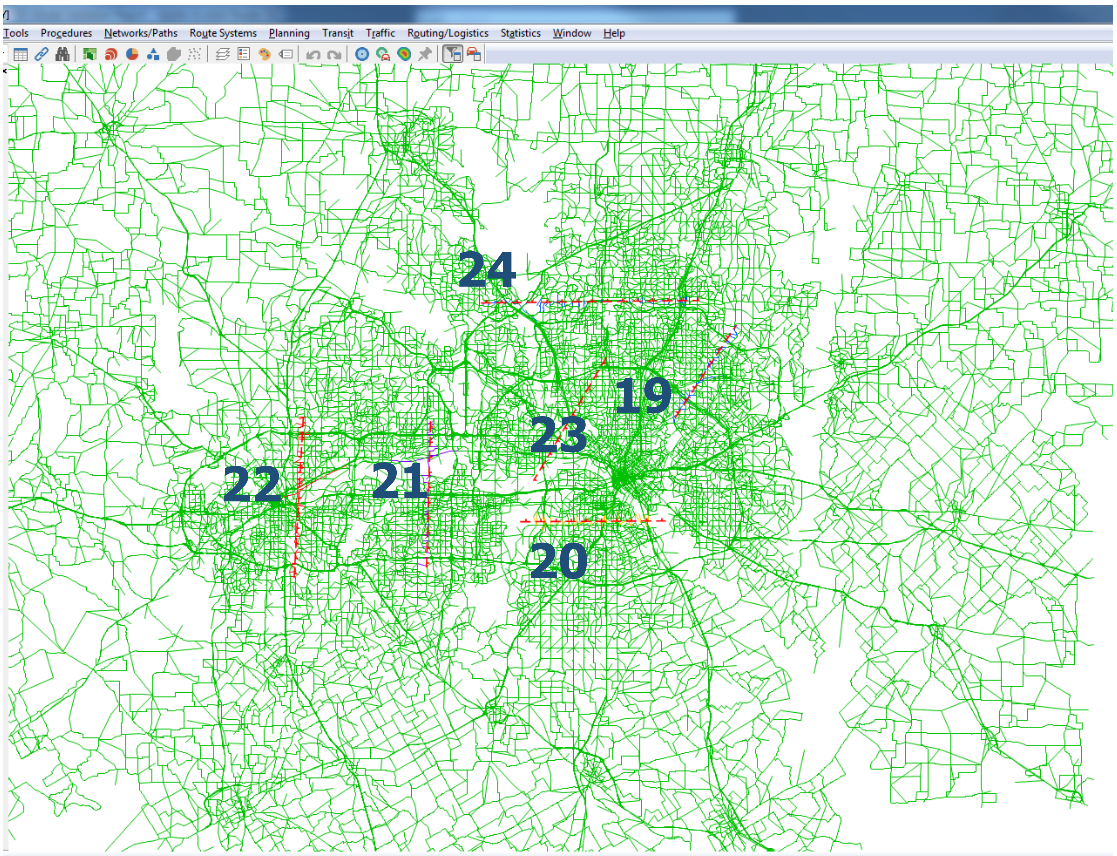

Exhibit 4-75. Screen line (19-24)

Exhibit 4-76. Screen line analysis (19-24), day

Screen Line	#obs	Total flow	Total Count	%Error	%RMSE
19	21	323,490	348,054	-7.06	38.00
20	23	605,306	656,506	7.04	40.40
21	25	392,891	380,379	3.29	48.57
22	24	329,152	337,237	-2.4	48.94
23	29	753,781	653,834	15.29	63.52
24	40	1,037,654	965,234	7.50	37.69

The time of day screenline analysis is tabulated in Exhibit 4-77 to 4-79, for AM peak, PM peak and OP respectively. The percent error in AM for vertical and horizontal lines (screenlines 1-11) is worse than PM. For AM, percent error more than10% includes screenline 1 (15.69%), 4 (10.67%) and 9 (12.16%); in contrast, PM all vertical and horizontal screenlines have percent error less than 10%. Overall the percent errors in vertical and horizontal lines are within +/-20%, meeting the standard. In terms of %RMSE, PM peak is also better than AM peak. Among vertical and horizontal screenlines, time of day analyses show that most have a negative percent error, which means the model is less than counts. This trend is consistent with daily results. Overall the daily result is better than the one in time of day, which indicates that the time of day compensate each other in the summation process in daily analysis.

Among the polygon screenlines (screenlines 12-18), time of day also shows the model overestimate in Dallas and Fort Worth downtown (screenlines 13 and 15). Downtown of McKinney (screenline 17) and airport (screenline 18) are also overestimated in the model. Those screenlines are consistently high in the model among all time of day periods and daily. Except Dallas and Fort Worth downtown, other screenlines percent error is within +/-20%, meet the standard.

Among the random-cut short-segment screenlines, the time-of-day percent errors all meet the standard. The time-of-day %RMSE is generally between 30% and 60%. Screenline 19 overestimates in AM but underestimates in PM and OP, because of directionality of traffic. Among screenlines 19-24, screenline 23 has the worst performance; percent error is 15% in AM, 17% in PM, and 12% in OP. This is consistent with the daily result that screenline 23 is high around I-35 northwest side of downtown.

Exhibit 4-77. Screen line analysis - AM (1-24)

Screen Line	#obs	Total flow	Total Count	%Error	%RMSE
1	21	44,365	52,623	-15.69	39.34
2	66	244,802	238,083	2.82	56.69
3	85	375,781	381,833	-1.58	44.33
4	57	199,373	180,144	10.67	54.13
5	57	130,117	124,553	4.47	83.82
6	57	186,395	189,471	-1.62	48.94
7	70	300,944	291,650	3.19	41.92
8	90	335,227	335,912	-0.20	45.31
9	131	433,371	386,379	12.16	80.59
10	79	203,501	216,165	-5.86	44.36
11	48	114,862	116,735	-1.60	41.24
12	98	389,192	356,395	9.20	54.38
13	44	197,809	135,000	46.53	87.75
14	53	180,405	200,789	-10.15	41.48
15	25	66,792	54,251	23.12	67.90
16	17	49,065	53,986	-9.12	55.93
17	7	39,770	33,810	17.63	31.99
18	36	202,043	171,959	17.49	71.01
19	21	70,977	65,611	8.18	52.26
20	23	95,910	91,865	4.40	56.46
21	25	69,055	60,776	13.62	60.09
22	24	60,555	56,696	6.81	47.12
23	29	132,946	116,028	14.58	42.76
24	40	200,149	178,106	12.38	44.22

Exhibit 4-78. Screen line analysis - PM (1-24)

Screen Line	#obs	Total flow	Total Count	%Error	%RMSE
1	21	59,596	63,053	-5.48	31.61
2	66	352,766	387,169	-8.89	39.96
3	85	566,131	595,680	-4.96	34.78
4	57	285,132	286,036	-0.32	33.91
5	57	202,756	209,527	-3.23	67.60
6	57	273,792	298,951	-8.42	48.91
7	70	431,298	422,780	2.01	33.73
8	90	487,486	514,262	-5.21	36.72
9	131	678,259	639,017	6.14	63.37
10	79	309,828	343,831	-9.89	35.30
11	48	168,197	180,382	-6.76	38.42
12	98	606,259	564,543	7.39	46.05
13	44	307,664	204,641	50.34	72.11
14	53	251,401	286,076	-12.12	50.81
15	25	112,403	86,351	30.17	80.20
16	17	77,364	91,248	-15.22	59.30
17	7	62,714	57,144	9.75	31.25
18	36	291,697	244,573	19.27	49.65
19	21	88,478	99,592	-11.16	30.38
20	23	150,601	146,910	2.51	45.08
21	25	103,653	102,279	1.34	44.64
22	24	84,826	88,904	-4.59	52.95
23	29	206,469	176,115	17.24	40.81
24	40	279,009	257,141	8.50	29.61

Exhibit 4-79. Screen line analysis – OP (1-24)

Screen Line	#obs	Total flow	Total Count	%Error	%RMSE
1	21	137,038	145,850	-6.04	41.53
2	66	683,958	780,710	-12.39	47.46
3	85	1,184,883	1,231,076	-3.75	37.86
4	57	613,158	597,905	2.55	39.52
5	57	437,700	458,510	-4.54	63.98
6	57	593,377	658,480	-9.89	46.41
7	70	876,489	844,578	3.78	44.52
8	90	1,054,866	1,069,111	-1.33	44.32
9	131	1,447,460	1,336,508	8.30	76.17
10	79	637,664	715,638	-10.90	38.09
11	48	375,114	378,087	-0.79	35.25
12	98	1,389,057	1,232,203	12.73	54.63
13	44	694,022	493,329	40.68	58.92
14	53	521,586	618,275	-15.64	44.09
15	25	256,097	184,133	39.08	99.70
16	17	178,947	212,537	-15.80	60.48
17	7	146,759	118,023	24.35	44.95
18	36	646,184	537,581	20.20	57.94
19	21	164,035	182,851	-10.29	46.23
20	23	358,795	326,731	9.81	38.66
21	25	220,183	217,324	1.32	61.39
22	24	183,771	191,637	-4.10	66.47
23	29	404,366	361,691	11.80	66.88
24	40	558,496	529,987	5.38	40.19

4.8 Model Comparison on Freeway Corridors

Comparison of traffic counts on major freeway corridors is summarized in Exhibit 4-80. The coverage of corridor length with counts show that IH635 has a poor coverage, with only 3 links with coverage around 1 mile. US 75 and SH 360 are with coverage of 10 miles and 16 miles respectively; the coverage is also low. Statistics on corridors with low coverage are not convincing. Other corridors have a coverage at least 40 miles, which should be the focus of comparison.

For corridors IH30, IH 20, IH35W, IH35E, IH45, the percent errors are within +/-10%. In Cambridge Systematics (2008), the standard of percent error for freeway is +/-7%. Most corridors with good coverage meet this criterion, except for IH35W SB, whose percent error is 8.5%. R^2 is between 0.71 and 0.97, which indicates there is almost a linear relationship between modeled volume and counts. For %RMSE, all corridors with good coverage are generally less than 20%, except for IH20 WB which has %RMSE 21.7%, and IH45 SB which has %RMSE 26.3%. MAE result is similar to %RMSE. All corridors with good coverage have MAE less than 20%.

Exhibit 4-80. Model comparison on freeway corridors

Freeway	#obs	Corridor length with counts (mile)	%Error	R^2	%RMSE	MAE
IH30 WB	87	50.02	-2.27	0.89	14.62	10.76
IH30 EB	106	61.80	-0.36	0.90	15.67	15.74
IH20 WB	104	72.65	3.93	0.88	21.70	15.21
IH20 EB	105	76.25	-1.18	0.94	13.18	10.56
IH35W SB	83	53.19	8.51	0.95	15.38	11.57
IH35W NB	87	60.33	3.54	0.95	12.74	12.80
IH35E SB	129	71.94	6.21	0.97	12.19	12.07
IH35E NB	126	72.81	-1.96	0.94	13.82	12.02
US75 SB	14	11.48	-22.72	0.98	33.30	18.64
US75 NB	25	12.46	-18.92	0.63	28.80	23.04
IH635 WB	3	1.36	14.30	0.99	25.36	24.40
IH635 EB	3	1.05	1.92	0.00	25.16	20.77
IH635 SB	16	6.89	-7.95	0.85	11.76	7.50
IH635 NB	9	4.29	-7.38	0.87	11.18	7.12
SH360 SB	45	16.94	-13.94	0.86	18.29	13.60

Freeway	#obs	Corridor length with counts (mile)	%Error	R^2	%RMSE	MAE
SH360 NB	43	16.89	-18.86	0.93	22.04	17.77
IH45 SB	62	38.97	-4.60	0.71	26.32	14.37
IH45 NB	67	40.62	0.70	0.82	19.86	12.29

4.9 Travel Time Comparison

The source of the travel time data was the National Performance Management Research Data Set (NPMRDS) for year 2014. These travel time data were collected by the company HERE. or the purposes of the travel model calibration, the data was averaged at 30-minute intervals. The data was transferred from the speed segments of NPMRDS, defined as TMCs, to the model roadway network. Since the TMCs and the roadway segments are not geographically similar, only the speed data was transferred and the travel times for each link of the roadway network was recalculated based on the length of the link.

Travel time on links are not meaningful in comparison. Rather, corridor travel times are used. We define segments in the network which contain corridors in the network for travel time comparison. The segments on the freeway system are depicted in Exhibit 4-81. There are 198 segments in total, with approximately 900 centerline miles.

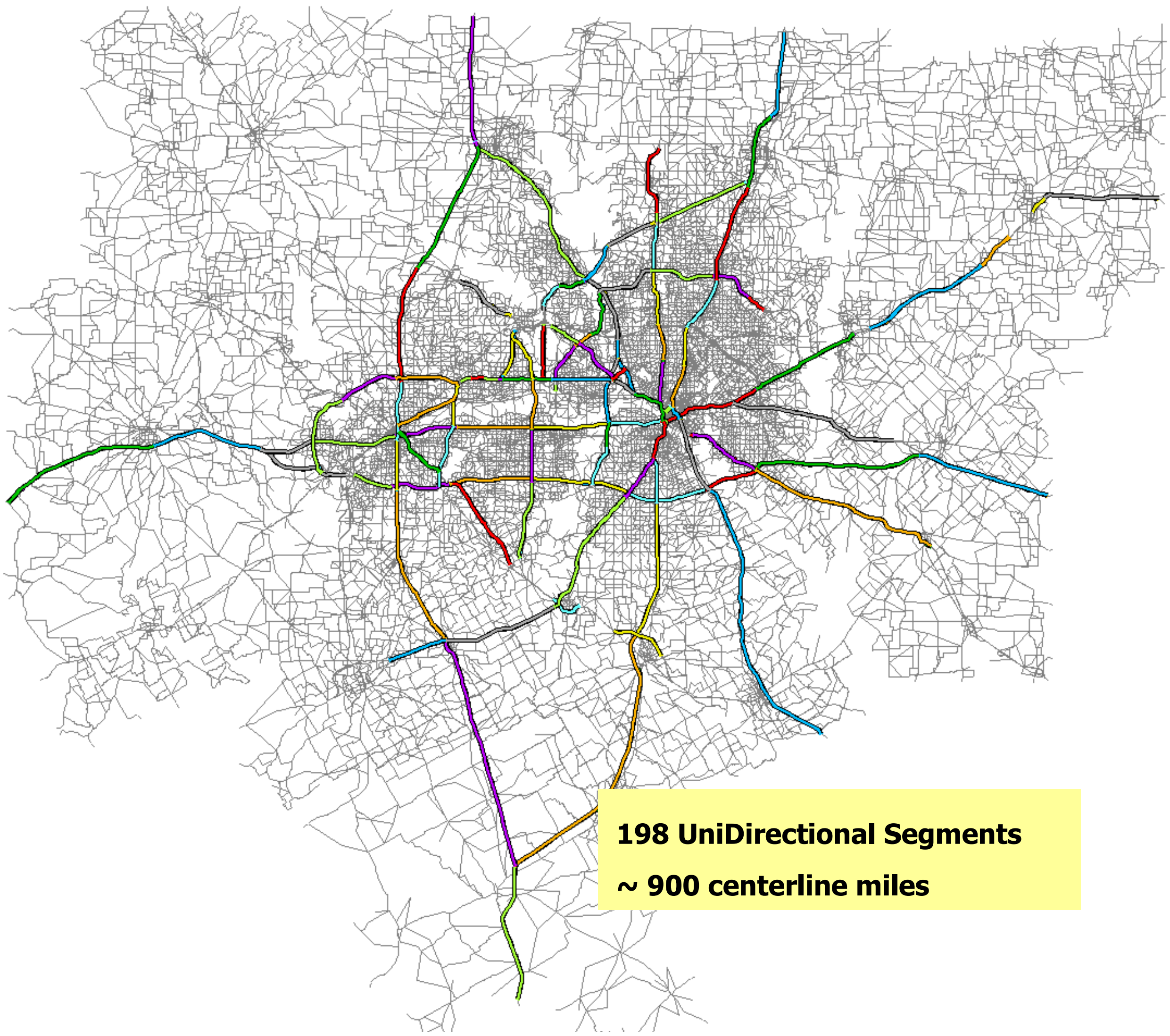

Exhibit 4-81. Freeway travel time segments

Travel times for time of day are compared in Exhibit 4-82 to 4-84. Overall OP is better than PM, which is better than AM. Since there is little congestion in OP, the travel time is basically free flow, and one would expect little error. In AM peak, percent error is 7%, which means travel time in the model is slightly longer. R^2 is 0.87; %RMSE is 29%, and MAE is 20%. In PM peak, percent error is 3%; R2 is 0.9; %RMSE 19%; and MAE is 15%.

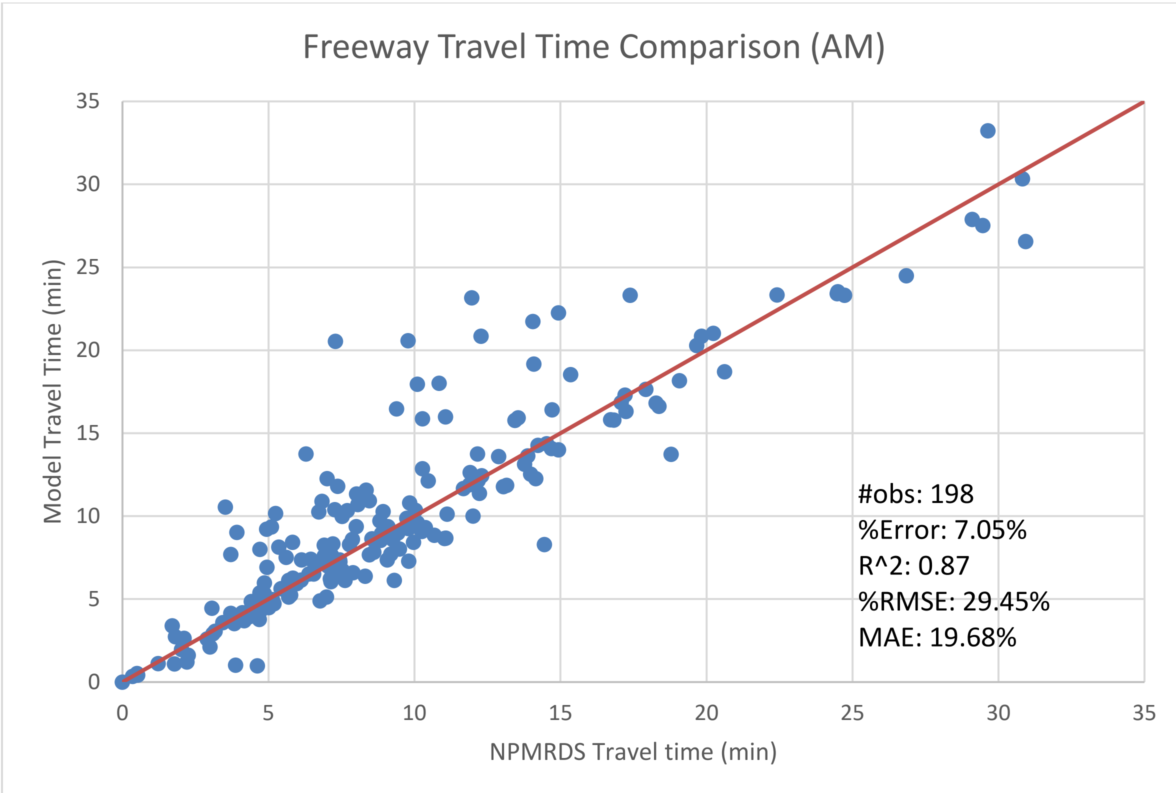

Exhibit 4-82. Freeway travel time comparison, AM

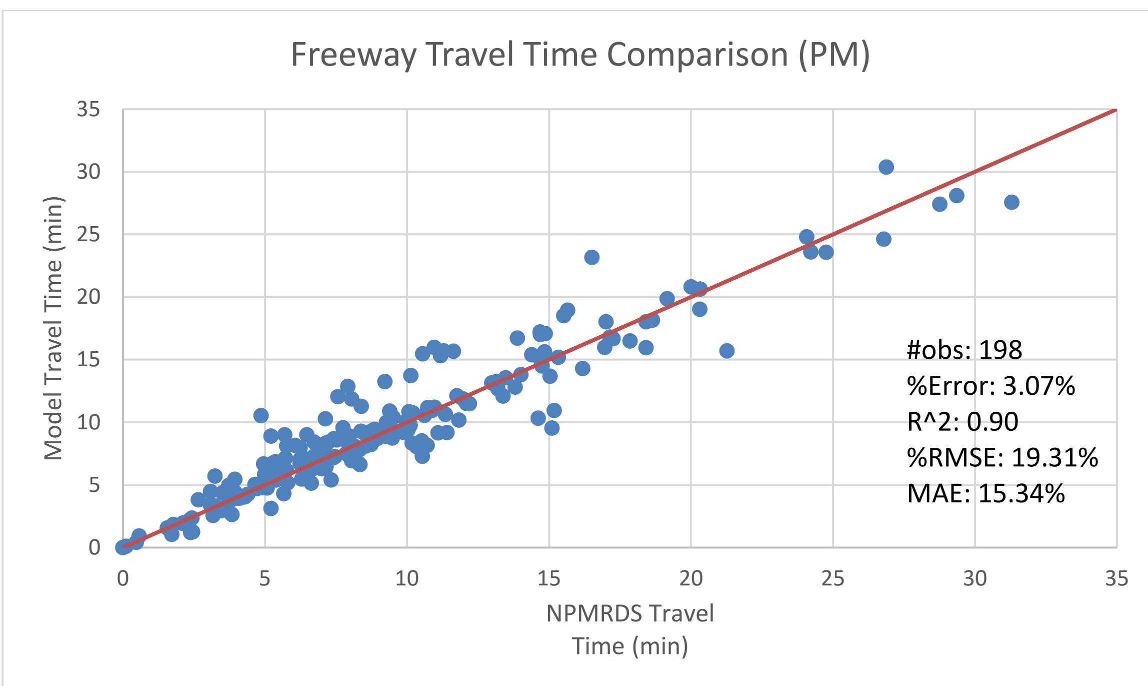

Exhibit 4-83. Freeway travel time comparison, PM

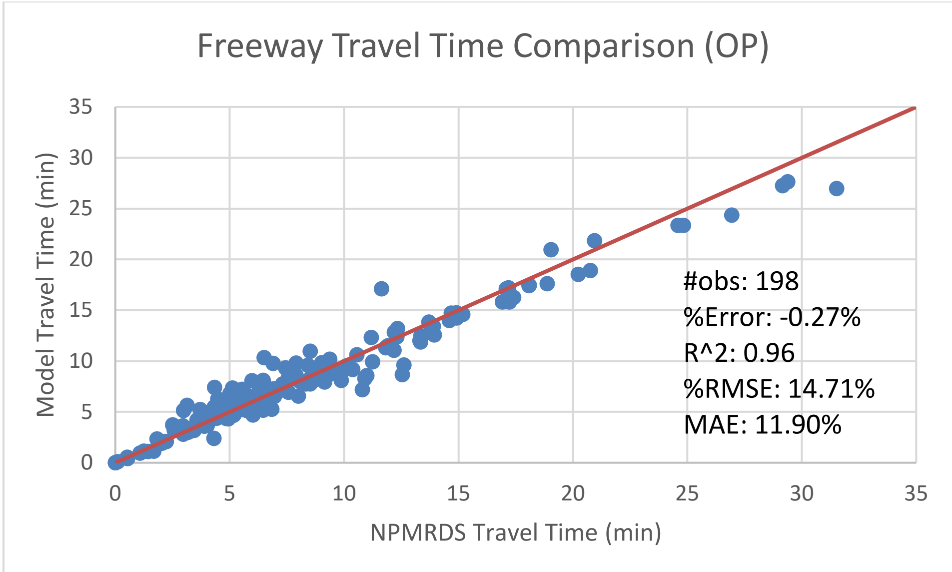

Exhibit 4-84. Freeway travel time comparison, OP

On arterials there are 357 segments, with centerline miles around 1500. As shown in Exhibit 4-85, those segments are mainly on major arterials. Travel times on arterials for time of day are compared in Exhibit 4-86 to 4-88. From the figures, it is clear that NPMRDS HERE data has longer travel times than those predicted by the model. This pattern is throughout AM peak, PM peak and off peak. To have better understanding of the results, we further compare 2014 HERE data and 2017 INRIX data, which shows consistently longer travel time for HERE data. Therefore, we believe that the inconsistency is because the HERE data may be overestimating travel time.

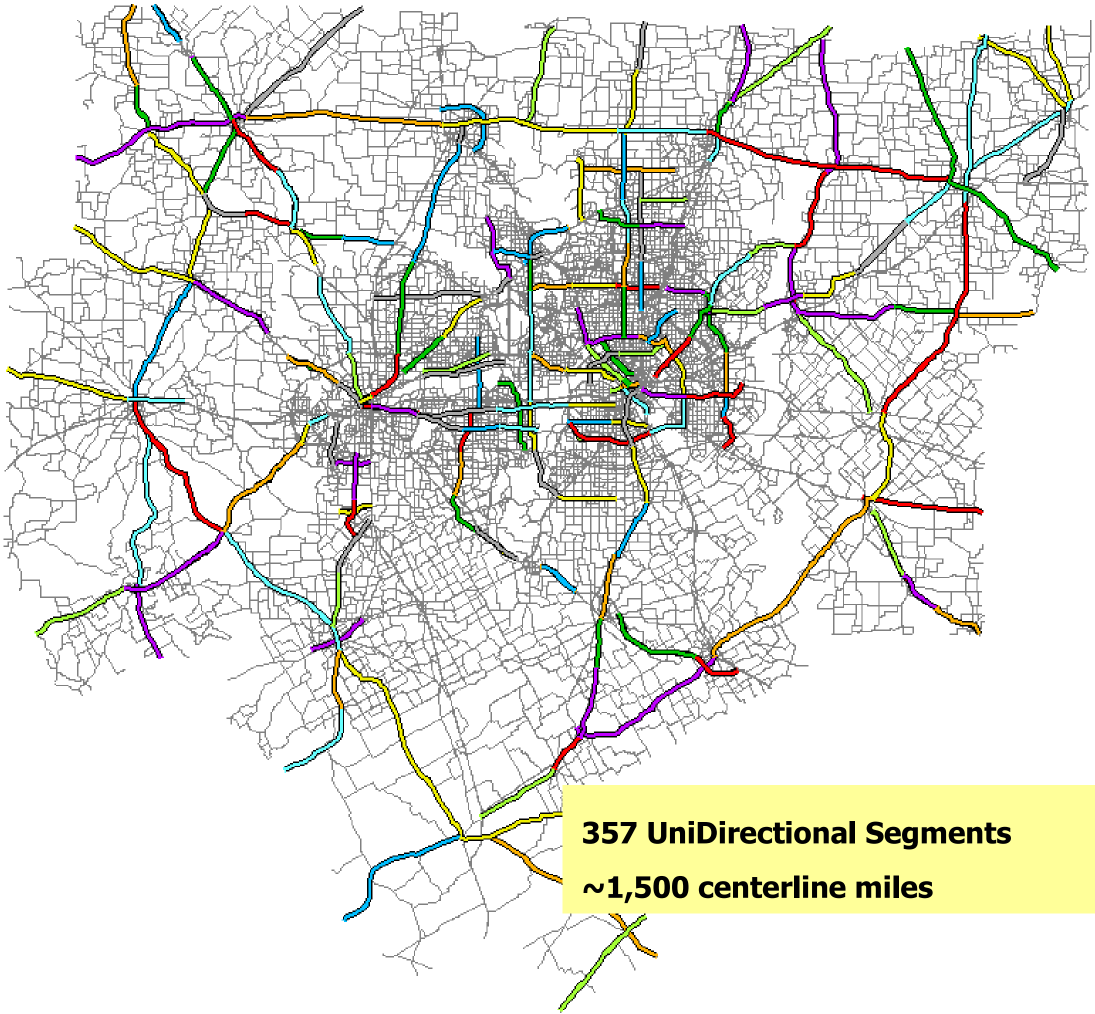

Exhibit 4-85. Arterial travel time segments

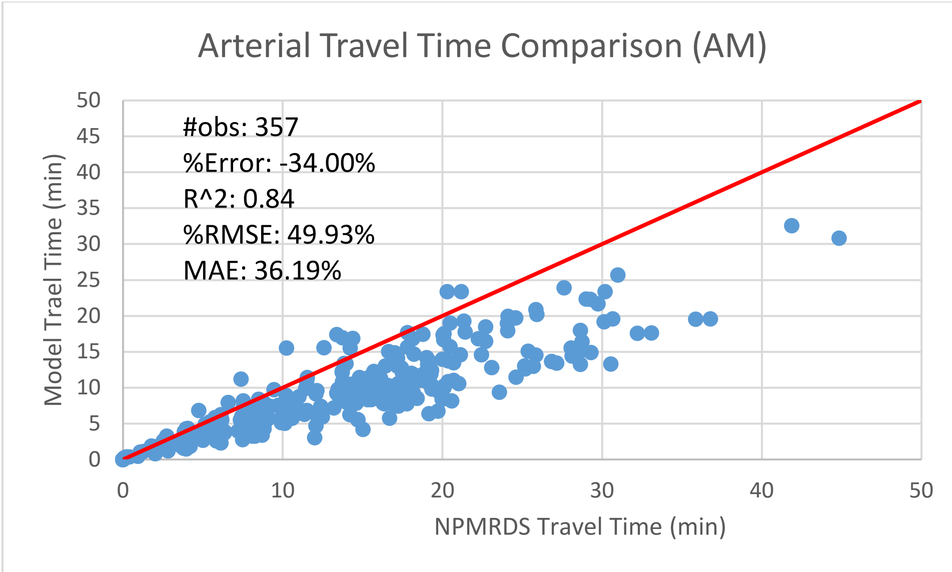

Exhibit 4-86. Arterial travel time comparison, AM

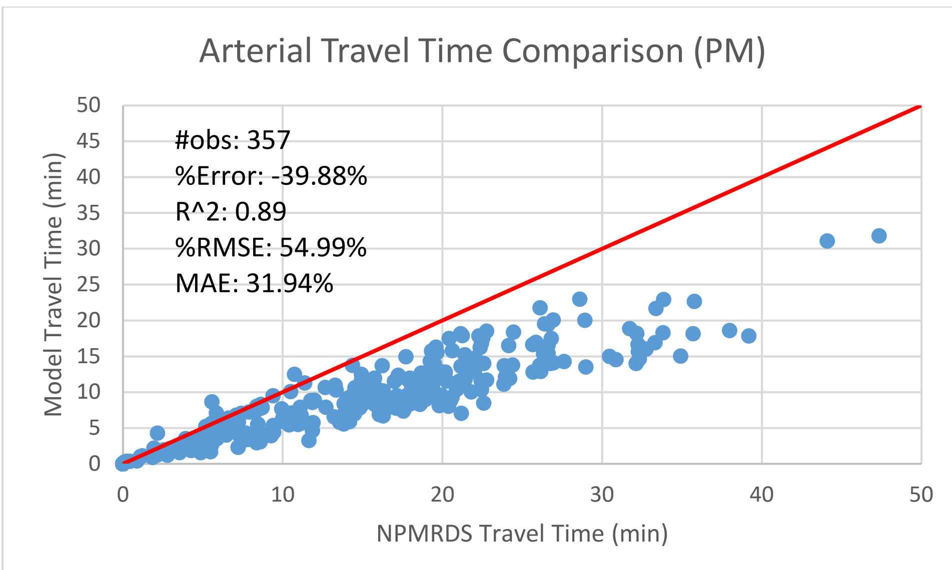

Exhibit 4-87. Arterial travel time comparison, PM

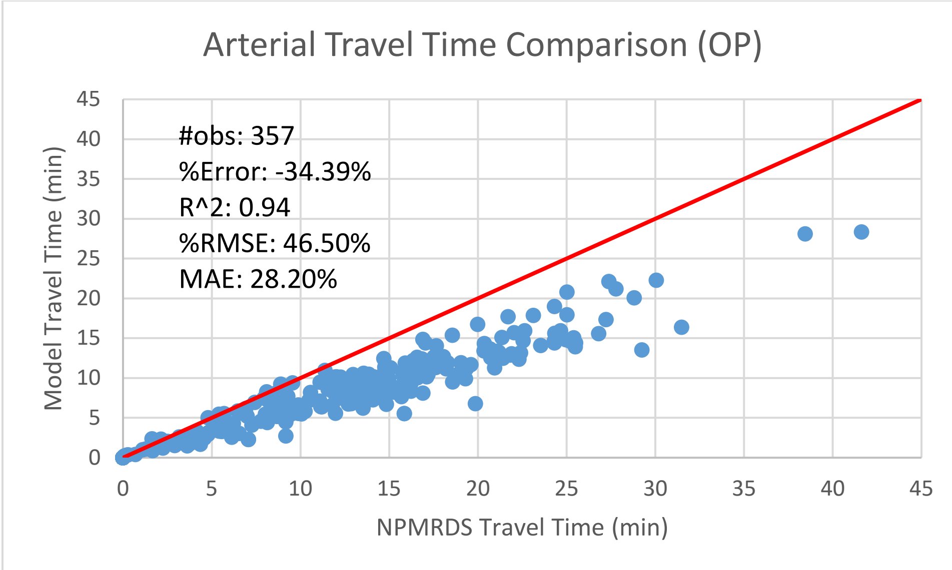

Exhibit 4-88. Arterial travel time comparison, OP

4.10 Model Comparison by County

The model vs. count comparison by functional class and by county are tabulated in Exhibit 4-89-4-100 (12 counties). Among them, Collin, Dallas, Denton and Tarrant are the major counties to look at. The overall %error for all links for the 4 counties is between -6% and 8%. The overall %RMSE for all links for the 4 counties are within 40%-50%. The %Error for freeway for the 4 counties is between -11% and 6%, the %RMSE for freeway for the 4 counties are within 14%-22%. Among the 4 counties, according to %RMSE for all links, the sequence from best to worst is Tarrant, Denton, Collin and Dallas. According to %RMSE for freeway, the sequence from best to worst is Denton, Dallas, Tarrant and Collin.

Exhibit 4-89. Model comparison by functional class by county (Collin)

Funcl	**Collin, Day**				
	#obs	**%Error**	**R^2**	**%RMSE**	**MAE (%)**
1	167	-10.83	0.80	22.26	15.28
2	312	-5.94	0.68	30.49	25.35
3	981	3.80	0.53	50.03	45.63
4	684	-17.38	0.27	91.51	88.37
6	222	-0.50	0.56	62.45	96.06
7	67	-4.71	0.04	76.26	255.78
All	2,433	-4.71	0.87	47.08	63.35

Exhibit 4-90. Model comparison by functional class by county (Dallas)

Funcl	Dallas, Day				
	#obs	%Error	R^2	%RMSE	MAE (%)
1	753	6.08	0.88	17.92	15.49
2	1,186	6.28	0.28	53.60	48.90
3	2,551	13.91	0.33	64.50	60.42
4	2,136	-10.72	0.28	83.12	79.62
6	1,208	13.10	0.52	74.39	67.88
7	321	6.49	0.56	73.26	121.33
All	8,155	7.34	0.89	48.82	63.13

Exhibit 4-91. Model comparison by functional class by county (Denton)

Funcl	Denton, Day				
	#obs	%Error	R^2	%RMSE	MAE (%)
1	186	-1.64	0.89	14.21	11.79
2	310	-7.97	0.42	30.43	47.76
3	510	19.40	0.37	68.99	58.59
4	665	-15.79	0.27	95.82	88.08
6	250	3.46	0.64	66.79	58.75
7	70	-25.03	0.49	71.06	122.19
All	1,991	-1.28	0.89	42.69	64.64

Exhibit 4-92. Model comparison by functional class by county (Ellis)

Funcl	Ellis, Day				
	#obs	%Error	R^2	%RMSE	MAE (%)
1	207	4.27	0.81	17.53	14.87
2	104	-2.35	0.65	37.39	36.95
3	205	-15.62	0.56	64.68	69.99
4	290	-19.96	0.21	117.97	126.96
6	179	-18.42	0.51	77.74	87.77

Funcl	Ellis, Day				
	#obs	%Error	R^2	%RMSE	MAE (%)
7	48	-49.56	0.23	107.22	73.83
All	1,033	-2.46	0.92	38.06	74.87

Exhibit 4-93. Model comparison by functional class by county (Hood)

Funcl	Hood, Day				
	#obs	%Error	R^2	%RMSE	MAE (%)
1	0	-	-	-	-
2	49	-11.56	0.43	32.80	24.64
3	62	0.58	0.71	53.63	60.12
4	45	-6.06	0.08	143.00	196.38
6	0	-	-	-	-
7	0	-	-	-	-
All	156	-7.29	0.72	49.88	88.28

Exhibit 4-94. Model comparison by functional class by county (Hunt)

Funcl	Hunt, Day				
	#obs	%Error	R^2	%RMSE	MAE (%)
1	38	20.68	0.45	29.75	22.70
2	127	6.35	0.10	85.20	70.16
3	137	1.92	0.44	108.02	83.01
4	6	-44.08	0.27	127.96	150.53
6	57	-2.91	0.55	79.29	63.90
7	20	-71.02	0.29	120.12	91.90
All	385	8.45	0.71	77.93	71.50

Exhibit 4-95. Model comparison by functional class by county (Johnson)

Funcl	Johnson, Day				
	#obs	%Error	R^2	%RMSE	MAE (%)
1	44	-3.58	0.87	12.86	11.84
2	120	-23.87	0.45	39.22	79.79
3	161	8.91	0.62	57.17	62.00
4	261	-16.99	0.30	117.25	108.78
6	54	-6.75	0.83	49.44	93.08
7	24	-58.77	0.43	98.32	76.57
All	664	-11.38	0.83	49.88	83.33

Exhibit 4-96. Model comparison by functional class by county (Kaufman)

Funcl	Kaufman, Day				
	#obs	%Error	R^2	%RMSE	MAE (%)
1	97	19.09	0.60	30.78	34.58
2	100	3.79	0.14	70.72	49.96
3	170	-7.36	0.49	75.50	71.54
4	108	-0.08	0.22	142.48	155.35
6	104	-1.80	0.45	97.95	108.85
7	16	-57.48	0.05	107.17	94.23
All	595	8.46	0.79	61.76	84.23

Exhibit 4-97. Model comparison by functional class by county (Parker)

Funcl	Parker, Day				
	#obs	%Error	R^2	%RMSE	MAE (%)
1	53	-5.31	0.93	14.07	11.52
2	81	-15.24	0.15	42.57	33.06
3	109	0.32	0.32	72.63	63.06
4	153	-36.32	0.08	134.84	98.57

Funcl	Parker, Day				
	#obs	%Error	R^2	%RMSE	MAE (%)
6	49	-22.43	0.63	55.57	56.04
7	28	-44.21	0.65	81.19	74.28
All	473	-11.68	0.88	45.73	63.57

Exhibit 4-98. Model comparison by functional class by county (Rockwall)

Funcl	Rockwall, Day				
	#obs	%Error	R^2	%RMSE	MAE (%)
1	20	-13.94	0.69	26.56	17.86
2	59	-2.65	0.74	33.63	53.63
3	72	-12.76	0.42	56.27	100.51
4	79	-31.14	0.32	97.14	114.95
6	23	-23.85	0.82	41.39	36.82
7	10	-71.17	0.34	94.69	61.04
All	263	-14.34	0.87	50.97	80.97

Exhibit 4-99. Model comparison by functional class by county (Tarrant)

Funcl	Tarrant, Day				
	#obs	%Error	R^2	%RMSE	MAE (%)
1	578	-4.40	0.80	20.36	16.94
2	622	-0.22	0.27	42.71	39.61
3	1,268	-5.14	0.26	54.14	49.88
4	1,175	-15.98	0.27	73.71	84.53
6	722	-9.11	0.53	63.23	57.18
7	249	-27.94	0.64	66.27	76.04
All	4,614	-6.01	0.89	42.43	55.75

Exhibit 4-100. Model comparison by functional class by county (Wise)

Funcl	Wise, Day				
	#obs	%Error	R^2	%RMSE	MAE (%)
1	19	-22.83	0.87	26.53	21.23
2	120	-25.44	0.55	45.24	42.35
3	127	-2.55	0.30	85.42	60.60
4	117	-14.78	0.27	143.79	104.88
6	34	-39.82	0.23	95.00	64.85
7	11	-68.35	0.00	192.32	67.90
All	428	-21.93	0.75	63.89	66.36

The screenline analysis by 12 counties is summarized in Exhibit 4-101-4-112. At each county, 4 screenline are drawn along the boundary of the county in the direction of clockwise. 4 screenlines that encompass the county are located at the south, north, east and west side of the county respectively. Each screenline compares the daily modeled volume and daily traffic count.

In Collin County, the screenline %error is between -15% to 6%. In the north side of Collin, the are only 9 observations, therefore the data is volatile. In South, East and West sides, there are enough observations and therefore %error is low.

Dallas County is one of the major counties in the study area, and all four sides have enough observations. The south, north, east and west sides have %error 8%, 4%, 2% and 14% respectively. The west side of Dallas is also east side of Tarrant, and this boundary is in the metroplex of the region. The %error is 14%, meaning the model is 14% more than traffic count, indicating the model may overestimate in the core region of the metroplex.

In Denton County, south side and east side have enough observations, and the %error is low, -1% and -3% respectively.

Tarrant County is located at the west side of Dallas County. As mentioned above, east side of Tarrant is also west side of Dallas, and %error is 14%. In the west side Tarrant, %error is -14%, meaning the model is less than count 14%. In the north and south side of Tarrant, %error is fairly good, both are 4%.

Exhibit 4-101. Screen line analysis by county (Collin)

Collin, Day	South	North	East	West
#obs	35	9	13	30
Total Counts	534,461	63,070	92,369	527,795

Collin, Day	South	North	East	West
Total Model	563,989	53,804	95,722	513,599
%Error	5.52	-14.69	3.63	-2.69

Exhibit 4-102. Screen line analysis by county (Dallas)

Dallas, Day	South	North	East	West
#obs	26	45	14	40
Total Counts	216,050	1,092,337	203,420	870,506
Total Model	234,082	1,138,728	206,490	995,745
%Error	8.35	4.25	1.51	14.39

Exhibit 4-103. Screen line analysis by county (Denton)

Denton, Day	South	North	East	West
#obs	39	7	30	5
Total Counts	782,438	60,780	527,795	18,034
Total Model	773,247	63,221	513,599	16,277
%Error	-1.17	4.02	-2.69	-9.74

Exhibit 4-104. Screen line analysis by county (Ellis)

Ellis, Day	South	North	East	West
#obs	4	26	-	10
Total Counts	48,592	214,966	-	77,097
Total Model	41,360	235,850	-	89,443
%Error	-14.88	9.72	-	16.01

Exhibit 4-105. Screen line analysis by county (Hood)

Hood, Day	South	North	East	West
#obs	1	2	3	2
Total Counts	6,889	4,492	27,360	6,724
Total Model	7,109	6,672	29,809	6,429
%Error	3.19	48.53	8.95	-4.39

Exhibit 4-106. Screen line analysis by county (Hunt)

Hunt, Day	South	North	East	West
#obs	4	3	6	13
Total Counts	11,866	3,186	35,593	92,369
Total Model	14,547	2,852	37,386	95,722
%Error	22.59	-10.48	5.04	3.63

Exhibit 4-107. Screen line analysis by county (Johnson)

Johnson, Day	South	North	East	West
#obs	4	22	5	4
Total Counts	39,573	191,304	34,732	32,624
Total Model	39,278	199,117	41,215	37,060
%Error	-0.75	4.08	18.67	13.60

Exhibit 4-108. Screen line analysis by county (Kaufman)

Kaufman, Day	South	North	East	West
#obs	2	8	6	9
Total Counts	8,869	32,550	56,246	81,604
Total Model	11,923	37,614	46,098	93,874
%Error	34.43	15.56	-18.04	15.04

Exhibit 4-109. Screen line analysis by county (Parker)

Parker, Day	**South**	**North**	**East**	**West**
#obs	5	9	23	7
Total Counts	29,559	23,754	170,441	37,823
Total Model	29,252	25,847	147,075	43,678
%Error	-1.04	8.81	-13.71	15.48

Exhibit 4-110. Screen line analysis by county (Rockwall)

Rockwall, Day	**South**	**North**	**East**	**West**
#obs	5	8	3	4
Total Counts	24,251	75,259	14,989	90,084
Total Model	26,457	85,684	15,140	82,234
%Error	9.10	13.85	1.01	-8.71

Exhibit 4-111. Screen line analysis by county (Tarrant)

Tarrant, Day	**South**	**North**	**East**	**West**
#obs	20	19	40	23
Total Counts	173,219	195,317	870,506	170,441
Total Model	180,705	203,750	995,745	147,075
%Error	4.32	4.32	14.39	-13.71

Exhibit 4-112. Screen line analysis by county (Wise)

Wise, Day	**South**	**North**	**East**	**West**
#obs	8	4	5	2
Total Counts	45,891	26,994	18,034	3,582
Total Model	38,715	17,857	16,277	2,659
%Error	-15.64	-33.85	-9.74	-25.77

Chapter 5. Year 2014 Validation Conclusion

The validation of a travel demand model is essential to accurately model future travel for a metropolitan area. This report documents TAFT model validation results for traffic assignment in order to provide users of the travel forecasts to establish the confidence in the model. The purpose of this report is to carry a number of inexpensive evaluation and reasonableness checks that can enhance TAFT forecasting capability and build the confidence of the model. It covers both limitations and capabilities of the model.

The TAFT validation mainly uses scatter plot between modeled traffic volumes versus the observed traffic counts and four performance measures, including %Error, R^2, %RMSE and MAE, as tools to validate the model. Among these tools, we mainly focus on comparing results using scatter plot, %Error and %RMSE. %Error measures the difference between modeled traffic volume and traffic count, as a percentage of the traffic count. It is a useful tool for determining the precision of the modeled volume. %RMSE is a measure of accuracy of the traffic assignment measuring the average error between the observed traffic count and modeled traffic volumes. Scatter plot provides a visual image of the correlation between traffic counts and model estimates, and it assesses dispersion visually.

The TAFT traffic assignment model is validated through the comparison of the following performance measures:

- Model comparison statistics, including %Error, R^2, %RMSE, MAE, by functional class for daily and time of day traffic;
- Scatter plot of model vs. count by functional class and by time of day;
- The percentage link vs percentage error for daily traffic on freeway and principal arterials;
- Model comparison statistics, including %Error, R^2, %RMSE, MAE, on toll roads for daily and time of day traffic;
- Scatter plot of toll roads for daily and time of day traffic;
- Model comparison statistics, including %Error, R^2, %RMSE, MAE, by area type and by functional class for daily traffic;
- Model comparison statistics, including %Error, R^2, %RMSE, MAE, by volume for daily and time of day traffic;
- Model comparison statistics, including %Error, R^2, %RMSE, MAE, by truck for daily and time of day traffic;
- Screenline analysis;
- Travel time comparison on freeway and arterials;
- Model comparison statistics, including %Error, R^2, %RMSE, MAE, by functional class and by county;
- Screenline analysis by county.

The percent error by functional class is compared with standard by Cambridge Systematics, Inc. (2008) (Exhibit 4-2). The performance measures are fairly well for freeway and arterials, and become worse on collectors. But overall, all functional classes satisfy the standard. The scatter plots show that it has good match with traffic counts for all links, freeway, and principal arterials. The variation in the scatter plots becomes large on minor arterials, collectors, freeway ramps and frontage roads.

It shows 40% freeway links are with error +/-10%; 70% freeway links have error +/-20%; and 85% freeway links have error +/-30%. On principal arterials, it shows 40% arterial links are with error +/-20%; 55% arterial links have error +/-30%; and 77% arterial links have error +/-50%.

Chapter 6 Backcast Year 2010 Validation

The 2010 validation for TAFT is a backcast model run. TAFT is calibrated and validated using 2014 data. Then this calibrated TAFT runs a backcast model in Year 2010, and is compared with 2010 traffic count to validate the developed TAFT model.

The majority of the traffic counts used in the calibration of the travel demand model were collected by the Texas Department of Transportation (TxDOT) as part of the Saturation Count program of 2010. It covers 20%-30% of the coded links in the network. The time-of-day counts is much less than daily counts. The total time-of-day counts is around 3500, compared to 7500 daily counts. For this reason, the 2010 validation focuses on daily count comparison.

6.1 Volume over count, daily, by functional class

The model comparisons by functional class for daily traffic is in Exhibit 6-1. For all functional class, the %error is 0% and %RMSE is 41%. For functional class 1 (freeway), %error is -3% and %RMSE is 20%. For arterials (F2-F4) the %RMSE is around 40%-65%, which means the arterials with low volume is more difficult to match. For principal arterial and minor arterial, %error is within 10%. For collectors, %error is within 20%. These statistics indicate the model quality is good in the daily traffic counts comparison. Scatter plot for all and each functional class in daily counts comparison are shown in Exhibit 6-2 to 6-8. The statistics in TAFT 2010 are better than those in the DFX model vs. count comparison.

Exhibit 6-1. Model comparisons by functional class, 2010 validation

Funcl	**2010 Day**				
	#obs	**%Error**	**R^2**	**%RMSE**	**MAE(%)**
1	926	-3%	0.86	20%	17%
2	1,246	4%	0.65	41%	37%
3	2,199	4%	0.56	49%	43%
4	1,369	-16%	0.29	65%	53%
6	1,321	8%	0.53	60%	50%
7	377	2%	0.34	66%	61%
All	7,439	0%	0.85	41%	43%

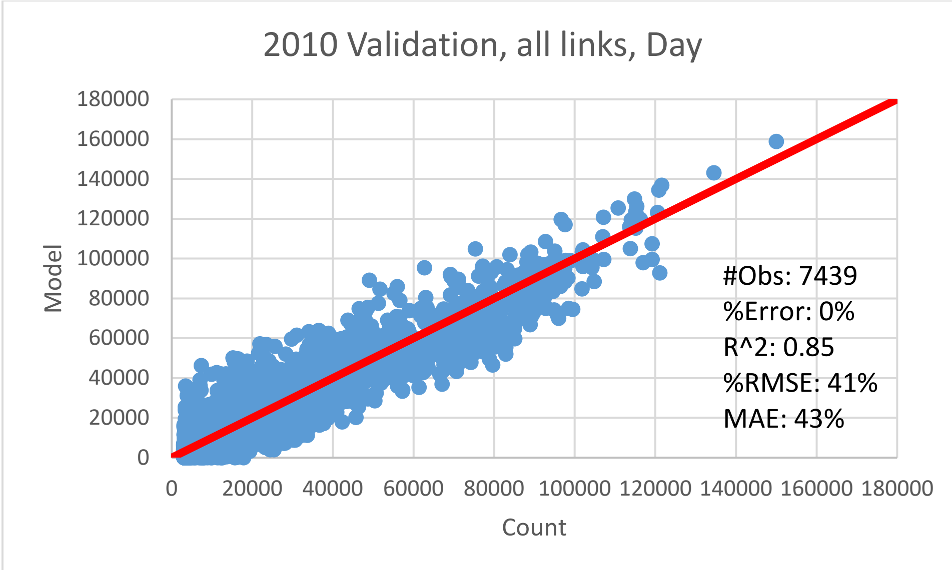

Exhibit 6-2. Scatter plot for all links, day, TAFT model vs. count, 2010 validation

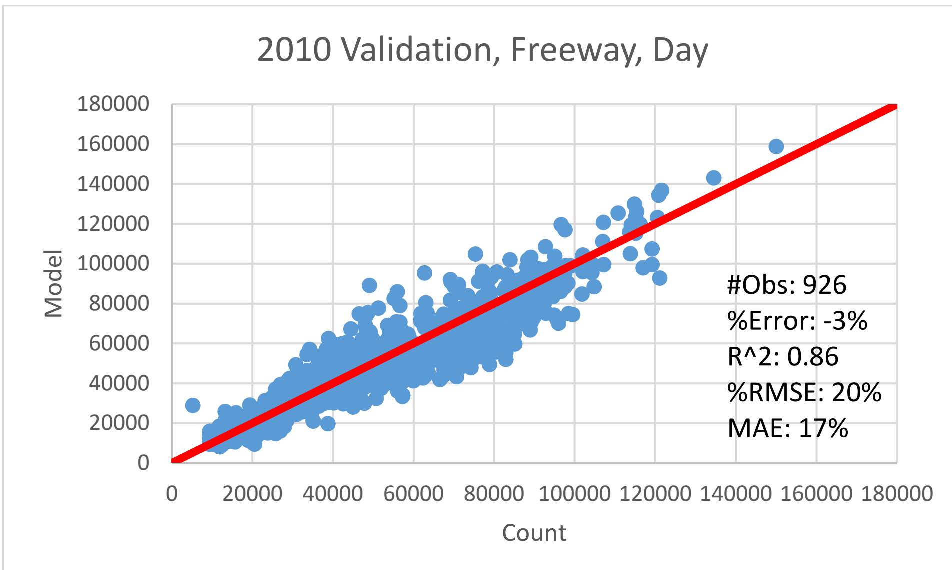

Exhibit 6-3. Scatter plot for freeway, day, TAFT model vs. count, 2010 validation

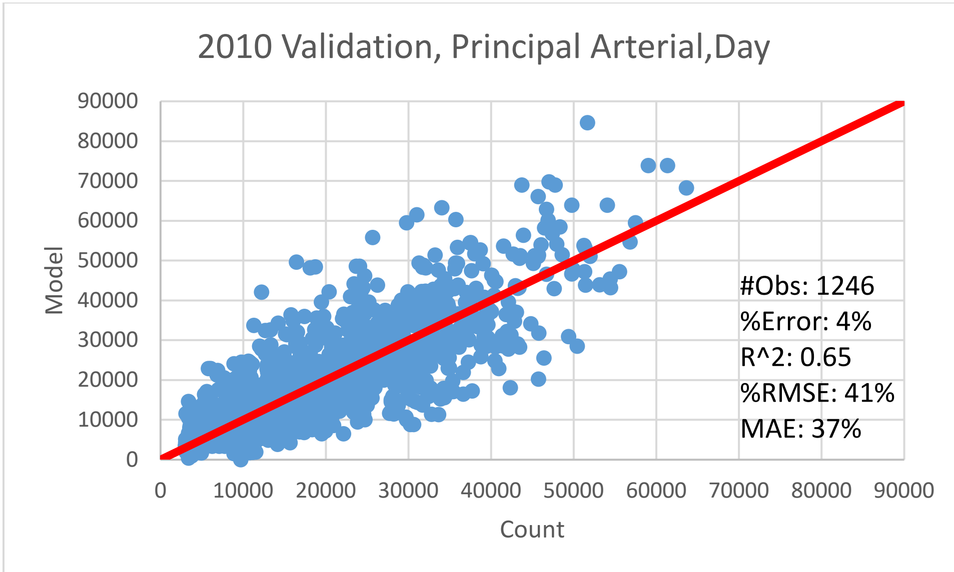

Exhibit 6-4. Scatter plot for principal arterial, day, TAFT model vs. count, 2010 validation

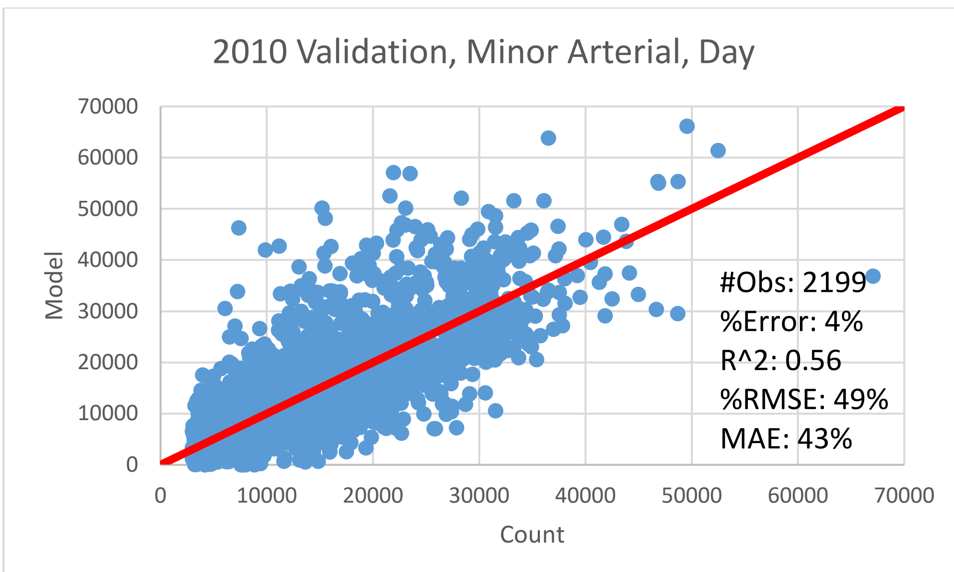

Exhibit 6-5. Scatter plot for minor arterial, day, TAFT model vs. count, 2010 validation

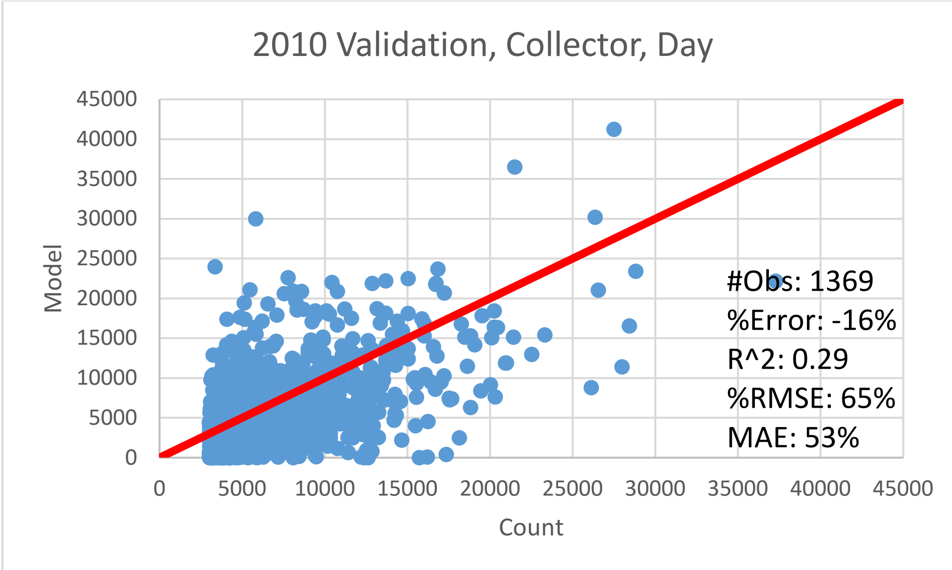

Exhibit 6-6. Scatter plot for collectors, day, TAFT model vs. count, 2010 validation

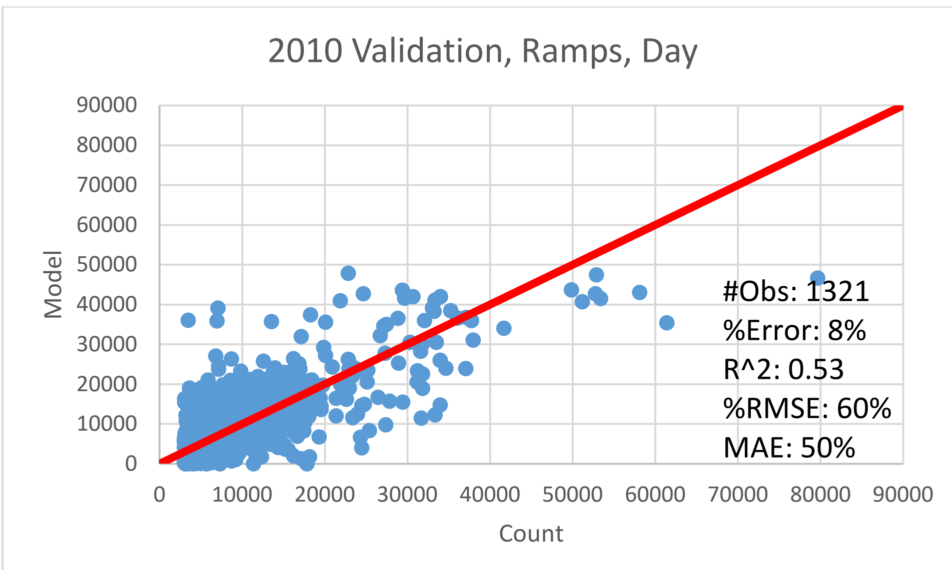

Exhibit 6-7. Scatter plot for freeway ramps, day, TAFT model vs. count, 2010 validation

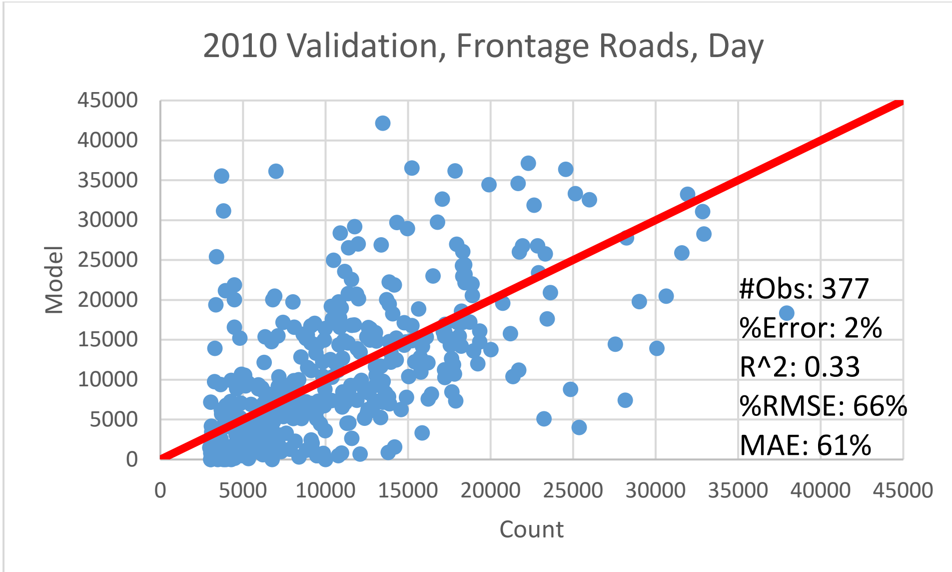

Exhibit 6-8. Scatter plot for frontage roads, day, TAFT model vs. count, 2010 validation

6.2. Conclusion

The backcast TAFT model for year 2010 validation is compared to the TxDOT traffic counts in the daily basis. Performance measures of %Error, R^2, %RMSE and MAE are statistic tools to validate the model. Statistics of %RMSE and MAE show the 2010 TAFT matches the traffic counts better than 2014, particularly on arterials and ramp and frontage roads. On freeway both 2010 and 2014 achieve the %RMSE 20%. From the %Error standpoint, year 2014 matches traffic counts better than 2010. Nevertheless, both 2010 and 2014 meet the preferable standard in Exhibit 4-2. In summary, the scatter plots and the compared statistics support the conclusion that the year 2010 TAFT model validation is successful.

Chapter 7. Forecast Year 2019 Validation

The 2019 validation for TAFT is a forecast model run. TAFT is calibrated and validated using 2014 data. Then this calibrated TAFT runs a forecast model in Year 2019, and is compared with 2019 traffic count to validate the developed TAFT model.

The majority of the traffic counts in Year 2019 were collected by the Texas Department of Transportation (TxDOT) as part of the Saturation Count program of 2019. The coverage of the traffic counts is summarized in Exhibit 3-1. On freeways the TxDOT counts are limited, only 215 observations. Therefore, we used another source of traffic counts on freeway, the side fire device traffic counts, to supplement the traffic counts on freeway. There are around 1,100 observations collected by side fire device on freeways.

7.1 Volume over count, daily, by functional class

The model comparisons by functional class for daily traffic is in Exhibit 7-1. For all functional class, the %error is 5% and %RMSE is 48%. For functional class 1 (freeway), %error is 2% and %RMSE is 20%. This number is consistent with Year 2010 and Year 2014 validation, where %RMSE is all 20%. For arterials (F2-F4) the %RMSE is around 36%-70%, because the arterial with low volume is more difficult to match. For principal arterial, %error is within 3%. For minor arterials, the %error is 9%. For collectors, %error is -7%. The result on collectors is better than that in Year 2010 and Year 2014 validation, where the %error on collectors is among 14%-16%. In Year 2019 validation, freeway ramps are with high %error and %RMSE. One possible reason is that the counts on ramps are fewer with only 300 observations. In Year 2014 the counts on ramps are around 3,000. Counts with fewer observations are more difficult to match. Frontage roads are with %error -15% and %RMSE 76%. It means the standard of +/- 20%. Overall, the statistics in Year 2019 validation is good in the daily traffic counts comparison. Scatter plot for all and each functional class in daily counts comparison are shown in Exhibit 7-2 to 7-8.

Exhibit 7-1. Model comparisons by functional class, 2019 validation

Funcl	2019 Day				
	#obs	%Error	R^2	%RMSE	MAE(%)
1	215	2%	0.91	20%	17%
2	2,391	3%	0.54	36%	32%
3	4,498	9%	0.42	52%	48%
4	2,054	-7%	0.28	71%	73%
6	313	37%	0.4	99%	116%
7	475	-15%	0.55	76%	74%
All	9,808	5%	0.79	48%	54%

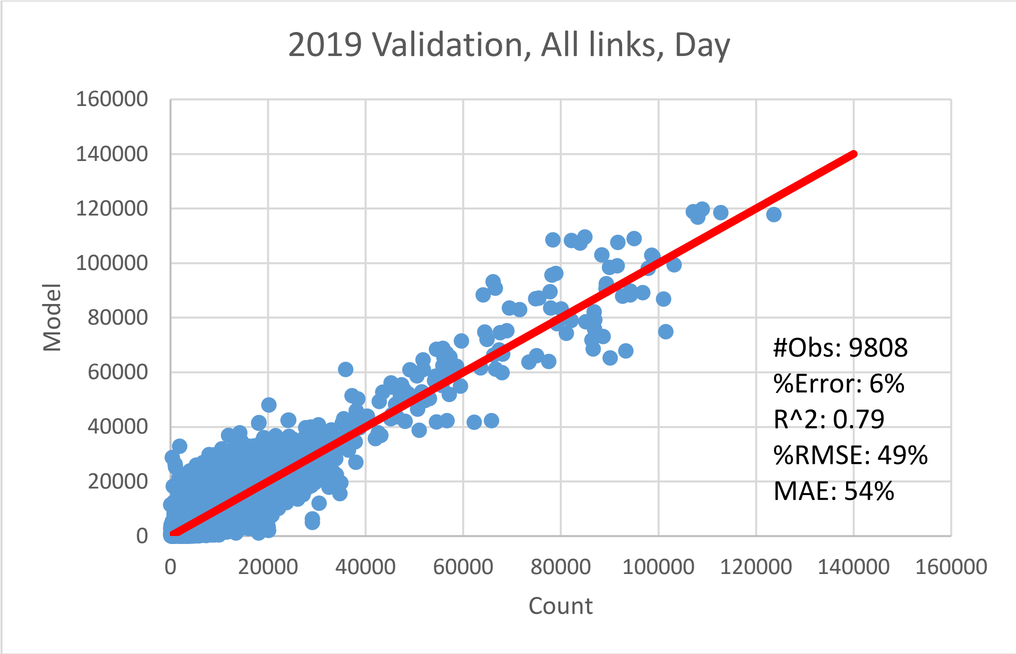

Exhibit 7-2. Scatter plot for all links, day, TAFT model vs. count, 2019 validation

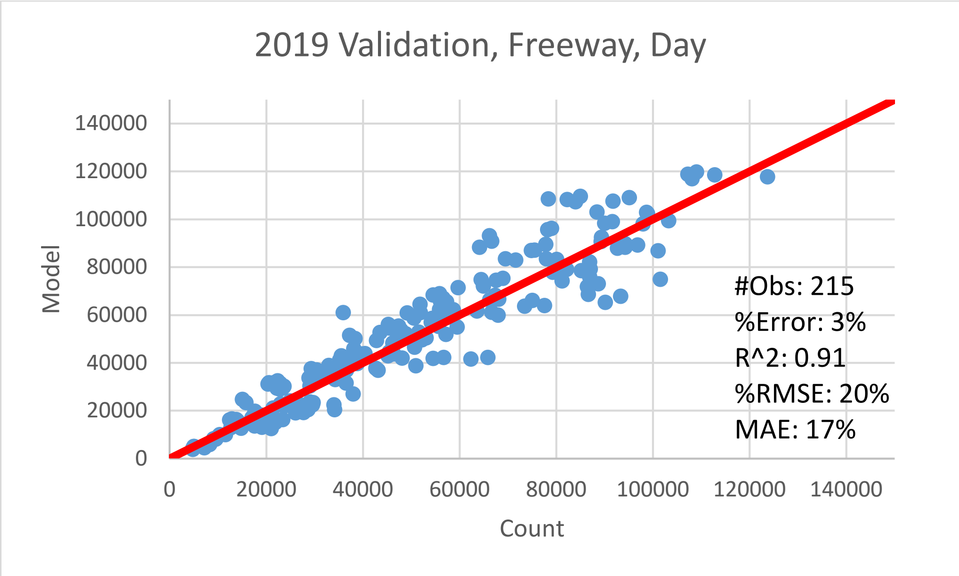

Exhibit 7-3. Scatter plot for freeway, day, TAFT model vs. count, 2019 validation

It is noticed that the freeway in TxDOT saturation counts are few, with only 215 observations. Therefore we further compared freeway counts with side fire device, which has 1,100 observations. The daily comparison is shown in Exhibit 7-4.

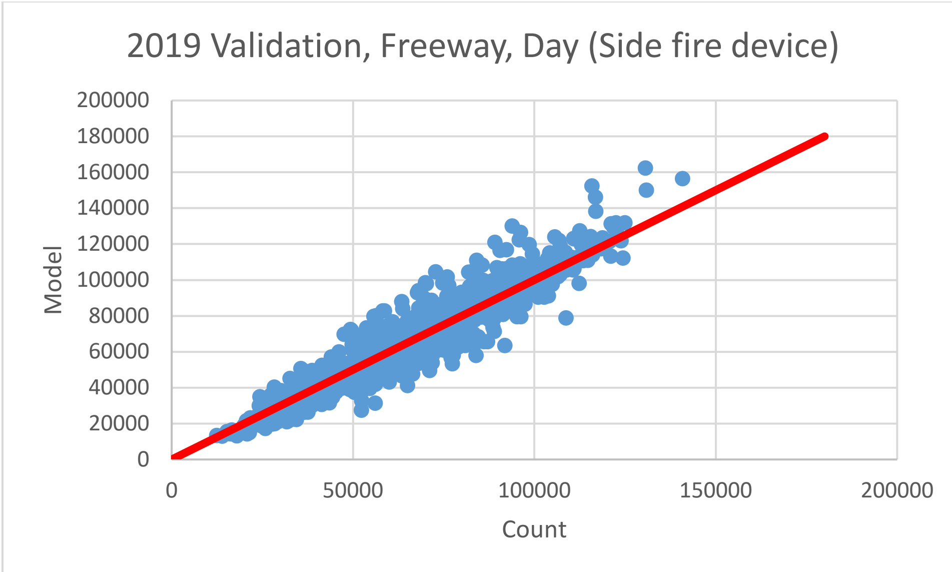

Exhibit 7-4. Scatter plot for freeway, day, TAFT model vs. count (side fire device), 2019 validation

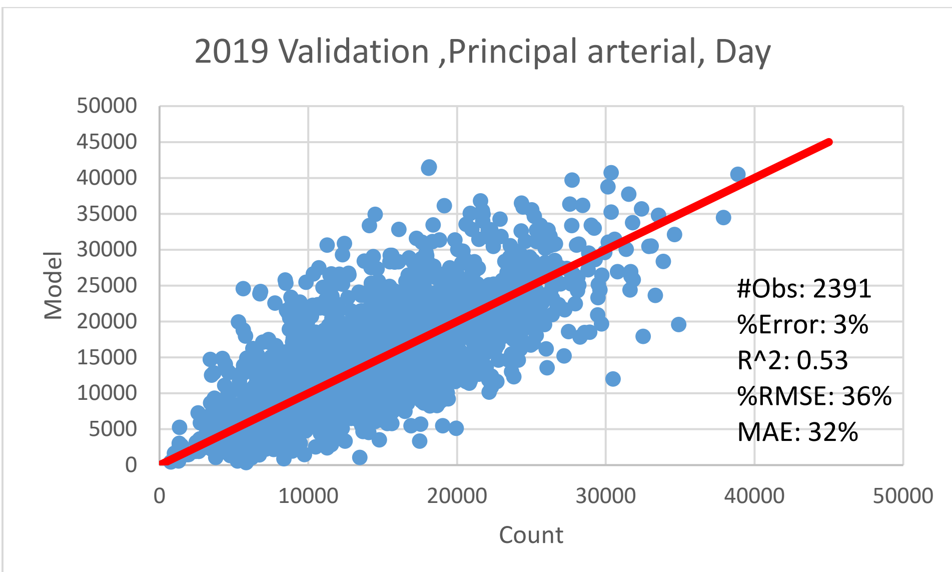

Exhibit 7-5. Scatter plot for principal arterial, day, TAFT model vs. count, 2019 validation

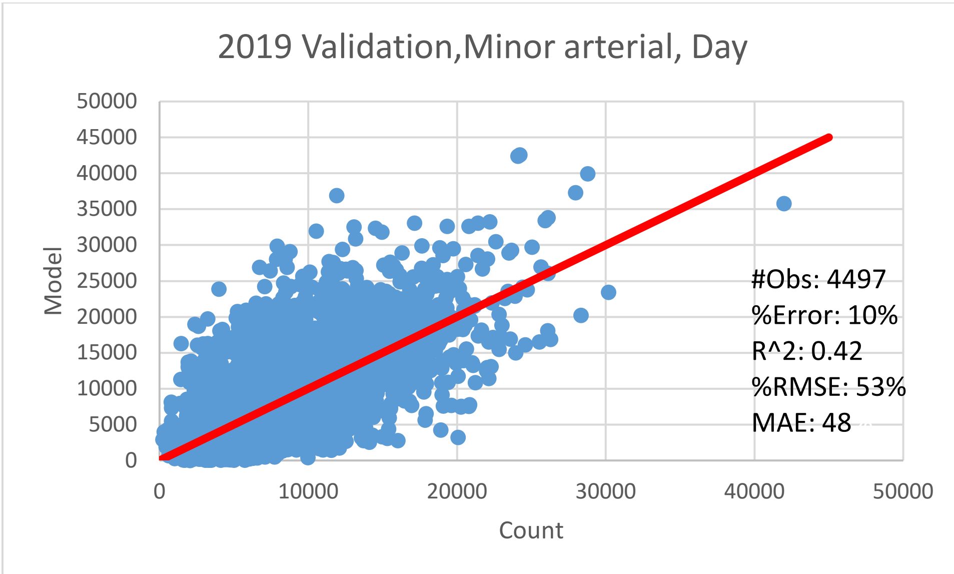

Exhibit 7-6. Scatter plot for minor arterial, day, TAFT model vs. count, 2019 validation

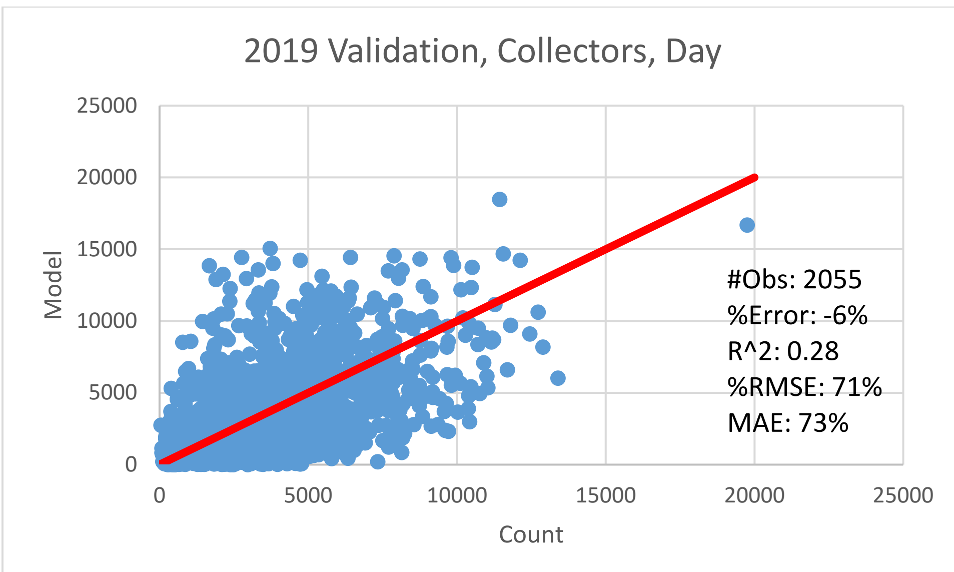

Exhibit 7-7. Scatter plot for collectors, day, TAFT model vs. count, 2019 validation

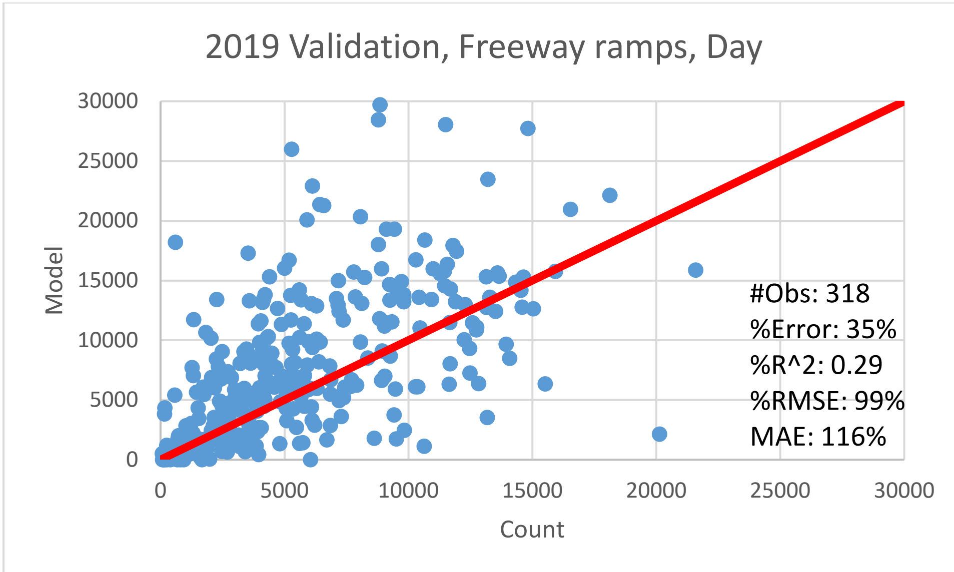

Exhibit 7-8. Scatter plot for freeway ramps, day, TAFT model vs. count, 2019 validation

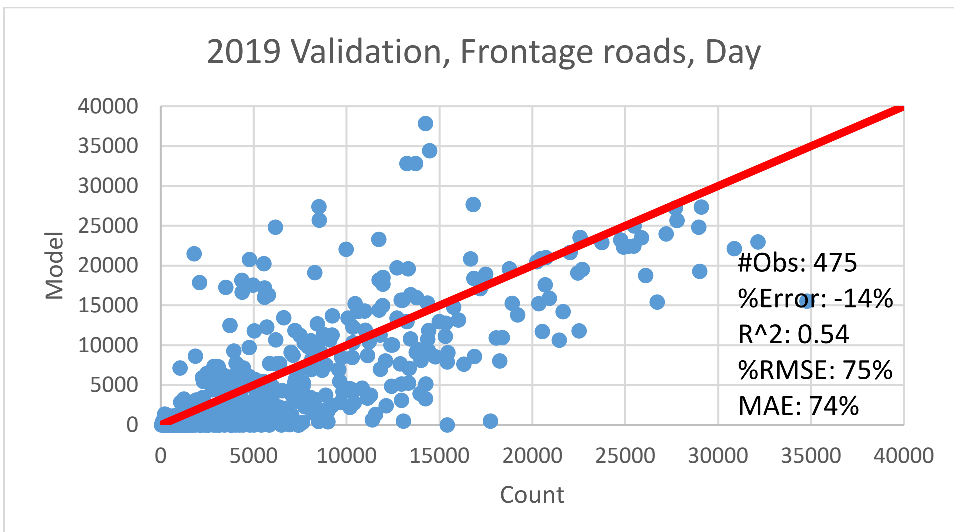

Exhibit 7-9. Scatter plot for frontage roads, day, TAFT model vs. count, 2019 validation

7.2 Volume over count, by functional class, time-of-day

Model comparison by functional class for time of day is summarized in Exhibit 7-10 to 7-12. The results by time of day are generally worse than that of daily. From percent error (%Error) standpoint, the model has a fairly good match to traffic counts for freeway and principal arterials. Minor arterials in AM has a large %error of 24%, which is beyond the standard of +/- 10%. Collectors is well behaved compared to Year 2014 and Year 2010 validation, the AM, PM and OP time periods meet the preferable standard of +/- 20%. The statistics for ramp have large errors, among all time-of-day, which behaves similarly to the daily count comparison; it could be a sign of limited number of counts difficult to match. %Error for frontage roads meet the preferable standard +/-20%. It is noticed that the MAE for collectors and freeway ramps are high, we suspect the reason is that errors among the low-volume counts are high.

From %RMSE standpoint, freeway has the best result, about 30%. It is followed by principal arterial, about 40%-50%. On minor arterials, %RMSE is about 55% to 75%. On collectors, %RMSE is about 75% - 90%. The %RMSE on freeway ramps are high, which is consistent to statistics of %error and MAE analyzed on ramps. They all show that the freeway ramps come with the large error which could be due to sparse of limited number of counts.

Exhibit 7-10. Model comparison by functional class AM, 2019 validatlion

Funcl	2019 AM				
	#obs	%Error	R^2	%RMSE	MAE(%)
1	215	7%	0.8	33%	28%
2	2,395	11%	0.52	55%	61%
3	4,506	24%	0.48	77%	76%
4	2,120	6%	0.27	92%	130%
6	315	46%	0.33	114%	154%
7	465	5%	0.49	96%	103%
All	9,917	16%	0.69	70%	87%

Exhibit 7-11. Model comparison by functional class PM, 2019 validation

Funcl	2019 PM				
	#obs	%Error	R^2	%RMSE	MAE(%)
1	215	17%	0.85	32%	28%
2	2,395	2%	0.5	39%	76%
3	4,514	8%	0.42	55%	114%
4	2,134	-12%	0.26	75%	209%
6	315	31%	0.36	90%	142%
7	465	-15%	0.55	71%	77%
All	9,939	5%	0.72	52%	123%

Exhibit 7-12. Model comparison by functional class OP, 2019 validation

Funcl	2019 OP				
	#obs	%Error	R^2	%RMSE	MAE(%)
1	215	-3%	0.89	22%	19%
2	2,392	1%	0.46	43%	36%
3	4,511	7%	0.35	62%	54%
4	2,093	-8%	0.28	83%	76%
6	315	38%	0.27	113%	127%
7	465	-18%	0.5	84%	82%
All	9,868	3%	0.76	56%	61%

The scatter plots for functional class and time-of-day are shown in Exhibit 7-13 to 7-33.

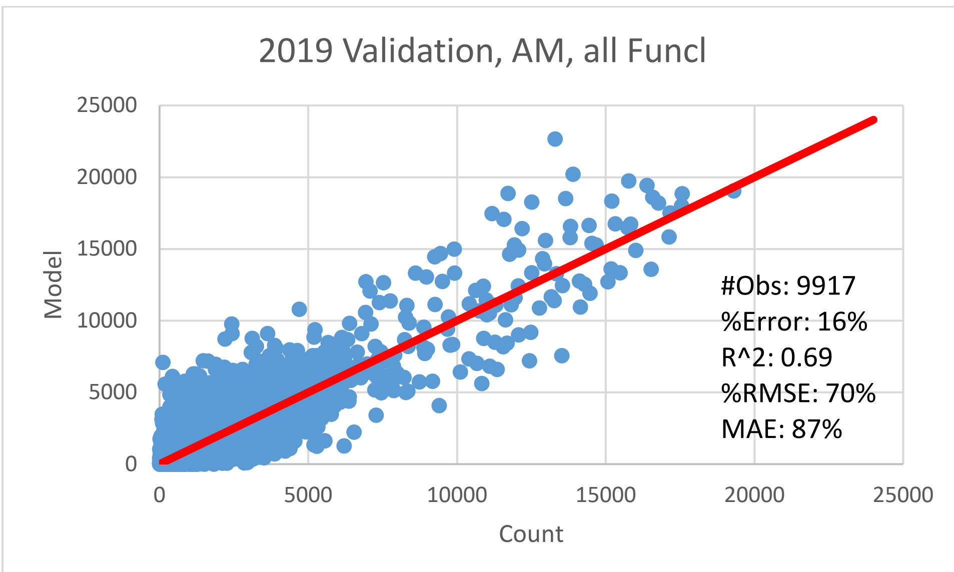

Exhibit 7-13. Scatter plot for all funcl, AM, TAFT model vs. count, 2019 validation

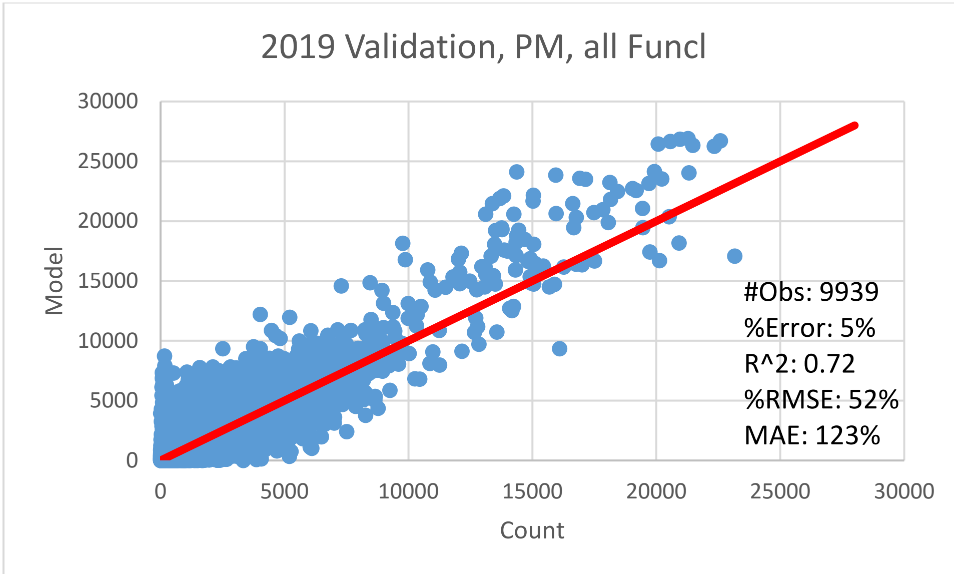

Exhibit 7-14. Scatter plot for all funcl, PM, TAFT model vs. count, 2019 validation

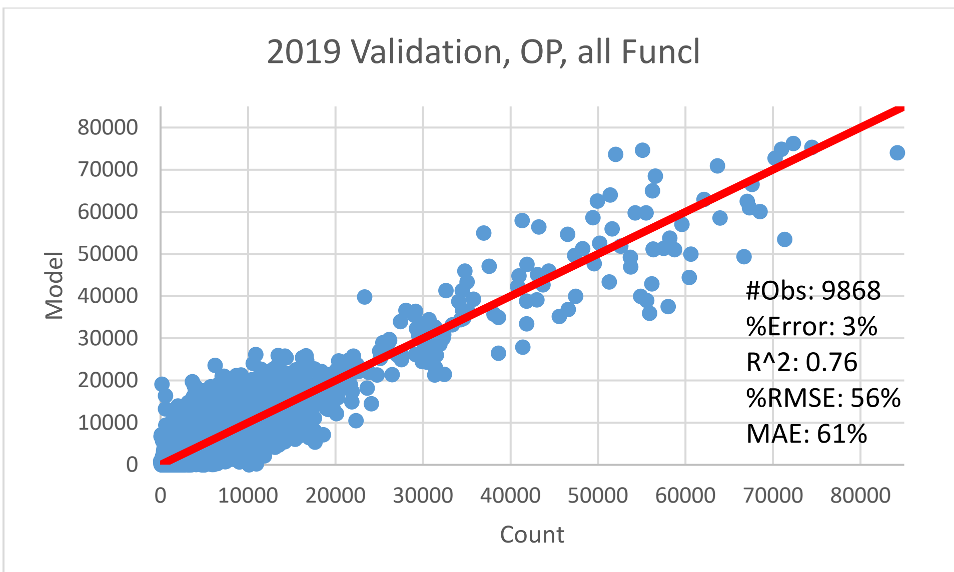

Exhibit 7-15. Scatter plot for all funcl, OP, TAFT model vs. count, 2019 validation

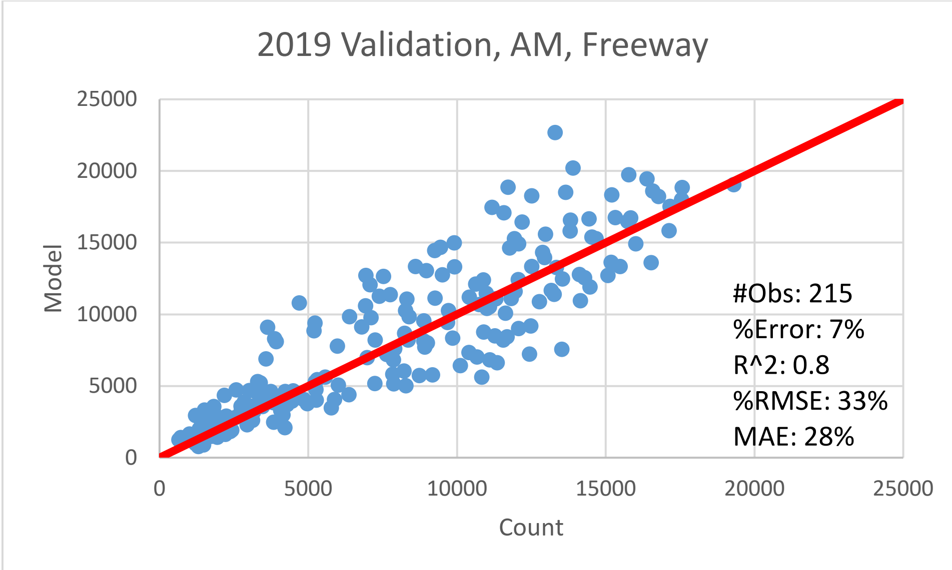

Exhibit 7-16. Scatter plot for freeway, AM, TAFT model vs. count, 2019 validation

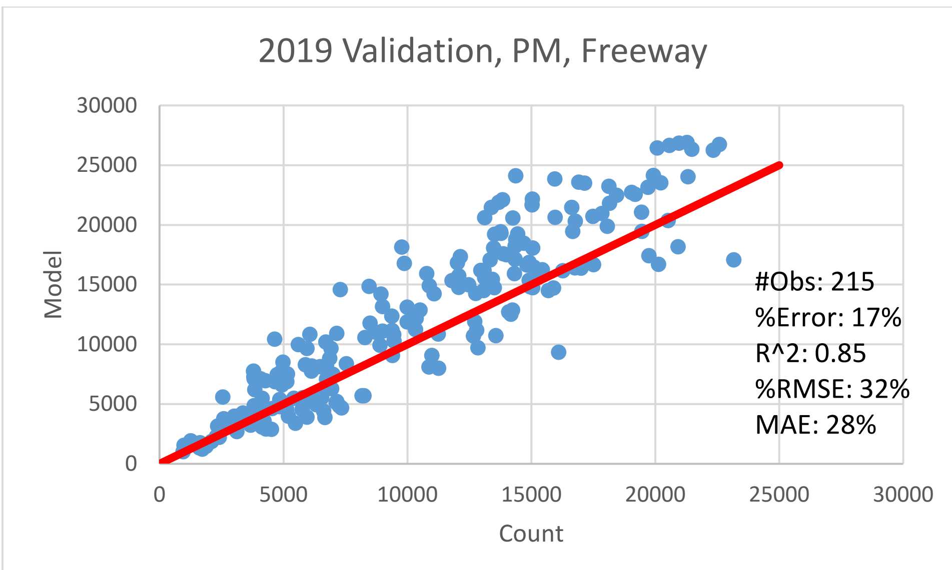

Exhibit 7-17. Scatter plot for freeway, PM, TAFT model vs. count, 2019 validation

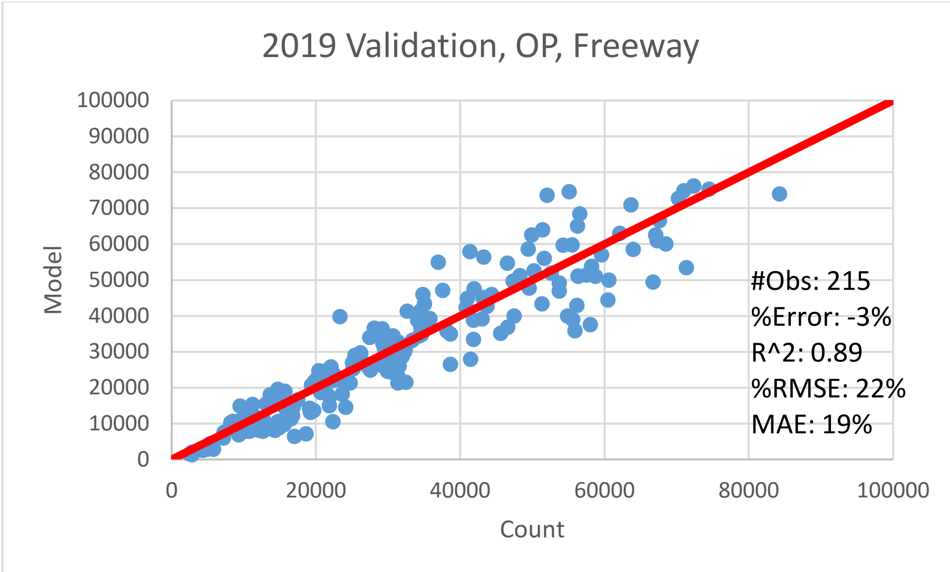

Exhibit 7-18. Scatter plot for freeway, OP, TAFT model vs. count, 2019 validation

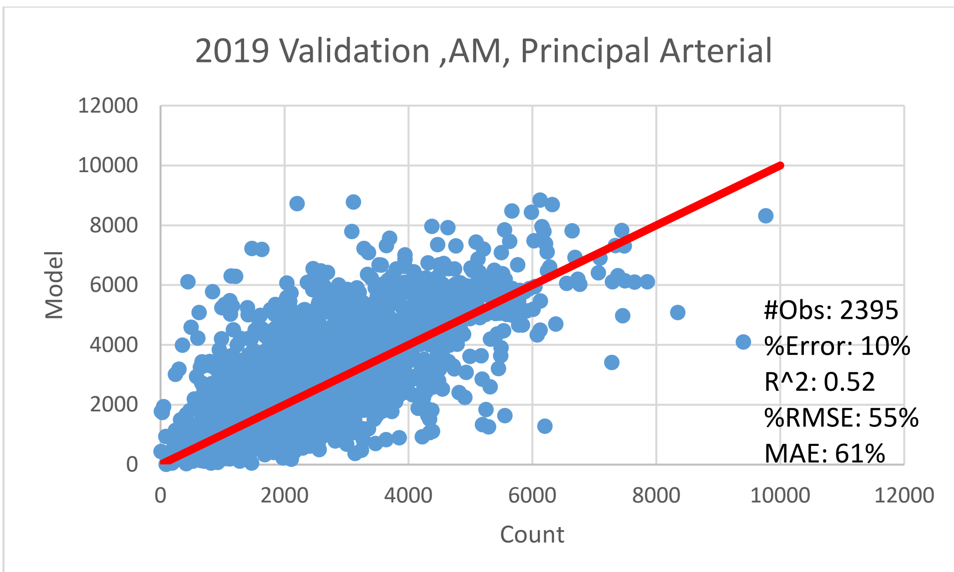

Exhibit 7-19. Scatter plot for Principal Arterial, AM, TAFT model vs. count, 2019 validation

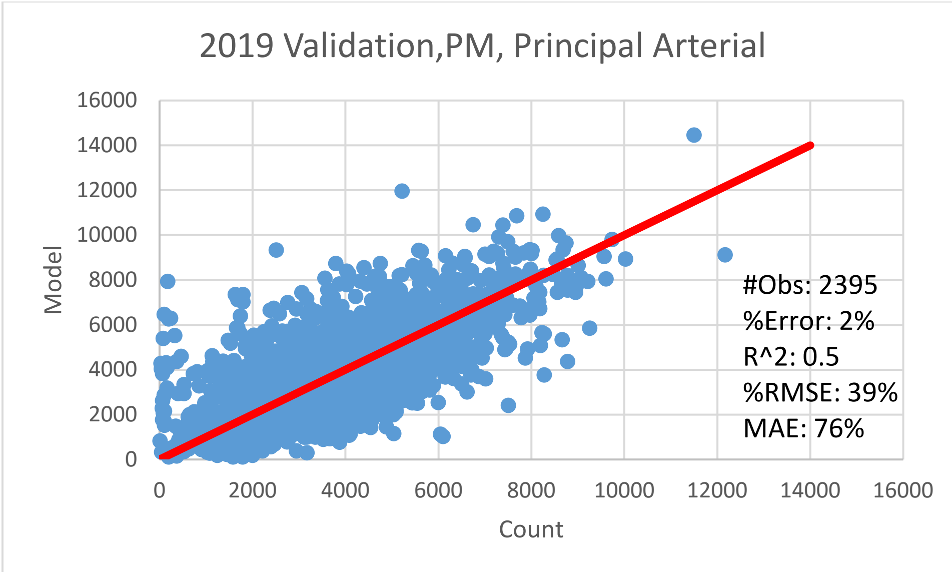

Exhibit 7-20. Scatter plot for Principal Arterial, PM, TAFT model vs. count, 2019 validation

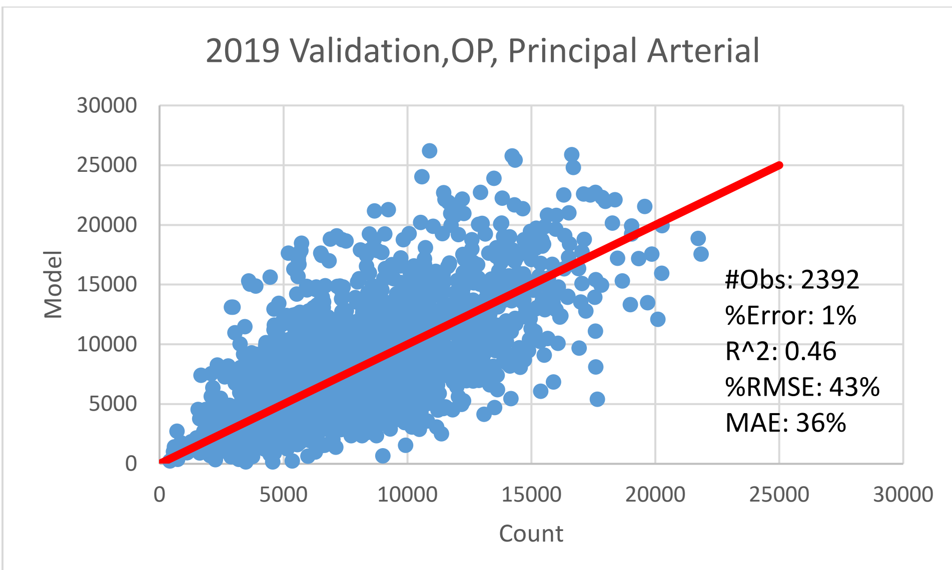

Exhibit 7-21. Scatter plot for Principal Arterial, OP, TAFT model vs. count, 2019 validation

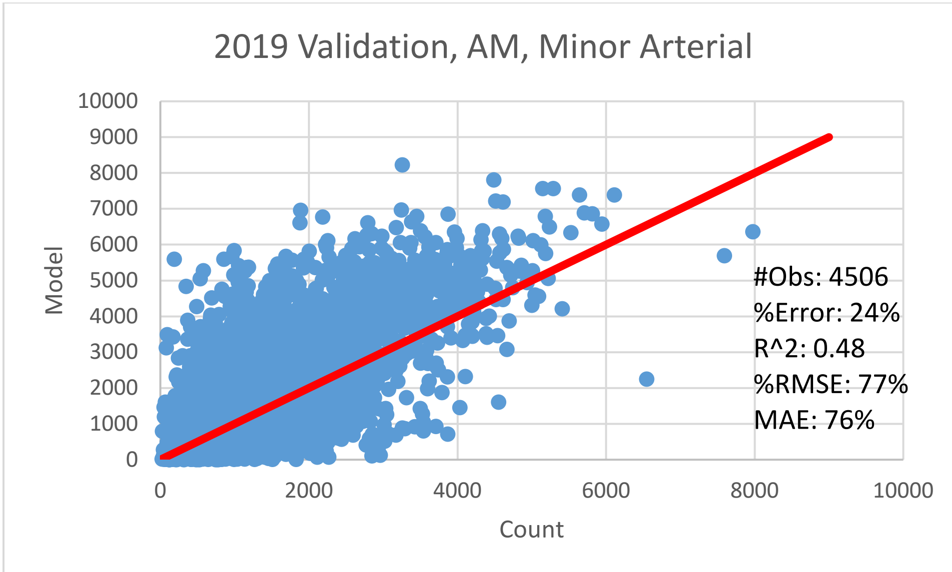

Exhibit 7-22. Scatter plot for Minor Arterial, AM, TAFT model vs. count, 2019 validation

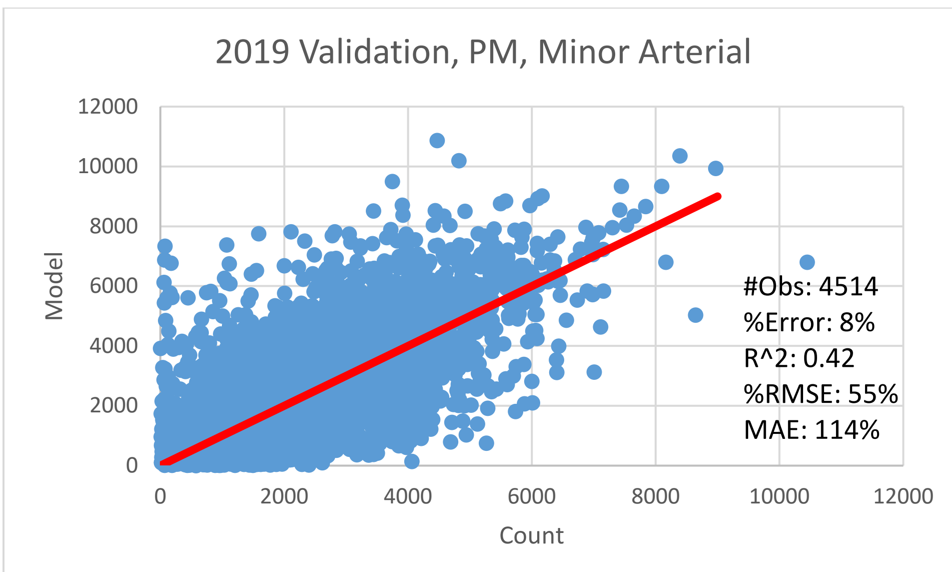

Exhibit 7-23. Scatter plot for Minor Arterial, PM, TAFT model vs. count, 2019 validation

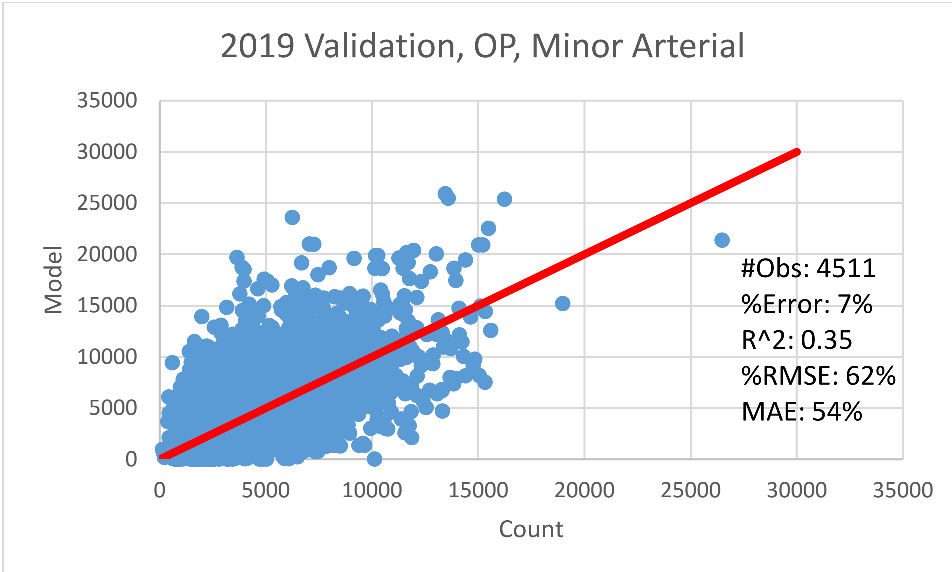

Exhibit 7-24. Scatter plot for Minor Arterial, OP, TAFT model vs. count, 2019 validation

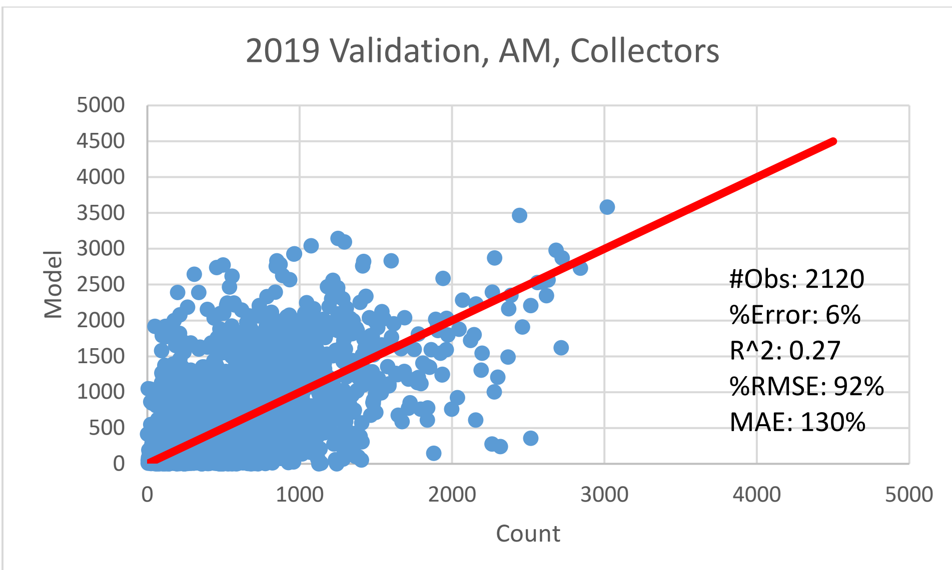

Exhibit 7-25. Scatter plot for Collectors, AM, TAFT model vs. count, 2019 validation

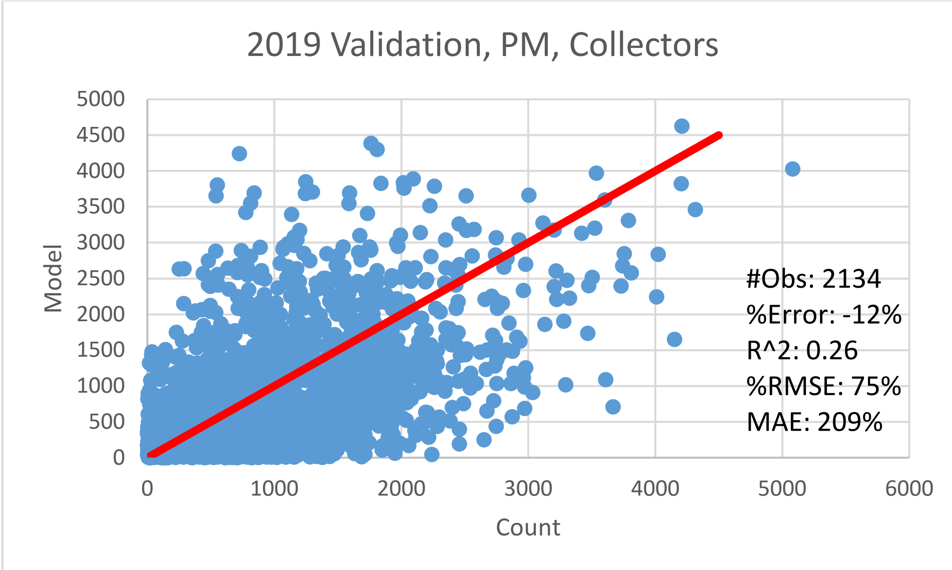

Exhibit 7-26. Scatter plot for Collectors, PM, TAFT model vs. count, 2019 validation

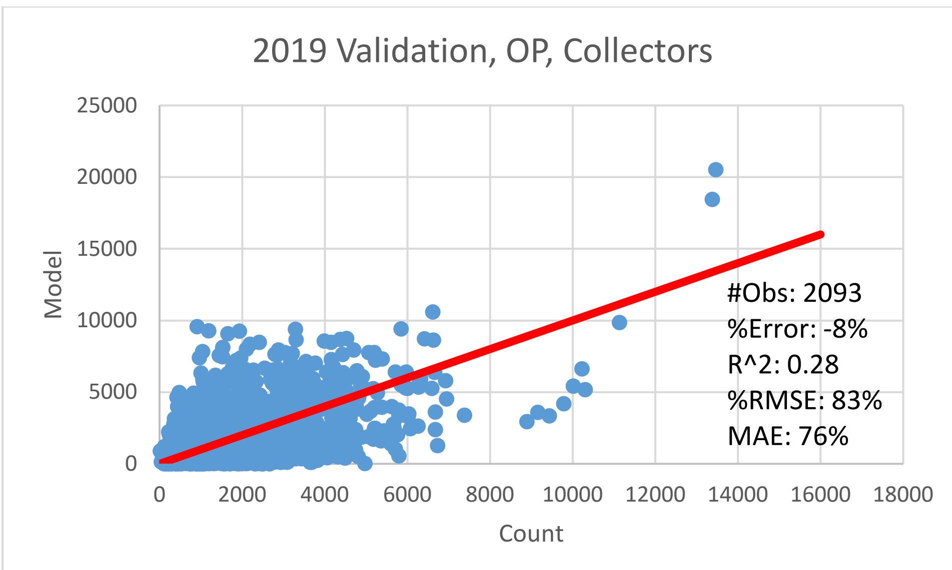

Exhibit 7-27. Scatter plot for Collectors, OP, TAFT model vs. count, 2019 validation

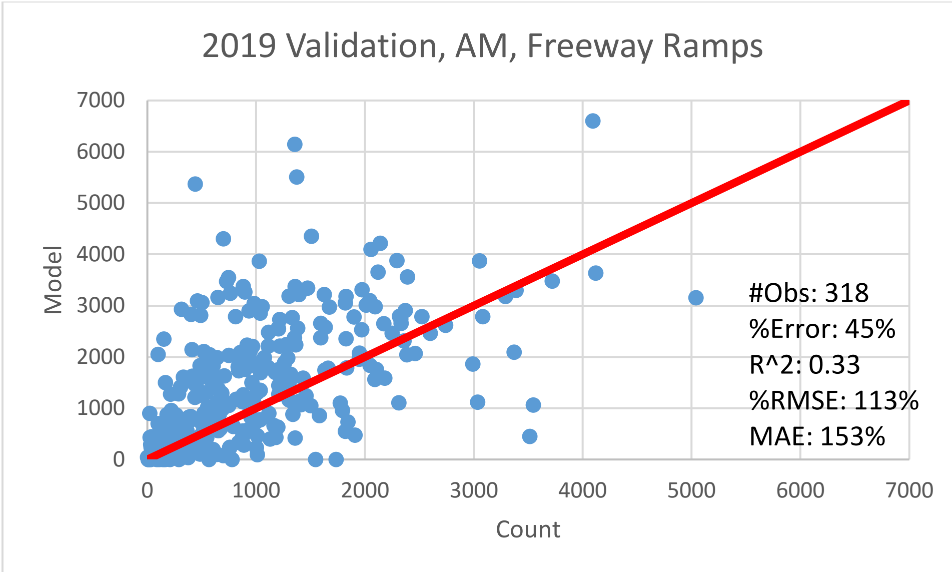

Exhibit 7-28. Scatter plot for freeway ramps, AM, TAFT model vs. count, 2019 validation

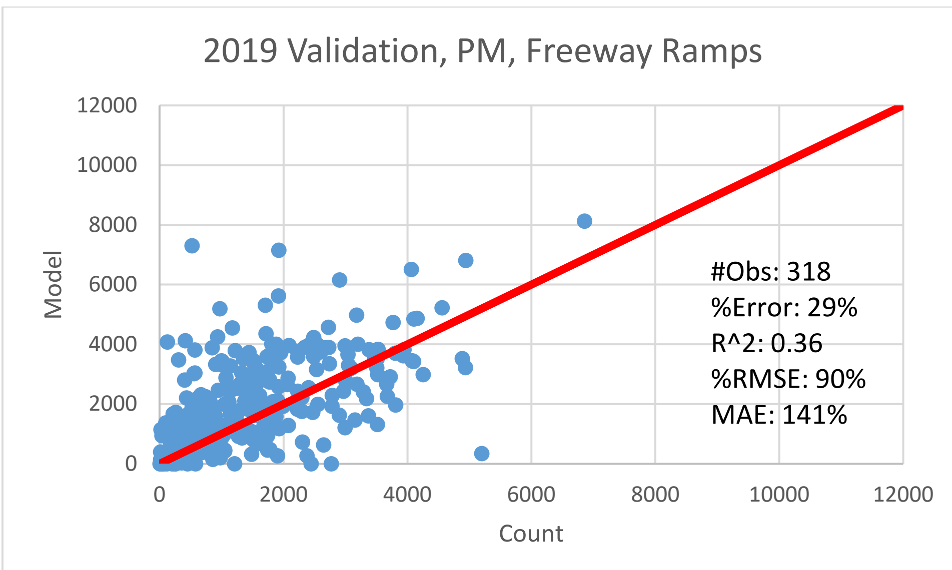

Exhibit 7-29. Scatter plot for freeway ramps, PM, TAFT model vs. count, 2019 validation

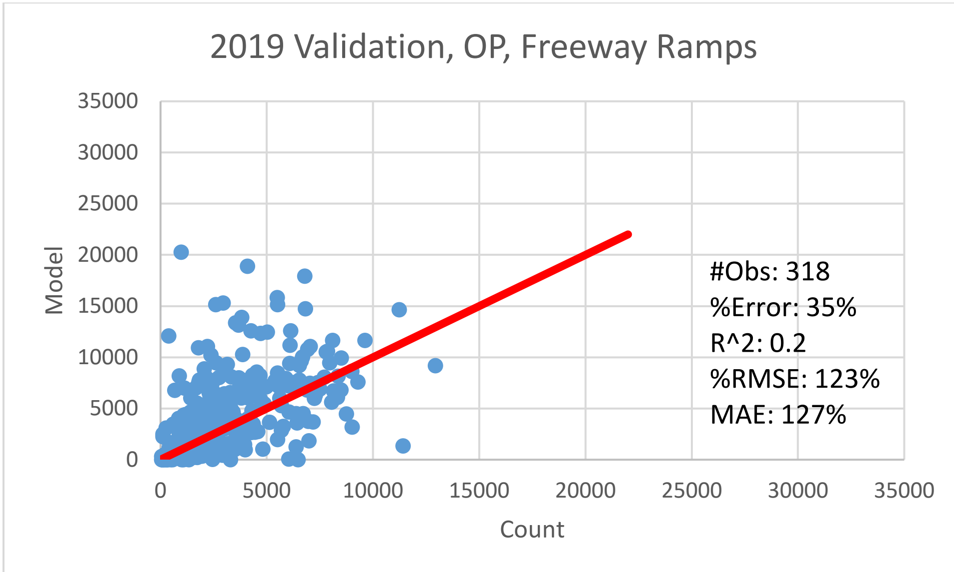

Exhibit 7-30. Scatter plot for freeway ramps, OP, TAFT model vs. count, 2019 validation

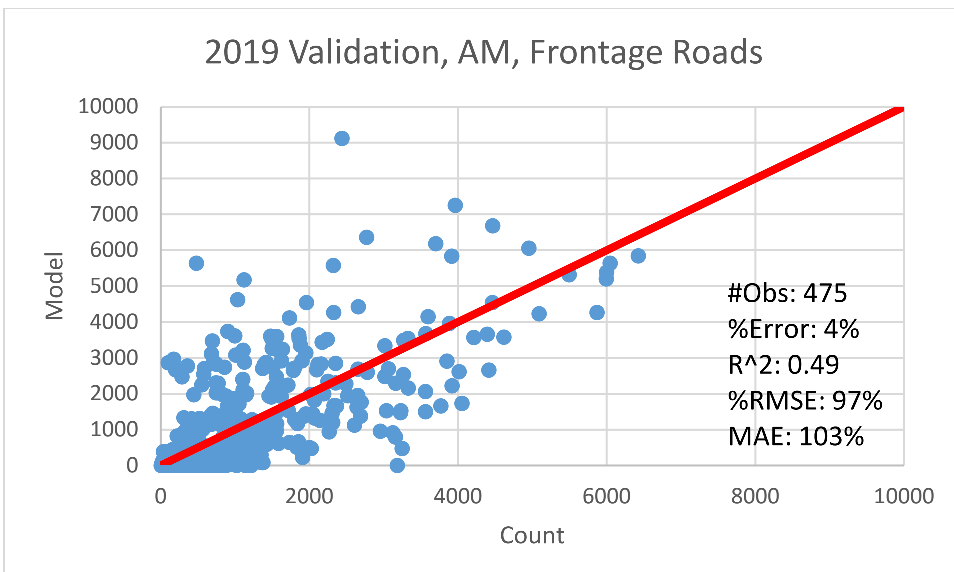

Exhibit 7-31. Scatter plot for frontage roads, AM, TAFT model vs. count, 2019 validation

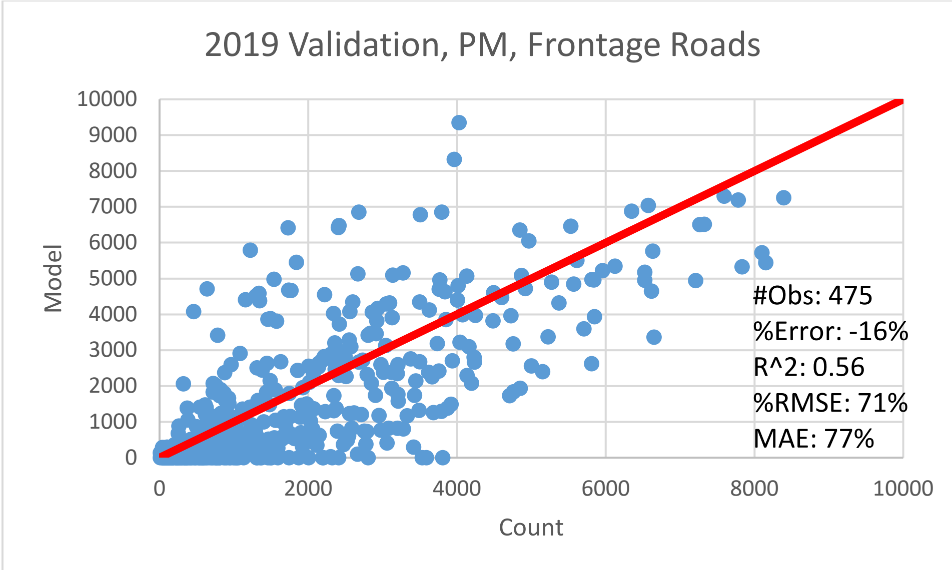

Exhibit 7-32. Scatter plot for frontage roads, PM, TAFT model vs. count, 2019 validation

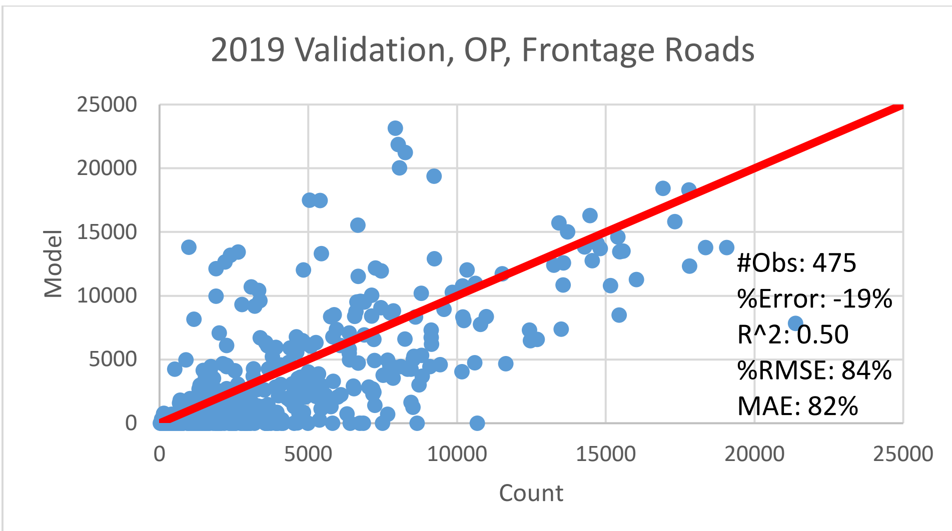

Exhibit 7-33. Scatter plot for frontage roads, OP, TAFT model vs. count, 2019 validation

7.3 Conclusion

In this section we conduct the validation of TAFT using YR 2019 traffic count data, mainly TxDOT saturation count on freeway and arterials, supported by the side fire device count on freeway.

The Year 2019 validation examines the comparisons between model and count by functional class for daily traffic, and by functional class for time-of-day. For all functional class, the %error is 5% and %RMSE is 48%. For functional class 1 (freeway), %error is 2%, which meets the standard of +/- 6%. The %RMSE is 20%, which is consistent with Year 2010 and Year 2014 validation on freeway. For arterials (F2-F4) the %error is between -7% to 9%, which meets the standard of +/- 10%. The %RMSE is around 36%-70%, which does not differ very much from the Year 2014 and 2010 validation results.

The Year 2019 validation also compare by functional class for time of day. The results by time of day are generally worse than that of daily. The percent error (%Error) exhibits that TAFT model has a fairly good match to traffic counts for freeway and principal arterials. Minor arterials in AM has a large %error of 24%, which is beyond the standard of +/- 10%. Collectors have better statistics compared to Year 2014 and Year 2010 validation, the AM, PM and OP time periods meet the preferable standard of +/- 20%. The statistics for ramp have large errors, among all time-of-day, because ramps have limited number of counts and thus difficult to match. Statistics for frontage roads meet the standard.

The comparison of %RMSE show that freeway has the best result, about 30%. It is followed by principal arterial, about 40%-50%. On minor arterials, %RMSE is about 55% to 75%. On collectors, %RMSE is about 75% - 90%. The %RMSE on freeway ramps are high, which is consistent to statistics of %error and MAE analyzed on ramps.

Based on the comparison statistics performed in the above section, we conclude that for the Year 2019 the TAFT model passes the validity test.

References

Cambridge Systematics, Inc. (2008). FSUTMS – Cube Framework Phase II Model Calibration and Validation Standards, prepared for Florida Department of Transportation Systems Planning Office.

TMIP (2010). Travel Model Validation and Reasonableness Checking Manual Second Edition. Report prepared for Federal Highway Administration. Prepared by Cambridge Systematics, Inc.

USDOT (2015). The Value of Travel Time Savings: Departmental Guidance for Conducting Economic Evaluations Revision 2 (2015 Update). Office of the Secretary of Transportation, USDOT.

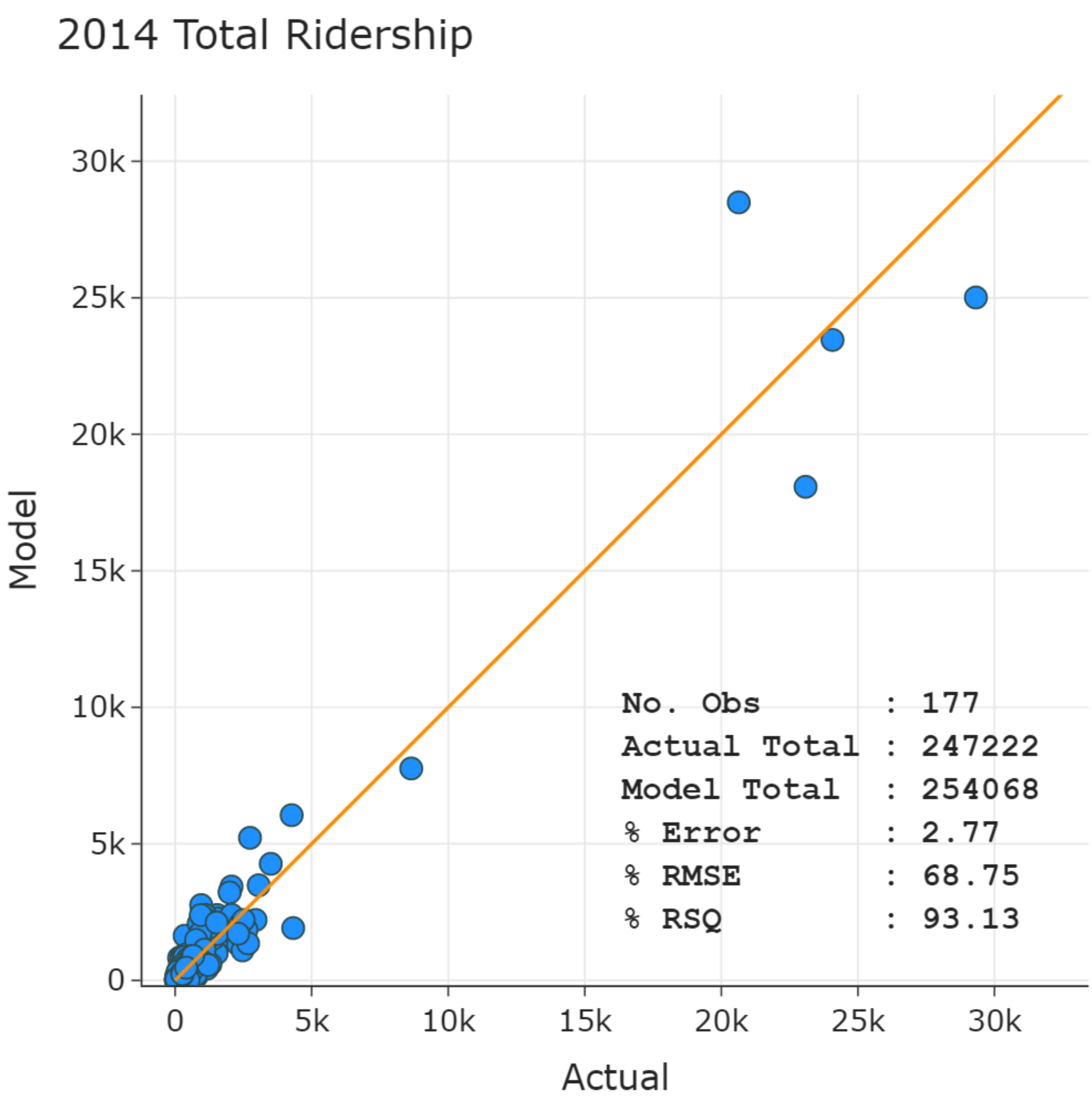

Exhibit Appendix A -1. 2014 Total Transit Ridership Comparison – Model vs Actual

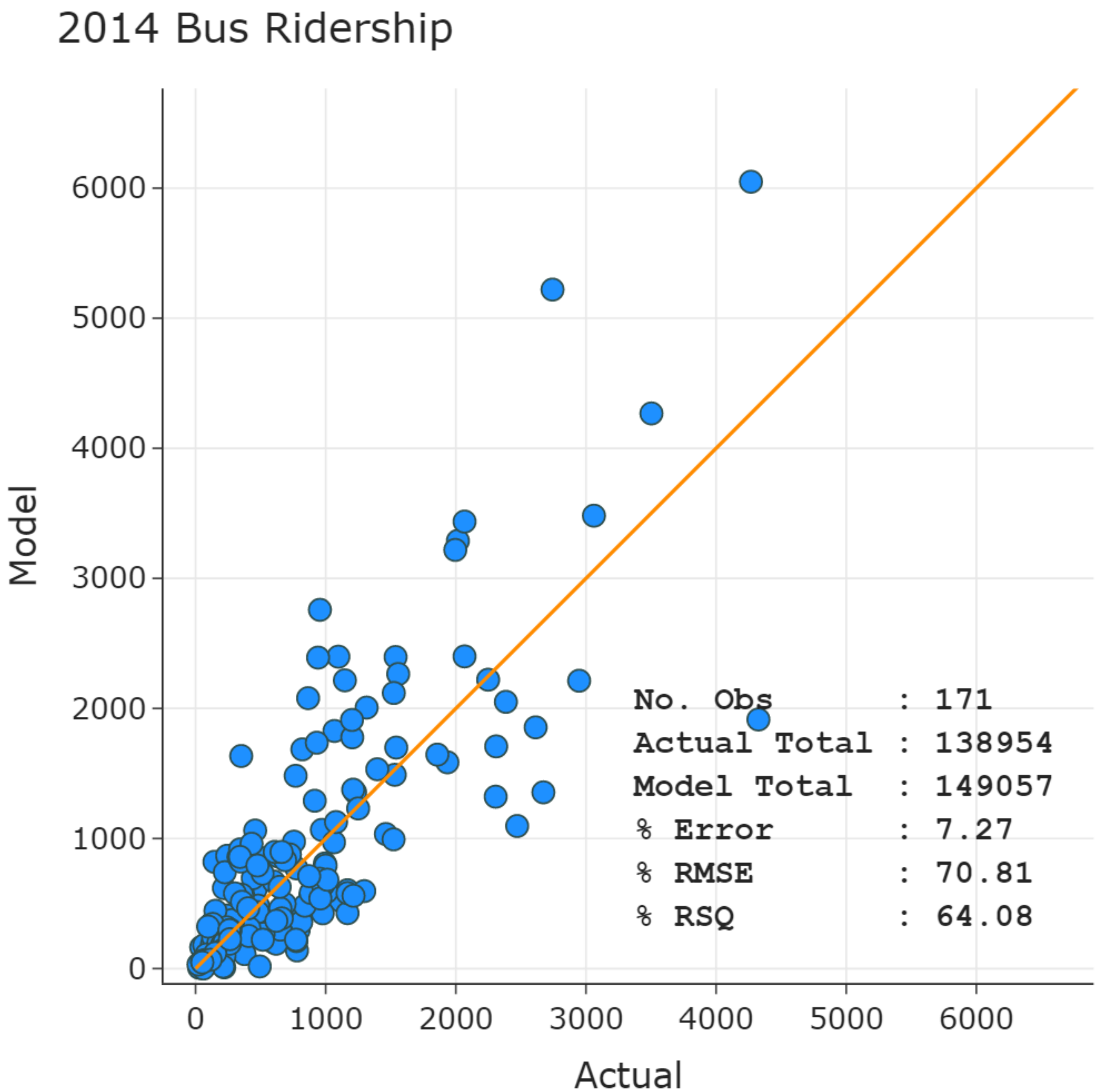

Exhibit Appendix A-2: 2014 Bus Ridership Comparison – Model vs Actual

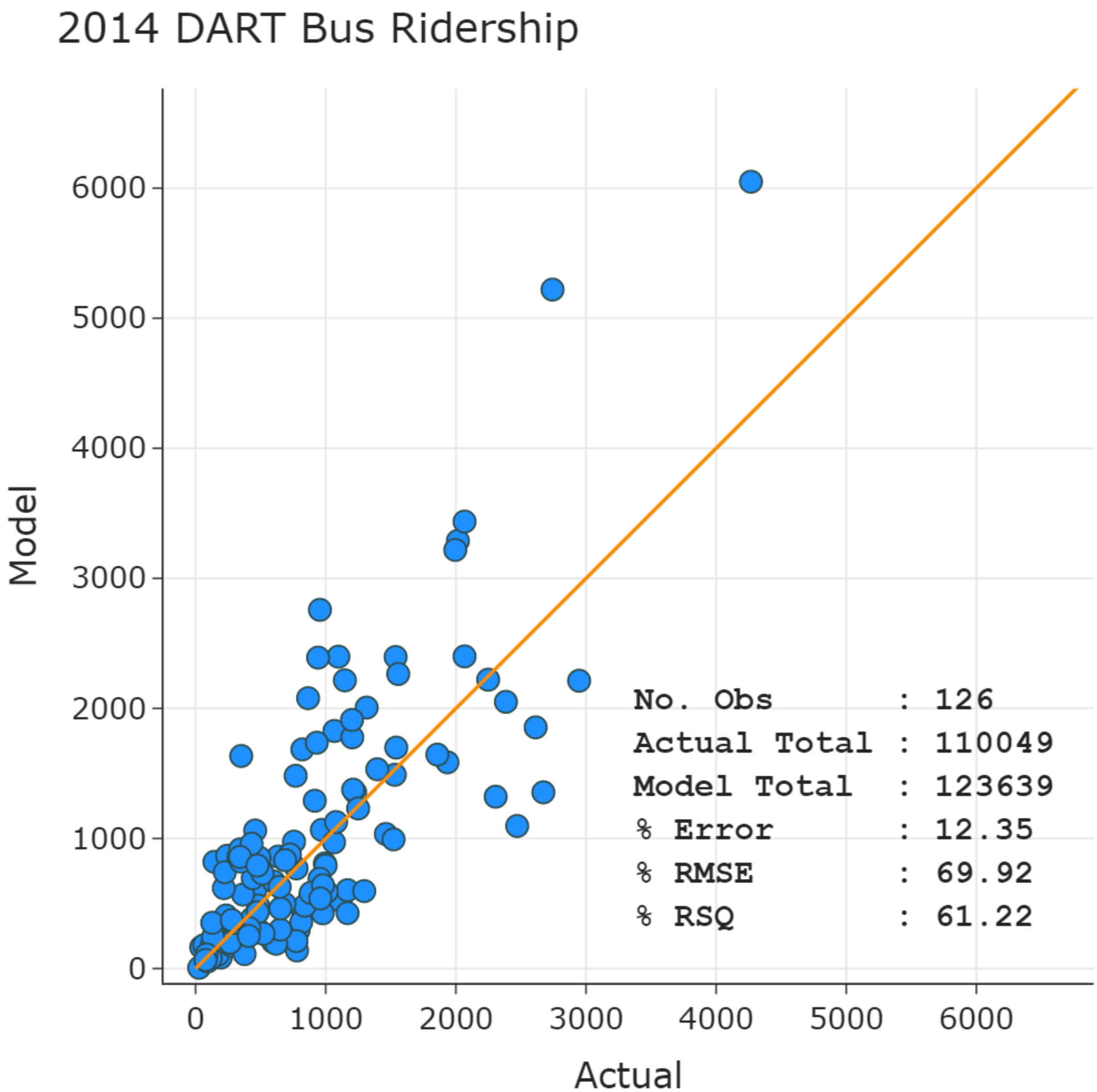

Exhibit Appendix A-3. 2014 DART Bus Ridership Comparison – Model vs Actual

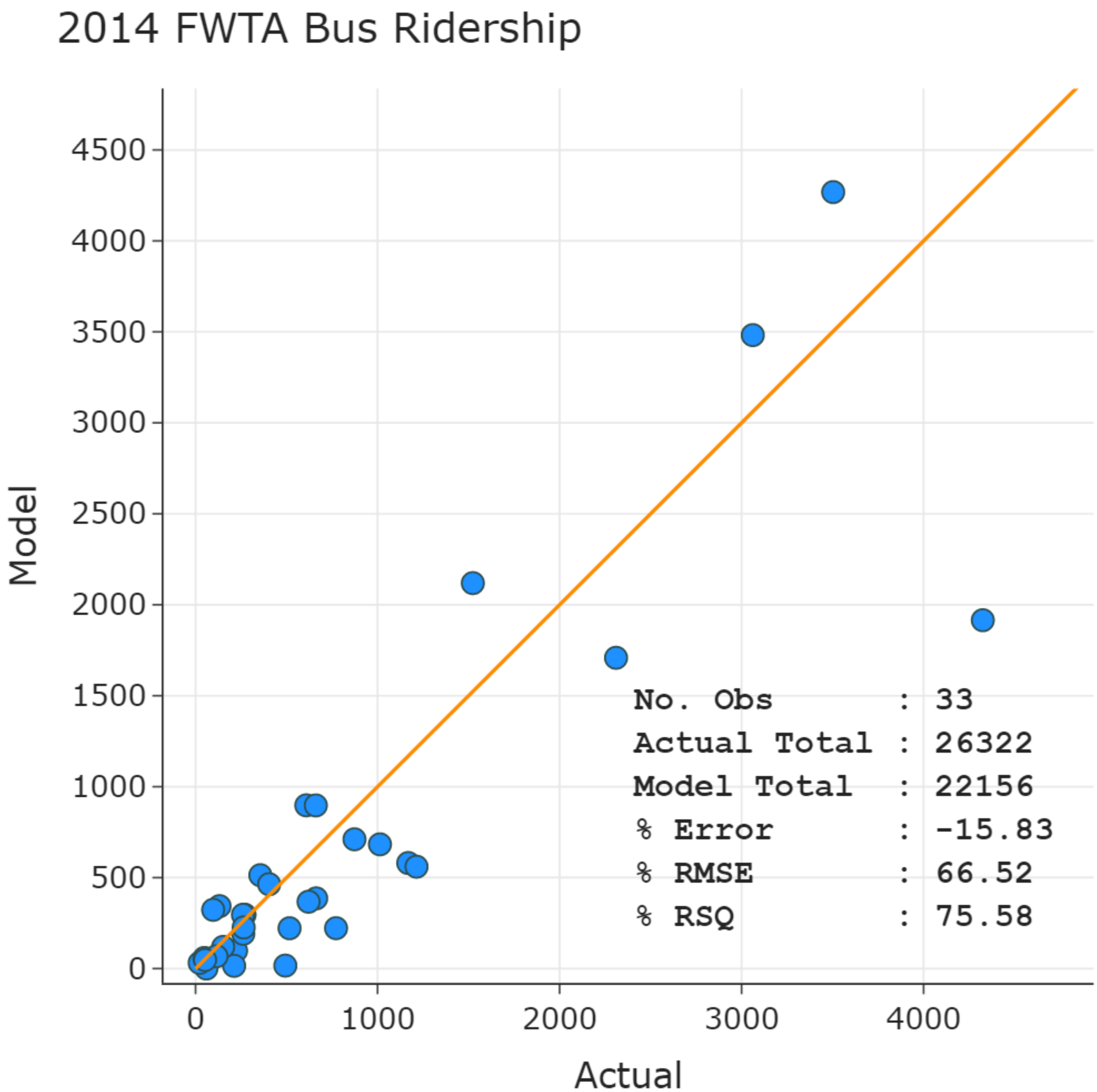

Exhibit Appendix A-4. 2014 FWTA Bus Ridership Comparison – Model vs Actual

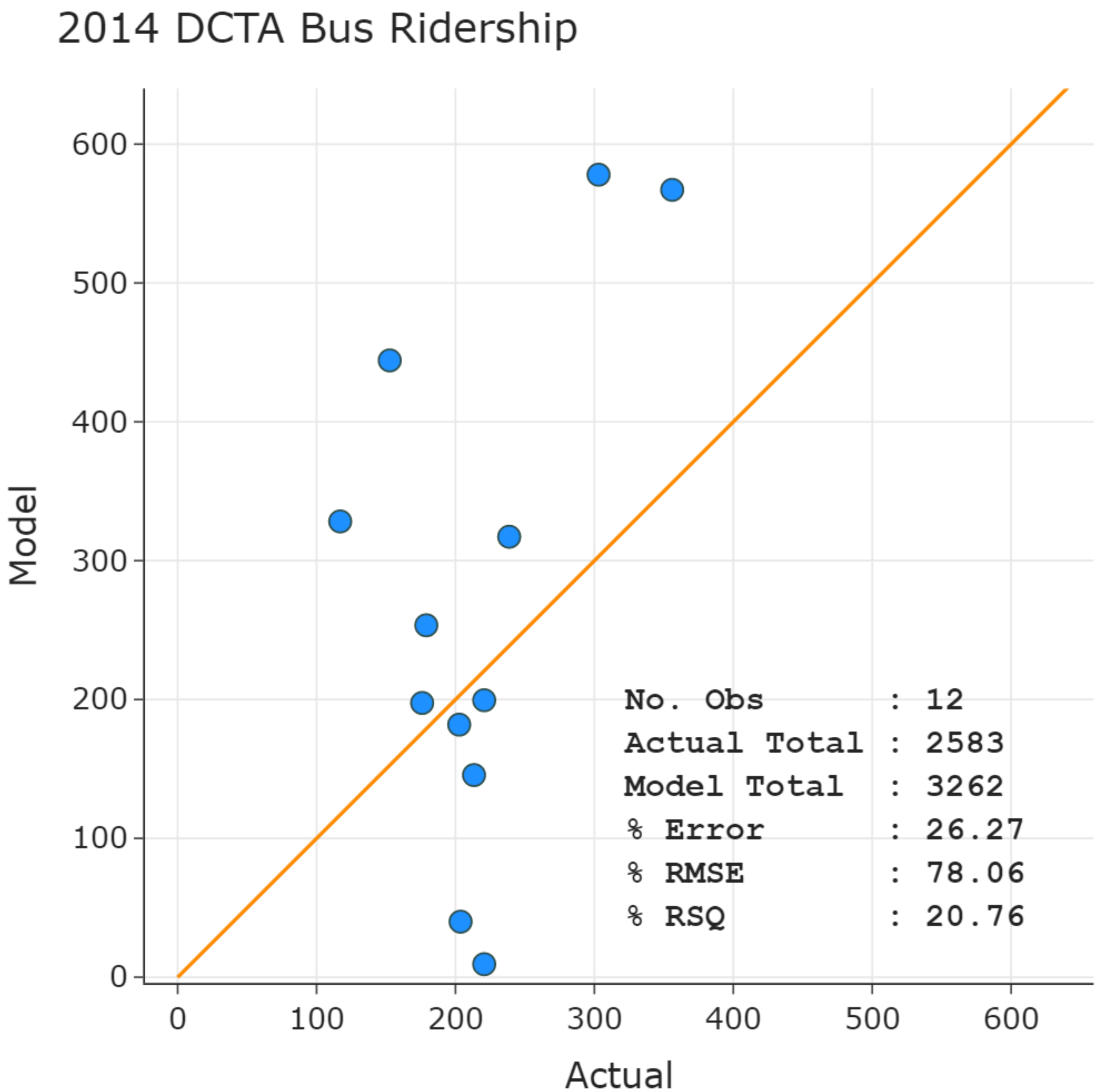

Exhibit Appendix A-5. 2014 DCTA Bus Ridership Comparison – Model vs Actual

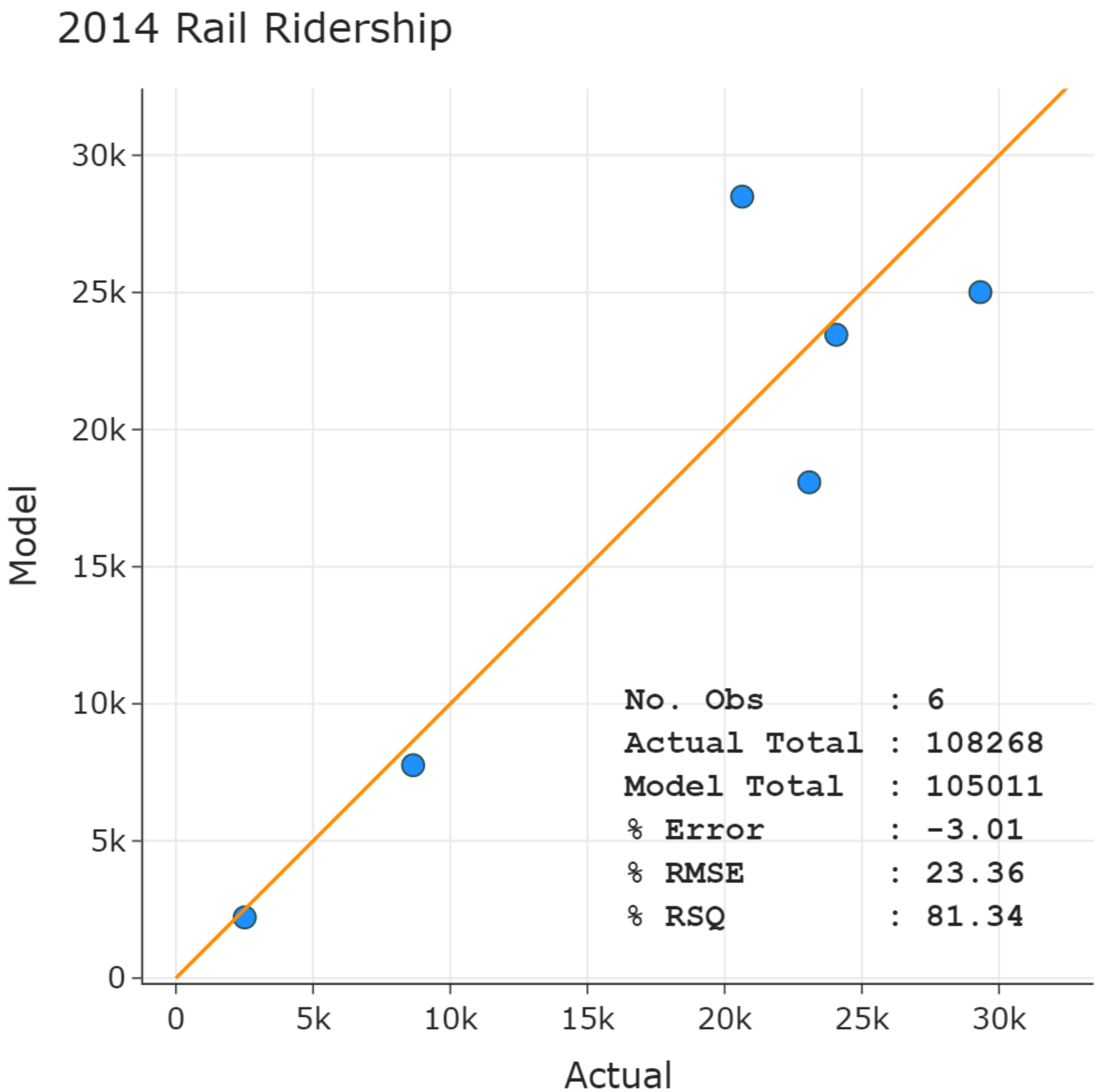

Exhibit Appendix A-6. 2014 Rail Route Ridership Comparison – Model vs Actual

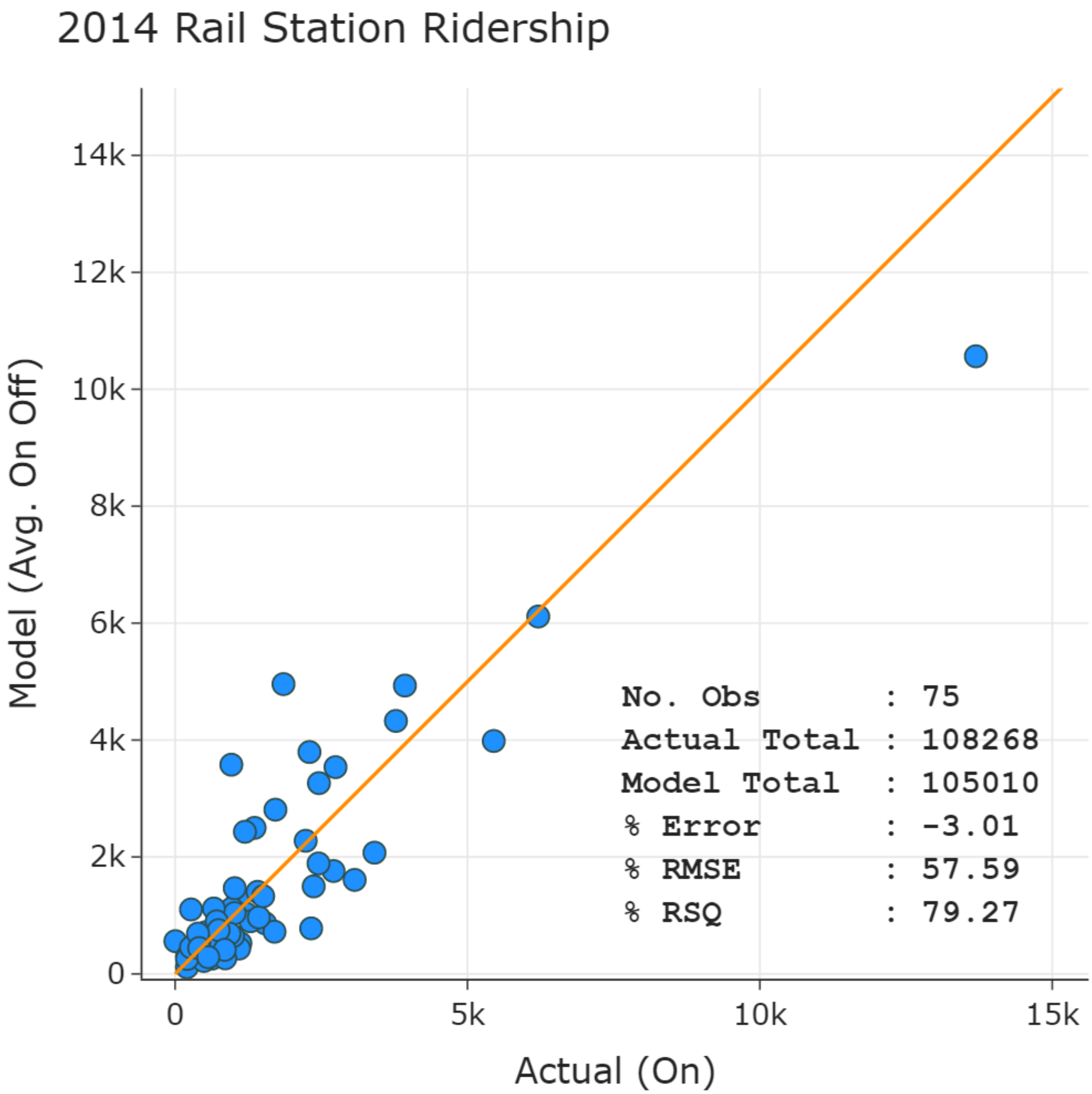

Exhibit Appendix A-7. 2014 Rail Station Ridership Comparison – Model vs Actual

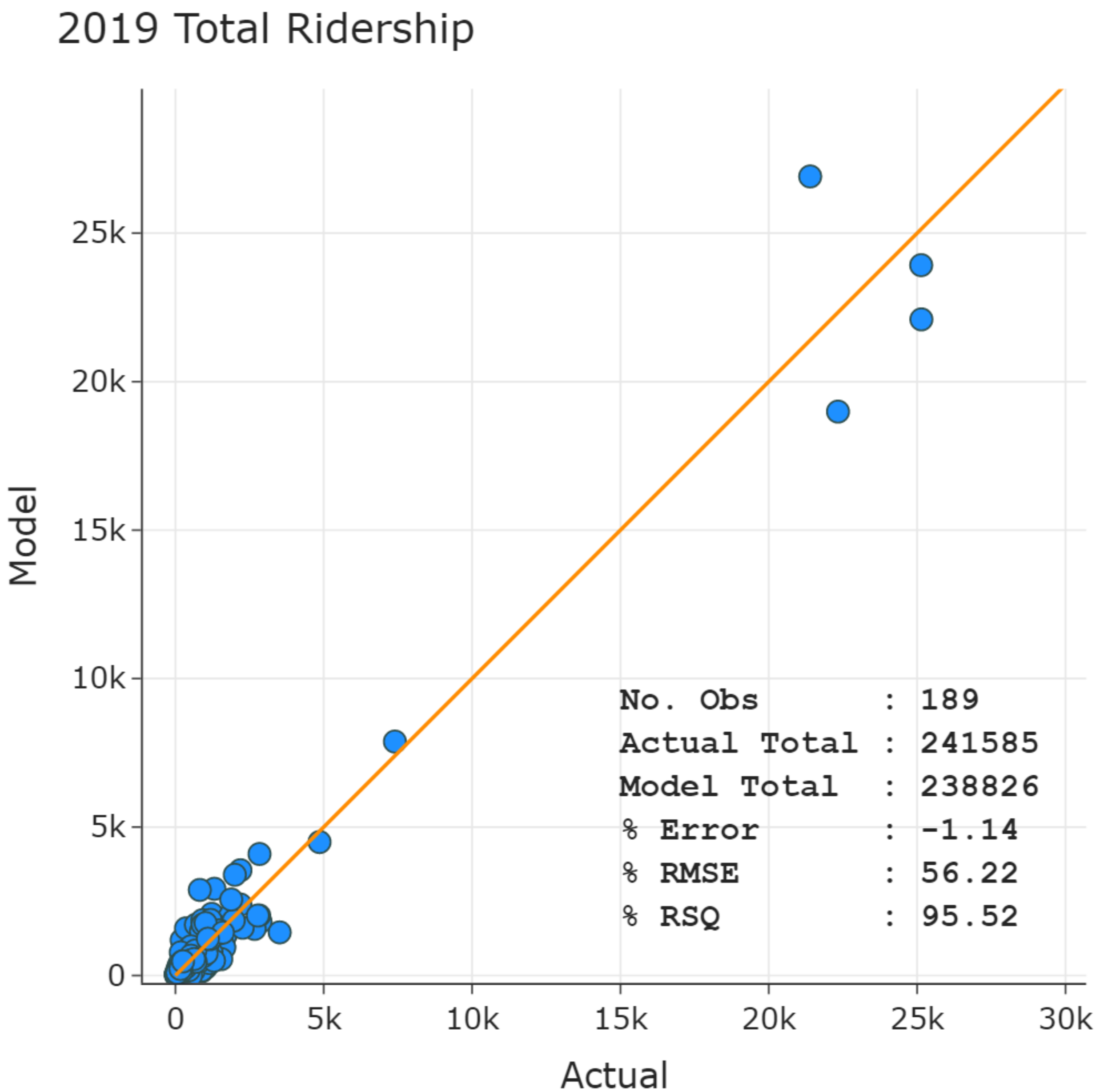

Exhibit Appendix B-1. 2019 Total Transit Ridership Comparison – Model vs Actual

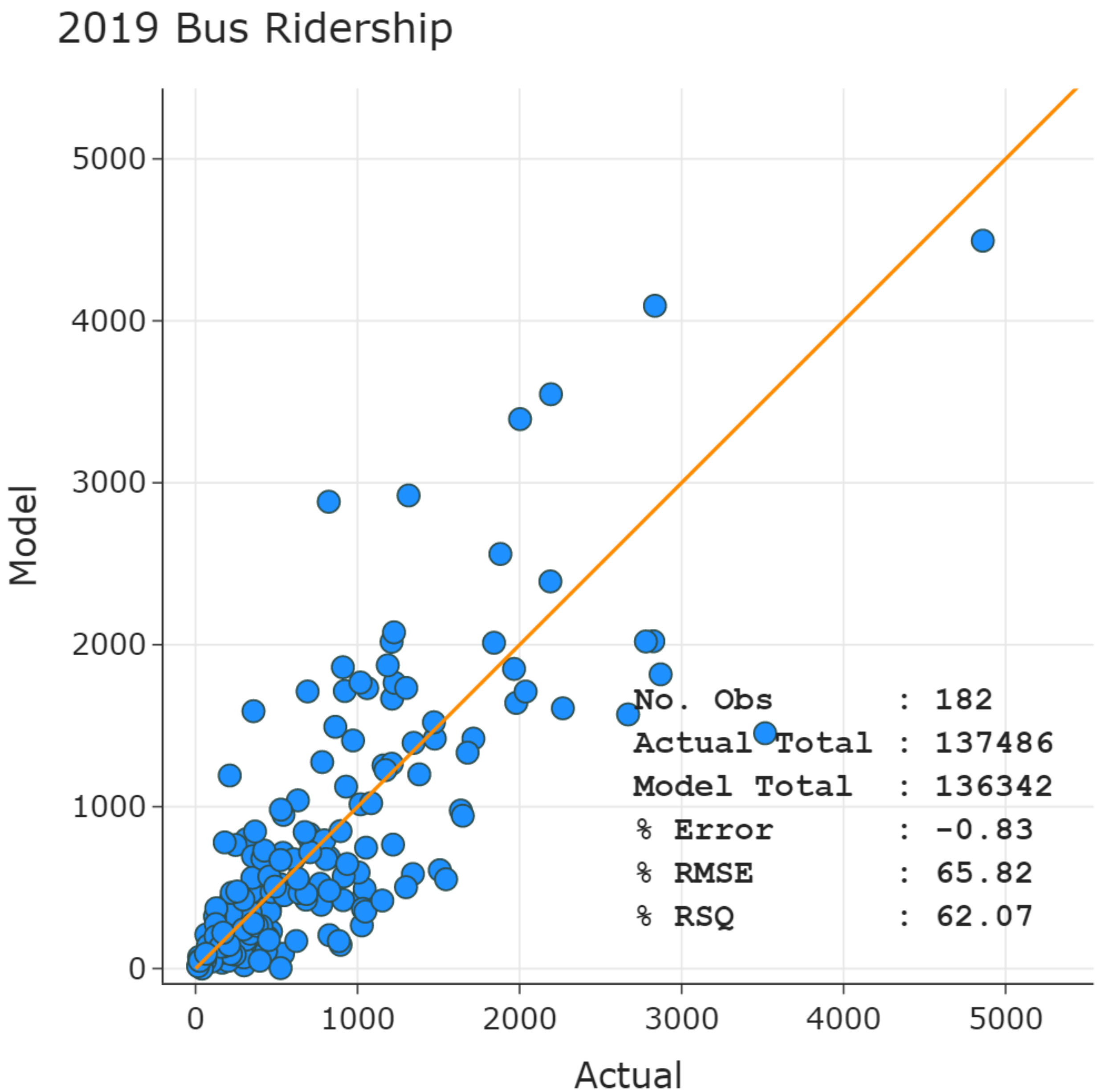

Exhibit Appendix B-2. 2019 Bus Ridership Comparison – Model vs Actual

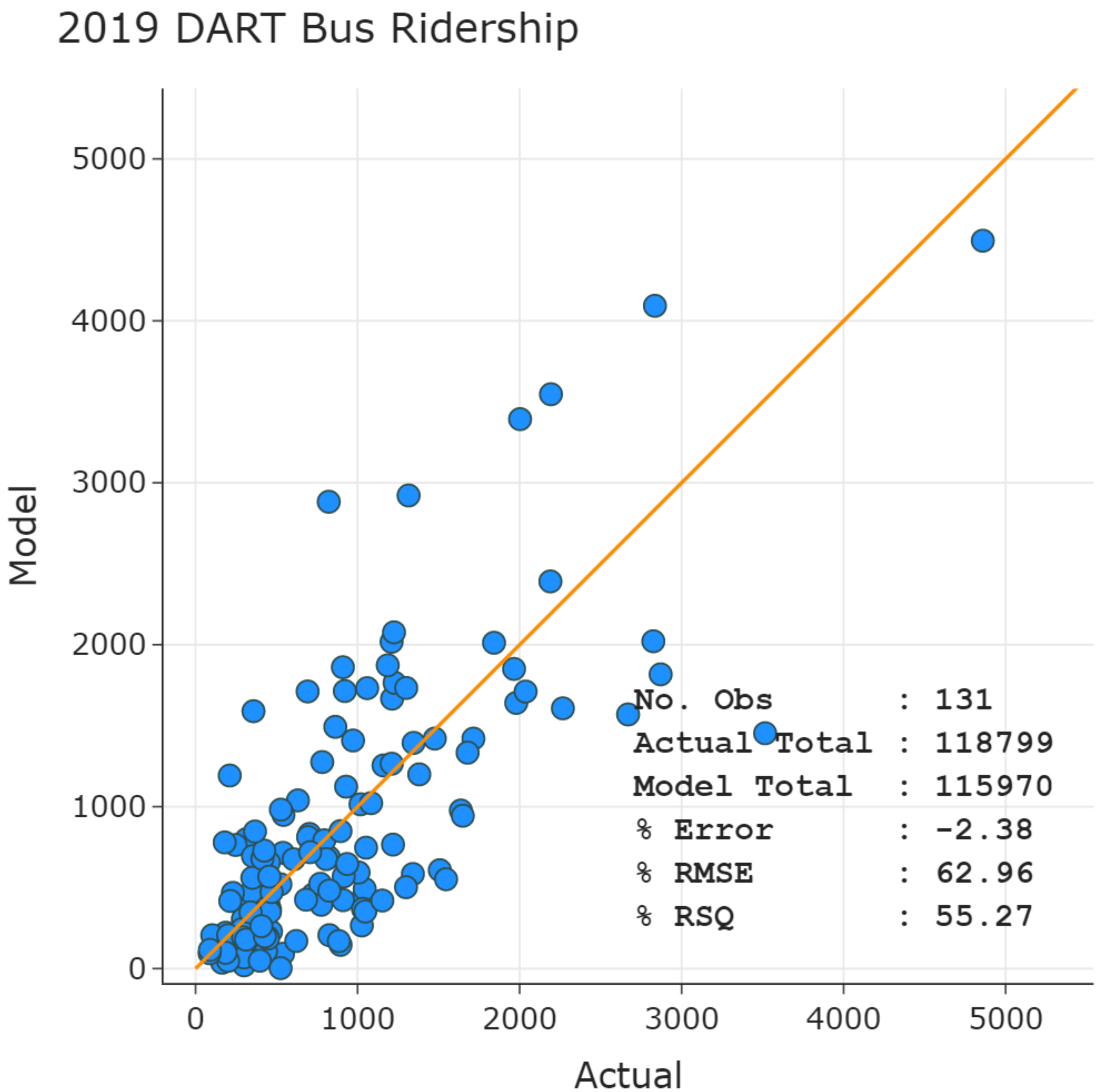

Exhibit Appendix B-3. 2019 DART Bus Ridership Comparison – Model vs Actual

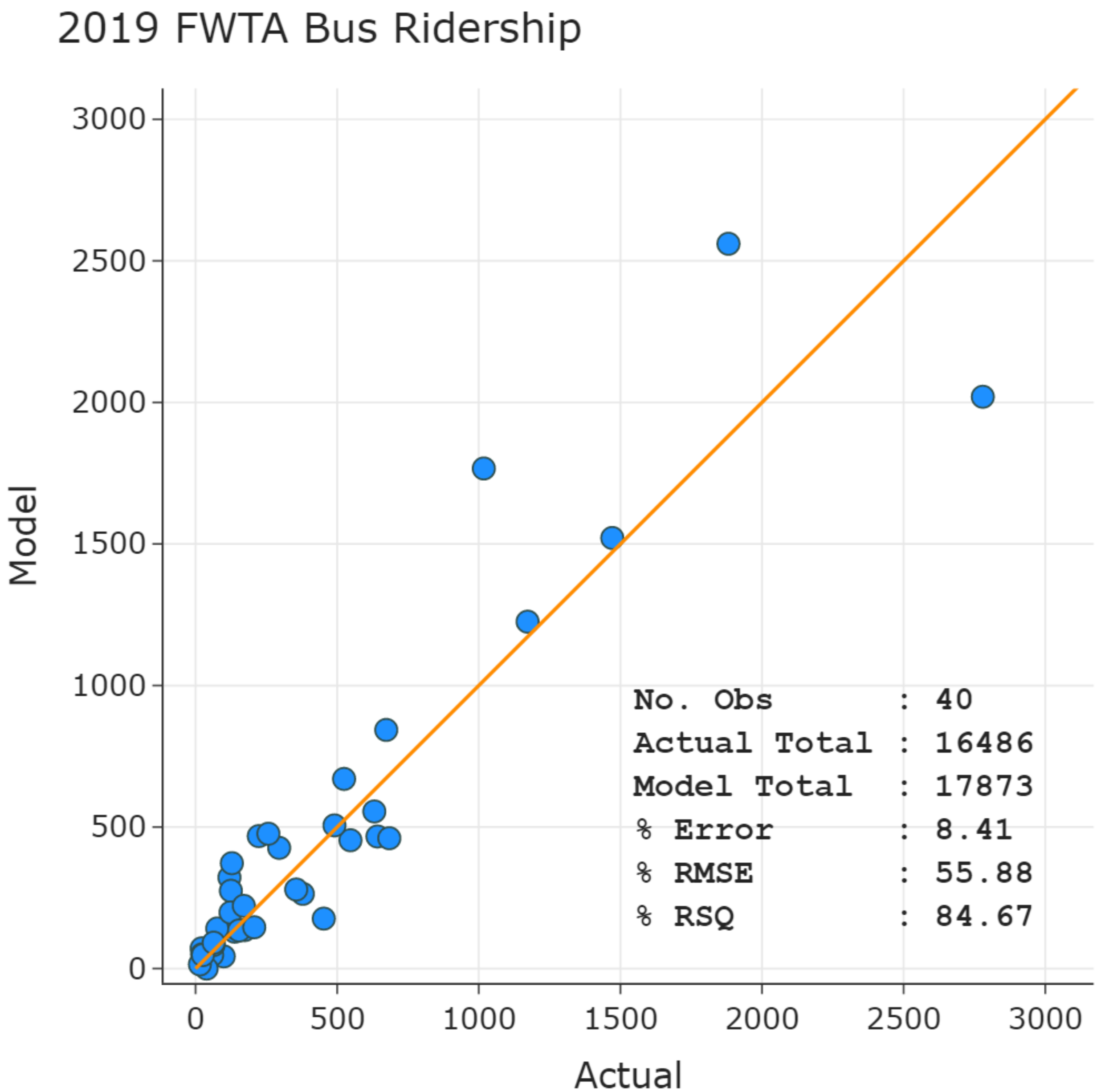

Exhibit Appendix B-4. 2019 FWTA Bus Ridership Comparison – Model vs Actual

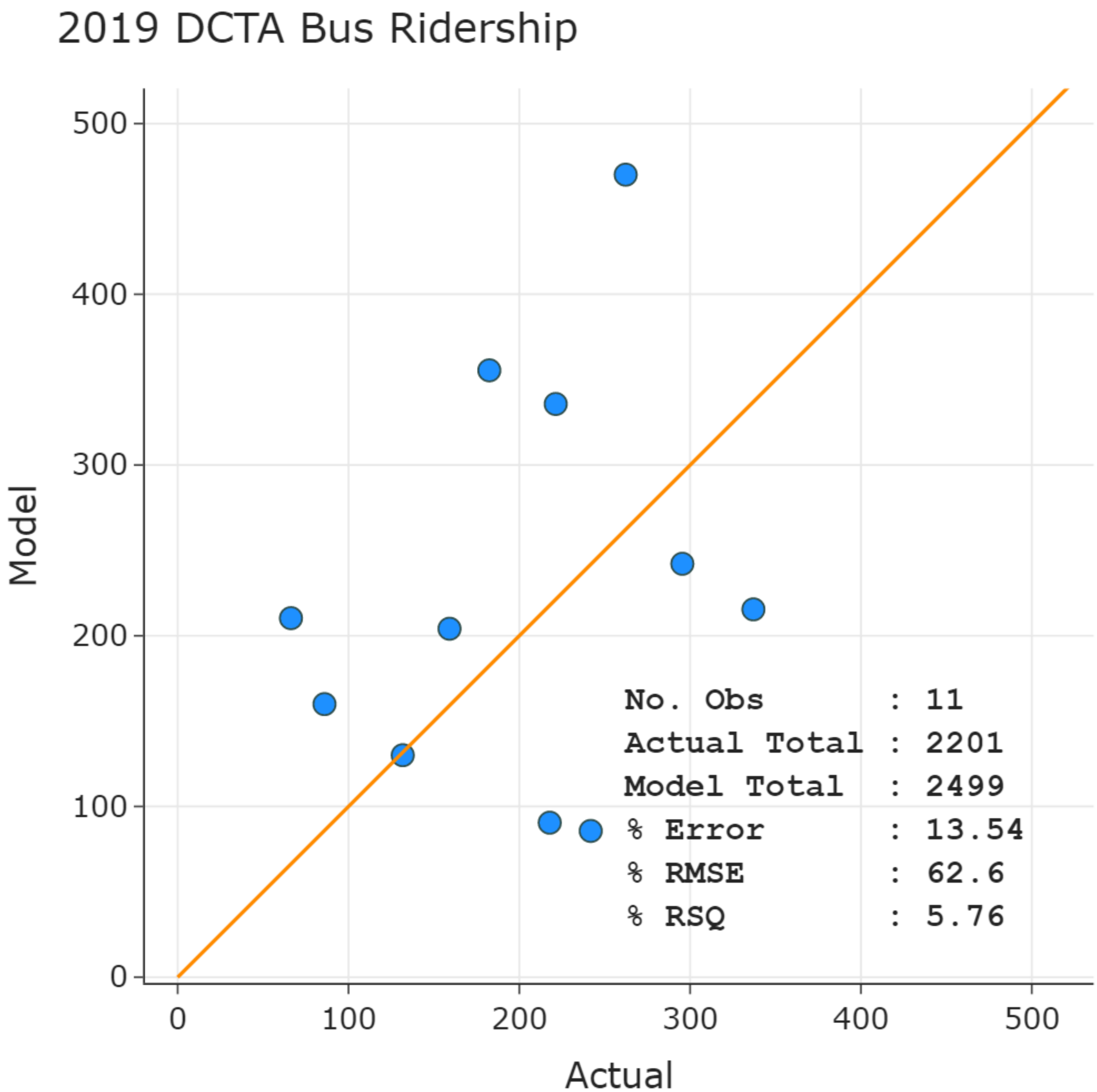

Exhibit Appendix B-5. 2019 DCTA Bus Ridership Comparison – Model vs Actual

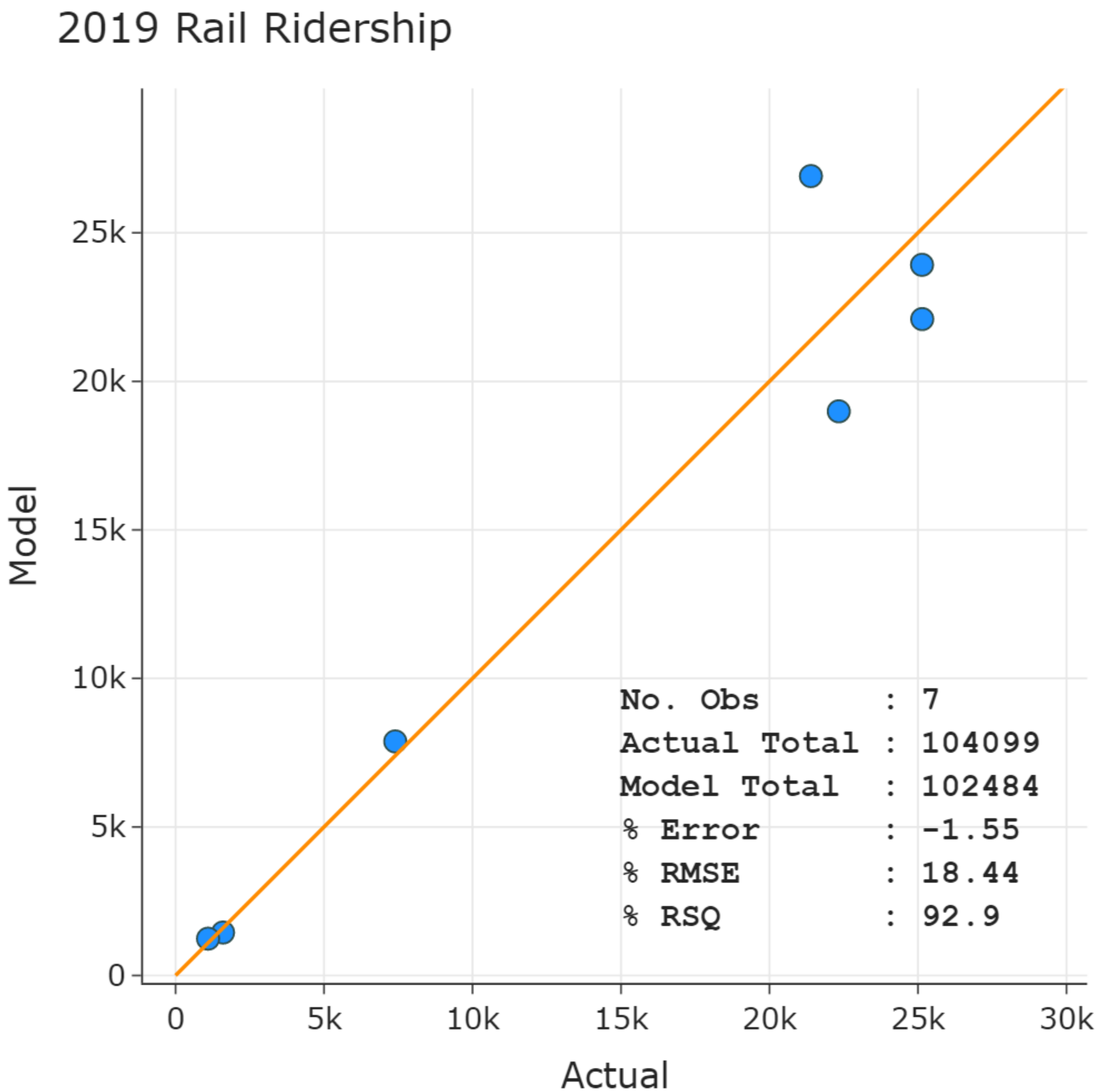

Exhibit Appendix B-6. 2019 Rail Route Ridership Comparison – Model vs Actual

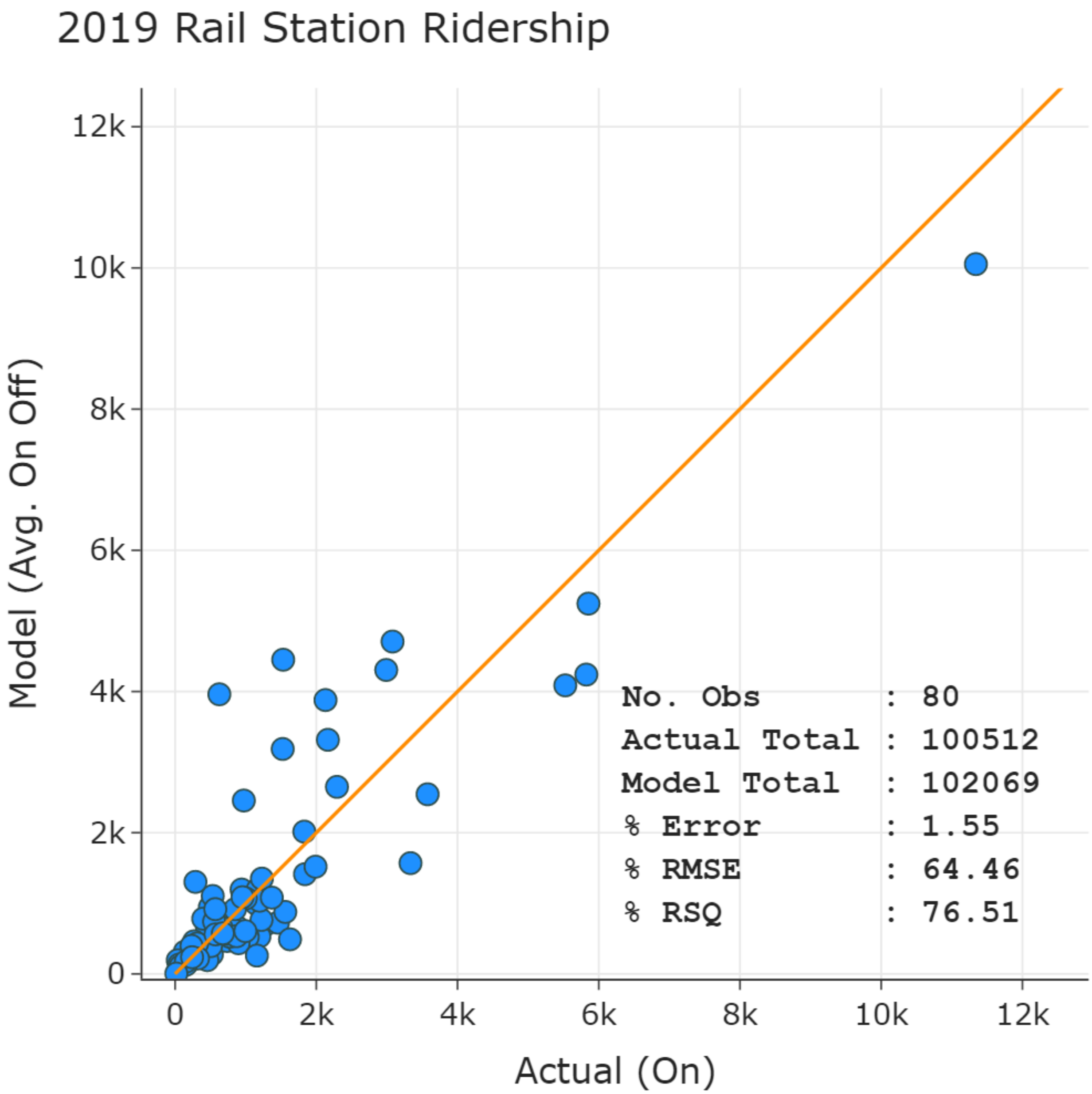

Exhibit Appendix B-7. 2019 Rail Station Ridership Comparison – Model vs Actual