CAMBRIDGE SYSTEMATICS

Front Range Rail Forecasting

Model Validation

draft

technical report

prepared for

Colorado Department of Transportation

prepared by

Cambridge Systematics, Inc.

August 25, 2020

www.camsys.com

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date

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Table of Contents

List of Tables

List of Figures

Executive Summary

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1.0 Introduction

The proposed Front Range passenger rail system spans over 250 miles from Fort Collins to Pueblo, Colorado. The major commuter corridors would be between Fort Collins and Denver (~65 miles); Denver and Colorado Springs (~70 miles); and Fort Collins to Colorado Springs (~130 miles). The Denver metropolitan area has a population close to 3 million while the Fort Collins metropolitan area has a population of roughly 300,000, and Colorado Springs has a metropolitan population of just over 700,000.

2.0 Comparison to Existing Rail Forecasting Models

Based on a survey conducted for NCHRP Synthesis 514: Statewide and Megaregional Travel Forecasting Models: Freight and Passenger (2017), thirteen statewide models included passenger heavy rail within their models. Eleven included commuter rail within their short-distance model: Arkansas, California, Connecticut, Florida, Iowa, Maine, Maryland, Massachusetts, Ohio, Oregon, and Texas. Seven included rail in their long-distance model: Iowa, Maryland, North Carolina, Ohio, Oregon, Texas, and Virginia. Five states included high-speed rail as a separate mode: California, Iowa, Maryland, Oregon, and Texas. It is unclear at this point which models may be the most similar to Colorado with respect to model design (i.e., no distinction between short and long-distance trips). However, the next section discusses similar existing rail systems within the U.S. that may provide insight into which statewide (or regional) models should be explored further for potential transferability of model coefficients or as a check for mode share reasonableness, if desired.

3.0 Comparison to Existing Rail Systems in U.S.

Table 3.1 highlights intercity rail systems across the country that provide more than one daily round-trip per day and have only one rail line serving the corridor. Therefore, most of the Northeast and mid-Atlantic city pairs, South Florida, and Southern California rail routes are not included, as well as most trains from Chicago, as multiple train lines serve many of the city pairs or the trains serve city pairs that are not a reasonable comparison to the Front Range corridor. Neither New Mexico nor Wisconsin has a statewide model that includes rail, and so the New Mexico Rail Runner Express line and the Hiawatha line ridership information may only be useful as reasonableness checks during validation. The Oregon and California statewide models are worth exploring further with regard to mode choice coefficients, mode share outputs, and level-of-service sensitivities. However, transferability may be an issue as both models split their models between short and long-distances.

It is unclear at this point if the Front Range rail will have characteristics more similar to commuter rail (i.e. many stops within the metropolitan area; high frequency service, especially during the week) or more similar to intercity rail (i.e. fewer stops within metropolitan areas; less frequent service). If the former, then adapting CDOT's existing rail mode coefficients may be a reasonable path forward. Other commuter rail lines that provide intercity rail travel include Utah's UTA Frontrunner, which provides 28 trains per day along an 88 mile corridor north and south of Salt Lake City, and Southeast Florida's Tri-Rail and Brightline, which together provide 28 trains per day within the populous corridor that includes West Palm Beach, Ft. Lauderdale, and Miami. Sounder Commuter Rail in the Seattle area provides 13 trains per day of service along 83 miles north and south of Seattle, Washington. Florida does include rail in the short-distance component of their statewide model while the other states either do not have a statewide model or do not include rail.

Table 3.1 Comparable Rail System Ridership

Heavy/Commuter Rail System	Total Length (miles)	MSA Population	Trains Per Day			Number of Stations	Average Station Spacing	2017 Annual Ridership
			Peak	Off-peak	Total			
CO Front Range Passenger Rail	177	4,125,354						
Orlando SunRail	62	2,509,831	11	9	20	16	3.8	851,881
South Florida Tri-Rail	72	6,019,790	13	12	25	18	4.0	4,287,400
Caltrain	77	4,641,820	26	21	47	32	2.4	18,820,000
Amtrak Hiawatha	80	11,124,330	4	3	7	5	16.0	836,277
UTA FrontRunner	81	1,170,057	11	17	28	17	4.8	4,854,000
Altamont Corridor Express (ACE)	86	2,694,050	2	2	4	10	8.6	1,322,200
New Mexico Rail Runner Express	97	1,052,563	4	4	8	11	8.8	811,900
Amtrak Capitol Corridor (California)	168	6,909,825	3	4	7	17	9.9	1,634,000
Missouri River Runner	283	4,893,828	2	0	2	10	28.3	167,399
Lincoln Service (Chicago-St. Louis)	284	12,354,227	3	1	4	11	25.8	579,119
Amtrak San Joaquin	315	4,118,365	3	4	7	18	17.5	1,065,362
Amtrak Cascades	467	8,874,038	2	1	3	18	25.9	802,000
Wolverine	489	15,254,533	3	0	3	26	18.8	477,710

Notes: 2017 annual ridership obtained from APTA: https://www.apta.com/wp-content/uploads/2018-Q4-Ridership-APTA.pdf
Peak Period include trains between 6-9am and 4-7pm

4.0 StateFocus Model Validation along the Front Range Corridor

Model validation was reassessed in terms of its ability to estimate and forecast Front Range Rail ridership. Key to estimating interregional transit ridership are ensuring that the model is producing:

- reasonable interregional and long-distance travel, and
- accurate representation of transit ridership today.

The model was calibrated and validated to 2015 conditions. Observed data is available for years 2010, 2015, and 2018, depending on the type of data required for validation. The 2010 Front Range Travel Counts (FRTC) Household Survey is latest available data on person- and household-level travel patterns and the best source of data available for understanding the impacts of socioeconomic characters of travel behavior choices along the Front Range. 2015 observed data includes vehicle counts across the state and transit ridership data for providers along the Front Range. 2018 data from StreetLight provides location-based services (LBS) data for a more comprehensive understanding of travel movements throughout the state.

This document provides only a few select summaries from the model calibration and validation efforts, as they are particularly relevant to Front Range Rail forecasts. Detailed summaries of calibration and validation efforts for the entire model can be found in separate documentation, *StateFocus Model Calibration and Validation*.

4.1 Region to Region Total Travel

Key to Front Range Rail forecasting includes ensuring that overall trip-making is reasonable, particularly interregional and long-distance travel. Modeled person flows (**Table 4.1**) are compared to all observed data available: 2018 StreetLight data (**Table 4.2**) and 2010 FRTC data (**Table 4.3**). In comparing these tables, StateFocus total travel seems reasonable and often falling in line between FRTC data from 2010 and StreetLight data from 2018.

Table 4.1 2015 StateFocus Region to Region Trip Flows

From / To	NFRMPO	DRCOG	PPACOG	PACOG	Total
NFRMPO	1,327,600	54,800	800	200	1,383,300
DRCOG	52,600	8,152,100	27,100	800	8,232,600
PPACOG	600	28,100	1,746,400	8,200	1,783,300
PACOG	100	1,400	8,500	375,700	385,600
Total	1,381,000	8,236,300	1,782,700	384,900	11,784,800

“Trips” in this context refer to primary destinations of tours, not trips along a tour.

Table 4.2 2018 StreetLight Region to Region Trip Flows

From / To	NFRMPO	DRCOG	PPACOG	PACOG	Total
NFRMPO	1,412,700	84,800	800	200	1,498,400
DRCOG	84,300	7,580,000	31,900	1,900	7,698,000
PPACOG	800	33,800	1,936,200	9,500	1,980,300
PACOG	100	1,800	9,200	343,600	354,700
Total	1,497,900	7,700,400	1,977,900	355,200	11,531,500

"Trips" in this context refer to a custom analysis by StreetLight that was meant to better capture primary destinations of travel by classifying a "trip" as ending when a devise is stationary (moves less than 5 meters) for 45 minutes.

Table 4.3 2010 FRTC Region to Region Trip Flows

From / To	NFRMPO	DRCOG	PPACOG	PACOG	Total
NFRMPO	1,167,300	53,800	700	200	1,221,900
DRCOG	54,200	7,274,500	20,400	800	7,349,900
PPACOG	1,300	21,000	1,601,000	7,400	1,630,700
PACOG	200	1,400	7,700	366,200	375,500
Total	1,223,000	7,350,700	1,629,700	374,600	10,578,000

"Trips" in this context refer to primary destinations of tours, not trips along a tour.

In addition to trips that flow between each region, this information can be aggregated to the number of trips that pass through key interregional boundaries to be compared with available vehicle counts. As shown in **Table 4.4**, modeled vehicle counts are within 3% of counts at these interregional boundaries, resulting in an excellent representation of travel at those boundaries. While the person trip flows between NFRMPO and DRCOG regions are lower in the model than shown StreetLight data, the StreetLight data seems unrealistically high or may reflect significant growth in that travel market between 2015 and 2018. Modeled person flows between DRCOG-PPACG and PPACG-PACOG fall between the 2010 FRTC and 2018 StreetLight flow estimates. There is no observed data here to suggest that the model does not represent interregional travel inaccurately.

Table 4.4 Interregional Boundary Flows

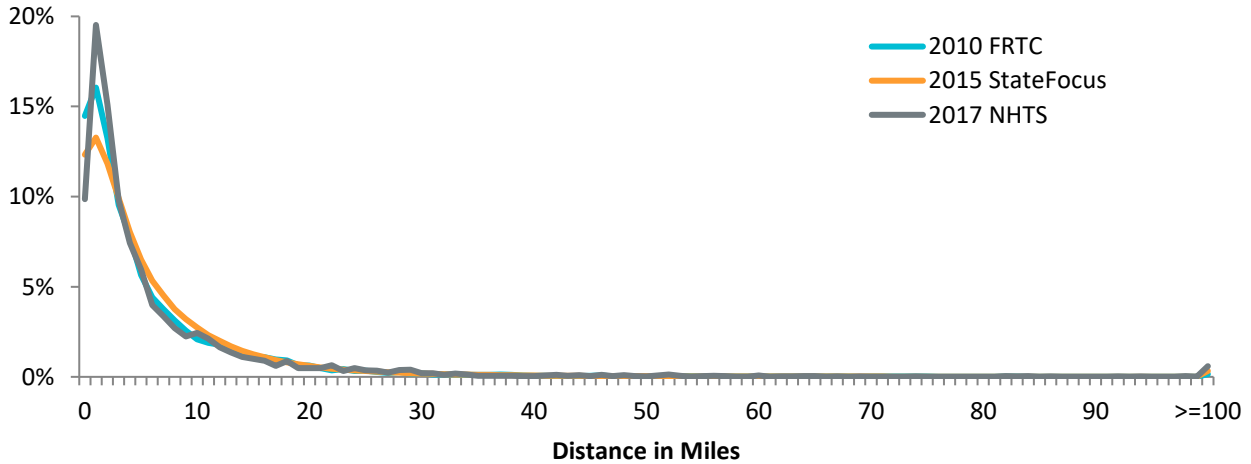
Screenline	2018 StreetLight Flows [1]	2015 StateFocus Resident Flows[2]	2010 FRTC Resident Flows[3]	2015 StateFocus Vehicle Assignment[4]	2015 Vehicle Counts[5]
NFRMPO-DRCOG	170,900	109,000	110,300	141,200	137,200
DRCOG-PPACG	69,400	59,000	43,700	73,800	75,900
PPACOG-PACOG	22,700	19,200	17,700	33,700	34,600

[1] 2018 StreetLight flows reflect a calibrated StreetLight Volume.
[2] 2015 StateFocus resident flows include only person trips made by Colorado residents for personal travel. Visitor travel is not included here since it is not subject to mode choice and cannot be included in Front Range Rail estimates.
[3] 2010 FRTC flows include only person trips made by Colorado residents for personal travel.
[4] 2015 StateFocus vehicle assignment includes conversion from person trips to vehicle trips and also includes truck travel and visitor travel at interregional boundary roadways.
[5] 2015 vehicle counts reflect on-the-road counts of every vehicle at interregional boundary roadways.

4.2 Trip Length Frequency Distribution

Another way to look at interregional travel is to look at trip lengths to ensure sufficient long-distance travel by examining the frequency distribution of trip lengths. StreetLight trip data was provided in aggregated zones which were too large to accurately determine trip length. Furthermore, few records of long-distance trips were included in the 2010 FRTC survey. Therefore, the 2017 National Household Travel Survey (NHTS) was summarized to provide another point of observation. Because of the low NHTS sample size in Colorado, neighboring states (Wyoming, Utah, New Mexico, Arizona, Nevada, and Kansas) were included in the data summarized for this report. **Figure 4.1** and **Table 4.5** show a reasonable modeled distribution of long-distance trips, when compared to the 2010 FRTC and 2017 NHTS data.

Figure 4.1 Trip Length Frequency Distribution



Note: 2015 StateFocus data includes trips by Front Range residents, to most closely match FRTC survey data and the catchment area of the Front Range Rail.

Table 4.5 Share of Trips by Trip Length

Trip Length (miles)	Share of All Trips		
	2010 FRTC	2015 StateFocus*	2017 NHTS**
0-4	53.3%	47.4%	54.3%
4-8	21.6%	24.5%	20.7%
8-12	9.7%	12.0%	9.5%
12-16	5.7%	6.3%	5.1%
16-20	3.6%	3.5%	2.8%
20-50	5.2%	5.3%	5.9%
50+	0.9%	1.0%	1.6%

* 2015 StateFocus data includes trips by Front Range residents, to most closely match FRTC survey data and the catchment area of the Front Range Rail.
** NHTS includes weighted data for CO, NV, UT, WY, AZ, NM, KS.

4.3 Mode Choice

Transit tour and trip calibration targets were developed for key characteristics of the traveler: household income, household auto sufficiency (relationship between number of vehicles available and number of workers in the household), person type (employment status and student enrollment), sex and age, trip origin and destination by area type, trip purpose, and time of day.

Observed data for transit mode shares was obtained from the 2010 FRTC and 2017 NHTS. **Table 4.6** provides the transit mode trips and share by trip length, showing similar trends in overall mode shares, in that the highest mode shares occur for trips between 12 and 20 miles (with the exception of NHTS data, which may be a result of low sample size or insufficient samples in that distance bin with transit options outside of Colorado).

Table 4.6 Transit Mode Shares by Trip Length

Trip Length (miles)	Number of Transit Trips			Transit Mode Share		
	2010 FRTC	2015 StateFocus	2017 NHTS*	2010 FRTC	2015 StateFocus	2017 NHTS*
0-4	91,000	146,000	138,662,035	1.2%	1.9%	1.3%
4-8	68,000	58,000	54,466,926	2.2%	1.5%	1.3%
8-12	41,000	36,000	26,916,568	3.0%	1.9%	1.4%
12-16	35,000	22,000	39,145,250	4.3%	2.2%	3.9%
16-20	24,000	12,000	4,159,998	4.6%	2.2%	0.7%
20-50	29,000	13,000	22,215,760	3.9%	1.5%	1.9%
50+	3,000	1,000	13,658,053	2.3%	0.6%	4.3%

* NHTS includes weighted data for CO, NV, UT, WY, AZ, NM, KS. There was a very low sample size for transit trips, including only 6 samples for transit trips greater than 50 miles.

Information from the 2010 FRTC Survey was used for mode choice overall. However, the FRTC provided a relatively small number of sampled transit trips. An RTD systemwide onboard survey provided many more samples of transit trips than the FRTC and provided more reliable information for developing calibration targets for transit trips and trip-makers at a disaggregate level of detail.

Table 4.7 provides the total trips by mode, and ***Table 4.8*** provides the distribution of those trips by tour mode. ***Table 4.9*** and ***Table 4.10*** provide the distribution of trips by mode by auto sufficiency and household income. These tables reflect comparisons between the 2010 FRTC data and modeled data for the entire Front Range.

Table 4.7 Total Trips by Mode

Mode	Closed Tours					Non-Closed Tours				
	2010 Front Range Travel Counts		2015 StateFocus Model Run		Percentage Point Difference	2010 Front Range Travel Counts		2015 StateFocus Model Run		Percentage Point Difference
Drive Alone	6,575,410	46.9%	7,583,511	46.9%	2.3%	120,304	45.8%	214,053	54.6%	8.8%
Shared Ride (2)	3,333,368	23.8%	3,460,399	23.8%	-1.3%	71,934	27.4%	90,720	23.1%	-4.3%
Shared Ride (3+)	2,674,926	19.1%	2,628,692	19.1%	-2.0%	48,911	18.6%	74,189	18.9%	0.3%
Walk to Transit	186,998	1.3%	219,726	1.3%	0.1%	4,705	1.8%	2,074	0.5%	-1.3%
Drive to Transit	94,349	0.7%	64,788	0.7%	-0.3%	1,375	0.5%	785	0.2%	-0.3%
Walk	701,123	5.0%	919,144	5.0%	1.0%	10,390	4.0%	5,460	1.4%	-2.6%
Bike	152,837	1.1%	224,130	1.1%	0.4%	967	0.4%	4,844	1.2%	0.9%
School Bus	296,289	2.1%	318,342	2.1%	0.0%	4,053	1.5%	0	0.0%	-1.5%

Table 4.8 Distribution of Trips by Tour and Trip Mode

Trip Mode / Tour Mode	2010 Front Range Travel Counts								2015 StateFocus Model Run							
	Drive Alone	Shared Ride (2)	Shared Ride (3+)	Walk to Transit	Drive to Transit	Walk	Bike	School Bus	Drive Alone	Shared Ride (2)	Shared Ride (3+)	Walk to Transit	Drive to Transit	Walk	Bike	School Bus
Drive Alone	99.6%	0.0%	0.0%	0.1%	0.0%	0.3%	0.0%	0.0%	99.5%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%
Shared Ride (2)	25.4%	73.2%	0.0%	0.0%	0.0%	1.3%	0.1%	0.0%	22.0%	77.1%	0.0%	0.0%	0.0%	0.7%	0.2%	0.0%
Shared Ride (3+)	10.7%	17.6%	70.4%	0.0%	0.0%	1.3%	0.1%	0.0%	10.6%	14.2%	73.0%	0.0%	0.0%	2.0%	0.2%	0.0%
Walk to Transit	0.8%	5.9%	3.6%	76.0%	0.0%	13.1%	0.6%	0.0%	0.2%	1.5%	1.9%	92.2%	0.0%	4.2%	0.0%	0.0%
Drive to Transit	10.5%	9.1%	1.8%	4.8%	71.7%	2.1%	0.0%	0.0%	3.2%	10.2%	0.8%	1.3%	84.4%	0.2%	0.0%	0.0%
Walk	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%
Bike	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	98.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	8.7%	91.3%	0.0%
School Bus	0.5%	11.9%	12.7%	0.0%	0.0%	1.8%	0.1%	73.0%	0.0%	4.0%	9.6%	0.0%	0.0%	6.7%	0.0%	79.7%

Table 4.9 Share of Trips by Mode by Auto Sufficiency (Closed Tours)

Mode	2010 Front Range Travel Counts				2015 StateFocus Model Run			
	Zero Auto	Auto < Worker	Auto = Worker	Auto > Worker	Zero Auto	Auto < Worker	Auto = Worker	Auto > Worker
Drive Alone	8%	33%	48%	48%	7%	46%	52%	50%
Shared Ride (2)	13%	30%	22%	25%	12%	20%	22%	24%
Shared Ride (3+)	7%	16%	20%	19%	10%	13%	17%	18%
Walk to Transit	29%	3%	1%	1%	15%	7%	1%	1%
Drive to Transit	0%	1%	1%	1%	0%	1%	0%	0%
Walk	27%	9%	6%	4%	37%	8%	5%	4%
Bike	13%	6%	1%	1%	16%	5%	1%	1%
School Bus	1%	1%	2%	2%	1%	1%	2%	2%

Table 4.10 Share of Trips by Mode by Household Income (Closed Tours)

Mode	2010 Front Range Travel Counts					2015 StateFocus Model Run				
	Low Income	Moderate Income	Middle Income	Upper Income	Top Income	Low Income	Moderate Income	Middle Income	Upper Income	Top Income
Drive Alone	42%	50%	46%	47%	47%	41%	47%	51%	54%	52%
Shared Ride (2)	25%	23%	24%	23%	23%	23%	23%	22%	22%	22%
Shared Ride (3+)	16%	18%	21%	21%	21%	17%	18%	17%	16%	18%
Walk to Transit	4%	1%	1%	1%	1%	3%	1%	1%	1%	0%
Drive to Transit	1%	1%	1%	1%	1%	1%	0%	0%	0%	0%
Walk	7%	5%	4%	5%	5%	10%	6%	5%	5%	4%
Bike	2%	1%	1%	1%	1%	3%	1%	1%	1%	1%
School Bus	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%

Transit calibration targets were developed based on the 2015 RTD systemwide onboard survey for the DRCOG region and the 2017 Transfort systemwide onboard survey (and additional trip information for COLT and GET services) for the NFRMPO region, adjusted to 2015 ridership. ***Table 4.11*** provides the total transit trips by purpose for each region. ***Table 4.12***, ***Table 4.13***, and ***Table 4.14*** provide transit trips by region by household income, auto sufficiency, and person type.

Table 4.11 Total Transit Trips for DRCOG and NFRMPO

Region	Trip Purpose	2015 Calibration Targets (based on Onboard Survey data)			2015 StateFocus Model Run		
		Walk to Transit	Drive to Transit	Total Transit	Walk to Transit	Drive to Transit	Total Transit
DRCOG	Work	97,605	39,490	137,095	77,798	41,064	118,862
	School	38,770	17,560	56,331	32,848	16,655	49,503
	Other	60,708	6,248	66,956	79,827	4,217	84,044
	Total	197,083	63,298	260,381	190,473	61,936	252,409
NFRMPO	Total	13,896	1,557	15,452	12,864	986	13,850

Table 4.12 Total Transit Trips for DRCOG and NFRMPO, by Household Income

Region	Trip Maker's Household Income	Calibration Targets (based on Onboard Survey data)			2015 StateFocus Model Run		
		Walk to Transit	Drive to Transit	Total Transit	Walk to Transit	Drive to Transit	Total Transit
DRCOG	Low Income	50%	17%	41%	38%	20%	34%
	Moderate Income	31%	44%	34%	24%	24%	24%
	Middle Income	14%	24%	17%	21%	25%	22%
	Upper Income	3%	10%	5%	13%	22%	15%
	Top Income	1%	4%	2%	5%	9%	6%
NFRMPO	Low Income	78%	52%	75%	57%	47%	56%
	Moderate Income	11%	19%	12%	13%	15%	13%
	Middle Income	5%	13%	5%	11%	8%	10%
	Upper Income	6%	13%	6%	14%	23%	15%
	Top Income	1%	2%	1%	5%	8%	5%

Table 4.13 Total Transit Trips for DRCOG and NFRMPO, by Auto Sufficiency

Region	Trip Maker's Household Auto Sufficiency	2015 Calibration Targets (based on Onboard Survey data)			2015 StateFocus Model Run		
		Walk to Transit	Drive to Transit	Total Transit	Walk to Transit	Drive to Transit	Total Transit
DRCOG	Zero Auto	35%	7%	29%	30%	3%	23%
	Auto < Worker	30%	23%	29%	30%	10%	25%
	Auto = Worker	26%	48%	31%	19%	37%	23%
	Auto > Worker	8%	22%	11%	21%	51%	28%
NFRMPO	Zero Auto	27%	3%	25%	36%	5%	34%
	Auto < Worker	2%	0%	2%	21%	2%	20%
	Auto = Worker	8%	0%	8%	13%	19%	13%
	Auto > Worker	63%	97%	65%	30%	74%	33%

Table 4.14 Total Transit Trips for DRCOG and NFRMPO, by Person Type

Region	Trip Maker's Person Type	2015 Calibration Targets (based on Onboard Survey data)			2015 StateFocus Model Run		
		Walk to Transit	Drive to Transit	Total Transit	Walk to Transit	Drive to Transit	Total Transit
DRCOG	Full-time Worker	47%	61%	50%	48%	58%	50%
	Part-time Worker	7%	4%	6%	9%	9%	9%
	Non-worker (65+)	3%	2%	2%	7%	2%	6%
	Other Non-worker	8%	3%	7%	7%	3%	6%
	University Student	19%	29%	22%	14%	25%	17%
	Driving Age Student	5%	1%	4%	2%	4%	3%
	Pre-driving Age Student	11%	1%	8%	10%	0%	8%
	Preschool Child	1%	0%	1%	3%	0%	2%
NFRMPO	Full-time Worker	15%	31%	16%	30%	17%	29%
	Part-time Worker	12%	13%	12%	6%	3%	6%
	Non-worker (65+)	3%	8%	4%	7%	3%	7%
	Other Non-worker	9%	4%	8%	8%	3%	8%
	University Student	32%	42%	33%	35%	70%	37%
	Driving Age Student	1%	2%	1%	2%	5%	2%
	Pre-driving Age Student	12%	0%	12%	10%	0%	9%
	Preschool Child	14%	0%	14%	3%	0%	2%

4.4 Highway Assignment

Roadway volumes resulting from traffic assignment were compared to traffic count data. This process, called traffic assignment validation, ensured the model is reasonably representing observed traffic patterns. Traffic count data were obtained from CDOT and placed on the roadway network. Travel model results were compared to traffic count data using a variety of techniques, including regional comparisons and inspection of individual link values.

4.4.1 Overall Activity Level

Overall vehicle trip activity was validated by comparing count data to model results on all links where count data is available using model volume to count volume comparisons. These statistics were reviewed at facility type and area type, as shown in **Table 4.15** and **Table 4.16**.

Table 4.15 Difference Between Model Volumes and Counts

Facility Type	Number of Counts	Percent Difference Between Model and Counts)	Target
Freeway	675	-8%	+/- 7%
Expressway	202	7%	+/- 7%
Principal Arterial	2355	5%	+/- 10%
Minor Arterial	2056	-9%	+/- 10%
Collector	2163	-24%	+/- 15%
Ramp	95	20%	
Total (Statewide)	7546	-2%	+/- 5%

Notes: Activity level targets are based on industry standard practice guidelines, not a rule.
Targets provided were obtained from the FHWA Travel model Validation and Reasonableness Checking Manual.

Table 4.16 Percent Difference by Facility Type and by Area Type

Facility Type	Area Type					
	CBD	CBD Fringe	Urban	Suburban	Rural	**Total**
Freeway	n/a	-10%	-6%	-7%	-10%	**-8%**
Expressway	n/a	-17%	7%	6%	10%	**7%**
Principal Arterial	10%	14%	9%	-1%	-13%	**5%**
Minor Arterial	19%	-10%	-7%	-13%	-8%	**-9%**
Collector	-22%	-17%	-24%	-23%	-28%	**-24%**
Ramp	n/a	45%	24%	12%	-5%	**20%**
Total	**10%**	**3%**	**1%**	**-5%**	**-11%**	**-2%**

4.4.2 Disaggregate Measures

While the model should accurately represent the overall level of activity, it is also important to verify that the model reasonably represents activity at a more disaggregate level. It is expected the model will not perfectly reproduce count volumes on every link, but the differences should be monitored. The plot shown in **Figure 4.2** demonstrates the ability of StateFocus to match individual traffic count data points and notes the resulting R-squared value.

Table 4.17 lists percentage root mean square error (% RMSE) values and target values for each facility type. General guidelines suggest that % RMSE should be near 40 percent in regional models, with values below 30 percent for high volume facility types such as freeways. The % RMSE measure tends to over-represent errors on low volume facilities, and so values on collectors are not particularly meaningful. **Table 4.18** shows percent error and % RMSE values by district. **Table 4.19** shows the % RMSE values by volume group.

Figure 4.2 Modeled to Observed Volume for All Count Locations

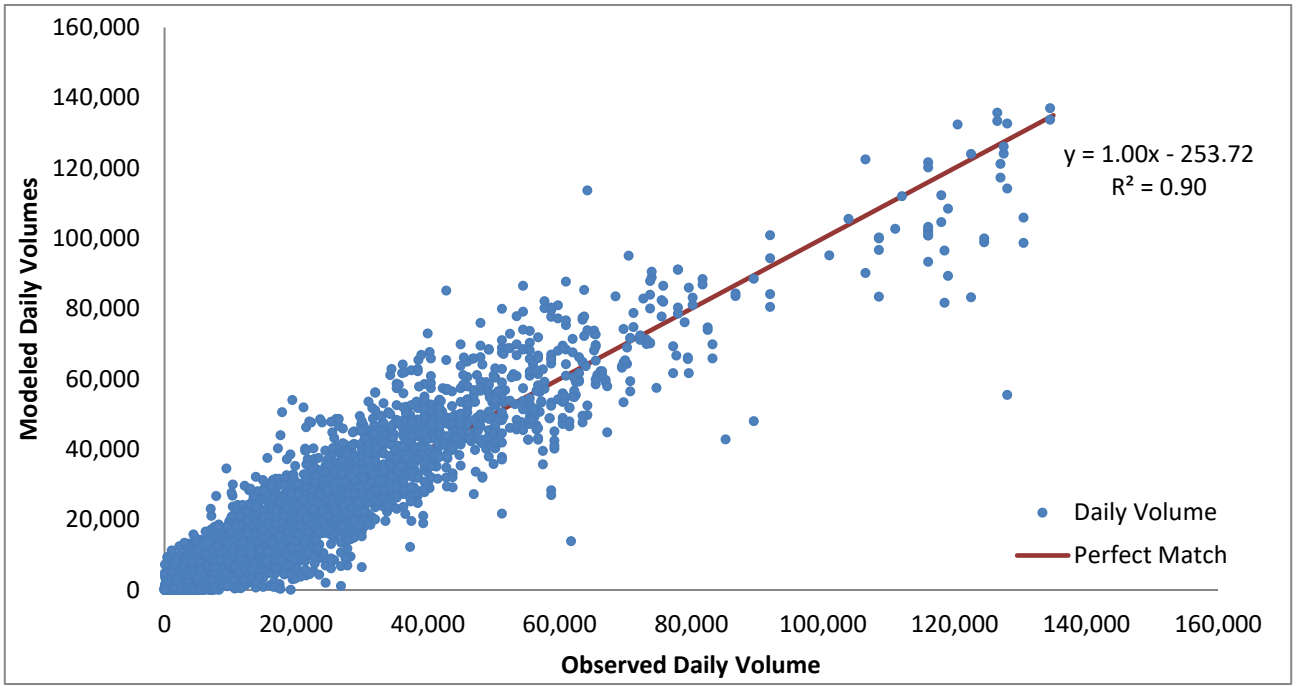


Table 4.17 RMSE Statistics by Facility Type

Facility Type	Number of Counts	Average Volume of Counts	RMSE	% RMSE	Target
Freeway	675	36,400	8,395	23%	24%
Expressway	202	27,600	9,184	33%	26%
Principal Arterial	2355	18,800	7,323	39%	28%
Minor Arterial	2056	6,500	3,486	54%	42%
Collector	2163	3,200	2,660	84%	54%
Ramp	95	6,700	5,478	82%	42%
Total (Statewide)	7546	12,600	5,567	44%	34%

Notes: Targets provided were obtained from the Ohio DOT recommended targets for %RMSE by volume group, using the average volume of counts in each facility type group as the group midpoint volume.

Table 4.18 Percent Deviation and RMSE by District

District	Number of Counts	Percent Difference Between Model and - Observed)	Percent RMSE
Larimer	449	-2%	36%
Northern Weld	317	-6%	34%
DRCOG	2829	5%	36%

District	Number of Counts	Percent Difference Between Model and - Observed)	Percent RMSE
PPACG	867	-3%	42%
PACOG	375	-28%	61%
Total (Statewide)	**7546**	**-2%**	**44%**

Table 4.19 RMSE Statistics, by Volume Group

Volume Group	Number of Counts	RMSE	% RMSE
0 - 1,000	942	997	186%
1,000 - 5,000	2,394	1,928	70%
5,000 - 10,000	1,371	3,479	49%
10,000 - 20,000	1,283	6,129	43%
20,000 - 30,000	618	8,348	34%
30,000 - 50,000	625	9,731	26%
50,000 - 100,000	271	12,269	20%
100,000 and up	42	20,053	17%
All Links	**7,546**	**5,567**	**44%**

4.4.3 VMT Analysis

Highway Performance Monitoring System (HPMS) data provides an independent source of data related to aggregated, observed traffic count data for the entire State. HPMS data were used for reasonableness checks only and not considered reliable enough for strict validation. Reasonableness was determined by comparing total VMT for the state, as shown in **Table 4.20**. While this table is segmented by facility type and area type, it should be noted that the two distinctions are not consistent across data sources. The model does not include all roadways, collector, and local roads, which is another important distinction between the two data sources. Given these inconsistencies, the model is determined to have a reasonable amount of VMT.

Table 4.20 Total Daily VMT (millions)

StateFocus				HPMS			
Facility Type	**CBD, Urban, and Suburban**	**Rural**	**Total**	**Facility Type**	**Urban**	**Rural**	**Total**
Freeway	24.2	17.1	41.3	Interstate	28.9	14.1	43.0
Expressway	7.3	3.9	11.2	Freeways and Expressways	16.7	0.8	17.5
Principal Arterial	29.7	12.0	41.7	Principal Arterial	29.3	13.4	42.7

Minor Arterial	10.3	6.9	17.2	Minor Arterial	20.1	6.7	26.8
Collector	5.8	5.7	11.4	Major and Minor Collectors	8.7	5.8	14.5
Ramp	2.5	0.3	2.8		0.0	0.0	0.0
Centroid Connector	6.6	5.8	12.4	Local	11.5	4.8	16.3
Total	**86.3**	**51.7**	**138.0**	**Total**	**115.2**	**45.7**	**160.9**

Source: HPMS data from October 2015 for State of Colorado. Annual VMT was converted to an estimated daily VMT by assuming an annualization factor of 300.
https://www.fhwa.dot.gov/policyinformation/statistics/2014/vm2.cfm

4.4.4 Screenline Analysis

StateFocus includes 18 screenlines, shown in **Figure 4.3**. Screenlines capture distinct inter-regional travel patterns and can be useful in understanding the model's trip generation and trip distribution characteristics. Screenlines have been drawn to cover links that either have observed traffic volumes or are known to carry very low traffic volumes. As demonstrated in **Figure 4.4**, error on each screenline falls within the maximum desirable error as defined in NCHRP Report 255. **Figure 4.5** provides the modeled and count volumes for each screenline.

Figure 4.3 Screenlines

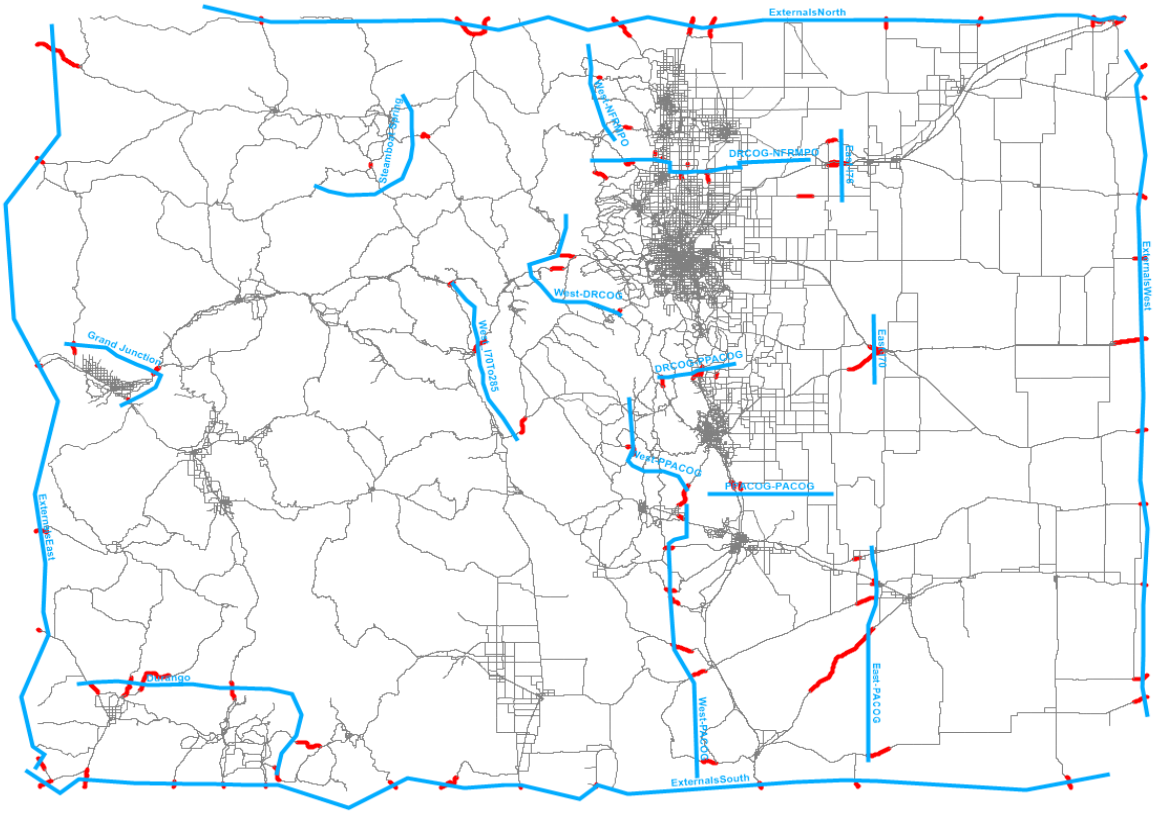


Figure 4.4 Screenline Volume and Maximum Allowable Percent Deviation

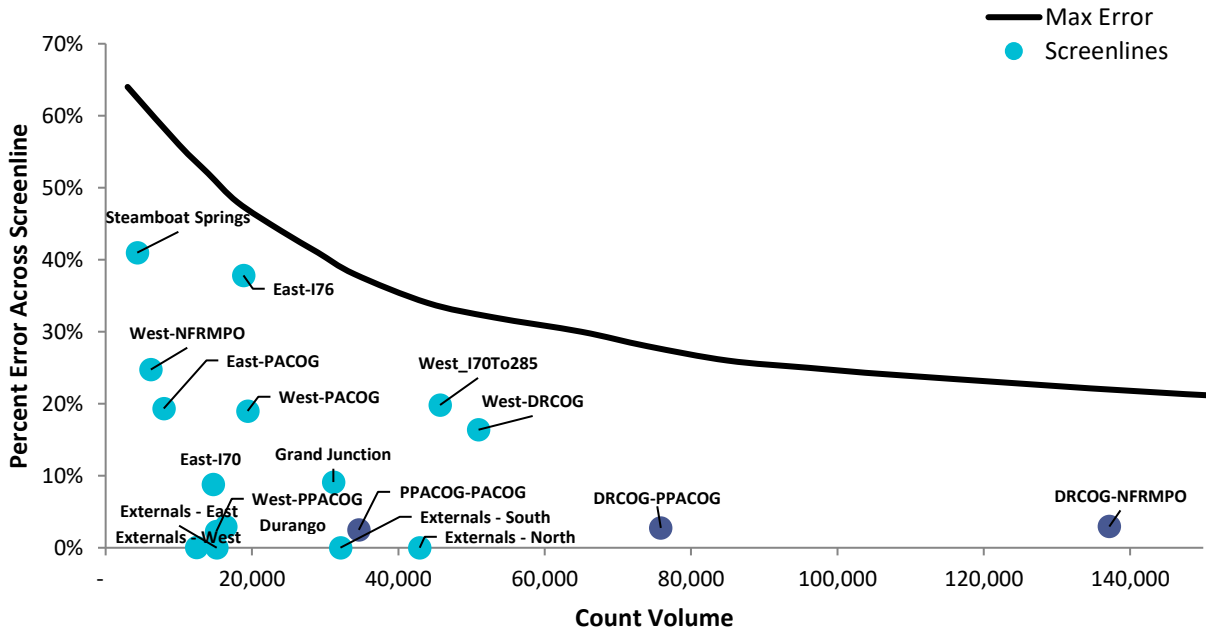
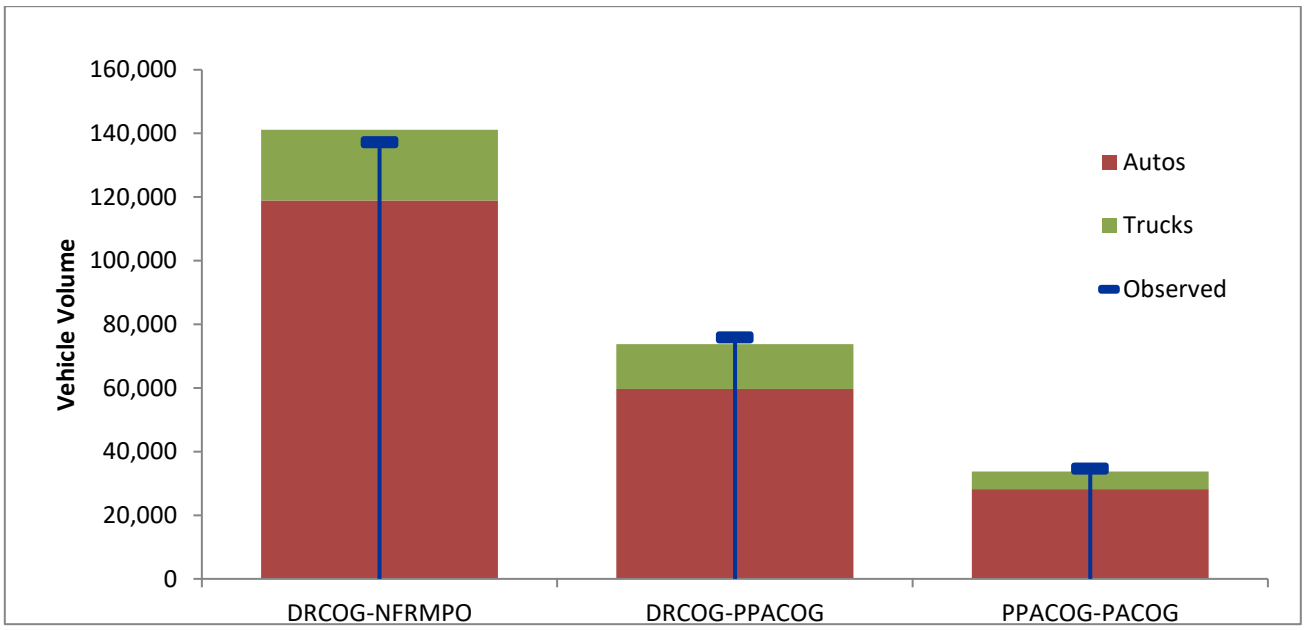


Figure 4.5 2015 Screenline Volumes along the Front Range (Modeled and Observed)



4.5 Transit Assignment

Transit assignment has been validated to observed route boardings by operator. As shown in

Table 4.21, the overall number of boardings for routes and operators within the Front Range is within 3 percent of observed values. For Denver RTD, which represents over 90 percent of statewide transit

ridership, the total number of system boardings is nearly identical to the observed boardings. The Mountain Metro, Transfort, and Pueblo Transit systems have higher percentage differences. In comparing modeled and observed ridership by individual routes, four Mountain Metro routes (10, 11, 27, and 39) account for 52% of overestimation for the system, and three of those routes (10, 11, and 27) have stops at Pikes Peak Community College. Examining the Transfort routes, one route (31) has a modeled volume 2,400 boardings less than the observed ridership; this route is a circulator around Colorado State University. The Statewide Model includes only one set of parameters for the entire state. Regionally, transit utilization by university students may vary, which is not accounted for in the model.

Table 4.21 Transit Boardings by System in the Front Range

System	2015 Boardings			
	Observed	Modeled	Difference	Percent Difference
Bustang	500	300	-163	-36%
Mountain Metro	11,000	21,300	10,318	94%
Pueblo Transit	2,700	5,300	2,616	99%
Denver RTD	364,100	365,500	1,400	0%
Transfort	14,000	11,100	-2,875	-21%
Total Boardings	**392,200**	**403,500**	**11,300**	**3%**

* Bustang boardings here only include the North and South routes along the Front Range.

Boardings were also evaluated by submode, with a particular interest in how the model performs in estimating rail ridership. **Table 4.22** provides the observed and modeled boardings for Denver RTD services compared to StateFocus as well as results from two Denver regional models (Compass and Focus). Results show StateFocus producing reasonable estimates of Light Rail ridership (within 3%).

Table 4.22 Denver RTD Boardings by Submode

Denver RTD Submode	2015 Observed Boardings	2015 Modeled Boardings			Difference			% Diff		
		State Focus	RTD Compass	DRCOG Focus	State Focus	RTD Compass	DRCOG Focus	State Focus	RTD Compass	DRCOG Focus
Free Services	46,500	22,300	52,100	27,800	-24,200	5,600	-18,700	-52%	12%	-40%
Denver Local	152,700	154,100	144,800	134,200	1,400	-7,900	-18,500	1%	-5%	-12%
Denver Limited	25,300	36,000	24,400	30,100	10,600	-900	4,800	42%	-4%	19%
Express	16,900	23,000	8,200	13,600	6,200	-8,700	-3,300	36%	-52%	-20%
Regional	5,000	17,600	11,300	10,100	12,600	6,300	5,100	252%	126%	101%
Boulder Local	21,800	19,900	21,000	13,300	-1,900	-800	-8,500	-9%	-4%	-39%
Longmont Local	3,100	2,400	1,900	800	-700	-1,200	-2,400	-24%	-38%	-75%
Light Rail	85,100	82,600	76,400	79,100	-2,500	-8,700	-6,000	-3%	-10%	-7%
Sky Ride	7,700	7,700	6,500	4,800	0	-1,200	-2,900	0%	-15%	-38%
Total	364,100	365,500	346,600	313,700	1,400	-17,500	-50,400	0%	-5%	-14%

Particularly relevant to Front Range Rail forecasting is the ability of the model to estimate long-distance or interregional transit ridership. Table 4.19 provides the interregional bus services available in Colorado in 2015. Bustang service was introduced in 2015 with limited routes; by 2018, additional routes outside of the Front Range were added. As a reasonableness check, those additional lines were added to the 2015 scenario to determine if the model produced reasonable results compared to observed ridership in these markets. Overall, the model is a little high on Bustang ridership for all routes except Bustang-North (serving Denver and the North Front Range). Where the model is too low on Bustang, it is too high on FLEX, a route that also provides service between Denver and the North Front Range. In all cases, the observed ridership is low, and the model produces reasonable ridership for the interregional markets.

Table 4.23 Interregional Transit Route Boardings

Interregional Routes	Observed		Modeled 2015*
	2015	2018	
FLEX	560		1,470
Bustang-North	200	340	50
Bustang-South	190	260	240
Bustang-West	60	210	300
Bustang-Alamosa	n/a	10	230
Bustang-Gunnison	n/a	40	0
Bustang-Durango	n/a	10	5
Bustang-Lamar	n/a	5	280
Total Bustang	**450**	**880**	**1,110**
Total Interregional	**1,010**	**2,580**	**1,570**

* 2015 modeled results include 2018 Bustang service.