2026

PACOG2050LRTP

Moves the Region

GREENHOUSE GAS TRANSPORTATION REPORT

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Acronyms and Abbreviations

ACS	American Community Survey
APCD	Air Pollution Control Division
CCR	Colorado Code of Regulations
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CO2e	carbon dioxide equivalent
DOLA	Colorado Department of Local Affairs
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
LRTP	Long Range Transportation Plan
MMT	Million Metric Tonnes
MOVES	Motor Vehicle Emission Simulator
MPO	Metropolitan Planning Organization
MUT	Multi-unit trucks
PACOG	Pueblo Area Council of Governments
PPM	Pueblo Planning Model
SB	Senate Bill
SUT	Single-Unit trucks
TAZ	Traffic Analysis Zone
TC	Transportation Commission
VMT	Vehicle Miles Traveled

Introduction

This document outlines the actions taken by the Pueblo Area Council of Governments (PACOG) to incorporate regional greenhouse gas (GHG) reduction strategies into the planning and modeling of the PACOG 2050 Long Range Transportation Plan (LRTP). This document satisfies state requirements for Metropolitan Planning Organizations (MPOs) to develop a GHG Transportation Report (Report) as outlined in the Code of Colorado Regulations (2 CCR 601-22).

To ensure compliance, the Pueblo Planning Model (PPM) and the Environmental Protection Agency Motor Vehicle Emission Simulator (MOVES) air quality model were used to quantify GHG emissions.

The planning measures, modeling methods, and emissions analysis results documented in this Report demonstrate that the 2050 LRTP meets these regulations. The analysis concludes that no additional GHG mitigation measures or Mitigation Action Plan is currently needed for PACOG to satisfy GHG reduction requirements.

Background

Colorado Greenhouse Gas Requirements

In June 2021, the Colorado legislature passed Senate Bill (SB) 21-260 titled *"Sustainability of the Transportation System."* The bill created new sources of funding for transportation and also directed the Transportation Commission (TC) to adopt implementation guidelines and procedures to address GHG emissions in transportation planning.

Subsequently, the TC adopted the "Rules Governing Statewide Transportation Planning Process and Transportation Planning Regions" (2 CCR 601-22) in December 2021. These rules address the GHG reduction requirements outlined in SB21-260 by setting GHG reduction targets for CDOT and each Colorado MPO across multiple forecast years. CDOT, working with Cambridge Systematics, used the Energy Emissions Reduction and Policy Analysis Tool, along with CDOT's statewide travel demand model and the MOVES model, to develop the initial GHG baseline estimates and reduction targets, shown in **Table 1**.

Table 1: GHG Transportation Planning Reduction Levels in MMT of CO2e

Note: MMT = million metric tonnes; MPO = metropolitan planning organization; N/A = not applicable

Regional Areas	2025 Reduction Level (MMT)	2030 Reduction Level (MMT)	2040 Reduction Level (MMT)	2050 Reduction Level (MMT)
Denver Regional Council of Governments (DRCOG)	0.27	0.82	0.63	0.37
North Front Range Metropolitan Planning Organization (NFRMPO)	0.04	0.12	0.11	0.07
Pikes Peak Area Council of Governments (PPACG)	N/A	0.15	0.12	0.07
Grand Valley Metropolitan Planning Organization (GVMPO)	N/A	0.02	0.02	0.01
Pueblo Area Council of Governments (PACOG)	**N/A**	**0.03**	**0.02**	**0.01**
CDOT/Non-MPO	0.12	0.36	0.30	0.17
Total	**0.43**	**1.50**	**1.20**	**0.70**

Source: Rules Governing Statewide Transportation Planning Process and Transportation Planning Regions (2 CCR 601-22)

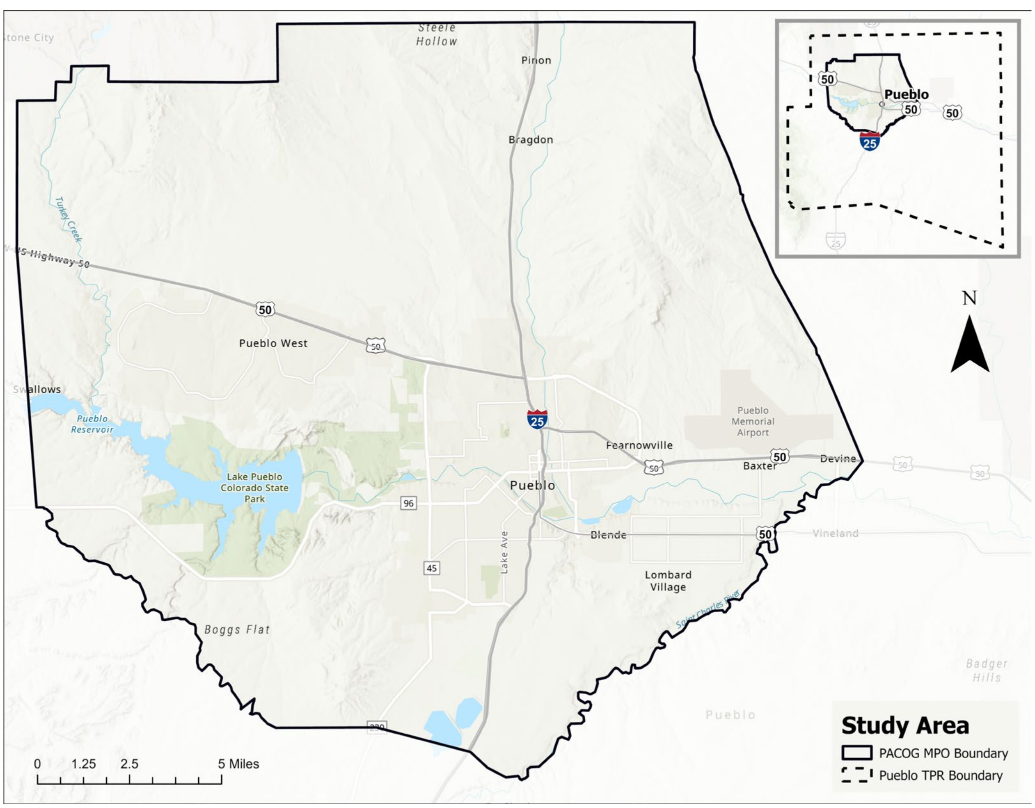
2 CCR 601-22 requires PACOG to model GHG emissions from transportation projects included in their plans and to take steps to reduce GHG emissions compared to what would be expected under the previously adopted 2045 LRTP (Baseline Plan). PACOG has specific GHG reduction targets in three forecast years: 2030, 2040, and 2050. Currently, the 2050 LRTP is the only applicable planning document used to model future GHG emission reductions and demonstrate compliance with Rule 8.02.5.3, as no prior plans were adopted since October 1, 2022.

Planning Area

PACOG provides regional planning and programming services for the multimodal transportation systems (automobile, transit, biking, walking, freight, and rail). Following federal guidelines, PACOG collaborates regularly with local, state, and federal governments to ensure transportation projects and plans are comprehensive, coordinated, and continuously updated. The PACOG MPO boundary, as shown on **Figure 1**, covers portions of Pueblo County, including the City of Pueblo, Pueblo West, and Blende (Census Designated Place). Additionally, Colorado City, Beulah Valley, Avondale, and Boone are Census Designated Places included within PACOG's Transportation Planning Region (TPR).

The PACOG's GHG analysis focuses specifically on the transportation network and projects within its MPO boundaries. CDOT evaluates transportation projects outside the five MPOs separately and incorporates them into their statewide modeling to meet GHG reduction targets for non-MPO areas of the state.

Figure 1: PACOG MPO Boundary (2025)



The Long Range Transportation Plan and the Pueblo Planning Model

Every five years since 1988, PACOG has updated its LRTP, which looks ahead at least 20 years. The LRTP sets the region's transportation vision and goals, assesses the current transportation system, and identifies strategies to effectively use public funds to achieve those goals. It provides decision-makers a framework to consider the broader social, economic, and environmental effects of transportation and land-use choices. All regionally significant transportation projects within the PACOG MPO boundary must be included in the LRTP.

The PPM is an important tool used to develop the LRTP. It accounts for factors such as where people live and the density of housing, where people work, and how people choose to travel (that is, car, walk, bike, bus). The model analyzes how population, employment, and land -use changes over time have the potential to affect the transportation network. Proposed projects for the LRTP are then incorporated into the PPM to determine how they impact future travel and whether they help achieve the plan's goals such as reducing GHG emissions. The PPM ultimately estimates future traffic volumes, average travel speeds, and typical travel patterns.

Updated for the 2050 LRTP, the PPM supports GHG analysis and was used along with the Environmental Protection Agency (EPA) Motor Vehicle Emission Simulator (MOVES) model to demonstrate conformity with 2 CCR 601-22. PACOG received funding from CDOT’s American Rescue Plan Act (ARPA) fund to support updates to the four-step travel demand model and completion of modeling requirements to meet the GHG standard for transportation planning. The following represent key updates to the PPM:

- **Extended Model Forecast Horizon**: Extends the planning horizon to 2050 (five years beyond the previous 2045 horizon). Adds interim scenarios for 2030 and 2040, along with the 2020 base year and the 2050 planning horizon. The 2050 planning horizon scenario replaces the 2045 horizon for the 2050 LRTP cycle.

- **Updated Observed Traffic Data**: Integrates 2023 traffic count data by autos, Single-Unit (SUT) trucks, and Multi-Unit (MUT) trucks.
- **Zone System Revisions**: Aligns zonal coverage with CDOT's Traffic Analysis Zone (TAZ) structure to improve geographic resolution and consistency between CDOT and PACOG for base and forecast land-use assumptions.
- **Zonal Data Updates**
  - Updates socioeconomic data (population, households, median income, group quarters) using the 2020 U.S. Census data and 2023 projections from the Colorado Department of Local Affairs (DOLA).
  - Updates employment data using 2020 Quarterly Census Employment and Wages from the Colorado Department of Labor and Employment, including 2021 employment point data.
  - Trip-generation disaggregation values and trip-distribution targets use the 2010 Pueblo Front Range Household Survey. (An updated statewide travel survey is in progress.)
- **More Detailed Truck Vehicle Classes**: Earlier model versions collapsed SUT and MUT into a single truck class in later steps. The 2024 model carries SUT and MUT through all steps and outputs.
- **Transit Network / Model**: Now includes transit routes, stops, and service characteristics to support transit skimming for mode choice modeling and transit assignment. Expands roadway network details and attributes to support transit modeling.
- **Mode Choice Modeling**: Adds an explicit representation of auto vs. transit choices by trip purpose and journey characteristics to improve sensitivity to future scenarios. This addition significantly affects outputs and downstream steps, including Production-Attraction to Origin-Destination conversion.
- **Expanded Traffic Assignment**: Provides traffic flow outputs for AM peak, PM peak, the remaining 22 off-peak hours, and daily totals. Reports vehicle classes separately for autos, SUT, and MUT. Applies a Passenger Car Equivalent (PCE) methodology to account for trucks' higher capacity usage. Includes daily transit route assignment with corresponding outputs and reports.

- **Updated User Interface, Analysis, and Reporting**: Updates and expands reporting for the new components to summarize mode choice and transit assignment results. Now customizes and produces GHG reporting/output in comma-separated values format for easy import to Excel to support the GHG emissions calculations process.

In conformity with Rule 8.02.2.1, PACOG has prepared and published (on a publicly accessible website) a calibration and validation report for the PPM. The PACOG 2024 Model Update/Validation Methodology Report (June 2024) (**Appendix A**) documents detailed information about the 2024 PPM update, including model components, key parameters, and addresses how the model accounts for induced travel demand associated with changes to the transportation system.

Pueblo Area Greenhouse Gas Emissions Analysis

Since the PACOG is in attainment for national air quality standards, this is the first time the PACOG conducted a GHG analysis. This analysis compares GHG emissions for the PACOG "Baseline Plan" and "Updated Plan." The results, shown in **Table 2**, detail the GHG emissions for both plans across the various compliance years in million metric tonnes (MMT). The table highlights the "PACOG Reductions," which represent the difference in emissions between the two plans.

In addition to the emissions data, **Table 2** shows the GHG Reduction Levels established in 2 CCR 601-22 for PACOG for each compliance year. The 2050 LRTP meets or exceeds the required GHG Reduction Levels in each of the three compliance years, demonstrating compliance with 2 CCR 601-22.

Baseline Plan: The Baseline Plan represents the adopted 2045 LRTP and supporting programs, using updated socioeconomic forecasts for population, housing, and employment, used as the reference condition for greenhouse gas analysis.

The 2045 LRTP was adopted by the CDOT TC in February 2020; amended by PACOG in December 2021.

Updated Plan: The Updated Plan represents the 2050 LRTP and builds on the Baseline Plan using the same socioeconomic assumptions while incorporating additional funded projects and targeted operational and policy strategies to reduce vehicle travel and demonstrate achievable greenhouse gas emissions reductions.

The 2050 LRTP is expected to be adopted by the PACOG Board in April 2026.

Table 2: PACOG GHG Emission Results, Million Metric Tonnes (MMT)

Regional Areas	2030 GHG Emissions	2040 GHG Emissions	2050 GHG Emissions
Baseline Plan: 2045 LRTP	0.540	0.326	0.217
Updated Plan: 2050 LRTP	0.494	0.297	0.202
PACOG Reduction from Baseline Plan	0.046	0.029	0.015
PACOG Required Reductions 2 CCR 601-22	0.030	0.020	0.010
Pass/Fail	**Pass**	**Pass**	**Pass**

Note: Some numbers in this chart may not sum correctly due to rounding.

Source: Pueblo Planning Model and 2 CCR 601-22

Baseline Plan Model

The **Baseline Plan** represents the transportation network and programs adopted in the PACOG 2045 LRTP before the GHG Transportation Planning Standard (2 CCR 601-22) became effective.

Baseline Plan Model Network

The Baseline Plan includes roadway, transit, and non-motorized projects that were fiscally constrained and adopted in the 2045 LRTP, along with continuation of existing policies and trends. No projects or strategies that advanced after adoption of the 2045 LRTP are included in the Baseline Plan.

The travel modeling for the adopted 2045 LRTP consisted of a 2020 base year and a single 2045 horizon year. To enable comparison between the Baseline and Updated Plan, the Baseline Plan horizon year was disaggregated into 2030, 2040, and 2050, with projects assigned to the corresponding staging year. A summary of the PACOG GHG Strategy Scenario Sensitivity Modeling (May 2025) (**Appendix B**) documents the process to develop the 2030, 2040, and 2050 staging years. Projects are listed in **Table 3** below, and further detail on project limits is in **Appendix B**:

Table 3: Baseline Plan Project Summary

Project	Funding Program	Planning Horizon	Total Programmed Cost
I-25 through Pueblo	RPP; SB1	2021-2024	$3,728,633
U.S. 50B Mill and Overlay I25 to 36th Lane	CWP	2021-2024	$378,000
ADA Improvements in the Pueblo TPR Area	ADA	2021-2024	$1,350,162
U.S. 50 Scour Critical Counter Measures K-18-BY, BZ	CBP	2021-2024	$541,160
U.S. 50B - I 25 to 26th Lane	CBP	2021-2024	$2,077,893
S Pueblo - PURHAR-0.1 FRNT	BRO	2021-2024	$523,377
Santa Fe Ave Streetscape Phase 1B	MMO; TAP	2021-2024	$261,349
Arkansas River Trail Phase 4	MMO; TAP	2021-2024	$970,618
Minnequa Lake Trail Connection	TAP; MMO	2021-2024	$388,000
City of Pueblo Prairie Avenue MM Upgrades	MMO	2021-2024	$1,300,000
U.S. 50 West	RPP	2021-2024	$1,469,963
U.S. 50C Drainage Improvements	RPP; SUR	2021-2024	$1,710,922
I-25 Dillon Frontage Road	RPP	2021-2024	$4,200,000
Elizabeth - U.S. 50 to Ridge Drive	SUR	2021-2024	$1,600,000
U.S. 50B Mill and Overlay I25 to 36th Lane	SUR	2021-2024	$19,030,001
U.S. 50A Pueblo County Line to West of Purcell Blvd	SUR	2021-2024	$13,340,700
SH 47A Preventative Maintenance	SUR	2021-2024	$1,372,500
I-25 and U.S. 50B Interchange	SUR	2021-2024	$161,732
Pueblo West SDS Trail North Park	TAP	2021-2024	$513,176
City of Pueblo Northern Avenue Phase 3	TAP	2021-2024	$625,000
Joe Martinez Trail in Pueblo West	TAP	2021-2024	$1,081,741
Arkansas Levee Construction	TAP	2021-2024	$634,328
SH 96A West of Pueblo Safety Improvements	-	2025-2030	$11,500,000
I-25 Improvements North of 13th Street	-	2025-2030	$28,000,000
SH 47 Four Lane Extension to US 50B	-	2025-2030	$8,000,000
I-25 Exit 108 Replace Single Box Culvert	-	2025-2030	$11,000,000
U.S. 50C Drainage Improvements	-	2025-2030	$5,500,000
SH 45 North Extension Study	-	2025-2030	$1,000,000
Dillon Drive East of I-25 Frontage Road Improvements	-	2025-2030	$3,000,000
U.S. 50B Continuous Left Lane at U.S. 50C	-	Beyond 2030	$2,000,000
U.S. 50B Drainage Improvements Pueblo to Granada	-	Beyond 2030	$30,000,000
Pueblo Boulevard Improvements, Multiple Segments	-	Beyond 2030	$23,800,000
Pueblo Boulevard Phase 2 Improvements	-	Beyond 2030	$51,700,000
U.S. 50B East Guardrail Improvements	-	Beyond 2030	$3,000,000
SH 78 Bridge and Shoulder Widening	-	Beyond 2030	$4,000,000

U.S. 50C Drainage Improvements	-	Beyond 2030	$5,500,000
Interstate 25 and U.S. 50B Corridor Improvements	-	Beyond 2030	$262,000,000
U.S. 50A Capacity and Interchange Improvements	-	Beyond 2030	$50,000,000
SH 78 Raised Median and Intersection Improvements	-	Beyond 2030	$3,400,000

Baseline Plan Socioeconomic Data

For both the Baseline Plan and the Updated Plan, the socioeconomic data inputs used in the greenhouse gas modeling are the same. Population, housing, and employment forecasts are based on 2020 U.S. Census data and updated 2023 projections from the Colorado State Demographer's Office and are applied consistently across all scenarios and compliance years. Using identical socioeconomic assumptions ensures that differences in greenhouse gas emissions between the Baseline Plan and the Updated Plan are attributable to changes in transportation projects, policies, and operational strategies rather than differences in underlying growth assumptions.

Baseline Plan Model Validation and Calibration

Model calibration and validation were conducted to ensure the PPM accurately reflects observed travel patterns in the Pueblo region. Validation used traffic count data for autos, SUT, and MUT vehicles and incorporated 2020 CDOT counts and other local datasets. Screenline analysis and trip length frequency distributions were used to benchmark the model. Transit validation used route-level ridership and on-board survey data.

Updated Plan Model

The **Updated Plan** represents the Draft 2050 LRTP and builds upon the Baseline Plan by incorporating additional projects, network enhancements, and system-level strategies that advanced following adoption of the 2045 LRTP.

Model Changes to the Updated Plan

A clear distinction is maintained between projects included in the Baseline Plan and those included in the Updated Plan. The additions to the Updated Plan include new or modified roadway and transit connections, expanded active transportation investments, and policy or operational strategies intended to reduce vehicle miles traveled (VMT) and GHG emissions. The Updated Plan was developed for 2030, 2040, and 2050 compliance years.

The project list presented in **Table 4** below identifies the highway/streets and transit projects modeled in the Updated Plan. The PACOG GHG Strategy Scenario Sensitivity Modeling (May 2025) includes the Updated Plan project list (**Appendix B**).

Table 4: Updated Plan Project Summary

Category	Improvement	Implementation Year(s)
Fixed Route Transit	Shopping Shuttle Bus Route(s)	2030, 2040, 2050
Highway/Streets	Medal of Honor Blvd (Purcell Blvd-Pueblo Blvd)	2030, 2040, 2050
Highway/Streets	Drew/Dix Split Diamond Interchange	2030, 2040, 2050
Highway/Streets	Pueblo Blvd FR (Medal of Honor Blvd-Spaulding Ave)	2030, 2040, 2050
Highway/Streets	Spaulding Ave (31st St-24h St; Pueblo Blvd-Pueblo Blvd FR)	2030, 2040, 2050
Highway/Streets	Spaulding Ave (24th St)	2040, 2050
Highway/Streets	24th St (Tuxedo Blvd-Atlanta Ave)	2040, 2050
Highway/Streets	Mc Carthy Blvd (CO96/ Thatcher Ave-CO78/ Northern Ave)	2040, 2050
Highway/Streets	Bandera Pkwy (CO96/Thatcher Ave-Siena Dr)	2040, 2050
Highway/Streets	Red Creek Springs Rd (Mc Carthy Blvd-Bandera Pkwy)	2040, 2050
Highway/Streets	Lehigh Ave (Mc Carthy Blvd-Bandera Pkwy)	2040, 2050
Highway/Streets	Baltimore Ave (Kachina Dr-29th St)	2040, 2050
Highway/Streets	Spaulding Ave (31st St-11th St)	2040, 2050
Highway/Streets	18th St (Spaulding Ave-Perry Ave)	2040, 2050
Highway/Streets	Baker Stesmer Rd (Lowell Ave-24th St)	2050
Highway/Streets	Hollywood Dr Extension (Farabaugh Ln-Unnamed1 and Unnamed2)	2050
Highway/Streets	Little Burnt Mill Dr Connection (Rambo Trail-Salt Creek Crossing)	2050
Highway/Streets	Unnamed Loop1 Connection (Lake Ave-CO 78/Northern Ave)	2050
Highway/Streets	Bandera Pkwy (Bridal Trail-Unnamed Loop1)	2050
Highway/Streets	Bridal Trail Extension (Bandera Pkwy-Unnamed Loop1)	2050
Highway/Streets	Unnamed Loop2 (Unnamed Loop1-Little Burnt Mill Dr)	2050

Modeling with the GHG Scenario Builder

The 2024 PPM introduced a GHG Scenario Builder tool that allows users to assess the effects of policy and operational strategies on regional GHG emissions, including changes to work-from-home participation, transit service levels, transit frequency, and active transportation enhancements.

The GHG analysis conducted for the 2030, 2040, and 2050 forecast years compared the Baseline against the Updated Plan.

Three primary strategies were applied in the GHG Scenario Builder to develop the Updated Plan compliance scenarios:

- Work-from-home participation by income level
- Transit frequency and speeds
- Non-motorized travel mode

These strategies were selected to represent feasible measures applicable within the PACOG region. Model outputs were formatted in accordance with CDOT and Colorado Department of Public Health and Environment (CDPHE) Air Pollution Control Division (APCD) requirements to facilitate MOVES processing. **Table 5** below summarizes GHG strategies selected for the 2030, 2040, and 2050 Updated Plan compliance scenarios and justification for the relevant aspects that support the GHG strategy assumptions follow.

Table 5: Supplemental GHG Strategies

Strategies	2030, 2040, 2050 Baseline Assumptions	2030 Compliance Supplemental	2040 Compliance Supplemental	2050 Compliance Supplemental
Work from home participation*	Income 1: 1% Income 2: 3% Income 3: 6% Income 4: 11% Weighted average: 5%	Income 1: 10% Income 2: 15% Income 3: 30% Income 4: 30% Weighted average: 20%	Income 1: 10% Income 2: 15% Income 3: 30% Income 4: 30% Weighted average: 20%	Income 1: 10% Income 2: 15% Income 3: 30% Income 4: 30% Weighted average: 20%
Transit frequency	Existing service levels (30 / 60 minutes)	20 / 45 minutes	20 / 45 minutes	20 / 45 minutes
Transit speed	50% of vehicular speed	65% of vehicular speed	65% of vehicular speed	65% of vehicular speed
Increase in Non-motorized travel Over 2020 Calibration**	1% of trips	5.5% of trips	5.5% of trips	5.5% of trips

*Income 1 = less than $41,999, Income 2 = $41,999 to $49,999, Income 3 = $50,000 to $65,999, Income 4 = over $65,999

**Percent of total trips up to 5 miles in length

Work from Home

Work-from-home participation represents a systemic change in travel behavior that has emerged since the adoption of the 2045 LRTP and has been incorporated into both regional and statewide planning practice. Expanded access to remote technologies, changes in employer policies, and increased acceptance of hybrid work arrangements have reduced the frequency of commute trips for a portion of the workforce and altered overall travel demand. The concept of working from home encompasses a wide range of employment arrangements beyond full-time remote work, including self-employed individuals, home-based businesses, part-time employment, non-standard work hours, and hybrid schedules of working from home at least one day per week. These shifts have influenced travel behavior that may not have been captured in previous models.

Work-from-home assumptions in the Updated Plan are informed by American Community Survey (ACS) Journey-to-Work data[1]. ACS Table B08119 shows an increase in work-from-home participation in the Pueblo Metro Area following the pandemic period. Between 2015–2019 and 2020–2024, the share of workers reporting that they usually worked from home increased from approximately 3 percent to 9 percent, while total employment also grew over the same period. This increase indicates a long-term shift in commuting behavior rather than a short-term anomaly.

Note: ACS Table B08119 reports the number of workers who identify working from home as their primary work location, rather than those who do so only a few days per week. As a result, the table captures full-time or predominant remote work but undercounts hybrid schedules where workers split time between home and an external workplace. It is assumed that ACS Table B08119 provides a conservative estimate for work-from-home participation but does not fully reflect weekday participation under hybrid schedules.

The ACS data show a differentiation in work-from-home participation by income level. Lower-income categories below $35,000 account for smaller shares of workers who usually work-from-home. Participation increases in middle-income categories and reaches its highest level among workers earning $75,000 or more. This pattern demonstrates that even in a smaller metro area like Pueblo, work-from-home participation is associated with income levels. Therefore, modeling differentiated work from home participation rates by income is consistent with observed data.

The modeled work-from-home participation in the Updated Plan align with ACS evidence when applied as effective weekday participation rather than permanent remote

[1] [1] U.S. Census Bureau, American Community Survey, Table B08119, 5-Year Estimates, 2015–2019 and 2020–2024.

work. Lower modeled rates (10-15 percent) for lower-income groups are assumed to remain modest, consistent with ACS findings, and higher modeled rates (30 percent) for upper-income groups reflect the concentration of ACS-reported work-from-home participation in those income ranges and account for hybrid schedules. This approach results in commuting levels for most workers while representing reductions in peak-period travel among higher-income, telework-capable occupations.

Note: While higher-income workers are assumed to have higher work-from-home participation rates, they represent a smaller share of Pueblo's workforce. Nearly 60 percent of workers fall into the two lowest income categories. As a result, when participation rates are weighted by the distribution of workers across income groups, the higher participation rates applied to upper-income workers reflect hybrid work patterns within a smaller proportion of the labor force.

Statewide Colorado data from the same ACS table reinforce the income-based pattern observed in Pueblo. In Colorado overall, the share of workers who usually worked from home averaged 21 percent from 2020-2024. In comparison, the workforce-weighted average of the work-from-home participation in the Updated Plan is 20 percent. This consistency supports the use of statewide context to validate the Pueblo-specific modeling assumptions.

Work-From-Home Implementation Measures

Since 2023, the City of Pueblo has had a significant uptick in the number of households with access to Fiber Optic internet. Fiber optic service provides high-speed and consistent internet access which greatly increases the opportunity for citizens to access and work jobs which allow for Work-From-Home or Hybrid schedules. Combined with the local power company's efforts to underground its infrastructure, increasing the reliability of uninterrupted electricity access, Pueblo expects to see a steady increase in the percentage of its population with access to employment opportunities that provide work-from-home benefits.

Transit Frequency and Speed

The Updated Plan assumes increased transit frequency and improved operating speeds relative to the Baseline Plan. In the Baseline Plan, transit service frequency varies by route and by time of day. Most routes operate at 60-minute headways during both peak and off-peak periods, while select routes provide enhanced peak hour service with 30-minute headways. In the model, increased transit frequency is applied as a systemwide factor across bus routes to capture the potential benefits of more frequent service. Higher frequency reduces perceived travel time and improves convenience, making transit more attractive for a wider range of trips. While this approach supports overall transit performance, more targeted service changes can be evaluated separately by defining new or modified transit routes with specific operating characteristics.

Additionally, improved transit operating speeds reflect investments that reduce travel time while vehicles are in motion. These improvements may include strategies such as transit signal priority, dedicated or separated rights-of-way, and faster boarding and alighting. Within the model, transit speed is represented through in-vehicle travel time assumptions applied to roadway links. Baseline conditions assume that transit vehicles operate at a lower effective speed than that of general traffic, while future scenarios allow this relationship to shift as transit receives greater operational priority. Increasing transit speeds in the model reflects how these improvements can enhance travel time competitiveness and support higher transit use.

These assumptions are supported by transit investments and policies outlined in the Draft 2050 LRTP, including planned service expansions, route refinements, and operational improvements identified through coordination with local transit providers (LRTP Chapter 7: Transit). Implementation of these improvements is anticipated through a combination of federal transit funding programs (e.g., FTA Sections 5307 and 5339), state transit programs, and local operating and capital funding. Improvements to transit operating speed reflect strategies such as improved stop spacing, signal priority, and other operational enhancements that are consistent with planned LRTP policies and ongoing transit planning efforts.

The following transit projects, drawn from the Draft 2050 LRTP, represent key investments that support the region's implementation of expanded transit access.

Transit Implementation Measures

- I-25 Exit 108 Purcell Boulevard Mobility Hub
- Pueblo Transit $15M grant for new vehicles
- Zero Emissions Transition Plan (2025)
- Route restructuring (Northside/Southside shopping routes)
- Youth Ride Free program
- MyRide App (service usability & reliability)
- 11 new bus stops + 56 upgraded stops on west side
- CSU Hydrogen Fuel Station (supports fleet transition)
- Funding from CTE Grant Program

Non-motorized Travel

Mode choice modeling is used to capture how people choose from available transportation options for different types of trips. In the 2020 calibrated model and the Baseline Plan model, a 1 percent active transportation mode share is applied to all trip purposes by shifting short-distance auto trips of up to five miles in length to non-motorized modes. The Baseline assumption of 1 percent represents a conservative condition because non-motorized modes were an approximation that were not explicitly modeled and because robust local survey data were not available to support calibration. Updated Plan assumptions reflected in the model include an increased percentage of trips made using non-motorized transportation modes.

The mode choice assumptions in the Updated Plan reflect observed and anticipated regional and state-wide growth in walking and bicycling. One contributing factor is the increased use of electric bicycles and scooters, which has expanded the practical range of active modes and made them viable for a broader range of users and longer trip lengths. The availability of these devices, supported by state and local incentive programs, has helped lower physical and time-related barriers to bicycling or walking for everyday travel.

In addition, Colorado has emphasized active transportation through policy, funding, and infrastructure investment. Statewide and local plans increasingly prioritize walking and bicycling, and many communities have adopted multimodal or complete streets approaches that improve connectivity and user comfort. Continued investment in sidewalks, bikeways, shared-use paths, and related facilities has made active modes more competitive with motorized travel and encouraged higher participation rates.

The increase in the assumed non-motorized mode share reflects a refinement of earlier conservative modeling assumptions, in addition to better reflect cumulative infrastructure improvements, supportive land use patterns, expanded access to electric bicycles and scooters, and policy commitments that make short trips under five miles increasingly feasible by active modes.

Increases in non-motorized travel assumed in the Updated Plan are supported by active transportation investments and policies included in the Draft 2050 LRTP (LRTP Chapter 6: Active Transportation). These include fiscally constrained bicycle and pedestrian projects, application of Complete Streets principles, and continued coordination with CDOT and local partners on active transportation implementation. Funding sources that support these improvements include the Transportation Alternatives Program, Highway Safety Improvement Program, CDOT multimodal programs, and local capital improvement programs. While individual sidewalk or bicycle projects may not be modeled specifically, their cumulative effect is reflected through increased non-motorized mode share assumptions in the Updated Plan. Additionally, PACOG is kicking off an update to the region's current bicycle and pedestrian master plan which should also support non-motorized travel throughout the region as additional projects and linkages will be determined.

The following active transportation projects, drawn from the Draft 2050 LRTP, represent key investments that support the region's implementation of non-motorized travel opportunities.

Active Transportation Implementation Measures

- Medal of Honor Boulevard Multimodal Corridor
- RAISE-funded trail connections:
  - Medal of Honor Multimodal Trail
  - 11th Street Trail connection
  - Mobility hubs
  - Waterworks Park access
- Pueblo River Trails Master Plan update
- Complete Streets initiative (2026)
- Bicycle & Pedestrian Master Plan update (2026)

Non-Modeled Land Use and Trip Reduction Context Supporting Updated Plan Assumptions

The land use forecasts used in both the Baseline and Updated Plan models reflect development conditions that have materially changed since adoption of the 2045 LRTP. The forecasts incorporate updated population and employment projections from DOLA and reflect coordination with member jurisdictions to account for adopted plans, entitled projects, and anticipated future development patterns. However, additional alternative land use scenarios or further land use changes were not modeled specifically in the Updated Plan.

Since 2045, PACOG member jurisdictions have advanced a coordinated set of land use policies, development regulations, and private investments that support shorter trip lengths, improved access to daily needs, increased viability of transit, walking, and bicycling. These actions provide contextual support for the Updated Plan's assumed reductions in vehicle travel and increases in non-motorized and transit use, even where individual land use changes cannot be directly represented in the travel demand model.

Adopted Plans and Regulatory Updates

Since adoption of the 2045 LRTP, multiple jurisdictions within the PACOG region have adopted or initiated comprehensive plan and development code updates that prioritize compact growth, mixed-use development, and multimodal accessibility. These include:

- Adoption of the Pueblo Regional Comprehensive Plan (2022), which directs higher-density and mixed-use development toward the urban core and along arterial and collector corridors.
- Ongoing updates to zoning and subdivision regulations to create a Unified Development Code, improving alignment between land use and multimodal transportation planning.
- Implementation of zoning code amendments to comply with recent state legislation, including:
    - House Bill 24-1152 (Accessory Dwelling Units), supporting incremental residential density in established neighborhoods.
    - House Bill 24-1304 (Minimum Parking Requirements), reducing excess parking supply and supporting more compact, walkable development patterns.

High-Density, Mixed-Use, and Infill Development

Recent and ongoing development activity within the PACOG region further reinforces the Updated Plan's assumptions regarding trip length reduction and mode shift. The increased non-motorized mode share is especially effective to reflect land use scenarios that emphasize density and infill development, where new trips are generally shorter and more conducive to active transportation. Examples include:

- Pikes Peak Park, a planned mixed-use development encompassing approximately 74 acres with over 600 residential units and associated commercial services.
- Pueblo Springs Apartments, a multifamily residential development providing nearly 200 dwelling units in proximity to arterial corridors.
- The Cottages on the Boulevard, a higher-density residential development designed to support future mixed-use opportunities.
- Downtown infill and adaptive reuse projects, including conversion of historic structures and renovation of upper-story residential units along Main Street, increasing residential proximity to employment, services, and transit.

Implications for Travel Behavior and GHG Reduction

Collectively, these land use initiatives support:

- Shorter average trip lengths by co-locating housing, employment, and daily services.

- Increased feasibility of walking and bicycling for short trips.
- Improved transit access and ridership potential through higher residential and employment densities along key corridors.
- Reduced dependence on single-occupancy vehicle travel.

While these land use changes are not modeled independently in the Updated Plan, they reinforce the feasibility of the assumptions related to work-from-home participation, transit use, and non-motorized travel. As such, they represent an important supporting context for the Updated Plan's demonstrated compliance with the GHG reduction targets established in 2 CCR 601-22.

Relationship to the 2050 LRTP

The Updated Plan is directly aligned with the policies, strategies, and fiscally constrained investments described in the Draft 2050 LRTP, available at www.pacogmovestheregion.com. The Updated Plan translates adopted and anticipated investments, programs, and policies into modeled assumptions that reflect their combined influence on regional travel behavior and emissions outcomes consistent with 2 CCR 601-22.

Policies, Programs, and Funding

The Updated Plan represents a reasonable and achievable pathway for the PACOG region to meet the GHG reduction targets established in 2 CCR 601-22. While the scenario is expressed in the model through changes in travel behavior – such as increased transit use, higher non-motorized mode share, and reduced vehicle travel – it is grounded in adopted plans, fiscally constrained projects, and established funding programs that support implementation of these outcomes.

The Updated Plan builds upon the Baseline Plan by incorporating projects, programs, and policy directions that have advanced since adoption of the 2045 LRTP and are reflected in the Draft 2050 LRTP. These actions include both regionally significant transportation investments and system-level strategies that influence travel behavior but cannot always be represented as individual projects within the travel demand model. Examples of these elements are listed in **Table 6**.

Table 6: Policies, Programs, and Funding that Support Modeled Strategies

Modeled Strategy	2050 LRTP Policies/Programs	Funding/Implementation Mechanism
Work from Home Participation	Observed post-2020 trends reflected in the PACOG model update as well as statewide and adjacent MPO best practices	Empirical assumption (ACS-based), not project dependent.
Increased transit frequency & speed	Transit service expansion noted in the 2050 LRTP; Pueblo Transit route refinements since 2045 LRTP (ongoing)	FTA 5307/5339, local operating funds, IIJA discretionary transit programs.
Increased non-motorized travel	Fiscally constrained bike/ped projects in the 2050 LRTP; Complete Streets policies	TAP, HSIP, CDOT Multimodal, local capital programs

Model Output Summary

Table 7 presents key inputs and outputs from the PPM for the three compliance years for the Baseline Plan and the Updated Plan. The table identifies demographic data and travel forecasts for all of Pueblo County.

Compared to the Baseline Plan, the Updated Plan has a slight increase in non-motorized trips, a slight decrease in vehicle trips, and a slight decrease in VMT reflecting the previously described Updated Plan scenarios. Additionally, the increase in transit ridership reflects the fact that transit service was increased between the Baseline Plan and Updated Plan.

Table 7: Modeling Output Summary

Category	Baseline Plan 2030	Baseline Plan 2040	Baseline Plan 2050	Updated Plan 2030	Updated Plan 2040	Updated Plan 2050
Socioeconomic Data						
Population	182,758	193,288	198,327	182,758	193,288	198,327
Households	72,315	76,153	79,350	72,315	76,153	79,350
Population Employed	80,382	84,768	86,914	80,382	84,768	86,914
Lane Miles by Roadway Type						
Interstate	194	194	194	194	194	194
Expressway	326	326	326	326	326	326
Principal Arterial	301	373	380	314	387	404
Minor Arterial	393	470	481	396	481	491
Collector	306	1,006	1,095	310	1,016	1,128
Ramps	19	23	23	19	23	23
Centroid Connectors	659	684	684	664	684	689
Total Lane Miles	**2,197**	**3,074**	**3,182**	**2,222**	**3,111**	**3,255**
Person Trip Mode Share						
Vehicle: Drive Alone	71.9%	71.1%	71.4%	68.0%	67.9%	68.0%
Vehicle: Shared Ride (2+)	26.6%	27.5%	27.3%	26.0%	26.2%	26.1%
Transit	0.5%	0.3%	0.3%	0.8%	0.8%	0.8%

Category	Baseline Plan 2030	Baseline Plan 2040	Baseline Plan 2050	Updated Plan 2030	Updated Plan 2040	Updated Plan 2050
Vehicle Trips diverted to Non-Motorized	1.0%	1.0%	1.0%	5.2%	5.1%	5.2%
Vehicle and Transit Data (Daily)						
Vehicle Miles Traveled (VMT)	5,615,909	6,193,646	6,223,802	5,237,613	5,759,488	5,957,018
VMT per Capita	30.7	32.0	31.4	28.7	29.8	30.0
Transit Boardings	2,465	2,606	2,673	7,170	6,831	7,059

Source: Pueblo Planning Model

Table 8: Modeling Output Comparison

Category	Change 2030	Change 2040	Change 2050
Socioeconomic Data			
Population	0	0	0
Households	0	0	0
Population Employed	0	0	0
Lane Miles by Roadway Type			
Interstate	0	0	0
Expressway	0	0	0
Principal Arterial	13	14	24
Minor Arterial	3	11	10
Collector	4	10	33
Ramps	0	0	0
Centroid Connectors	5	0	5
Total Lane Miles	**24**	**37**	**73**
Person Trip Mode Share			
Vehicle: Drive Alone	-3.9%	-3.2%	-3.4%
Vehicle: Shared Ride (2+)	-0.6%	-1.3%	-1.2%
Transit	0.3%	0.5%	0.5%
Vehicle Trips Diverted to Non-Motorized	4.2%	4.1%	4.2%
Vehicle and Transit Data (Daily)			
Vehicle Miles Traveled (VMT)	-378,296	-434,158	-266,784
VMT per Capita	-2.0	-2.2	-1.4
Transit Boardings	4,705	4,225	4,386

Quantification of GHG Emissions

GHG emissions are quantified by multiplying the PPM outputs (in VMT) and MOVES emission rates (in grams per mile) of carbon dioxide equivalent (CO2e). Key steps in this process are described below.

PACOG defined the geographic extents of the GHG compliance area to be consistent with the PACOG planning area boundary shown on **Figure 1**. Roadway links outside this area were clipped at the boundary edge and removed from the analysis. CDOT reviewed the boundary and split links for consistency (**Appendix C**). The remaining roadway links were imported into a Microsoft Access (Access) database provided by CDPHE APCD in conjunction with CDOT. Key datasets within the database included:

- **MOVES Emission Rates**: CDOT conducted MOVES modeling, with review from APCD. The resulting emission rates were disaggregated to include a unique rate for each combination of hour, speed, vehicle type, and road type. **Appendix E** includes additional details on the MOVES modeling methodology.
- **Hourly VMT and Speed Distribution**: PACOG developed a process specific to the PACOG GHG compliance area in collaboration with CDOT and APCD. It defines how traffic volumes and speeds are distributed throughout a 24-hour day. **Appendix F** documents the hourly assignments.

PACOG used the Access database to calculate the predicted total annual GHG emissions. This process was completed for the “Baseline” and “Updated” plans for the horizon years 2030, 2040, and 2050. Results were sent to CDOT and APCD for verification (**Appendix G**). **Table 2** shows the resulting GHG emissions necessary to demonstrate compliance with 2 CCR 601-22 for the three compliance years.

Public Participation

The PACOG Public Participation Plan guides public participation activities for all plans and programs. The 2050 LRTP included two phases of public participation, with the first involving more significant public and stakeholder outreach through social media, focus groups, an online survey, public open houses, and pop-up events as described in **Chapter 2: Uplifting our Communities**. The first phase also included an interactive map that allowed the public to provide specific input related to their lived experience using the current roadway network. Public comments were used to determine overlap with planned fiscally constrained projects and aspirational projects included in the 2050 LRTP.

The second phase of public engagement will begin in January 2026 to present the findings from the 2050 LRTP process and draft documents. The draft document will be available at pacogmovestheregion.com. Additionally, a public open house will be held to present the key findings from the plan.

The PACOG Board will entertain adoption of the 2050 LRTP, which will include this report, at their regular monthly meeting in April 2026. A summary of public comments submitted during the public comment period will be presented, and the public will be encouraged to attend.

Continued Efforts to Reduce Greenhouse Gas

Although compliance was achieved, the PACOG MPO and partner governments will continue to seek opportunities to reduce GHG emissions as growth and development in the region continues to occur. Efforts may include:

- Increased frequency of transit service
- Funding for a sustainability study
- Travel demand management
- Zero-emission vehicles
- Regionally significant multimodal projects

Appendix A. PACOG 2024 Travel Model Update Methodology Report

2024 MODEL Update/Validation

Pueblo Planning Model Methodology Report

PACOG
MOVES THE REGION

2024 MODEL UPDATE

June 2024

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List of Acronyms

AADT	Average Annual Daily Traffic
ACS	American Community Survey
BPR	Bureau of Public Roads
CDOH	Colorado Department of Highways
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health & Environment
FTA	Federal Transit Administration
GHG	Greenhouse Gas
GIS	Geographic Information System
GPS	Global Positioning Satellite
GUI	Graphical User Interface
HCM	Highway Capacity Manual
HCS	Highway Capacity Software
HHTS	Household Travel Survey
LOS	Level of Service
LRP	Long Range Plan
MMT	Million Metric Tons
MPO	Metropolitan Planning Organization
MUT	Multi-Unit Trucks
NAICS	North American Industry Classification System
NCHRP	National Cooperative Highway Research Program
NHTS	National Household Travel Survey
OTIS	Online Traffic Information System
PACOG	Pueblo Area Council of Governments
PEL	Planning and Environmental Linkages
PRMSE	Percent Root Mean Square Error
QCEW	Quarterly Census of Employment & Wages
QRM	Quick Response Manual
RMSE	Root Mean Square Error
CO	Colorado State Highway
SUT	Single-Unit Trucks
TAZ	Traffic Analysis Zone
TCRP	Transit Cooperative Research Program
TIP	Transportation Improvement Plan
TLFD	Trip Length Frequency Distributions
TMIP	Travel Model Improvement Program
TRB	Transportation Research Board
USDOT	United States Department of Transportation
UTPS	Urban Transportation Planning System
VDF	Volume Delay Function
VHT	Vehicle Hours Traveled
VMT	Vehicle Miles Traveled

1 Introduction

1.1 The Need for Travel Demand Models

Since the passage of the 1962 Highway Act, urban areas within the United States have been required to base their transportation investments on a comprehensive, cooperative, and continuing transportation planning process. While various congressional acts have modified the specific legal requirements over the years, the essential requirement for a logical, rational transportation planning process remains a prerequisite for Federal transportation funding assistance, and in many areas, for state participation in funding transportation improvement projects.

One significant element of the transportation planning process involves projecting future transportation needs for the next 20 to 30 years. The most accepted method of projecting these future transportation needs, and for evaluating alternative improvement strategies to serve the projected travel demand needs, is using travel demand models. Travel demand models use socioeconomic land use data to estimate the demand for travel, and they use a coded representation of the transportation system to simulate the ability of the transportation system to serve the estimated travel demand.

When travel demand models are provided with projections of future socioeconomic land use data, they can be used to forecast the projected performance of alternative transportation improvement strategies. The reliability of these models is directly related to the likelihood that the input data correctly represents how land will develop in the future. The accuracy of traffic models is assessed by comparing the traffic volumes estimated by a model to observed traffic counts for a specific base year, for which socioeconomic land use data is also available. The development of a consistent base year database containing a transportation network and socioeconomic data is critical to the development and validation of a travel forecasting model.

1.2 Background of the PACOG Travel Model

The 2020 Pueblo Area Council of Governments (PACOG) travel demand model has profited from development and application in the last fifteen years. It has been updated and enhanced in this 2024 cycle in several important ways. These elements will be presented and discussed in this report, and include:

1. **Extended Model Forecast Horizon** – The new modeling system accommodates forecasts out to 2050, extending the model horizon an additional five years from the previous 2045 limit.
2. **Updated Observed Traffic Data** – The model integrates 2020 traffic count data by auto, Single Unit (SUT) and Multi Unit (MUT) truck.
3. **Zone System Revisions** – Zonal coverage was changed to match CDOT's Traffic Analysis Zone (TAZ) structure to provide better geographic resolution, and total consistency between the DOT and PACOG regarding base and forecast land use assumptions.
4. **Zonal Data Update** – Socioeconomic data was updated for population, households, median income, and group quarters (2020 Census). Employment data updated using the 2020 Quarterly Census of Employment & Wages (QCEW), data obtained from the Colorado Dept. of Labor & Employment, including employment point data (2021). Trip generation disaggregation values, and trip distribution targets utilize the 2010 Pueblo Front Range Household Survey data. An updated statewide travel survey is in progress.
5. **More Detailed Truck Vehicle Classes** – Previous versions of the model used Single Unit (SUT) and Multi Unit (MUT) trucks in trip generation and internal trip distribution, but then collapsed this category into a generic truck category in later model steps. This version carries SUT and MUT classes through all model steps and outputs.

6. **Addition of Transit Network** –Transit routes, stops, and service characteristics are included in the PACOG model for the first time. The additional transit network information is used to support transit skimming used in Mode Choice modeling and later in transit assignments. Roadway network detail and data attributes were expanded to support transit modeling as well.

7. **Added Mode Choice Modeling** – This is a new model component that was added to improve the model's sensitivity to anticipated future scenarios. This component explicitly models individual choices related to traveling by auto and transit depending on trip purpose and characteristics of the journey to the destination location. Addition of the mode choice step significantly changed outputs and subsequent model steps related to Production-Attraction to Origin-Destination (PA-OD) conversion.

8. **Expanded Traffic Assignment** – The PACOG model provides traffic flow outputs for am and pm peak hours, the remaining 22 Off Peak hours, and daily totals. Outputs for vehicle classes are now split into Autos, SUT, and MUT. The process adds a Passenger Car Equivalent (PCE) methodology that accounts for the fact that trucks use more road capacity than autos. A daily transit route assignment is added as well, with transit outputs and reporting.

9. **User Interface, Analysis, and Reporting** – The PACOG model's original reporting capabilities were updated to work with the new components/updates. Several new reporting outputs were added to summarize mode choice and transit assignment results. Additionally, the various roadway traffic assignment results can be summarized and processed for further greenhouse gas analysis. As part of the greenhouse gas analysis capabilities, the user interface allows users to apply some general assumption changes affecting travel demand/mode choice which can be applied in special model scenario runs. Reporting capability now includes customized Greenhouse Gas (GHG) reporting/output.

The PACOG travel model extent covers the entirety of Pueblo County which is almost 2,400 square miles. The base year is 2020. The validated 2020 base year model presented in this report captures the movements of over 169,000 persons in 67,000+ households. The entire PACOG model is implemented using Caliper Corporation's TransCAD computer software package, Version 9.0.

The PACOG travel demand model has a long history. The original PACOG travel model was specified in a mainframe Urban Transportation Planning System (UTPS) platform and was developed and maintained by the then Colorado Department of Highways (CDOH). The model was transitioned to the MPO in 1984 after migration to the MinUTP software platform. The first survey-supported comprehensive update of the model by PACOG was completed in February 1994. Migration of the MinUTP model to the Colorado Department of Transportation's preferred Caliper Corporation software, TransCAD, was completed in 2002 to support use for the New Pueblo Freeway Environmental Impact Statement. The 2014 model update continued with the TransCAD software platform, while integrating, within TransCAD, key functionality established in the 1994 work. In 2020, updating model parameters with a 2020 base year and recent household survey data paved the way for long range planning. The current 2024 update took a significant step forward in adding the first transit network with a supporting mode choice module. Additionally, the truck model was broadened to two classes of trucks and the model reporting capability expanded to produce data input files to Greenhouse Gas (GHG) models. The Covid-19 pandemic, spanning the years 2020 through 2022, has challenged the effort to prepare a representative 2020 base year. The PACOG travel demand model addressed these years by adjusting the work from home component of socioeconomic forecasting, and reviewing traffics counts from years 2020-2023 for identification of a "mid-point" base year best representing 2020. The result is a base year that captures 2020 while staying true to the changing travel patterns that emerged in the past four years.

During three decades of evolution, the PACOG model has continued to provide the agency with the capability to capture existing and future traffic for planning purposes as well as a tool for numerous traffic studies. The 2024 updated PACOG travel model extent with the revised zone system is shown below in **Figure 1**.

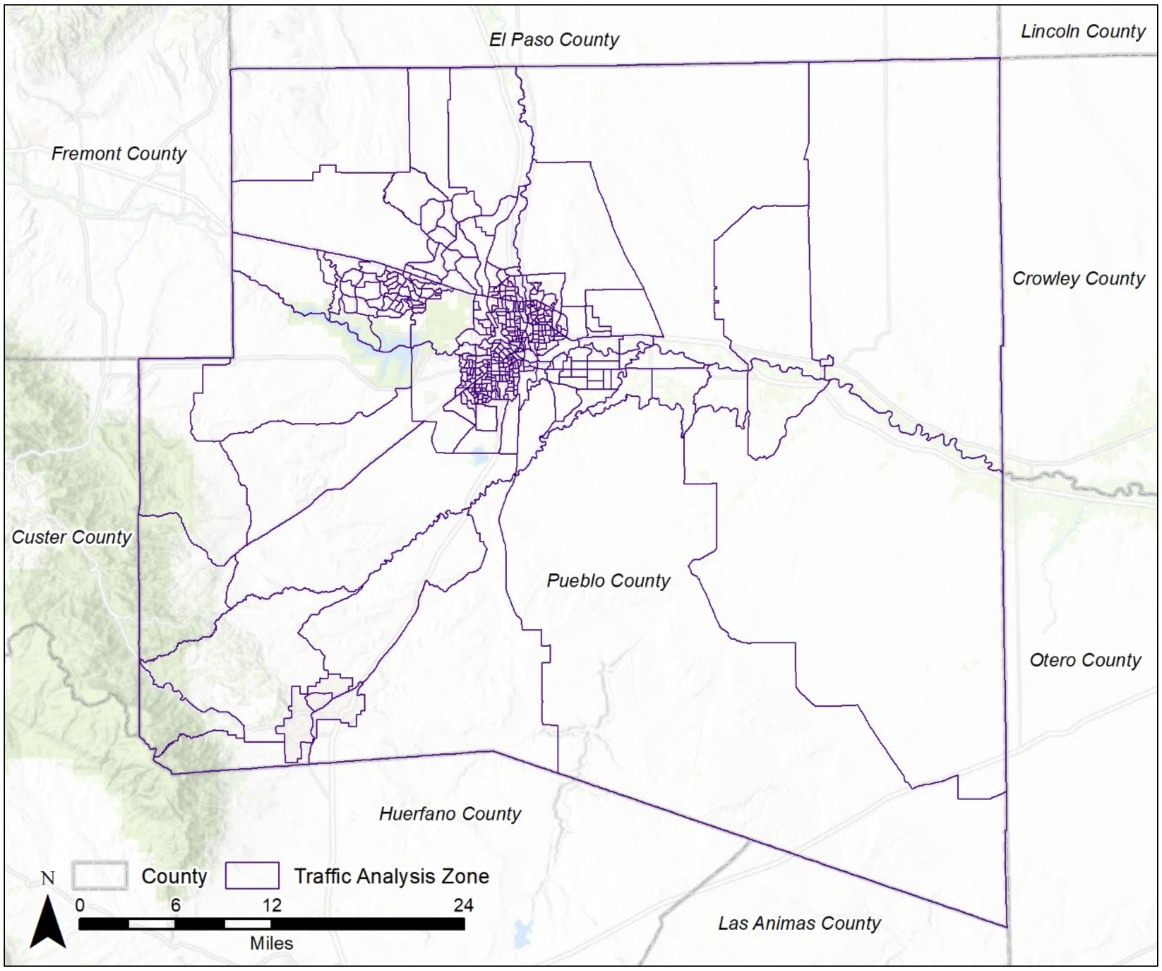

Figure 1: PACOG TAZ Layer and Travel Model Extent

1.3 The Traffic Forecasting Modeling Process

Standard four-step traffic forecasting models have the following basic components:

- Trip Generation
- Trip Distribution
- Mode Split
- Traffic Assignment

The PACOG travel model incorporates these four basic modeling components listed above to produce travel demand forecasts. The model contains three time periods. The am peak is 7:30 am - 8:30 am and the pm peak is 4:30-5:30 pm. The off-peak is composed of all other times of the day. These three time periods are summed to produce daily modeled traffic. A base year of 2020 and future year of 2050 are provided in the model. Intermediate years can be generated.

The process flow of the PACOG model will be described using the four-step model sequence. Information about data acquisition, processing and use will also be included in this report. The goal is to capture the details of the update and address issues related to their integration in the model.

2 Traffic Analysis Zones and Socioeconomic Data Development

2.1 Overview

The transportation demand side of the PACOG travel model was developed using an enhanced Traffic Analysis Zone (TAZ) layer covering the MPO extent, which is Pueblo County. This TAZ layer is consistent with the CDOT Statewide Travel Model. The 2024 update purposely adopted this TAZ system to streamline communication between the PACOG and statewide models.

2.2 Traffic Analysis Zones

A TAZ summary of zone type is presented in **Table 1**, and shows a total of 393 zones, including the eight external zones/stations.

Table 1: PACOG 2024 Traffic Analysis Zone Summary

Zone Type	TAZ ID Sequence	TAZ Count
Regular Traffic Analysis Zone	1 through 385	385
External Zones	401 through 408	8
Total		**393**

The Traffic Analysis Zone GIS database holds the master ID and the input attributes as shown in **Table 2**. The socioeconomic forecasts prepared for the model update are joined to this basic TAZ level layer during each model run.

Table 2: Zonal Attributes for the TAZ Layer

Attribute	Description
ID	PACOG Zone ID
Area	Area in Square Miles
County_ID	FIPS County ID
ST_ID	FIPS State ID
MPO	All TAZ are PACOG
Area_Type	Area Type (1 through 5)
Area_Type Description	Area Type (1=CBD, 2=Fringe, 3=Urban, 4=Suburban, 5=Rural)

2.3 Socioeconomic Data Development

2.3.1 Overview of Data Sources

Covid-19 Discussion

A wide array of data was used to update the TAZ layer for the PACOG model. An issue that needed discussion at the outset of the update was how to handle data selection for the year 2020 given the fluctuations that occurred during the Covid-19 pandemic. In every part of the country, reductions in traffic, employment, and travel in general occurred during the span of time when Covid-21 was active – in general years 2020 through 2022+. Data from these years needed to be reviewed and adapted thoughtfully. The challenge, then, was to assert a strategy for capturing a base year, call it ***2020****, that would serve as a reasonable starting point for future year scenarios. On the observed traffic side, the decision was made to utilize 2022 and 2023 observed traffic to capture a realistic base year. On the household and population side, the recently released Census 2020[1] information on households and population was available, represented conditions in 2020, and was used; this information was verified,

[1] *U.S. Census 2020 Data, https://data.census.gov/, accessed December 2023.*

and adjusted, using the Colorado Department of Local Affairs[2] (DOLA) forecasts. PACOG 2020 households and population are also consistent with the CDOT statewide model. Employment base year and forecasts required both a point employment database from the CDOT Statewide Model, LODES employment summaries, DOLA summaries and data from the Colorado Quarterly Census of Employment & Wages (QCEW). Employment data was also verified, and adjusted, using the DOLA forecasts. PACOG staff also collaborated on the systematic collection and review of GIS files useful in model development; these included current streets, city boundaries, traffic counts, and transit route information. These GIS layers, combined with state and national data such as U.S. Census 2020 data and selected CDOT state travel model files, were used. **Table 3** shows the standard attributes developed from the various sources cited above for the 2020, 2030, 2040 and 2050 study years.

Table 3: Socioeconomic Attributes

Attribute	Description
TAZ	Traffic Analysis Zone ID
DISTRICT	District ID for Summary
AREA_TYPE	Area Type ID for Link Speed/Capacity Lookup
POP	Total Population
POPINHH	Population in Households
GQPOP	Population in Group Quarters
HH	Number of Households
INC	Median Income
HHSIZE	Average Household Size
TOTEMP	Total Employment
RETAIL	Retail Employment
BASIC	Basic Employment
SERVICE	Service Employment
GOVERNMENT	Government Employment
ELEM_ENROLL	Elementary School Enrollment
SEC_ENROLL	High School Enrollment
COLL_ENROLL	Collage Enrollment
ST	State (FIPS)
CNTY	County (FIPS)

2.3.2 Household & Population Data Development

The fundamental requirements for the socioeconomic data development are information on the number of households, the number of persons in households, the median household income, and the number of persons in group quarters. These attributes were available to the project from the 2020 U.S. Census with attributes available at the Census block, block group, or tract level, all of which can be aggregated into the PACOG TAZ geography. **Figure 2** shows the scale of the geographic aggregation process for block-to-TAZ; almost 6,000 Census blocks were used to populate the 385 PACOG TAZs.

[2] *Colorado Department of Local Affairs (DOLA), https://demography.dola.colorado.gov/, accessed December 2023.*

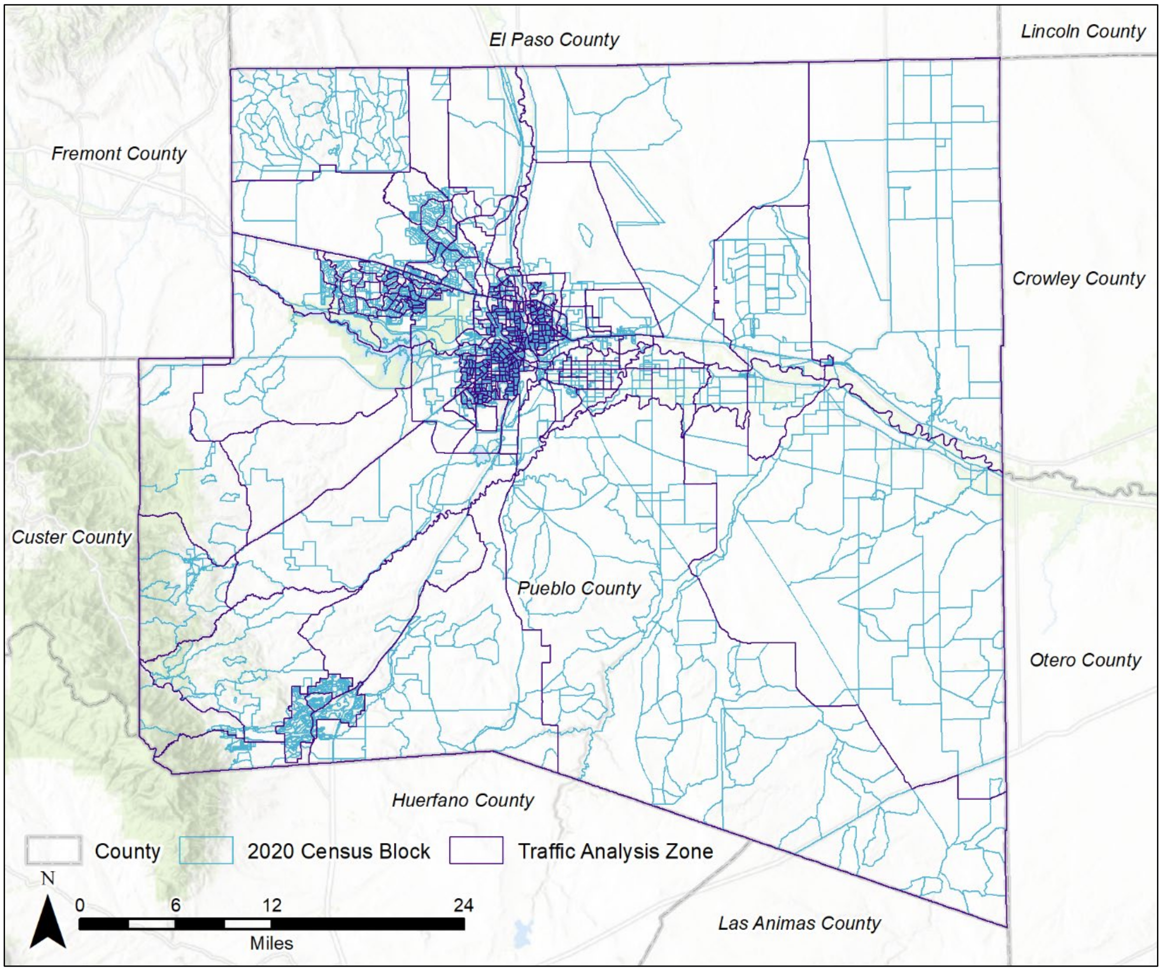

Figure 2: Census Block and PACOG TAZ Geography

Median income and group quarter location and population were derived from the Census tract layer. Group quarters facilities include college/university dormitories, health/rehab centers, assisted living, and correctional facilities, Persons in group quarters make up about 3% of the total population in Pueblo County. The Census values for group quarters were cross-checked with local maps and information and converted to PACOG TAZ geography. Forecasts utilized the DOLA totals for households, population, and jobs as control totals.

2.3.3 School Populations

School data is a small but key component of the travel model. School enrollment is required for trip generation. The enrollment numbers are required at three levels of academics:

- Kindergarten through 8th grade – 2020 enrollment was 16,990.
- High School – 2020 enrollment was 12,390.
- College/University – 2020 enrollment was 8,400.

The key data source used was the Colorado Public Health & Environment online school location GIS point file[3]. Both public and non-public schools in the K-12 level are included in this geodatabase. A secondary data collection investigation was conducted into "hybrid" schools, such as the GOAL

[3] *CDPHE CDOE School Locations and District Office Locations | CDPHE CDOE School Locations and District Office Locations | Colorado Department of Public Health and Environment (arcgis.com)*, accessed September 2023.

Academy system which combines online learning platforms with in-person support at student drop-in classrooms; GOAL serves about 5,900 students in Pueblo County. According to a GOAL administrator, on an average weekday 10-25% of the GOAL students report to a "bricks and mortar" location[4]. The GOAL Academy schools, and drop-in locations were identified, added to the geodatabase, after once adjustment by the percentage of students who are typically on-site. Forecasting for school attendance is done using the observed ratio of students to households. Colorado State University and Pueblo Community College enrollment is found on their websites.

2.3.4 Employment Data Development

The employment data task was to develop TAZ level employment by the four categories for all study years. The 2007 North American Industry Classification System[5] (NAICS) was used to establish four categories of employment as shown in **Table 4.**

Table 4: PACOG Employment Categories by NAICS Code

Employment Category	NAICS Range
BASIC	<= 425120
RETAIL	441110 - 454390
SERVICE	481111 - 814110
GOVERNMENT	> 814110

The employment categories can be described as follows:

- **Basic** includes farming, forestry, fishing, mining, oil and gas extraction, major construction and manufacturing of all kinds including food, tobacco, lumber and paper, printing, chemicals, medical and optical goods, and wholesale trade.
- **Retail** includes the sale of building materials, hardware, garden, mobile homes, general merchandise, food, automotive, gasoline, clothing, furniture, eating and drinking places, and miscellaneous.
- **Government** includes public administration and other.
- **Service** includes information, finance and insurance, real estate, and rental services, professional and technical, educational, health care, entertainment, accommodation, transportation, and warehousing.

Data sources were the CDOT Statewide Model 2015 job establishments point file, the Colorado 2020 Quarterly Census of Employment & Wages (QCEW), LODES[6] quarterly workforce indicators, and DOLA county level employment totals by category and by control totals. The CDOT point data was factored to 2020 DOLA totals then converted into the PACOG four employment categories to establish employment by classification at the zonal level. Growth rates by the employment categories were tied to the DOLA economic forecasts which include growth expectation by sector.[7]

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4 *Telephone call to GOAL regional administrative offices, September 2023.*

5 *North American Industry Classification System (NAICS) U.S. Census Bureau*, accessed November 2023.

6 Longitudinal Employer-Household Dynamics (LODES) data, https://lehd.ces.census.gov/data/#lodes, accessed November 2023.

7 Labor Force Economic Forecasts*, https://gis.dola.colorado.gov/economy-labor-force/economic-forecasts/, accessed December 2023.*

2.3.5 Summary

In summary, DOLA control totals guided the socioeconomic development of the PACOG Model. Local, state, and national data provided input data, corroboration of values and control totals. **Table 5** shows the resulting totals for the four study years. **Table 6** shows the growth rates. Over the span of the 30-year forecast available, population grows 15%, households grow 20% and employment grows 17%.

Table 5: Colorado Department of Local Affairs (DOLA) Totals for Pueblo County

Socioeconomic Attribute	2020	2030	2040	2050
Population	168,311	178,217	188,514	193,446
Households	65,911	72,315	76,153	79,350
Employment	74,593	80,382	84,768	86,914

Table 6: Colorado Department of Local Affairs (DOLA) Growth Rates for Pueblo County

Socioeconomic Attribute	2020-2030	2030-2040	2040-2050	2020-2050
Population	6%	6%	3%	15%
Households	10%	5%	4%	20%
Employment	8%	5%	3%	17%

To summarize the socioeconomic data development step:

- Census 2020 provides a solid basic framework for the population, households, income, and group quarters model components.
- Colorado DOT statewide model employment point data is used as the primary input for employment data.
- County level growth by Colorado DOLA provides control totals for population, households, and employment.

2.4 Travel Model External Zones/Stations

Travel to and from locations outside of the PACOG region is captured using information from traffic flows located at the eight major external stations or portals to the region. In the current update, the previous all truck traffic vehicle class was expanded from all trucks to truck traffic by two size classifications, Single and Multi-Unit Trucks.

2.4.1 The Eight PACOG Model External Stations

The updated 2020 PACOG model captures eight external station or points as listed in **Table 7**. These points represent the major locations where highways link Pueblo County with all areas outside of the county. **Figure 3** shows the station locations.

Table 7: PACOG Model External Stations

External Stations	TAZ ID
Interstate 25 (North)	401
State Highway 96 (East)	402
US Highway 50 (East)	403
Interstate25 (South)	404
State Highway 165 (West)	405
State Highway 78 (West)	406
State Highway 96 (West)	407
US Highway 50 (West)	408

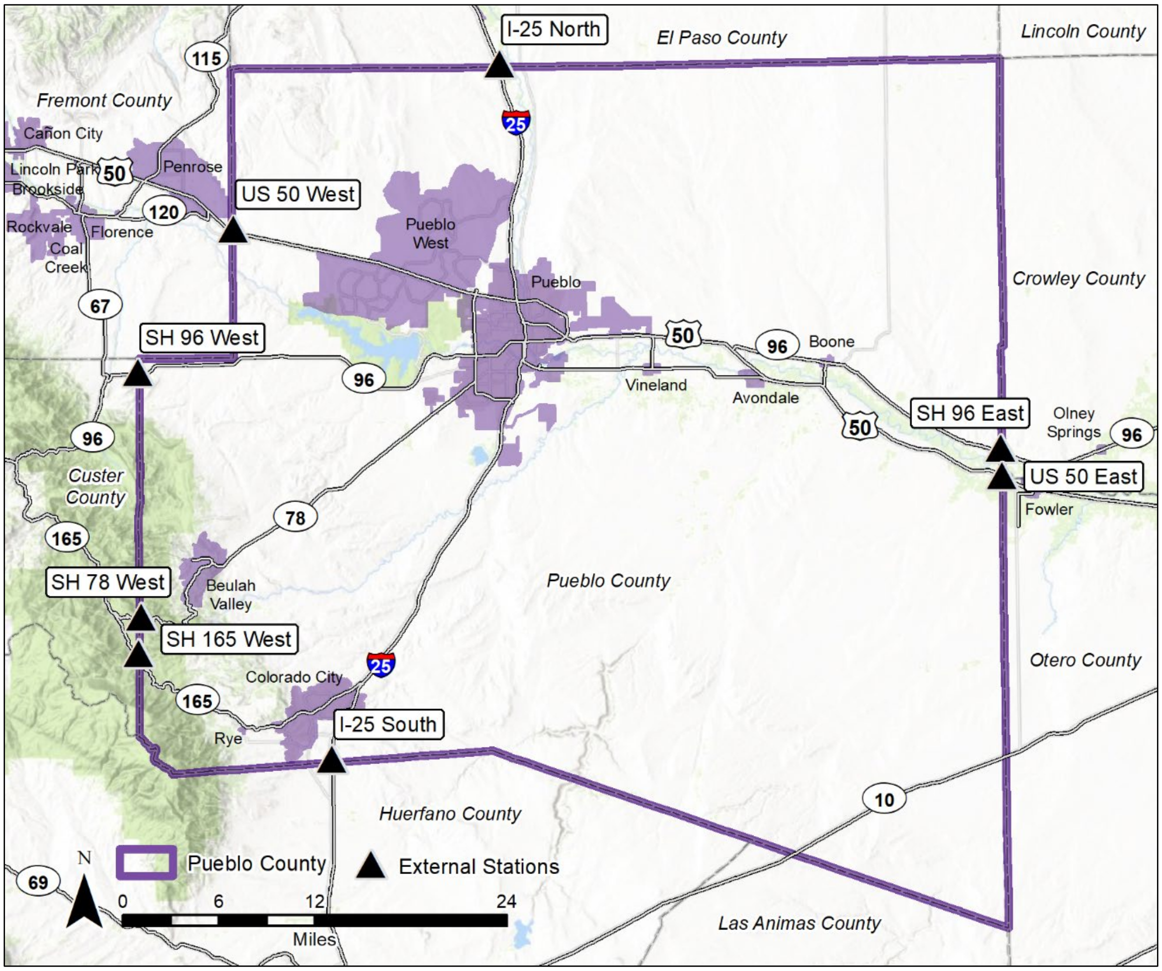

Figure 3: Location of PACOG External Stations

2.4.2 Estimating Base Year External Station Volumes

To estimate traffic volumes at the external stations for the 2020 base year, the following process was used:

- Available data for total traffic (AADT) and for SUT and MUT trucks were collected and tabulated. Analysis on the trend for observed traffic in Pueblo County was conducted to understand the impact of the Covid-19 pandemic with 2022-2023 traffic data selected for use.
- Through-traffic percentages were developed for each external-external pair to represent the external-external traffic share of total traffic at each external point.

A spreadsheet capturing the process was created for use in replicating the trip table approach for future years. The following data resources were used to develop the external station traffic volume estimates:

- 2022 Average Annual Daily Traffic (AADT) values were obtained from the Colorado Department of Transportation (CDOT) database, which is available online.[8] The database provides historic and current traffic count data for CDOT facilities, and includes all highways represented by external stations in the PACOG model.
- Growth rates developed by CDOT.

8 http:www.cdot.com (Colorado Department of Transportation), accessed in 2023.

These data resources enabled the establishment of the 2020 estimated external station baseline counts summarized in **Table 8**. Truck percentages were also available for major highways from the CDOT database.

Table 8: PACOG Model External Station Observed Traffic

Route Location	External Zone	2-Way Traffic Autos	2-Way Traffic SUT	2-Way Traffic MUT
Interstate 25 (North)	401	26,000	1,000	3,000
State Highway 96 (East)	402	1,000	40	40
US Highway 50 (East)	403	3,000	140	370
Interstate 25 (South)	404	7,000	360	1,000
State Highway 165 (West)	405	1,000	30	30
State Highway 78 (West)	406	1,000	40	30
State Highway 96 (West)	407	1,000	30	60
US Highway 50 (West)	408	8,000	160	370

Source: Colorado DOT Online Transportation Information System (OTIS)

2.4.3 Estimating Future External Station Volumes

To estimate external traffic for future years, annual growth factors were obtained from CDOT. For consistency with statewide forecasts, 20-year growth factors from the CDOT web site were used to derive annual growth factors for each of the CDOT highways. First, a one-year, annual growth rate (F_1) was calculated for each CDOT 20-year facility growth factor (F_{20}) using a simple interest formulation, where: the annual growth (i) was calculated as the 20th root of the CDOT 20-year factor, minus 1 (e.g. i= F20^(1/20)-1 so for a 20-year factor F20 of 1.570, i = 0.0228). Using the calculated annual growth rate value, required growth factors could be calculated using: $F_n = (1+i)^n$.

Table 9 summarizes the calculated equivalent annual growth factors. These rates were used to prepare a 2050 traffic estimate for the external stations of the Pueblo model.

Table 9: External Station Future Year Traffic Counts Estimation

Route Location	External Zone	2-Way AADT	20-Yr Factor	Annual Factor	2-Way ADT
		2020	$F_{20} = (1+i)^{20}$	$F_A = (1+i)^1$	2050
Interstate 25 (North)	401	29,000	1.4	1.017	40,600
State Highway 96 (East)	402	1,000	1.52	1.0212	1,500
US Highway 50 (East)	403	3,700	1.08	1.0039	4,000
Interstate 25 (South)	404	8,100	1.31	1.0136	10,600
State Highway 165 (West)	405	800	1.29	1.0128	1,000
State Highway 78 (West)	406	1,000	1.32	1.014	1,300
State Highway 96 (West)	407	1,000	1.49	1.0201	1,500
US Highway 50 (West)	408	8,100	1.35	1.0151	10,900
Total		**56,120**			**71,500**

2.5 Area Type

Five distinct area types were updated from the legacy Pueblo model and adjusted to fit the revised 2020 zone system. A review of the model documentation shows that area type is used in the link speed assumptions and the trip distribution step. The area type designation is related to population/employment density as well as to the density of the street grid. Central Business District (CBD) zones have a dense street grid compared to outlying areas and feature significant walkability. CBD Outlying area type maintains some of the features of CBD, while being slightly less dense. Urban areas have a regular street grid and feature less walkability than CBD and CBD Outlying. The suburban and rural area types move toward a street grid and design most consistent with the auto mode.

Table 10 shows the number of TAZs by area type in the Pueblo model. **Figure 4** shows the area type in plot form with **Figure 5** illustrating a close-up of this attribute in the urban area. The area type has been permanently saved on the TAZ and link layer for use in the model update.

Table 10: Number of TAZs by Area Type

Area Type	Number of TAZs
Central Business District (CBD)	10
Outlying CBD	16
Urban	109
Suburban	217
Rural	33
Total	**385**

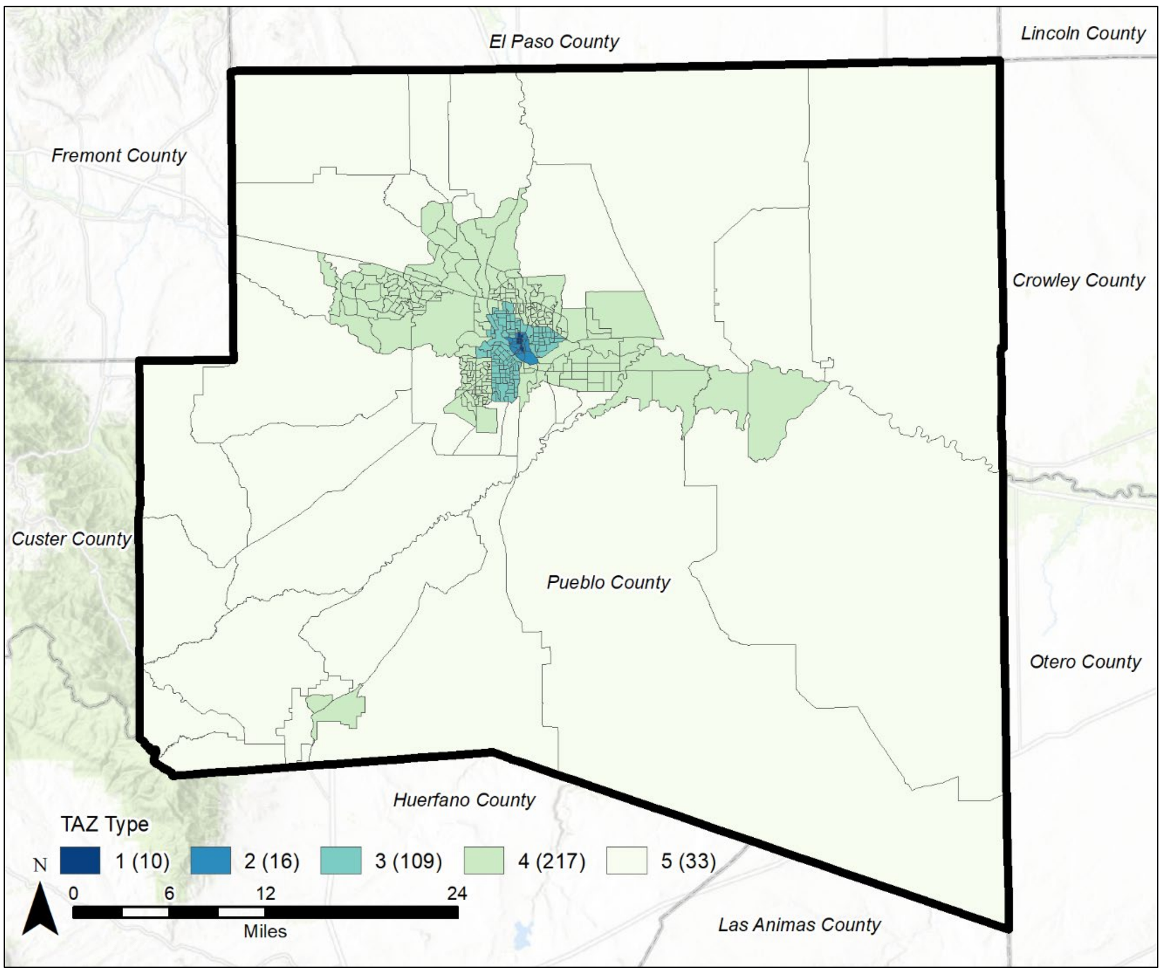

Figure 4: Area Type

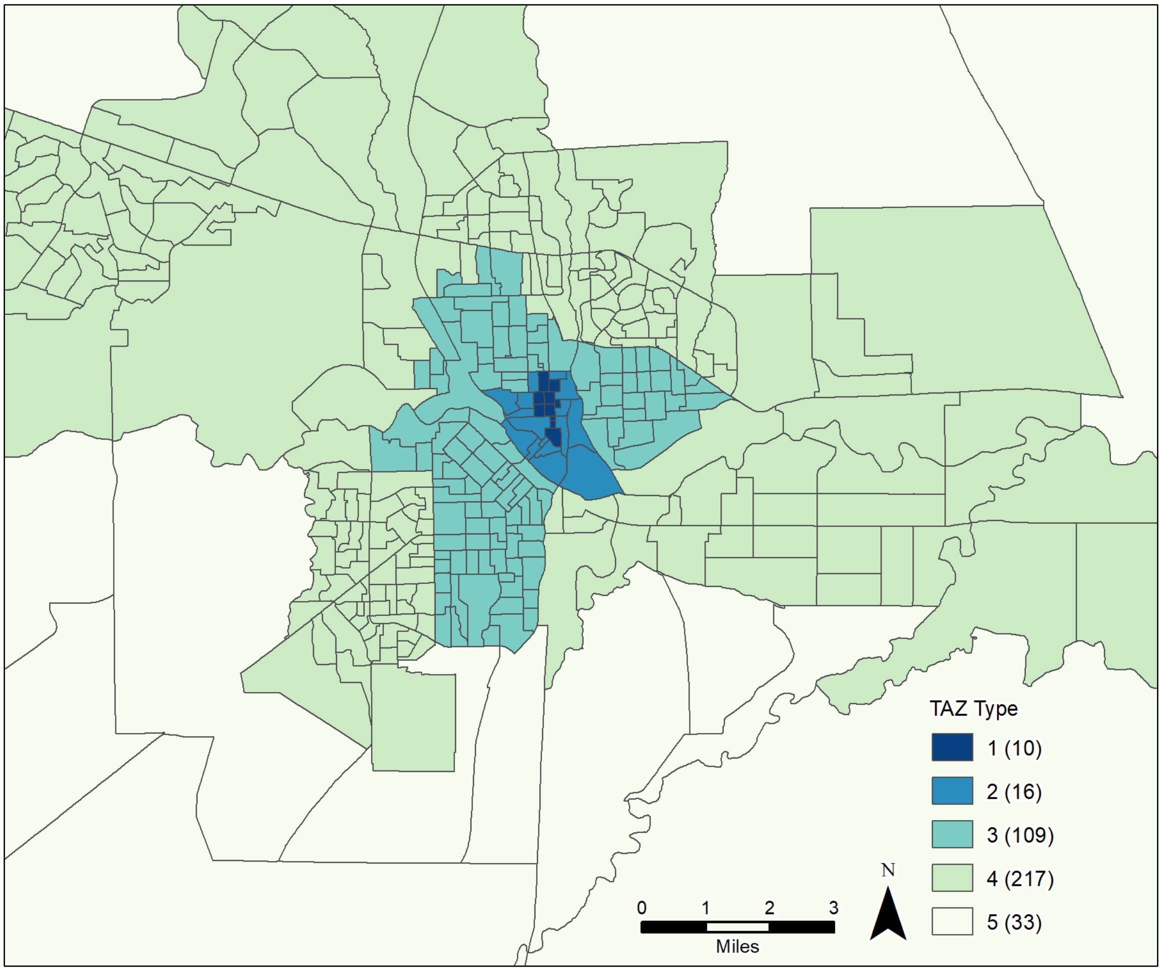

Figure 5: Area Type (Inset)

3 Highway Network Update

3.1 Background

The 2020 PACOG network model was updated using the TransCAD software Version 9.0, a product of Caliper Corporation. There are three highway network building blocks:

- **Nodes** are elements that describe the position of intersections or shape points on roadway networks.
- **Links** are network model segments that connect the nodes, represent roadways, and have attributes including direction, speed, capacity, and functional classification.
- **Centroid Connectors** are links that connect the zones to the network. They represent the distance to be covered between a zone's center of gravity (the center of trip generating and attracting activity) and the model links serving that zone.

3.2 Base Year Network Development

The 2020 highway network from the travel model update and long-range plan work of 2020 was identified and updated for the current model. This development required review and editing of the previous network to capture the changes in the region over the past four years. Network verification was conducted using aerial imagery and street layer geospatial data. The most extensive revisions were needed to implement the expanded traffic analysis zones and the addition of a transit network. Legacy centroid connectors were removed, and new connectors were put in place to serve the updated traffic analysis zones and to capture bus stop locations. Link locations and attributes were also verified, new roadways and widening projects completed in recent years were added. Traffic counts representing 2020 were added. Finally, network connectivity was tested.

3.3 Development of Link Speeds and Lane Capacities

PACOG travel models network use Level of Service (LOS) C capacities for roadway facilities. This conforms to an approach that constrains traffic volumes to desired design level of service volumes. National Academy of Sciences Transportation Research Board (TRB) guidance recommends that travel demand model capacity settings be set at "ultimate capacity," the point at which congestion-induced delays would result in diversion of traffic to alternate routes, and that applicable capacity assumptions should be developed in accordance with procedures detailed by the current Highway Capacity Manual (HCM) or from the Highway Capacity Software (HCS) or similar analysis tool.

A speed capacity look-up table was used to transfer the Level of Service associated capacities and link speeds to the PACOG highway network. The look-up table maps the appropriate capacity assumption to each functional classification in the model network. The capacity of centroid connectors is typically assumed to be very large, since these links represent the numerous ways that travelers within a zone can reach the larger highway network. **Table 11** shows the seven functional classes of highway links used in the PACOG travel model.

Table 11: PACOG Link Functional Class

Facility Type (Fac_Type)	Description
1	Interstate
2	Expressway
3	Principal Arterial
4	Minor Arterial
5	Collector
6	Ramp
7	Centroid Connectors

Speed-capacity assumptions for the newly updated PACOG travel model were developed through review and iterative testing of speed and capacities used in the four most recent legacy model versions, as well as a LOS C, HCM-based assumption set. The final capacity assumptions, shown in the rightmost column of **Table 12,** are somewhat lower than standard HCS values, adjusted to better reflect local conditions. These values and the associated travel speeds are also consistent with assumptions used for earlier PACOG travel model versions that were calibrated to local conditions. These values are also supported by literature research including the Highway Capacity Manual 2010 and comparison to peer model settings. Reduced congested speeds, used in the first iteration to “seed” the travel time skims, were implemented by the 1994 legacy model, and later abandoned. This option is retained, though not implemented in the current model update.

Table 12: PACOG Free-Flow Speeds and Ultimate Capacity/Lane

Link Type	Area Type Description	Area Type	Facility Type	Congested Speed	Free Flow Speed	Capacity
11	CBD	1	1	55	55	1600
12		1	2	22	22	650
13		1	3	17	17	500
14		1	4	17	17	450
15		1	5	15	15	450
16		1	6	10	10	350
17		1	7	15	15	1200
21	CBD Outlying	2	1	48	48	1700
22		2	2	25	25	700
23		2	3	28	28	600
24		2	4	28	28	500
25		2	5	25	25	500
26		2	6	10	10	350
27		2	7	15	15	1200
31	Urban	3	1	50	50	1900
32		3	2	35	35	900
33		3	3	30	30	750
34		3	4	30	30	650
35		3	5	25	25	650
36		3	6	20	20	400
37		3	7	15	15	1500
41	Suburban	4	1	55	55	1900
42		4	2	40	40	900
43		4	3	38	38	750
44		4	4	35	35	600
45		4	5	30	30	600
46		4	6	15	15	400
47		4	7	15	15	1500
51	Rural	5	1	60	60	1900
52		5	2	50	50	800
53		5	3	46	46	650
54		5	4	45	45	600
55		5	5	35	35	600
56		5	6	20	20	450
57		5	7	15	15	1500

3.4 Node Attributes

The node layer supports the links and serves as the source of the centroid and zone ID. **Table 13** shows the node attributes. Note that any nodes at which turns are to be saved during assignment can be selected prior to the network assignment using “Turn_Flag=1”.

Table 13: Node Fields - PACOG Travel Model

Name	Type	Description
ID	Integer	TransCAD Internal Node ID
Longitude	Integer	Node Latitude
Latitude	Integer	Node Longitude
Elevation	Real	Node Elevation (not active)
Centroids	Integer	1 if the Node is a Centroid
Turn_flag	Integer	1 if the Node Turn movement is to be saved during assignment

3.5 Link Attributes

The following revisions were done to the network during review and re-dimensioning:

- I-25/Dillon Drive area was reviewed, and connector links added to capture traffic prior to Dillon Drive entering the intersection.
- Nodes were added where bus stops are present (transit network functionality).
- A review of the functional class and number of lanes was performed.
- Traffic counts for AADT, SUT and MUT were added to represent 2020.

Key input link attributes are shown in **Table 14.** Note that inputs for the three time periods, am, pm and off-peak link segment inputs are held in this single network. The input network is found in the PACOG model input folder with a name keyed to the study year; an example is “2020_BaseNetwork.DBD”

Table 14: Input Link Fields - PACOG Travel Model

	Name	Type	Description
Input	ID	Integer	TransCAD Internal Node ID
	Dir	Integer	Direction with 0=two-way and 1 or -1 = one-way
	Length	Real	Link Length in Miles
	TYPE	Integer	Link Type (Area/Functional Class)
	Distance	Real	Link Length in Miles
	Mode	Integer	1=Non-Centroid Connector link; 2= Centroid Connector Link
	Area_Type	Integer	Area Type
	Fac_Type	Integer	Facility Type
	AB_Num_LANES	Integer	Number of Lanes (by direction)
	BA_Num_LANES	Integer	Number of Lanes (by direction)
	AB_FFSpeed	Integer	Free Flow Speed (by direction)
	BA_FFSpeed	Integer	Free Flow Speed (by direction)
	AB_FFTime	Integer	Free Flow Travel Time (by direction)
	BA_FFTime	Integer	Free Flow Travel Time (by direction)
	AB_CongSpeed	Integer	Congested Speed (by direction)
	BA_CongSpeed	Integer	Congested Speed (by direction)
	AB_CongTime	Integer	Congested Travel Time (by direction)
	BA_CongTime	Integer	Congested Travel Time (by direction)
	AB_AM_CAP	Integer	AM Link Capacity (By Direction)
	BA_AM_CAP	Integer	AM Link Capacity (By Direction)
	AB_PM_CAP	Integer	PM Link Capacity (By Direction)
	BA_PM_CAP	Integer	PM Link Capacity (By Direction)
	AB_OP_CAP	Integer	Off Peak Link Capacity (By Direction)
	BA_OP_CAP	Integer	Off Peak Link Capacity (By Direction)
	AB_NAME	Integer	Street Name
	BA_NAME	Integer	Street Name
	AB_DIR	Integer	AB Direction
	BA_DIR	Integer	BA Direction
	AB_DES	Integer	Street Description
	BA_DES	Integer	Street Description
	Count_Year	Character	Street Name
	AB_Daily_Count	Real	AB Direction ADT Count
	BA_Daily_Count	Real	BA Direction ADT Count
	TwoWay_Count	Real	Two-Way ADT Count
	Source	Character	Source of County Data
	Year	Integer	Year of Count Collection
	AB_SUT_2022	Integer	Single Unit Truck Count (by direction)
	BA_SUT_2022	Integer	Single Unit Truck Count (by direction)
	AB_MUT_2022	Integer	Multi-Unit Truck Count (by direction)
	BA_MUT_2022	Integer	Multi-Unit Truck Count (by direction)
	WalkMode	Integer	All set to value 3
	WalkT	Real	Walk Time: Length/(3/60) assuming walk at 3 mph
	IVTT	Real	In Vehicle Time for Bus: Length/(14/60) assuming bus speed at 14 mph

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Once the network is used in a model scenario, it emerges as a "loaded network," a GIS ready network with daily assigned traffic as attributes. An example is "LoadedDailyNetwork_2020.DBD. Its attributes are shown in **Table 15**.

Table 15: Output Link Fields - PACOG Travel Model

	Name	Type	Description
Output	AB_AM_Flow	Real	1 hour AM period Total Traffic (by direction)
	BA_AM_Flow	Real	1 hour AM period Total Traffic (by direction)
	AB_OP_Flow	Real	22-hour off-peak period Total Traffic (by direction)
	BA_OP_Flow	Real	22-hour off-peak period Total Traffic (by direction)
	AB_PM_Flow	Real	1 hour PM period Total Traffic (by direction)
	BA_PM_Flow	Real	1 hour PM period Total Traffic (by direction)
	AB_Daily_Flow	Real	Daily Traffic (by direction)
	BA_Daily_Flow	Real	Daily Traffic (by direction)
	TwoWay_Daily	Real	Total Daily Traffic
	VMT_Daily	Real	Daily Vehicle Miles Traveled
	Vol_Range	Integer	Volume Range
	AB_AM_VC	Real	Volume to Capacity Value for AM period (by direction)
	BA_AM_VC	Real	Volume to Capacity Value for AM period (by direction)
	AB_OP_VC	Real	Volume to Capacity Value for off-peak period (by direction)
	BA_OP_VC	Real	Volume to Capacity Value for off-peak period (by direction)
	AB_PM_VC	Real	Volume to Capacity Value for PM period (by direction)
	BA_PM_VC	Real	Volume to Capacity Value for PM period (by direction)
	AB_DAILY_VC	Real	Volume to Capacity Value for Daily (by direction)
	BA_DAILY_VC	Real	Volume to Capacity Value for Daily (by direction)

Table 16 shows the link facility type (Fac_Type) used in the mapping. **Figure 6** shows the 2020 PACOG Highway Network with **Figure 7** showing a close-up of the urban area. The link attribute "Facility Type" is used to differentiate the links.

Table 16: Facility Type for Highway Links

Facility Type (Fac_Type)	Description
1	Interstate
2	Expressway
3	Principal Arterial
4	Minor Arterial
5	Collector
6	Ramp
7	Centroid Connectors

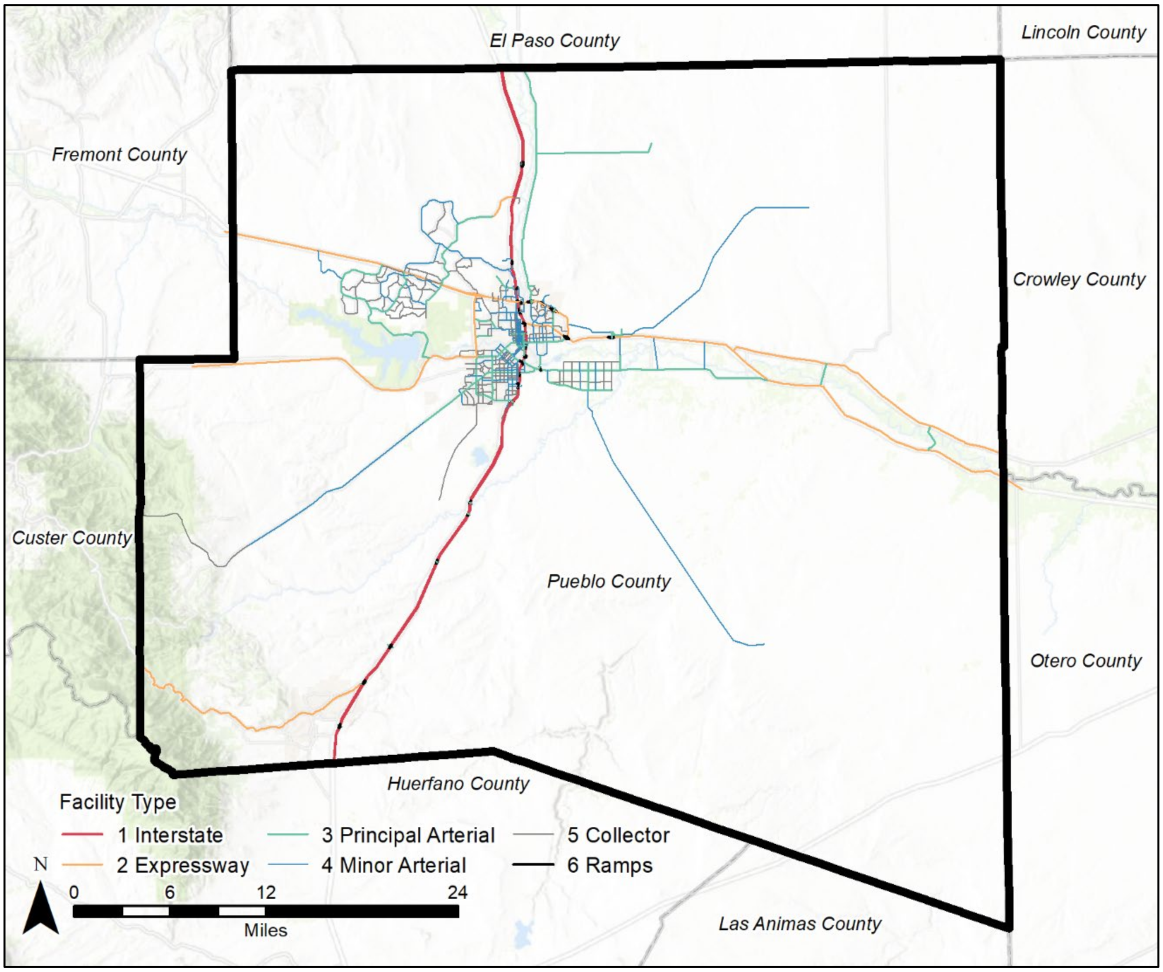

Figure 6: 2020 Link Facility Type

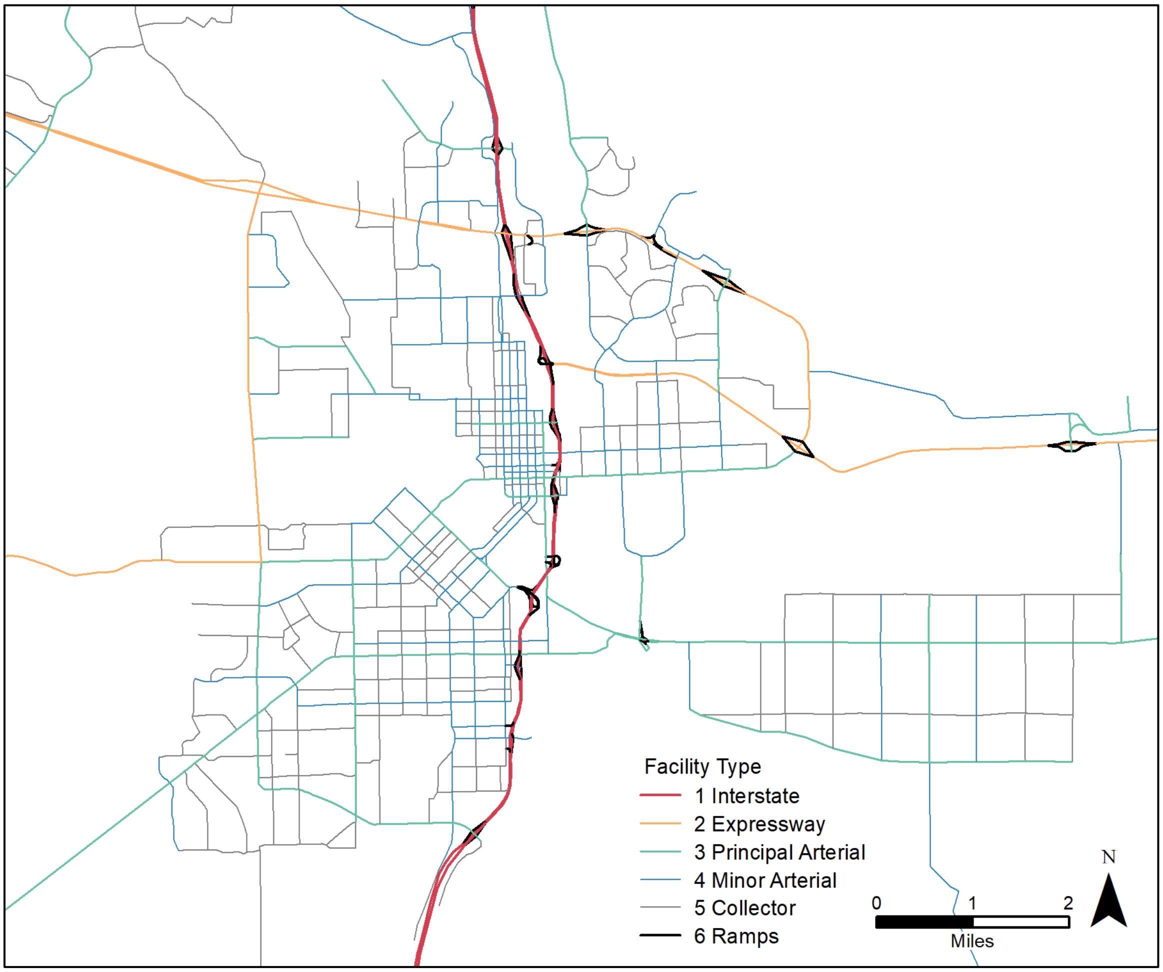

Figure 7: 2020 Link Facility Type Inset

3.6 Time of Day Capacity Assumptions

The PACOG Travel Demand Model contains three time periods. These are the am peak (7:30-8:30 am), the pm peak (4:30-5:30 pm) and the off-peak which is composed of the sum of all other times of the day. The link segment capacity multiplier for each of the two peak periods is set as "1" since they each represent one hour. During network building the "1" is multiplied by the lane capacity and the number of lanes to calculate the carrying capacity of the link segment during that one hour. The off-peak period is composed of all remaining hours spread throughout the day including late morning, midday, afternoon, evening and overnight. It will naturally have a larger capacity multiplier than do each of the peak hours. Since the off-peak period traffic is not evenly spread over the 22 off-peak hours, the network factor is not 22. Rather a factor of 11 has been determined to represent the traffic flow that takes place within the off-peak period. The factor of 11 was estimated based on an analysis of the time-of-day of travel data summarized from the 2010 Front Range Household Survey. **Table 17** shows the am, pm, and off-peak capacity factors used for the traffic assignments. The sum of traffic from the three time-period assignments adds up to daily traffic.

Table 17: Capacity Factors for Traffic Assignment

Period Name	Length (Hours)	Capacity Factor
AM Peak	1	1
PM Peak	1	1
Off Peak	22	11

3.7 Turn Movements and Prohibitions/Penalties

The PACOG Travel Model application of TransCAD software has the capability to conduct analysis reporting on turning movements.

Turn Movements – Turn movements are activated by placing a "1" in the "Turn_Flag" attribute of the network node file. All nodes with this setting will be selected during each of the three time of day model runs. During assignment all turn movements from the selected nodes will be exported to a "Turn Movement" assignment output file.

Turn Prohibitions & Penalties – Turn prohibitions and penalties (in minutes) are available for the PACOG travel model. A file called "turnpen.dbf" in the parameter folder can be activated. In model application the turn prohibitors are listed in a file that TransCAD reads during the assignment process. Activating turn movements can be of value in conducting corridor traffic studies or similar small-scale efforts where turn delay data is available. At the regional level there is risk in activating some turns but not all as this approach can perturb regional patterns of traffic. Global settings are activated in the current model to disallow U-turns throughout the region.

4 Truck Model

The PACOG travel model features a three-step truck model that expands upon the previous one truck class model by generating, distributing, and assigning two classes of truck.

4.1 Truck Model Approach

The truck model is framed using CDOT's vehicle classification definition[9] which is drawn from the FHWA vehicle classification scheme. The FHWA approach is shown in **Table 18** and in **Figure 8**. There are two truck classes in the PACOG model:

- Single Unit Trucks - Vehicles larger than pickup trucks built on a single chassis and consistent with FHWA Classes 4-7.
- Combination or Multi Unit Trucks – trucks with 3 or more axles-single trailer or multiple trailers and consistent with FHWA Classes 8-13.

The TMIP Quick Response[10] modeling approach was utilized as a starting point. Adjustment to Pueblo conditions was required, with both truck trip generation and distribution rates adjusted using feedback from the assignment process. SUTs were set to 1.5 and MUT to 2.5 Passenger Car Equivalents (PCE) during assignment. The Colorado DOT provided sufficient observed truck data to validate the PACOG MPO model by SUT and MUT classes. The observed truck data consists of 132 locations delivering 322 directional truck counts in the PACOG region.

Table 18: FHWA Truck Vehicle Classification

PACOG Vehicle Classification	FHWA ID	Description
Passenger Vehicles	Class 1 Class 2 Class 3	Motorcycles, Autos and Trucks
Single-Units	Class 4	Buses
	Class 5	Two Axle, Six Tire, Single Unit Trucks
	Class 6	Three Axle Single Unit Trucks
	Class 7	Four or More Axle Single Unit Trucks
Multi-Units	Class 8	Four or Fewer Axle Single Trailer Trucks
	Class 9	Five Axle Single Trailer Trucks
	Class 10	Six or More Axle Single Trailer Trucks
	Class 11	Five or fewer Axle Multi Trailer Trucks
	Class 12	Six Axle Multi Trailer Trucks
	Class 13	Seven or More Axle Multi Trailer Trucks

[9] CDOT Catalog Search / Glossary, https://dtdapps.coloradodot.info/otis/catalog, accessed November 2023.

[10] *Source: NCFRP Report 31: Incorporating Truck Analysis into the Highway Capacity Manual (2014), accessed November 2023.*

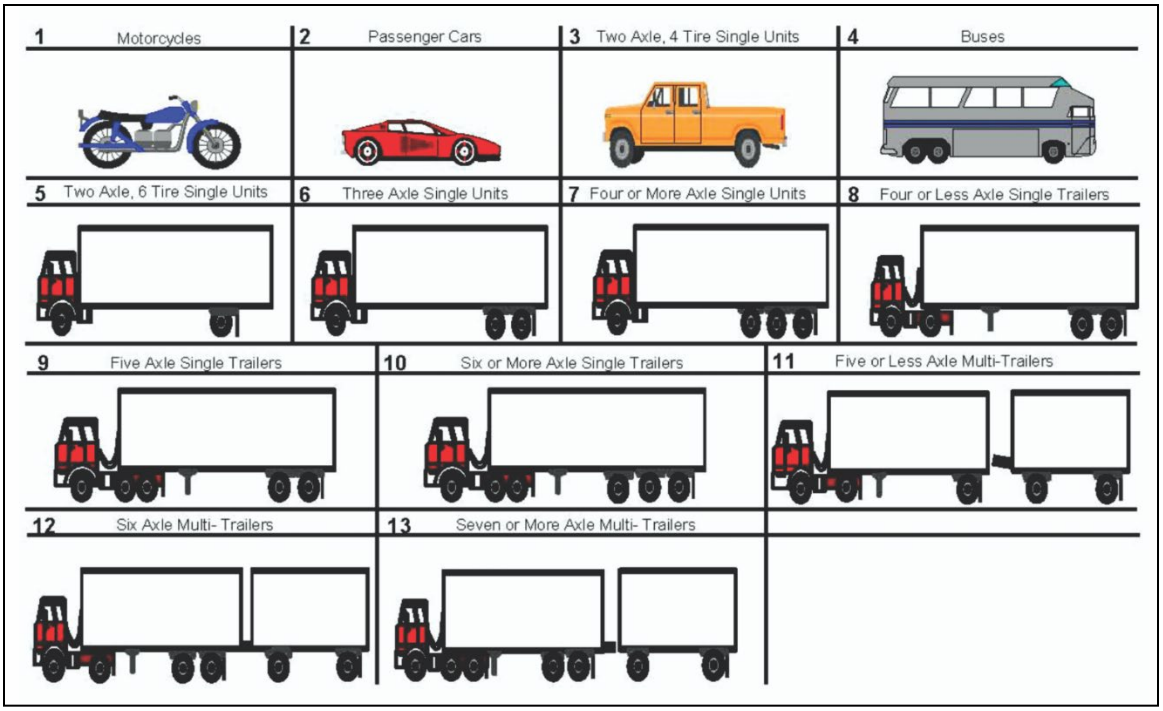

Figure 8: FHWA Truck Vehicle Classification

4.2 Truck Trip Generation and Distribution

Two sizes of trucks are generated using attraction rates only. These rates are written to the production side of the distribution model. Through truck trips are to be developed in a separate step. The general concepts used in the TMIP approach were utilized for this 2020 update with input adjustments for local conditions. Truck trip generation rates and distribution values are shown in **Table 19** and **Table 20**.

Table 19: Truck Trip Generation Rates

Purpose	HH	Retail	Basic	Service	Government	Elem_Enroll	Sec_Enroll	Colleg_Enroll
SUT	0.042	0.100	0.024	0.190	0.090	0.030	0.030	0.030
MUT	0.022	0.080	0.015	0.013	0.009	0.010	0.010	0.010

Table 20: Truck Trip Distribution Rates

Purpose	Alpha	Beta	Gamma
SUT	--	--	0.227
MUT	--	--	0.048

4.3 Truck Model Validation

The two classes of trucks, SUT and MUT, were subjected to validation tests.

Single Unit Trucks had 322 directional counts available for validation. At the daily level, the count and model flow volume for these trucks differed by 1.6%. The Root Mean Square Error (RMSE) was 53. The scatterplot shows an R-squared of 75% with a good fit between modeled and observed SUTs as shown by the adherence to the diagonal.

Table 21: SUT Validation Statistics

Truck Class	Type ID	# of Obs.	RMSE	RelRMSE	Sum of Counts	Sum of Flows	% Difference
Single Unit	SUT	322	114.66	52.97	69,706	70,852	1.6%

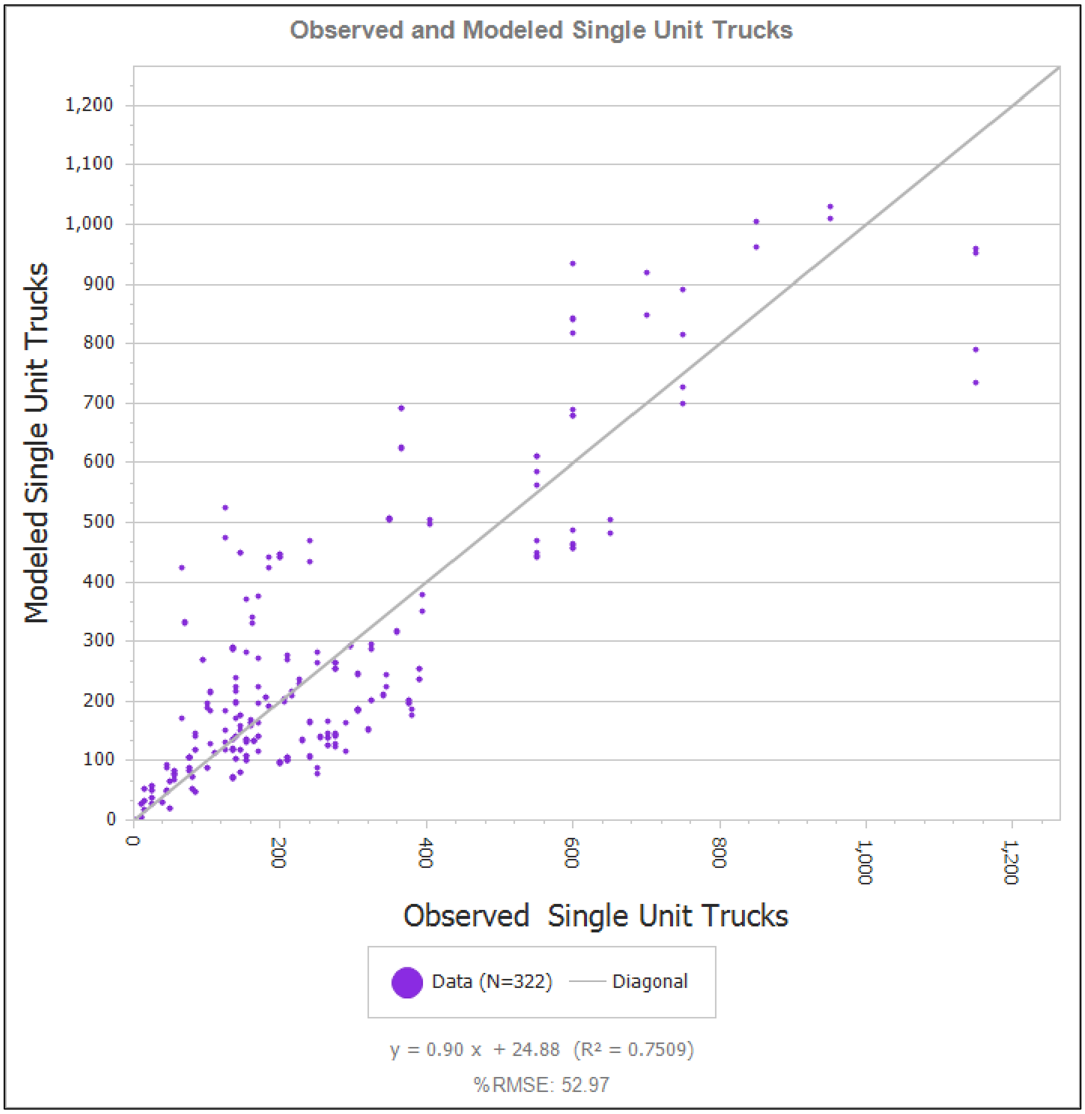

Figure 9: SUT Validation Scatterplot

Multi-Unit Trucks had 322 directional counts available for validation. At the daily level, the count and model flow volume for these trucks differed by 2.8%. The Root Mean Square Error (RMSE) was 40. The scatterplot shows an R-squared of 92% with a good fit of modeled to observed MUTs as shown by the adherence to the diagonal.

Table 22: MUT Validation Statistics

Truck Class	Type ID	# of Obs.	RMSE	RelRMSE	Sum of Counts	Sum of Flows	% Difference
Multi-Unit	MUT	322	90.84	39.61	73,849	75,921	2.8%

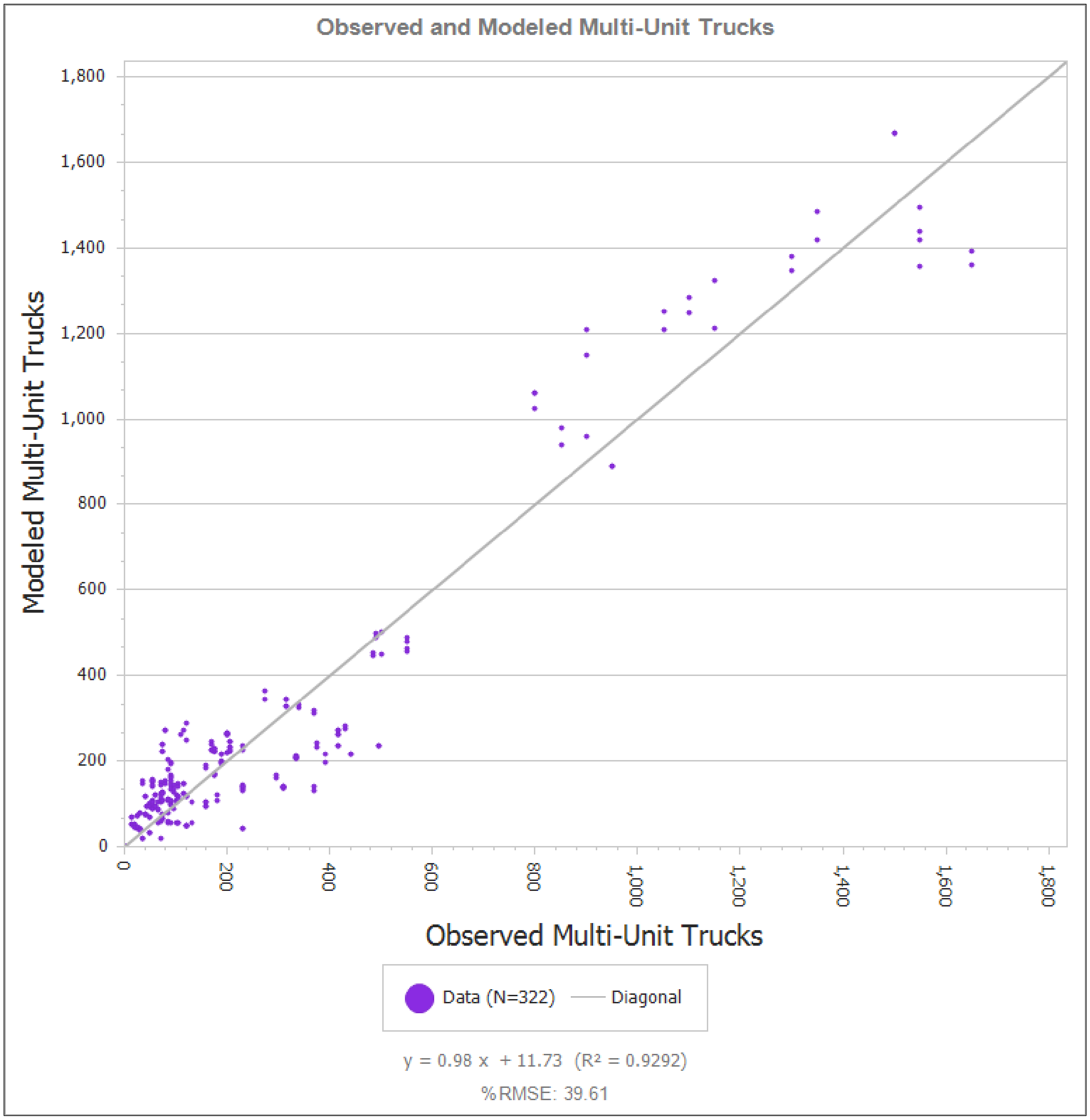

Figure 10: MUT Validation Scatterplot

5 Trip Generation

The first step in the four-step travel demand model development process is accomplished by the trip generation models. Trip generation is composed of two fundamental components: 1) household trip rate development and application, and 2) special generator approach. Household trip generation steps include socioeconomic disaggregation, trip production and attraction models, and external trip models, all of which are developed using a household travel survey. Special generator models are built for facilities whose traffic is not driven by household-based trip generation. In the Pueblo region, special generator approaches have been developed for recreational and tourist destinations. These facilities use data and information, such as annual visitors, to estimate trip-making behavior.

5.1 Overview of Components

5.1.1 Household Trip Generation

Household trip generation includes procedures to estimate the travel demand associated with specific socioeconomic characteristics and land use activities. The goal of the trip generation model is to estimate trip productions and trip attractions for use in the model steps that follow. There are four key components of trip generation:

- **Socioeconomic Disaggregation** – These models begin with aggregate data such as the total number of households and the mean household size per TAZ. The data is then disaggregated to obtain the finer level detail needed to generate trips by cross-classification. This step is conducted within the TransCAD trip generation cross-classification module by four income and five household size categories.
- **Trip Production Models** – These models estimate trip productions on a TAZ level. Productions are typically a function of population or number of households along with a measure of wealth such as income or auto ownership. In the Pueblo travel demand model, household size and income level were used to produce trip rates for eight purposes.
- **Trip Attraction Models** – These models estimate trip attractions on a TAZ level. Attractions are typically a function of socioeconomic activity, households, employment by type, or school enrollment but they may also be land-use based such as retail square feet, open space or parks, gross floor area of manufacturing, or other.
- **External Trip Models** – These models estimate the number of trips that enter/exit the study area at the external stations of the travel model. Both external-internal/internal-external and external-external trips are estimated for Pueblo.

5.1.2 Truck Trip Generation

Trucks are generated in the Pueblo model using a modified Quick Response Manual (QRM) approach. Both Single Unit Trucks (SUTs) and Multi Unit Trucks (MUTs) are generated and distributed.

5.1.3 Special Trip Generators

In travel demand modeling, separate trip attraction models are recommended for special generators within a region, such as airports and other facilities that produce significant traffic that is not predicted by the household and employment information. Trip rates for these facilities can be developed by adapting national or ITE[11] rates, but are best based upon specific local surveys, data and counts if this data is available. For the Pueblo travel model a combination of both methodologies was used. In the Pueblo area, special generators include:

- Colleges and Universities
- Recreational Generators
- Tourist Destinations
- The Pueblo Airport (PUB)

[11] Institute of Transportation Engineers, Trip Generation, 9th Edition, ITE, 2012.

5.2 Household Socioeconomic Disaggregation

The PACOG travel model uses the number of households stratified by household size and income group as the primary independent variables for estimating trip productions. The stratification is applied at the TAZ level.

5.2.1 Household Income Categories

The four income categories used in trip generation were established to stratify the model's households. Income affects the rate of trip making and the stratification captures this differential. The income categories were stratified using the 2021 American Community Survey data. **Table 23** lists the income categories with the number of households in each category as well as the percentage each category is of the total.

Table 23: Household Income Ranges

Income Level	Number of Households	% of Total	Income Category
less than $41,999	15,817	24%	1
$41,999 to $49,999	16,901	25%	2
$50,000 to $65,999	15,989	24%	3
over $65,999	17,735	27%	4
Total	**66,442**	**100%**	

5.2.2 Household Trip Production Model

The production model selected for Pueblo is a two-way cross classification model which estimates motorized person trip rates by household stratified by two independent variables: household size and household income.

5.2.3 Trip Purposes

Fundamental to the trip generation model is an understanding of trip purpose. People travel for a multitude of reasons—work, shopping, recreation, school, doctor, post office, and dropping or picking up passengers. Because each distinct reason for trip making cannot be included in the trip generation model, a set of major trip purposes were established and used in the PACOG travel model to serve the year 2020. These purposes were adapted from the previous PACOG model which used the 2010 Colorado Front Range Household Survey. An updated Household Survey is expected to be completed in 2025 at which time these rates will be available for a model update. Eight final trip purposes are defined:

- Home-based work
- Home-based elementary or middle school
- Home-based high school
- Home-based college/university
- Home-based shopping
- Home-based other
- Non-home-based from work
- Non-home-based from other (note work)

5.2.4 Cross-Classification Approach

The procedure used for the PACOG trip production model is a cross-classification technique. Cross-classification offers the advantage that trip rates can be applied as a series of non-linear relationships. It has been shown that the number of trips generated by a household does not behave in a purely linear manner. For example, a three-person household does not make three times as many shopping trips as a one-person household. The second advantage that cross-classification provides is that it reduces the error associated with using zonal averages for household income and size. Cross-classification analysis is based on this fundamental assumption that trip generation rates are neither continuous nor linear in nature, and that the defined categories of independent variables are stable across the sample and through time.

For the PACOG study area, trip rates are estimated at the most disaggregate level available – the household – and continue to use the Pueblo Front Range 2010 Household Travel Survey[12]. The survey effort began in August 2009 and concluded in the fall of 2010. The survey looked at urban household travel behavior along Colorado's Front Range – from Fort Collins to Pueblo. Before this effort, surveys were done separately in each individual geographic area. A total of 989 households in Pueblo County participated in the survey effort. **Figure 11** shows the location of the sample households in the PACOG region.

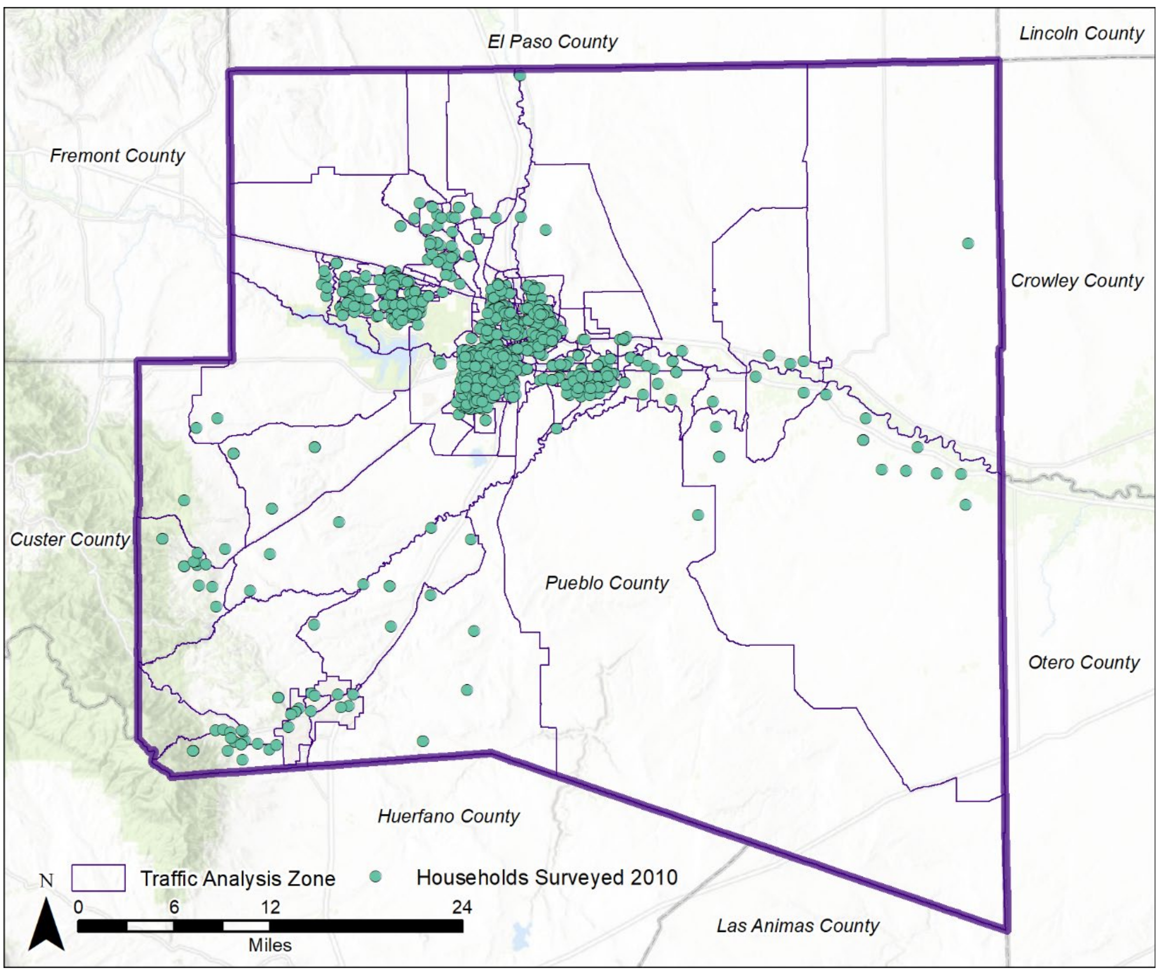

Figure 11: Front Range 2010 Surveyed Households

12 Front Range Travel Counts: PACOG Household Travel Survey Final Report, NuStats, July 2012.

The survey database was used in the development of household trip rates by purpose for the trip generation step. It was also used to revise the trip distribution, mode choice, trip length, auto occupancy and time of day information. The survey responses contain records representing households, persons, and trips in Pueblo County[13]

Each trip record of the home interview was tagged with the appropriate income and household size indicator. The number of regional trips was then summed for each trip purpose, by both income and size category. The mean household trip production rate was calculated by dividing the number of trips by the number of households for each income and household size category. The results are the trip rates shown below in **Table 24** through **Table 31**. The trip production rates were then applied to the households by income and household size category for each TAZ. The result was trip productions for each TAZ for each trip purpose.

Table 24: Home-Based Work Trip Production Rates

Income	Household Size				
	1	2	3	4	5+
less than $41,999	0.38	1.02	1.09	1.16	1.16
$41,999 to $49,999	0.73	1.27	1.44	1.82	1.82
$50,000 to $65,999	0.70	1.70	1.56	2.61	2.61
over $65,999	0.70	1.79	2.37	2.35	2.35

Table 25: Home-Based Other Trip Production Rates

Income	Household Size				
	1	2	3	4	5+
less than $41,999	0.56	1.15	2.46	2.73	3.58
$41,999 to $49,999	0.54	1.47	2.46	4.43	6.52
$50,000 to $65,999	0.68	1.30	2.41	3.26	4.38
over $65,999	0.60	1.38	1.79	4.06	5.25

Table 26: Home-Based Shop Trip Production Rates

Income	Household Size				
	1	2	3	4	5+
less than $41,999	0.64	1.00	1.69	1.36	1.81
$41,999 to $49,999	1.00	1.73	1.74	2.17	2.79
$50,000 to $65,999	1.04	1.71	2.41	2.10	2.10
over $65,999	1.20	2.12	1.65	1.56	1.60

Table 27: Non-Home-Based Work-Related Trip Rates

Income	Household Size				
	1	2	3	4	5+
less than $41,999	0.20	0.60	0.71	0.82	0.82
$41,999 to $49,999	0.72	0.54	1.18	1.74	1.74
$50,000 to $65,999	0.70	0.84	0.98	1.23	1.23
over $65,999	0.85	1.57	1.87	1.84	1.84

[13] Regional Travel Survey Summary Report, Pueblo, CO, NuStats, 2011.

Table 28: Non-Home Based Other Related Trip Rates

Income	Household Size				
	1	2	3	4	5+
less than $41,999	0.84	1.29	1.46	3.55	3.55
$41,999 to $49,999	0.79	1.63	2.05	3.70	4.92
$50,000 to $65,999	1.08	1.57	2.34	3.00	4.00
over $65,999	1.05	1.47	2.19	3.68	3.72

Table 29: Home-Based Elementary/Middle School Trip Production Rates

Income	Household Size			
	2	3	4	5+
less than $41,999	0.13	0.23	0.36	0.70
$41,999 to $49,999	0.02	0.28	0.70	0.98
$50,000 to $65,999	0.01	0.12	0.97	0.89
over $65,999	0.01	0.31	1.44	1.30

Table 30: Home-Based High School Trip Production Rates

Income	Household Size			
	2	3	4	5+
less than $41,999	0.04	0.08	0.11	0.14
$41,999 to $49,999	0.04	0.18	0.17	0.17
$50,000 to $65,999	0.01	0.10	0.39	0.50
over $65,999		0.29	0.30	0.39

Table 31: Home-Based College/University Trip Production Rates

Income	Household Size			
	2	3	4	5+
less than $41,999	0.07	0.08	0.09	0.10
$41,999 to $49,999	0.02	0.15	0.22	0.22
$50,000 to $65,999	0.01	0.32	0.29	0.29
over $65,999	0.01	0.15	0.13	0.11

5.3 Trip Attraction Models

Trip attraction models are the complement of trip productions. They are calibrated from household travel survey data using a process referred to as "aggregate cross-classification." This process can be used because the "type of ending place" that a person traveled to is generally known from the household survey efforts. The type of ending place can be used to determine the land use at the attraction end: residential, basic, retail, or service. The resulting number of trips attracted to each land use can be divided by the appropriate independent variable to estimate the trip attraction rates. These are presented in **Table 32.** The socioeconomic (independent) variables used by the PACOG travel model are households, school enrollment at three levels, basic employment, retail employment, government employment, and service employment. These variables were summarized for the study area. Employment data and school enrollment were also collected and verified.

Regional totals for trip productions and attractions calculated using survey-based, cross-classified trip rates, may be similar, but not exactly equal. In the distribution step of the model, zonal attractions are used to distribute trip productions (origin of non-home-based trips or non-home end of or non-home end of (trips to and from work) to employment location zones. Households are the most verifiable zonal attribute. Thus, after the attraction equations are applied, the home-based trip attractions are balanced to match total home-based trip productions.

5.3.1 Home-Based Work (HBW)

The home-based work (HBW) attraction models are stratified by household income group. This approach ensured consistency with the trip production approach by linking productions by income group with trip attractions by income group. A recent report including a survey of sixteen MPOs[14] provided guidance is checking the attraction rate values.

5.3.2 Home-Based School (School)

The home-based school trip attractions are provided for each school level - elementary/middle, high school, and college. These trips are best predicted using school enrollment alone and are balanced to the productions. Because the 2010 Pueblo Front Range Survey did not explicitly break out school trips by the age of the traveler, a step to link the trip with the person traveling was added to the survey processing.

5.3.3 Home-Based Shop (HBShop)

The home-based shop trip attraction rate is generally tied to retail employment. Given the growth in service jobs, and the blending of retail and service activity, for example, in a copy shop, tax accountancy or health club, service employment was added to this trip purpose attraction equation.

[14] National Cooperative Highway Research Program (NCHRP), Travel Demand Forecasting Parameters and Techniques. Report 716, National Academy Press, 2012.

Table 32: Trip Attraction Rates

Trip Attraction Purpose	Households	Retail Employees	Service Employees	Basic Employees	Government	Elementary School Enrollment	High School Enrollment	College Enrollment
Home-Based Work								
Income 1	0.006	0.367	0.500	0.230	0.270			
Income 2	0.006	0.719	0.631	0.320	0.631			
Income 3	0.006	0.509	0.361	0.460	0.631			
Income 4	0.020	0.284	0.239	0.360	0.590			
Home-Based School								
HB Elementary School						1.100		
HB High School							0.800	
HB College								1.300
HB Shop	0.0000	5.500	2.300	0.284	0.100			
HB Other	0.9000	2.100	2.100	0.208	0.184	0.100	0.100	0.100
Non-Home-Based Work	0.1240	1.877	0.100	0.793	0.200	0.100	0.100	0.100
Non-Home-Based Other	0.3270	3.735	0.198	1.533	0.200	0.100	0.100	0.100

5.3.4 Home-Based Other (HBO)

The home-based other category includes trips made for eating a meal, personal business, recreational, serving a passenger, and other unstated reasons. Because of the variety of destinations that drive this trip purpose, it is reasonable to assume that all land uses explain, in part, home-based other trip-making.

5.3.5 Non-Home-Based Work (NHBW)

Non-home-based work attractions are explained by all socioeconomic variables. The highest coefficient is associated with the retail employment variable, which suggests that a high number of trips made from work to a place other than the home are made to a retail destination.

5.3.6 Non-Home Based Other (NHBO)

The non-home-based non-work attractions are explained by all socioeconomic variables. The highest coefficient is associated with retail employment.

5.4 External Trip Model

The external trip totals guiding both internal-external and external-external trips were obtained from AADT information provided by CDOT, the City of Pueblo and Pueblo County. All internal-external attractions are assumed to occur at internal zones. Internal-external attractions were developed by assuming that attractions are equal to exogenously developed productions.

5.5 Work from Home (WFH) Adjustment to Work Trip Rates

5.5.1 Rationale for Work Trip Rate Adjustment

The Colorado Department of Public Health & Environment (CDPHE) is currently working actively to reduce air pollution from mobile sources through a variety of innovative programs. One of the strategies is to establish goals for mobile source emissions by having MPOs measure auto and truck GHG emissions in future years, test reductions strategies, and ultimately reach pre-established goals. PACOG must model GHG emissions (using the PACOG travel model and MOVES) with and without projects from planning documents (2050 RTP, TIPs) for 2030, 2040 and 2050. PACOG must achieve GHG reductions of 0.03 million Metric Tons (MMT) in 2030; 0.02 MMT in 2040; and 0.01 MMT in 2050.

PACOG requested that the 2024 update of the PACOG Travel Demand Model include a tool to measure the impact of selected GHG reduction strategies, including work from home initiatives, which would reduce some of the work trips in the region. The question that rose immediately was “How do we account for WFH trip reduction that was already in place prior to 2020?” Travel demand in the PACOG region to date has not addressed this issue, which would require the removal of a small percentage of work trips from the model. To design an accurate tool for measuring reduction strategies, a baseline needs to be established.

5.5.2 Work from Home Development and Application

Work from home (WFH) existing conditions were then accessed from ACS[15] (Census) Journey to Work data for years 2019 and 2022 and reviewed. These facts emerged:

- In 2019, Pueblo County work from home WFH average was 2.8%. Across the 54 Census tracts the average value ranged from 0% to 9.7%.
- In 2022 the Pueblo County WFH average was 5.8%. Across the 57 Census tracts the average value ranged from 0% to 14.4%.
- Colorado counties vary in the average WFH percentage with 2019 averages: Denver and Douglas Counties 14%; El Paso County 8%; and Pueblo County 3%. WFH averages for 2022, collected when Covid-19 workplace changes had solidified, were Denver County 27%, Douglas County 31%; El Paso County 18%; and Pueblo County 9%. Local understanding of Pueblo with its focus on manufacturing and high-tech industrial jobs, explains why the Pueblo County WFH average tends to be lower than that of counties with a high percentage of Information Technology, sales, and related work.
- County level work from home percentages for 2020 are sufficient for the PACOG Model GHG tool; these must be stratified for the four income levels in the PACOG model.
- National research has shown that WFH share increases as the household level increases[16].

Given this trend data, and the fact that WFH is continuing to evolve with employees being required in some cases to return to the office, it was asserted that the WFH percentages by income level be set at a mid-point between the 2019 and 2022 Pueblo County percentages. **Table 33** shows the final rates used to adjust work trips in the 2020 PACOG model. **Figure 12** shows the midpoint designation in plot format. The WFH values established for the 2020 base: 1%, 3%, 6% and 11% respectively, were used to reduce work trip productions permanently in the PACOG Travel Model.

Table 33: Work From Home (WFH) Percentages by Income Class Pueblo County

Year 2020 Quartiles	# of Workers	% Worked from Home	WFH Estimate for 2020 Model
INC01	18,031	0.01	180
INC02	16,133	0.03	484
INC03	10,735	0.06	644
INC04	12,953	0.11	1,425
Total	**57,851**		**2,733**

[15] *American Community Survey (ACS) Table C08301, years 2019 and 2022, accessed March 2024.*

[16] "*Home-Based Workers and the COVID-19 Pandemic, American Community Survey Reports, ACS-52, April 2023, accessed March 2024.*

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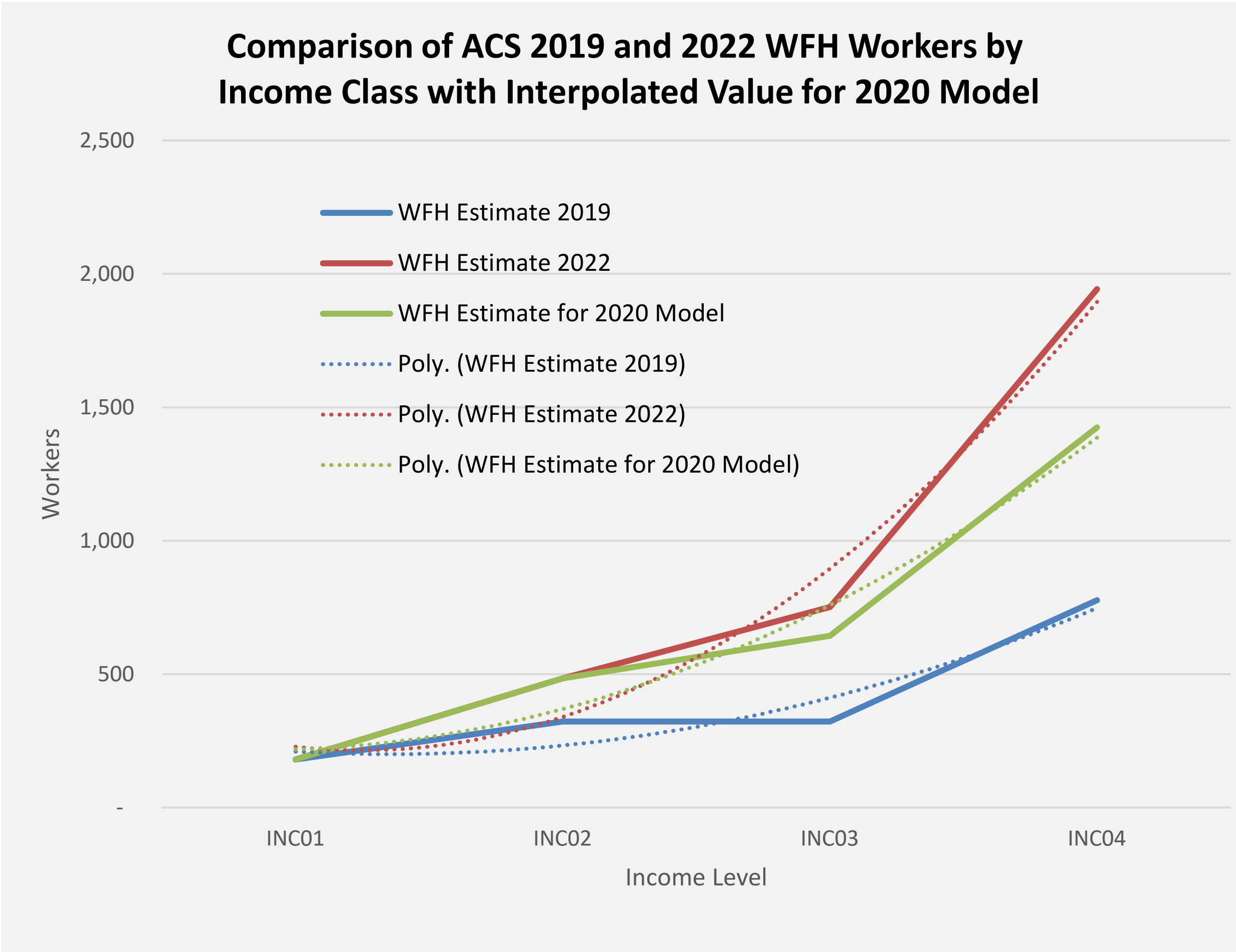

Figure 12: Midpoint Designation for Pueblo County WFH Percentages

5.6 Validation of Attraction-Production Models

5.6.1 Introduction to Trip Production

Trip production rates were developed from the most recent observed data, the 2010 Pueblo Front Range Household Travel Survey. Surveys do not provide direct estimates of zonal trip ends. Thus, there is not an observed number of trip ends to compare with model-estimated trip ends. Summary statistics such as vehicle trips per household, person trips per household, and the percentage of person trips by each trip purpose for a similar study area can be used. Guidance is available on the acceptable range of average trips per households and average trips per person.[17] A very recent source of validation targets is the Transportation Research Board (TRB) online Travel Forecasting Resource[18] website. This electronic site was launched in 2009 to serve as "a national travel forecasting handbook to be developed and kept current providing salient information to those practicing travel demand forecasting*".* The Travel Forecasting Resource was a valuable resource to the PACOG model validation. Finally, the 2024 report on Household Travel characteristics from the 2009 National Household Travel Survey was used[19].

Some key issues are related to the review of average trip generation production rates:

- Activity-based travel models are becoming "standard practice" in many larger urban areas. The need for well-built four-step models, however, is still strong. Continuing research and tabulation are available and needed for four-step model work.
- City or MPO size is not automatically thought to be a direct factor in the average number of trips per household. Smaller cities or towns have been shown to have trip-making rates as high as, or higher than, those in large cities. There is also anecdotal information regarding a decrease in motorized trip rates in U.S. cities between 2000 and 2024. More study of this possible trend is needed in Pueblo, and indeed across the U.S.
- Household travel survey fidelity to actual household trip patterns may be a better indicator of trip rate than is city size. The continued realization that surveyed trip rates do not capture the full extent of household travel, and that non-work trips are the most likely to be under-reported continues to affect travel model trip production rate study.
- With the increase in total trips made by U.S. households comes a decrease in the percentage of work trips of total trips. Some of this shift is due to better reporting on household travel surveys.
- Some recent work during survey data collection in the U.S. used a joint diary and GPS (Global Positioning Satellite) tabulation to capture the movement of a household's vehicles. This strategy records all motorized trips, not just those reported in the diary part of the survey. For example, in a 2013 survey effort in Albuquerque, New Mexico, an overall rate of underreporting of approximately 18% of trips occurred. These trips were detected by GPS but not reported by participants. To further leverage the data collected by the GPS subsample in this survey effort, a statistical model was tested using the trips database and key socio-demographic variables to generate Trip Rate Correction Factors. The results indicated that household vehicle ownership, trip duration, and household size were significantly associated with trip under-reporting. The analysis suggested that likely mis-reporters were respondents between 40-49 years of age, respondents who were either not employed or were students, and households with 0-1 vehicles. Trip duration was also a significant variable in reporting accuracy. In this study, trips greater than 7 minutes in length were more likely to be reported than trips less than 7 minutes in duration.
- There is some evidence that trip rates have a ceiling—households reach a saturation point at which additional trips are neither necessary nor pleasant. In the current decade, U.S. cities may be at this point. Generational differences may also be at play.

[17] Transit Cooperative Research Program "Characteristics of Urban Demand Report 73", National Academy Press, 2002.

[18] Transportation Research Board (TRB) online Travel Forecasting Resource http://tfresource.org/, accessed 2014; requires registration.

[19] "Summary of Travel Trends: 2009 National Household Travel Survey" , Washington, D.C. USA, US DOT, FHA, A Santos, N. McGuckin, H.Y. Nakamoto, D. Gray & S. Liss, June 2011.

5.6.2 Trip Production Validation

Validation for trip generation was prepared using the sources cited above. The first step was to review the average household and person trip making rates.

Average Household Trips - The National Household Travel Survey (NHTS)[20] is a good source of both the trend and the current average of trips per household and trips per person. The average weekday household trip rate is calculated by dividing the total number of trips produced in trip generation by the total number of households in 2020. Trips per household are shown from 1983 to 2022 in **Table 34.** Trips per household increased between 1983 and 2001 then declined between 2001 and 2022. The person trips per household of 9.65 weekday trips for all purposes estimated for Pueblo is generally consistent with these national rates.

Table 34: Trends in Average Daily Household Trips (NHTS)

Year	1983	1990	1995	2001	2009	2017	2022
Daily Household Trip Rate	7.92	9.45	10.76	10.90	9.30	8.18	5.18

Average Person Trips - The average weekday person trip rate is calculated by dividing the total number of trips produced in trip generation by the total number of persons living in households in 2020. This trend is shown in **Table 35** a summary of travel characteristics from the NHTS. As in the household trip rate, travel increased up to year 2001 then declined between 2001 and 2022. The person rate of 3.78 weekday trips per person for all purposes estimated for Pueblo is generally consistent with these national rates.

Table 35: Trends in Average Daily Household Trips (NHTS)

Year	1990	1995	2001	2009	2017	2022
Daily Person Trip Rate	3.76	4.30	4.09	3.79	3.37	2.28

A review of daily per capita trip rates from Albuquerque, NM; Tucson, AZ; Fort Collins, CO; Madison, WI; and Sacramento, CA was conducted. These cities have similarities to Pueblo both in size, region (Western states), and/or local characteristics, and as such, can provide reference points with respect to the daily trip rates estimated from their household travel surveys. A summary is provided below.

Daily Per Capita Trip Rate

U.S. cities surveyed daily person trip rate range is 2.40–5.55. Cities similar to Pueblo include:

Albuquerque, NM: Rate 3.97
Madison, WI: Rate 3.83
Tucson, AZ: Rate 3.54

Pueblo rate of 3.78 is within these limits.

Daily Household Trip Rate

For the U.S. cities surveyed the daily household rate range is 7.02–12.99. Cities similar to Pueblo include:

Albuquerque, NM: Rate 10.08
Fort Collins, CO: Rate 10.66
Sacramento, CA: Rate 9.72

Based on this data, the Pueblo rate of 9.65 is within these limits.

[20] *2022 National Household Travel Survey, Summary of National Trends, Report no. FHWA-HPL-24-009, published 2024.*

Percentage of Home-Based Work Trips of Total

U.S. cities surveyed have a range of 13 percent to 28 percent home-based work trips as a percentage of total daily trips. Cities similar to Pueblo include:

Albuquerque, NM: HBW 17.7 percent
Fort Collins, CO: HBW 13.0 percent
Tucson, AZ: HBW 17.6 percent

Percentage of Trips by Purpose – There is value in looking at the percentage of trips produced by each of the three major trip types: home-based work (HBW), home-based other (HBO), and non-home-based (NHB). Evidence points to a trend of HBW trips taking up a diminishing percentage of total daily trips in recent years. Surveys from the 1970s and early 1980s show HBW at 19 percent to 28 percent trending in the mid 25 percent area. More recent surveys set the HBW percentage of total range at 13 percent to 28 percent trending in the low 20 percent. Based on this data, the Pueblo home-based work trip percentage of 13 percent of total daily trips is within normal limits.

5.6.3 Trip Production Ratio Validation

On the production side, it is recommended that selected trip production totals be compared to observed “on-the-ground” socioeconomic totals. Two measures are suggested: (1) Home-based work production ratio to total employment; (2) and Home-based shop productions to retail employment. In the Pueblo area, the home-based work person trip production ratio to total employment is 1.14. The retail productions per retail worker are 13.38.

5.6.4 Total Productions versus Total Attractions

Table 36 shows the unbalanced productions and attractions for each of the eight trip purposes. The total number of attractions (about 616,695) is about 3 percent lower than the total number of productions. The home to/from work difference is likely due to a more accurate capture of employment locations for the updated 2020 base year.

Table 36: 2020 Total Productions and Attractions by Trip Purpose

Trip Purpose	Productions	Attractions	Difference	% Difference
Home Based Work	85,227	85,260	33	0%
Home Based Elementary School	23,304	21,439	-1,864	-8%
Home Based High School	10,605	9,913	-693	-7%
Home Based College	10,597	9,750	-848	-8%
Home Based Shop	119,405	109,852	-9,552	-8%
Home Based Other	159,628	148,490	-11,138	-7%
Non-Home-Based Work	78,202	82,682	4,480	6%
Non-Home-Based Other	149,196	149,309	113	0%
All Trip Purposes	**636,164**	**616,695**	**-19,469**	**-3%**

Overall, the trip generation model performs within the limits indicated by national practice while reflecting in a reasonable manner the local Pueblo observed information on households, schools, and employment.

5.7 Summary

There were no major changes to the trip generation model in the updated 2020 model. The most recent household survey data continued to serve as the observed data for trip rates. Socioeconomic updates, however, captured the most recent input data to the models. The PACOG model:

- Continued to use the trip rates and trip distribution targets developed from the 989 households in the 2010 Pueblo Front Range household travel survey.
- Reviewed and verified the trip attraction rates established in the previous PACOG model.
- Reviewed the results of trip generation to ensure results consistent with recent national averages.
- Referenced Covid-19 impacts of trip rates and selected a “middle ground” that reflects HBW activity on the ground in the PACOG region.

6 Special Generators

6.1 Introduction

The special generator approach is important to capture activity at sites that are not accounted for by the household trip generation process. Trip generation rates for most sites were obtained from NCHRP 365 (update of NCHRP 187)[21]. The sites and vehicle trip generation rates included are shown in **Table 37.**

The areas of the special generators were estimated from computerized zone and geographic maps. Vehicle trips were converted to person trips (where appropriate) assuming an auto mode share of 1.0 and average auto occupancy of 1.3 persons per vehicle (which is the average for Pueblo for the trip types included. The table shows the special generator name and the vehicle trips per acre that are used for 2020. The special generator attractions are added to the standard trip generation attractions during the model run. For example, if the trip generation module produced 500 trip attractions for a zone and the special generator produced 300 attractions, the file would simply be modified to show 800 trip attractions for that zone. Note that the special generator trips will not change over time unless one of the sites is expanded or reduced in size.

Table 37: Special Generators & Rates

TAZ	Name	Trip Rate
23	Mineral Palace Park	60 vehicles / acre
54	City Park	60 vehicles / acre
59	Pueblo Country Club	7 vehicles / acre
83	Elmwood Golf Course	7 vehicles / acre
92	YMCA (Future)	1.64 vehicles / 1000 SF GFA
106	Walking Stick Golf Course	7 vehicles / acre
121	Lake Minnequa	3.6 vehicles / acre
146	Desert Hawk Golf Course	7 vehicles / acre
196	Hollydot Golf Course	7 vehicles / acre
155	Juniper Breaks Rock Canyon	Pueblo Lake State Park entrance: trip generation per state visitor counts and forecasts
167	Northern Plains North Shore	Pueblo Lake State Park entrance: trip generation per state visitor counts and forecasts
203	Arkansas Point South Shore	Pueblo Lake State Park entrance: trip generation per state visitor counts and forecasts

6.2 Pueblo Airport (PUB)

Air passenger trips constitute a distinct travel segment in a regional travel demand model. For the PACOG region, there is one commercial airport that requires review, the Pueblo Memorial Airport (PUB) located at 31201 Bryan Circle, Pueblo, CO 81001. The TAZ ID of the airport zone is 28 as shown in **Figure 13**.

Pueblo falls under the Essential Air Service program in which the U. S. Government subsidizes an airline to provide air service to a city. This federal program guarantees smaller communities access to the national transportation grid by subsidizing carriers that fly from the smaller communities to hub airports. This subsidy comes up for bid every two years; therefore, Pueblo has seen its air service provider frequently change. There have also been times where there has been no commercial air service to Pueblo, such as in the spring of 2014 and the summer and fall of 2015.

[21] National Cooperative Highway Research Program, Travel Estimation Techniques for Urban Planning, Report 365," National Academy Press, 1998.

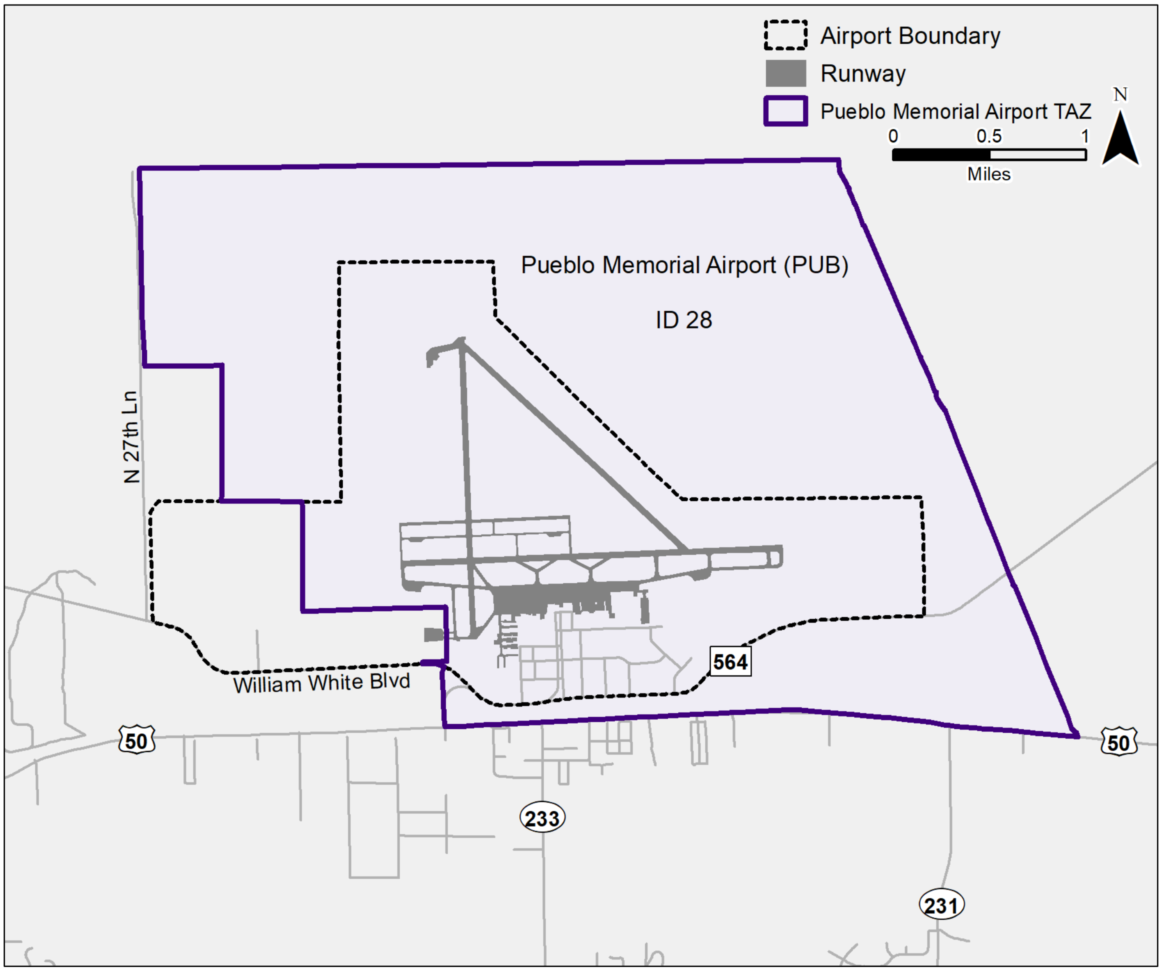

Figure 13: Pueblo Airport Area

Up until the mid-1990s, Pueblo was served by multiple airlines and for much of the year 1991, four airlines were operating at Pueblo simultaneously: America West, TWA, Continental Express, and United Express. Pueblo has also seen mainline jet service (727s, 737s, and MD-80s) by four airlines. Since 1995, however, service has only been provided by one airline with commuter or regional jet flights to Denver apart from the Allegiant Air service in 2010–2012.

Starting January 2023, Southern Airways Express LLC has been offering daily scheduled air service between Pueblo and Denver, providing an air commute link between Pueblo and Denver International Airport. Under the contract, Southern Airways will provide Pueblo with a total of 24 weekly nonstop round trips to Denver using a 9-seat Beechcraft King Air 200 plane. In exchange for the airline's willingness to serve the market, the federal government will pay an annual subsidy of $2.9 million in 2023 and $3.06 million in 2024, according to the department's order[22].

The travel model currently does not reflect these boardings and alighting air passengers generated by the Southern Airways Express service. The airport TAZ, however, contains significant employment, related to general aviation workers as well as to other employment types, which is included in the PACOG model.

[22] *The Pueblo Chieftain, "We Have Liftoff: Southern Airways begins flights from Pueblo to Denver,* *https://www.chieftain.com/story/business/2023/01/18/southern-airways-offering-24-weekly-flights-between-pueblo-and-denver/69816584007/, January 18, 2023.*

7 Distribution Model

7.1 PACOG Distribution Model Formulation

Within the PACOG travel model, trips are distributed geographically, for all but the external-external trip purpose, using a gravity model-based procedure. This approach was also used in the previous PACOG travel models. The basic theory underlying the gravity model is that the number of trips between two zones is directly proportional to the number of trips produced at the production zone and the number of trips attracted to the attraction zone and inversely proportional to the impedance between the two zones.

$$T_{i,j} = P_i \times \left(\frac{A_j F_{i,j}}{\sum_{k=1}^{n} A_k F_{i,k}} \right)$$

where: $T_{i,j}$ = trips from zone i to zone j

P_i = trip productions in zone i

A_j = trip attractions in zone j

$F_{i,j}$ = the "attractiveness" between zone i and zone j

The "attractiveness" factor in the equation (Fi,j), often referred to as the "friction factor," represents the spatial separation such that as separation between zones increases, the attractiveness to travel between these zones decreases. The gravity models used in the PACOG travel model distribution procedures were calibrated by trip purpose to observed data (the 2010 Front Range Pueblo household travel survey data). As in previous PACOG travel models, the formulation (gamma or exponential) used for the PACOG gravity model "friction factor" varied by trip purpose. The gamma function was used for all person trips and the exponential function for all truck trips. The formulations of these functions are as follows:

1) the gamma function:

$$F_{i,j} = a \times t_{i,j}^{b} \times e^{c \times t_{i,j}}$$

2) the exponential function:

$$F_{i,j} = a \times e^{c \times t_{i,j}}$$

where: $t_{i,j}$ = the travel impedance between zone I and zone j
a, b, and c are calibrated coefficients.
e = the base of the natural logarithm (2.71828)

Each of the "friction factor" (Fij) formulations (gamma or exponential) used by the PACOG travel model for gravity model-based trip distribution include a travel impedance term, $t_{i,j}$. Although composite impedances including costs for travel (fuel, depreciation, tolls, fares, etc.) are often used for representing $t_{i,j}$, the PACOG gravity model formulations use travel times alone for the interzonal travel impedance ($t_{i,j}$) friction factor terms. The PACOG model incorporates a feedback loop from assignment to distribution to utilize the most recent congested times in distribution.

Testing was considered to determine the value of adding "terminal times" at the origin and destination of each time skim. Standard practice no longer supports this step which is seen as a constant on the zone-to-zone times with little explanatory value and therefore this step was not implemented with this current update.

Recognizing that intrazonal travel times may be needed for model application, these times were also calculated and added to the initial congested auto travel time skims. The intrazonal travel times were calculated using a standard process whereby the zone-to-zone travel time was assumed to be one half of the average of travel time between that zone and all adjacent zones. The calculation assumes that roughly one half of the intrazonal travel time relates to the origin zone, with the other half of the travel time to the destination zone. Averaging this function for all adjacent zones has the effect of dampening the effect on the calculation of anomalies that may be created by irregular zone shapes or uneven major network coverage. TransCAD standard procedures were available to process the required calculations.

7.2 Distribution Model Development

7.2.2 Gravity Model Calibration

The gravity model was first calibrated in 1993 using the 1990 Household Survey data for Pueblo County. The 1993 trip distribution coefficients served as the starting point for the 2010 model update. The distribution was calibrated using the survey, testing the fit of the resulting gamma function gravity model formulations, revising coefficients, and optimizing the model's performance. Trip length frequency distributions (TLFDs) were prepared for each purpose using utility programs in TransCAD GISDK. Iterative testing was done with the model coefficients until a fit with observed distributions was achieved. For the current 2020 update, observed data remains the 2010 Front Range Household Survey.

Figure 14 through **Figure 19** show the fit of modeled travel time distribution vs. observed travel time distribution for each trip purpose. Final coefficients are presented in **Table 38** together with a comparison of "observed" and modeled average trip lengths.

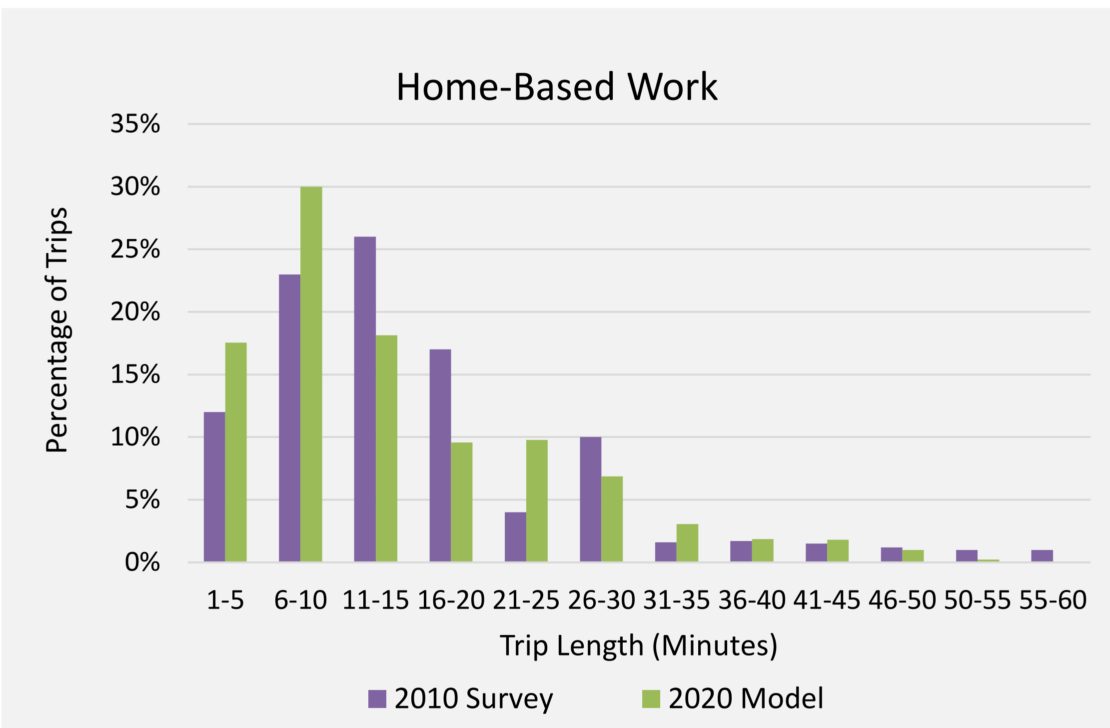

Figure 14: Home-Based Work Trip Length Frequency Comparison

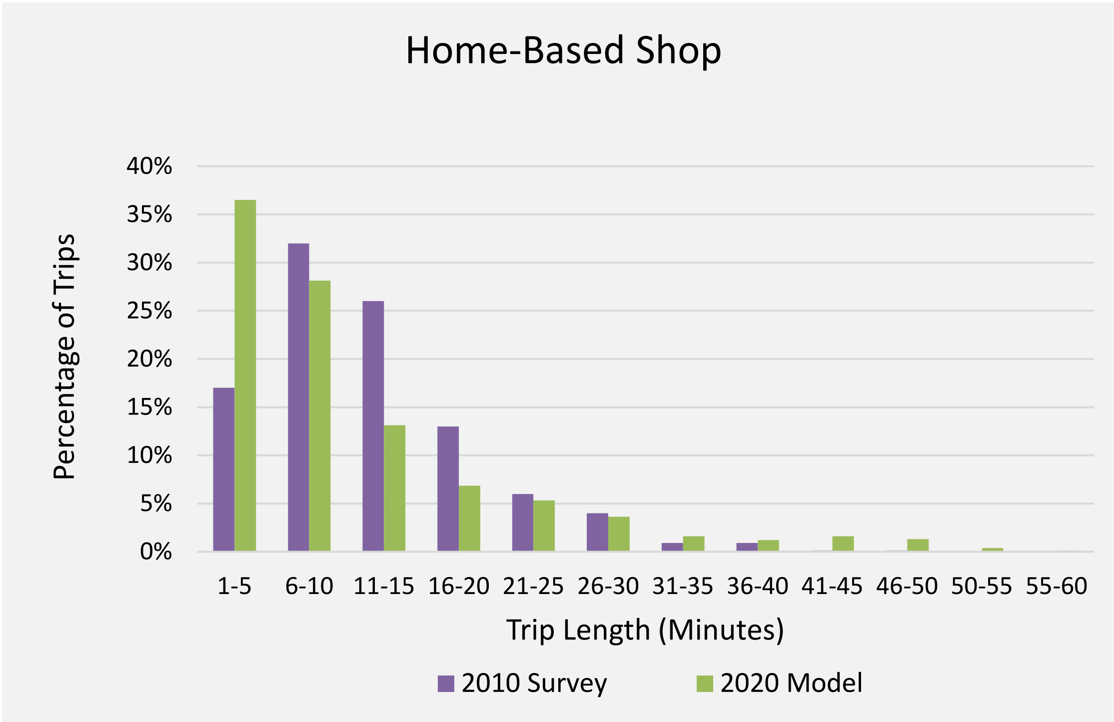

Figure 15: Home-Based Shopping Trip Length Frequency Comparison

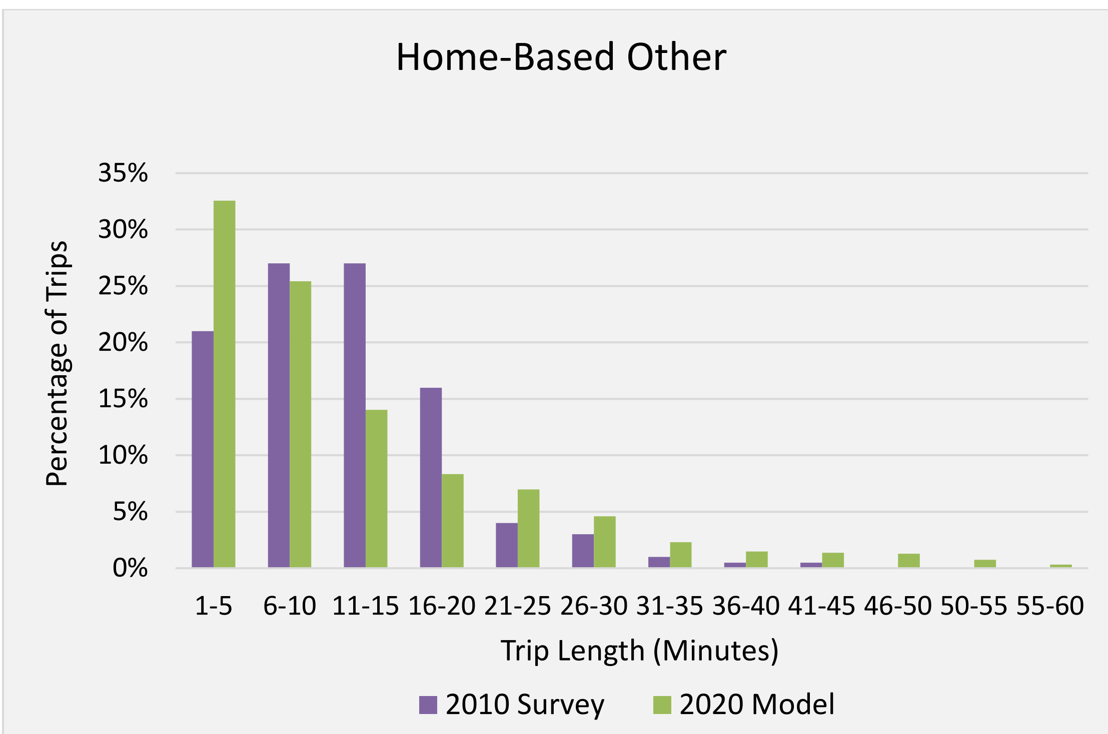

Figure 16: Home-Based Other Trip Length Frequency Comparison

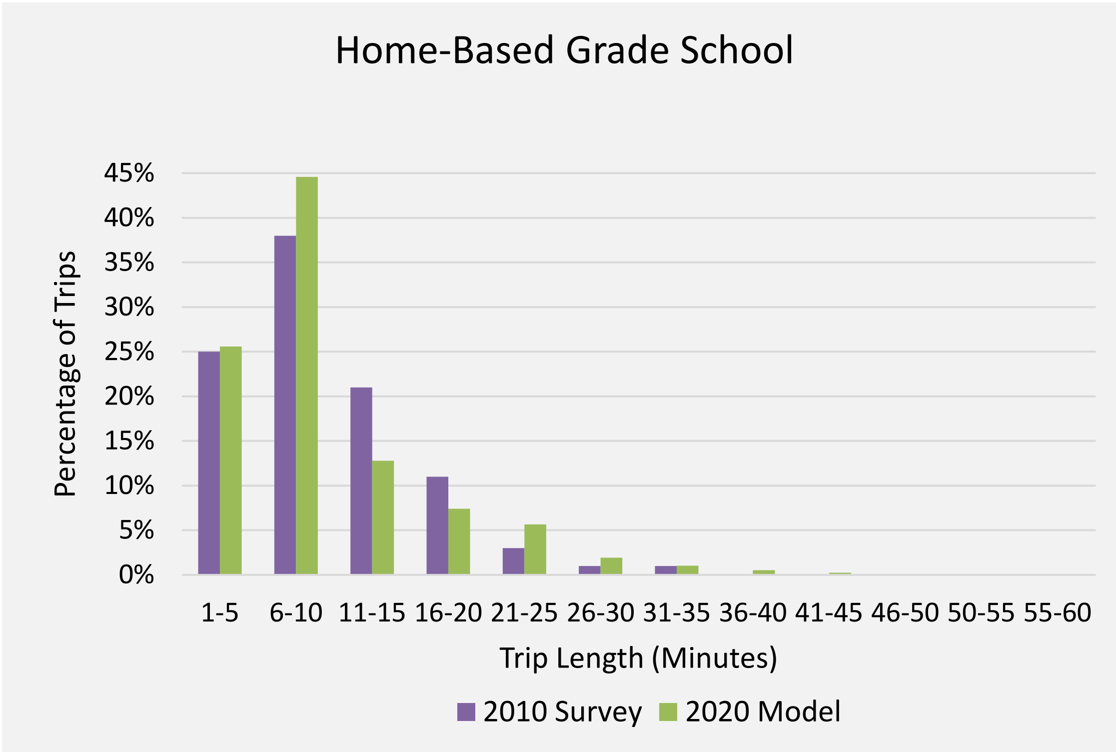

Figure 17: Home-Based Elementary & Middle School Trip Length Frequency Comparison

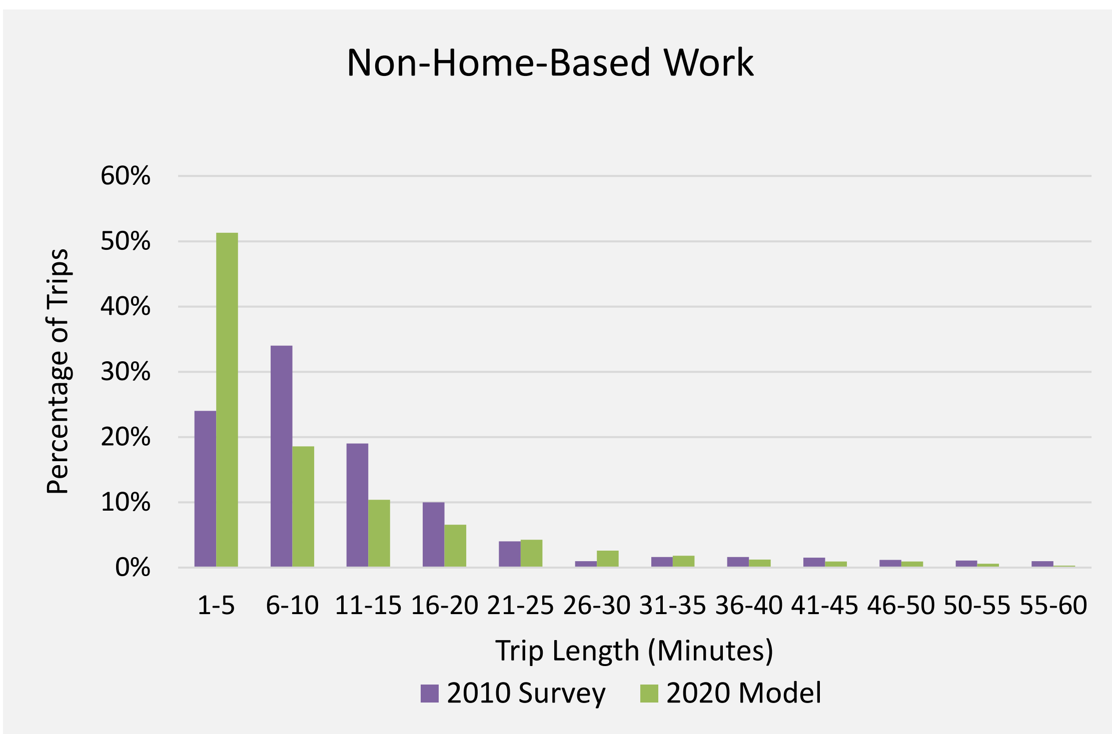

Figure 18: Non-Home-Based Work Trip Length Frequency Comparison

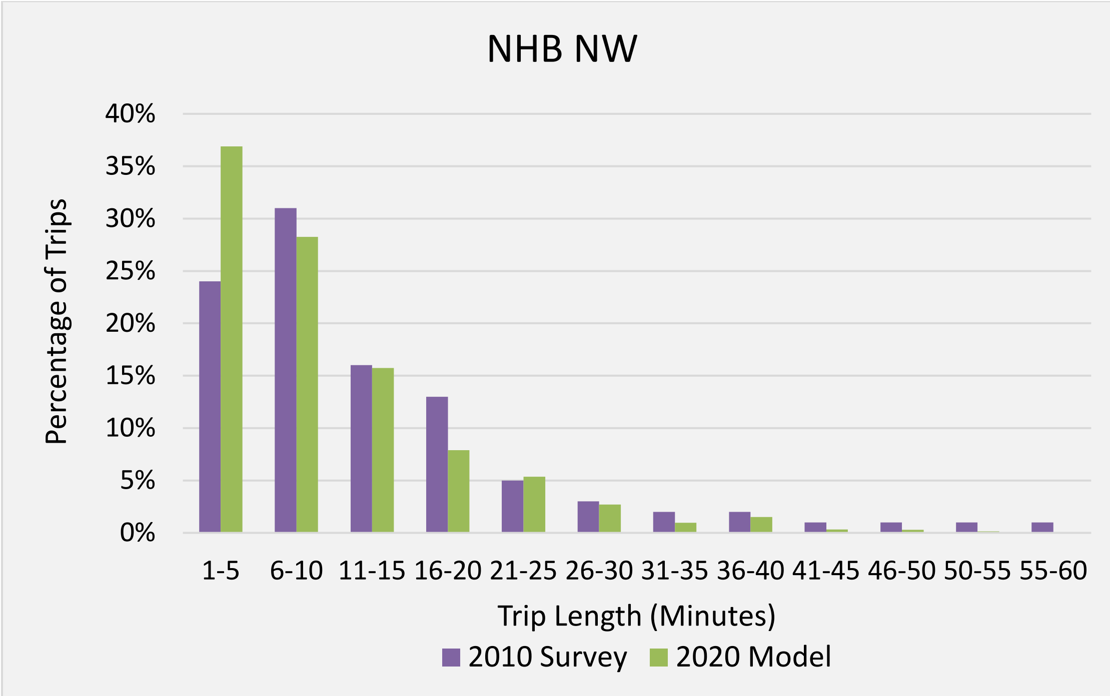

Figure 19: Non-Home-Based Other Trip Length Frequency Comparison

Table 38: Trip Distribution Parameters by Purpose

Trip Purpose	Friction Factor Function Coefficients				Average Trip Length	
	a	b	c	Function	2010 Front Range Pueblo Survey	2020 Modeled
Home-Based Work						
Low-Income	28507	0.3260	0	gamma	15.8	10.3
Lower Middle Income	28507	0.3568	0	gamma	15.8	10.7
Middle Income	28507	0.0200	0.123	gamma	16.7	13.1
Upper Income	28507	0.0200	0.2	gamma	17.5	20.0
Home-Based School						
Home-Based Elementary	139173	0.1000	0.2000	gamma	10.8	10.5
Home-Based High School	43057	1.0000	0.0500	gamma	12.1	12.1
Home-Based College	28507	0.0200	0.1230	gamma	20.5	12.6
Home-Based Shop	139173	1.2534	0.0345	gamma	13.5	11.8
Home-Based Other	139173	1.2850	-0.0200	gamma	13.0	13.3
Non-Home-Based Work	219113	1.3320	0.0100	gamma	12.4	13.9
Non-Home-Based Other	219113	1.0561	0.0591	gamma	10.9	10.8

7.2.3 External-External Trip Distribution

External-external (E-E) trip distribution was performed using the Fratar process. This approach is used since the true origins and destinations of the trips are not known. For example, a trip traveling through Pueblo County on I-25 could have started in Denver and be destined for Albuquerque or to many other points south.

Typically, external-external trip tables are estimated using a base year trip table obtained from an external station survey. Since no such survey was available for Pueblo in 2024, a different technique had to be used. This approach is adapted from the National Cooperative Highway Research Program (NCHRP) guidance on travel model development.[23]

Specifically, the starting point was the AADT at each of the eight external portals. A set of factors was established to calculate both the percent through traffic at each external station and the distribution of the through traffic to the other external stations. As an example, some of the traffic observed at the I-25 portal on the north continues through the county to exit at I-25 south. The scores were based on the functional classification of the external station as well as the volume and type of traffic at each candidate destination external portal. Certain movements were disallowed – if, for example, the trip is a U-turn or another illogical movement. The starting external movements are shown in **Table 39**. The estimated through traffic can then be calculated to match external-external origins and destinations at each external station using derived growth factors and Fratar Model methods. The rows and columns are balanced to achieve symmetry about the diagonal. Through trips were estimated for autos and two classes of trucks separately.

Table 39: External Station 2020 Traffic Worksheet

Location	TAZ ID	2-Way AADT	2 Way SUTs	2 Way MUTs	IX Productions	XX AADT Trips	XX Origins	XX Destinations
I-25 (North)	401	29,000	941	2,570	19,500	9,500	4,750	4,750
SH 96 E	402	1,000	42	40	700	300	150	150
US 50 E	403	3,700	141	370	2,800	900	450	450
I-25 South	404	8,100	357	1,160	600	7,500	3,750	3,750
SH 165 W	405	800	28	30	600	200	100	100
SH 78 W	406	1,000	37	30	800	200	100	100
SH 96 W	407	1,000	28	60	800	200	100	100
US 50 W	408	8,100	157	370	6,300	1,800	900	900
Total		**52,700**	**1,731**	**4,630**	**32,100**	**20,600**	**10,300**	**10,300**

The future year external movements for truck and auto were estimated using the growth factors provided by CDOT, and the Fratar Expansion calculation process.

[23] National Cooperative Highway Research Program (NCHRP) Travel Estimation Techniques for Urban Planning (Report 365), TRB National Academy Press, 1998.

8 PACOG Transit Modeling

With this PACOG Travel Demand Model update, transit routes, stops, and service characteristics are included in the PACOG model for the first time. Additional transit network information is used to support transit skimming which is an input to mode choice modeling and later in transit assignments. Roadway network detail and data attributes were expanded to support transit modeling as well.

8.1 Pueblo Transit System

The Pueblo Transit System consists of eleven bus lines in 2023 offering peak and off-peak service with differing frequencies. All buses begin and end at the Pueblo Transit Center in downtown Pueblo. There were approximately 1,600 weekday boardings in 2022, down from about 3,000 in 2016. This bus system served as the input for the transit model. **Table 40** and **Figure 20** show the system profile.

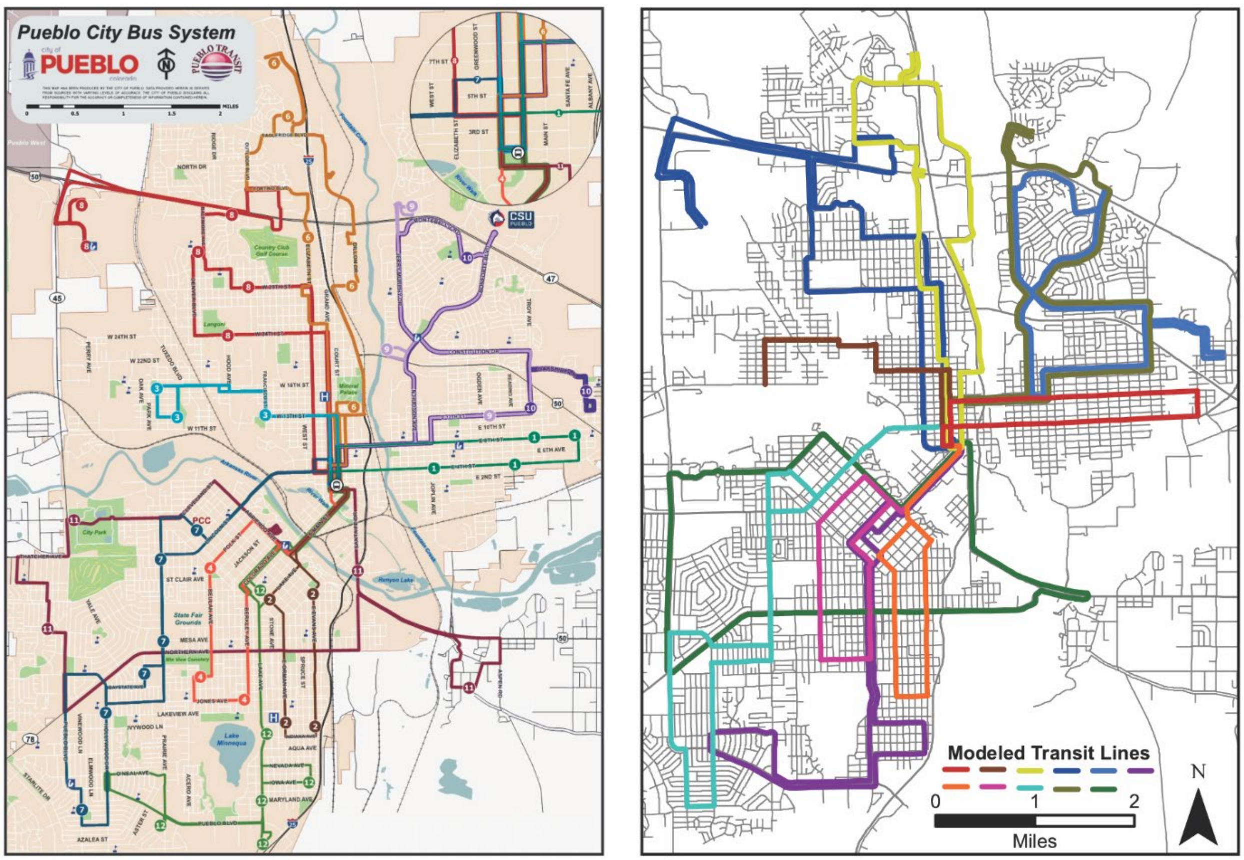

Figure 20: Pueblo Transit System, Observed and Modeled

Table 40: Pueblo Transit System

Bus Line	Headways		Line Haul Time in Minutes
	Peak	Off Peak	
1-Eastside	30	60	25
2-Bessemer	30	60	25
3-Irving Place	30	60	25
4-Berkley/Beulah	30	60	25
6-Pueblo Mall	60	30	50
7-Highland Park	30	30	55
8-Hwy 50-West	60	60	50
9-University	60	60	55
10-Belmont	60	60	50
11-Red Creek Ride	60	60	55
12-Lake Avenue	30	60	55

8.2 Pueblo Transit Model Processing for Mode Split

During a model run, the model script calls a macro that conducts transit skimming. The process begins by generating a transit network that is sensitive to:

- **Peak Headway** – "PK_Headway," is an attribute of the Transit Route System that represents the time between buses along a given route during peak service periods.

- **Walk Time** – "WalkT" is an attribute of the roadway file and is used to estimate the travel time due to the walk components of a transit trip (walk to bus stop from trip origin, walk to transfer, walk to destination).

- ***In Vehicle Travel Time*** – IVTT is an attribute of the roadway file and is used to estimate the travel time due to the in-vehicle portion of a transit trip (riding on the bus, waiting for other riders to get on/off the bus). The IVTT value is computed inside the SPCAP portion of the script, and the default value uses 2 x Auto Travel Time to account for the frequent stops and slower overall travel speeds of buses in mixed traffic.

The resulting transit "network" is encoded in a TransCAD network file but is not ready to be used until Transit Settings are designated. The Transit Settings process establishes a set of weights and upper/lower limits to key variables that allow TransCAD to find the best transit path between every pair of TAZs. Some key transit path building assumptions are listed below:

- **Access/Egress Walk Time**: capped at 15 minutes, if the walk trip to/from the nearest bus stop exceeds this threshold, then transit is not feasible.
- **Initial Waiting Time**: ½ of the headway, and a maximum of 60 minutes.
- **Transfers**: maximum of 1 transfer, 40% fare on the second bus, 3-minute time penalty.

The resulting transit network and settings are then ready for skimming. The transit skimming process results in a matrix file with each of the following variables representing the characteristics of a transit trip between the zone pairs. Several key elements from the transit skim are copied into a mode choice input matrix for the mode choice step.

Transit related elements in the mode choice skims are as follows:

- **Bus Availability**: "BUS_AVAIL": computed by the skim, set to 1 if bus is feasible between zones, 0 if not feasible.
- **Bus In Vehicle Time**: "BUS_INVTT': sum of the transit journey travel time spent inside the bus between a zone pair, includes dwelling time.
- **Bus Initial Waiting Time**: "BUS_INWAIT": sum of the transit journey's time spent waiting at the initial bus stop.
- **Bus Walk Time**: "BUS_WLKTIM": sum of the transit journey's travel time spent walking to the bus stop.
- **Bus Transfer Wait**: BUS_TRWAIT: sum of the transit journey's travel time spent waiting for a transfer bus if a transfer is needed to reach the destination.

As a first effort to integrate the transit mode into the PACOG model, the above transit network and skimming approach successfully prepared a set of inputs to bring transit to the mode choice model.

9 Mode Choice

9.1 Introduction

During the mode choice step, trips from zone to zone by trip purpose are further divided into trips by various transportation modes and then converted to vehicle trips and passenger trips for the purpose of predicting vehicle flows on the roadway network and demand for alternative modes. Mode Choice models are mathematical expressions used to estimate the share of travel on each available mode given the time and cost characteristics of each mode and the demographic and socio-economic characteristics of trip makers.

The mathematical formulation of the nested multinomial logit model structure is as follows.

The generalized mode choice model structure is represented by a logit formulation. This mathematical relationship estimates the probability of choosing a specific mode using the following equation:

$$P_i = \frac{e^{U_i}}{\sum_k e^{U_i}}$$

where:

P_i	is the probability of a traveler choosing mode i;
U_i	is a linear function of the attributes of mode i that describe its attractiveness;
$\sum_k e^{U_i}$	is the summation of the linear functions of the attributes of all the alternatives (k) for which a choice is feasible.

The utility expression for each available mode (i) is specified as a linear function which incorporates a range of variable types, including time and cost incurred by a traveler using a given mode. For example:

$$U_i = b_1 * INVTT_i + b_2 * IWAIT + b_3 * WALKT + b_4 * TRFRT + b_0$$

where:

U_i	is the utility for mode i;
b_0	is a constant specific to mode i that captures the overall effect of any significant variables that are missing or unexplained in the expression (i.e., comfort, convenience, safety);
b_1	is a coefficient applied to a variable describing the level-of-service (in-vehicle travel time) provided by mode i;
b_2	is a coefficient applied to a variable describing the wait time for the bus mode for the specific origin-destination pair;
b_3	is a coefficient applied to a variable describing the walk time to the boarding bus stop for the bus mode for the specific origin-destination pair;
b_4	is a coefficient applied to a variable describing the wait time if a transfer is required for the bus mode for the specific origin-destination pair.

9.2 Formulation and Nesting Structure

The travel time variables are disaggregated into in-vehicle and out-of-vehicle time for the bus mode; the out-of-vehicle time is broken out by initial wait time, access walk time, and transfer walk time. And finally, a mode specific constant reflects non-included variables such as comfort or reliability of service. The individual coefficients associated with each variable reflect the relative importance of each attribute.

In the nested logit model structure shown in **Figure 21**, the formulation employs two levels of multinomial logit models; one for the primary choice of mode among auto and transit, then a second level choice among auto driver or auto shared ride. A composite of the utilities of the auto sub-mode modes then represents each nest mode respectively in the upper tier of the model structure. This composite measure is the natural logarithm of the denominator of the logit model, often termed the *"LogSum".* The LogSum term is effectively the combined utility provided by the sub-modes of a particular primary mode.

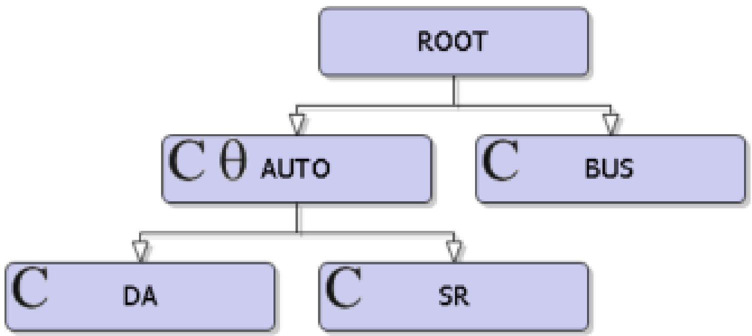

Figure 21: Mode Choice Nesting Structure

There are alternative options for developing the mode choice model coefficient estimates for each of the modal utility expressions, and in the past, it was common to estimate unique coefficients for each model via analysis of combined household travel/on-board transit survey datasets. However, FTA research has shown that spurious models often result. For the PACOG mode choice model, the models by trip purpose used coefficients within the ranges recommended under current best practice guidance by NCHRP 716[24] for work trip purposes (see **Table 41** below). For non-work trip purposes, coefficients were borrowed from the North Front Range Model's non-work trip mode choice model settings for in-vehicle, walk time, and wait times.

Table 41: Pueblo Transit System

Model	In-Vehicle Time	Out-of-Vehicle Time	Walk Time	First Walk Time	Transfer Walk Time
A	-0.021	--	-0.054	-0.098	-0.098

Source: NCHRP Report 716, Table 4.8 Coefficients from survey of MPO mode choice models.

Mode specific constants are then used to calibrate the PACOG mode choice model to fit local conditions. During the calibration process, unique mode specific constants were initially borrowed from a recently completed model for the Flagstaff Arizona MPO, by trip purpose. Then the initial constant settings were adjusted using a heuristic process whereby the full set of constants was factored until the PACOG model produced the correct total transit system boardings. In the future, if observed mode shares by purpose becomes available via a new household travel survey, then these constants can be re-estimated to match observed mode shares by trip purpose. Mode Choice model parameters used in the PACOG model are listed below in **Table 42**.

[24] National Cooperative Highway Research Program (NCHRP) Report 716: Travel Demand Forecasting: Parameters and Techniques, January 2014, accessed November 2023.

Table 42: PACOG Mode Choice Model Parameters

HBW1 – Home-Based Work, Income Quartile 1

NEST	AUTO		
MODE	DA	SR	BUS
Coeff. INVIT	-0.0210	-0.0210	-0.0210
Coef. IWAIT			-0.0980
Coef. WALKT			-0.0540
Coef. TFRT			-0.0980
Constant	0.0000	-2.6000	-0.5000

HBSE – Home-Based Elementary School

NEST	AUTO		
MODE	DA	SR	BUS
Coeff. INVIT	-0.0250	-0.0250	-0.0250
Coef. IWAIT			-0.0375
Coef. WALKT			-0.0540
Coef. TFRT			-0.0375
Constant	-99.0000	0.0000	-2.6000

HBO – Home-Based Other

NEST	AUTO		
MODE	DA	SR	BUS
Coeff. INVIT	-0.0250	-0.0250	-0.0250
Coef. IWAIT			-0.0375
Coef. WALKT			-0.0540
Coef. TFRT			-0.0375
Constant	0.0000	-0.1500	-2.8000

HBW2 – Home-Based Work, Income Quartile 2

NEST	AUTO		
MODE	DA	SR	BUS
Coeff. INVIT	-0.0210	-0.0210	-0.0210
Coef. IWAIT			-0.0980
Coef. WALKT			-0.0540
Coef. TFRT			-0.0980
Constant	0.0000	-2.6000	-0.6000

HBSS – Home-Based Secondary School

NEST	AUTO		
MODE	DA	SR	BUS
Coeff. INVIT	-0.0250	-0.0250	-0.0250
Coef. IWAIT			-0.0375
Coef. WALKT			-0.0540
Coef. TFRT			-0.0375
Constant	0.0000	0.0000	-1.9000

NHBW – Non-Home-Based, Work Related

NEST	AUTO		
MODE	DA	SR	BUS
Coeff. INVIT	-0.0250	-0.0250	-0.0250
Coef. IWAIT			-0.0375
Coef. WALKT			-0.0540
Coef. TFRT			-0.0375
Constant	0.0000	-3.0000	-4.2000

HBW3 – Home-Based Work, Income Quartile 3

NEST	AUTO		
MODE	DA	SR	BUS
Coeff. INVIT	-0.0210	-0.0210	-0.0210
Coef. IWAIT			-0.0980
Coef. WALKT			-0.0540
Coef. TFRT			-0.0980
Constant	0.0000	-2.9000	-0.7000

HBSH – Home-Based Shop

NEST	AUTO		
MODE	DA	SR	BUS
Coeff. INVIT	-0.0250	-0.0250	-0.0250
Coef. IWAIT			-0.0375
Coef. WALKT			-0.0540
Coef. TFRT			-0.0375
Constant	0.0000	-2.5000	-1.7000

NHBO – Non-Home-Based, Other

NEST	AUTO		
MODE	DA	SR	BUS
Coeff. INVIT	-0.0250	-0.0250	-0.0250
Coef. IWAIT			-0.0375
Coef. WALKT			-0.0540
Coef. TFRT			-0.0375
Constant	0.0000	-3.0000	-4.2000

HBW4 – Home-Based Work, Income Quartile 4

NEST	AUTO		
MODE	DA	SR	BUS
Coeff. INVIT	-0.0210	-0.0210	-0.0210
Coef. IWAIT			-0.0980
Coef. WALKT			-0.0540
Coef. TFRT			-0.0980
Constant	0.0000	-3.2000	-1.0000

HBSU – Home-Based University

NEST	AUTO		
MODE	DA	SR	BUS
Coeff. INVIT	-0.0250	-0.0250	-0.0250
Coef. IWAIT			-0.0375
Coef. WALKT			-0.0540
Coef. TFRT			-0.0375
Constant	0.0000	-0.5000	-1.5000

9.3 Mode Choice Model Implementation

The PACOG model applies the eleven individual mode choice models (one for each household trip purpose) via a model specification file. A visual of the mode choice structure showing the connectivity to the skim matrices and matrix cores is shown in **Figure 22.**

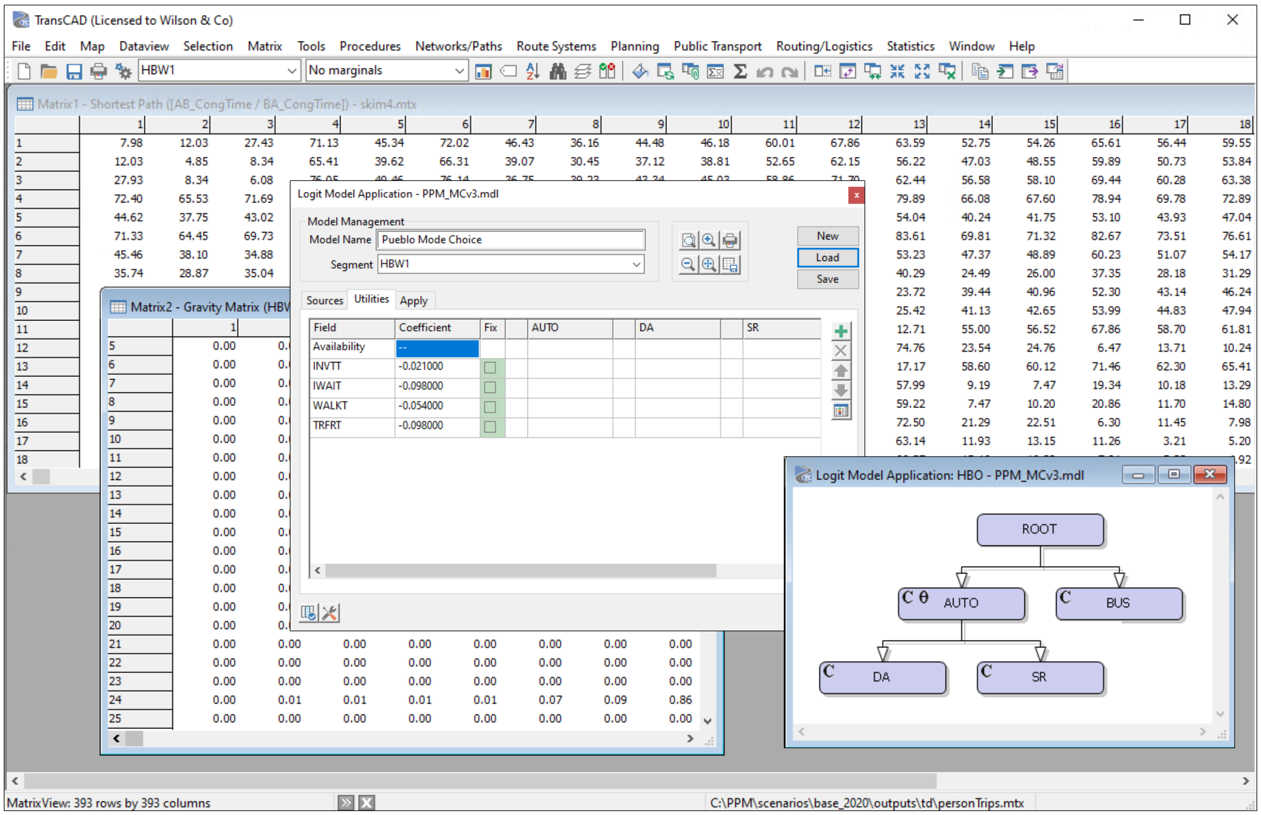

Figure 22: Viewing the Mode Choice Model Structure

9.4 Observed Mode Shares and Model Sensitivity

In addition to general base year mode choice calibration, the mode choice model's sensitivity to different scenarios was also evaluated to ensure that the model is appropriate for forecasting applications. For this, a full model run was conducted for an additional scenario:

- Year 2020 Base travel demand with base roadway network, and improved transit service with headways reduced to half of the current values (shorter wait time for bus). The results show a large increase in bus overall bus mode share, with a disproportionate share of the new riders shifting from drive alone work trips. However, the overall transit share is still under 1%. This is seen as a reasonable response.

The sensitivity results are summarized in **Table 43**.

Table 43: PACOG Mode Choice Sensitivity Test Report

Work Trip Purpose			
MODE -- >	AUTO		BUS
SCENARIO	DA	SR	
Base 2020	93,873	5,217	687
Transit Improvement 2020	92.749	5,142	1,888
Base 2020	94.1%	5.2%	0.7%
Transit Improvement 2020	93.0%	5.2%	1.9%
Non-Work Trip Purpose			
MODE -- >	AUTO		BUS
SCENARIO	DA	SR	
Base 2020	385,011	163,916	1,647
Transit Improvement 2020	384,364	163,438	2,773
Base 2020	66.9%	29.8%	0.3%
Transit Improvement 2020	69.8%	29.7%	0.5%
Total Trips			
MODE -- >	AUTO		BUS
SCENARIO	DA	SR	
Base 2020	478,884	169,133	2,334
Transit Improvement 2020	477,113	168,580	4,661
Base 2020	73.6%	26.0%	0.4%
Transit Improvement 2020	73.4%	25.9%	0.7%

9.5 Post Mode Choice Trip Processing

Auto mode outputs from the mode choice process, by trip purpose, are aggregated into a daily auto trip table. During this step, person trips designated as “auto-drive alone” or “auto-shared ride” are converted to vehicle trips. Drive alone trips are treated as one person per vehicle. Assumptions about persons per vehicle for Shared Ride trips varies by trip purpose as shown in **Table 44.**

Table 44: Shared Ride Persons per Vehicle

Purpose	HBW1	HBW2	HBW3	HBW4	HBSE	HBSS	HBSU	HBSH	HBO	NHBW	NHBO
Average Auto Occupancy	2.23	2.23	2.23	2.23	2.84	2.41	3.88	3.2	3.2	3.2	3.2

9.6 Time of Day Modeling and Directional Split Factors

The resulting vehicle trip matrix remains in production-attraction (PA) format. Next, the vehicle trips are converted from PA format to OD format using the time-of-day percentages. For each of the time periods (AM, PM, OP) the daily auto vehicle table is converted from PA to OD using the following time of day factors by trip purpose; see **Table 45**.

Table 45: Time of Day Factors by Trip Purpose

PURPOSE	AMO	AMI	PMO	PMI	OPO	OPI
HBW1	14.2%	0.5%	1.3%	11.8%	38.0%	34.1%
HBW2	14.2%	0.5%	1.3%	11.8%	38.0%	34.1%
HBW3	14.2%	0.5%	1.3%	11.8%	38.0%	34.1%
HBW4	14.2%	0.5%	1.3%	11.8%	38.0%	34.1%
HBSE	35.6%	0.0%	0.0%	4.0%	19.5%	40.9%
HBSS	41,6%	0.0%	1.0%	3.0%	17.8%	36.6%
HBSU	10.3%	1.7%	3.4%	3.4%	34.5%	46.6%
HBSH	1.9%	0.5%	3.9%	6.3%	39.1%	48.2%
HBO	9.5%	2.1%	3.5%	4.2%	37.7%	43.0%
NHBW	1.1%	5.4%	8.9%	1.3%	37.5%	45.8%
NHBO	6.8%		7.1%		86.1%	
SUT	10.0%		10.0%		80.0%	
MUT	10.0%		10.0%		80.0%	
EXT_AUTOS	10.0%		10.0%		80.0%	
EXT_SUT	6.1%		4.6%		89.4%	
EXT_MUT	6.1%		4.6%		89.4%	

During the am peak hour, 14.2 percent of the HBW trips occurred from home to work, and 0.5 percent occurred from work to home. In the pm peak hour, 1.3 percent of the trips were from home to work, and 11.8 percent of the trips were from work to home. During the off-peak 22 hours, the HBW directional split factors were 38.0 percent and 34.1 percent from home to work and work to home, respectively. The directional split factors for all trip purposes exhibit patterns and relationships that are supported by intuition and logic. Several examples of the temporal spread of trips are given in **Figure 23** through **Figure 27**.

The distribution of home-based work trips by time of day shown in **Figure 23** is characterized by a sharp high peak in the AM, another sharp, somewhat lower peak in the PM and a small but distinguishable peak during the midday.

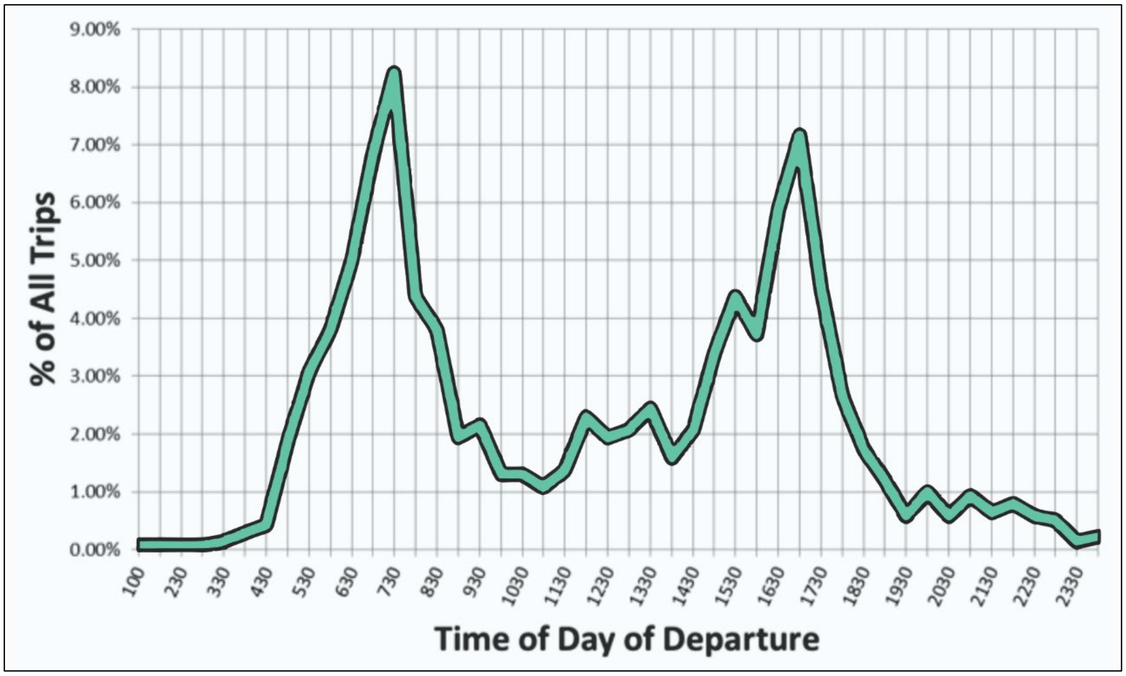

Figure 23: Home-Based Work Time of Day of Travel

The distribution of home-based shop trips by time of day, shown in **Figure 24** is a jagged line with an increasing trend that reaches a maximum in the PM before dropping off.

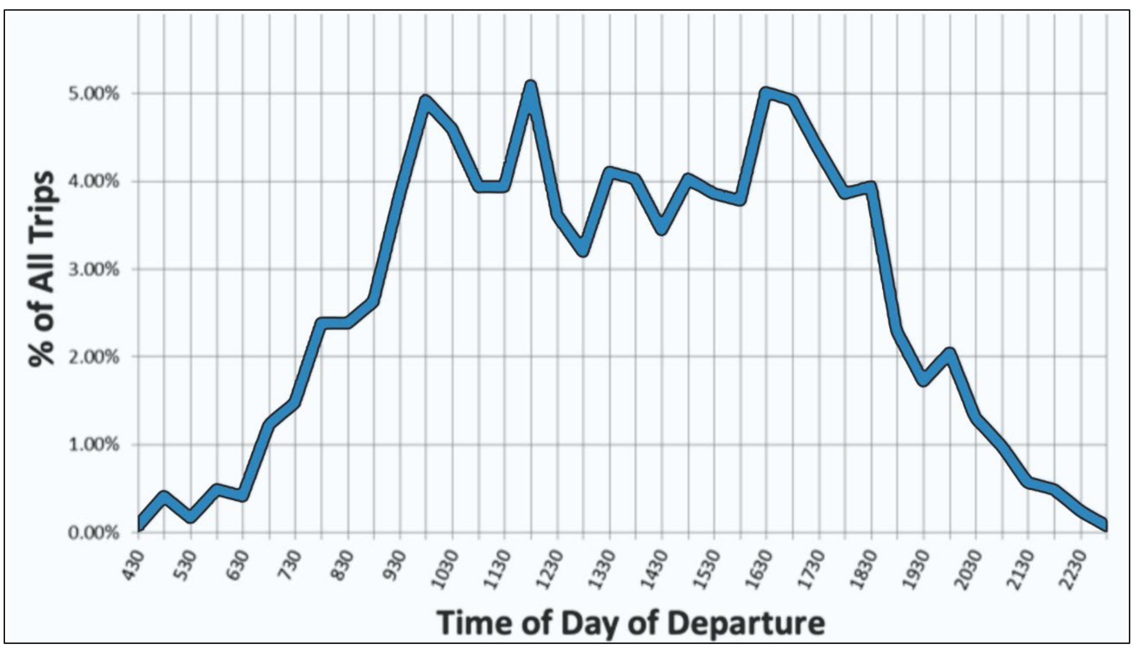

Figure 24: Home-Based Shop Time of Day of Travel

The Home-based other trips, plotted in **Figure 25** show that this purpose peaks sharply, reaching a maximum at approximately 7:30 AM. The distribution peaks again at approximately 3:00 PM.

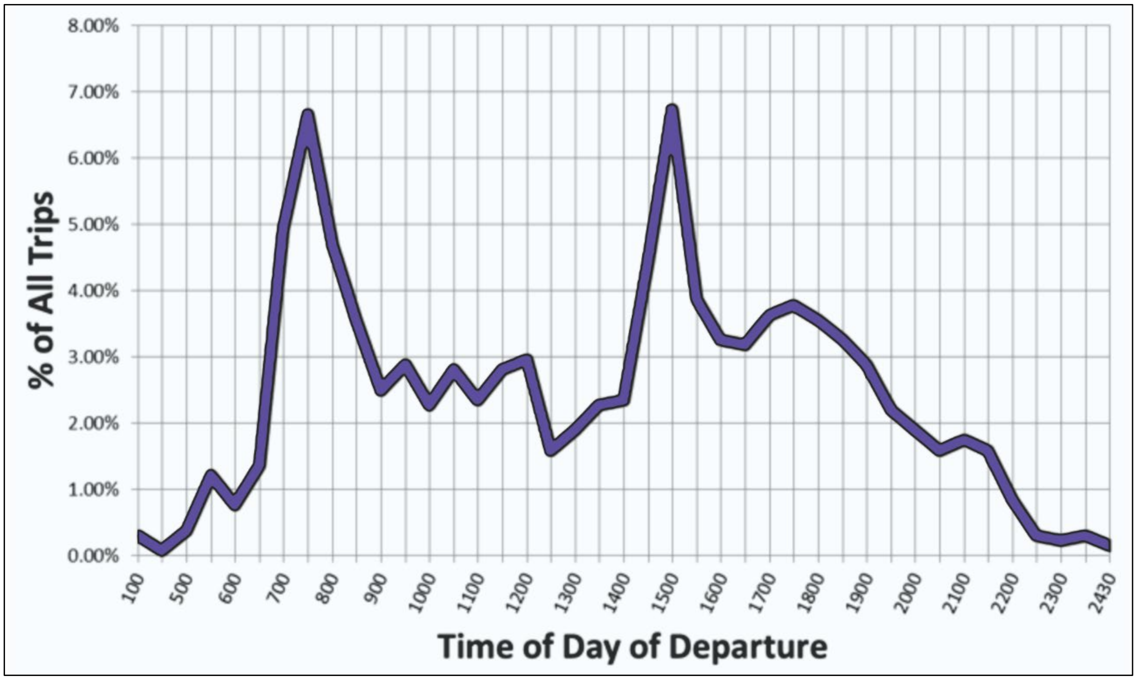

Figure 25: Home-Based Other Time of Day of Travel

The Non-Home-Based trips, shown in **Figure 26** have an early peak at about 7:30 am then maintain a continued presence throughout the day.

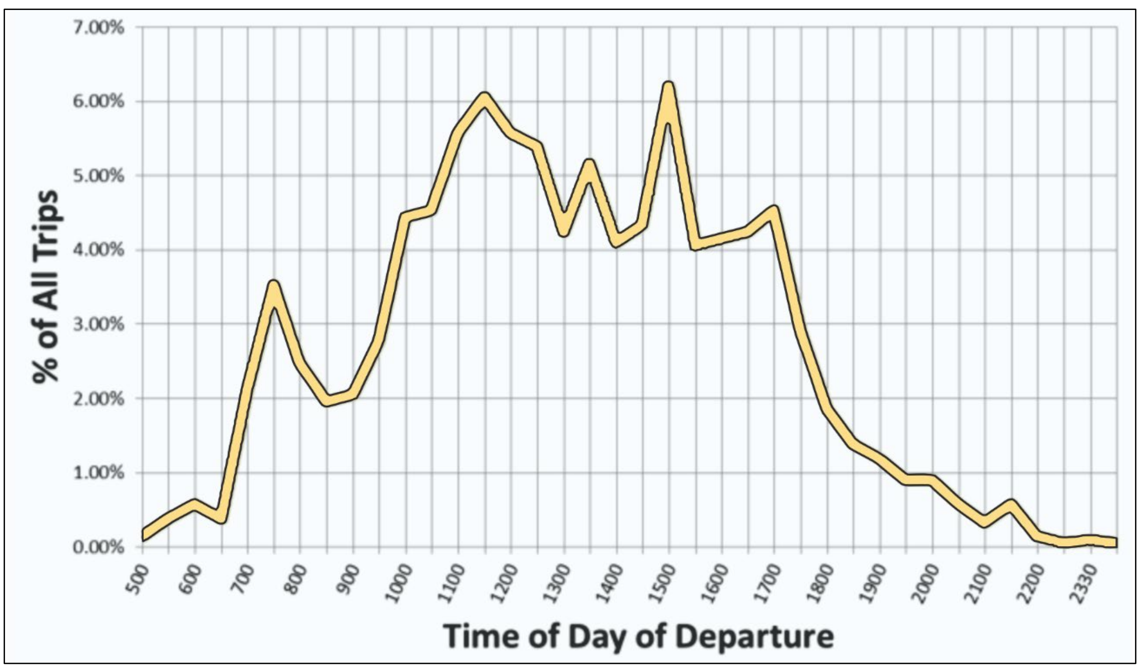

Figure 26: Non-Home-Based Time of Day of Travel

The distribution of all trips by time-of-day as a percentage of the sum of all trips for the 24-hour period is depicted in **Figure 27**.

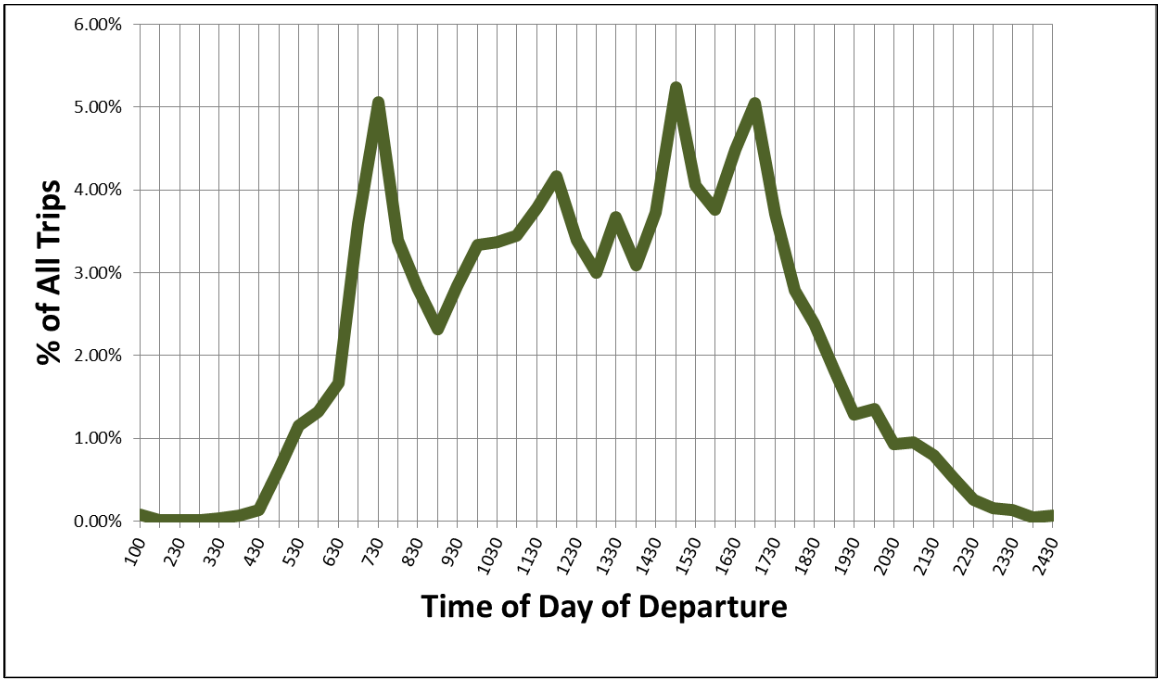

Figure 27: All Trips Time of Day of Travel

The trip tables produced at this point in the modeling process will be assigned to the highway and transit networks since they are now in origin-destination format. The trips have also been segmented by time of day. The results of the time-of-day factoring in vehicle trips for the 2020 validation run are shown in **Table 46.**

Table 46: Auto Vehicle Trips by Time of Day

Time of Day	Vehicle Trips
AM Peak Period Trips	48,365
PM Peak Period Trips	46,672
Off-Peak Period Trips	421,608

10 Highway and Transit Assignment Approach

10.1 Highway Assignment

The traffic assignment process runs for three time periods; am peak hour, pm peak hour, and off-peak hours. The capacity constrained assignment process uses TransCAD's multi-modal multi-class assignment with three vehicle classes, Auto and two truck classes (SUT and MUT). The assignment process is a user-equilibrium with time-period specific capacities and initial travel times pulled from the roadway attributes. Default alpha and beta parameters (0.15 and 4.0 respectively) are used in the volume-delay function. In addition, the volume-delay function uses a passenger car equivalent (PCE) of 1.5 for single unit trucks (SUT) and 2.5 for multi-unit trucks (MUT). The PCE adjustment is only used to determine the link travel time, and the actual SUT/MUT vehicle flow is reported later in the results. The assignment process runs through each of hundreds of iterations, and the volume-delay function computes a congested travel time that affects the shortest time paths used in the next iteration. As roads become congested, traffic diverts to other roadway paths until an equilibrium is achieved.

10.2 Transit Assignment

A daily transit route assignment is included with each model run. Transit assignment uses the daily bus trips from Mode Choice which have been afterward converted from PA to OD format. Transit network files and settings are identical to those set up during Transit Skimming. The daily transit assignment process results in the following outputs:

- Transit Ons and Offs – joins to the transit stops and shows boarding by stop. This file is used to aggregate boardings by route when the Transit Ridership report is requested from the user interface.
- Transit-Related Walk Flows – joins to the road network and shows walk flows resulting from the transit riders accessing/egressing transit.
- Transit Use on Road Network – joins to the road network and shows an aggregation of all person trips using transit on the road layer.
- Transit Flow by Route – joins to the transit route system and shows the number of people on each bus route between each pair of stops.

After a model run is completed for a given scenario, a transit ridership report can be generated from the Maps and Reports tab of the user interface. This report summarizes the total daily bus boardings in the system. Additional bus boarding results by line are provided in the 2020 base model scenario for validation purposes.

11 User Interface, GHG Analysis and Reporting

The PACOG model's original reporting capabilities were updated to work with the new components/updates. Several new reporting outputs were added under the Other Outputs section of the Graphical User Interface, namely:

- Mode Shares – summarizes modeled person trips by each mode and trip purpose into a single output table.
- Transit Ridership – summarizes transit assignment results into boarding by individual bus route and compares with observed boarding counts for the 2020 base and system totals for the future years.
- GHG Link Data – generates a comma delimited database that combines all highway assignment time period outputs for each link. This raw information can be converted for use in a MOVES (EPA air quality model) County Data Inventory run for greenhouse gas emissions.
- Trip Lengths – generates a trip length distribution chart and computes average trip length for each modeled trip purpose and truck type.

Guidance on the application of these reporting tools within the PACOG GUI are available in the "PACOG Travel Demand Model User Guide" prepared in 2024. Of note is the GHG sensitivity module designed to allow PACOG to test GHG reduction scenarios using Work from Home percentages, transit frequency and transit speed.

11.1 Greenhouse Gas Reduction Scenarios

As part of the greenhouse gas analysis capabilities, the PACOG Travel Demand Model user interface allows users to apply some general assumption changes impacting travel demand/mode choice which can be applied in special model scenario runs.

- Adjust Work from Home assumptions by each income quartile – If the model user changes from default values, then the net change is applied at the HBW trip generation step. This could be used to estimate the effects of employers requiring workers returning to in-person office jobs post-COVID. Increases in work from home can be modeled as well.
- Increase Transit Frequency – Allows model users to test the effectiveness of increased transit service via shorter wait times between buses. This is applied as a factor across all bus routes. For example, if the value is changed to 2, then buses would be twice as frequent. If a more complex scenario is desired, then the model user will need to create a separate Transit Route System with the characteristics to be tested (new route, itinerary, frequency and other).
- Improve Transit Speed – Allows model users to test the effectiveness of reducing transit travel times via various improvements (signal pre-emption, separated right of ways, improved boarding). In the model, this is accomplished by changing the In-Vehicle Travel Time (IVTT) encoded on each roadway link. The default setting is transit travel speed is 50% of the auto speed on a given road segment. If the user desires to increase the speed of transit service, then the value would be set to a value greater than 50%.

12 Daily Model Validation

12.1 Observed Traffic Data

Observed traffic in the form of Average Annual Daily Traffic (AADT) for years 2020 through 2023 was collected. The span of time during which the Covid-21 pandemic was active spanned the years 2020 through 2021+ rendering those years of limited use due to the observed suppressed traffic flow. Hence the decision was made to utilize 2022 and 2023 observed traffic to capture a realistic base year representing 2020. The AADT data was collected and stored in a GIS point file then transferred to the TransCAD model highway network for use in validation. Three parent files were used:

- Colorado DOT's Online Transportation Information System (OTIS)[25]
- Pueblo city traffic counts
- Pueblo County traffic counts

Truck traffic was obtained from OTIS site for both Single Unit (medium-sized) and Multi Unit (heavy or combination) trucks. Over 500 count locations from the three sources were processed for the project. The AADT values from 2020 through 2023 were reviewed for consistency with the established post Covid-21 base asserted to represent 2020. The final traffic data set was joined to prepare a count database that provided coverage throughout the PACOG region. **Figure 28** shows the locations of the traffic counts collected for the project.

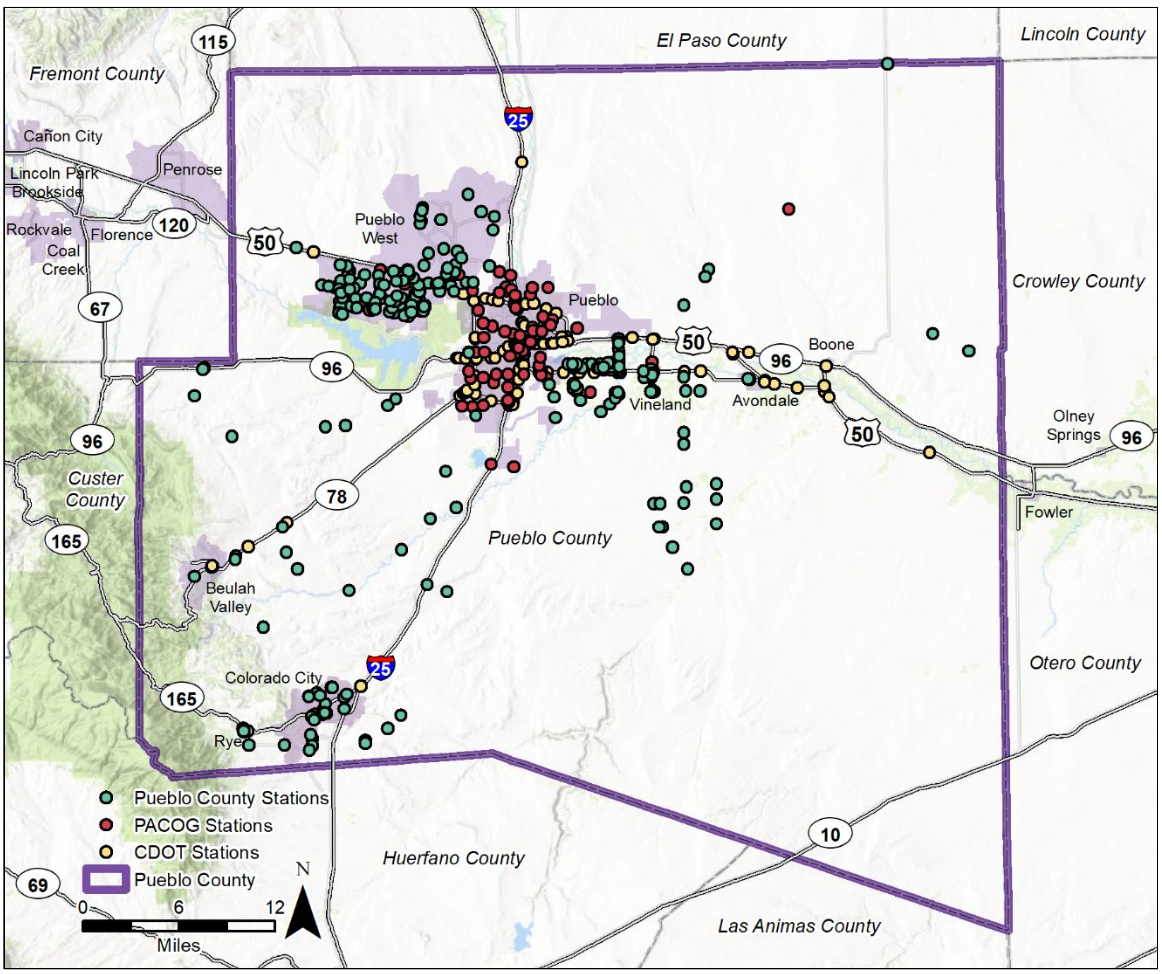

Figure 28: AADT Count Locations

25 *Online Transportation Information System (OTIS): https://dtdapps.coloradodot.info/otis, accessed December 2023.*

A comprehensive review of count values and locations provided a clean dataset for comparison with counts spread evenly throughout the county and across all functional classes of roadways. Care was taken to obtain multiple location counts on all major facilities such as I-25 and U.S. Highway 50. The count records were reviewed for consistency and to remove redundant records and entered as an attribute on the 2020 PACOG highway network file.

12.2 Validation Approach

12.2.1 Traffic Validation Link Categories

All validation was conducted using comparison of modeled to daily traffic. At the completion of the three time period traffic assignments: one-hour am peak, one-hour pm peak and 22 hours off-peak, the PACOG Travel Model time of day flows are summed into daily modeled traffic. This daily attribute includes both commercial vehicles (trucks) by two size classes, and autos from all time periods. The model daily traffic can then be compared to the observed base year AADT in different ways, measuring the goodness of fit across several summary categories. Three summary categories were selected for comparison:

Highway Functional Classification – Four highway functional classifications were identified: interstate, expressway, principal arterial, and minor arterial. Collectors, ramps, and centroid connectors are not included in this summary table.

Volume Range – Traffic counts can also be put into categories based on the volume ranges. This comparison allows the observed traffic itself to define a set of categories. For the PACOG model, volume ranges were established for every 10,000 AADT, except for the first two volume range bins which are 0-5,000, and 5,000 to 10,000 AADT. Ramps and centroid connectors are not included in this summary table.

Screenlines – Six screenlines were developed for the PACOG validation. Screenlines measure the regional traffic flows crossing selected roadways or natural features and provide a cross-check on regional traffic flows. As an example, the U.S. Highway 50 (West) screenline sums all the counts at locations crossing US Highway 50 from north to south and from south to north in the area west of Interstate-25.

12.2.2 Daily Highway Model Validation Tests

The following validation tests were performed on the PACOG Travel Demand Model traffic to validate the daily traffic assignment:

Observed and Modeled Traffic Flows Comparison – This test, which totals the observed and the modeled traffic using observed and counted link flows, is presented by functional classification, volume range, and screenline.

Percent Root Mean Square Error (% RMSE) – This test, which measures the absolute value of the difference between model volumes and observed traffic counts, is where the variability of the traffic counts is most evident. It is presented by functional classification, volume range, and screenline. If the model fit were perfect, the percent root mean square error would be zero; the lower the % RMSE value, the better the model fit.

Volume Range Scatter Plot – Volume range scatter plots are used as a test to provide a visual comparison of the difference between the observed and modeled traffic. Each point represents a traffic count and the model volume from assignment. When the data points conform to the diagonal where the y-axis (model) equals the x-axis (counts), the fit is exact.

12.3 Highway Model Validation Results

12.3.1 Validation by Facility Type

The first test of highway validation was conducted using the category of facility type. Four facility types were analyzed: Interstates, Expressways, Principal Arterials, and Minor Arterials. **Table 47** shows the validation results for these categories. Overall, the daily model flows were about 1% higher than the observed value. Interstates and expressways have a highly accurate percent difference (less than 1%), demonstrating a close fit to observed values on roads where traffic is heaviest. RMSE of 30 shows good fire of modeled to observed traffic.

Table 47: Traffic Validation by Facility Type

Facility Type	Facility Type ID	Number of Observations	Flow Comparison			% Root Mean Square Error
			Sum of Counts	Sum of Flows	% Difference	
Interstate	1	22	537,000	533,142	-0.7	11
Expressway	2	39	732,205	731,330	-0.1	26
Principal Arterial	3	66	927,746	949,910	2.4	35
Minor Arterial	4	20	148,828	158,842	6.7	69
Total		**147**	**2,345,779**	**2,373,223**	**1.2**	**30**

12.3.2 Validation by Volume Range

The second test of highway validation is that of volume range as shown in **Table 48**. Volume range operates by establishing intervals of observed values, usually by steps of 10,000 AADT and then using them as categories to compare modeled flows to observed. There are six volume range categories used in the PACOG model. The lowest two categories are subcategories: 0-5,000 and 5,000-10,000 AADT which were established to capture the volume range validation more readily on low traffic facilities.

Overall, the daily assigned volume was 1.2 percent higher than the observed value with a % RMSE of 30. The higher volume classes, 20,000 AADT and above, have the most accurate % RMSE, demonstrating a closer fit to observed values on the facilities where traffic is heaviest. The % Root Mean Square Error (RMSE) values of 30 or higher on segments of less than 10,000 AADT communicates that a large part of the model traffic variation is confined to the lower volume highway segments, which typically are more of a challenge to load evenly in assignment. Of note is the I-25 call-out with a -1% difference model to observed, and a % RMSE of 11 indicating a very close fit on this facility.

Table 48: Traffic Validation by Volume Range

Volume Range	Volume Range ID	Number of Observations	Flow Comparison			% Root Mean Square Error
			Sum of Counts	Sum of Flows	% Difference	
Less than 5,000	1	10	45,229	75,855	67.7	97
5,000-10,000	2	38	272,219	331,645	21.8	54
10,000-20,000	3	61	914,563	931,477	1.8	30
20,000-30,000	4	26	645,768	609,870	-5.6	21
30,000-40,000	5	7	245,000	227,861	-7.0	16
40,000-50,000	6	5	223,000	196,515	-11.9	20
Total		**147**	**2,345,779**	**2,373,223**	**1.2**	**30**
I-25	*special*	*22*	*537,000*	*533,142*	*-1*	*11*

12.3.3 Validation by Screenline

The six screenlines developed for the PACOG validation are shown in **Figure 29**. **Table 49** shows the traffic validation using the screen lines. The total of the six screenlines yielded crossing volumes about 1% below the observed total traffic summed from all locations. No screenlines were higher than plus or minus 14% of observed totals from the traffic assignment.

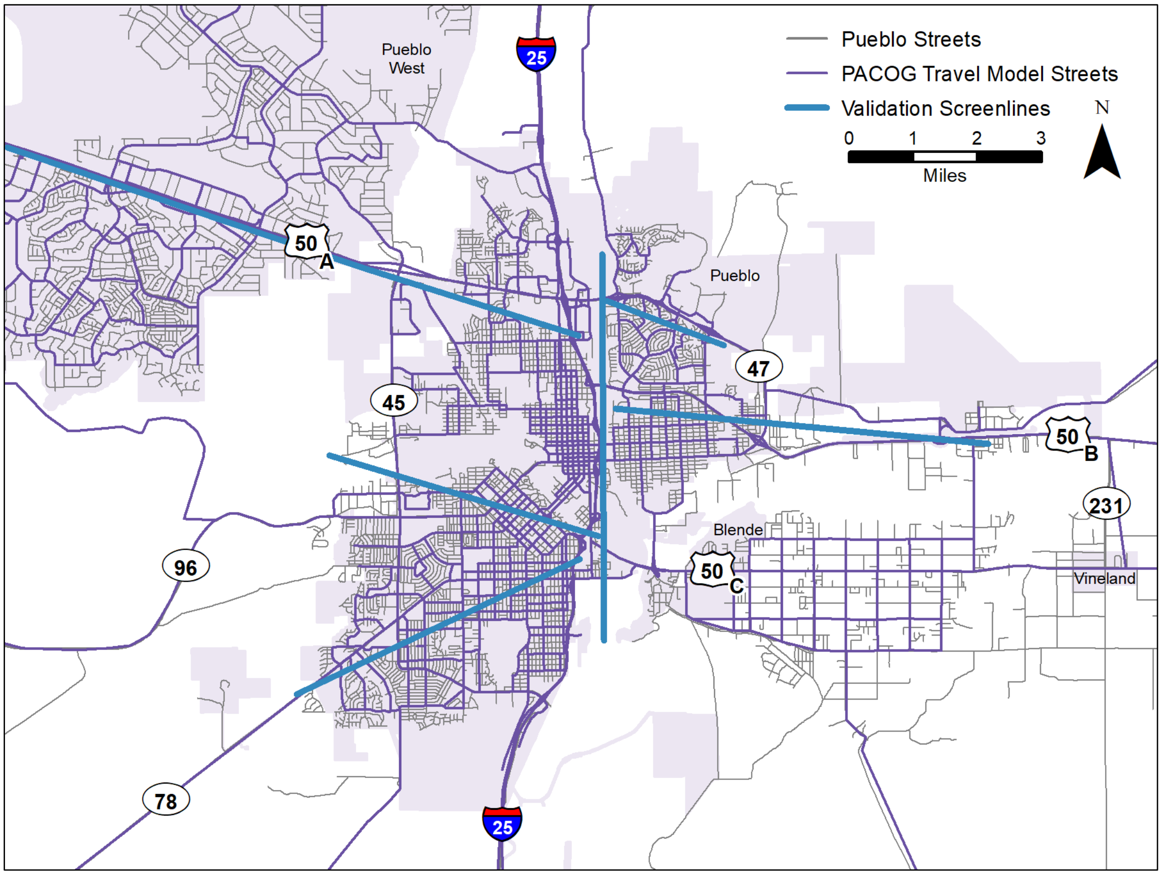

Figure 29: Location of PACOG Travel Model Screenlines

Table 49: Traffic Validation by Screenline

Screenline Name	ID	Number of Observations	Flow Comparison			% Root Mean Square Error
			Sum of Counts	Sum of Flows	% Difference	
N-S Fountain Creek	1	4	64,000	62,450	-2	26
E-W Arkansas River (west of town)	3	6	126,428	129,847	3	8
E-W parallel to CO 47, east of I-25	4	2	10,682	11,147	4	45
E-W, parallel to US 50, west of I-25	5	3	83,465	72,568	-13	14
E-W, parallel to US 50, east of I-25	6	5	36,542	41,674	14	56
E-W parallel to SH 78, southwest part of town	7	2	43,000	44,022	2	3
All Screenlines		**22**	**364,117**	**361,707**	**-1**	**20**

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12.3.4 Validation by Scatterplot

Figure 30 illustrates the comparison between observed and modeled traffic flow in scatterplot format for all PACOG Travel Model traffic counts (AADT) used for validation. This test shows a good fit of modeled to observed traffic with the data points generally following the diagonal line of x-axis equals y-axis.

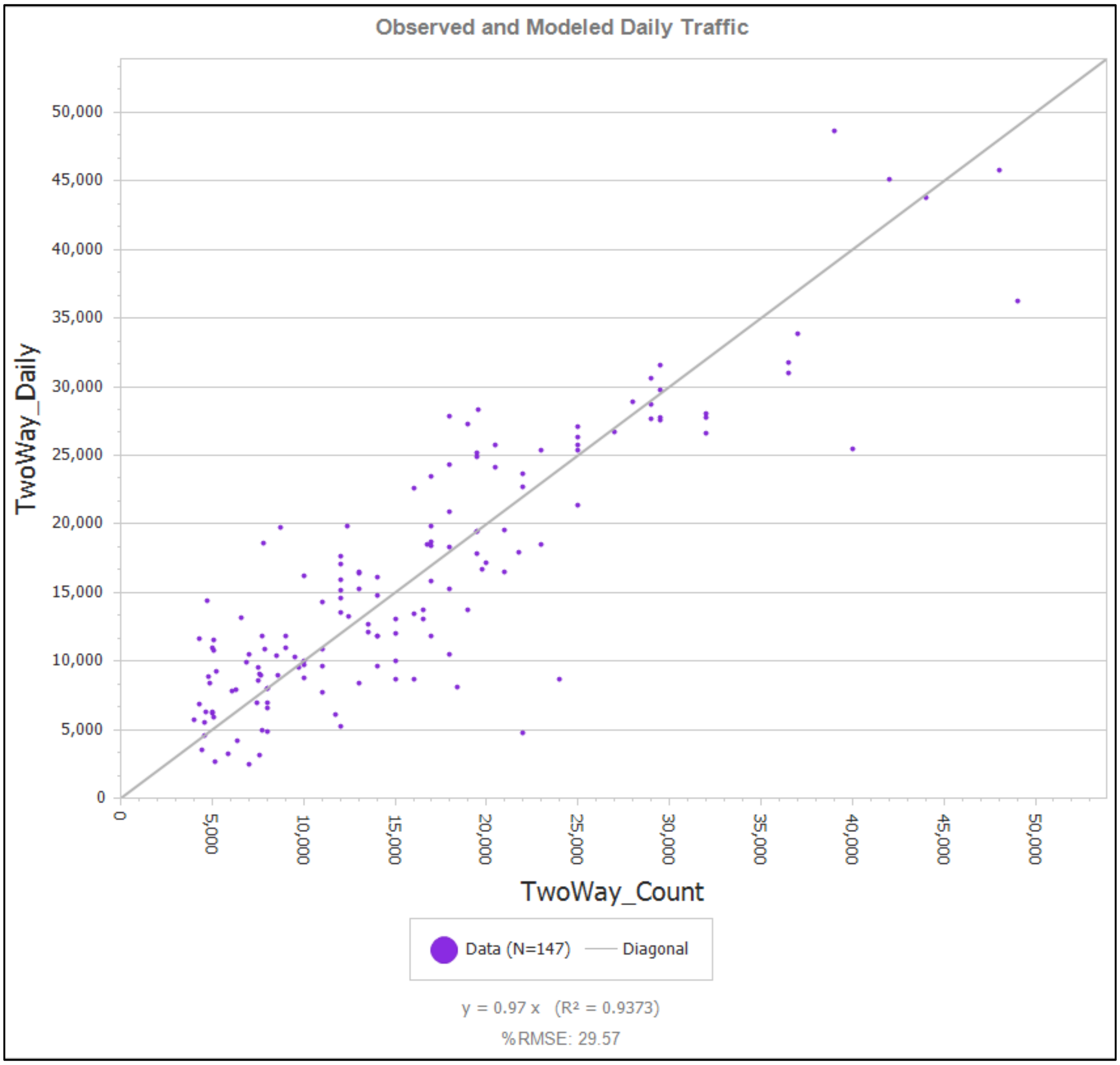

Figure 30: Scatterplot of all Counted Link Segments

12.3.5 Summary of Highway Validation

Three tests were run and on each, the 2020 PACOG Travel model performed well. With respect to relative difference over all counted link segments, an acceptable range within 10 percent (+/-) was set as a target for validation, consistent with standard practices and was exceeded with a 1.2% deviation delivered by the 2020 PACOG model. A Percent RMSE in the low thirties with descending values as the volume class increases is also a target which was met (see **Table 48**). Interstate-25, a key facility in the PACOG region with 22 segments analyzed, performed within 1% of modeled to observed traffic. The highway network 2020 count and model validation, including the review of the full set of model inputs, has yielded a validated 2020 base and a predictive future year travel demand model that is ready for application in the MPO environment.

Pueblo Area Council of Governments

Methodology Report

Appendix B. GHG Strategy Scenario Sensitivity Modeling

GHG CONFORMITY REPORT

PACOG MOVES THE REGION

2024 MODEL UPDATE

PACOG “Proof of Concept” Greenhouse Gas Conformity Report

“Proof of Concept” Demonstration of Conformity with the GHG Transportation Planning Standard

Prepared by: Wilson & Company
For: Pueblo Area Council of Governments

May 2025

Contents

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List of Abbreviations

Abbreviation	Term/Phrase/Name
APCD	Air Pollution Control Division
BY	Base Year
CCR	Code of Colorado Regulations
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CFR	Code of Federal Regulations
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
GHG	Greenhouse Gas
IACT	State Interagency Consultation Team South.
LRTP	Long Range Transportation Plan
MMT	Million Metric Tons
MOVES	MOtor Vehicle Emission Simulator Model
MPA	Metropolitan Planning Area
MPO	Metropolitan Planning Organization
PACOG	Pueblo Area Council of Governments.
PMT	Person Miles Traveled
PPM	Pueblo Planning Model
RTDM	Regional Travel Demand Model
RTP	Regional Transportation Plan
SIP	State Implementation Plan
SDO	State Demography Office
STIP	State Transportation Improvement Program
TAZ	Traffic Analysis Zone
TC	Transportation Commission
TDM	Transportation Demand Management
TIP	Transportation Improvement Program
TMA	Transportation Management Area
VHT	Vehicle Hours Traveled
VMT	Vehicle Miles Traveled
WFH	Work From Home

1 Purpose

This report documents the process to be used by the Pueblo Area Council of Governments (PACOG) to demonstrate conformity with Colorado's greenhouse gas (GHG) Transportation Planning Standard ("GHG Planning Standard"). For this "proof of concept" GHG Conformity Report, modeling of GHG emissions used the 2024 Pueblo Planning Model (PPM) Update for scenario years 2030, 2040 and 2050 as the "Baseline Plan." Calculation of GHG emissions for each of the modeled scenarios was completed by the Colorado Department of Health and Environment (CDPHE) Air Pollution Control Division (APCD) the using the Environmental Protection Agency's Motor Vehicle Emission Simulator (MOVES3) air quality model. The PACOG 2024 Travel Model Update was completed in 2024. The focus of the model update was the extension and enhancement of PACOG's PPM to better support the GHG conformity demonstration that is to be completed by PACOG in early 2026 as specified in Colorado Revised Statutes §43-4-1103 and the Code of Colorado Regulations (2 CCR 601-22, Section 8.02.5.1).

For this "proof of concept" GHG Conformity Report, the "Updated Plan," a surrogate for the 2050 LRTP that PACOG will adopt in 2026, was developed through an iterative process much like the process that PACOG will use to develop the actual 2050 LRTP. Because PACOG does not plan to rely on GHG Mitigation Measures to demonstrate compliance with the GHG Planning Standard, this "proof of concept" GHG Conformity Report does not include a Mitigation Action Plan (MAP).

The analysis and modeling results documented herein are based on analysis of all trips. Travel modeling was conducted by PACOG. GHG emissions calculations for each modeled scenario using a MS Access Database tool that was developed and validated by APCD. The PACOG MS Access Database tool was developed by APCD for PACOG and was supported by emissions rates developed using the Environmental Protection Agency's (EPA's) Motor Vehicle Emission Simulator (MOVES3) air quality model.

APCD used MOVES3 modeling as input to MS Access Databases that were developed for each of the five Colorado MPOs and CDOT. APCD also post-processed of travel model GHG link data and traffic ground counts provided by CDOT and the MPOs, and then assessed and validated the MS Access Database GHG emissions calculator tool, using "Baseline Plan" scenarios and first-pass "Updated Plan" (Action) scenarios provided by the MPOs or CDOT.

This report is not the official 2050 LRTP planning cycle GHG Transportation Report. Rather, this report is intended to serve as a template for the PACOG 2050 LRTP GHG Transportation Report to be approved by the Colorado Transportation Commission in February of 2026.

2 Background

In 2021, SB21-260: Sustainability of the Transportation System was enacted. The bill, which substantially increases funding for transportation, also required the Colorado Transportation Commission (TC) to adopt the implementing guidelines and procedures for addressing GHG emissions in transportation planning. In December 2021, the TC adopted revisions to the statewide transportation planning rules to incorporate a new GHG Planning Standard to address the GHG requirements in SB21-260.

The GHG Planning Standard requires the Colorado Department of Transportation (CDOT) and the Metropolitan Planning Organizations (MPOs) in Colorado to determine the amount of GHG emissions from transportation projects included in transportation plans and to take steps to reduce GHG emissions relative to estimated emissions resulting from Baseline Plans. Baseline Plans are defined as the plans in place at the time the GHG Planning Standard became effective on January 30, 2022. Because PACOG is not required to demonstrate conformity with the GHG Planning Standard until 2026, their applicable Baseline Plan is the adopted 2025 Long Range Transportation Plan (LRTP) and their Plan Update and supporting interim year implementation programs (e.g., TIP, !0-Year CIP) will be the 2050 Long Range Transportation and its supporting implementation programs. The adopted 2045 LRTP and supporting TIP and 10-Year Plan can be accessed at: https://www.pacog.net/mpodocs.

The PACOG is the MPO for the Pueblo Area Council of Governments Planning Area which includes Pueblo County. The PACOG Planning Area and smaller Pueblo Urban Area Boundary are as shown in **Figure 1** on the following page. The Pueblo Planning Model coverage/extents include all of Pueblo County.

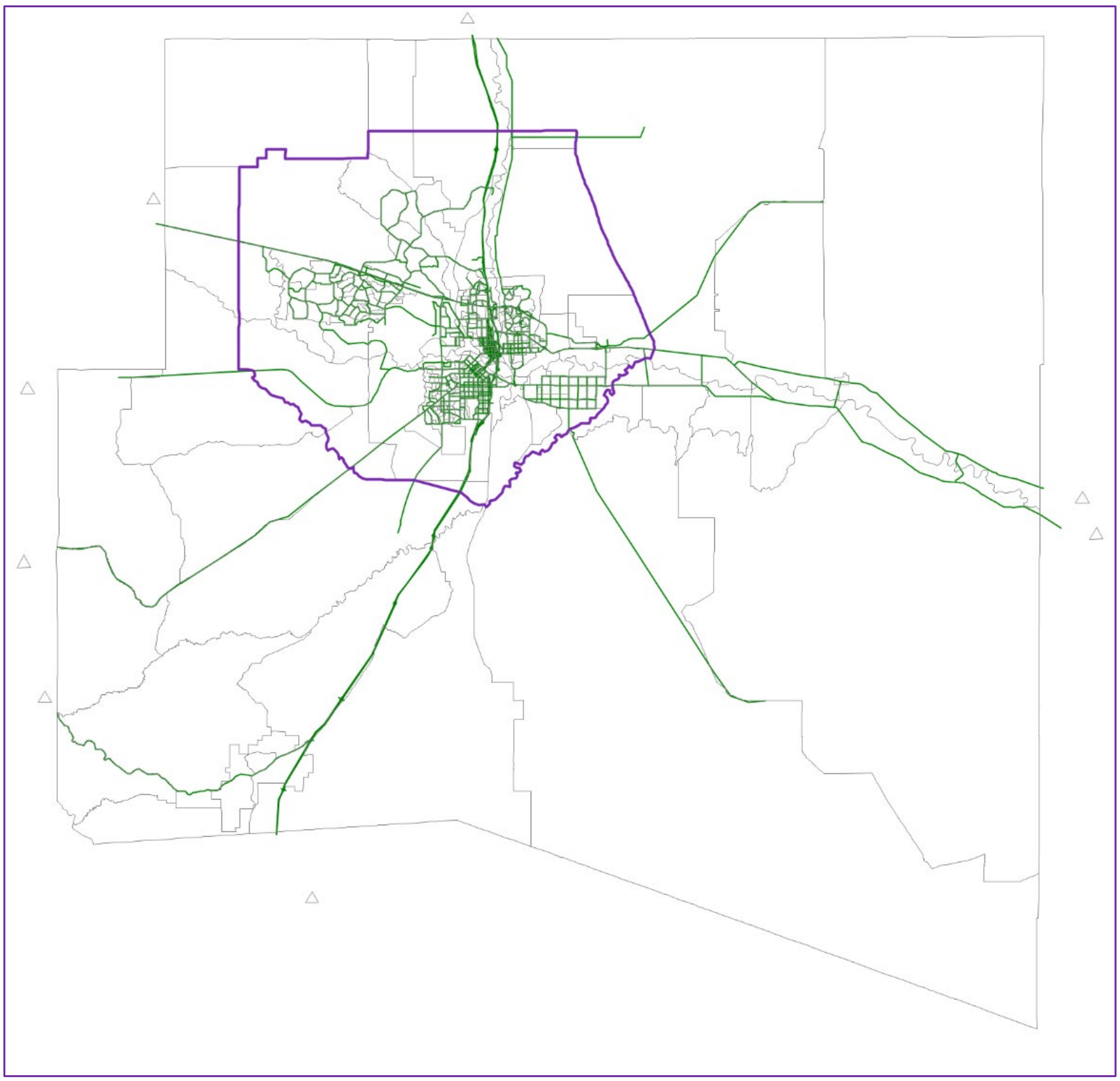

Figure 1: PACOG Model Extents and Urban Area Boundary

The Baseline Plan that was used for 2030, 2040 and 2050 reference scenarios for this GHG modeling and analysis exercise are based on the adopted PACOG 2045 LRTP. The PACOG 2045 LRTP was adopted by the PACOG Board in April of 2021.

For purposes of this “proof of concept” GHG Transportation Report, the adopted 2045 LRTP is referred to as the Baseline Plan. The 2024 Travel Model Update version of the PPM that was validated for a 2022 base year scenario was used to develop both Baseline Plan and Updated Plan scenarios for GHG analysis. The Baseline Plan scenarios represent the adopted 2045 LRTP and supporting Transportation Improvement Program (TIP) and 10-Year Plan. The Updated Plan scenarios were developed for 2030, 2040 and 2050 analysis years using the 2024 Travel Model Update version of the PPM and its on-board GHG Scenario Builder to iteratively evaluate GHG/VMT reduction strategies to achieve GHG emissions reduction target for the 2030, 2040 and 2050 planning horizons.

An Intergovernmental Agreement (IGA) will be developed by CDOT, the Pueblo MPO (PACOG),and the Air Pollution Control Division (APCD) of the Colorado Department of Public Health and Environment (CDPHE) and once completed it will be included in Appendix A of the official GHG Report for the PACOG 2050 LRTP. The IGA will identify the roles and responsibilities of each agency for model execution and address modeling assumptions for compliance demonstrations for the GHG Planning Standard.

The PPM modeling extents include all of Pueblo County. This “proof of concept” GHG conformity demonstration is for the area within the Pueblo Urban Area boundary the comprises the MPO planning area. The PACOG travel model update and validation report, *2024 Model Update/Validation Pueblo Planning Model Methodology Report* (June 2024). A separate technical memorandum, *Modeling Methodology for Non-Motorized GHG Strategy* (April 2025), describes updates to the GHG Scenario Builder to generate Esri shapefile GHG link data output from model runs and to model increases in non-motorized mode share. Both documents were reviewed by CDOT to confirm the suitability of the 2024 Model Update version of the PPM for GHG modeling.

3 Greenhouse Gas (GHG) Emissions Analysis

The “proof of concept” GHG emissions analysis documented by this GHG Transportation Report utilized 2030, 2040 and 2050 scenarios based on the adopted PACOG fiscally constrained 2045 LRTP as the Baseline Plan and a prototype 2050 RTP as the Updated Plan. Only highway/streets and transit improvements included in the 2030, 2040 and 2050 Baseline Plan network scenarios.

As a starting point for developing Updated Plan scenarios for 2030, 2040 and 2050 highway and transit systems improvement projects that had advanced to “funded” status since adoption of the 2045 LRTP, either supported by state/federal funding, grants, or private investment, were added to Baseline Plan network scenarios for 2030, 2040 and 2050. With these networks as the foundational (Action1 Scenario) for Updated Plan 2030, 2040 and 2050 scenarios, policy and operational GHG reduction strategies were iteratively applied at varying levels and in various combinations to achieve “proof of concept” GHG emissions reductions.

The final Updated Plan (Action8 Scenario) scenarios include roadway and transit improvement projects that were "funded" since adoption of the 2045 LRTP plus multi-strategy packages of policies and operational improvements that support mode shift from travel by automobile to travel by active transportation and/or transit modes. The analysis results demonstrated "proof of concept" the "GHG Reduction Levels" established for the PACOG in the GHG Planning Standard for all three compliance years.

GHG emissions for the 2045 LRTP Baseline Plan (Base) and final Updated Plan (Action8) scenarios are shown in **Table 1** for each of the three compliance years: 2030, 2040, and 2050.

Table 2: GHG Emissions Results, Million Metric Tons (MMT) per Year

	2030	2040	2050
Baseline Plan	0.48	0.30	0.17
Updated Plan	0.44	0.27	0.16
GHG Emissions Reduction (Baseline Plan- Update Plan)	0.04	0.03	0.01
Required GHG Reduction Level	0.03	0.02	0.01
Pass/Fail	**PASS**	**PASS**	**PASS**

4 Baseline and Updated Plan Descriptions

4.1 Baseline Plan Description

The GHG analysis of the Baseline Plan includes the roadway, transit, and active transportation (non-motorized modes) facility improvements identified in the adopted 2045 Long Range Transportation Plan (LRTP). The 2045 RTP identified major capacity projects, including regionally significant roadway and transit capacity expansion, which are fiscally constrained and planned for the region through 2045. Each of these major capacity projects are identified in maps and tables included in Chapter 9, Sections 9.2, 9.3, and 9.4 of the 2045 LRTP.

As part of the 2024 Update of the Pueblo Planning Model (PPM), a new scenario was built for 2030. For purposes on this "proof of concept' GHG conformity demonstration, it assumed that for the Baseline Plan no projects would be added between 2045 and 2050.

Working from the supporting 2021-2023 TIP and 10-Year CIP associated with the PACOG 2045 LRTP, and considering anticipated year of completion, Baseline Plan projects were assigned to one of three staging periods, including 2021-2030, 2031-2040, and 2041-2050.

Baseline Plan Highway/Streets and Non-Motorized Projects - 2021-2030 Staging Period
Twenty-two funded highway/streets and nonmotorized facilities projects from the 2021-2023 TIP were assigned to the earliest staging period. The locations of these projects are shown below, in **Figure 2**. **Table 2**, on the following page, lists the 2021-2023 TIP projects along with associated funding sources and levels.

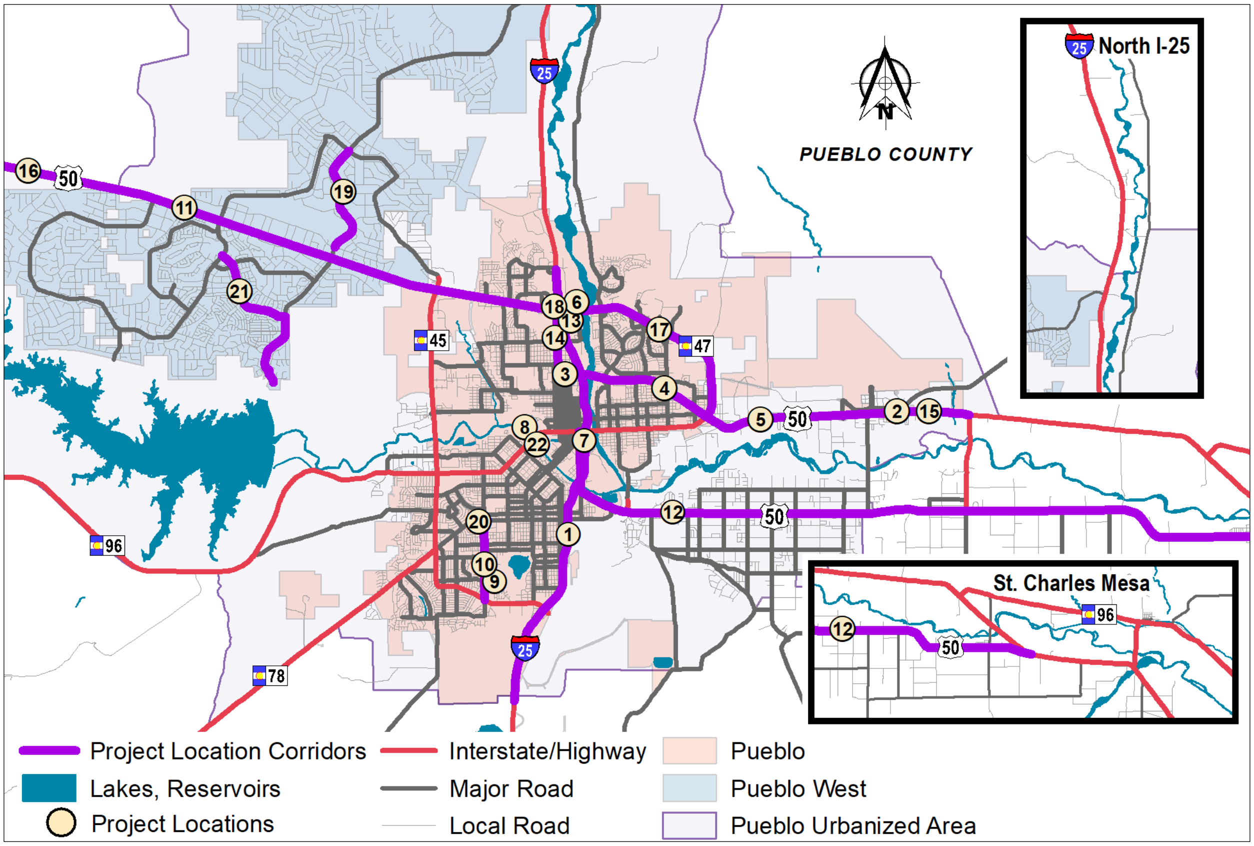

Figure 2: Transportation Improvement Program (2021- 2024) Project Locations

Table 2: 2021 - 2024 Transportation Improvement Program Projects by Funding Year

ID#	Funding Program	Project	2021	Rolled	2022	2023	2024	4 Year Total
1	Regional Priority Program (RPP); Senate Bill 1 Sales & Use Tax (SB1)	I-25 through Pueblo	$2,750,000	$978,633				$3,728,633
2	Construction Wall Program (CWP)	U.S. 50B Mill and Overlay I25 to 36th Lane	$847,674		$436,987	$93,339		$,378.000
3	Curb Ramp Upgrades to ADA Compliance (ADA)	ADA Improvements in the Pueblo TPR Area	$939,273		$410,889			$1,350,162
4	Construction Bridge Program (CBP)	U.S. 50 Scour Critical Counter Measures K-18-BY, BZ	$541,160					$541,160
5	Construction Bridge Program (CBP)	U.S. 50B - I 25 to 26th Lane	$422,608			$1,655,285		$2,077,893
6	Bridge Off Systems (BRO)	S Pueblo-PURHAR-0.1 FRNT	$523,377					$523,377
7	Multi-Modal Options (MMO); TAP - Region (TAP)	Santa Fe Ave Streetscape Ph 1B - 1st Street and I-25		$261,349				$261,349
8	Multi-Modal Options (MMO); TAP - Region (TAP)	Arkansas River Trail Phase 4		$970,618				$970,618
9	TAP - Region (TAP); Multi-Modal Options (MMO)	Minnequa Lake Trail Connection	$194,000	$194,000				$388,000
10	Multi-Modal Options (MMO)	City of Pueblo Prairie Avenue MM upgrades		$1,300,000				$1,300,000
11	Regional Priority Program (RPP)	U.S. 50 West	$1,469,963					$1,469,963
12	Regional Priority Program (RPP); Surface Treatment (SUR)	U.S. 50C Drainage Improvements	$1,710,922					$1,710,922
13	Regional Priority Program (RPP)	I-25 Dillon Frontage Road			$1,200,000	$3,000,000		$4,200,000
14	Surface Treatment (SUR)	Elizabeth-U.S. 50 to Ridge Drive	$1,440,000		$160,000			$1,600,000
15	Surface Treatment (SUR)	U.S. 50B mill and overlay I25 to 36th lane			$12,013,733	$4,839,200	$2,177,068	$19,030,001
16	Surface Treatment (SUR)	U.S. 50A Pueblo County Line to West of Purcell Blvd					$13,340,700	$13,340,700
17	Surface Treatment (SUR)	SH 47A Preventative Maintenance					$1,372,500	$1,372,500
18	Surface Treatment (SUR)	I-25 and US 50 B Interchange					$161,732	$161,732
19	TAP - Region (TAP)	Pueblo West-SDS Trail N Park		$513,176				$513,176
20	TAP - Region (TAP)	City of Pueblo Northern Avenue Phase 3		$625,000				$625,000
21	TAP - Region (TAP)	Joe Martinez Trail in Pueblo West		$671,294	$410,447			$1,081,741
22	TAP - Region (TAP)	Arkansas Levee Construction		$634,328				$634,328
Total Cost			**$10,839,047**	**$6,148,398**	**$14,632,056**	**$9,587,824**	**$17,052,000**	**$58,259,325**

Seven projects highway/street projects included in the 2045 Fiscally Constrained LRTP 10-Year were also assigned to the earliest staging period. These projects are in **Table 3**, along with 2020 total cost estimates. The table includes a note that project funding earmarked for the projects is nearly twice the estimated total cost in 2020 dollars.

Table 3: 2045 Fiscally Constrained LRTP 10-Year CIP Projects (2025-2030)

ID/#	Project	From	To	2020 Total Cost
23	SH 96A West of Pueblo - Shoulder Widening, Bridge Rail Replacement, Bike Lane, and Other Safety Improvements	West of Pueblo		$11,500,000
24	I-25 Improvements	North of 13th St	North of U.S. Highway 50B	$28,000,000*
25	SH 47 four (4) Lane Extension to US50B (Approximately .5 Mile) Interchange Improvements	13th St	U.S. Highway 50B	$8,000,000
26	I-25 Exit 108 Replace Single Box Covert	MP 107.5 South of Exit 108	MP 108.5 North of Exit 108	$11,000,000
27	U.S. Highway 50C Drainage Improvements	1 Block East of 36th Lane	1 Block West of 36th Lane	$5,500,000
28	SH 45 North Extension Study	U.S. Highway 50A	Interstate-25 at Exit 108	$1,000,000
29	Dillon Drive E. of I-25 Frontage Road Construct a New 2-Lane Facility; In Addition, Construct a Roundabout at Exit 104 West of I-25	MP 104.5 South of Platteville Blvd	MP 104.5 N. of Platteville Blvd	$3,000,000
			Total Cost	**$68,000,000.00**

*Project funding includes $60 M SB267, $3.4 M Surface Treatment, $6.6 M Faster Safety, $30 M Bridge for a Total of S128,000,000 M

Baseline Plan Transit Projects - 2021-2030 Staging Period

Committed transit funding is identified in the 2020-2023 Transportation Improvement Program. Funding in the FTA-5307 Small Urban Transit category is earmarked to support Pueblo Transit fixed route services. Funding in the FTA-5310 category is earmarked to support specialized transportation services for seniors and individuals with disabilities. Funding in the FTA-5311 Rural Area Formula Grants category is earmarked for transit services to areas outside of the Urbanized Area. FASTER funds provided additional transit enhancement projects.

The adopted 2020-2023 Transportation Improvement Program (TIP) included no transit service expansion projects. Capital expenditure was limited to vehicle replacement. Remaining funding was dedicated to supporting maintenance and operations. Transit investments included in the first three years of the Baseline Plan 2021-2030 Staging Period for the are listed by Program Category, Funding Program and Funding Source below in **Table 4**.

For the remainder of the Baseline Plan 2021-2030 Staging Period (2024-2030), it was assumed that operating and maintenance levels would be maintained at levels needed to support the existing urban and rural transit service.

Table 4: Transit Operating Funding (2020-2023)

Program Category	Funding Program	Fund Source	SFY 2020	SFY 2021	SFY 2022	SFY 2023	4- Year Funding Total
Small Urban Transit	FTA - 5307	FTA	$2,092,862	$2,092,862	$2,092,862	$2,092,862	$8,371,448
		City of Pueblo	$1,418,933	$1,418,933	$1,418,933	$1,418,933	$5,675,732
Small Urban Transit Totals			$3,511,795	$3,511,795	$3,511,795	$3,511,795	$14,047,180
Enhanced Mobility of Seniors and Individuals with Disabilities	FTA - 5310 Admin & Operating	FTA	$84,269	$84,269	$84,269	$84,269	$337,076
		Local	$84,269	$84,269	$84,269	$84,269	$337,076
Enhanced Mobility Administration & Operating Totals			$168,538	$168,538	$168,538	$168,538	$674,152
Enhanced Mobility of Seniors and Individuals with Disabilities	FTA - 5310 Capital Projects-SRDA	FTA	$64,488	$56,623	$56,623	$56,623	$234,357
		Local	$16,372	$18,874	$18,874	$18,874	$72,994
Enhanced Mobility Capital Projects Totals			$80,860	$75,497	$75,497	$75,497	$307,351
Rural Area Formula Grants	FTA - 5311	FTA	$100,751	$100,751	$100,751	$100,751	$403,004
		Local	$28,843	$28,843	$28,843	$28,843	$115,372
Rural Area Formula Grants Totals			$129,594	$129,594	$129,594	$129,594	$518,376
Small Urbanized Capital Projects Vehicle Replacement of 35' Hybrid Vehicle	FTA - 5399	FTA	$544,800	TBD	TBD	TBD	$544,800
		Local	$136,200	TBD	TBD	TBD	$136,200
Small Urbanized Capital Projects Totals			$681,000	TBD	TBD	TBD	$681,000
ITS Project with FASTER Funds IT Equipment (Farebox & Mobile Ticketing)	FASTER	State	$233,600	TBD	TBD	TBD	$233,600
		Local	$58,400	TBD	TBD	TBD	$58,400
ITS Project with FASTER Funds Totals			$292,000	TBD	TBD	TBD	$292,000
Small Urbanized Capital Projects Replacement of three 30' vehicles	FTA - 5339	FTA	$158,436	TBD	TBD	TBD	$158,436
		Local	$39,609	TBD	TBD	TBD	$39,609
Small Urbanized Capital Projects Totals			**$198,045**	**TBD**	**TBD**	**TBD**	**$198,045**
Total Funding (2020-2023)			**$5,061,832**	**$3,885,424**	**$3,885,424**	**$3,885,424**	**$16,718,104**

Baseline Plan Highway/Streets and Non-Motorized Projects - 2031-2045 Staging Period
The adopted Fiscally Constrained 2045 LRTP grouped all projects that were anticipated to come online between 2031 and 2045 into a single staging period. The Baseline Plan scenarios for 2040 and 2050 include all of these projects that could be modeled directly or indirectly through their effects on mode shares. Examples of projects that could not be modeled are resurfacing and drainage improvement projects.

In addition to directly and indirectly modeled highway/streets and transit projects, existing and projected "no action" levels of Work from Home (WFH) participation (based on continuation of current policy and trends represented by ACS Journey to Work Survey data) and non-motorized travel mode shares were represented by the Baseline Plan for all GHG compliance year scenarios.

Table 5: 2045 Planning Horizon Funded Projects (Beyond 2030)

ID#	2015 Total Cost	From	To	2020 Total Coat
30	U.S. 50B (MP 332.1 and 333.9) (Continuous Left Lane where U.S. 50C and U.S. Highway 50B Meet)	Intersection of U.S. Highway 50C and U.S. Highway 50B		$2,000,000
31	US 50B Drainage Improvements	Pueblo	Granada	$30,000,000
32	Pueblo Boulevard - US 50 to Platteville Road	U.S. Highway 50 West	Railroad Crossing	$11,100,000
		Railroad Crossing	Eagleridge Blvd	$7,500,000
		Eagleridge Blvd	Drew Dix Blvd	$5,200,000
33	Pueblo Blvd Platteville Road to I-25 Exit 108	PHASE 2 OF CONSTRUCTION		
		Drew Dix Blvd	Railroad Crossing	$24,900,000
		Railroad Crossing	Purcell Blvd	$7,500,000
		Purcell Blvd/I-25 Interchange Improvements		$12,000,000
		Railroad Crossing		$7,300,000
34	U.S. 50B East at Troy to Pueblo Airport – Guardrail	Troy Ave	Pueblo Memorial Airport	$3,000,000
35	SH 78 at MP 20 & MP 28 Bridge Widening and Shoulder Widening	MP 20	MP 28	$4,000,000
36	U.S. Highway 50C Drainage Improvements	1 Block East of 36th Lane	1 Block West of 36th Lane	$5,500,000
37	Interstate-25	City Center (1st St)	13th St	$200,000,000
		U.S. 50B	North of 29th St	$62,000,000
38	US Highway 50A - Add 3rd Thru Lane on US 50A Eastbound & Westbound between Purcell Blvd & McCulloch Blvd. Construct a Grade-Separate Interchange at U.S. 50A/McCulloch. Improve the Median Safety and Intersections on U.S. 50A between McCulloch & Swallows Rd	Purcell Blvd	Swallows Road	$50,000,000
39	SH 78 - Raised Median between Bandera Parkway and Surfwood Lane with Intersection Improvements and Raised Median	Bandera Parkway	Surfwood Lane	$3,400,000
			Total Cost	**$435,400,000**

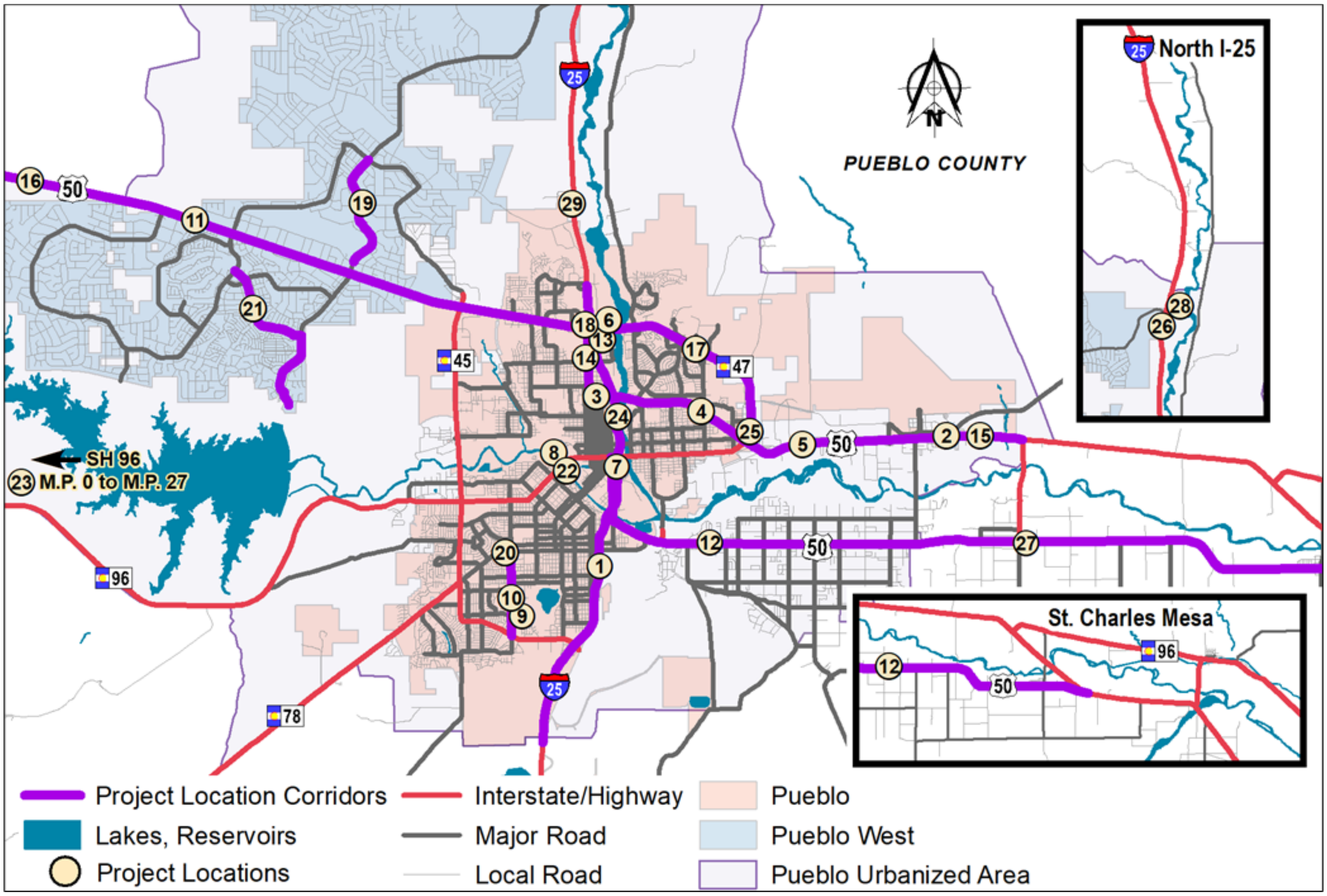

Figure 3: 2045 Planning Horizon Funded Projects (Beyond 2030)

4.2 Updated Plan Description

A “proof of concept” Updated Plan was identified through iterative scenario-based evaluation of GHG emissions for eight “Action”/Updated Plan scenarios. The base for all of the Updated Plan scenarios for 2030, 2040 and 2050 includes a set of transit and highway/streets projects that have advanced through varying levels of implementation since adoption of the PACOG 2045 LRTP, or that were identified by the 2045 LRTP Vision Plan. Thes projects represent connections or extension roadway and transit segments that had potential to reduce out of direction travel/VMT. These system extension/connection projects are listed in **Table 6**, along with the compliance year scenarios to which they were added.

Updated Plan Transit and Highway/Street Connection and Extension Projects
The extensions and connections listed in **Table 6** represent known development activity at the time that the PACOG 2045 LRTP. Since that time, Pueblo has adopted a new Comprehensive Plan and development activity has become more vigorous. In this context, new “projects” whether highway/streets connections and extensions or additional transit service/routes, which are not included in the fiscally constrained 2045 LRTP and the 2045 LRTP Vision Plan may be added. Additionally, “projects” included in this “proof of concept” Updated Plan may be replaced by alternative routing and/or may be renamed in the modeling for this “proof of concept” Updated Plan and GHG Transportation Report.

Table 6: Updated Plan Modeled Highway/Street and Transit Projects by Scenario Year

Category	Improvement	Scenario Year(s)
Fixed Route Transit	Shopping Shuttle Bus Route(s)	2030, 2040, 2050
Highway/Streets	Medal of Honor Blvd (Purcell Blvd-Pueblo Blvd)	2030, 2040, 2050
Highway/Streets	Drew/Dix Split Diamond Interchange	2030, 2040, 2050
Highway/Streets	Pueblo Blvd FR (Medal of Honor Blvd-Spaulding Ave)	2030, 2040, 2050
Highway/Streets	Spaulding Ave (31st St-24h St; Pueblo Blvd-Pueblo Blvd FR)	2030, 2040, 2050
Highway/Streets	Spaulding Ave (24th St-)	2040, 2050
Highway/Streets	24th St (Tuxedo Blvd-Atlanta Ave)	2040, 2050
Highway/Streets	Mc Carthy Blvd (CO96/ Thatcher Ave-CO78/ Northern Ave)	2040, 2050
Highway/Streets	Bandera Pkwy (CO96/Thatcher Ave-Siena Dr)	2040, 2050
Highway/Streets	Red Creek Springs Rd (Mc Carthy Blvd-Bandera Pkwy)	2040, 2050
Highway/Streets	Lehigh Ave ((Mc Carthy Blvd-Bandera Pkwy)	2040, 2050
Highway/Streets	Baltimore Ave (Kachina Dr-29th St)	2040, 2050
Highway/Streets	Spaulding Ave (31st St-11th St)	2040, 2050
Highway/Streets	18th St (Spaulding Ave-Perry Ave)	2040, 2050
Highway/Streets	Baker Stesmer Rd (Lowell Ave-24th St)	2050
Highway/Streets	Hollywood Dr Extension (Farabaugh Ln-Unnamed1 and Unnamed2)	2050
Highway/Streets	Little Burnt Mill Dr Connection (Rambo Trail-Salt Creek Crossing)	2050
Highway/Streets	Unnamed Loop1 Connection (Lake Ave-CO 78/Northern Ave)	2050
Highway/Streets	Bandera Pkwy (Bridal Trail-Unnamed Loop1)	2050
Highway/Streets	Bridal Trail Extension (Bandera Pkwy-Unnamed Loop1)	2050
Highway/Streets	Unnamed Loop2 (Unnamed Loop1-Little Burnt Mill Dr)	2050

Updated Plan TDM, Active Transportation and Transit Operations Strategies
The "proof of concept" Updated Plan GHG also includes commitments to expand non-motorized facilities, to implement transit operational improvements, and adopt policy-based TDM strategies to shift the mode share of trips made within the Pueblo Urban Area away from automobile trips. The specific strategies included in the "proof of concept" Updated Plan are summarized in **Table 7**.

Table 7: Updated Plan TDM, Active Transportation and Transit Operations Strategies

Category	TDM, Active Transportation and Transit Operational Strategy	Scenario Year(s)
Transit	Transit average speed increased to 65% of average auto speed	2030, 2040, 2050
Transit	Transit headways decreased by 23% (e.g., 60-minute headways decreased to 46-minute headways)	2030, 2040, 2050
TDM	WFH participation by income quartile increased to (10%,15%,30%, 30%)	2030, 2040, 2050
Active Transportation	Active transportation mode share for trips 5 miles or less in length increased 3.5% (trips shifted from automobile to non-motorized modes)	2030, 2040, 2050

4.3 Modeling Summary

Model Description and Process

The PACOG's travel demand model (TDM), the Pueblo Planning Model (PPM), was updated in 2024 to add key components to the model to support GHG analysis and demonstration of conformity with the GHG Planning Rule by PACOG. Key updates and new components of the 2024 Travel Model Update, fully documented in the *2024 Model Update/Validation Pueblo Planning Model Methodology Report*, included:

- **Extended Model Forecast Horizon** – The new modeling system extends the planning horizon to 2050, extending the model horizon an additional five years from the previous 2045 planning horizon. The model update also added interim year scenarios for 2030 and 2040 to the 2020 base year and 2050 planning horizon scenarios, with the 2050 planning horizon scenario replacing the 2025 Travel Model Update's 2045 planning horizon scenario in preparation for the 2050 LRTP planning cycle.
- **Updated Observed Traffic Data** – The model integrates 2020 traffic count data by auto, Single Unit (SUT) and Multi Unit (MUT) truck vehicle classifications.
- **Zone System Revisions** – Zonal coverage was changed to match CDOT's Traffic Analysis Zone (TAZ) structure to provide better geographic resolution, and consistency between the DOT and PACOG regarding base and forecast land use assumptions.
- **Zonal Data Update** – Socioeconomic data was updated for population, households, median income, and group quarters (2020 Census). Employment data updated using the 2020 Quarterly Census of Employment & Wages (QCEW), data obtained from the Colorado Dept. of Labor & Employment, including employment point data (2021). Trip generation disaggregation values, and trip distribution targets utilize the 2010 Pueblo Front Range Household Survey data. An updated statewide travel survey is in progress.
- **More Detailed Truck Vehicle Classes** – Previous versions of the model used Single Unit (SUT) and Multi Unit (MUT) trucks in trip generation and internal trip distribution but then collapsed this category into a generic truck category in later model steps. This version carries SUT and MUT classes through all model steps and outputs.
- **Transit Network/Model** –Transit routes, stops, and service characteristics are included in the PACOG model for the first time. The additional transit network information is used to support transit skimming used in Mode Choice modeling and later in transit assignments. Roadway network details and data attributes were expanded to support transit modeling as well.

- **Addition of Mode Choice Modeling** – This is a new model component that was added to improve the model's sensitivity to anticipated future scenarios. This component explicitly models individual choices related to traveling by auto and transit depending on trip purpose and characteristics of the journey to the destination location. Addition of the mode choice step significantly changed outputs and subsequent model steps related to Production-Attraction to Origin-Destination (PA-OD) conversion.
- **Expanded Traffic Assignment** – The PACOG model provides traffic flow outputs for AM and PM peak hours, the remaining 22 Off Peak hours, and daily totals. Outputs for vehicle classes are now split into Autos, SUT, and MUT. The process adds a Passenger Car Equivalent (PCE) methodology that accounts for the fact that trucks use more road capacity than autos. A daily transit route assignment is added as well, with transit outputs and reporting.
- **Updated User Interface, Analysis, and Reporting** – The PACOG model's original reporting capabilities were updated to work with the new components/updates. Several new reporting outputs were added to summarize mode choice and transit assignment results. Reporting capability now includes customized Greenhouse Gas (GHG) reporting/output. In accordance with guidance from CDOT and APCD at the time GHG output was formatted in comma separated variable (csv) format that could be readily imported to an Excel worksheet. The intent was to support input to MOVES GHG emissions calculations.
- **Addition of a GHG Scenario Builder** - A set of steps and processes were formalized in a GHG Scenario Builder. The GHG Scenario Builder allows PACOG technical staff to rapidly evaluate policy and operational GHG reduction strategies using their updated travel model for Greenhouse Gas (GHG) testing and subsequent processing using the PACOG MS Access Database GHG emissions calculator created by APCD. The 2024 Model Update GHG Scenario builder included three policy/operational tools to facilitate evaluation of Work from Home (WFH) participation by income quartile, increased transit service frequency (reduced headways), and increased transit operating speeds.

Following significant changes to the Colorado GHG modeling process that were put in place by the Statewide Modeling Coordination Groups (SMCG), the 2024 Travel Model Update version of the PPM was modified to generate Esri shapefile formatted GHG link data as the output of GHG analysis. This was done to facilitate APCD review, acceptance, and use as input (as table export in MS Excel format) to MS Access Database for model results processing to calculate total GHG emissions for the Baseline Plan and Updated Plan scenarios.

APCD, CDOT and PACOG were all involved in the development of PACOG-specific parameters implemented for the PACOG MS Access Database. APCD developed the supporting data and methodology that is/was used to disaggregate total vehicle assignments to HPMS vehicle types (based on classification count data). Methodology to disaggregate the PPM model assignment results (speeds and volumes) for the Off-Peak assignment period (22 hours) into 22 one-hour periods was developed jointly by PACOG and CDOT and accepted by APCD. The emission factors used by the MS Access database tool were developed by APCD using MOVES3.

Model Baseline Plan and Updated Plan Assumptions and Results

Key inputs and outputs from travel model runs for the Baseline Plan and the Updated Plan for each of the three compliance years for the respectively are provided in **Table 8** and **Table 9**. The data provided for each scenario and compliance year includes demographic data and travel forecasts for the full extents of the PACOG 2024 Update Travel Model, including all of Pueblo County. PACOG Urban Area, for which GHG emissions were calculated, is a subset of the larger PPM 2024 Model Update modeling extents. The demographic data is consistent with the State Demographer's Office (SDO) updated forecasts. The same demographic data was used for both the Baseline Plan and the Updated Plan for this "proof of concept" GHG analysis.

Table 8: PACOG Modeling Summary, Baseline Plan

	2030	2040	2050
Socioeconomic Data			
Population	182,758	193,288	198,327
Housing	72,315	76,153	79,350
Employment	80,382	84,768	86,914
Lane Miles by Roadway Type			
Interstate	194	194	194
Expressway	326	326	326
Principal Arterial	301	373	380
Minor Arterial	393	470	481
Collector	306	1,006	1,095
Ramp	19	23	23
Centroid Connector	659	684	684
Total Lane Miles	2,197	3,074	3,182
Person Trip Mode Share			
Drive Alone	71.9%	71.1%	71.4%
Shared Ride	26.6%	27.5%	27.3%
Transit	0.5%	0.3%	0.3%
Non-Motorized	1.0%	1.0%	1.0%
Vehicle and Transit Data			
Vehicle Miles Traveled (VMT)	5,615,909	6,193,646	6,223,802
VMT per Capita	30.7	32.0	31.4
Transit Boardings	4,265	2,606	2,673

Table 9: PACOG Modeling Summary, Updated Plan

	2030	2040	2050
Socioeconomic Data			
Population	182,758	193,288	198,327
Housing	72,315	76,153	79,350
Employment	80,382	84,768	86,914
Lane Miles by Roadway Type			
Interstate	194	194	194
Expressway	326	326	326
Principal Arterial	314	387	404
Minor Arterial	396	481	492
Collector	310	1,016	1,128
Ramp	19	23	23
Centroid Connector	664	684	689
Total Lane Miles	2,222	3,111	3,255
Person Trip Mode Share			
Drive Alone	73.2%	68.0%	68.2%
Shared Ride	21.7%	26.3%	26.2%
Transit	0.6%	1.2%	1.1%
Non-Motorized	4.5%	4.5%	4.5%
Vehicle and Transit Data			
Vehicle Miles Traveled (VMT)	5,232,778	5,751,863	5,951,124
VMT per Capita	28.6	29.8	30.0
Transit Boardings	10,777	12,429	11,583

5 Impact

Based on the proposed investments, the Pueblo Metropolitan Planning Organization (MPO) region expects to see a decrease in overall trips taken and miles driven, increase in active transportation and transit usage, and a decrease in VMT. In order to determine which investments would best achieve these targets, PACOG evaluated eight multi-strategy scenarios to identify the investments that would produce the greatest reduction in GHG emissions.

Table 10 shows the overall impacts comparing the *Baseline Plan* to each of the *Updated Plan* scenarios that were evaluated. Reductions that meet the GHG reduction targets that were set for PACOG are shown in **bold colored text**. An overall explanation for reduction in VMT and non-SOV trips is a multifaceted approach that combines strategies for increasing WFH shares, improving transit operations, and increasing mode share of non-motorized modes for trips of five miles or less in length.

Table 10: Scenarios Evaluated and GHG Emissions Results

Scenarios Modeled		GHG Emissions Million Metric Tons (MMT)			GHG Emissions Reduction Million Metric Tons (MMT)		
Scenario	**Description**	**2030**	**2040**	**2050**	**2030**	**2040**	**2050**
Baseline	2045 LRTP Network/Bus Routes	0.4836	0.3017	0.1705			
Action1	Funded Projects, Existing % WFH	0.4791	0.2994	0.1696	0.0045	0.0024	0.0009
Action 2	Funded Projects, Increased % WFH (2-8-18-25)	0.4683	0.2930	0.1659	0.0153	0.0087	0.0045
Action 3	Funded Projects, Increased % WFH (9-13-23-30), Increased Transit Frequency (45-Minute Headways)	0.4612	0.2889	0.1579	0.0224	0.0129	**0.0126**
Action 4	Funded Projects, Increased % WFH Participation (10-15-30-40), Increased Transit Frequency (45-Minute Headways)	0.4542	0.2855	0.1617	**0.0294**	**0.0162**	**0.0088**
Action 5	Funded Projects, Increased % WFH Participation (9-13-23-30), Increased (+1%) Non-Motorized Mode Share	0.4599	0.2875	0.1628	**0.0237**	**0.0143**	**0.0077**
Action 7	Funded Projects, Increased % WFH Participation (10-15-30-40), Increased (+3%) Non-Motorized Mode Share, Improved transit speed (+25%)	0.4446	0.2779	0.1575	**0.0390**	**0.0239**	**0.0130**
Action 8	Funded Projects, Increased % WFH Participation (12-20-33-42), Increased (+3%) Non-Motorized Mode Share, Improved transit speed (+25%)	0.4393	0.2750	0.1558	**0.0443**	**0.0267**	**0.0146**
Action 9	Funded Projects, Increased % WFH Participation (12-20-33-42), Increased (+3%) Non-Motorized Mode Share, Improved transit speed (+25%)	0.4402	0.2737	0.1582	**0.0434**	**0.0280**	**0.0123**
				Required GHG Reduction	**0.03**	**0.02**	**0.01**

Appendix C. PACOG GHG Analysis and Modeling Technical Documentation Memorandum

Memorandum

To: Eva Cosyleon, PACOG MPO Manager

From: Maureen Paz de Araujo (W), Mary Lupa (W), Dean Munn (CP)

Date: 5/23/2025

Re: PACOG Greenhouse Gas (GHG) Analysis and Modeling Technical Documentation

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SUMMARY OF CONTENTS

In this memo, the following sections are provided to users of the 2024 PACOG GHG Travel Model:

- A review of the updated PACOG Model, conducted in 2024, including an overview of the Scenario Builder and the GHG strategies available for testing.
- Methodologies underlying the Work from Home, Transit Sensitivity, and Non-Motorized Trip Adjustment Features.
- Attachments containing detailed steps in the PACOG GHG process:
  - Attachment A: Using the PACOG GHG Scenario Builder
  - Attachment B: GHG Emissions Calculations Guidance
  - Attachment C: Work from Home Analysis and Modeling Methodology
  - Attachment D: Non-motorized Trip Adjustment Modeling Methodology

PROOF OF CONCEPT

To summarize, the PACOG GHG Model / Scenario Builder was successfully applied to a battery of "proof of concept" Updated Plan/Action Scenario tests and the results are summarized in the PACOG GHG Conformity Report. The analysis and modeling used the PACOG adopted 2045 Long Range Transportation Plan as the Baseline Plan/Reference Scenario. Eight Updated Plan/Action scenarios were evaluated producing varying levels of GHG emission reduction conformity/compliance with the targets set for PACOG. The Baseline Plan and an Updated Plan scenarios that achieved compliance with the PACOG GHG emission reduction targets are presented in Table 10 of the "proof of concept" PACOG GHG Conformity Report. This report provides descriptions of the Updated Plan scenarios that were evaluated and their results, demonstrating that the PACOG model is an incisive tool for building successful GHG strategies.

PACOG 2024 TRAVEL MODEL UPDATE OVERVIEW

In early 2024 PACOG completed an update to the MPO's Travel Demand Model, the Pueblo Planning Model (PPM). The Model Update added key components to the model that were needed to support GHG analysis and demonstration of conformity with the Colorado GHG Planning Rule. Key updated and new components of the 2024 Model Travel Update, fully documented in the separate *2024 Model Update/Validation Pueblo Planning Model Methodology Report*, included:

- **Extended Model Forecast Horizon** – The new modeling system accommodates forecasts out to 2050, extending the model horizon an additional five years from the previous 2045 LRTP planning horizon. The model update also added interim year scenarios for 2030 and 2040 to the 2020 base year and 2050 planning horizon scenarios, with the 2050 planning horizon scenario replacing the 2025 Travel Model Update's 2045 planning horizon scenario in preparation for the 2050 LRTP planning cycle.

- **Updated Observed Traffic Data** – The model integrates 2020 traffic count data by auto, Single Unit (SUT) and Multi Unit (MUT) truck.
- **Zone System Revisions** – Zonal coverage was changed to match CDOT's Traffic Analysis Zone (TAZ) structure to provide better geographic resolution, and total consistency between the DOT and PACOG regarding base and forecast land use assumptions.
- **Zonal Data Update** – Socioeconomic data was updated for population, households, median income, and group quarters (2020 Census). Employment data updated using the 2020 Quarterly Census of Employment & Wages (QCEW), data obtained from the Colorado Dept. of Labor & Employment, including employment point data (2021). Trip generation disaggregation values, and trip distribution targets utilize the 2010 Pueblo Front Range Household Survey data. An updated statewide travel survey is in progress.
- **More Detailed Truck Vehicle Classes** – Previous versions of the model used Single Unit (SUT) and Multi Unit (MUT) trucks in trip generation and internal trip distribution but then collapsed this category into a generic truck category in later model steps. This version carries SUT and MUT classes through all model steps and outputs.
- **Transit Network/Model** –Transit routes, stops, and service characteristics are included in the PACOG model for the first time. This additional transit network information is used to support transit skimming used in Mode Choice modeling and later in transit assignments. Roadway network details and data attributes were expanded to support transit modeling as well.
- **Addition of Mode Choice Modeling** – This is a new model component that was added to improve the model's sensitivity to anticipated future scenarios. This component explicitly models individual choices related to traveling by auto and transit depending on trip purpose and characteristics of the journey to the destination location. Addition of the mode choice step significantly changed outputs and subsequent model steps related to Production-Attraction to Origin-Destination (PA-OD) conversion.
- **Expanded Traffic Assignment** – The PACOG model provides traffic flow outputs for AM and PM peak hours, the remaining 22 Off Peak hours, and daily totals. Outputs for vehicle classes are now split into Autos, SUT, and MUT. The process adds a Passenger Car Equivalent (PCE) methodology that accounts for the fact that trucks use more road capacity than autos. A daily transit route assignment is added as well, with transit outputs and reporting.
- **Updated User Interface, Analysis, and Reporting** – The PACOG model's original reporting capabilities were updated to work with the new components/updates. Several new reporting outputs were added to summarize mode choice and transit assignment results. Reporting capability now includes customized Greenhouse Gas (GHG) reporting/output. In accordance with guidance from CDOT and APCD at the time GHG output was formatted in comma separated variable format that could be readily imported to an Excel worksheet. The intent was to support input to MOVES GHG emissions calculations.
- **Addition of a GHG Scenario Builder** - A set of steps and processes were formalized in a GHG Scenario Builder. The GHG Scenario Builder allows PACOG technical staff to rapidly evaluate policy and operational GHG reduction strategies using their updated travel model for Greenhouse Gas (GHG) testing and subsequent processing using MOVES. The 2024 Model Update GHG Scenario builder included three policy/operational tools that allow the user to evaluate scenarios that include shifts in Work from Home (WFH) participation by income quartile, increased transit service frequency (reduced bus transit headways), and increased transit operating speeds.

- **Addition of GHG Link Data Report** – It was important to streamline the output of model assignment results to conform with input requirements to MOVES during the 2024 Travel Model Update. A preset report was added to create a comma separated variable report of assignment results for the AM and PM peak hour and 22-hour off-peak period for input to and processing by MOVES to calculate GHG emissions.

2024 TRAVEL MODEL GHG ANALYSIS SCENARIO BUILDER OVERVIEW

The 2024 PACOG Travel Model Update added a GHG Scenario Builder tool. To streamline the integration and testing of GHG reduction strategy packages the GHG Scenario Builder add-in uses check boxes and spinners to facilitate rapid configuration of multiple strategy GHG Reduction Plan Update scenarios for processing through the EPA Motor Vehicle Emission Simulator (MOVES) model to estimate the mobile source emissions associated with each scenario modeled using the 2024 PACOG Travel Model.

2024 PACOG Travel Model Update GHG Scenario Builder

The GHG Scenario Builder supports scenario-based analysis of multiple non-supply (highway network/transit system) GHG reduction/mitigation strategies to support GHG Conformity demonstration. Initially, three basic demand side strategies that were deemed to be applicable and feasible in the Pueblo MPO context were incorporated into the 2024 PACOG Travel Model Update GHG Scenario Builder. These three strategies step beyond highway network and transit system "projects" to produce GHG emissions reductions. The GHG Scenario Builder facilitates rapid analysis and sensitivity evaluating the effectiveness of these GHG reduction strategies, either individually or as multi-strategy inputs that affect travel demand. Multi-strategy approaches include greater Work from Home participation, and strategies that influence mode choice and result in shifting travel to transit and/or non-motorized travel modes. The initial three GHG Scenario Builder tools are as follows:

1. **Increased Work from Home Participation** – Prior to the Covid-19 pandemic, and certainly during and after this pandemic, workers who were able to conduct their work off-site were either allowed or required to do so. The trend toward allowing WFH has continued. Future GHG scenarios evaluate potential increased WFH percentages using four income classifications. These strategies would be implemented at a policy level working with employers.
2. **Increased Transit Service Frequency** – Increased transit service frequency can make transit more attractive as a travel mode, resulting in a shift from personal automobile to transit as a preferred mode of travel. With more attractive bus service, additional travelers for all trip purposes will shift to bus transit. The 2024 PACOG Travel Model includes a comprehensive bus system/transit model that can be used to evaluate new routes/services as GHG reduction projects. Systemwide modifications to transit service frequency can also be evaluated using the GHG Scenario Builder. The user can apply service frequency multipliers e.g., to implement 40-minute headways in the place of existing 60-minute headways.
3. **Increased Transit Travel Speeds** – Transit buses generally travel at average speeds that are less than automobiles. This is due to the impact of dwell times at stops and delays at signals and when entering and exiting through travel lanes from bus stops. Increased transit operating speeds can make transit more attractive as a travel mode, resulting in a shift from personal automobile to transit as a preferred mode of travel. With more attractive bus service, additional travelers for all trip purposes will shift to bus transit. The validated 2024 PACOG Travel Model set the transit bus speeds at 50% of automobile running speeds. The GHG Scenario Builder can be used to modify the relationship between auto speeds and transit auto speeds. From an operating perspective, increased transit operating speeds can be achieved by implementing improvement projects such as transit signal priority (TSP) signal phases combined with nearside bus stops.

Updated 2024 PACOG Travel Model GHG Analysis Scenario Builder

Through a collaborative process, the Colorado Statewide Modeling Coordination Group (SMCG) reset the GHG Planning Rule conformity determination modeling requirements and approval processes as well as the roles of CDOT, APCD, and the five MPO's in the process. The outcome of the SMCG collaboration significantly changed the modeling and approval process from the process that was in place for the 2022 GHG conformity demonstrations by CDOT, DRCOG and the NFRMPO. The MPOs would no longer be required or even allowed to run MOVES for their GHG Conformity demonstrations. Output of GHG link data from the PACOG models would be required to be in a georeferenced format, at this time an Esri shapefile to be clipped to include only the officially adopted Urban Area in place in 2022. As a result of these changes, and to make the GHG Scenario Builder more robust, PACOG updated the 2024 Travel Model and GHG Scenario Builder to include the following:

- **Output of GHG Link Data as an Esri Shapefile** – The Maps and Reports GHG Link Data option was modified to produce Esri shapefile output when the Maps and Reports GHG Link Data box was checked. The shapefile is retrieved from the scenario folder Outputs > Reports > Link Maps.
- **Non-motorized (Bicycle and Walk) Enhancement** – An active transportation strategy option was added to the GHG Scenario builder. Investment in walking and bicycle paths and trails, including on-street bicycle lanes, increases the tendency of travelers to use non-motorized modes of travel for shorter distance trips. A new GHG Scenario Builder tool was added to facilitate evaluation of the effect of shifts from auto to bicycle or walk modes for trips up to five miles in length.
- **Addition of 2030 and 2040 Networks and Routes Files in Reference Scenario** – Highway network and transit routes data bases for the 2030 and 2040 interim years required for GHG analysis were added to the PACOG Travel Model Reference Scenario to facilitate building new Plan Update scenarios with additional GHG reduction "projects."

A guide on using the PACOG GHG Scenario Builder is addressed in greater detail in **Attachment A: Using the PACOG GHG Scenario Builder*.***

A companion guide to taking the travel model outputs step by step through the GHG emissions calculation process is included as **Attachment B: GHG Emissions Calculations Guidance.**

GHG SCENARIO BUILDER STRATEGY DEVELOPMENT METHODOLOGY

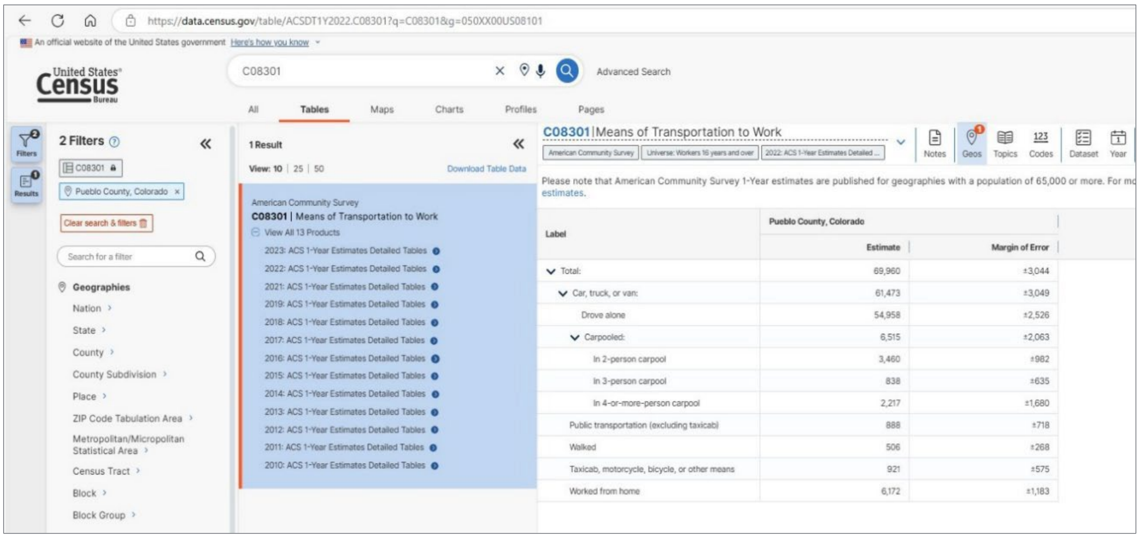
Work From Home Approach and Methodology

The WFH approaches for both the 2024 PACOG Travel Model Update and GHG Scenario Builder were developed using the following steps:

1. **Research the Existing Model Base Year WFH Percentage** – Prior to the advent of WFH becoming widely permitted by selected employers, and prior to the Covid-19 pandemic, some workers did work from home. The U.S. Census American Community Survey (ACS) Table C0301, "Means of Transportation to Work" captures this fact in the question on how workers travel to work, as shown in Figure 1.

Most of the workers in the United States use a private vehicle to travel to work. However, some workers historically have responded that they "Worked from Home." To focus on the need for 2022 model input assumptions, pre-Covid and post-Covid WFH percentages were collected. In Pueblo County, CO, the WFH average increased from an average of 2.8 to 5.8 percent of workers over the period from 2019 to 2022, likely a reflection of the Covid-19 lockdowns.

Figure 1. Capture of ACS Data on Means of Travel to Work, Table C08301



Source: American Community Survey (ACS) Table C08301,
C08301: Means of Transportation - Census Bureau Table, accessed November 2024.

What this work trip information meant was that, for the base year (2022) travel model, it was necessary to remove 5.8 percent of the Home-Work trip productions from the trip generation model step. If a chunk of Home-Work productions is removed from the model to capture base year WFH percentages, the travel model will no longer validate to base year observed traffic.

This raised a few issues which were addressed in the 2024 PACOG Travel Model Update as follows:

- From most households, work trips tend to be longer than shop or recreational trips. The removal of some work trips perturbed the model and resonated through all model steps. This issue was addressed in the PACOG model by conducting the base year WFH correction during the model update/validation work.
- A decision on what the WFH percentage will be in the future must be made – for example, to model years as distant as the 2050 horizon year used in Pueblo. A relatively safe assumption is that the base year value, in this case 5.8 percent, will persist in the coming decades. These assertions must be tempered with the knowledge that Covid-19 created WFH habits which some workers are reluctant to give up, that some employers are requiring a return to office, and that understanding the overall increasing digital nature of daily work is a fact of life, allowing people to do almost anything online from anywhere.
- Some employment types, such as manufacturing, retail, or agriculture, require employees to be present at the work site. WFH percentages are available by employment type, but this area - linking household WFH factors with employment by category - is still under research and development. Externals such as a shift in gasoline prices, employee retention, and others are not captured in travel models but could affect the impact of WFH.

2. Apply WFH Reduction Factor to Home-Work Trip Production Cross Classification Table – Work from Home for a base year model, once researched, was used to reduce the values used in the trip generation production step in the travel model. In a cross-classification trip generation model, typically household size and a wealth attribute are used to create an input table, as in Table 1 below. In the PACOG model there are five household size bins (1, 2, 3, 4, or 5+ persons) and four household income bins, established by quartile from the most recent ACS information. Work productions increase as the household size increases, reflecting the likelihood of more than one worker within the home. The factors in the trip production table are fractional. To reduce the work trips by 5.8%, the Home-Work production factor is simply multiplied by (1 minus 0.058 or 0.942. Ideally, this reduction is done by revising the entire home-work production table during a model update/validation process.

Table 1. Sample Home-Based Work Trip Production Rate Cross-Classification

Income	Household Size				
	1	2	3	4	5+
less than $41,999	0.38	1.02	1.09	1.16	1.16
$41,999 to $49,999	0.73	1.27	1.44	1.82	1.82
$50,000 to $65,999	0.70	1.70	1.56	2.61	2.61
over $65,999	0.70	1.79	2.37	2.35	2.35

A very rough first pass would multiply each of these 20 values in the PACOG model by .942 and run the model. However, national research has shown that WFH share increases as the household income level increases. Thus, it would make sense to establish a reduction factor for each of the four income categories.

3. Develop a Reduction Factor for each of the Four Income Categories – A resource useful in developing income sensitive WFH factors is the U.S. Census Bureau's publication called "Home-Based Workers and the COVID-19 Pandemic." This report discusses average national percentages of WFH by income quartiles estimated before and during Covid-19. These numbers facilitated the estimation of a base year WFH factor by income categories for the PACOG model using national factors by decile. Values sensitive to the four PACOG model income levels were then prepared for the PACOG model. Review and comparison of the PACOG WFH reduction rates to those of other MPO models is underway. Table 2 shows that the rough effect is to remove about 2,700 workers from the travel model.

Table 2: WFH Percentages, PACOG Travel Model 2024

Year 2020 Quartiles	# of Workers	% Worked from Home	WFH Estimate for 2020 Model
INC01	18,031	0.01	180
INC02	16,133	0.03	484
INC03	10,735	0.06	644
INC04	12,953	0.11	1,425
Total	**57,851**		**2,733**

4. Move Beyond the Base Year WFH Adjustment – With a base year fitted to the existing WFH factors using the revised Home-Work trip production table, GHG scenarios can be generated and run to reflect the base year percentage of WFH trips. Any increase or decrease in WFH levels can be modeled by:

    - Manually altering the trip production factors in a particular scenario and running the model.
    - Editing the TransCAD GISDK code to allow scenario specific factors to be called up, stored and run in that scenario.

    The 2024 PACOG Travel Model's GHG Scenario Builder integrates the approach summarized by the second bullet to allow sensitivity testing of a range of WFH percentages by income quartile.

The analysis of and implementation of WFH strategies within the PACOG GHG Scenario Builder is addressed in greater detail in **Attachment C:** ***Work from Home Analysis and Modeling Methodology***.

Transit Operational Improvements Approach and Methodologies

Transit service enhancements also provide a means of shifting trip makers away from the automobile mode. Selected for the PACOG travel model were two potential transit changes: increasing the frequency of buses and increasing the speed at which buses travel during their route. In general, time is a critical feature of transit travel with out-of-vehicle time, such as waiting for a bus, is weighted more heavily by the rider than in-vehicle time, such as riding on a bus. Hence the two choices for enhancing the bus mode may be applied individually or as a set, with each choice affecting potential riders in a distinct manner. Given transit system funding, both choices are feasible enhancements to a transit system.

Non-Motorized Travel Mode Approach and Methodology

Since non-motorized modes are not included in the PACOG mode choice model, a travel time adjustment cannot be implemented as was done by other Colorado MPO's. Instead, an elasticity concept was developed, where an increase in non-motorized trips impacts the auto trips. The impact on auto trips is greatest for short distance trips and is almost negligible for trips over five miles. This approach was derived from the Flagstaff AZ travel model, where household survey data and Streetlight data on non-motorized trips were available. The non-motorized adjustment occurs inside the model, just after mode choice, and reduces auto trips using the elasticity equation which is summarized in Table 3 on the following page.

Table 3: Auto Mode Share Factor for Increases in Non-Motorized Share by Trip Distance

Dist	Pct Non-Motorized Mode Share Change									
	0%	1%	2%	3%	4%	5%	10%	20%	30%	100%
0.25	1	0.990	0.980	0.970	0.960	0.950	0.900	0.801	0.701	0.004
0.50	1	0.997	0.994	0.990	0.987	0.984	0.968	0.936	0.905	0.682
0.75	1	0.998	0.996	0.995	0.993	0.991	0.982	0.965	0.947	0.824
1.00	1	0.999	0.998	0.997	0.995	0.994	0.988	0.977	0.965	0.885
1.25	1	0.999	0.998	0.998	0.997	0.996	0.992	0.984	0.976	0.918
1.50	1	0.999	0.999	0.998	0.998	0.997	0.994	0.988	0.982	0.939
1.75	1	1.000	0.999	0.999	0.998	0.998	0.995	0.991	0.986	0.954
2.00	1	1.000	0.999	0.999	0.999	0.998	0.996	0.993	0.989	0.964
2.25	1	1.000	0.999	0.999	0.999	0.999	0.997	0.994	0.991	0.971
2.50	1	1.000	1.000	0.999	0.999	0.999	0.998	0.995	0.993	0.977
2.75	1	1.000	1.000	0.999	0.999	0.999	0.998	0.996	0.994	0.981
3.00	1	1.000	1.000	1.000	0.999	0.999	0.998	0.997	0.995	0.985
3.25	1	1.000	1.000	1.000	0.999	0.999	0.999	0.997	0.996	0.987
3.50	1	1.000	1.000	1.000	1.000	0.999	0.999	0.998	0.997	0.990
3.75	1	1.000	1.000	1.000	1.000	1.000	0.999	0.998	0.997	0.991
4.00	1	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.998	0.993
4.25	1	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.998	0.994
4.50	1	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.998	0.995
4.75	1	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.996
5.00	1	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.996

Factors are applied to auto trips immediately after mode choice

The auto adjustment affects traffic assignment outputs from each model scenario with Vehicle Miles Traveled (VMT) reductions appearing in the modeled output when the non-motorized mode share is increased. Using the GHG Scenario Builder, non-motorized mode share for trips up to five miles in length may be increased by shifting auto trips to non-motorized modes.

This GHG Scenario Builder component strategy may be adaptable to evaluation of land-use based GHG reduction strategies because should also be sensitive to land use scenarios where there is more density/in-fill, and the resulting new trips would be expected to be shorter. The methodology is described in greater detail in Attachment D: *Non-Motorized Trip Adjustment Modeling Methodology*.

Appendix D. PACOG Coordinated Agency Review Memorandum

COLORADO
Department of Transportation
Division of Transportation Development

PACOG Coordinated Agency Review Memorandum

To: Transportation Commission.
From: Sabrina Williams, Scott Ramming; CDOT
Date: January 13, 2026.

Subject: Overview of Coordinated Modeling Approaches for Compliance with GHG Rule (2 CCR 601-22)

Background

PACOG has completed its efforts to model Greenhouse Gas (GHG) emissions within the PACOG MPOIO boundary in order to comply with 2 CCR 601-22, referred to herein as the Standard. Throughout this process, CDOT coordinated closely with Colorado Air Pollution Control Division (APCD) as well as members of the Statewide Model Coordination Group (SMCG) on the most appropriate ways to proceed. After reaching agreement on the process for representing emissions in the PACOG area, CDOT was given opportunity to review and comment on this representation of travel and emissions as presented in PACOG's Long Range Transportation Plan and GHG emissions analysis through an interagency review. This memorandum documents CDOT's interagency review period and comments received on the boundary file that spatially represents the PACOG area as well as the appropriateness of any links that were required to be split at this boundary file for the purposes of performing GHG emissions calculations associated with the Updated Plan.

Boundary File Representing the PACOG Compliance Area

Reviewing Agency: CDOT

PACOG provided CDOT the boundary file developed by PACOG and consultant staff for spatially representing the PACOG GHG compliance area, which comprised a representation of the MPO boundary on a statewide scale. PACOG requested CDOT to review and either propose revisions/modifications of the representation of their MPO boundary or provide concurrence. CDOT identified no errors in the representation of PACOG's MPO boundary as legally defined for this Long Range Transportation Plan. Therefore, CDOT approved the use of the boundary file initially developed by PACOG and consultant staff for representing the roadways within the MPO boundary for this plan without modifications.

Splitting Links at the PACOG MPO Boundary

Reviewing Agency: CDOT

Following CDOT review and approval of the representation of the PACOG MPO area for the purposes of calculating GHG emissions, PACOG split the roadway links from the travel model at locations where portions of roadways extended outside of the MPO area into another GHG compliance area's boundary. PACOG provided CDOT with the statewide roadway network with the split links at the approved PACOG boundary file and requested CDOT to review that all links crossing outside of the MPO boundary had been correctly split at their MPO boundary. CDOT confirmed in the review that the correct boundary file had been used to split the roadway network links and that links crossing outside the PACOG MPO boundary as represented in the PACOG travel model had been correctly split with links or sections of links crossing outside the MPO boundary.

Appendix E. MOVES Methodology Memorandum

2025 MOVES4 Modeling and Greenhouse Gas Emissions Calculation Methodology Memorandum

To: Transportation Commission.

From: Sabrina Williams - CDOT and Dale Wells - CDPHE.

Date: December 22, 2025.

Subject: CDOT Greenhouse Gas Transportation Planning Standard — 2025 MOVES4 Modeling and Greenhouse Gas Emissions Calculations Methodology Documentation.

Introduction

This document summarizes the methodology used to calculate greenhouse gas (GHG) emissions for demonstrating compliance with the CDOT Greenhouse Gas (GHG) Transportation Planning Standard (Standard). Previous GHG emissions calculations to support CDOT were conducted by the Air Pollution Control Division (APCD). This methodology represents a coordinated approach between CDOT and APCD's modeling teams to represent likely future on-road GHG emissions as accurately as possible. The approach was also agreed upon by the Statewide Model Coordination Group (SMCG). Several refinements and improvements were made compared to the previous methodology for calculating GHG emissions due to the availability of new models, data and assumptions. All data and files utilized in the GHG emissions analysis methodology were reviewed by an individual other than the person who developed the data and/or performed the modeling as documented throughout.

The process for calculating GHG emissions begins with generating emission rates using the EPA's Motor Vehicle Emissions Simulator Model (MOVES). The GHG emissions rates developed in MOVES are the same statewide and applied consistently between all agencies to calculate mass total GHG emissions for a compliance area. The emission rates are multiplied by the vehicle miles traveled (VMT) from the Travel Demand Model (travel model) at the link level for individual hours of the days based on the observed vehicle mix from CDOT's statewide Automated Traffic Recorder (ATR) station network within a Microsoft (MS) Access relational database. The result of querying the database is the predicted total mass emissions of GHGs for the roadways represented in the travel model for an average weekday. This requires a series of data analysis and post-processing steps to correctly compile these three main parameters (emissions rates, travel behavior, vehicle mix) into compatible formats within the database.

In 2025 the three significant new considerations for how GHG emissions are calculated for the purposes of an agency demonstrating compliance with the Standard were adopted by consensus through the Statewide Model Coordination Group (SMCG). These considerations involve updates to (1) vehicle emissions rates, (2) vehicle mix assumptions, and (3) the number of vehicle classes considered.

Each step in the emissions calculation process results in standalone datasets (emissions rates, vehicle mix, travel modeling) that are created independently, but compiled in a manner that allows this data to interface with each other through relational database software (MS Access) that calculate total GHG mass emissions for a compliance agency. All data used in the emissions analysis developed by an individual (or agency) was then independently reviewed by another individual (or agency) for data validity and accuracy prior to incorporation into the final GHG emissions calculations methodology. In addition to the analysts and reviewers noted throughout, all SMCG member agencies were extended the opportunity to perform additional data review at each step in development of the emissions calculations, including contributing to the underlying framework that established the methodology and resultant procedures.

Vehicle Emissions Rates

Performed by: Sabrina Williams-CDOT

Reviewed by: Dale Wells-CDOT

New GHG Rates were required to incorporate the State Interagency Coordination Team (IACT) determination, as defined under 2 CCR 601-22 Section 1.44, May 5, 2025 that the CDOT Department of Accounting and Finance (DAF) projections on future EV adoption be used in the GHG emissions rates development. The previous GHG emissions rates were developed using asserted adoption curves of early, mid and late term EV adopters annually with individual forecasts for passenger vehicles and SUVs/light-duty trucks through 2050. CDOT DAF, as part of CDOT's 10-Year Plan development, created a forecast of expected revenue through the year 2050. As part of their revenue forecasting effort, DAF also generated a forecast of light-duty EV fleet growth in Colorado (since revenue from EVs is different from revenue from fossil-fueled vehicles). DAF's forecast estimated 950,000 light-duty EVs in Colorado in 2031, with an estimate of 95% of light-duty vehicles being EVs in 2050.

Separate EV adoption rates were initially developed for passenger cars and SUVs/light-duty trucks as at that time very few EV SUVs/light-duty trucks were available for purchase and it was unknown when additional electrified SUVs/light-duty trucks would be commercially available. Since the time the initial EV planning assumptions were used to develop the original GHG rates, numerous electrified SUV make and models are now commercially available and auto manufacturers continue to release additional EV SUVs for sale. Furthermore, manufacturers have indicated that electrified light-duty trucks will become more broadly available in future years. The Colorado Energy Office (CEO) has completed numerous studies on likely future EV adoption for planning purposes such as EV charging infrastructure needs. These studies also project greater levels of electrification of these larger passenger vehicles within the next five years. Given that a significant percentage of passenger vehicles registered in the state are classified as SUVs and light-duty trucks, the earlier SUV/light-duty truck EV adoption rates was adjusted to reflect the quicker levels of EV adoption now expected. Therefore, in future years the rate of EV adoption is assumed to be the same between passenger cars and SUVs/light-duty trucks in developing the new GHG rates whereas previously they differed.

Vehicle Mix Assumptions

Performed by: Juan Robles-CDOT

Reviewed by: Sabrina Williams-CDOT, Dale Wells-CDPHE

Overview

The vehicle mix represents the type (i.e., motorcycles, passenger cars, SUVs, vans, trucks, etc.) of vehicles operating on a roadway. The GHG emissions rates are highly variable by vehicle class and generally increase with the size of the vehicle. For example, passenger cars emit significantly less GHGs per vehicle mile traveled (VMT) than heavy-duty trucks. While travel demand models forecast total on-road travel behavior, including trips from commercial vehicles, no travel demand model in the state is calibrated for commercial travel accurately enough to properly assign the on-road vehicle mix. Therefore, the real-world observed vehicle mix used to calculate GHG emissions for the Standard is developed from traffic observations (counts) collected by CDOT's vehicle count stations.

Vehicle mix is assigned from ATR data using both continuous and short-duration counts stratified by hour of the day, the 13 Federal Highway Administration (FHWA) vehicle classifications as well as roadway and urban or rural area type updated for more recently observed years. Each ATR station's counts were used in conjunction with VMT weighting for the roadway to develop a ratio of vehicle types by hour for all of the major roadway types in Colorado. The VMT-weighting of the counts is a refinement of the previous vehicle mix assignment that used unweighted (straight) counts in the previous emissions calculations. The VMT-weighting method was developed by CDOT and APCD in order to better reflect the vehicle mix outside the Front Range where the majority of ATR stations are located. Furthermore, for the 2025 vehicle mix used to calculate GHG emissions rates, post-pandemic (2023) vehicle classification counts were used. In the previous GHG emissions calculations methodology, pre-pandemic (2017-2019) vehicle classification counts were used. SMCG determined that an update to post-pandemic vehicle classification counts should be made statewide to the emissions calculation methodology in order to more accurately reflect the vehicle mix that is currently present on roadways in the state as transportation behavior has altered since COVID due to factors including increased remote employment and land use changes.

ATR Count Data Methodology

To assign the vehicle mix percentages by roadway functional category, a total of 316 statewide count stations that collect hourly classification data were used. Of these count locations, 75 of them are permanent traffic recorders (ATRs), and 241 were short-term counts for the years 2022 and 2023. The 13-bin FHWA hourly counts were then grouped into the five Highway Performance Monitoring System (HPMS) class groups used in MOVES to calculate emission rates (passenger vehicles [including SUVs and light-duty trucks], motorcycles, buses, single unit heavy-duty trucks and combination heavy-duty trucks)

To calculate the vehicle mix fractions or percentages for each functional class by individual hours, the VMT-weighted sum of all hourly volumes from each class was divided by the total number of counts for each class. This means that ATR stations have a larger weight than short-term count locations because there are many more hourly counts available from ATRs, and that count stations with higher volumes or VMT have a higher weight than stations with low volumes or VMT.

A simplified example would be if the number of total individual hourly volumes at an ATR station were 20,000 vehicles and 17,000 vehicles were observed to be passenger vehicles and 1,000 vehicles were single unit (SU) trucks. In this case, the percentage of passenger vehicles for that station in that individual hour is assigned to be 85% and the fraction of SU trucks would be 15%.

Figure 1 shows percentages for the Urban Freeways and Expressways functional category with reliance on 11 ATRs. The average percentages for this class are shown in green and the percentages for each of the ATRs are below the green bar. Only the aggregated values for the entire area type and roadway functional classification are used to calculate emissions for the state, the individual data shown for each ATR station is used in the calculation of average vehicle mix percentages.

Figure 1. Example illustrating calculation of vehicle mix percentages as a weighted average of count data from multiple locations

Sta_ID	Rural_Urban	Func_Class	Average VMT	M-cycles	Pass_veh	Buses	SU	Combo
	Urban	**(2) Freeway & Ex**	109,926	**0.17%**	**97.37%**	**0.13%**	**1.25%**	**1.09%**
000003	Urban	(2) Freeway & Expr	134,451	**0.19%**	**97.38%**	**0.06%**	**1.12%**	**1.25%**
000004	Urban	(2) Freeway & Expr	168,873	**0.07%**	**98.27%**	**0.29%**	**0.76%**	**0.61%**
000503	Urban	(2) Freeway & Expr	57,247	**0.10%**	**98.96%**	**0.07%**	**0.50%**	**0.37%**
000504	Urban	(2) Freeway & Expr	246,762	**0.18%**	**97.05%**	**0.23%**	**1.53%**	**1.02%**
000506	Urban	(2) Freeway & Expr	91,498	**0.13%**	**97.97%**	**0.10%**	**1.24%**	**0.56%**
100331	Urban	(2) Freeway & Expr	131,878	**0.20%**	**98.27%**	**0.20%**	**0.85%**	**0.48%**
103608	Urban	(2) Freeway & Expr	104,847	**0.11%**	**98.44%**	**0.09%**	**0.72%**	**0.64%**
103684	Urban	(2) Freeway & Expr	81,433	**0.12%**	**89.91%**	**0.25%**	**3.38%**	**6.34%**
103712	Urban	(2) Freeway & Expr	11,012	**0.10%**	**89.71%**	**0.11%**	**3.29%**	**6.78%**
105548	Urban	(2) Freeway & Expr	164,048	**0.19%**	**97.45%**	**0.07%**	**1.22%**	**1.08%**
107556	Urban	(2) Freeway & Expr	121,040	**0.13%**	**96.99%**	**0.10%**	**1.77%**	**1.02%**

Of the seven roadway functional categories:

(1) Interstate

(2) Freeway & Expressway

(3) Other Principal Arterial

(4) Minor Arterial

(5) Major Collector

(6) Minor Collector

(7) Local

CDOT does not collect classification data on Minor Collectors, Ramps or Local roads that would permit the calculation of accurate mix percentages for these roadways. Thus, there is no vehicle classification count data available at a statewide level for these roads. However, travel models must account for vehicle travel for all road types in the state to accurately predict passenger trips and associated VMT whose emissions need to be accounted for. CDOT and APCD determined the most suitable approach for assigning the vehicle mix on these access roads for the purposes of calculating GHG emissions was to assign the same vehicle mix as the most similar roadway functional classification for which vehicle classification was available. In this case, functional classes six and seven would use the rates from Major Collectors.

The result is a compiled table of the observed individual hourly vehicle mix by HPMS category for the seven roadway functional classifications that are represented in the travel modeling for a GHG compliance area.

The vehicle mix is applied to the travel model run data in the MS Access database that calculates the mass total emissions and is not considered directly within the MOVES modeling to develop the GHG emissions rates as discussed later in the documentation of the GHG emissions analysis methodology.

Vehicle Classes Considered

Performed by: Mobility Analysis Section-CDOT

Reviewed by: Sabrina Williams-CDOT, Juan Robles-CDOT

The original GHG rates developed in MOVES for use in prior analyses to demonstrate compliance with the standard had unique rates for six HPMS vehicle categories: motorcycle, passenger cars, passenger trucks, buses, single unit heavy trucks, and combination heavy trucks. These GHG emissions rates by HPMS category are applied to the travel model data in the MS Access database in conjunction with the observed vehicle mix fractions (observed vehicle classification counts) to calculate total mass GHG emissions for a compliance area. However, Division of Transportation Development Mobility Analysis Section staff realized that because vehicle classification counts are recorded by the number of axles and length of a given vehicle, the CDOT count network often records SUVs and light-duty trucks as passenger cars. Furthermore, in MOVES the type of vehicles are not grouped by the body style of a vehicle, rather by similar characteristics of the engines and associated emissions profiles. This results in many vehicles that are commonly thought of as passenger vehicles, such as wagons and crossovers, being considered to be passenger trucks in the MOVES model.

To more accurately account for the number of larger passenger vehicles and to minimize the discrepancy between the CDOT count network's data collection mechanism and the MOVES model vehicle source types, a refinement was made to the number of vehicle classes considered in the GHG emissions calculations to combine passenger cars and SUVs/light-duty trucks to reflect total passenger vehicles. This was performed by aggregating the observed vehicle classification counts to a new HPMS25 vehicle category representing all passenger vehicles instead of differentiating between passenger cars and SUVs/light-duty trucks. This resulted in reducing the number of HPMS classes considered in the MOVES model to develop the updated GHG emissions rates from six to five categories of vehicles: motorcycles, passenger vehicles, buses, single-unit heavy trucks, and combination heavy trucks.

The refinements to the number of vehicle classes considered results in an increased representation of SUVs/light-duty trucks and their associated GHG emissions in the state that more accurately depicts present real-world observed conditions. Furthermore, the approach of representing all passenger vehicles as a single HPMS category is now consistent with the manner in which CDOT reports HPMS data for the state.

MOVES4 GHG Emissions Rates

Performed by: Sabrina Williams, CDOT

Reviewed by: Dale Wells, APCD-CDPHE

Overview

Incorporating the DAF future EV planning assumptions required new emissions rates to be developed in MOVES. Emissions rates were generated using the MOVES version 4.1.2 (MOVES4). Previously MOVES version 3.0.1 (MOVES3) was used to generate the original GHG emissions rates. The change in GHG emissions rates specific to changing to model versions is minimal due to the previous and continued high levels of EV/ZEV adoption assumed in future years, which is discussed in later sections. For more information about GHG modeling using MOVES, see the Using MOVES for Estimating State and Local Inventories of On-road Greenhouse Gas Emissions and Energy Consumption guidance document. The MOVES4 Run Specifications used to generate the GHG emissions rates may also be found in later sections.

MOVES4 Run Specifications

The run specification (RunSpec) parameters outlined below were used to calculate GHG emission rates with MOVES. CDOT performed the MOVES4 modeling to develop the new GHG emissions rates and model results and inputs were reviewed and verified by APCD for accuracy. The MOVES modeling methodology is largely consistent with APCD's previous process to calculate GHG emissions except where noted.

The three modeled years: 2030, 2040, and 2050, used the same run specifications except for where specified (e.g., the year being modeled). Each of the three modeled years has five related run specifications to separate the emission rates by vehicle type, as described in the On-road Vehicles section, i.e., five MOVES runs per compliance year. This denotes a change from the previous GHG emissions rates that were generated using six model runs to represent vehicle types by aggregating passenger cars with SUVs and light-duty trucks into a single MOVES run. When used for modeling compliance with the Standard the GHG emissions rates are applied identically between an agency(s) baseline plan and compliance plan demonstrations, e.g., there is no emissions benefit given to a compliance demonstration for future EV/ZEV adoption. If an MPO or CDOT were to develop a project in a long-range transportation plan specific to switching vehicle types or vehicle fuel types in a future year, this will be revisited by SMCG for consideration on how to best represent these types of planning actions.

Scale

The “Scale” parameters define the model type (on-road or non-road), domain/scale, and calculation type.

Model Type

On-road was the model type selected. This estimates emissions from motorcycles, cars, buses, and trucks that operate on roads.

Non-road/off-network emissions were not included. These emissions are from equipment used in applications such as recreation, construction, lawn and garden, agriculture, mining, etc. and are outside of the scope of this analysis.

Domain/Scale

MOVES allows users to analyze mobile emissions at various scales: National, County, and Project. While the County scale is necessary to meet statutory and regulatory requirements for State Implementation Plans (SIPs) and transportation conformity, either the County or National scale can be used for GHG inventories at the federal level. EPA recommends using the County scale for GHG analysis.

The County scale allows the user to enter locally-specific data through the County Data Manager whereas under the National Scale only MOVES default values are used. Providing local data significantly improves the precision of the modeling results and allows the MOVES users to better evaluate future planning scenarios. Therefore, the County Scale was used.

County Scale in MOVES can be used to model a single county, or a larger representative group of counties such as a nonattainment area or entire state that share common emissions characteristics such as fuel types and blends, emissions testing programs, vehicle age and other considerations. For this modeling, Adams County was used as the representative county on MOVES to develop the statewide GHG emissions rates. All non-default inputs in MOVES4 used in the County Data Manager are representative of the most currently available statewide vehicle data compiled by APCD for EPA’s National Emissions Inventory (NEI) Reporting, with the exception of future EV/ZEV adoptions rates at the direction of IACT.

Calculation Type

MOVES has two calculation types - Inventory (total emissions in units of mass) or Emissions Rates (emissions per unit of distance for running emissions or per vehicle for starts and hotelling emissions) in a look-up table format that must be post-processed to produce an inventory. Either may be used to develop emissions estimates for GHGs.

The Emission Rates calculation type was used. Emissions Rates calculation type requires more post-processing; however, this also allows for a consolidated set of GHG emissions rates that can be used statewide by any GHG compliance agency with minimal emissions modeling required from an MPO. Furthermore, this method provides for not needing to rerun MOVES if there is a change to an agency's travel model.

Time Span

The "Time Span" parameters define the years, months, days, and hours that emissions are calculated.

When Emission Rates is specified in the RunSpec, users may choose to approach the selection of options in the Time Spans Panel differently than when running MOVES in Inventory mode. For example, when modeling running emission rates, instead of entering a diurnal temperature profile for 24 hours, users can enter a range of 24 temperatures in increments that represent the temperatures over a period of time. By selecting more than one month and using a different set of incremental temperatures for each month, users could create a table of running emission rates by all the possible temperatures over an entire season or year.

When using Emission Rates instead of Inventory, the time aggregation level is automatically set to Hour and no other selections are available. Pre-aggregating time does not make sense when using Emission Rates and would produce emission rates that are not meaningful. However, the year, month, and day must still be specified and will affect the emission rates calculated.

The time span parameters specified in the following subsections were also used because the travel model outputs represent an average weekday. These daily emissions are then translated into annual emissions in the final step of the emissions calculation process.

Years

The County scale in MOVES allows only a single calendar year in a RunSpec. Users who want to model multiple calendar years using the County scale will need to create multiple RunSpecs, with local data specific to each calendar year, and run MOVES multiple times.

The years used were 2030, 2040, and 2050. Emission rates for each of these years were calculated separately. This accounts for information such as a changing age distribution of vehicles, fleet turnover and their corresponding fuel types and fuel efficiencies.

Months

MOVES allows users to calculate emissions for any or all months of the year. If the user has selected the Emission Rates option, the Month can be used to input groups of temperatures as a shortcut for generating rate tables for use in creating inventories for large geographic areas.

The months used were January and July to match the previous modeling by APCD. These represent winter and summer months and generally the extremes in annual weather conditions. This accounts for changes in fuel efficiency between warm and cold temperatures throughout the year. The arithmetic averages of emission rates from January and July were used for the final emissions inventory to represent an annual average GHG emissions rate.

Days

Weekdays and weekend days can be modeled separately in MOVES. MOVES provides the option of supplying different speed and VMT information for weekdays and weekend days to allow the calculation of separate emissions estimates by type of day.

The days used were weekdays to match the TDM output data. These represented the emission rates for an average weekday. The results are annualized in one of the final steps for calculating the GHG emissions to approximate a full year.

Hours

The hours used were all 24 hours of the day (i.e., clock hours ending at 1:00 AM, 2:00 AM, 3:00 AM, etc.). These represent the emission rates for individual hours of a day. This accounts for changes in fuel efficiency between warm and cold temperatures throughout the day.

Geographic Bounds

The "Geographic Bounds" parameter defines the county(s) used. For a county-scale run, only one county can be selected per RunSpec. The county used was Adams County, Colorado; however, any county in Colorado could have been selected as the MOVES modeling defined input parameters such as the vehicle age used to estimate emission rates using statewide data.

On-Road Vehicles

MOVES describes vehicles by a combination of vehicle characteristics (e.g., passenger car, passenger truck, light commercial truck, etc.) and the fuel that the vehicle is capable of using (gasoline, diesel, etc.). This is required to specify the vehicle types included in the MOVES run.

The "On-road Vehicles" parameter defines the source types (i.e., vehicle types) and their fuels (gasoline, diesel, electricity, etc.). All combinations of vehicle types and fuels available in MOVES4 were used to calculate the emission rates; except that no EV/ZEVs are assumed for buses or commercial vehicles. The process for assigning what vehicle types are represented in the model run has been refined from the previous method that used separate MOVES runs to represent passenger cars vs. SUVs and light-duty trucks. The MOVES model runs used in the GHG rates update now match the MOVES HPMS types defined in the model that aggregates all passenger vehicles into a single category (HPMS=25).

Table 1 illustrates the HPMS categories.

Table 1. Composition of vehicle types used for MOVES emissions modeling

MOVES Vehicle Source Type	HPMS Name	HPMS (Current)	HPMS (Previous)
Motorcycle	Motorcycles	10	10
Passenger Car	Light-Duty Vehicles	25	20
Passenger Truck	Light-Duty Vehicles	25	30
Light-Commercial Truck	Light-Duty Vehicles	25	30
Other Buses	Buses	40	40
Transit Bus	Buses	40	40
School Bus	Buses	40	40
Refuse Truck	Single Unit Trucks	50	50
Single Unit Short-Haul Truck	Single Unit Trucks	50	50
Single Unit Long-Haul Truck	Single Unit Trucks	50	50
Motor Home	Single Unit Trucks	50	50
Combination Short-Haul Truck	Combination Trucks	60	60
Combination Long-Haul Truck	Combination Trucks	60	60

Road Type

The Road Type in MOVES is used to define the types of roads that are included in the run. There are four categories of road types in MOVES used to represent onroad emissions and they are separated between urban vs. rural and ramp-controlled (Interstates) vs. non ramp-controlled (local roads). Assignment of the correct road type when calculating emissions is important because in MOVES the vehicle drive cycles assumed in the model are variable by road type, e.g., MOVES assumed more stop and go traffic on local roads associated with intersection controls than interstates, as well as area type, e.g., MOVES assumes a greater level of congestion on local roads in urban areas than rural areas. MOVES also has an option for Off-Network road types which would be associated with vehicle emissions not occurring in traffic, e.g., idling vehicles at a large transit station. All road types were selected in MOVES. The Off-Network road type must be selected for MOVES to execute in Emissions Rate mode, but was not used in the emissions calculations as they are not on-road emissions.

Pollutants and Processes

The Pollutants and Processes Panel allows users to select from various pollutants, types of energy consumption, and associated processes of interest. In MOVES, a pollutant refers to particular types of pollutants or precursors of a pollutant but also includes energy consumption choices. Processes refer to the vehicle mechanism by which emissions are released, such as running exhaust or start exhaust. Users should select all relevant processes associated with a particular pollutant to account for all emissions of that pollutant. Generally, for this project, that includes running emissions, e.g., emissions processes associated with vehicle start-ups, extended idling and refueling occur on Off-Network road types in MOVES.

The CO2 Equivalent pollutant is the sum of the global warming potential of Carbon Dioxide (CO2) and all other greenhouse gases expressed as a unit CO2 Equivalents. (CO2e) is the pollutant of interest in MOVES as it accounts for all greenhouse gas emissions considered in MOVES. MOVES requires several other prerequisite pollutants for CO2e, e.g., methane; whose individual global warming potentials are calculated within the model and appropriately summed with CO2 and reported as CO2e.

General Output

The General Output parameters define the output database, units, and activity.

Output Database

Results from the five related HPMS RunSpecs for a given analysis year (2030, 2040, 2050) can be stored together in a single output database for convenience, or separate databases can be created for each run. The RunSpecs must have the same units and aggregation or MOVES will not execute. A different output database is required for each year and varying MOVES RunSpec. A consistent and informative naming convention for the output database assists in file housekeeping. Five output databases were used for each year modeled representing a single HPMS category for that year. Each output database contained results for the modeled year and vehicle HPMS category.

Units

Users can select from any of the mass unit selection options but should generally choose a unit whose magnitude is appropriate for the parameters being analyzed.

The units selected in the MOVES RunSpecs are grams for mass, joules for energy, and miles for distance.

Activity

MOVES allows the user to select multiple activity output options. As Emissions Rates were selected MOVES automatically reports emissions in mass units per distance traveled (grams/VMT) for each month and hour selected in the MOVES Time Spans panel for each Road Type selected in MOVES.

Output Emissions Detail

This panel allows the users to make selections that will additionally disaggregate the data beyond what is automatically reported by MOVES. Certain selections are automatically made by MOVES based on the RunSpec definition and cannot be unselected.

No optional details were selected in this panel as the outputs automatically reported by MOVES for these RunSpecs contain sufficient detail for calculating GHG emissions in this manner.

Input Database (Formerly the County Data Manager)

The previous panels in MOVES defined the RunSpec and the format of the output data. The next step is to create the input database where files with local data are imported.

The RunSpec parameters selected in the other panels in MOVES define the file structure and required data for the input database and constrain all files imported into MOVES to this structure or errors are generated and the model will not execute. Therefore, it is recommended that the MOVES user make this Input Database the last panel used in the MOVES graphical user interface (GUI) as any alterations to the RunSpec can result in needing to recreate its settings.

One input database was created for each model year for each vehicle HPMS category; a total of 15 MOVES model runs. Data is imported into the input database for each MOVES run, as specified below.

Age Distribution

The Age Distribution in MOVES represents the distribution of the age of each vehicle type in MOVES from 0-30 years old (vehicles whose model years are 31 years and older). The age distribution is a critical input in MOVES as this directly assigns the specific vehicle model years and vehicle characteristics, e.g., fuel types and associated emissions rates. MOVES allows the user to import locally specific data as was performed in this analysis. APCD develops locally specific age distributions from all vehicles registered in the state every three years for the EPA's National Emissions Inventory (NEI) reporting at the county and statewide level, as well as for the Denver Metro/North Front Range 8-hr Ozone Nonattainment Area. For this analysis, the statewide age distribution for the 2024 NEI reporting was imported into MOVES4 except for long-haul commercial vehicles. National default values were used for long-haul commercial vehicles as a significant portion of these vehicles in the state are registered elsewhere in the country.

Average Speed Distribution

Vehicle tailpipe emissions rates are highly affected by the speed the vehicle is traveling. At lower speeds associated with congestion emissions rates are higher and rates decrease until vehicles are traveling at speeds of approximately 55 miles per hour (mph) where at that point emissions rates begin to increase again. MOVES requires an Average Speed Distribution be imported to perform a model run. This distribution is an important input in Inventory Mode as it represents the detailed information concerning the on-road speeds of vehicles and related emissions rates by road type, hour of the day, day of the week, and month of the year. In Emissions Rates mode, however, the average speed distribution is not used and for this analysis national default values were used.

Fuel

The fuels data in MOVES assigns the specific fuel formulations, including chemical properties, for all petroleum vehicles as well as the fuel types for each vehicle type by model year including representation of EV/ZEVs in the model through the Alternative Vehicles Fuels and Technologies (AVFT) file. For the GHG analysis, default fuel values were used with the exception of the AVFT data.

The AVFT file specifies the fraction of each fuel used by a vehicle type, e.g., gas, diesel, ethanol and electricity, for vehicle model years 1960-2060. It is important to specify these fractions by model year as this provides a more accurate estimate of the fuel economy standards and emissions improvements associated with fleet turnover as older higher emitting vehicles are retired and replaced with lower emitting vehicles than assuming an average fuel mix for an entire vehicle type in MOVES.

In a MOVES run, vehicle data is only considered for the same vehicle model year as the analysis year selected in the RunSpec and the previous 30 vehicle model years, i.e., the fuel mix considered in a specific run is assigned from the Age Distribution in MOVES.

Although EV/ZEVs have zero GHG emissions, these vehicles do have emissions of other pollutants, such as particulate matter, and should be represented within MOVES. Therefore, future EV/ZEV planning assumptions are directly considered within MOVES and there is no “zeroing” out of EV/ZEV VMT, because that VMT corresponds to a GHG tailpipe emissions rate of zero. For this analysis, the AVFT file used the same motor vehicle registration data for the 2024 NEI as the Age Distribution through vehicle model year 2024 after which the DAF EV planning assumptions for light-duty vehicles were incorporated to represent future EV adoption levels. MOVES4 contains default values for future EV adoption for commercial vehicles; however, this data was not used in the model and no EV/ZEVs were considered for commercial vehicles.

Meteorology

Vehicle emissions rates can vary by temperature and humidity, particularly for criteria pollutants and mobile source air toxics. However, GHG emissions from vehicles relate to atmospheric conditions solely based on a driver’s comfort and their likely usage of air conditioning in a vehicle and resultant impacts to fuel economy. The default values for Meteorology in MOVES represent actual climate data for all individual counties in the nation as collected from the National Climate Data Center. MOVES default data for Adams County, Colorado was used for the months of January and July in the analysis, which is consistent with the RunSpec.

Road Type Distribution

MOVES does not have default data for the Road Type Distribution and it must be created and imported by the user. In Emissions Rates the Road Type Distribution data in a MOVES run does not impact the results and is not an important file in the analysis, but must be present and correctly compiled for the model to run. A Road Type Distribution file was provided by APCD imported in MOVES for the analysis.

Source Type Population

MOVES requires the Source Type Population file to be present in MOVES and there is no national default data available in MOVES. However, this file does not change the results in Emissions Rates as this data is used for calculating vehicle emissions associated with off-network activity, e.g., extended periods of idling at a truckstop or a large number of vehicles congregating at a transit station. As these vehicle emissions are not truly occurring “on-road” they are not accounted for in the analysis or present in the Emissions Rates output files. The Source Type Population was provided by APCD from the 2024 NEI and used in the analysis.

Vehicle Type VMT

The Vehicle Type VMT is required to run MOVES and is very important if Inventory is selected in the RunSpec. However, in Emissions Rates mode this data does not change the results; moreover, a single vehicle classification is considered in this analysis so the VMT considered in MOVES does not vary by vehicle category. Default Vehicle Type VMT data was imported in MOVES for all runs with the exception of the annual HPMS file that was provided by APCD from the 2024 NEI in order for MOVES to run.

Inspection and Maintenance Program

The Denver Metro/North Front Range Ozone Nonattainment Area has a vehicle inspection and maintenance (I/M); i.e., emissions testing program as an emissions reduction strategy in the state implementation plan (SIP) for all or a portion of these nine counties in the state. However, in MOVES there is no GHG tailpipe emissions benefit associated with I/M programs as emissions control devices such as catalytic converters and diesel particulate filters do not reduce emissions of GHGs. In MOVES there is a slight methane credit given to I/M programs associated with evaporative emissions; however, these emissions reductions are insignificant compared to net GHG emissions that are dominated by tailpipe exhaust. The check box for “No I/M Program” was selected since there is not a statewide I/M program and accounting for the minimal GHG emissions credit within the ozone nonattainment area would result in no meaningful change to the results.

MOVES Output Data and Post-processing

Output Database (HeidiSQL)

After MOVES has successfully completed a model run the results are stored in the output database that was created in the RunSpec. The MOVES install package includes HeidiSQL which is an open source database software and results are automatically stored here as well as the data that was imported into the input database for that RunSpec.

The main output file of interest in MOVES for this analysis is the “Rate Per Distance” table. The file associated with each MOVES run contains the emissions rates for the HPMS category being analyzed for the months, road types and pollutants specified in the

RunSpec for every individual hour of the day by speed bin. This table was queried in HeidiSQL to select only emissions of CO2eq as that is the pollutant of interest in the analysis and those results were exported from the HeidiSQL as a .csv file for each MOVES run.

Post-Processing Emissions Rates by Speed and Month

Emissions Rates mode in MOVES does not produce emissions rates associated with speed changes at the level of rates at individual integer speeds in miles per hour values. Rather MOVES aggregates emissions by speed into groups of 16 speed bins with each bin corresponding to a five mile per hour maximum and minimum range of vehicle speeds, e.g., 42.5 mph to 47.5 mph. This results in faster model run times and smaller output files, and could be appropriate in instances where only a qualitative analysis is needed. However, for the purposes of this quantitative analysis a greater level of granularity concerning emissions rates by speeds is needed for GHG emissions results precise enough for accurate comparison to the absolute standards associated with each compliance year.

Previously the emissions rates were post-processed to produce emissions rates in grams per mile at individual integer speeds through interpolation in an additional MS Access database that was separate from the database utilized to calculate total mass GHG emissions for a compliance area. In revising the analysis, the interpolation methodology to develop GHG emissions rates in individual integer mph values remains unchanged, but APCD has consolidated this step into the same MS Access database used by an agency to calculate the total GHG emissions for a compliance area. Average annual emissions rates were similarly generated from a straight average of the emissions rates from the representative months of January and July in MOVES output data in the MS Access database.

Calculation of Mass GHG Emissions

Performed by: Dale Wells-ACPD

Reviewed by: Sabrina Williams-CDOT

Total mass GHG emissions for a compliance area are calculated in MS Access databases for 2030, 2040 and 2050 that are developed by APCD and are unique for each MPO/non-MPO area based on the design and structure of each compliance agency's travel modeling platform as well as the format the travel model runs data is provided.

Each database contains lookup tables for the GHG emissions rates and vehicle mix ratios that are consistent statewide, and the travel model run files specific to each individual agency. There are additional tables in each database that appropriately assign each link a road type from MOVES based on the area type and roadway functional classification based on an agency's travel modeling metadata.

Travel Model Data Considerations

Prior to calculating GHG emissions an agency must remove all links extending outside of their GHG compliance area that are represented in the travel model run. This is performed by a compliance agency splitting any sections of links that may go outside a compliance area in comparison to their boundary in appropriate spatial software, e.g., ESRI geographic information system (GIS) or TransCAD, so that only the portions of the link within a compliance area boundary are considered in the GHG emissions calculations for the agency. Following the splitting of links, the length of those split links must be recalculated. Whether this calculation is done automatically or manually depends on the particular software platform in use. Once the lengths of any split links are calculated, the VMT for the split links can be calculated by multiplying the recently-calculated link length by the predicted travel volumes.

GHG emissions rates are highly variable by vehicle speeds, and to a much lesser extent individual hours of the day based on temperature and use of cooling in the cab of the vehicle. Ideally, some form of dynamic traffic assignment would be used (such as the Simulation-Based Assignment of PTV VISUM) to estimate such within-day variation in travel speed. Static assignment of 24 individual hours would produce similar output data for GHG emissions calculations. Conversely, if an agency's travel model has less than 24 time periods, coordination is required between CDOT, APCD and individual MPOs on an agreed upon process for disaggregating travel model data with predicted vehicle volumes and speeds from time periods representing multiple hours to discrete individual hours. This is particularly important for agencies with a traffic assignment process that contains a single off-peak period representing 22 hours travel behavior in a day. In this instance simply dividing the predicted volumes on a link by the number of hours in the period is likely to greatly underestimate travel volumes during the AM and PM peak shoulders and midday hours, while overestimating travel volumes in nighttime hours. Furthermore, the use of the predicted speed for a link from a four-step model during an off-peak hours is likely to overestimate speeds during the AM and PM peak shoulders and midday hours which results in underestimating emissions during this time of day.

Querying the Database

The MS Access databases developed by APCD each contain numerous queries that run in sequence. These queries assign the correct GHG emissions rates and vehicle mix ratios at the link level through a series of joins. The length of each link is multiplied by the predicted hourly volume to calculate the VMT for that hour that then is multiplied by the vehicle mix ratio and appropriate GHG emissions rate for that vehicle class to calculate the emissions. Emissions for the links are then summed together to calculate the final database output which is daily GHG emissions in short-tonnes for each travel model scenario.

Calculation of Annual Emissions and Modeled Reductions

The emissions in GHG short-tons/day from the MS Access database are extracted into spreadsheet workbooks, e.g., MS Excel, and annualized through multiplying the weekday emissions by 338 to get annual emissions. Standard unit conversions (one US short ton = 0.907185 metric tons) are applied to calculate the GHG emissions in million metric tons (MMT) per year for each agency's baseline and compliance travel model scenarios for 2030, 2040, and 2050. The modeled emissions reduction for each year is simply calculated by subtracting the compliance emissions from the baseline emissions. The modeled emissions reduction is then compared to the agency's reduction target for that compliance year to determine if compliance with the Standard has been demonstrated through modeling or if mitigation is required.

Appendix F. Hourly VMT Distribution Methodology Memorandum

PACOG GHG Emissions Modeling Memorandum

To: Transportation Commission of Colorado
From: Sabrina Williams, Scott Ramming
Date: December 1, 2025

Subject: Methodology for Assigning Individual Hourly Volumes and Speeds from PACOG's Travel Model in the GHG Emissions Database.

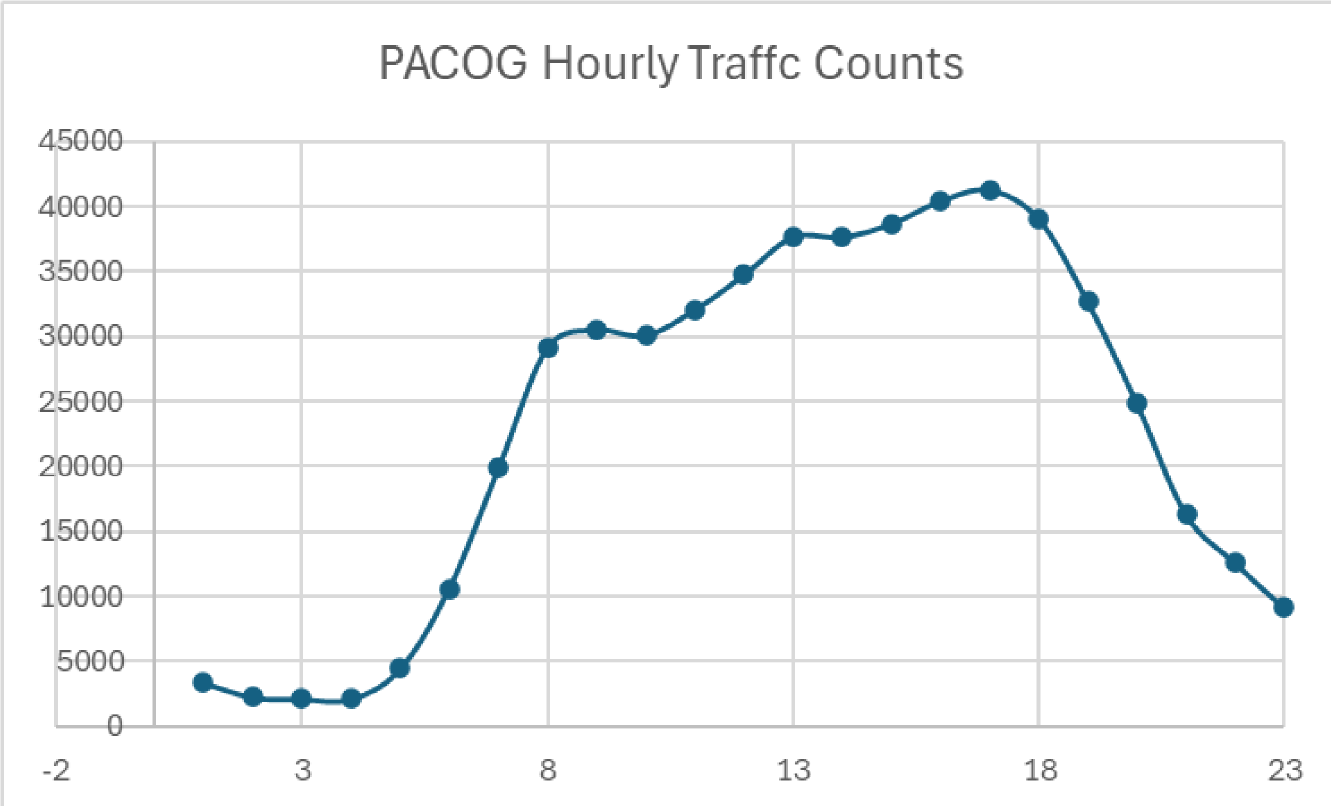
Background

The MOVES modeling conducted by APCD generated greenhouse gas (GHG) emissions rates in grams of CO2eq/VMT for each individual hour of the day (24hrs) that is further disaggregated by speed, vehicle type, and road type. APCD uses the MOVES emissions rates in conjunction with a GHG compliance area's predicted total daily on-road travel activity for each compliance year within a database platform to calculate predicted total annual GHG emissions (million metric tonnes, MMT/yr) to verify whether an area can demonstrate compliance with GHG Rule for Transportation Planning. To accurately calculate total daily and annual GHG emissions it is necessary for the GHG database to assign individual hourly volumes and speeds (24hrs/day) at the link level from the travel model's daily output. Most travel models for GHG compliance areas in Colorado do not use 24 time periods that facilitate this individual hourly assignment. Therefore, GHG compliance areas with fewer than 24 time periods, in consultation with CDOT and APCD, need to develop a mutually agreed upon process for the assignment of individual hourly volumes and speeds within the GHG database that interacts with the travel model output to calculate GHG emissions.

PACOG has a 4-step travel model that includes a 1-hour AM peak period from 8:30 AM to 9:30 AM, a 1-hour PM peak period from 4:30 PM to 5:30 PM, and a 22-hour off-peak period from 9:30 AM to 4:30 PM and 5:30 PM to 8:30 AM. Thus, it is necessary to disaggregate the 22-hour off-peak period into individual hourly speeds and volumes at the link level for the purposes of GHG emissions calculations. Similarly the half-hour-offset PM peak period is split between the individual clock hours (that is, 4:00 to 4:59 PM and 5:00 to 5:59 PM) in which the MOVES emissions rates are created and output.

Methodology

The Pueblo Area Council of Governments (PACOG) actively engaged with CDOT's Travel Modeling Unit and APCD to coordinate on a process for assignment of individual hourly volumes and speeds from their travel model's off-peak period. All agencies agreed that the use of hourly traffic counts used in the PACOG's travel model validation was the most appropriate dataset for this purpose. The hourly travel counts are plotted below:



The visual representation of PACOG count data indicates a high variability in individual hourly volumes during the 22-hour off-peak period, with noticeably increased travel activity during the daytime off-peak hours from 7:00 AM to 8:30 AM, 9:30 AM to 4:30 PM and 5:30 PM to 7:00 PM (10 hours) as compared to the remaining nighttime hours. Based on the count data it was determined that use of a simple hourly average of the travel model's predicted off-peak volumes would not be most representative of realistically expected travel behavior. The large variability in count data during the off-peak period was also determined to indicate that individual hourly speeds would likely not agree between the daytime and nighttime off-peak hours at the link level. Additionally, the predicted average speeds at the link level from the travel model output for the full 22-hour off-peak period would not be accurate for the purposes of emissions calculations as speeds during the daytime off-peak hours are likely lower than during the nighttime off-peak hour speeds (when lower volumes means operating speeds approach free-flow). This is particularly important as GHG emissions rates are highly sensitive to vehicle speeds, with lower speeds resulting in higher associated GHG emissions rates until vehicles reach speeds of approximately 50-60 mph at which point emissions rates begin to increase. Thus, use of a 22-hour average speed would likely result in an underestimation of GHG emissions during the daytime off-peak hours, as well as a likely overestimation of GHG emissions from the nighttime off-peak hours. Further, because of the non-linear nature of congested traffic speeds (relative to volumes) and emissions rates (relative to operating speeds), it would not be reasonable to assume that the overestimation during daytime hours simply offsets the overestimation during nighttime hours.

To facilitate an accurate assignment of individual hourly volumes and speeds, the hourly count data was further numerically analyzed as follows:

HOUR	Counts	%	Peak	OP SUM	OP%
12:00 AM	3361	0.6%		0.6%	0.7%
1:00 AM	2268	0.4%		0.4%	0.5%
2:00 AM	2121	0.4%		0.4%	0.5%
3:00 AM	2122	0.4%		0.4%	0.5%
4:00 AM	4452	0.8%		0.8%	1.0%
5:00 AM	10636	2.0%		2.0%	2.3%
6:00 AM	19857	3.7%		3.7%	4.3%
7:00 AM	29151	5.4%		5.4%	6.2%
8:00 AM	30510	5.7%	50.0%	2.8%	3.3%
9:00 AM	30090	5.6%	50.0%	2.8%	3.2%
10:00 AM	32048	6.0%		6.0%	6.9%
11:00 AM	34724	6.5%		6.5%	7.4%
12:00 PM	37654	7.0%		7.0%	8.1%
1:00 PM	37638	7.0%		7.0%	8.1%
2:00 PM	38648	7.2%		7.2%	8.3%
3:00 PM	40404	7.5%		7.5%	8.7%
4:00 PM	41236	7.7%	50.0%	3.8%	4.4%
5:00 PM	39051	7.3%	50.0%	3.6%	4.2%
6:00 PM	32681	6.1%		6.1%	7.0%
7:00 PM	24882	4.6%		4.6%	5.3%
8:00 PM	16348	3.0%		3.0%	3.5%
9:00 PM	12609	2.3%		2.3%	2.7%
10:00 PM	9141	1.7%		1.7%	2.0%
11:00 PM	5844	1.1%		1.1%	1.3%

In this table, the column labeled **%** indicates what fraction each hours count represents of the total 24-hour count. The **Peak** column represents what percentage of the AM or PM peak hour occurs during each clock hour. Since PACOG's PM peak hour is 4:30 to 5:30 pm, it is split evenly between the 4 PM and 5 PM clock hours. The **OP sum** column represents the percentage of the daily count that occurs during each clock hour. Since half of the 4 PM hour's 7.7% of the daily count occurs during the PM peak hour, the remaining half (3.8% of the daily count after rounding) occurs during the 22-hour off-peak period. The total of the OP sum column, 86.5%, indicates that the remaining 13.5% of travel occurs during the two peak hours. In the **OP%** column, the OP sum column is normalized to sum to 100% (by dividing each hourly percentage by 86.5%) to create factors to convert the 22-hour off-peak period volumes to hourly volumes.

The analysis of the count data was supportive of the assumption that during the daytime off-peak hours, the individual hourly volumes and speeds would be in better agreement with the AM and PM peak period predicted travel activity that had a similar level of counts than the nighttime off-peak period hours that had noticeably fewer counted vehicles during these hours. Based on the count data, PACOG, CDOT and APCD agreed to assign individual hourly volumes and speeds within the GHG database during the off-peak period at the link level as shown below (note that the travel model provides outputs for links in both the AB and BA direction for each period, with the reverse/”wrong way” direction volumes equal to zero for one-way links.

PACOG Individual Hourly Volume and Speed Assignments at the Link Level Within the GHG Database

Hour	AB Direction		BA Direction	
	Volume	Speed	Volume	Speed
12:00 AM	AB_OP_VOL*OP%	FreeFlow	BA_OP_VOL*OP%	FreeFlow
1:00 AM	AB_OP_VOL*OP%	FreeFlow	BA_OP_VOL*OP%	FreeFlow
2:00 AM	AB_OP_VOL*OP%	FreeFlow	BA_OP_VOL*OP%	FreeFlow
3:00 AM	AB_OP_VOL*OP%	FreeFlow	BA_OP_VOL*OP%	FreeFlow
4:00 AM	AB_OP_VOL*OP%	FreeFlow	BA_OP_VOL*OP%	FreeFlow
5:00 AM	AB_OP_VOL*OP%	FreeFlow	BA_OP_VOL*OP%	FreeFlow
6:00 AM	AB_OP_VOL*OP%	FreeFlow	BA_OP_VOL*OP%	FreeFlow
7:00 AM	AB_OP_VOL*OP%	FreeFlow	BA_OP_VOL*OP%	FreeFlow
8:00 AM	(0.5*AB_AM_VOL) + 0.5*(AB_OP_VOL*OP%)	AM_AB_SPD	(0.5*BA_AM_VO) + (0.5^AB_OP_VOL*OP%)	AM_BA_SPD
9:00 AM	(0.5*AB_AM_VOL) + (0.5*AB_OP_VOL*OP%)	AB_AM_SPD	(0.5*BA_AM_VO) + (0.5^AB_OP_VOL*OP%)	AM_BA_SPD
10:00 AM	AB_OP_VOL*OP%	AB_AM_SPD	BA_OP_VOL*OP%	BA_AM_SPD
11:00 AM	AB_OP_VOL*OP%	(0.5*AB_AM_SPD)+(0.5_AB_PM_SPD)	BA_OP_VOL*OP%	(0.5*BA_AM_SPD)+(0.5_BA_PM_SPD)
12:00 PM	AB_OP_VOL*OP%	(0.5*AB_AM_SPD)+(0.5_AB_PM_SPD)	BA_OP_VOL*OP%	(0.5*BA_AM_SPD)+(0.5_BA_PM_SPD)
1:00 PM	AB_OP_VOL*OP%	(0.5*AB_AM_SPD)+(0.5_AB_PM_SPD)	BA_OP_VOL*OP%	(0.5*BA_AM_SPD)+(0.5_BA_PM_SPD)
2:00 PM	AB_OP_VOL*OP%	(0.5*AB_AM_SPD)+(0.5_AB_PM_SPD)	BA_OP_VOL*OP%	(0.5*BA_AM_SPD)+(0.5_BA_PM_SPD)

Hour	AB Direction		BA Direction	
	Volume	Speed	Volume	Speed
3:00 PM	AB_OP_VOL*OP%	AB_PM_SPD	BA_OP_VOL*OP%	BA_PM_SPD
4:00 PM	(0.5*AB+PM+VOL)+(0.5*AB_OP_VOL*OP%)	AB_PM_SPD	(0.5*AB+PM+VOL)+(0.5*AB_OP_VOL*OP%)	BA_PM_SPD
5:00 PM	(0.5*AB_PM_VOL)+(0.5*AB_OP_VOL*OP%)	AB_PM_SPD	(0.5*BA_PM_VOL)+(0.5*BA_OP_VOL*OP%)	BA_PM_SPD
6:00 PM	AB_OP_VOL*OP%	AB_PM_SPD	BA_OP_VOL*OP%	BA_PM_SPD
7:00 PM	AB_OP_VOL*OP%	(0.25*AB_PM_SPD)+(0.75*FreeFlow)	BA_OP_VOL*OP%	(0.25*BA_PM_SPD)+(0.75*FreeFlow)
8:00 PM	AB_OP_VOL*OP%	FreeFlow	BA_OP_VOL*OP%	FreeFlow
9:00 PM	AB_OP_VOL*OP%	FreeFlow	BA_OP_VOL*OP%	FreeFlow
10:00 PM	AB_OP_VOL*OP%	FreeFlow	BA_OP_VOL*OP%	FreeFlow
11:00 PM	AB_OP_VOL*OP%	FreeFlow	BA_OP_VOL*OP%	FreeFlow

Note: The 4 PM speed calculation reflects half of the volume (from 4:00 to 4:29/30 PM) traveling at the daytime speed, which is the average of the AM and PM peak hour speeds, averaged with the other half of the volume traveling at the PM peak speed.

Individual Hourly Volume Assignment

For the AM peak period occurring from 8:30 AM to 9:30 AM and for the PM peak period occurring from 4:30 PM to 5:30 PM that each span two individual hours of the day, a 50% weighting coefficient was applied to the both the peak and off-peak hourly assigned volumes at the link level that were then summed together for the individual hours representing 4:00 PM to 6:00 PM. As shown in the equations, rather than performing a simple average of the 22-hour total predicted volumes, the percentage of observed off-peak hourly counts for PACOG was applied to the total predicted 22-hour off-peak travel volumes to assign individual hourly off-peak volumes at the link level.

Individual Hourly Speed Assignment

For the AM peak period occurring from 8:30 AM to 9:30 AM and for the PM peak period that occurs from 4:30 PM and 5:30 PM that each span two individual hours of the day, the individual hourly speeds at the link level occurring from these peak hours were assigned a 100% weighting of the AM and PM peak period predicted average speed. The individual hourly speeds at the link level occurring from 11:00 AM PM to 2:00 PM PM were assigned a 50% weighting of the predicted hourly PM peak period average speed and a 50% weighting of the nighttime offpeak speed assignment of average hourly speed = free flow to represent an equal weighting between the partial PM peak hour of 5:00 to 5:30 PM and the partial nighttime peak hour of 5:30 PM to 6:00 PM. Further detail on the assignment of individual hourly speeds during the 22-hour offpeak period is provided below.

Professional judgement was used to assume that during the daytime offpeak individual hours occurring from 9:00 AM to 4:30 PM, speeds at the link level were likely to largely agree with the predicted speeds during the AM and PM peak periods as the count data indicated volumes would also be similar. To represent individual hourly volumes and speeds at the link level during the daytime offpeak hours an average of the AM peak period predicted speed and the PM peak period predicted average speed were assigned at the link level. Similarly, professional judgement was used to analyze the observed count data during the nighttime offpeak hours from 5:30 PM to 8:00 AM and a determination was made that given the low overall percentage of counts observed during these nighttime hours in relation to the total observed offpeak hourly travel counts speeds were unlikely to be reduced by congestion and were assigned the free flow speeds as defined in their travel model to represent the individual hourly speeds during the nighttime offpeak hours.

Conclusion

PACOG coordinated with CDOT and APCD to develop an agreed upon process for assigning individual hourly volumes and speeds at the link level that is appropriate for the purposes of calculating GHG emissions for the GHG compliance area. All agencies involved had familiarity with PACOG's travel model platform, reviewed the travel counts used in the analysis for the individual hourly assignments and reached consensus that the methodology described in this memo should result in an accurate depiction of individual hourly daily travel activity in the area required for use in the GHG database. The result of this process is a table housed within the GHG database containing the equations provided in this memo, that interacts with the travel model output table, as well as the MOVES GHG emissions rates that result in prediction of annual GHG emissions for the PACOG GHG compliance area to determine whether the GHG reduction targets established in CDOT's GHG rule have been met.

Appendix G. APCD Verification Memorandum

COLORADO
Department of Public Health & Environment

January 27, 2026

Eva Coslyeon
MPO Manager
Pueblo Area Council of Governments (PACOG)
211 East D Street, Pueblo, CO 81003

Subject: Greenhouse Gas Transportation Report as required by the Colorado Greenhouse Gas Pollution Reduction Planning Rule

Dear Eva,

Thank you for providing the Pueblo Area Council of Governments (PACOG) Transportation Greenhouse Gas Report for the PACOG boundary area for Colorado Department of Public Health and Environment, Air Pollution Control Division (Division) review.

Per 2 CCR 601-22, Rules Governing Statewide Transportation Planning Process and Transportation Planning Regions, the Division is respectfully submitting our verification of the PACOG 2050 Long Range Transportation Plan Amendment.

Based on the analysis of the report, supporting datasets, and information provided, we can verify that the report and data inputs address the requirements of the Colorado Greenhouse Gas Pollution Reduction Planning Rule. The submitted package describes the baseline and compliance travel demand modeling runs and how they meet the Rule requirements. The submitted package describes how the travel demand model was deployed and how emissions were calculated. The Division finds the outputs to be mathematically correct.

The Division would like to thank the PACOG for providing the necessary data files and Report. The Division would also like to thank Dale Wells, Megan Carroll, and Cody Johnston from the Division who performed the verification analysis and Sabrina Williams and Scott Ramming of the Colorado Department of Transportation for their efforts in validating the results.

Sincerely,

Michael Ogletree
Director, Air Pollution Control Division
Colorado Department of Public Health and Environment

CC:

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