CO and PM_{10} 2050 MVRTP Conformity Determination

for the DRCOG Fiscally Constrained Element of the 2050 Metro Vision Regional Transportation Plan

and the DRCOG 2022-2025 Transportation Improvement Program

and the Southern Subarea Portion of the Upper Front Range 2045 Regional Transportation Plan

and the 2022-2025 State Transportation Improvement Program for the Upper Front Range Transportation Planning Region

Draft, January 19, 2021

For Air Quality Control Commission Public Meeting on February 18th, 2021

Denver Regional Council of Governments

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Tables and Figures

Executive Summary

The Denver Regional Council of Governments (DRCOG) has completed this transportation conformity determination as part of the transportation and air quality planning process. DRCOG's update to the long-range transportation plan triggered the need to perform the conformity analysis. This document demonstrates the area meets federally prescribed air pollution emissions budget tests for carbon monoxide (CO),PM_{10}, and NO_x associated with PM_{10}. The attainment maintenance areas continue to meet air quality conformity standards associated with DRCOG's long-range transportation plans and short-range transportation improvement programs.

Emission Test Results

The modeled emissions estimates were generated by the Air Pollution Control Division outputs from DRCOG's transportation model, Focus, as in input to the Motor Vehicle Emission Simulator (MOVES) model.. The modeled emissions must be below the budgets to pass conformity tests. All staging year results for the Denver region are reported in **Error! Reference source not found.** Model results for emissions are below the budgets, thus all tests are passed and conformity requirements are met.

Table 1. Conformity Emissions Test Results

Pollutant	Test	Result<Budget (tons per day)	Pass/Fail
Carbon Monoxide (CO)	2021 Staging ≤ Budget[1]	405 < 1,600	Pass
	2030 Staging ≤ Budget	N/A < 1,600	N/A
	2040 Staging ≤ Budget	198 < 1,600	Pass
	2050 MVRTP ≤ Budget	187 < 1,600	Pass
PM_{10}	2022 Staging ≤ Budget[2]	28 < 55	Pass
	2030 Staging ≤ Budget	N/A < 55	N/A
	2040 Staging ≤ Budget	34 < 55	Pass
	2050 MVRTP ≤ Budget	37 < 55	Pass
NO_x associated with PM_{10}	2022 Staging ≤ Budget[3]	34 < 56	Pass
	2030 Staging ≤ Budget	N/A < 56	N/A
	2040 Staging ≤ Budget	16 < 56	Pass
	2050 MVRTP ≤ Budget	15 < 56	Pass

N/A – Not yet available. Results will be available upon completion of model runs, anticipated prior to public meeting. Results are expected to pass.

[1] 2021 derived from interpolation of 2020 and 2023 emission estimates.
[2] 2022 derived from interpolation of 2020 and 2023 emission estimates.
[3] 2022 derived from interpolation of 2020 and 2023 emission estimates.

Chapter 1. What is Transportation Conformity?

Background and Federal Requirements

The Denver Regional Council of Governments is the Metropolitan Planning Organization for the Denver Transportation Management Area shown in Figure 1. The region has been redesignated as an attainment maintenance area for CO and $PM_{10,}$ from the previous designation of nonattainment. The pollutants and their violation status for the Denver region are shown in Table 2. DRCOG is required to show conformity of its fiscally constrained transportation plan and Transportation Improvement Program with the State Implementation Plan for air quality before these transportation plans and programs are adopted. This action is required under Section 176(c) of the Clean Air Act, as amended in 1990.

The Clean Air Act defines conformity as compliance to the implementation plan's purpose of eliminating or reducing the severity and number of violations of the National Ambient Air Quality Standards (NAAQS) and achieving expeditious attainment of such standards. In addition, activities may not cause or contribute to new violations of air quality standards, exacerbate existing violations, or interfere with the timely attainment of required emissions reductions towards attainment. The U.S. Environmental Protection Agency criteria and procedures vary according to the status of the State Air Quality Implementation Plans for individual pollutants. Transportation plans and programs must satisfy different criteria depending on whether the state has submitted a SIP revision, and whether the EPA has approved the revision. For pollutants for which a region currently meets standards but was formerly in nonattainment, the applicable State Implementation Plan may also be referred to as a maintenance plan, which demonstrates continued attainment of the standards. The EPA final transportation conformity rule is located at 40 CFR Part 93. To address revised standards and changes in conformity requirements, the EPA promulgated several amendments to the final rule as detailed in Table 3.

Table 2. Pollutant Status in the Denver Region

Pollutant	Standard	Status
Carbon Monoxide (CO)	A violation of the carbon monoxide standard occurs when a monitoring station shows more than one exceedance per year of the 8-hour (9 parts per million (ppm)) or 1-hour (35 ppm) standard.	The carbon monoxide standard was last violated in 1995. There has been no violation for CO in the Denver region since.
$PM_{2.5}$	An exceedance of the $PM_{2.5}$ standard occurs when a monitoring station exceeds the annual average of 12 $\mu g/m^3$ or the 24-hour average of 35 $\mu g/m^3$. A violation of the 24-hour standard occurs only if the 3-year average of the 98^{th} percentile of all 24 hour readings at a monitor exceeds 35 $\mu g/m^3$ or the 3-year average of the annual averages exceeds 12 $\mu g/m^3$.	The Denver metropolitan area has never violated either of the two $PM_{2.5}$ standards.

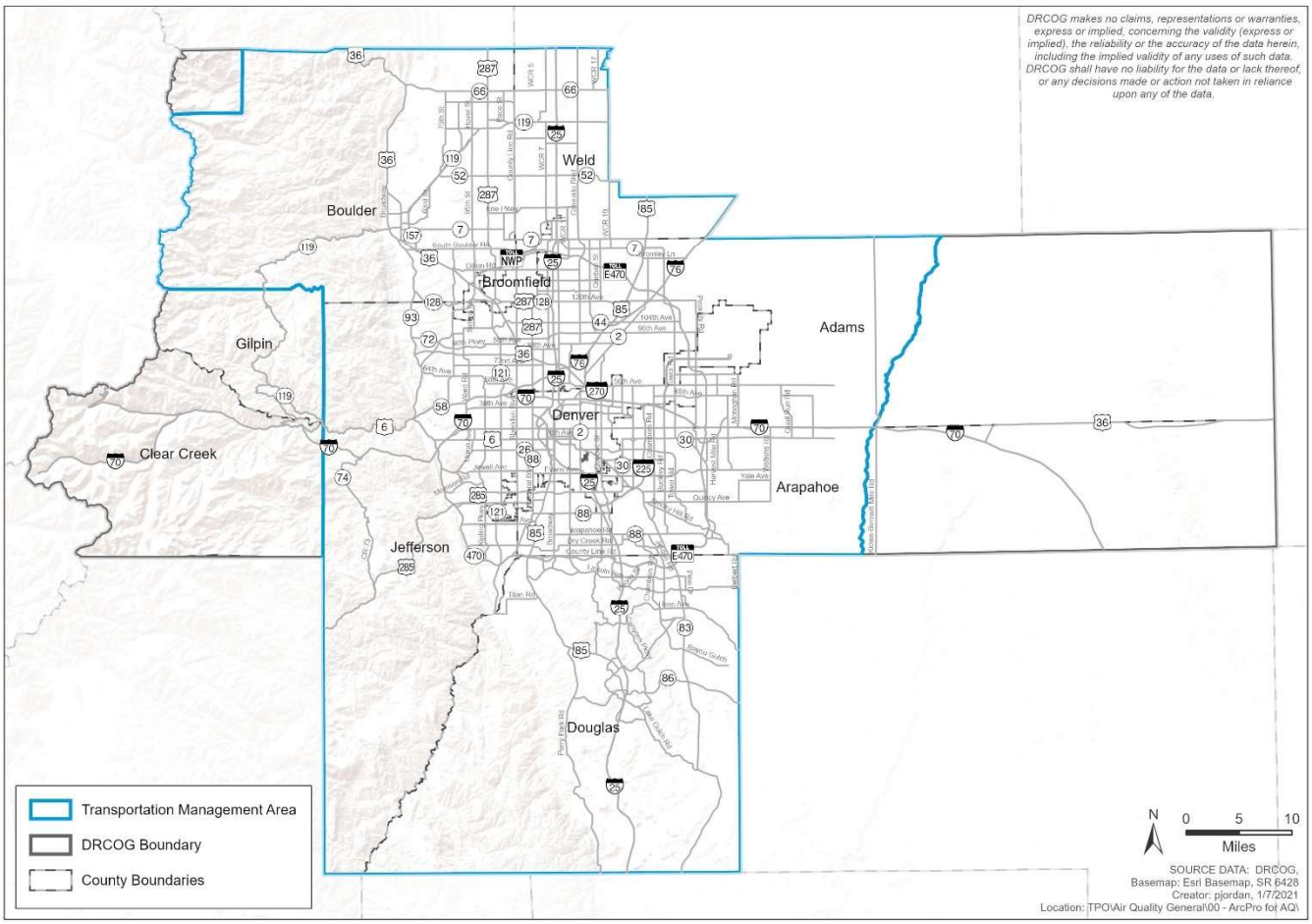
PM_{10}	An exceedance of the PM_{10} standard occurs when a monitoring station exceeds a 24-hour average of 150 µg/m^3. If the 24-hour standard is exceeded more than three times over a three-year period, it is a violation.	The PM_{10} standard was last violated on three days in 1993. There has been no violation for PM_{10} in the Denver region since.

Table 3. Historical Summary for NAAQS in the Denver Region

Date	Milestone	Comments
July 1, 2004	EPA issued amendments to the final transportation conformity rule.	These addressed conformity regulations for the 8-hour ozone and fine particulate matter (PM2.5) NAAQS, the incorporation of existing federal guidance that is consistent with a U.S. Court of Appeals decision, and streamlining and improving of the rule[4].
March 10, 2006	EPA issued revisions addressing $PM_{2.5}$ and PM_{10} Hot-Spot Analyses in Project-Level Transportation Conformity Determinations.	These project-level conformity analyses are the responsibility of project sponsors. This conformity finding covers plan and program level conformity only.
January 24, 2008	The U.S. Department of Transportation and EPA issued the transportation conformity rule.	Titled: "Transportation Conformity Rule Amendments To Implement Provisions Contained in the 2005 Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU)."
March 8, 2012	EPA issued amendments which restructure several sections of the existing transportation conformity rule.	Included restructuring two sections of the conformity rule, 40 CFR 93.109 and 93.119, so that the existing rule requirements clearly apply to areas designated for future new or revised NAAQS, thus reducing the need to amend the transportation conformity rule merely to reference specific new NAAQS. Conformity rules applies to any future new NAAQS.
October 17, 2020	EPA submitted a letter that the conformity requirements no longer apply to the Longmont CO maintenance area due to the expiration of the 20-year maintenance plan.	The Longmont CO maintenance area showed continuous maintenance of the CO NAAQS from November 23, 1999 through October 16, 2020, meeting its obligation to demonstrate maintenance of the CO NAAQS for 20 years. Therefore, as of October 17, 2020, DRCOG is no longer required to address transportation conformity determination for the Longmont CO maintenance area.

[4] 40 CFR Part 93

Figure 1 - Transportation Management Area



Relevant Agencies and Ongoing Planning Efforts

DRCOG Metro Vision Regional Transportation Plan

DRCOG's Metro Vision plan is the long-range growth and development strategy for the Denver region. It integrates plans for growth and development, transportation and environmental quality into a single comprehensive foundation for regional planning. Metro Vision calls for a balanced multimodal surface transportation system including rapid transit, a regional bus network, bicycle and pedestrian facilities, and improvements to the existing roadway system. Among Metro Vision's regional objectives is to "Improve air quality and reduce greenhouse gas emissions," which reflects the region's commitment to improve air quality through local and regional initiatives that reduce ground-level ozone, greenhouse gas emissions and other air pollutants. Supporting objectives include:

- Increase collaboration with local and regional partners on air quality initiatives.
- Increase public awareness of air quality issues.
- Improve the fuel economy of the region's vehicle fleet.

The Metro Vision Regional Transportation Plan implements the transportation element of Metro Vision. The Metro Vision Regional Transportation Plan contains an unconstrained vision plan, outlining the region's total transportation needs, as well as the Fiscally Constrained Regional Transportation Plan, which includes those projects that can be implemented given reasonably anticipated revenues through 2050. When the 2050 Metro Vision Regional Transportation Plan is referenced in this document it denotes the fiscally constrained element of the plan.

The 2022-2025 Transportation Improvement Program identifies transit, multimodal and roadway projects to be funded from fiscal year 2022 through fiscal year 2025. Regionally significant projects funded in the TIP must first be identified in the 2050 Metro Vision Regional Transportation Plan. Regionally significant projects are listed in Appendix A. The TIP will implement selected projects and strategies identified in the first staging periods of the 2050 Metro Vision Regional Transportation Plan. DRCOG staff fostered public participation throughout development of the 2050 Metro Vision Regional Transportation plan and 2022-2025 Transportation Improvement Program, and continue to facilitate youth and civic engagement on a regular basis. DRCOG has provided numerous public participation opportunities, including workshops, county forums, stakeholder meetings, surveys, interactive online forums, a Youth Advisory Panel and a Civic Advisory Group.

Air Quality Planning

The status of air quality planning is important as it determines the emissions tests that must be met to show conformity. The most recent revised CO maintenance plan for Denver, approved by the Colorado Air Quality Control Commission on December 15, 2005, established the emission budget at 1,625 tpd through 2020, and 1,600 tpd for 2021 and beyond. On May 3, 2007, EPA found the revised CO budget of 1,600 tpd adequate for use in conformity determinations for 2021 and beyond. EPA's approval of the revised Denver CO Maintenance Plans became effective on October 16, 2007.

The State of Colorado submitted the latest Denver particulate matter equal to and less than 10 microns in aerodynamic diameter (PM_{10}) maintenance plan to the EPA in December 2005. EPA approved this latest PM_{10} State Implementation Plan Revision on January 7, 2008. This latest PM_{10} Maintenance Plan revision contains the PM_{10} budgets of 54 tpd for the years 2015 through 2021, and 55 tpd for 2022 and

beyond, respectively, as well as the wintertime NOx budgets of 70 tpd and 56 tpd for the years 2015 through 2021, and 2022 and beyond, respectively.

On December 14, 2012, EPA strengthened the annual $PM_{2.5}$ standard from 15 to 12 micrograms per cubic meter ($\mu g/m^3$) and retained the 24-hour $PM_{2.5}$ standard of 35 $\mu g/m^3$. The agency also retained the existing standard for PM_{10}. Based on the existing $PM_{2.5}$ monitor data, the Denver region does not violate either the new annual $PM_{2.5}$ standard, or the existing 24-hour $PM_{2.5}$ standard.

Agency Roles

The Conformity State Implementation Plan was developed by the Air Quality Control Commission and adopted in 1998. It formally defines the process for finding conformity. The EPA approved the Conformity State Implementation Plan on September 21, 2001 (66 FR 48561), making it federally enforceable.

DRCOG, as the Metropolitan Planning Organization, and the Federal Transit Administration and Federal Highway Administration, as representatives of the U.S. Department of Transportation, are charged with determining conformity for the Denver Transportation Management Area. The development of this conformity determination has been a cooperative process between DRCOG and the Regional Air Quality Commission, the Air Pollution Control Division of the Colorado Department of Public Health and Environment, the U.S. Environmental Protection Agency, the and the Federal Transit Administration and Federal Highway Administration, the Colorado Department of Transportation, and the Regional Transportation District. In 2015, a memorandum of agreement was signed by DRCOG, the North Front Range Metropolitan Planning Organization, the Colorado Department of Public Health and Environment, and the Regional Air Quality Commission for the purpose of defining the specific roles and responsibilities in conformity evaluations and findings.

Chapter 2. Transportation Control Measures

For this conformity determination, there are no transportation control measures identified for timely completion or implementation as part of the applicable implementation plan. All transportation control measures associated with the CO or PM10 State Implementation Plans were completed by 2006.

Chapter 3. Emissions Test Process and Assumptions

Background and Budgets

The transportation plan and program must pass a series of emissions tests to demonstrate conformity. These emissions tests relate to the pollutants and their precursors for which the Denver region is designated as attainment-maintenance of the NAAQS.

These pollutants and precursors include:

- Carbon monoxide (CO)
- PM_{10}
- Nitrogen oxides (NO_x) as a precursor for PM_{10} (wintertime estimate)

Each pollutant and precursor in specific geographic areas must pass a number of tests. The plan and program must respect the motor vehicle emissions budget in the applicable State Implementation Plan or State Implementation Plan submittal. Satisfying these tests involves demonstrating that relevant emissions in future years are less than or equal to the emissions budget established in the applicable maintenance plan. As required by 40 CFR 93.118, consistency with the motor vehicle emissions budget(s) must be demonstrated for each year for which the applicable implementation plan specifically establishes motor vehicle emissions budget(s), for the attainment year (if it is within the timeframe of the transportation plan), for the last year of the transportation plan's forecast period, and for any intermediate years as necessary so that the years for which consistency is demonstrated by analysis are no more than ten years apart.

In addition, when a maintenance plan has been submitted, emissions must be less than or equal to the motor vehicle emissions budget(s) established for the last year of the maintenance plan and any year for which the maintenance plan establishes budgets. Applying these tests for the prescribed time periods for each of the pollutants results in 16 emissions tests as listed in Table 4[5]. The analysis areas are shown in Figure 2.

[5] Transportation model runs represent the beginning of a calendar year. Test dates listed in Table 4 refer to model run dates.

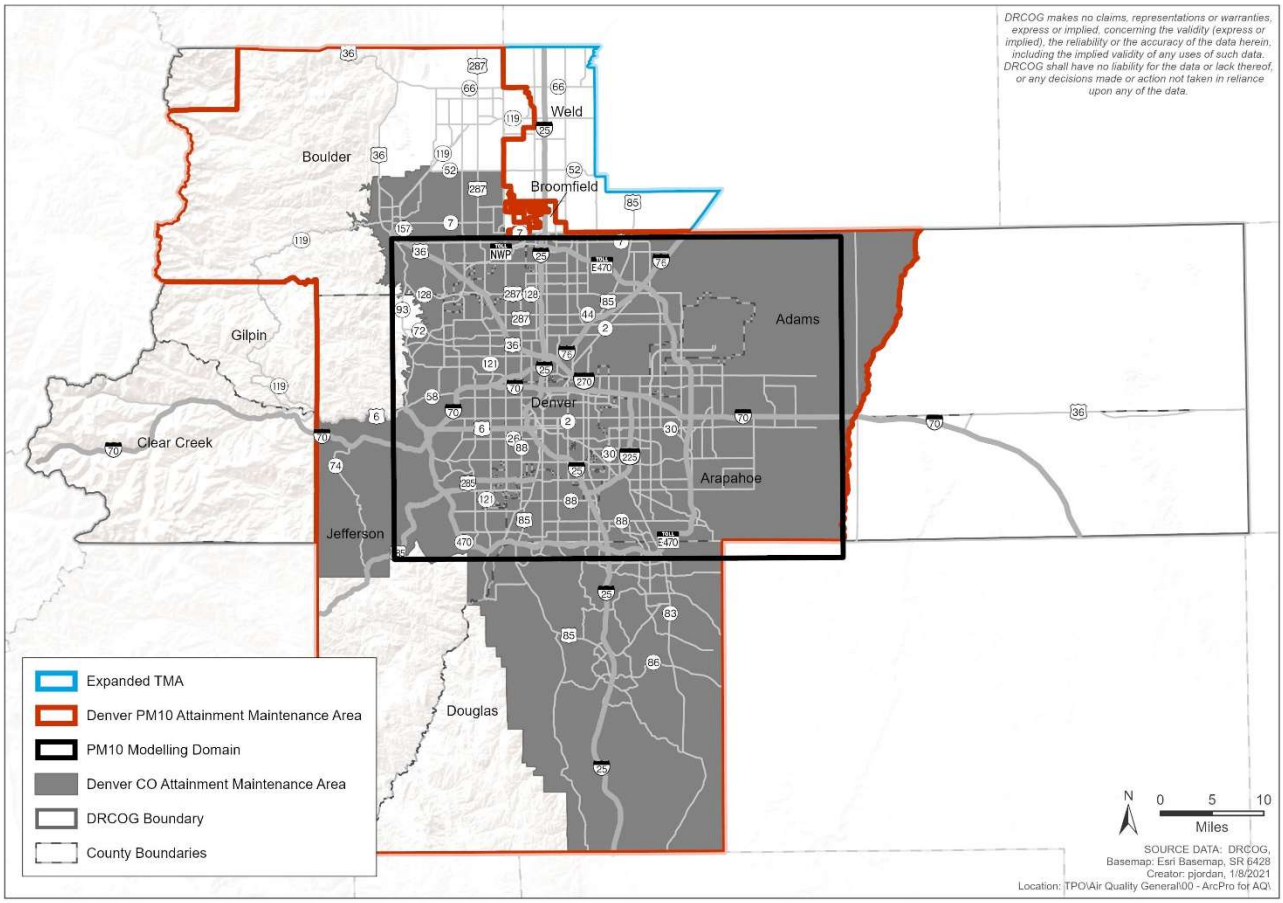
Table 4
Conformity Emissions Tests

Pollutant	Tests
Carbon Monoxide (CO)	2021 staging ≤ Budget of 1,600 tpd 2030 staging ≤ Budget of 1,600 tpd 2040 staging ≤ Budget of 1,600 tpd 2050 MVRTP ≤ Budget of 1,600 tpd
PM_{10}	2022 staging ≤ Budget of 55 tpd 2030 staging ≤ Budget of 55 tpd 2040 staging ≤ Budget of 55 tpd 2050 MVRTP ≤ Budget of 55 tpd
NO_x associated with PM_{10}	2022 staging ≤ Budget of 56 tpd 2030 staging ≤ Budget of 56 tpd 2040 staging ≤ Budget of 56 tpd 2050 MVRTP ≤ Budget of 56 tpd

Technical Process

The technical process used to estimate future pollutant emission levels is based on the latest planning assumptions in effect at the time of this conformity determination. Assumptions behind the analysis were derived from estimates of current and future population, employment, travel, and congestion most recently developed by DRCOG. Information concerning vehicle miles traveled and operating speeds were updated as part of this conformity finding process. Appendix B describes the modeling structure and recent enhancements for the DRCOG travel demand model in more detail. The assumptions are also used in the Motor Vehicle Emission Simulator model (MOVES) to estimate emissions.

Figure 2. Attainment Maintenance Areas



Demographic Assumptions

The population forecast for the full DRCOG region in 2050 is 4,382,172. This is a 31 percent increase over the 2020 estimated population of 3,337,670. Employment is forecast to be 2,948,530 in 2050 compared to the 2020 estimate of 2,147,815, an increase of 37 percent. Growth in population and employment will be the principal factor for the increased demand for travel on the region's transportation facilities and services. Table 5 shows the latest forecasts of population and employment for 2020, 2023, 2030, 2040, and 2050 for the DRCOG region. Table 6 lists 2020 and 2050 population and employment estimates by each of the nine counties, as well as the southwest portion of Weld County within the DRCOG region.

Table 5
Population and Employment Forecasts –

	2020	2023	2030	2040	2050
Population	3,337,670	3,498,995	3,785,201	4,159,665	4,382,172
Employment	2,147,815	2,228,303	2,427,498	2,687,506	2,948,530

Source: State Demography Office, Colorado Department of Local Affairs 2019 Data Pull. Weld County portioning applied by DRCOG staff.
Counties included in totals: Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, Jefferson and southwestern Weld.

Table 6. 2020 and 2050 Population and Employment Estimates by County –

Southern Subarea

County	Population		Employment	
	2020	2050	2020	2050
Adams County	523,778	842,689	267,686	365,949
Arapahoe County	659,564	837,991	426,173	584,069
Boulder County	331,025	420,105	248,111	339,920
Broomfield County	72,773	98,239	48,254	66,192
Denver County	736,531	883,165	646,251	885,225
Douglas County	354,508	464,189	174,176	238,725
Jefferson County	586,965	661,332	313,198	429,177
Southwestern Weld County	72,526	174,462	23,966	39,273
Total CO and PM10 Nonattainment Area	**3,337,670**	**4,382,172**	**2,147,815**	**2,948,530**

Source: State Demography Office, Colorado Department of Local Affairs 2019 Data Pull. Weld County portioning applied by DRCOG staff.
Counties included in totals: Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, Jefferson and southwestern Weld.

DRCOG Transportation Assumptions

In order to complete the emissions tests, the 2020, 2023, 2030, 2040, and 2050 transportation networks must first be defined. DRCOG's 2050 Metro Vision Regional Transportation Plan specifies financially constrained highway and transit system improvements and resulting networks to be completed by the year 2050. The 2022-2025 TIP identifies funding to complete regionally significant projects on the designated regional roadway and rapid transit system that are also contained in the 2050 Metro Vision Regional Transportation Plan. All roadway and rapid transit network and staging assumptions through 2050 are shown in the figures found in Appendix A.

Air Quality Modeling Assumptions

The APCD of the CDPHE calculates air pollutant emissions using MOVES. The conformity analysis began in December 2016. The models and assumptions used by APCD in the conformity analysis were consistent with those used in the development of the CO and PM_{10} SIPs. The MOVES model accounts for estimates of vehicle types by miles traveled, effects on emissions caused by vehicle regulations, street sweeping commitments, and more.

PM_{10} Street Maintenance Actions

There are several actions or projects described or assumed in the SIPs that are federally enforceable control measures. PM_{10} street maintenance actions are one of the control measures.

DRCOG must demonstrate that future year estimates of PM_{10} emissions will be less than or equal to the maintenance PM_{10} emissions budgets to show conformity with the PM_{10} SIP. The mobile source PM_{10} budgets are 54 tons per day (tpd) through 2021, and 55 tpd for 2022 and beyond.

Air Quality Control Commission Regulation 16 is essential to the control of mobile source emissions. Adopted on August 15, 1991, the regulation has undergone several revisions, with the latest occurring on April 19, 2001. Re-entrained road dust in the Denver metropolitan area from winter street sanding causes between 40 and 60 percent of PM_{10} emissions. It is the single largest contributor to PM_{10} emissions[6]. Regulation 16 targets street sanding and sweeping practices.
Since October 1, 1991, street sanding material providers have been required to meet set standards for the sanding materials they provide to state, city, and county governments. The regulation applies to

[6] In June 1998, the Colorado Department of Transportation, with technical assistance of Midwest Research Institute, concluded a study of the role of sand in PM_{10} emissions. Findings from this study demonstrated that the percentage of the total PM_{10} emissions from road traffic that consist of road dust increases from about 50 percent to as much as 80 or 90 percent during the high impact 24-hour period following road sanding. Previously, the PM_{10} emissions analysis had been using a sand share of 33.8 percent or about half of the recent study findings. Increasing the role of sand in producing PM_{10} emission increases the benefits of reduced street sanding. Over the past few years, local governments, CDOT, RTD and the E-470 Public Highway Authority have made major strides to reduce PM_{10} emissions from street sand by reducing the amount of sand spread on the streets during snow storms by about 40 percent from 1989 street sanding levels and increasing the sweeping of sanded streets within four days of each snow storm from none to 40 percent.

both new and recycled sanding materials. All materials must meet requirements regulating their angularity, percent fines, and degree of durability. The burden of material testing to meet these standards falls on the private companies supplying the materials. An independent laboratory must conduct all testing.

Reductions in the applied amount of sanding material are also set for all the local governments and street maintaining agencies (Colorado Department of Transportation, Regional Transportation District, E-470 Authority, Northwest Parkway Authority) within the nonattainment area. A reduction of 30 percent from their established baseline amount is mandated. Baseline amounts are typically based on 1989 practices. In the defined "foothills" area, a 20 percent reduction from the established baseline is mandated. In addition to the above requirements, there are specific requirements to the City and County of Denver and Colorado Department of Transportation:

- The City and County of Denver shall achieve a 72% reduction within the Denver central business district. The central business district is defined as the area bounded by and inclusive of Colfax Avenue, Speer Boulevard, Wynkoop Street, 20th Street, and Broadway.
- Colorado Department of Transportation shall achieve a 54% reduction from Interstate 25 and its entrance/exit ramps between 6th Avenue and University Boulevard.
- The City and County of Denver and Colorado Department of Transportation shall achieve a 50% reduction on roadways within the area bounded by, and including, Federal Boulevard, Downing Street, 38th Avenue, and Louisiana Avenue.

Records and reports of the reductions and practices used must be submitted yearly to the Air Pollution Control Division and the Regional Air Quality Council.

Finally, Regulation 16 sets rules for street sweeping to achieve reductions in PM_{10} emissions. These rules include time requirements for sweeping after deployments of street sanding materials, definition of the sweeping techniques to be used, and targeted areas for increased sweeping. Record keeping and reporting of dates, equipment use, and areas swept are required under these rules.

Preliminary estimates of emissions for the original 2035 Regional Transportation Plan in 2012 indicated that PM_{10} emissions would be higher than the 55 tpd emissions budget after accounting for the impacts of Regulation 16. Because of this anticipated exceedance of the PM_{10} emissions budget, local governments and road agencies were asked to provide commitments to further reduce emissions as part of the RTP update. These commitments are for additional reductions in sand application and an increase in street sweeping activities, above and beyond Regulation 16, to further reduce mobile source PM_{10} emissions. In 2020, 44 agencies submitted their commitments to DRCOG. The local governments and agencies have decided on the combination of the above actions to meet their commitments. The street sanding and sweeping commitments made by local governments and road agencies in 2020 are detailed in Appendix C.

Actions that can be employed to achieve PM_{10} reductions include:

- Reducing the total amount of sanding materials used.
- Using anti-icers, deicers, and other sand substitutes in place of sanding materials.
- Street sweeping within four days of each snow event.

The PM_{10} maintenance plan also identifies a test whereby the region must demonstrate that transportation construction emissions do not exceed those assumed in the emissions budgets. The budgets were established on the assumption that all of the facilities in the 2020 Fiscally Constrained Regional Transportation Plan. To pass the test, the rate of lane-mile construction proposed in the 2050 Metro Vision Regional Transportation Plan must be less than or equal to the rate of construction in the 2020 Fiscally Constrained Regional Transportation Plan. The construction emissions of the 2050 Metro Vision Regional Transportation Plan are less than the construction emissions assumed in the budgets and the test is passed.

Other Mobile Source Reduction Measures

Two categories of strategies to reduce regional emissions are funded and assumed to continue through 2050, but are not specifically analyzed in the future year transportation and air quality modeling:

- Travel demand management (TDM) programs such as DRCOG's Regional Way to Go Program, transit pass subsidies, and other TDM actions will help to reduce the amount of single-occupant-vehicle driving by the growing population of the region. TDM efforts will also take advantage of the increased provision of pedestrian and bicycling facilities across the region.
- The DRCOG Regional Transportation Operations and Technology Program will implement projects that allow the transportation systems to operate much more efficiently. The projects cover four key areas:
    - Traffic signal system equipment
    - Traffic signal coordination and timing
    - Transportation incident management and communications
    - Intelligent transportation systems (ITS) technological improvements covering a range of communications (vehicle and infrastructure), monitoring, public information, and other projects

Emission Test Results

The results of emissions tests are reported in Table 1. All tests are passed as the emissions test results for the Denver region are less than all of the budgets. The emissions estimates were generated by Air Pollution Control Division using transportation inputs and emissions models. The test results do not indicate any failures in the horizon years of the program or plan that would lead to a finding of non-conformity.

Table 1. Conformity Emissions Test Results

Pollutant	Test	Result<Budget (tons per day)	Pass/Fail
Carbon Monoxide (CO)	2021 Staging ≤ Budget[7]	405 < 1,600	Pass
	2030 Staging ≤ Budget	N/A < 1,600	N/A
	2040 Staging ≤ Budget	198 < 1,600	Pass
	2050 MVRTP ≤ Budget	187 < 1,600	Pass
PM_{10}	2022 Staging ≤ Budget[8]	28 < 55	Pass
	2030 Staging ≤ Budget	N/A < 55	N/A
	2040 Staging ≤ Budget	34 < 55	Pass
	2050 MVRTP ≤ Budget	37 < 55	Pass
NO_x associated with PM_{10}	2022 Staging ≤ Budget[9]	34 < 56	Pass
	2030 Staging ≤ Budget	N/A < 56	N/A
	2040 Staging ≤ Budget	16 < 56	Pass
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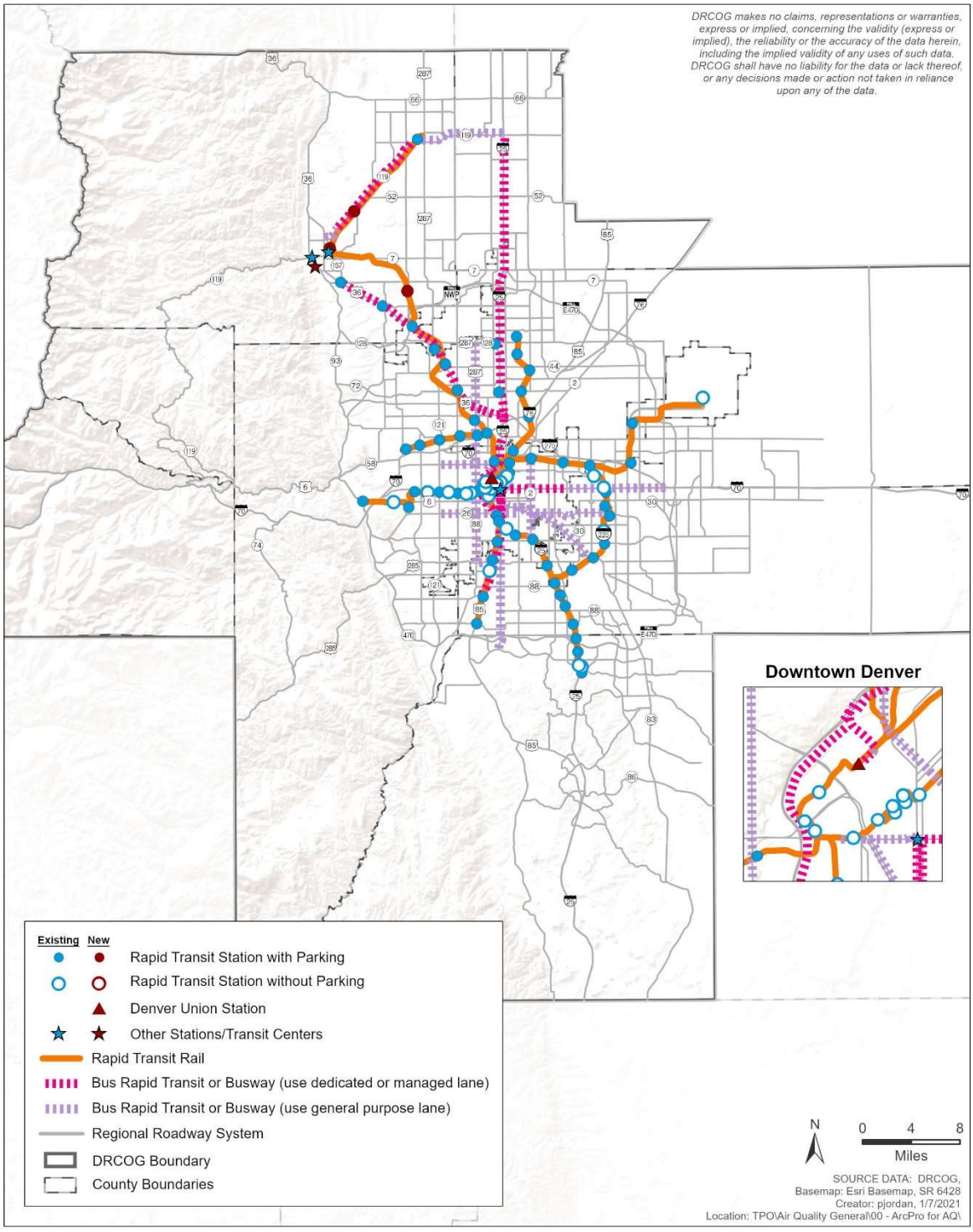
N/A – Not yet available. Results will be available upon completion of model runs, anticipated prior to public meeting. Results are expected to pass.

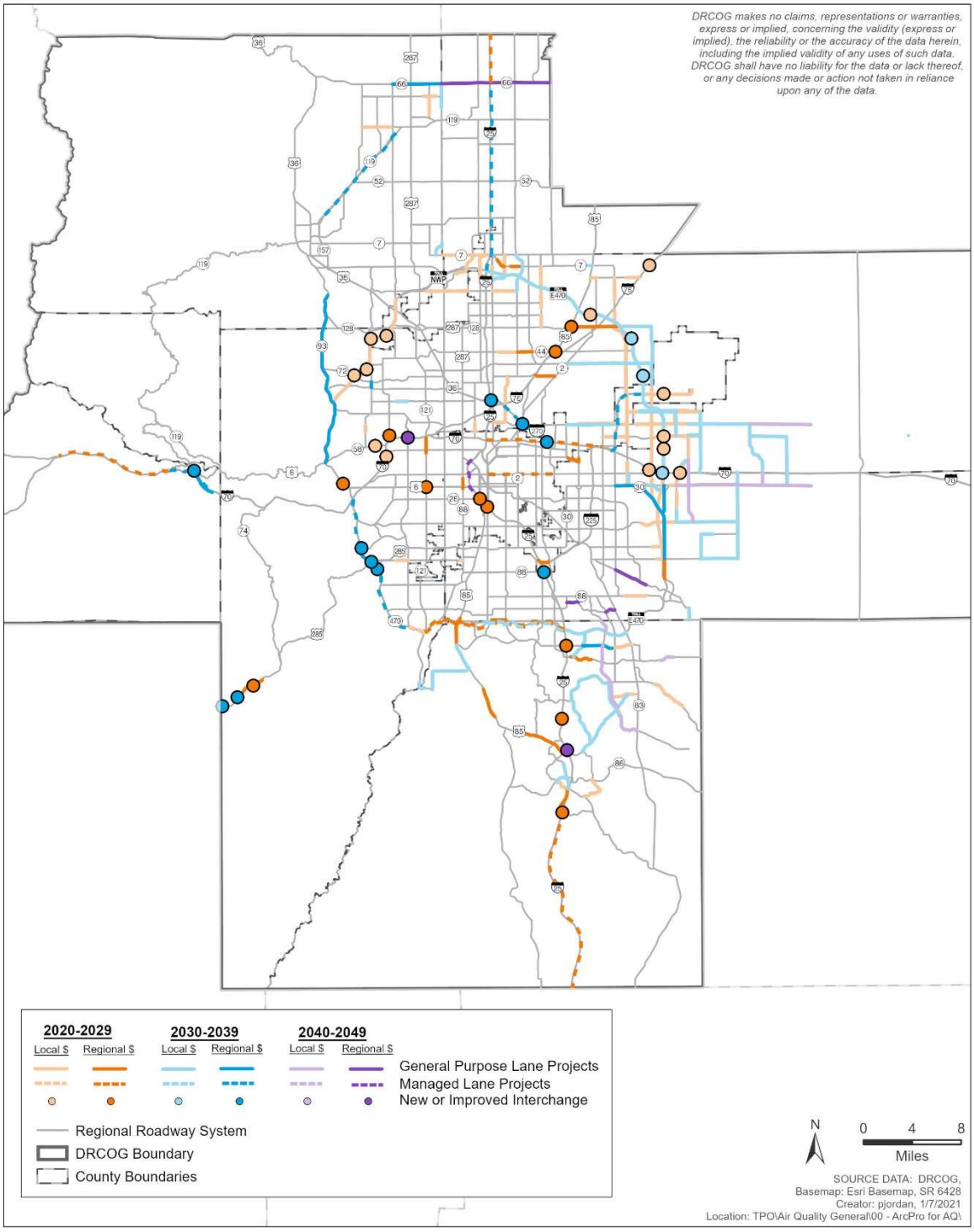
[7] 2021 derived from interpolation of 2020 and 2023 emission estimates.
[8] 2022 derived from interpolation of 2020 and 2023 emission estimates.
[9] 2022 derived from interpolation of 2020 and 2023 emission estimates.

Appendix A. DRCOG Transportation Network and Project Assumptions

2050 Fiscally Constrained Rapid Transit System
Guideway Facilities and Stations



2050 Staging of Fiscally Constrained Roadway Capacity Projects



APPENDIX A DRCOG Transportation Network and Project Assumptions

Project Name/Corridor	Location/Limits	Project Description	County	Project Cost (2020)	Staging Period	In 2022-2025 TIP	Funding Source
2050 MVRTP: Regionally-Funded Projects and Programs							
Colorado Department of Transportation (CDOT) Administered Mulitmodal Capital Projects							
US-85	104th Ave.	New Interchange	Adams	$100,000,000	2023-2029		CDOT
US-85	120th Ave.	New Interchange	Adams	$100,000,000	2023-2029	✓	CDOT
I-25 North	84th Ave. to 104th Ave.	Operational Improvements, Center-Loading Transit Station at 88th Ave., and GP Lane	Adams	$230,000,000	2045-2050		CDOT
Vasquez Boulevard	60th Ave.	Intersection Improvements	Adams	$80,000,000	2040-2044		CDOT
I-270	I-25/US-36 to I-70	New Managed Lanes	Adams	$500,000,000	2030-2039	✓	CDOT
I-270	I-25/US-36 and I-70	New Freeway "direct connects" at each end of I-270	Adams	$300,000,000	2030-2039		CDOT
I-25	Belleview	Interchange Reconstruction and Pedestrian Connections	Arapahoe	$112,000,000	2030-2039		CDOT
SH-83 (Parker Rd.)	SH-86 to East Mississippi Ave.	Corridor Planning/Investment for Multimodal Mobility, Operations, and Safety	Arapahoe/Douglas	$150,000,000	2030-2039		CDOT/DRCOG
SH-66	Lyons to Main St. (US-287)	Widen from 2 to 4 Lanes (Hover to St.	Boulder	$10,000,000	2030-2039	✓	CDOT

I-25 North	E-470 to SH-7	Main St.) and Operational/Safety Improvements from Lyons to Longmont Managed Lanes, SH-7 interchange reconstruction, & SH-7 Mobility Hub	Broomfield	$200,000,000	2030-2039	✓	CDOT
I-25 North (Segment 4)	SH-7 to SH-66	Managed Lanes, SH-119 Mobility Hub, ITS, Bicycle and Pedestrian Trail Connections	Broomfield/ Weld	$150,000,000	2030-2039		CDOT
I-70	Twin Tunnels to Empire Junction (US-40)	Add 1 WB Peak Period Managed Lane	Clear Creek	$0	2020-2022		CDOT
I-70 Floyd Hill Eastbound Improvements	Floyd Hill to Veterans Memorial Tunnel	TBD	Clear Creek	$250,000,000	2030-2039		CDOT
I-70 Floyd Hill Westbound Improvements	Floyd Hill to Veterans Memorial Tunnel	TBD	Clear Creek	$450,000,000	2030-2039		CDOT
Eisenhower Johnson Memorial Tunnels Maintenance	Eisenhower Johnson Memorial Tunnels	Major rehabilitation of the Eisenhower-Johnson Memorial Tunnels	Clear Creek	$142,000,000	2020-2050		CDOT
I-25	Santa Fe Dr. (US-85) to Alameda Ave.	Interchange Capacity	Denver	$30,000,000	2023-2029		CDOT
Central I-25 Buildout	Colfax Ave. to 20th St.	Ultimate Buildout of Corridor Improvements	Denver	$420,000,000	2040-2044	✓	CDOT
I-25 Valley Highway/Burnham Yard	Santa Fe Blvd. to Colfax Ave.	Managed Lanes, Includes ROW, Burnhan Yard, Central Main Line Relocation	Denver	$900,000	2045-2050	✓	CDOT

Federal Boulevard	6th Ave. to Howard Pl.	Widen from 5 to 6 Lanes	Denver	$0	2020-2022		CDOT
I-70	I-25 to Chambers Rd.	Add 2 New Managed Lanes	Denver/Adams	$0	2020-2022	✓	CDOT/DRCOG
I-25	El Paso County Line to North of Crystal Valley Parkway	Add 1 Toll/Managed Lane each Direction	Douglas	$0	2020-2022	✓	CDOT
US-85	Louviers to MP 191.75	Widen from 2 to 4 Lanes	Douglas	$0	2020-2022	✓	CDOT
US-85	Sedalia to Daniels Park	Widen from 2 to 4 Lanes	Douglas	$35,000,000	2023-2029	✓	CDOT
US-85	Daniels Park to Meadows	Widen from 2 to 4 Lanes	Douglas	$32,000,000	2023-2029	✓	CDOT
US-6	Wadsworth Blvd.	Interchange Capacity	Jefferson	$80,000,000	2023-2029	✓	CDOT
US-285	Pine Valley Rd. (CR 126)/Mt Evans Blvd.	New Interchange	Jefferson	$40,000,000	2030-2039		CDOT
US-285	Kings Valley Dr.	New Interchange	Jefferson	$15,000,000	2023-2029		CDOT
US-285	Kings Valley Dr. to Richmond Hill Rd.	Widen from 3 to 4 Lanes (Add 1 SB Lane)	Jefferson	$25,000,000	2023-2029		CDOT
US-285	Shaffers Crossing to Kings Valley Dr.	Widen from 3 to 4 Lanes (Add 1 SB Lane)	Jefferson	$60,000,000	2023-2029		CDOT
US-285	Parker Ave.	New Interchange	Jefferson	$25,000,000	2030-2039		CDOT
I-70 Kipling Interchange Reconstruction	Kipling	Interchange Reconstruction and Pedestrian Connections	Jefferson	$80,000,000	2045-2050		CDOT
C-470	US-285/Morrison/Quincy	Interchange Complex Reconstruction	Jefferson	$150,000,000	2030-2039		CDOT

C-470	Wadsworth to I-70	New Managed Lanes	Jefferson	$410,000,000	2030-2039		CDOT
I-25 North (Segment 5)	SH-66 to WCR 38 (DRCOG Boundary)	Add 1 Toll/Managed Lane each Direction	Weld	$175,000,000	2023-2029		CDOT
			CDOT Projects Total	**$4,351,900,000**			
Denver Regional Council of Governments (DRCOG) Administered Multimodal Capital Projects							
TIP Set-Asides	Varies	Investment in Transportation Demand Management, Air Quality, Operations and Technology, and Human Services Transportation	DRCOG Region	$372,862,551	2020-2050	✓	DRCOG
88th Ave.	I-76 NB Ramps to SH-2	Widen from 2 to 4 Lanes	Adams	$21,500,000	2020-2022	✓	DRCOG
104th Ave.	Colorado Blvd. to McKay Rd.	Widen from 2 to 4 Lanes	Adams	$8,100,000	2020-2022	✓	DRCOG
SH-7	164th Ave. to Dahlia St.	Widen from 2 to 4 Lanes	Adams	$24,000,000	2020-2022	✓	DRCOG
120th Avenue	US-85 to E-470	Widen to 4 Lanes	Adams	$24,000,000	2023-2029		DRCOG
I-25 North Improvements	104th Ave. to 120th Avenue	Shoulders; General Purpose Lanes; Bridge	Adams	$70,000,000	2045-2050		DRCOG
I-225/Yosemite	DTC Blvd. to I-25 on ramp	Interchange and Ramp Reconstruction	Arapahoe	$60,000,000	2023-2029		DRCOG
Smoky Hill Road	Buckley Road to Picadilly St	Widen from 4 to 6 Lanes	Arapahoe	$10,000,000	2040-2044		DRCOG
Gun Club Rd.	State Highway 30 to 6th Ave	Widen from 2 to 4/6 Lanes, Includes Stream Crossing	Arapahoe	$32,000,000	2030-2039		DRCOG

		Upgrade at Coal Creek					
Gun Club Rd.	Quincy to Aurora Pkwy.	Widen from 2 to 6 Lanes	Arapahoe	$15,000,000	2023-2029		DRCOG
Broncos Parkway/Easter/Dry Creek Corridor Improvements	Parker Road to Havana	Widening to 6 Lanes, Bridge Widening, and Intersection Improvements	Arapahoe	$35,000,000	2040-2044		DRCOG
SH-30	Airport Blvd. to Quincy Ave.	Widen from 2 to 6 Lanes	Arapahoe	$175,000,000	2030-2039		DRCOG, CDOT, Local
US-85 (Santa Fe) Improvements	C-470 to Bowles	Corridor Planning/Investment for Multimodal Mobility, Operations, and Safety	Arapahoe	$150,000,000	2040-2044	✓	DRCOG, CDOT
SH 66	US-287/Main Street to East County Line Road	Capacity, Operations, and Bicycle/Pedestrian	Boulder	$15,000,000	2030-2039		DRCOG
US 287/120th Ave.	Midway Blvd. to Lowell Blvd.	Improve circulation, safety, active transportation access, business access, congestion and transit operations	Broomfield	$15,000,000	2023-2029	✓	DRCOG
I-25	Broadway	Interchange Capacity	Denver	$50,000,000	2020-2022	✓	DRCOG
Martin Luther King Jr. Blvd.	Havana St./Iola St. to Peoria St.	Widen 2 to 4 Lanes; New 4 Lane Road	Denver	$0	2020-2022	✓	DRCOG
Pena Boulevard	I-70 to 64th Avenue	Add one managed lane in each direction	Denver	$139,000,000	2030-2039		DRCOG, Local

Pena Boulevard	64th Avenue to E-470	Add one managed lane in each direction	Denver	$124,000,000	2030-2039		DRCOG, Local
County Line Rd.	Phillips St. to University Blvd.	Widen from 2 to 4 Lanes	Douglas	$9,500,000	2020-2022	✓	DRCOG
I-25	Lincoln Ave.	Interchange Capacity	Douglas	$49,400,000	2020-2022	✓	DRCOG
Ridgegate Pkwy.	Havana St. to Lone Tree E. City Limit	Widen from 2 to 4 Lanes	Douglas	$0	2020-2022	✓	DRCOG
US-85	Highlands Ranch Pkwy. to n/o County Line Rd.	Widen from 4 to 6 Lanes	Douglas	$0	2020-2022	✓	DRCOG
I-25	Crystal Valley Pkwy.	New Interchange & South Frontage Road	Douglas	$80,000,000	2023-2029	✓	DRCOG, Local
I-25	Happy Canyon Rd.	Interchange Reconstruction	Douglas	$30,000,000	2023-2029		DRCOG, Local
Lincoln Ave.	Oswego to Keystone	Widen 4 to 6 lanes	Douglas	$24,000,000	2030-2039		DRCOG, Local
I-25	Meadows/Founders	Interchange Reconstruction	Douglas	$50,000,000	2045-2050		DRCOG, Local
Wadsworth Blvd.	35th Ave. to 48th Ave.	Widen from 4 to 6 Lanes	Jefferson	$31,000,000	2020-2022	✓	DRCOG
SH-93	SH-58 to SH-170	Widen to 4 Lanes and Safety/Transit Improvements	Jefferson	$200,000,000	2030-2039		DRCOG
US-6	Heritage Rd.	New Interchange	Jefferson	$30,000,000	2023-2029	✓	DRCOG
Indiana (SH-72)	W. 80th Ave. to W. 86th Pkwy.	Widen to 4 Lanes	Jefferson	$39,000,000	2030-2039		DRCOG
Kipling St.	Kentucky Ave. to I-70	Multimodal Corridor Improvements	Jefferson	$250,000,000	2040-2044		DRCOG

Wadsworth Blvd.	17th Ave. to 35th Ave.	Multimodal Corridor Improvements	Jefferson	$60,000,000	2040-2044	DRCOG
SH-66	WCR 1 - WCR 19	Widen 2 to 4 Lanes, Pedestrian Improvements	Weld	$35,000,000	2045-2050	DRCOG
SH-52	WCR 1 - WCR 13	PEL Outcomes - Safety, Operational, and Multimodal Improvements	Weld	$20,000,000	2045-2050	DRCOG
			DRCOG Projects Total	**$2,248,362,551**		
Regional Transportation District (RTD) Administered Multimodal Capital Projects						
Northwest Rail	Westminster Station to Downtown Longmont	Implement Peak Period Service Plan	Adams/Boulder/Broomfield/Jefferson	$700,000,000	2045-2050	RTD
			RTD Projects Total	**$700,000,000**		
Regional Bus Rapid Transit (BRT) Projects						
Colfax Ave. BRT	Lincoln St. to I-225	BRT Service and Supporting Safety/Mulitmodal Improvements	Adams/Arapahoe/Denver	$250,000,000	2023-2029	CDOT, DRCOG, 53019-CIG, Local
Colfax Ave. Extension BRT	I-225 to E-470	BRT Service and Supporting Safety/Mulitmodal Improvements	Adams/Arapahoe	$100,000,000	2040-2044	DRCOG, CDOT, Local
SH-119 BRT	Downtown Boulder to I-25/SH-119 Mobility Hub	BRT Service and Supporting Safety/Mulitmodal Improvements	Boulder/Weld	$350,000,000	2030-2039	CDOT, DRCOG, RTD, Local

Colorado Blvd. BRT	University of Colorado A Line to I-25	BRT Service and Supporting Safety/Mulitmodal Improvements	Denver	$35,000,000	2023-2029	DRCOG, CDOT, 5309-CIG, Local
Alameda BRT	Wadsworth to R-Line	BRT Service and Supporting Safety/Mulitmodal Improvements	Arapahoe/Denver/Jefferson	$61,000,000	2030-2039	DRCOG, CDOT, 5309-CIG, Local
Broadway/Lincoln BRT	Colfax to Highlands Ranch Pkwy	BRT Service and Supporting Safety/Mulitmodal Improvements	Arapahoe/Denver/Douglas	$61,000,000	2040-2044	DRCOG, 5309-CIG, Local
38th/Park BRT	Wadsworth to Colfax	BRT Service and Supporting Safety/Mulitmodal Improvements	Denver/Jefferson	$40,000,000	2045-2050	DRCOG
Speer/Leetsdale/Parker BRT	Colfax to I-225	BRT Service and Supporting Safety/Mulitmodal Improvements	Arapahoe/Denver	$95,000,000	2030-2039	DRCOG, CDOT
Federal Blvd. BRT	120th to Santa Fe/Dartmouth	BRT Service and Supporting Safety/Mulitmodal Improvements	Adams/Denver	$94,000,000	2030-2039	DRCOG, CDOT, 5309-CIG, Local
North I-25 BRT	Union Station to SH-119	BRT Service and Supporting Safety/Mulitmodal Improvements	Adams/Broomfield/Denver/Weld	$97,000,000	2045-2050	DRCOG, CDOT, 5309-CIG, Local

New Bus Maintenance Facility	TBD-northern area of RTD District	Construction of a new bus maintenance facility in the RTD's northern area	TBD	$50,000,000	2023-2029		DRCOG
			Regional BRT Total	**$1,233,000,000**			
Corridor Transit Planning Projects and Programs							
Regional Mobility Hubs	Varies	Construction of Multomodal Mobility Hubs	DRCOG Region	$200,137,636	2020-2050		CDOT, DRCOG, RTD
South Boulder Rd.	Lafayette to Boulder	Multimodal Corridor Improvements	Boulder	$75,000,000	2040-2044		DRCOG
SH-7	Boulder to Brighton	Multimodal Corridor Improvements	Adams/Boulder/Broomfield	$100,000,000	2030-2039	✓	CDOT
US-287	US-36 to Larimer County Line	Safety, Operational, and Multimodal Improvements	Boulder/Broomfield	$200,000,000	2030-2039		CDOT, DRCOG
West Colfax	Sheridan to Broadway/Lincoln	Transit Corridor and Supporting Safety/Multimodal Improvements	Denver	$26,573,077	2045-2050		DRCOG
RidgeGate Parkway Transit Mobility Corridor	Mainstreet in Parker to Lone Tree City Center RTD station	Transit Corridor	Douglas	$100,000,000	2045-2050		DRCOG
Castle Pines Transit Mobility Corridor	Castle Pines to RidgeGate RTD station	Transit Corridor	Douglas	$20,000,000	2030-2039		DRCOG
Golden/Mines Autonomous Circulator	Downtown Golden, School of Mines, RTD W Line	Autonomous Circulator	Jefferson	$3,500,000	2023-2029		DRCOG
			Transit Corridor Planning Total	**$725,210,713**			
Arterial Safety/Regional Vision Zero Projects and Programs							

Arterial Safety/Regional Vision Zero Set-Aside	High Injury Network and Critical Corridors identified in the Taking Action on Regional Vision Zero	Vision Zero and Safety Improvements	DRCOG Region	$151,672,902	2020-2050	✓	DRCOG
Federal Boulevard Multimodal Improvements	52nd Avenue to 120th Avenue	Bicycle/Pedestrian/Transit Improvements; Turn Lanes; Bus/Business Access Lanes	Adams	$50,000,000	2023-2029		DRCOG
US-285 Congestion Mitigation Improvements	Knox Ctt/Lowell Blvd. (west) to Havana (east)	Speed and Reliability Corridor & Vision Zero Improvements	Arapahoe/Denver	$88,200,000	2023-2029	✓	DRCOG
US-36	Boulder to Lyons	Corridor Safety Improvements	Boulder	$20,000,000	2020-2022		DRCOG
US-36/28th St. & SH-93/Broadway	US-36/28th St. & SH-93/Broadway	Corridor Safety Improvements	Boulder	$15,200,000	2030-2039		CDOT
SH-42	Louisville and Lafayette	Safety and Operational Improvements	Boulder	$50,000,000	2030-2039	✓	CDOT, DRCOG
West Mississippi Avenue	South Federal Blvd. to S. Broadway	Vision Zero and Pedestrian Improvements	Denver	$18,600,000	2020-2022	✓	DRCOG
Brighton Boulevard	Race to York	Reconstruction, Vision Zero, Safety, and Freight Improvements	Denver	$19,762,500	2045-2050		DRCOG
Chambers Rd	E 56th Ave to E 40th Ave	Vision Zero Corridor Improvements	Denver	$16,712,500	2023-2029		DRCOG
Sheridan Safety Improvements	52nd to Hampden	Vision Zero Corridor Improvements	Denver/Jefferson	$17,100,000	2023-2029		DRCOG
Colfax Safety Improvements	Wadsworth to Sheridan	Multimodal Arterial Safety	Jefferson	$12,000,000	2020-2022	✓	DRCOG

US-85 Operational & Safety Improvements	Weld CR 2 to Weld CR 10	Safety and Operational Improvements	Weld	$6,100,000	2023-2029		CDOT
			Arterial Safety/Regional Vision Zero Total	**$465,347,902**			
Active Transportation Projects and Programs							
Active Transportation Set-Aside	Short-Trip Opportunity Zones identified in the Active Transportation Plan	Bicycle and Pedestrian Improvements	DRCOG Region	$31,598,521	2020-2050		DRCOG
Smith Road Bicycle/Pedestrian Facilities	Peoria Street to Powhaton Road	New Multi-Use Path	Adams	$4,000,000	2020-2022		DRCOG
RTD Rail Trail	Boulder to Erie	Regional Trail	Boulder	$6,000,000	2020-2022		DRCOG
St. Vrain Greenway	Longmont to Lyons	Regional Trail	Boulder	$4,000,000	2020-2022	✓	DRCOG
McCaslin Regional Trail	Rock Creeky Pkwy. to SH-128	Regional Trail	Boulder	$3,000,000	2020-2022	✓	DRCOG
Clear Creek Greenway	Jefferson County Line to Loveland Ski Area	Clear Creek Greenway portion of Peaks to Plains trail system	Clear Creek	$50,000,000	2045-2050		DRCOG
S. Platte River Trail	(not specified)	Complete Missing Links and Upgrade Trail Section	Denver	$50,000,000	2030-2039		DRCOG
Bear Creek Trail	(not specified)	Upgrade Trail for Safe Crossings and Consistent Cross Section. Integrate ITS/AI Equipment.	Denver	$31,200,000	2045-2050		DRCOG
			Active Transportation Total	**$179,798,521**			

APPENDIX A DRCOG Transportation Network and Project Assumptions

Freight Projects and Programs							
Freight Set-Aside	Varies	Freight improvements including but not limited to bridge reconstructions, overpasses/underpasses, new bridges	DRCOG Region	$75,836,451	2020-2050		DRCOG
Peoria Street Bridge	Sand Creek	Bridge Reconstuction	Adams	$19,000,000	2020-2022		DRCOG
Alameda Pkwy. Bridge over I-225	Between Potomac Street and Abilene Street	Bridge reconstruction	Arapahoe	$20,000,000	2020-2022		DRCOG
47th Avenue/48th Avenue	I-25 to Pecos	Bridge Reconstruction, New Multimodal Underpass, and New Bicycle/Pedestrian Bridge.	Denver	$45,225,000	2040-2044		DRCOG
Ward Rd./BNSF	I-70 FR North and Ridge Rd.	Multimodal Grade Separation	Jefferson	$60,000,000	2023-2029	✓	DRCOG
			Freight Total	**$220,061,451**			
Note: Projects with $0 cost have funds fully obligated prior to fiscal year 2020.			**Grand Total**	**$10,123,681,138**			

Appendix B. Summary of Transportation Model Calibration and Validation and Validation for the 2050 MVRTP, January 7, 2021

Introduction

In support of the conformity determination for the 2050 Metro Vision Regional Transportation Plan, the Denver Regional Council of Governments' maintains the Regional UrbanSim Socio-economic Model and the *Focus* regional travel modeling system.

The *Focus* travel demand model simulates the millions of trips made throughout the region on a typical weekday. The *Focus* model sums all travel to forecast how many vehicles will be driven on major roads; travel speed and delay; and how many people will walk, ride a bicycle or use transit to get to where they want to go. To realistically simulate each person's daily household travel, *Focus* models the many choices each person makes, thought the activity based model components including:

(1) where to work
(2) where to go to school
(3) how many automobiles are owned by the person's household
(4) how many trips each person makes in a day, and for what purposes
(5) which trips are chained together into home-to-home tours
(6) the location where each individual trip begins and ends
(7) the travel mode used for each trip
(8) which roadways or bus routes were chosen to reach each destination

In addition to the ABM components for household travel, Focus also incorporates three add-on gravity models for:

- Commercial Vehicle trips – by light, medium, and heavy duty vehicles
- External Station trips – starting or ending outside the DRCOG modeling area
- Denver International Airport (DIA) trips – for trips not captured by the ABM components

An UrbanSim model is used to forecast household and employment levels by small-area transportation analysis zones (TAZs) over time. The Focus model takes into account many characteristics of people, such as their age, gender, employment status, and income; and how the region will change demographically over time. It also takes into account characteristics of the built environment such as transit stops and stations, household and employment density, bicycling facilities and walkability.

The *Focus* travel model creates an origin and destination for each trip. Specific groupings of "O&Ds" were initially estimated based on detailed data from a 1998 survey called the Travel Behavior Inventory.

In 2016, *Focus* was recalibrated using more recent data sources including roadway counts, transit boardings, American Community Survey Census data, and results from the following surveys:

- RTD's 2008 Regional On-Board Transit Survey – a questionnaire handed out to light rail and bus travelers to understand how transit travel patterns have changed since the opening of the Southeast Corridor Light Rail in November 2006. The survey contains information on almost 24,000 transit trips.
- The 2010 Front Range Travel Counts Household Survey – A survey of over 12,000 households along the Colorado Front Range, including 7,000 in the DRCOG region, using a format similar to the 1997 Travel Behavior Inventory described above.

In 2020, further refinements were made to the Focus model based on additional results of the 2010 Front Range Travel Counts Survey, the 2016 Commercial Vehicle Survey and RTD's updated 2018 Regional On-Board Survey.

The final trip assignment outputs of *Focus* were validated against traffic counts, operating travel speed observations, and RTD ridership data to make sure the overall regional travel patterns being forecasted were reasonable.

Regional Socioeconomic Forecasts

DRCOG uses county-level forecasts of population, households and employment produced by the Colorado State Demography Office as the basis for future growth in the Focus model.

Small Area Development Estimates

To provide household and employment data at a level of detail necessary for the travel model, the regional urban activity forecasts are disaggregated into 2,800 transportation analysis zones (TAZs), as shown in Figure 1. The allocation to TAZs is carried out within the UrbanSim model based on the dynamics

of urban land markets and the simulated decisions of land developers, and residential and commercial land customers. The UrbanSim model considers questions such as:

- What parcels of land are profitable for development, and for what uses?
- Where should a firm locate to conduct its business in accordance with zoning regulations, and with suitable access to workers, supplies, and finished product markets?
- Does a family's current residence continue to meet its needs and be convenient to jobs, schools, and other activities, or should the family move to a “better” location?
- What size and types of residence does a family need based on the number and ages of its members and its household income?
- Where are designated open spaces, parks, and other undevelopable lands located?

The UrbanSim model outputs are used in a population synthesizer that creates a descriptive database record for each household in the region (about 1.3 million records for 2020) and each person (about 3.3 million records in 2020). Figure 2 shows a flowchart for the process of socioeconomic forecasting in the Denver region.

Figure 1. DRCOG Travel Analysis Zones

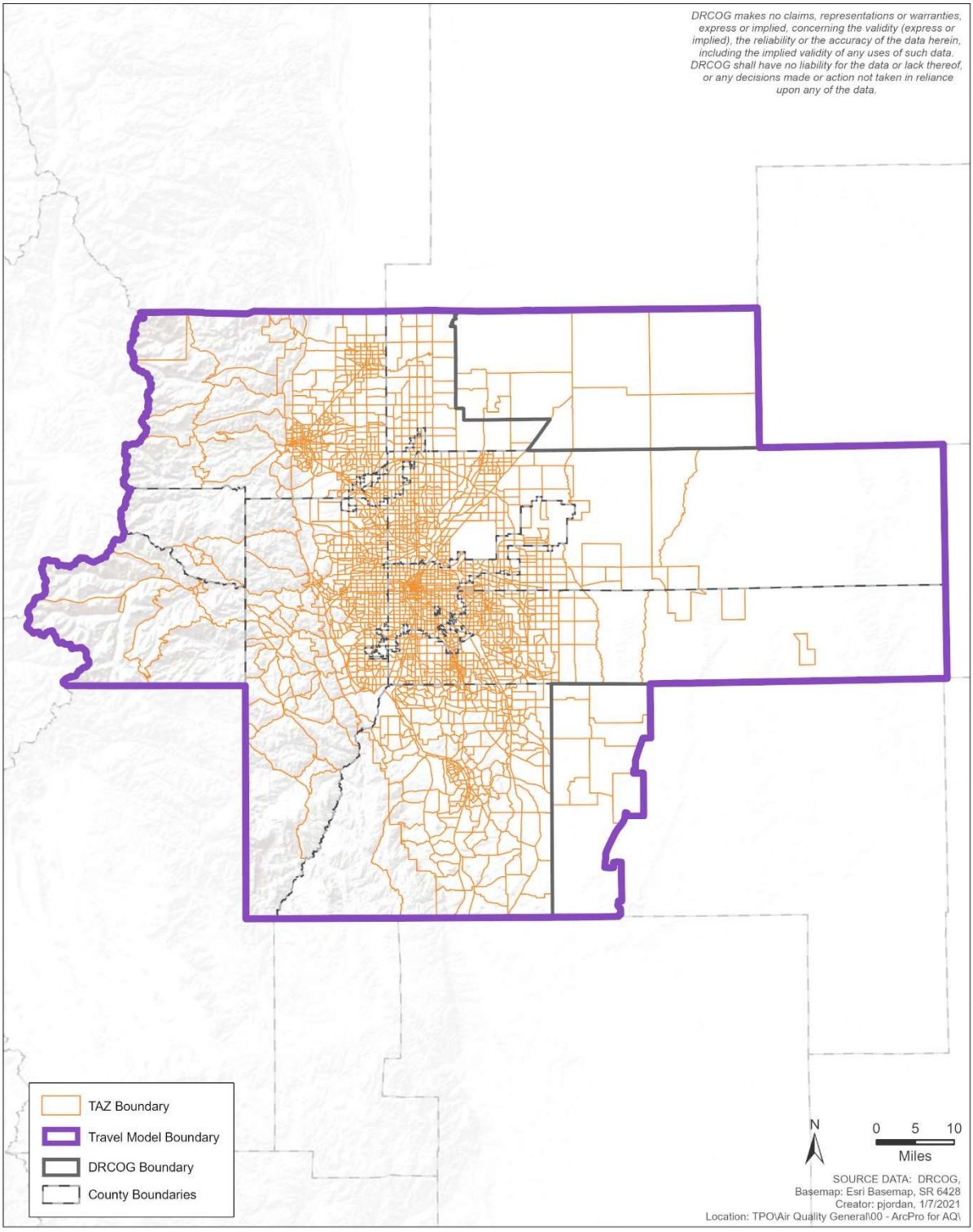
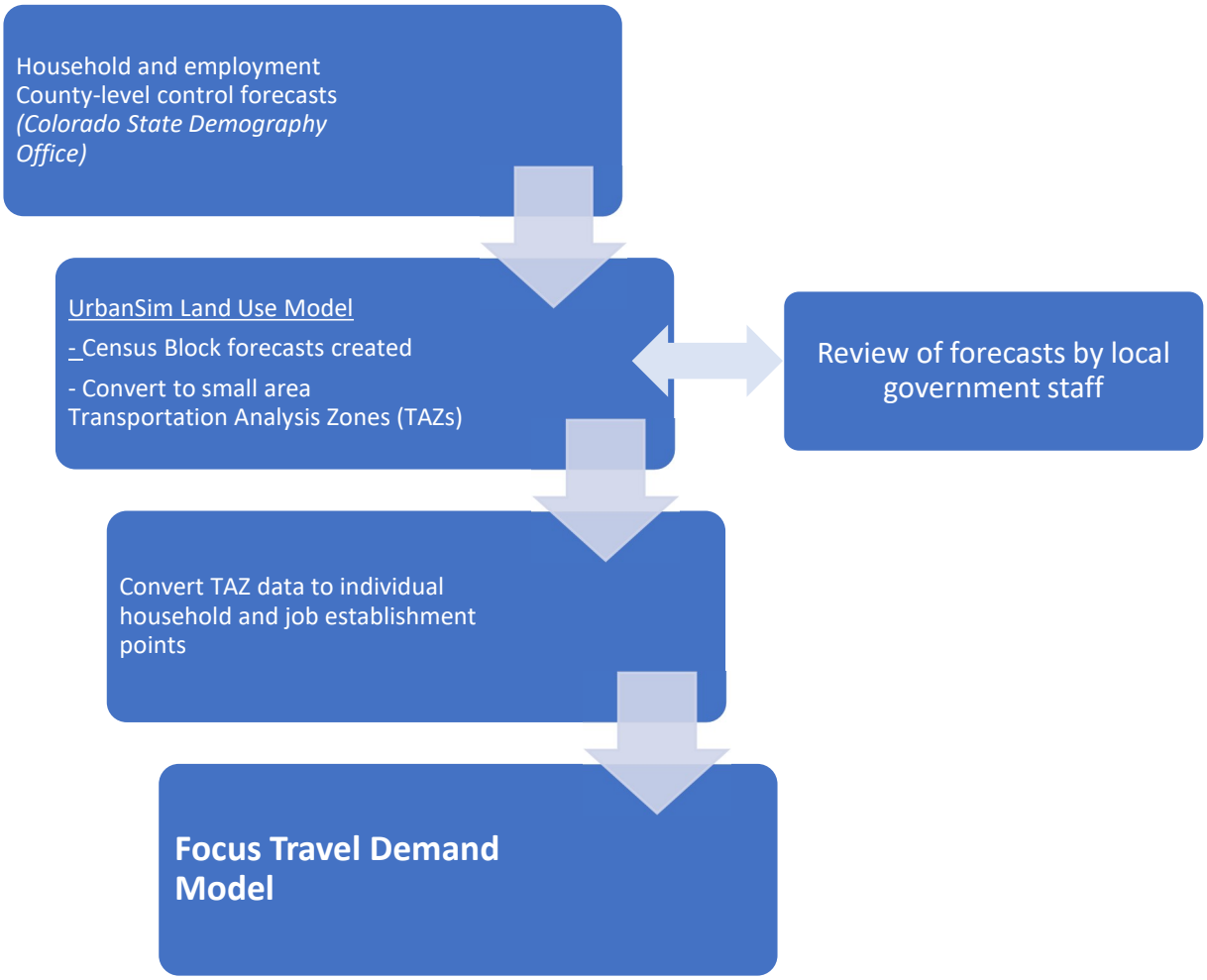


Figure 2
Socioeconomic Model Elements and Flow



Focus Model Process Overview

Figure 3 shows a simplified diagram of how the *Focus* model components flow after the socioeconomic forecast has been completed.

First, travel time and cost information between zones are calculated by travel mode and time of day. Tours are the first travel elements to be created. Figure 4 shows a diagram depicting an example set of tours for a person in one day, including intermediate stops.

The model runs through a set of steps for each tour, including activity generation, location choice, mode choice, and time of day choice model components. Then the model runs through a parallel set of model components for each trip within a tour.

Figure 3
Focus Activity Based Model Elements

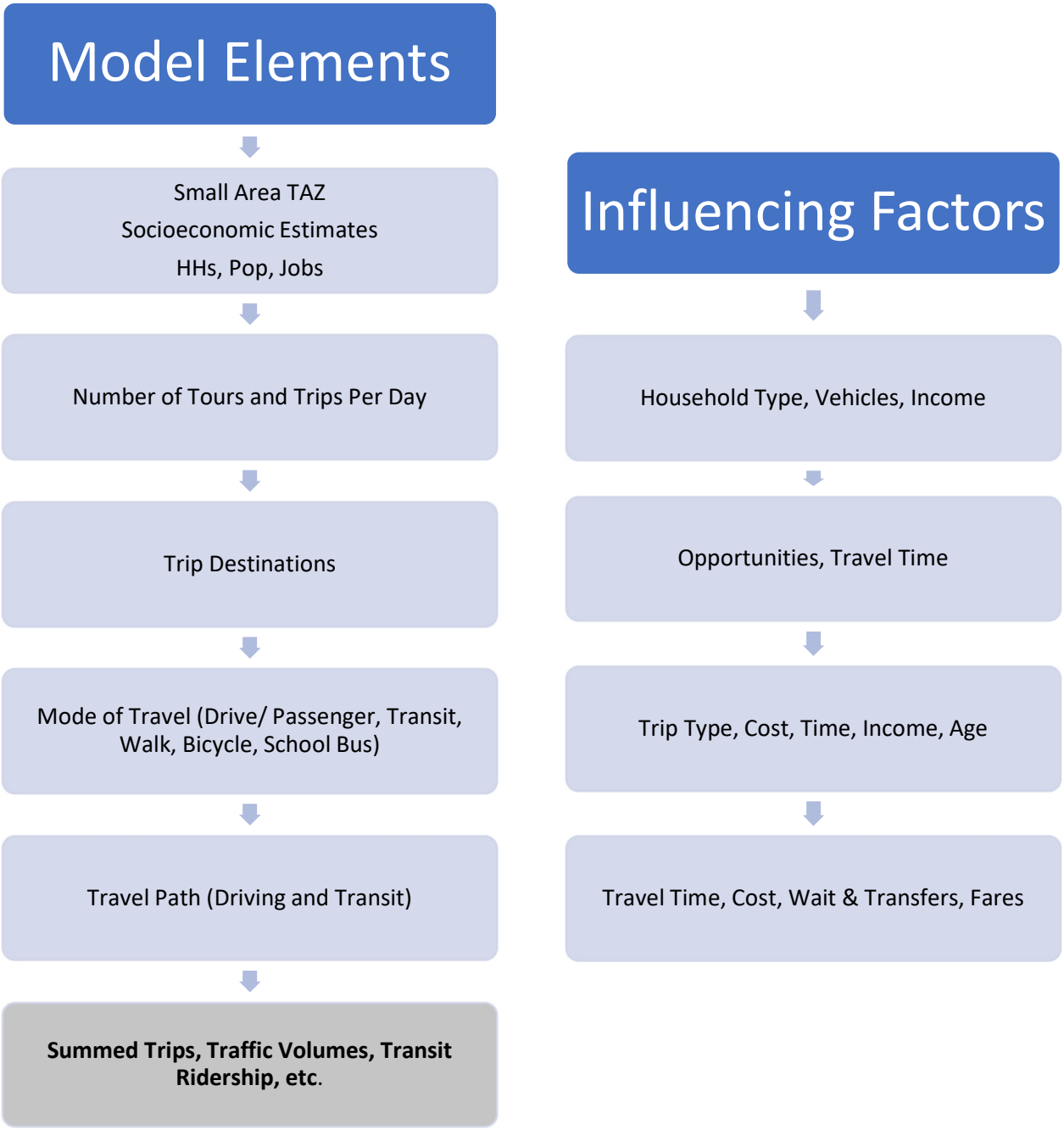
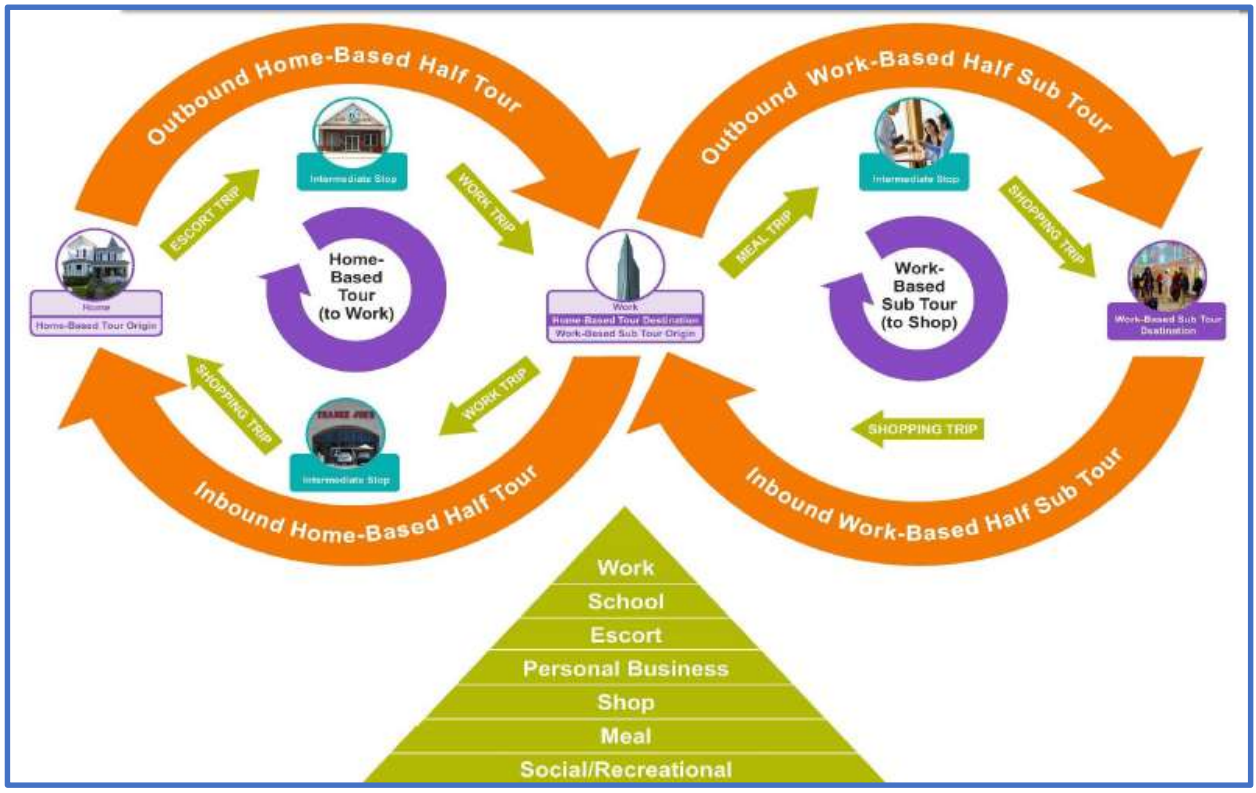


Figure 4
Sample Tour Diagram



Roadway and Transit System

One of the most critical components is the transportation network representation. The roadway network is represented by over 25,000 directional road segments, described by location, length, number of lanes, functional classification, and area type. High-occupancy vehicle (HOV) and managed lanes also are represented as special links. Tollway links are assessed an additional cost impedance to reflect toll charges. The model also includes a fully detailed representation of transit facilities, including all bus and rapid transit lines, Park-n-Ride lots, bus stops, stations, and walk access/egress routes. Bus routes follow the same roadway network as auto trips, and bus travel speeds are based on auto speeds. Overall transit travel time also includes access, wait, and transfer time. Rail speeds are developed based on transit schedule information. Capture areas for Park-n-Ride lots are quite broad, permitting trip-makers in the model to select the lot that produces the most convenient overall transit path to their destination. As part of the process of estimating roadway and transit use, minimum impedance paths are calculated using time, distance and toll cost over the roadway and HOV system, and time and cost over the transit system.

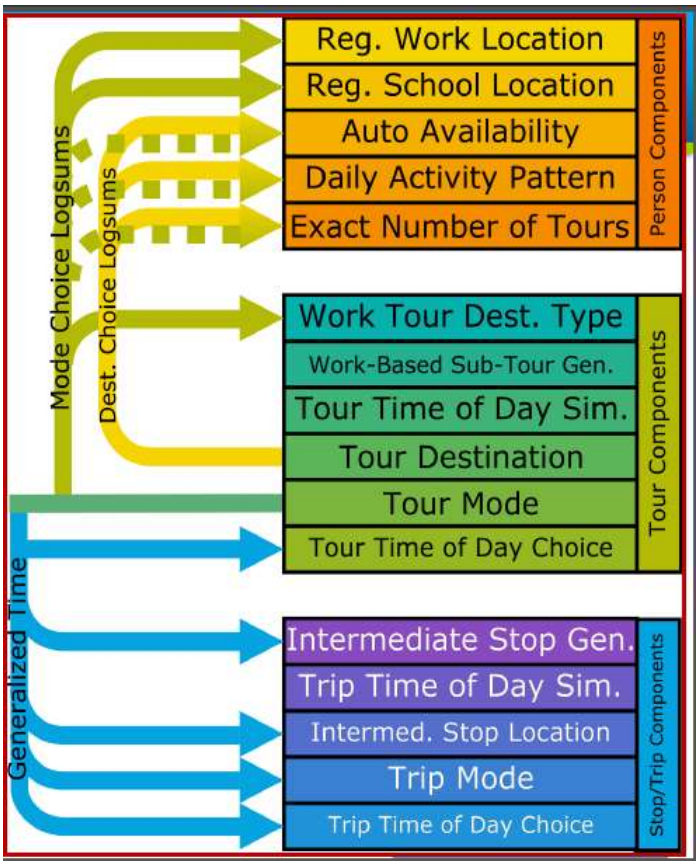
Model Components

The most important model components are briefly described in the sections below, and Table 1 lists all model components. Most model components are multinomial logit or nested logit models, which are statistical models that have two or more discrete choice outcomes.

Table 1. Key Focus Model Components

(Activity Based Model components in red)

1. TransCAD Initialization	14. Tour Time of Day Simulation
2. Size Sum Variable Calculator	15. Tour Primary Destination Choice
3. TransCAD Trip Generation	16. Tour Priority Assignment
4. TransCAD Skimming (Path Selection)	17. Tour Main Mode Choice
5. TransCAD Airport, Commercial Vehicle, and External Travel Distribution and Mode Choice	18. Tour Time of Day Choice
6. Regular Workplace Location	19. Intermediate Stop Generation Choice
7. Regular School Location	20. Trip Time of Day Simulation
8. Auto Availability	21. Intermediate Stop Location Choice
9. Aggregate Destination Choice Logsum Generation	22. Trip Mode Choice
10. Daily Activity Pattern	23. Trip Time of Day
11. Exact Number of Tours	24. Write Trips To TransCAD
12. Work Tour Destination Type	25. TransCAD Highway and Transit Assignment
13. Work-Based Subtour Generation	



Roadway and Transit Skims (Path Selection)

Representative roadway and transit paths are initially used for all origin-destination zone pairs (2,800 x 2,800) and each of the ten time-of-day periods. The paths consider travel time, travel cost, and other factors. The time and cost TAZ-to-TAZ matrices are used extensively in later model components such as location choice, mode choice, and time of day choice.

Denver International Airport/Commercial Vehicle/Internal-External/ External-External Trips

After optimal paths are identified via the skims, all Compass model components must be run to generate and assign airport trips, internal-external trips, commercial vehicle trips, and external-external trips.

Regular Workplace and School Location

The work location choice model takes all regional workers and assigns them a regular work location TAZ and point. Characteristics of the worker and their home TAZ are used in combination with TAZ characteristics to determine the desirability of any TAZ.

The regular school location choice model assigns each student a regular school location TAZ and school. The model uses information about the student, such as income and age, and information on school enrollment and distance from home to determine which schools will be attractive for students. There are four school location choice models by student grade level: pre-school, kindergarden-8th grade, 9th-12th grade, and university. Four separate models are used to reflect that the decision-making of school location for different grade ranges has significantly different characteristics. The models are all multinomial logit with the choice being the location of the school zone.

Auto Availability Choice

The auto availability choice model is a multinomial logit model that selects number of automobiles available for each household in the region. The choices range from no cars to 4+ cars. The model uses information about households such as income and their accessibility to work and school to determine how many autos are available to households.

Tour Models

After *Focus* has projected the long-term decisions about work and school location and auto availability, it forecasts daily activities on a tour-level.

The ***day activity pattern*** model determines which combinations of up to seven purposes (work, school, escort a family member, personal business, shopping, dining, and social or recreational) a person will make tours or stops along a tour.

The ***exact number of tours*** model determines how many tours of each type each person will make in his or her day. The tour types predicted for each person include: work, school, escort, personal business, shop, meal, and social recreation.

The ***work tour destination type*** model determines whether a person making a work tour will travel to his or her usual work location, or somewhere else, perhaps to meet with clients or customers, or for off-site training. If the regular workplace is selected, this information is entered into the tours table in the database.

Work-based subtour generation determines whether someone will leave their regular workplace and return during the middle of the day. Such a person may be eating out, running errands, or attending meetings, for example. After this point, the *Focus* model treats work-based subtours similarly to home-based ones.

In reality, a person might consider the interactions of destination, mode, and departure time choices together in creating an itinerary for the day's travel and activities. Despite its complexity, the *Focus* model needs to have some simplifying assumptions to make its mathematical relationships and software workable. ***Tour time of day simulation*** is one such simplification, allowing destination and mode choices to be modeled as if the time of travel is known (so the right time and cost matrices can be used) as an initial guess. The simulated times of days are based on observed survey distributions. The later ***tour time of day choice*** confirms whether the initially simulated time of day was reasonable, or whether a shift earlier or later might be justified.

The ***tour primary destination choice*** model selects the destination of tour based the development (e.g., jobs and households) located within the zone. It then assigns a point within each zone as the final destination.

After the tour destination is known, the ***tour main mode choice*** model predicts the main travel mode used on the tour. The mode chosen is based on the impedances associated with each mode from the tour origin to the tour destination, zonal characteristics such as density, travel mode facilities, and demographic person characteristics. The tour main mode is used for most of the distance of the tour, but not necessarily for all trips. For example, if a parent is driving a child to school, the return trip would necessarily be driving alone. In other cases, stops along a tour might be close enough that walking or bicycling would be more attractive than a motorized tour mode. The tour and trip modes are related by rules of precedence used to simplify the *Focus* model.

Given the known tour origin, destination and mode from previous models, the ***tour arrival and departure time model*** predicts the time arriving at the primary destination of the tour and the time leaving the primary destination, both to within one hour periods.

Trip Models

After the tour-level models are run, a series of trip-level models are run. The first trip level model is the ***intermediate stop generation*** model, which determines the number of intermediate stops on each tour (if any).

As with the tour models, there is a ***trip time of day simulation*** component to simplify the location and mode choices that are modeled next.

The ***intermediate stop location choice*** model selects the zone for each intermediate stop. The locations of all intermediate stops on tours are modeled one at a time, first for stops from home to the primary activity and then for stops from the primary activity to home.

The ***trip mode choice*** model determines the mode of travel for all trips. The tour mode is used in combination with skim data, zonal data, and person data to determine the modes for each trip on these tours.

Given the origin, destination and mode of each trip, the ***trip time of day choice*** model predicts the time each intermediate stop will occur. The trip time of day choice model has 24 alternatives corresponding to each hour period.

After the trip models have been run, the following information is known for every trip internal to the region:

- Origin and Destination Zone and Point Location
- Trip Purpose (work, school, escort, personal business, shop, social recreation)
- Trip Mode (drive alone, shared ride 2, shared ride 3+, walk to transit, drive to transit, walk, bicycle, school bus)
- Trip Time of Day (one of 24 hours)
- Which tour the trip is part of
- What person made the trip
- What household the person who made the trip belongs

The ***write trips to TransCAD*** component assembles the individual records for auto and transit trips into origin-destination trip tables (matrices) that TransCAD can use for assignment. These trip tables are then combined with those developed for DIA, commercial vehicle, internal-external, external-internal, and external-external trips developed earlier.

Network Assignment

Household vehicle, airport trips, internal-external trips, commercial vehicle trips, and external-external trips are assigned to the roadway network via a “user equilibrium” algorithm. The user equilibrium process assigns the trips between each origin and each destination TAZ in such a way that, by the end of the process, no trip can reduce its travel time by changing its path. The process takes into account the congestion produced by all other trips in the region, each trip is following its minimum path. High-occupancy vehicles (HOV) are loaded simultaneously with single-occupant vehicles (SOV). During this

process, TransCAD keeps track of which vehicles are eligible to use HOV facilities, and which might need to pay a toll to use High-Occupancy/Toll (HOT) lanes, such as the reversible I-25 Express Lanes north of downtown Denver. The model also takes into account the effect of toll costs in roadway route choice by converting toll costs into equivalent time cost using an estimated value of time for automobile trip-makers.

Transit assignment is performed separately, using an all-or-nothing algorithm that does not take into account the possibility that high demand or crowding on some transit routes may motivate some riders to shift to other routes. RTD has special modeling tools that allow them to use *Focus* model forecasts for more detailed operational planning.

Finally, the model is run through several iterations, feeding back the output speeds from roadway assignment to the input stages that require them as input (among them, the trip distribution stage) until the output speeds and the input speeds match closely enough.

Model Calibration and Validation

Each *Focus* model component was originally calibrated to 2010 inputs, comparing the model "forecast" for 2010 to external data sources such as:

- 2010 American Community Survey (ACS) means of travel to work
- 2010 Front Range Travel Counts
- 2010 HPMS estimated regional VMT
- 2019 Regional Transportation District (RTD) transit boardings

Once comparisons were made of model results against the observed datasets, each model component was calibrated. The calibration involved changing the coefficients describing the mathematical models and travel and adding variables. Then the model was re-run, results compared again, and modifications made again. This process was repeated until satisfactory results were achieved.

The major regional level model results of the validation review for 2020 are shown in Table 2 and Table 3. Note the 2020 values actually represent the time and travel patterns prior to the COVID-19 pandemic. These tables demonstrate that the aggregate model results reflect the observed representative counts

and transit boardings sufficiently well. When summed over the region, the links with observed traffic counts were observed to carry about 28.0 million vehicles per weekday. The sum of Focus Model estimates was within one percent difference.

Table 2. Sum of 2020 Observed Estimates and Modeled Weekday Counts

	2019/20 Observed (Est.) Counts ADT Sum VMT	2020 Model Results ADT Sum VMT	Model Variation
CDOT Roadways w/Counts	15,937,900	16,100,100	1.0%
HPMS Roadways w/Counts	20,619,200	20,018,600	-3.0%
HPMS Urbanized Area Network Est.	67,381,400	73,270,000	8.0%
All Model Links w/Counts	26,552,800	25,824,200	-2.8%

Table 3. Observed Estimates and Modeled 2020 Transit Weekday Boardings

	2019 Observed (Est.)	2020 Modeled	Model Variation
RTD Boardings	340,800	340,200	-0.2%
RTD Trips	237,900	222,900	-6.8%

Air Quality Modeling

Formal air pollutant emissions modeling is conducted by the APCD. However, DRCOG, the APCD, and other agencies work closely together in this effort, both in developing the modeling techniques, assumptions, and parameters, and in executing the model runs. Travel model link speed and VMT results are one of the principal inputs to the air pollutant emissions model. The model produces estimates of the amount of emissions of carbon monoxide (CO), volatile organic compounds (VOCs), oxides of nitrogen (NOx), and particulate matter (PM10) generated by motor vehicles. The results are then combined with numerous

assumptions concerning meteorology and atmospheric chemical reactions to produce air pollutant concentration estimates.

Appendix C. Modeling Summary Table

Table 1 – Denver Regional Council of Governments Assumptions for the Entire Modeling Area and Data for Base and Future Years

	2020	2050
Total Population	3,408,152	4,478,343
Employment	2,180,587	3,000,647
Dwelling Units (Households)	1,361,781	1,882,031
Persons/Dwelling Unit (Household)	2.50	2.38
VMT by Roadway Type		
-Freeway	34,777,226	48,560,516
-Expressway	5,306,800	7,173,836
-Principal	25,367,941	36,412,893
-Minor	8,533,124	12,053,757
-Other (Collectors, Centroid Connectors, Ramps)	17,388,152	26,333,878
Total	**91,373,242**	**130,534,879**
Speed by Roadway Type (miles per hour)		
-Freeway	58.3	53.2
-Expressway	42.7	39.1
-Principal	32.5	30.7
-Minor	29.2	27.7
-Other (Collectors, Centroid Connectors, Ramps)	27.3	27.1
Total (Average Speed)	**37.6**	**35.4**
Lane Miles by Roadway Type		
-Freeway	2,190	2,478
-Expressway	542	561
-Principal	4,280	5,130
-Minor	2,895	3,126
-Other (Collectors, Ramps)	6,507	6,555
Total	**16,414**	**17,851**

Appendix D. PM10 Street Emissions Reduction Commitments

Appendix E. U.S. Department of Transportation Conformity Finding