Transportation Greenhouse Gas Report

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Summary

The Colorado Department of Transportation's Regulation Governing Statewide Transportation Planning Process and Transportation Planning Regions (2 CCR 601-22, known as the Greenhouse Gas Transportation Planning Standard), adopted in December 2021, requires the Denver region to reduce surface transportation greenhouse gas emissions through the transportation planning process. Through impactful changes to the 2050 Metro Vision Regional Transportation Plan (2050 RTP) originally proposed and adopted in 2022 and carried forward and a commitment to further action through a Mitigation Action Plan, the DRCOG region meets the rule's greenhouse gas emission reduction requirements for all staging years defined by the rule.

The regulation (2 CCR 601-22, Section 8.02.6) establishes greenhouse gas emission reduction levels from an established baseline for four analysis years: 2025, 2030, 2040 and 2050. For the Denver region, baseline greenhouse gas values are established based on the defined transportation investments and planning assumptions identified in the 2050 RTP adopted in April 2021. The target greenhouse gas emissions are determined by subtracting the rule's greenhouse gas emission reduction levels from the total baseline emissions for each analysis year.

Following the update to the 2050 Metro Vision Regional Transportation Plan in 2022 to meet the state's GHG transportation planning standard, DRCOG staff initiated a cycle amendment process that concluded in 2024. The original strategies and concepts developed to meet the state greenhouse gas emission reduction levels have been carried forward into the 2024 Amended 2050 RTP. The descriptions have been included on the following pages.

Programmatic investment evaluation

- The adopted 2050 RTP includes over $1.34 billion in transportation investments associated with greenhouse gas emission reduction benefits not previously reflected in the travel model. The model was previously updated to reflect these important investments.

Project and program investment changes for the 2022 Updated 2050 RTP

- Reinvest funds from select roadway capacity projects to focus on multimodal elements and reduce the amount of increased roadway capacity;
- Accelerate multiple bus rapid transit projects; and
- Reallocate $900 million within the 2050 RTP's financial plan towards additional and accelerated regional complete streets and other multimodal programmatic investments.

Updates based on observed data for the 2022 Updated 2050 RTP

- Minor geographic adjustments to the household growth forecasts based on observed residential construction occurring at higher densities than originally forecast; and
- Updated work-from-home rates to reflect changes in behavior due to technological advancements, transportation demand management efforts, and the effects of the COVID-19 pandemic.

Mitigation Action Plan

- A Mitigation Action Plan (Appendix A) has been developed using the methods and processes in the Colorado Transportation Commission's Policy Directive 1610 (PD1610). The Mitigation Action Plan includes project types from Table 1 of PD1610 focused on parking management and rezoning in specific geographies (e.g., around rapid transit stations, vacant and underutilized land), as well as local adoption of complete streets ordinances and project implementation, and local adoption of multimodal design criteria/standards.

As shown in Table 1, DRCOG meets or exceeds the required greenhouse gas reduction levels in each staging year through these actions, demonstrating compliance with the greenhouse gas planning standard.

Table 1. Greenhouse gas emission reduction results, million metric tons per year

	2025	2030	2040	2050
2050 RTP update modeling (Network updates, programmatic funding and observed data)	0.68	0.68	0.57	0.35
Additional programmatic transportation investments (Active transportation, complete street retrofits, signal timing and CDOT Bustang)	N/A	0.07	0.05	0.03
Mitigation Action Plan (Commitment to further action in Appendix A)	N/A	0.10	0.12	0.08
Total greenhouse gas reductions	**0.68**	**0.85**	**0.74**	**0.46**
Reduction level requirement from Table 1 of the greenhouse gas rule (2 CCR 601-22, Section 8.02.6)	**0.27**	**0.82**	**0.63**	**0.37**
Reduction level achieved	**Yes**	**Yes**	**Yes**	**Yes**

Purpose

The purpose of this report is to document DRCOG's process for complying with Colorado's transportation greenhouse gas rule. The 2050 RTP was originally amended Sept. 21, 2022, to meet the Oct. 1, 2022 deadline specified in Colorado Revised Statutes §43-4-1103 and the Code of Colorado Regulations (2 CCR 601-22, Section 8.02.5.1)[1]. Since the amendment of the plan to meet compliance, DRCOG staff initiated an additional cycle amendments process that concluded in 2024. The analysis documented in this report demonstrates that the amended 2050 RTP complies with the regulation's requirements.

The demonstration is based on analysis conducted using the DRCOG's UrbanSim land use model and Focus travel demand model, and the Environmental Protection Agency's MOtor Vehicle Emission Simulator (MOVES) air quality model. Greenhouse gas reductions that could not be sufficiently modeled, such as signal timing and additional multimodal corridor enhancements, were calculated off-model using methodologies defined by the Colorado Transportation Commission's Policy Directive 1610. Additionally, the DRCOG Board has adopted a Mitigation Action Plan (Appendix A) to meet the reduction levels of the regulation.

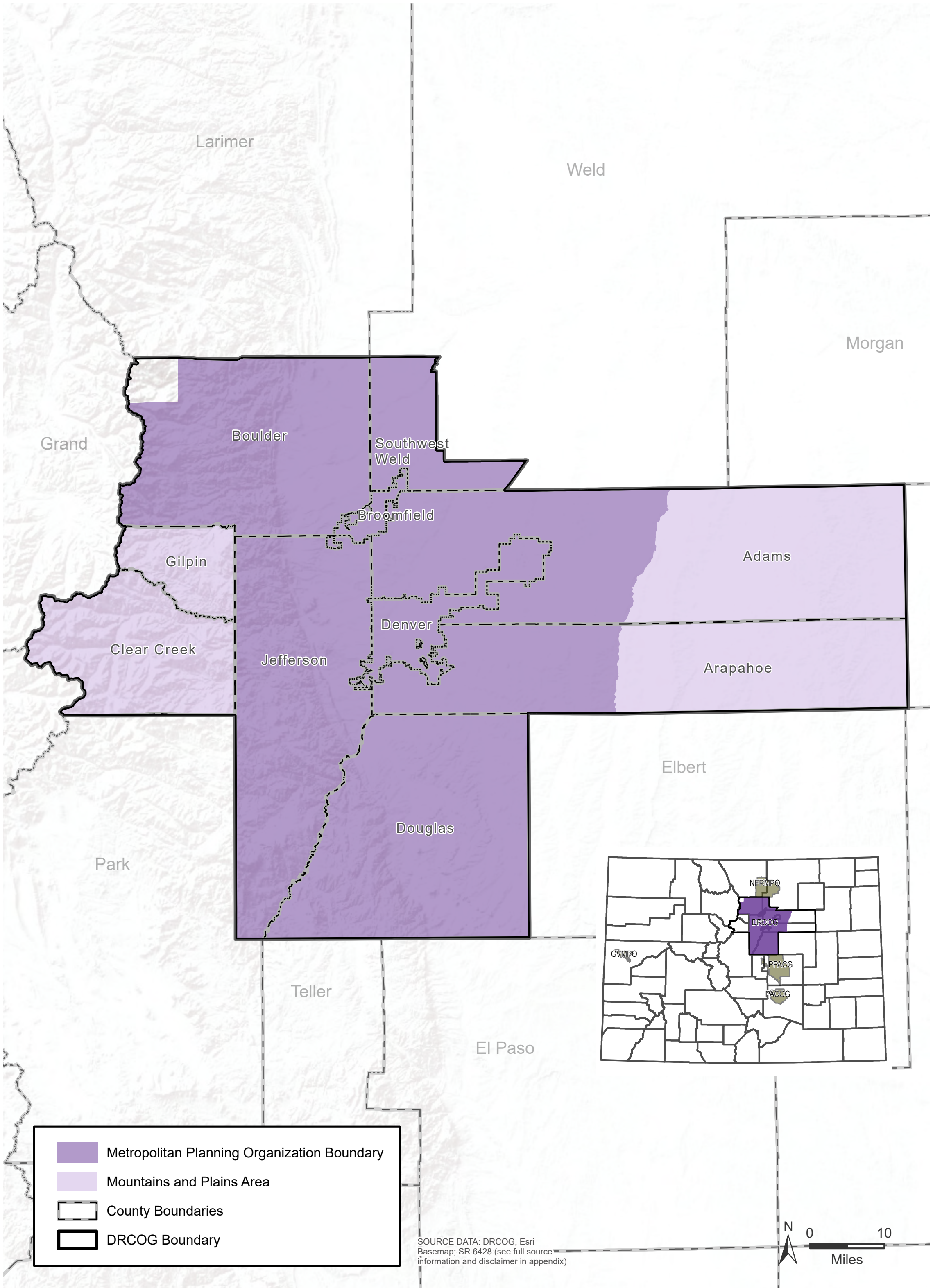
[1] Colorado Department of Transportation, "Rules Governing Statewide Transportation Planning Process and Transportation Planning Regions: 2 CCR 601-22", Accessed on 6/14/2022 from https://www.codot.gov/programs/environmental/greenhousegas/assets/5-2-ccr-601-22_final_clean.pdf.

Background

Colorado SB21-260 ("Sustainability of the Transportation System") was enacted in June 2021. The bill directed the Colorado Department of Transportation to develop rules for the state and Colorado's five metropolitan planning organizations to reduce surface transportation greenhouse gas emissions through transportation planning processes. Emission reductions due to vehicle technology, such as fuel efficiency and zero emission vehicles, are regulated in a separate process.

CDOT Regulation Governing Statewide Transportation Planning Process and Transportation Planning Regions (2 CCR 601-22), adopted December 2021, established reduction levels of annual greenhouse gas in million metric tons for four future analysis years: 2025, 2030, 2040 and 2050. The rule applies to the metropolitan planning organization area within DRCOG which includes all, or portions of, eight counties as shown in Figure 1. This report presents the modeled total greenhouse gas emissions of future surface transportation associated with the 2024 Amended 2050 RTP within the MPO area of DRCOG.

Figure 1: The DRCOG region



DRCOG's role

DRCOG is a planning organization where local governments collaborate to establish guidelines, set policy and allocate funding in the areas of transportation and personal mobility, growth and development and aging and disability resources. The Denver area is a dynamic region of 3.4 million people and 58 communities anchoring Colorado's Front Range. Consistently rated one of the best places to live in the country, the region will add a million more people and half a million more jobs by 2050.

The DRCOG region includes Adams, Arapahoe, Boulder, Clear Creek, Douglas, Gilpin and Jefferson counties, the City and County of Denver, the City and County of Broomfield and southwest Weld County. DRCOG is also the federally designated MPO for the Denver region, meaning DRCOG leads multimodal transportation planning activities in cooperation with CDOT, the Regional Transportation District and other stakeholders.

For over 25 years, DRCOG has been actively involved in efforts to reduce the amount of motor fuel burned, vehicle miles traveled and associated greenhouse gas emissions. This task is challenging due to the region's growth. However, DRCOG remains strongly committed to efforts to reduce greenhouse gas emissions and has invested significant funding towards those efforts for many years.

DRCOG's planning documents

DRCOG, in conjunction with its direct MPO partners CDOT and RTD, prepares and routinely updates three key planning documents:

Metro Vision

In addition to its role as an MPO, DRCOG serves as a regional planning commission under Colorado statutes. Metro Vision fulfils DRCOG's duty as an RPC to make and adopt a plan for the physical development of the region. As such, it reflects the long-range vision for the Denver region, establishing a set of shared outcomes and objectives that provide guidance and a framework for regional and local planning priorities, including the region's shared multimodal transportation planning priorities. While providing guidance and numerous example initiatives for regional and local implementation, Metro Vision acknowledges the unique characteristics and contributions of the region's 58 local governments.

To monitor progress towards Metro Vision outcomes the DRCOG incorporated vehicle miles traveled and greenhouse gas reduction targets, along with several other performance measures, into the plan – first in 2011 and again in the 2017 update. DRCOG continues to monitor and make progress towards these targets with strategic initiatives to achieve the shared outcome.

2050 Metro Vision Regional Transportation Plan

The 2050 RTP helps DRCOG and its many partners implement the shared aspirational vision of Metro Vision by identifying specific project and program investment priorities for the region's multimodal transportation system and its operations. It identifies six priorities: multimodal mobility, safety, air quality, regional transit, freight and active transportation. The RTP also identifies investments and regionally significant projects to be funded with "reasonably expected" future revenues over the next 30 years. The 2050 RTP balances planning for an additional million residents in the region while also maintaining the current transportation system and expanding travel options.

In particular, the RTP's project and program investment priorities include:

- Creating a safety program to increase the region's investments in projects to eliminate transportation fatalities and serious injuries.
- Continuing to invest in programs for community mobility planning and implementation, regional transportation operations and technology, regional air quality, commute options, and human service transportation through DRCOG's Transportation Improvement Program.
- Investing in a regional bus rapid transit system of corridors that can leverage federal funding opportunities, attract high volumes of ridership, are ready for implementation and reflect regional geographic equity considerations.
- Continuing to implement the DRCOG Active Transportation Plan through a program to further develop the region's high-comfort active transportation corridors, eliminate gaps and invest in the 2050 RTP's pedestrian focus areas and short-trip opportunity zones.

DRCOG staff used these priorities, along with the agency's Regional Complete Streets Toolkit, as the foundation for the greenhouse gas emission reduction strategies described in this report.

Transportation Improvement Program

The TIP is a four-year program of specific state and federally funded projects and programs to be implemented by CDOT, RTD, local governments, DRCOG and other partner agencies. The process to evaluate projects selected to receive DRCOG-administered funds has always included criteria associated with the reduction of vehicle miles traveled and greenhouse gas emissions. This includes application questions on air quality reduction, improving multimodal mobility and connectivity, expanding transit, increasing safety and reducing congestion delays.

Historically, DRCOG allocations have gone towards the following project types that work towards reducing vehicle miles traveled and greenhouse gas emissions:

- Active transportation projects, new and upgraded facilities.
- Transit funding, including capital purchases, new and expanded service operations, bus rapid transit infrastructure and passenger facilities.
- Grants for station area, transit-oriented development and urban center planning.
- Direct funding to support air quality improvement programs through the Regional Air Quality Council.
- Congestion management initiatives, including:
    - DRCOG's Way to Go Program.
    - Transportation demand management partnerships and non-infrastructure projects.
    - Transportation operations, traffic signal system upgrades, signal corridor retiming, intelligent transportation systems infrastructure.
    - Carpool, vanpool and school pool programs
    - One of the nation's largest Bike to Work Day programs.
- Roadway operational improvement projects.

It should be noted DRCOG administers a small percentage of total transportation funds within the region used to build, operate and maintain the region's transportation system. Over 95% of funding is administered by CDOT, RTD, toll authorities, and local governments.

Modeling greenhouse gas emissions

UrbanSim model

To understand how demands on the transportation system will change between now and 2050, DRCOG must forecast how growth and development will affect the distribution of households and jobs throughout the region. The State Demography Office in the Colorado Department of Local Affairs forecasts future population, household and job levels at the state and county-level. DRCOG uses the county-level growth forecast from the state demographer and applies a predictive model, the UrbanSim block model, to simulate household and employment location choices with real estate market dynamics and within natural and regulatory constraints.

DRCOG relies on extensive feedback from local partners on preliminary model results to improve model inputs before finalizing household and employment forecasts across 2,804 transportation analysis zones within the Denver region. With forecasts available for each transportation analysis zone, DRCOG and its partners can model future travel demand between zones to anticipate the effects on the transportation network and vehicle emissions, as well as mobility and accessibility for people and freight. More details about the UrbanSim Model can be found in Appendix C.

Regional travel demand model

DRCOG's activity-based travel demand model, Focus, uses socioeconomic outputs from the UrbanSim model along with numerous travel, demographic, and human decision-making factors to represent an average weekday of travel within the Denver region. The Focus model is calibrated to data obtained from regional and national travel surveys, along with several other data sources, to replicate the 15.3 million person-trips made every weekday on the regional transportation system. The model replicates the planned transportation system and land use attributes to generate trips across travel modes and assigns applicable trips to the roadway and transit network. The Focus model is calibrated to match real world observations of traffic volumes, transit boardings and numerous other travel, demographic and trip mode data metrics.

The key use of the Focus model is to forecast future travel metrics based on changes to the Denver region's population, employment and transportation system. Appendix C shows some of the key travel model outputs for both the baseline and compliance model runs. Appendix D provides more detailed information about the Focus model.

MOVES emissions model

The Focus model does not calculate greenhouse gas emissions. The U.S. Environmental Protection Agency created the MOVES model to estimate transportation emissions for various pollutants from surface transportation, including greenhouse gas. To calculate greenhouse gas emissions for the Denver MPO area, region-specific inputs to the MOVES model are developed and maintained by the Colorado Department of Public Health.

Key inputs to the MOVES model to calculate greenhouse gas emissions include:

- Traffic volumes and speeds by time of day from the Focus travel model.
- Number, type and age of vehicles in the regional vehicle fleet.
- Vehicle fleet mix by roadway type.
- Meteorological conditions.
- Fuel economy of vehicles (miles per gallon).
- Increase of electric and other non-internal combustion engine motor vehicles.

Further documentation of the MOVES model is provided in Appendix E.

Greenhouse gas emissions analysis process and results

Setting the baseline

To establish the greenhouse gas emission baseline, DRCOG followed the guidance found in 2 CCR 601-22, Section 1.04 which defines the baseline as: “For each MPO area and for the Non-MPO areas of the state, for each of the model years 2025, 2030, 2040, and 2050: the greenhouse gas emissions, in million metric tons (MMT), produced by the most recently adopted model for that area… as of the effective date of this rule.”

For DRCOG, the “most recently adopted model” is the 2050 RTP adopted in April 2021. As adopted, the 2050 RTP identifies the regionally significant transportation investments through the year 2050 along with other planning assumptions, such as demographic data, land use information, travel costs and travel time changes. The final baseline values, shown in Table 2, were derived from running the most current version of the UrbanSim, Focus and MOVES models, with the network and land use planning assumptions as adopted in April 2021 for the 2050 RTP.

Table 2. DRCOG greenhouse gas baseline by analysis year in million metric tons

	2025	2030	2040	2050
Greenhouse gas baseline (2050 RTP adopted April 2021)	10.50	9.23	6.22	3.70
Reduction requirement from Table 1 of greenhouse gas rule	0.27	0.82	0.63	0.37

The large decrease in baseline greenhouse gas emissions over time is due to the CDOT’s estimates for large increases in the share of electric vehicles into the overall fleet.

Modeling the 2024 Amended 2050 RTP

To originally comply with the greenhouse gas rule and reduce future surface transportation greenhouse gas emissions, DRCOG committed to meaningful changes to planned regionally-significant transportation projects, analyzed the effects of programmatic investments and reevaluated land use and travel parameters in light of more recent observed data. Through this process, DRCOG engaged the public and stakeholders to determine the changes. The changes discussed on the following pages remain reflected in the 2024 Amended 2050 RTP.

Project and program investment changes

DRCOG, CDOT and other project stakeholders have carried forward modifications to select 2050 RTP projects (CDOT-directed funds and DRCOG-directed funds) to accomplish the following:

- Freeway managed lane projects: Modify C-470 and central I-25 projects to focus on safety, operational, transit and other multimodal aspects and associated greenhouse gas benefits; redirect/ finance CDOT funds to advance bus rapid transit corridors and fund additional regional multimodal programmatic investments as shown in Table 3.
- DRCOG-directed funded roadway projects: Modify the scope of several projects to remove “six laning” components and re-focus those projects on multimodal, safety and complete streets investments as shown in Table 3.
- Bus rapid transit network: Advance four bus rapid transit corridors and complete five bus rapid transit corridors by 2030. These include East Colfax Avenue, East Colfax Avenue extension, State Highway 119, Federal Avenue and Colorado Boulevard; advance Broadway Avenue/Lincoln Avenue bus rapid transit corridor from 2040-2050 to 2030-2039 as listed in Table 3.
- Additional multimodal programmatic investments: allocate and finance $900 million made available through the specified project changes to fund additional multimodal programmatic investments ($500 million by 2030, $200 million more by 2040 $200 million more by 2050). A summary of the program investment changes is shown in Table 4.

These changes also incorporated previous sponsor-requested project-based amendments as part of DRCOG’s routine call for amendments to the 2050 RTP.

Table 3. Original Proposed project modifications, 2022 cycle amendments and greenhouse gas analysis for the 2022 Updated 2050 RTP

Project Name/ Corridor	Location/Limits	Current 2050 RTP Project Description
I-70 Floyd Hill Eastbound	Floyd Hill to Veterans Memorial Tunnel	Eastbound interchange improvements with frontage road extension from Hidden Valley interchange to US 6 interchange
I-70 Floyd Hill Westbound	Floyd Hill to Veterans Memorial Tunnel	Addition of a new express travel lane from the top of Floyd Hill to Veterans Memorial Tunnels, and eastbound auxillary lane from the bottom to top of Floyd Hill
I-270	I-25/US 36 to I-70	New managed lanes
C-470	Wadsworth to I-70	New managed lanes
	U.S. Route 285/Morrison/Quincy	Interchange complex reconstruction
I-25 Central Buildout	Colfax Ave. to 20th St.	Ultimate buildout of corridor improvements
I-25 Valley Highway/ Burnham Yard	Santa Fe Blvd. to Colfax Ave.	Managed lanes, includes right-of-way, Burnham Yard, Central Main Line relocation
Broncos Pkwy./ Easter/Dry Creek Corridor	Parker Rd. to Havana	Widening to 6 lanes, bridge widening and intersection improvements
Gun Club Rd.	State Hwy. 30 to 6th Ave.	Widen from 2 to 4/6 lanes, includes stream crossing upgrade at Coal Creek
Gun Club Rd.	Quincy to Aurora Pkwy.	Widen from 2 to 6 lanes
Smoky Hill Rd.	Buckley Rd. to Picadilly St.	Widen from 4 to 6 lanes
State Hwy. 30	Airport Blvd. to Quincy Ave.	Widen from 2 to 6 lanes
Lincoln Ave.	Oswego to Keystone	Widen 4 to 6 lanes
SH-66	Lyons to Longmont	Widen from 2 to 4 lanes (Hover St. to Main St.) and operational/safety improvements from Lyons to Longmont in alignment with PEL
South Platte River Trail		Complete missing links and upgrade trail section
Broadway/Lincoln BRT	Colfax to Highlands Ranch Pkwy.	Bus rapid transit service and supporting safety/multimodal improvements
Federal Blvd. BRT	120th to Santa Fe/Dartmouth	Bus rapid transit service and supporting safety/multimodal improvements
State Hwy. 119 BRT	Downtown Boulder to downtown Longmont	Bus rapid transit service and supporting safety/multimodal improvements
Colfax Ave. Ext. BRT	I-225 to E-470	Bus rapid transit service and supporting safety/multimodal improvements

Proposed Project Change/Description
Process requested amendment. Move from 2030-2039 stage to 2020-2029 stage
Process requested amendment. Move from 2030-2039 stage to 2020-2029 stage
Process requested amendment. Move from 2030-2039 stage to 2020-2029 stage
Remove managed lanes component; complete interchange complex reconstruction as planned
Remove managed lanes component
Widen to 4 lanes; bridge, multimodal corridor and intersection improvements
Widen from 2 to 4 lanes, includes stream crossing upgrade at Coal Creek, multimodal corridor improvements; advance stage period
Widen from 2 to 4 lanes, multimodal corridor improvements
Multimodal corridor improvements [Note: corridor remains at 4 lanes]; Advance stage period
Widen from 2 to 4 lanes, multimodal corridor improvements
Multimodal corridor improvements [Note: corridor remains at 4 lanes]; Advance stage period
Process requested amendment. Split project between the 2020-2029 (Hover to Main) and 2030-2039 (Lyons to Hover) stage periods
Process requested amendment. Split project cost between the 2020-2029 and 2030-2039 stage periods
Advance BRT implementation from 2040-2050 stage period to 2030-2039 stage period
Process requested amendment. Advance BRT implementation from 2030-2039 stage period to 2020-2029 stage period
Process requested amendment. Advance BRT implementation from 2030-2039 stage period to 2020-2029 stage period
Advance BRT implementation from 2040-2050 stage period to 2020-2029 stage period

Table 4. 2024 cycle amendments

Project Name/ Corridor	Location/ Limits	Current 2050 RTP Project Description	Proposed Project Change/Description
State Hwy. 7	US-36 and 28th St. to 63rd St.	Not applicable	Process requested amendment. Add project into the RTP. Convert two general purpose lanes to Business Access Transit (BAT) lanes.
96th Ave.	I-76 to Heinz Way	Not applicable	Process requested amendment. Add project into the RTP. Widen from 2 to 4 lanes.
Vasquez Blvd.	60th Ave.	Intersection improvements.	Process requested amendment. Move from 2040-2050 stage to 2020-2029 stage.
Havana St.	Lincoln Ave.	Not applicable	Process requested amendment. Add project into the RTP. Grade separation of Havana St and Lincoln Ave with safety, operational and multimodal improvements.
I-76	Weld County Road 8	Not applicable	Process requested amendment. Add project into the RTP. New interchange.

Representation of adopted 2050 RTP programmatic funding for the 2022 Updated 2050 RTP

As adopted in April 2021, DRCOG's fiscally constrained 2050 RTP contains over $15 billion in regional programmatic funding. These investments are shown as lump sums across various programs and individual projects are not yet identified in these programs. Programmatic funding categories include transit investments, active transportation, safety/Vision Zero, transportation demand management and intelligent transportation investments, all of which are key strategic investments to improve the region's multimodal transportation system, improve air quality and reduce greenhouse gas emissions.

DRCOG staff evaluated the programmatic 2050 RTP funding, which was not yet reflected in the travel model, and determined there were approximately $1.34 billion of investment associated with greenhouse gas emission reductions. Based on this information and in coordination with CDOT and North Front Range MPO travel modelers, DRCOG staff developed a method to reflect these investments in the travel model. Appendix D provides more detailed information about the 2050 RTP funding and the modeling process for greenhouse gas emissions analysis, including the research and CDOT guidance that supports these changes.

Updates reflecting new observed data for the 2022 Updated 2050 RTP

DRCOG compiles point-level housing data from a variety of local and proprietary sources. When the 2050 RTP was adopted in 2021, the most recent observation available was 2018. This was the same for point-level employment data licensed from the Colorado Department of Labor and Employment and subject to additional processing and cleaning at DRCOG. DRCOG staff use this data as a supplementary UrbanSim model input applied during the scheduled development step. DRCOG was able to incorporate housing and employment data through 2020, along with preliminary data from proprietary housing datasets to update those observations into 2022. DRCOG staff also incorporated insights from these same proprietary housing datasets to include anticipated housing construction through 2028. To accommodate these observations of more multifamily housing in more dense locations and counties, DRCOG staff had to make several adjustments to the previous county forecasts.

Additionally, factors influencing work-from-home rates were updated to reflect observed changes in behavior due to technological advancements, transportation demand management efforts from DRCOG and DRCOG's partners, and the effects of the COVID-19 pandemic. Further description of the model updates can be found in Appendix D.

Emission results

Table 5 shows the modeling results for the 2024 Amendments to the 2050 RTP with the greenhouse gas emission reductions from the baseline. Only in 2025 do the modeling results meet the greenhouse gas reduction levels on their own. DRCOG has carried forward the additional transportation investments that were evaluated using "off model" calculations to achieve further emission reductions developed for the 2022 Updated 2050 RTP.

Table 5. Greenhouse gas emission results in million metric tons per year

	2025	2030	2040	2050
Greenhouse gas baseline (2050 RTP, adopted April 2021)	10.54	9.20	6.21	3.70
2024 amended 2050 RTP	9.83	8.53	5.64	3.35
Greenhouse gas reduction from 2024 amended 2050 RTP modeling:	**0.71**	**0.67**	**0.57**	**0.35**

Additional programmatic investment for the 2022 Updated 2050 RTP

For the 2022 Updated 2050 RTP, in addition to modeling the greenhouse gas reductions associated with the programmatic (non-project specific) investments in the 2050 RTP as adopted, DRCOG also worked with CDOT to re-allocate $900 million in the 2050 RTP's fiscally constrained financial plan towards additional programmatic investments to help meet the greenhouse gas reduction levels for each analysis year, especially for 2030. Additionally, $190 million in 2050 RTP-adopted programmatic funding remained from the representation of programmatic funding in the Focus model described above and was also included in this analysis, for a total of $1.09 billion.

Because the greenhouse gas technical analysis indicated particular difficulty with attaining the 2030 reduction levels, the $1.09 billion in programmatic funding was allocated as follows:

- 2030: $605,000,000
- 2040: $242,000,000
- 2050: $242,000,000

The first step was to compare the programmatic categories in Table 3.1 of the adopted 2050 RTP with the mitigation measures in Policy Directive 1610 since the greenhouse gas reduction calculations for each type of programmatic investment used Policy Directive 1610's scoring and calculation methodologies. Based on this comparison, the following Policy Directive 1610 measures were used to represent the additional programmatic investment:

- Signal timing.
- CDOT Bustang expansion within the DRCOG area.
- Bicycle/pedestrian facility (primarily urban and suburban).
- Sidewalk/pedestrian facility (urban and suburban).
- Shared-use path (urban, suburban and rural).
- Complete streets retrofits (urban and suburban).

Each programmatic investment category originally developed for the 2022 Updated 2050 RTP and carried forward into the 2024 Amended 2050 RTP is described below.

Additional signal timing

Since 1989, DRCOG has been working with CDOT and local governments to coordinate traffic signals across jurisdictional boundaries on major roadways in the region. DRCOG has a proven record and the resources to continue to reduce traffic congestion and improve air quality through signal timing coordination plan development support.

The 2022 Updated 2050 RTP increased investments in the Regional Traffic Operations Program above this baseline to retime and optimize an additional 50 signals per year beginning in 2025 , which has been carried forward into the 2024 Amended 2050 RTP. Calculations for greenhouse gas emission reductions associated with this effort were made using the method described in Policy Directive 1610. Greenhouse gas emission reductions are calculated per 10,000 average annual daily traffic per signal optimized within five years prior to evaluation year. The emission reduction value declines over time due to increasing electric vehicles in the fleet and the calculations include an induced demand factor.

Table 6 shows the calculated greenhouse gas emission reduction for 2030, 2040, and 2050 based on 250 signals (50 per year) optimized during the five years preceding the analysis year and with an average annual daily traffic per signal of 45,000.

Table 6. Greenhouse gas emission results, in million metric tons per year

	2025	2030	2040	2050
Greenhouse gas emission reductions from additional signal timing	N/A	0.05	0.03	0.02

CDOT Bustang expansion within DRCOG area

CDOT indicated to DRCOG that as part of its own greenhouse gas rule compliance, it intends to expand Bustang service over time, including within the DRCOG MPO area. According to CDOT, its approach apportions the daily bus vehicle revenue miles of the Bustang expansion within each MPO boundary, as well as by route, since different patterns of weekday and weekend service for the routes will require different annualization factors. The West Line and the Outrider Routes have the same schedule seven days a week — suggesting that 365 is a reasonable annualization factor. The South Line to Denver's Union Station and North Line have one-third the number of round trips on weekends compared to week days (52 weeks * 5 weekdays = 260 days, plus 1/3 weighing to 52 weekends -> 104/3 - 34.67, so 260+34.67 = 204.67 as an annualization factor). The Colorado Springs to Denver Tech Center route only operates on weekdays, so a 260 annualization factor is most appropriate.

Table 7. Greenhouse gas emission results, in million metric tons per year

	2025	2030	2040	2050
Greenhouse gas emission reductions from increased Bustang service within DRCOG area	N/A	0.003	0.001	0.001

Bicycle and pedestrian facilities and Complete Streets retrofits

DRCOG staff analyzed its Regional Active Transportation Plan in terms of the plan's envisioned regional network buildout, such as for the Regional Active Transportation Network as well as proposed on-street facilities. DRCOG staff also reviewed its Complete Streets Toolkit and deployed its Complete Streets geographic information system prioritization tool developed under guidance from the federal Bipartisan Infrastructure Law to estimate the potential for complete street retrofits throughout the region for each analysis year. Using Policy Directive 1610's methodology, the mileage associated with each investment is multiplied by a factor to estimate the total points for each category.

Table 8. Greenhouse gas emission results, in million metric tons per year

	2025	2030	2040	2050
Bicycle/pedestrian facilities, Complete Street retrofits	N/A	0.02	0.02	0.01

Considering all the additional programmatic investments together, Table 9 shows the total estimated greenhouse gas reductions for each analysis year in million metric tons per year. While the total reduction amounts are modest, they are an important component of the overall framework to demonstrate compliance with the greenhouse gas rule. Perhaps even more importantly, they represent important needed investment in the region's multimodal transportation network.

Total emission reductions from off-model calculations

Table 9. Greenhouse gas emission results, in million metric tons per year

	2025	2030	2040	2050
Greenhouse gas emission reductions from additional signal timing	N/A	0.05	0.03	0.02
Greenhouse gas emission reductions from increased Bustang service within DRCOG area	N/A	0.003	0.001	0.001
Pedestrian facilities, Complete Street retrofits	N/A	0.02	0.02	0.01
Total additional programmatic investment greenhouse gas reduction calculations:	**N/A**	**0.07**	**0.05**	**0.03**

Mitigation Action Plan

To achieve additional emission reductions and meet the reduction requirements defined in the rule, DRCOG is pursuing a Mitigation Action Plan. The Mitigation Action Plan is detailed in Appendix A. DRCOG staff's commitment is to report annually on the progress of the measures listed in the Mitigation Action Plan, which include further commitments to land use planning efforts, complete streets standards and other strategies to reduce greenhouse gas emissions from on-road transportation sources. A summary of the greenhouse gas reductions by staging period and strategy can be found in Table 10.

Table 10. Greenhouse gas emissions reductions from Mitigation Action Plan strategies

	Greenhouse gas reduction in metric tons		
Measure	**2030**	**2040**	**2050**
Increase residential density from <10 units/acre to at least 15 to 25 units/acre	13,548	16,011	10,557
Increase job density from <0.5 floor area ratio to at least 1.0 floor area ratio	2,309	2,822	1,833
Mixed-use transit-oriented development higher intensity: Area rezoned for mixed-use transit-oriented development at least 25 units/acre and 150 jobs/acre	8,588	9,814	6,510
Mixed-use transit-oriented development moderate intensity: Area rezoned for mixed-use transit-oriented development at least 15 units/acre and 100 jobs/acre	18,397	21,157	14,455
Reduce or eliminate minimum parking requirements and set low maximum levels (residential)	37,750	43,795	29,573
Reduce or eliminate minimum parking requirements and set moderate maximum levels (residential)	18,332	21,281	14,347
Reduce or eliminate minimum parking requirements and set maximum levels (commercial)	4,373	3,940	3,511
Adopt local Complete Streets standards	369	243	44
Grand total	**103,666**	**119,063**	**80,829**

Table 11. Reduction through Mitigation Action Plan by staging year, in million metric tons per year

	2025	2030	2040	2050
Greenhouse gas reductions from Mitigation Action Plan (commitment to further action in Appendix A)	N/A	0.10	0.12	0.08

Summary

DRCOG complies with the requirements of the rule for all staging periods through the revising the 2050 RTP and pursuing a Mitigation Action Plan. DRCOG will monitor changes in the region that would require a re-baselining in future years as well as the effectiveness of strategies. DRCOG will continue to demonstrate compliance with the rule in every 2050 RTP amendment cycle.

Table 12. Greenhouse gas emission reduction results, in million metric tons per year

	2025	2030	2040	2050
Greenhouse gas reduction from 2024 Amended 2050 RTP modeling	0.71	0.67	0.57	0.35
Off-model greenhouse gas reduction calculations (active transportation funds, signal timing and Bustang)	N/A	0.07	0.05	0.03
Greenhouse gas reductions from Mitigation Action Plan (commitment to further action in Appendix A)	N/A	0.10	0.12	0.08
Total greenhouse gas reductions:	**0.71**	**0.84**	**0.74**	**0.46**
Reduction requirement from Table 1 of the greenhouse gas rule (2 CCR 601-22, Section 8.02.6)	**0.27**	**0.82**	**0.63**	**0.37**
Reduction requirement achieved	**Yes**	**Yes**	**Yes**	**Yes**

Public engagement for the 2022 Updated 2050 RTP

DRCOG conducted a 31-day public review period and held a public hearing on the 2022 Updated 2050 RTP and accompanying air quality and greenhouse gas documents. Additionally, staff engaged with the Civic Advisory Group and held five virtual open houses during the public comment period. For a full overview of the public and stakeholder engagement conducted during the 2022 Update process, see Appendix B of this report. For an overview of the public and stakeholder engagement conducted during the 2024 Cycle Amendments process, see Appendix C: Public and Stakeholder Engagement.

Appendix A: Mitigation Action Plan

Introduction and definition

DRCOG has prepared this Mitigation Action Plan to comply with the requirements of the Greenhouse Gas Transportation Planning Standard (known as the greenhouse gas rule) adopted by the Colorado Transportation Commission in December 2021. The greenhouse gas rule defines the Mitigation Action Plan as "an element of the GHG Transportation Report that specifies which GHG Mitigation Measures shall be implemented that help achieve the GHG Reduction Levels." While the greenhouse gas rule defined general content requirements for a Mitigation Action Plan, the Colorado Department of Transportation's Policy Directive 1610 specifies the following information to be included in a Mitigation Action Plan. An excerpt:

a. GHG Emissions Reductions: Summary of emissions analysis from GHG Transportation Report, including the estimated gap to achieve the GHG Reduction Levels specified for each horizon year.

b. GHG Mitigation Measure Summary/Description: Each measure shall include the following details as listed in Table 2 [of Policy Directive 1610].

(Source: Policy Directive 1610)

Both requirements are addressed below.

Greenhouse gas emissions reductions

As described in the Greenhouse Gas Transportation Report, DRCOG staff developed a framework of strategies to meet the greenhouse gas emission reduction levels for each analysis year as required by the greenhouse gas rule. Collectively, these strategies demonstrate meaningful progress toward achieving the reduction levels (and do so for the 2025 analysis year). However, there is a remaining gap for the 2030, 2040 and 2050 analysis years, demonstrating the need for mitigation measures and a Mitigation Action Plan. The analysis is shown in Table 1 of the Greenhouse Gas Transportation Report.

The analysis includes significant additional investments in the transportation projects and programs that result in estimated reductions in regional greenhouse gas emissions from the baseline as documented in the Greenhouse Gas Transportation Report. To address the remaining gap between these emission levels and the required reduction levels for each analysis year, DRCOG staff evaluated mitigation measure concepts and strategies included in Policy Directive 1610 for their feasibility and applicability within the DRCOG metro planning organization region. In doing so, DRCOG staff evaluated potential measures that are not already part of either the 2050 RTP or the Focus travel model. In other words, many of the measures included in Policy Directive 1610 are already directly included in the 2050 RTP or could be modeled or addressed within the Focus model. Therefore, DRCOG staff narrowed its focus to policy-oriented measures, such as land use, parking and other "non-project investment" measures.

Mitigation measures analysis

Land use and parking management measures

DRCOG staff analyzed vacant and redevelopable land parcels for various geographies where land use and parking strategies have the most potential for successful implementation and greenhouse gas reduction results. The specific geographies analyzed, shown in Figure 1, are areas within:

- A half-mile of an existing rail station.
- A quarter-mile of existing or planned bus rapid transit stations
- Existing urban centers as identified by local governments and then regionally designated in Metro Vision.
- Pedestrian focus areas identified in DRCOG's Active Transportation Plan.

DRCOG staff also created an interactive web map to illustrate the analyzed geographies.

DRCOG staff does not intend that the geographies it analyzed be considered "required" for implementing the mitigation measures. Rather, they are reasonable estimates of where (and to what extent) the measures could apply for calculating their greenhouse gas reduction potential.

DRCOG staff identified vacant and redevelopable parcels within each geography as those parcels where the ratio of improvement value to land value was less than or equal to 2.0. The areas were exclusive — in other words, a parcel was not counted in more than one of the following four geographies (in order of evaluation):

- Rail station areas.
- Bus rapid transit station areas outside of rail station areas.
- Urban centers outside the station areas.
- Pedestrian focus areas outside of station areas and urban centers.

No parcel was included that had 10 or more households in 2020 nor that is currently estimated to have 15 households or more in 2050, as this indicates pre-existing zoning not eligible for rezoning as required of the mitigation measures described in Policy Directive 1610. Additionally, to avoid counting property that could be difficult to assemble and reach required densities, no parcel smaller than a half-acre was included.

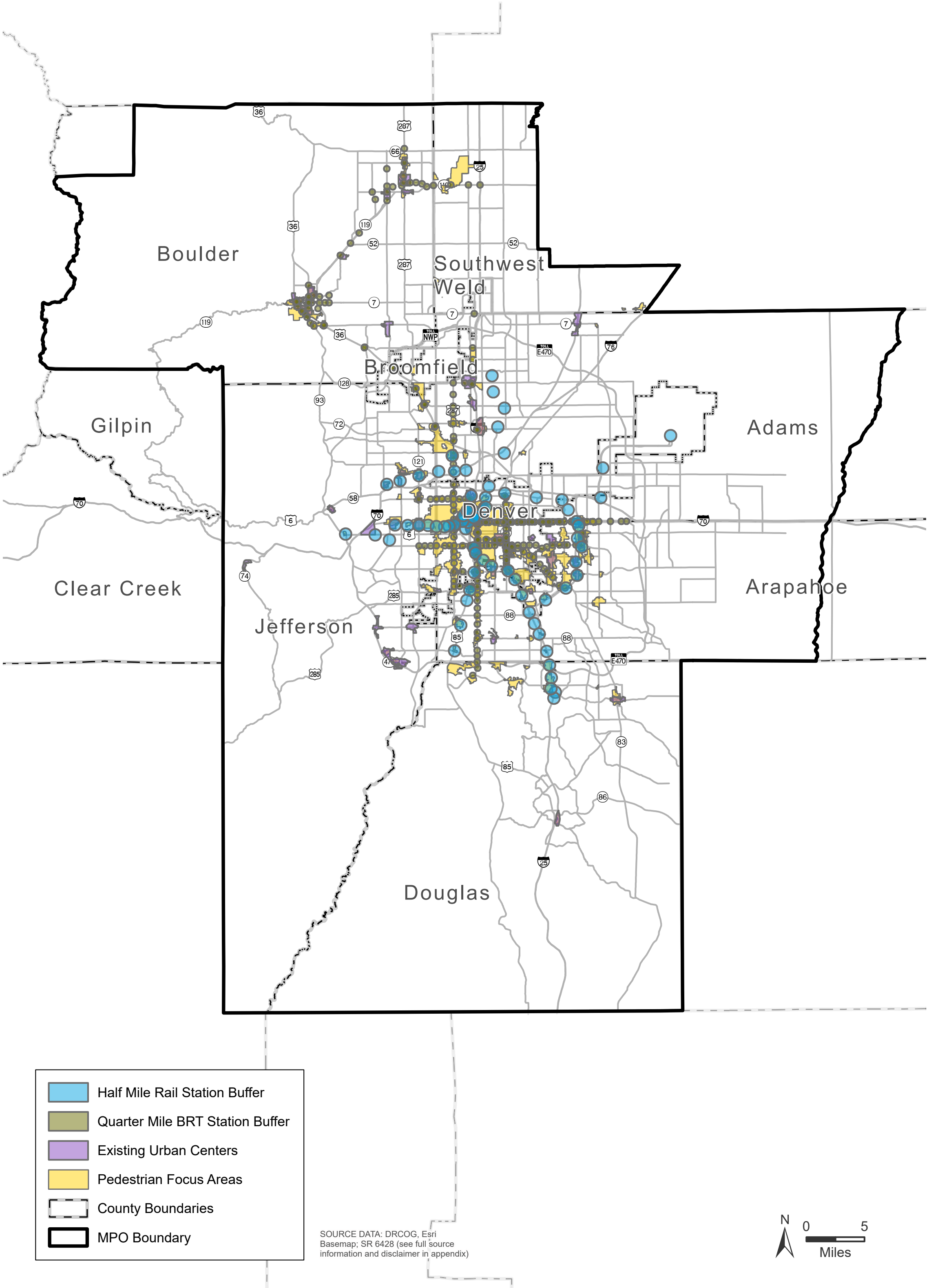
For the greenhouse gas reduction estimates associated with each mitigation measure, the vacant and redevelopable parcels were grouped into Station/Bus Rapid Transit Areas and Urban Center/Pedestrian Focus Areas since the nature of those groups of geographies have different levels of opportunity. The results of the analysis are summarized in Table 1.

Table 1: Vacant and redevelopable parcels by geography

Improvement to land value ratio	Category	Within a half-mile of rail station	Within a quarter-mile of bus rapid transit (non-rail station area)	Total Station/ Bus Rapid Transit Areas	Within existing urban center (non-Station/ Bus Rapid Transit Areas)	Within pedestrian focus area (non-Station/ Bus Rapid Transit/urban center areas)	Total Urban Center/ Pedestrian Focus Areas	Total of all areas
0	Vacant	3,463	1,135	4,598	697	2,056	2,753	7,351
greater than 0-1	redevelop-able	3,483	2,388	5,871	1,019	1,337	2,356	8,227
greater than 1-2		2,132	1,232	3,364	755	1,205	1,960	5,324
Subtotal vacant or redevelopable		9,078	4,755	13,833	2,471	4,598	7,069	20,902
greater than 2-3	developed	1,446	921	2,367	569	1,174	1,743	4,110
greater than 3		12,863	7,614	20,477	7,683	19,411	27,094	47,571

Note: Includes parcels in areas of fewer than 10 households per acre in 2020; excludes parcels in areas of 15 households or more per acre in 2050.

Figure 1: Mitigation measures analysis geographies



For each land use and parking measure, DRCOG staff made an assessment about the:

- Total available acres of the two geography combinations to which to apply the measure.
- Amount of the available acres that is likely to be developed or redeveloped by 2050.
- Amount of the potentially developed or redeveloped area that is subject to either being rezoned or parking management standards.

Overall, the analysis identified approximately 20% of all vacant and redevelopable acres as eligible to be rezoned or have parking standards adjusted to produce sufficient additional greenhouse gas emission reductions to reach the greenhouse gas emission reduction levels for 2030, 2040 and 2050. Table 2 summarizes the cumulative analysis of the mitigation measures.

Table 2: Greenhouse gas emission reduction summary

	Greenhouse gas reduction in metric tons		
Measure	2030	2040	2050
Increase residential density from fewer than 10 units per acre to at least 15- 25 units per acre	13,548	16,011	10,557
Increase job density from less than 0.5 floor area ratio to at least 1.0 floor area ratio	2,309	2,822	1,833
Mixed-use transit-oriented development-higher intensity: Area rezoned for mixed-use transit-oriented-development of at least 25 units per acre and 150 jobs per acre	8,588	9,814	6,510
Mixed-use transit-oriented development-moderate intensity: Area rezoned for mixed-use transit-oriented development of at least 15 units per acre and 100 jobs per acre	18,397	21,157	14,455
Reduce or eliminate minimum parking requirements and set low maximum levels (residential)	37,750	43,795	29,573
Reduce or eliminate minimum parking requirements and set moderate maximum levels (residential)	18,332	21,281	14,347
Reduce or eliminate minimum parking requirements and set maximum levels (commercial)	4,373	3,940	3,511
Adopt local complete streets standards	369	243	44
Grand total	**103,666**	**119,063**	**80,829**

The greenhouse gas emission reductions for each mitigation measure use the calculations as adopted in Policy Directive 1610. Detailed information on the calculated emission reductions is included in the next section.

Greenhouse gas mitigation measure summary

Land use strategies

Increase residential density. Increase residential density from fewer than 10 units per acre to at least 15-25 units per acre.

The analysis assumes that 1,759 acres in Urban Center/ Pedestrian Focus Areas (43.4%) and Station/Bus Rapid Transit Areas (56.6%) will be rezoned from fewer than 10 residential units per acre to allow at least 15 units per acre. This represents 763 acres of vacant or redevelopable land in Urban Center/Pedestrian Focus Areas (10.8% of the region total) and 996 acres of vacant and redevelopable land in Station/Bus Rapid Transit Areas (7.2% of the region total). According to the Policy Directive 1610 evaluation, increasing residential density as described reduces vehicle miles traveled per residential unit by 4,321 per year, resulting in 21.9 fewer tons of greenhouse gas emissions per rezoned acre in 2030, 12.7 tons per rezoned acre in 2040, and 6.0 tons per rezoned acre in 2050.

DRCOG staff estimates that 35% of the opportunity land areas would be rezoned by 2030, 35% by 2040, and 30% by 2050.

Assumptions:		
Amount of total Station/Bus Rapid Transit Areas included in measure	40%	5,533 acres
Amount of total Urban Center/Pedestrian Focus Areas included in measure	60%	4,241 acres
Amount of area that will be developed or redeveloped over 30 years	30%	2,932 acres
Amount subject to rezoning	**60%**	**1,759 acres**

Greenhouse gas reduction calculations

Greenhouse gas tons per acre rezoned	2025		2030		2040		2050	
	Reduction per acre		Reduction per acre		Reduction per acre		Reduction per acre	
	27		22		13		6	
Greenhouse gas tons reduced	2025		2030		2040		2050	
	Acres rezoned	Reduction	Acres rezoned	Reduction	Acres rezoned	Reduction	Acres rezoned	Reduction
	-	-	616	13,548	616	8,005	528	3,167
Amount rezoned per period	0%		35%		35%		30%	
Carryover	-	-	-	-	616	8,005	1,232	7,390
Total reduction		**-**		**13,548**		**16,011**		**10,557**

Increase job density. Increase job density from less than 0.5 floor area ratio to at least 1.0 floor area ratio.

The analysis assumes that 367 acres in Urban Center/ Pedestrian Focus Areas (43.3%) and Station/Bus Rapid Transit Areas (56.7%) will be rezoned from a floor area ratio of less than 0.5 to allow a floor area ratio of at least 1.0. This represents 159 acres of vacant or redevelopable land in Urban Center/Pedestrian Focus Areas (2.2% of the region total) and 208 acres of vacant and redevelopable land in Station/Bus Rapid Transit Areas (1.5% of the region total). According to the Policy Directive 1610 evaluation, increasing job density as described reduces vehicle miles traveled per employee by 445 per year, resulting in 18 fewer tons of greenhouse gas emissions per rezoned acre in 2030, 10.5 tons per rezoned acre in 2040, and 5 tons per rezoned acre in 2050.

DRCOG staff estimates that 35% of the opportunity land areas would be rezoned by 2030, 35% by 2040 and 30% by 2050.

Assumptions:		
Amount of total Station/Bus Rapid Transit areas Included in measure	10%	1,383 acres
Amount of total Urban Center/Pedestrian Focus Areas included in measure	15%	1,060 acres
Amount of area that will be developed or redeveloped over 30 years	25%	611 acres
Amount subject to rezoning	**60%**	**367 acres**

Greenhouse gas reduction calculations

	2025		2030		2040		2050	
Greenhouse gas tons per acre rezoned	Reduction per acre		Reduction per acre		Reduction per acre		Reduction per acre	
	22		18		11		5	
Greenhouse gas tons reduced	2025		2030		2040		2050	
	Acres rezoned	Reduction	Acres rezoned	Reduction	Acres rezoned	Reduction	Acres rezoned	Reduction
	-	-	128	2,309	128	1,411	110	550
Amount rezoned per period	0%		35%		35%		30%	
Carryover	-	-	-	-	128	1,411	257	1,283
Total reduction		**-**		**2,309**		**2,822**		**1,833**

Mixed-use transit-oriented development (moderate intensity). Rezone areas for mixed-use transit-oriented development accommodating at least 15 residential units per acre and 100 jobs per acre within a half-mile of a high-frequency bus transit or fixed-guideway station.

The analysis assumes that 1,314 acres in Urban Center/ Pedestrian Focus Areas (24.2%) and Station/Bus Rapid Transit Areas (75.8%) will be rezoned to allow mixed-use transit-oriented development accommodating at least 15 residential units/acre and 100 jobs/acre. This represents 318 acres of vacant/redevelopable land in Urban Center/Pedestrian Focus Areas (4.5% of the region total) and 996 acres of vacant and redevelopable land in Station/Bus Rapid Transit Areas (7.2% of the region total). According to the Policy Directive 1610 evaluation, increasing mixed-use transit-oriented development areas with moderate residential and job density as described reduces vehicle miles traveled per acre by 109,269 per year, resulting in 40 fewer tons of greenhouse gas emissions per rezoned acre in 2030, 23.2 tons per rezoned acre in 2040, and 11 tons per rezoned acre in 2050.

DRCOG staff estimates that 35% of the opportunity land areas would be rezoned by 2030, 35% by 2040, and 30% by 2050.

Assumptions:

Amount of total Station/Bus Rapid Transit areas Included in measure	40%	5,533 acres
Amount of total Urban Center/Pedestrian Focus Areas included in measure	25%	1,767 acres
Amount of area that will be developed or redeveloped over 30 years	30%	2,190 acres
Amount subject to rezoning	**60%**	**1,314 acres**

Greenhouse gas reduction calculations

	2025		2030		2040		2050	
Greenhouse gas tons per acre rezoned	Reduction per acre		Reduction per acre		Reduction per acre		Reduction per acre	
	49		40		23		11	
Greenhouse gas tons reduced	2025		2030		2040		2050	
	Acres rezoned	Reduction	Acres rezoned	Reduction	Acres rezoned	Reduction	Acres rezoned	Reduction
	-	-	460	18,397	460	10,578	394	4,336
Amount rezoned per period	0%		35%		35%		30%	
Carryover	-	-	-	-	460	10,578	920	10,118
Total reduction		**-**		**18,397**		**21,157**		**14,455**

Mixed-use transit-oriented development (higher intensity). Rezone areas for mixed-use transit-oriented development accommodating at least 25 residential units per acre and 150 jobs per acre within a half-mile of fixed-guideway transit stations.

The analysis assumes that 501 acres in Urban Center/Pedestrian Focus Areas (25.3%) and Station/Bus Rapid Transit Areas (74.7%) will be rezoned to allow mixed-use transit-oriented development accommodating at least 25 residential units per acre and 150 jobs per acre. This represents 127 acres of vacant or redevelopable land in Urban Center/Pedestrian Focus Areas (1.8% of the region total) and 374 acres of vacant and redevelopable land in Station/Bus Rapid Transit Areas (2.7% of the region total). According to the Policy Directive 1610 evaluation, increasing mixed-use transit-oriented developoment areas with higher residential and job density as described reduces vehicle miles traveled per acre by 174,706 per year, resulting in 49.1 fewer tons of greenhouse gas emissions per rezoned acre in 2030, 28.5 tons per rezoned acre in 2040, and 13.5 tons per rezoned acre in 2050.

DRCOG staff estimates that 35% of the opportunity land areas would be rezoned by 2030, 35% by 2040, and 30% by 2050.

Assumptions:		
Amount of total Station/Bus Rapid Transit areas Included in measure	15%	2,075 acres
Amount of total Urban Center/Pedestrian Focus Areas included in measure	10%	707 acres
Amount of area that will be developed or redeveloped over 30 years	30%	835 acres
Amount subject to rezoning	**60%**	**501 acres**

Greenhouse gas reduction calculations								
Greenhouse gas tons per acre rezoned	2025		2030		2040		2050	
	Reduction per acre		Reduction per acre		Reduction per acre		Reduction per acre	
	60		49		28		13	
Greenhouse gas tons reduced	2025		2030		2040		2050	
	Acres rezoned	Reduction	Acres rezoned	Reduction	Acres rezoned	Reduction	Acres rezoned	Reduction
	-	-	175	8,588	175	4,907	150	1,953
Amount rezoned per period	-	-	-	-	175	4,907	351	4,557
Carryover	-	-	-	-	175	4,907	351	4,557
Total reduction		**-**		**8,588**		**9,814**		**6,510**

Parking strategies

Eliminate minimum and set low maximum parking levels (residential). Adopt development code standards that do not require a minimum number of general-purpose parking spaces and set a low maximum number of general-purpose passenger vehicle parking spaces for new multifamily development (three-quarters of a parking space per one-bedroom, studio and efficiency unit; one space per two-bedroom unit; and one-and-a-quarter spaces per three-bedroom and larger unit). Required disabled spaces, accessible spaces and loading zone spaces do not count toward maximum parking limits.

The analysis assumes that 1,718 acres in Urban Center/ Pedestrian Focus Areas (15.4%) and Station/Bus Rapid Transit Areas (84.5%) will be subject to the parking standards described earlier. This represents 265 acres of vacant or redevelopable land in Urban Center/ Pedestrian Focus Areas (3.7% of the region total) and 1,452 acres of vacant and redevelopable land in Station/ BRT Areas (10.5% of the region total). According to the Policy Directive 1610 evaluation, adopting parking standards as described reduces annual vehicle miles traveled per dwelling unit by 4,500 in an urban core area, 4,700 in an urban area, and 5,400 in a suburban area.

Assumptions:		
Amount of total Station/Bus Rapid Transit areas Included in measure	70%	9,683 acres
Amount of total Urban Center/Pedestrian Focus Areas included in measure	25%	1,767 acres
Amount of area that will be developed or redeveloped over 30 years	30%	3,435 acres
Amount subject to rezoning	**50%**	**1,718 acres**

		Dwelling units			
Area		2025	2030	2040	2050
Percent urban core	30%				
Average residential density	75	-	13,526	13,526	11,593
Percent urban	45%				
Average residential density	45	-	12,173	12,173	10,434
Percent suburban	25%				
Average residential density	20	-	3,006	3,006	2,576

Greenhouse gas reduction calculations

Greenhouse gas tons per 1,000 dwelling units	2025	2030	2040	2050
	Reduction per 1,000 dwelling units	Reduction per 1,000 dwelling units	Reduction per 1,000 dwelling units	Reduction per 1,000 dwelling units
Urban core	1,535	1,265	734	347
Urban	1,603	1,321	766	362
Suburban	1,841	1,517	880	416

Greenhouse gas tons reduced	2025		2030		2040		2050	
	1,000 dwelling units	Reduction	1,000 dwelling units	Reduction	1,000 dwelling units	Reduction	1,000 dwelling units	Reduction
Urban core	-	-	13.526	17,110	13.526	9,928	11.593	4,023
Urban	-	-	12.173	16,081	12.173	9,325	10.434	3,777
Suburban	-	-	3.006	4,560	3.006	2,645	2.576	1,072
Urban core carryover	-	-	-	-	13.526	9,928	27.051	9,387
Urban carryover	-	-	-	-	12.173	9,325	24.346	8,813
Suburban carryover	-	-	-	-	3.006	2,645	6.011	2,501
Total urban core	-	-	13.526	17,110	27.051	19,856	38.645	13,410
Total urban	-	-	12.173	16,081	24.346	18,649	34.780	12,591
Total suburban	-	-	3.006	4,560	6.011	5,290	8.588	3,573
Total tons of greenhouse gas reduction		**-**		**37,750**		**43,795**		**29,573**

Eliminate minimum and set moderate maximum parking levels (residential). Adopt development code standards that do not require a minimum number of general-purpose parking spaces and sets a moderate maximum number of general-purpose passenger vehicle parking spaces (1.0 space per 1 bedroom, studio, and efficiency unit; 1.5 space per 2 bedroom unit; and 1.75 spaces per 3+ bedroom unit) for new multifamily development. Required disabled/accessible and loading zone spaces do not count toward maximum parking limits.

This analysis assumes that 2,481 acres in Urban Center/Pedestrian Focus Areas (56.1%) and Station/BRT Areas (43.9%) will be subject to these parking standards. This represents 1,392 acres of vacant/redevelopable land in Urban Center/Pedestrian Focus Areas (19.7% of the region total) and 1,089 acres of vacant and redevelopable land in Station/BRT Areas (7.9% of the region total). According to the Policy Directive 1610 evaluation, adopting parking standards as described reduces annual VMT per dwelling unit by 2,250 in an urban core area, 2,350 in an urban area, and 2,700 in a suburban area.

Assumptions:		
Amount of total Station/Bus Rapid Transit Areas included in measure	30%	4,150 acres
Amount of total Urban Center/Pedestrian Focus Areas included in measure	75%	5,302 acres
Amount of area that will be developed or redeveloped over 30 years	35%	3,308 acres
Amount subject to parking standards	**75%**	**2,481 acres**

		Dwelling units			
Area		2025	2030	2040	2050
Percent urban core	30%				
Average residential density	65	-	16,933	16,933	14,514
Percent urban	45%				
Average residential density	20	-	7,815	7,815	6,699
Percent suburban	25%				
Average residential density	15	-	3,256	3,256	2,791

Greenhouse gas reduction calculations

Greenhouse gas tons per 1,000 dwelling units	2025	2030	2040	2050
	Reduction per 1,000 dwelling units	Reduction per 1,000 dwelling units	Reduction per 1,000 dwelling units	Reduction per 1,000 dwelling units
Urban core	767	632	367	173
Urban	801	660	383	181
Suburban	921	759	440	208

Greenhouse gas tons reduced	2025		2030		2040		2050	
	1,000 dwelling units	Reduction	1,000 dwelling units	Reduction	1,000 dwelling units	Reduction	1,000 dwelling units	Reduction
Urban core	-	-	16.933	10,702	16.933	6,214	14.514	2,511
Urban	-	-	7.815	5,158	7.815	2,993	6.699	1,212
Suburban	-	-	3.256	2,472	3.256	1,433	2.791	581
Urban core carryover	-	-	-	-	16.933	6,214	33.866	5,859
Urban carryover	-	-	-	-	7.815	2,993	15.631	2,829
Suburban carryover	-	-	-	-	3.256	1,433	6.513	1,355
Total urban core	-	-	16.933	10,702	33.866	12,429	48.381	8,370
Total urban	-	-	7.815	5,158	15.631	5,987	22.330	4,042
Total suburban	-	-	3.256	2,472	6.513	2,866	9.304	1,935
Total tons of greenhouse gas reduction		**-**		**18,332**		**21,281**		**14,347**

Reduce or eliminate minimum and set maximum parking levels (commercial). Adopt development code standards that reduce or do not require a minimum number of general-purpose parking spaces and set a maximum number of general-purpose passenger vehicle parking spaces for new commercial development. Required disabled spaces, accessible spaces and loading zone spaces do not count toward maximum parking limits.

The analysis assumes that 217 acres in Urban Center/Pedestrian Focus Areas (20%) and Station/Bus Rapid Transit Areas (80%) will be subject to the parking standards described earlier. This represents 44 acres of vacant or redevelopable land in Urban Center/Pedestrian Focus Areas (0.6% of the region total) and 173 acres of vacant and redevelopable land in Station/Bus Rapid Transit Areas (1.3% of the region total). According to the Policy Directive 1610 evaluation, adopting parking standards as described reduces annual vehicle miles traveled per 10,000 square feet by 8,960 in an urban core area, 23,893 in an urban area, and 29,867 in a suburban area.

Assumptions:		
Amount of total Station/Bus Rapid Transit Areas included in measure	10.0%	1,383 acres
Amount of total Urban Center/Pedestrian Focus Areas included in measure	5.0%	353 acres
Amount of area that will be developed or redeveloped over 30 years	25%	434 acres
Amount subject to parking standards	**50%**	**217 acres**

		10,000 square feet			
Area		2025	2030	2040	2050
Percent non-central business district, maximum two-and-a-half spaces per 1,000 square feet	60%				
Average floor area ratio	3	-	613	545	545
Percent non-central business district, maximum two spaces per 1,000 square feet	30%				
Average floor area ratio	3	-	70	63	63
Percent central business district, maximum one-and-a-half spaces per 1,000 square feet	5%				
Average floor area ratio	10	-	170	151	151
Percent central business district, maximum one space per 1,000 square feet	5%				
Average floor area ratio	10	-	170	151	151

Greenhouse gas reduction calculations

Greenhouse gas tons per 1,000 dwelling units	2025
	Reduction per 10,000 square feet
Non-central business district, two-and-a-half parking spaces	6
Non-central business district, two parking spaces	8
Central business district, one-and-a-half parking spaces	5
Central business district, one parking space	9

Greenhouse gas tons reduced	2025	
	10,000 square feet	Reduction
Non-central business district, two-and-a-half parking spaces	-	-
Non-central business district, two parking spaces	-	-
Central business district, one-and-a-half parking spaces	-	-
Central business district, one parking space	-	-
Non-central business district, two-and-a-half parking spaces carryover	-	-
Non-central business district, two parking spaces carryover	-	-
Central business district, one-and-a-half parking spaces carryover	-	-
Central business district, one parking space carryover	-	-
Total non-central business district, two-and-a-half parking spaces	-	-
Total non-central business district, two parking spaces	-	-
Total central business district, one-and-a-half parking spaces	-	-
Total central business district, one parking space	-	-
Total tons of greenhouse gas reduction		**-**

2030		2040		2050	
Reduction per 10,000 square feet		Reduction per 10,000 square feet		Reduction per 10,000 square feet	
3		1		1	
7		4		2	
4		2		1	
8		5		2	
2030		2040		2050	
10,000 square feet	Reduction	10,000 square feet	Reduction	10,000 square feet	Reduction
612.8	1,838	544.7	545	544.7	545
70.3	492	62.5	250	62.5	125
170.2	681	151.3	303	151.3	151
170.2	1,362	151.3	757	151.3	303
-	-	612.8	613	1,157.5	1,157
-	-	70.3	281	132.9	266
-	-	170.2	340	321.5	322
-	-	170.2	851	321.5	643
612.8	1,838	1,157.5	1,157	1,702.2	1,702
70.3	492	132.9	531	195.4	391
170.2	681	321.5	643	472.8	473
170.2	1,362	321.5	1,608	472.8	946
	4,373		**3,940**		**3,511**

Adopt local complete street standards. Local jurisdictions adopt Complete Streets standards into their public works standards and apply those standards to locally funded arterial roadway improvements in the 2050 Metro Vision Regional Transportation Plan.

The analysis is based on the miles of locally funded arterial roadway projects that are four (or fewer) lanes wide and which are specifically listed in the adopted fiscally constrained portion of the 2050 Metro Vision Regional Transportation Plan. There are approximately 164 miles of such projects in the plan and DRCOG staff analyzed the projects within the plan staging year in which the project is programmed. DRCOG staff estimates that about 64% of the projects in the 2020-2029 staging period, 75% of the projects in the 2030-2039 staging period, and 80% of the projects in the 2040-2050 staging period will be constructed as Complete Streets.

Assumptions:		2025	2030	2040	2050
Miles of locally funded arterial roadway projects of four lanes or fewer		20	50	69	25
Percent constructed as Complete Streets		50%	70%	75%	80%
Miles of locally funded Complete Streets		**10**	**35**	**52**	**20**
Percent urban core	0%	-	-	-	-
Percent urban	30%	3	14	16	6
Percent suburban	70%	7	32	36	14

Greenhouse gas reduction calculations

Greenhouse gas tons per mile	2025		2030		2040		2050	
	Reduction per mile		Reduction per mile		Reduction per mile		Reduction per mile	
Urban core	54		44		26		12	
Urban	22		18		11		5	
Suburban	5		4		2		1	
Greenhouse gas tons reduced	2025		2030		2040		2050	
	Miles	Reduction	Miles	Reduction	Miles	Reduction	Miles	Reduction
Urban core	-	-	-	-			-	-
Urban	-	-	13.5	243	15.5	171	6.0	30
Suburban	-	-	31.5	126	36.2	72	14.0	14
Total tons of greenhouse gas reduction		**-**		**369**		**243**		**44**

Co-Benefits

One of the Policy Directive 1610 required elements is to quantify, where possible, specific co-benefits of the mitigation measures for each relevant compliance year in the project's lifetime, including:

- Reduction of co-pollutants (such as nitrogen oxides and particulate matter with diameters of 2.5 micrometers and smaller)
- Travel impacts (such as changes to vehicle miles traveled, pedestrian activity, bike use, transit ridership, as applicable).

As discussed in the introduction, DRCOG staff specifically selected policy-oriented mitigation measures outside of both the 2050 Metro Vision Regional Transportation Plan and Focus travel model for inclusion in this Mitigation Action Plan. As such, the selected measures cannot be modeled, and co-benefits cannot be estimated from a quantitative perspective. However, an important theme of DRCOG's work to comply with the Greenhouse Gas Transportation Planning Standard is not just compliance but to encourage continued meaningful multimodal transportation planning within the region. The mitigation measures, as implemented over time, are intended to encourage and support multimodal travel options and the co-benefits that come with thoughtfully integrated land use and transportation planning that provide more people with more travel choices.

As the Denver region continues to grow (with another million residents forecast to live in the region by 2050), the proposed mitigation measures are intended to help accommodate some of that growth in strategic areas to reduce the frequency and length of auto trips. The proposed measures also will help maximize the region's current and planned investment in rail, bus rapid transit and other multimodal travel options.

Vehicle emissions from internal combustion engines are chiefly related to the number of vehicle trips, the length of vehicle trips, and the operating conditions (such as speeds and idling) for those trips along with vehicle fuel efficiency. While the proposed mitigation measures probably will not have a significant regional impact on air quality and reducing co-pollutants (because they are voluntary and targeted to small, specific areas), they will result in policies and planning that are beneficial for air quality.

Benefits to disproportionally impacted communities

Policy Directive 1610 defines a disproportionally impacted community as "a community that is in a census block group…where the proportion of households that are low income is greater than 40%, the proportion of households that identify as minority is greater than 40%, or the proportion of households that are housing cost-burdened is greater than 40%."

Because the proposed mitigation measures are policy-based and not project-based — and not directly location-based — it is difficult to draw specific conclusions regarding disproportionally impacted community benefits or dollars spent. However, in analyzing and evaluating the proposed mitigation measures, DRCOG staff identified the conceptual geographies (discussed previously and shown in Figure 1). While the mitigation measures in this appendix are not constrained to these geographies, they provide a reasonable mechanism to spatially compare with disproportionally impacted community geographies.

To conduct this analysis, DRCOG staff first mapped the disproportionally impacted community geographies within the DRCOG metropolitan planning organization area (Figure 2). Then, staff used geographic information systems to compare the spatial overlaps between the conceptual mitigation measure analysis geographies (Figure 1) with the disproportionally impacted community geographies (Figure 2) to illustrate where both geographies overlap (Figure 3).

As shown, there is meaningful overlap between the two geographies. Because the mitigation measure analysis geographies are anchored around rail stations, future bus rapid transit corridors, urban centers, and pedestrian focus areas, the policy changes associated with the land use and parking mitigation measures can provide disproportionally impacted community benefits not just at specific locations — such as adjacent to a rail station — but through access to the rail network across the region. For example, increased residential densities in transit-efficient locations can lead to reduced total housing and transportation costs. Similarly, increased job densities in transit-efficient locations can increase accessible job opportunities for people with less access to private vehicles. In these ways, encouraging integrated land use and transportation planning through the mitigation measures provides potential disproportionally impacted community benefits at both the specific location level and the network or system level.

Of course, some policy changes associated with land use and parking mitigation may lead to displacement of current residents and existing market-rate affordable housing units. Additionally, because the mitigation measures are voluntary and not location-constrained, there is also flexibility to implement them over time where and when they are most effective and needed, including to maximize disproportionally impacted community benefits.

Figure 2: Disproportionally impacted communities geographies

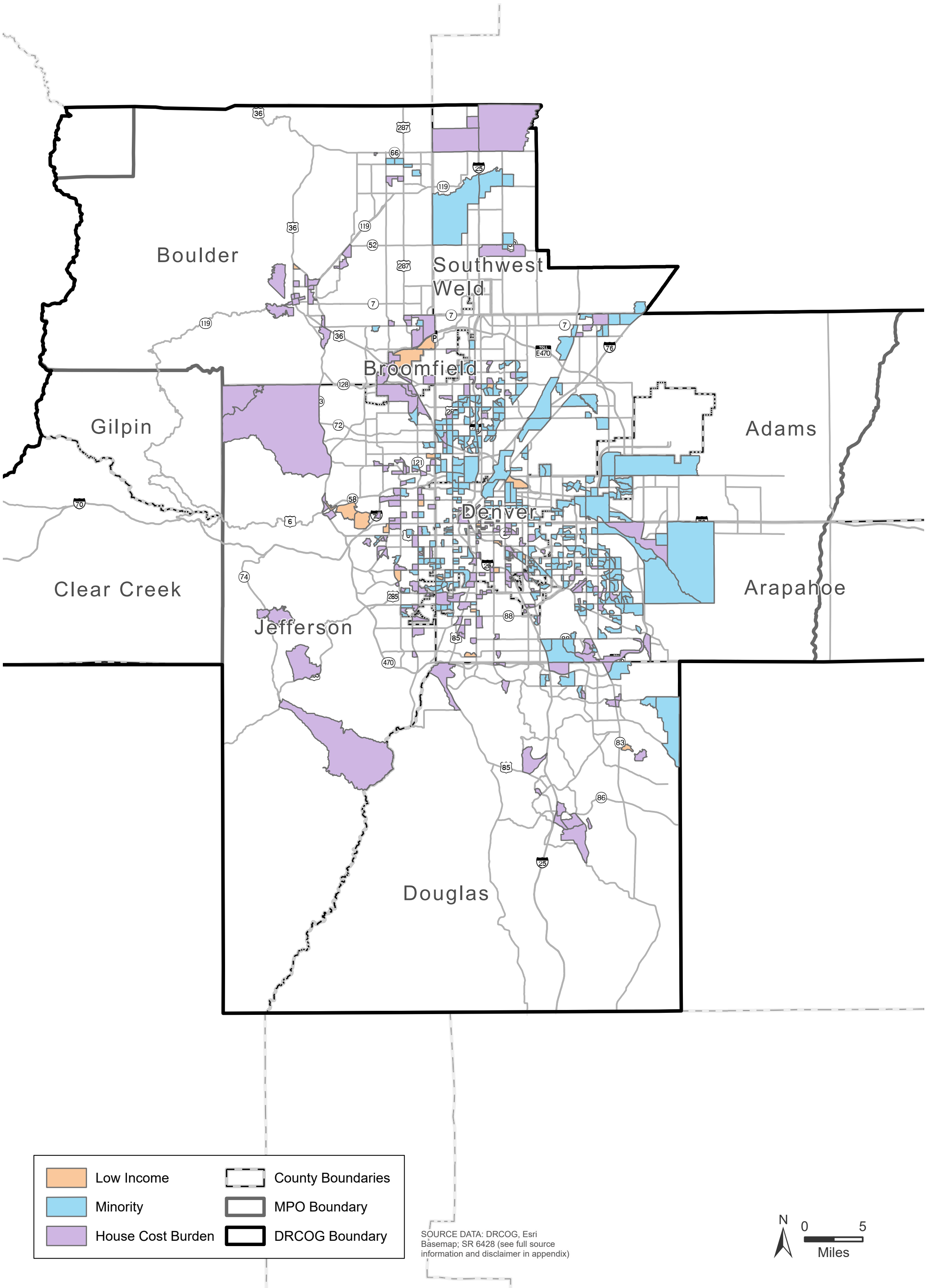
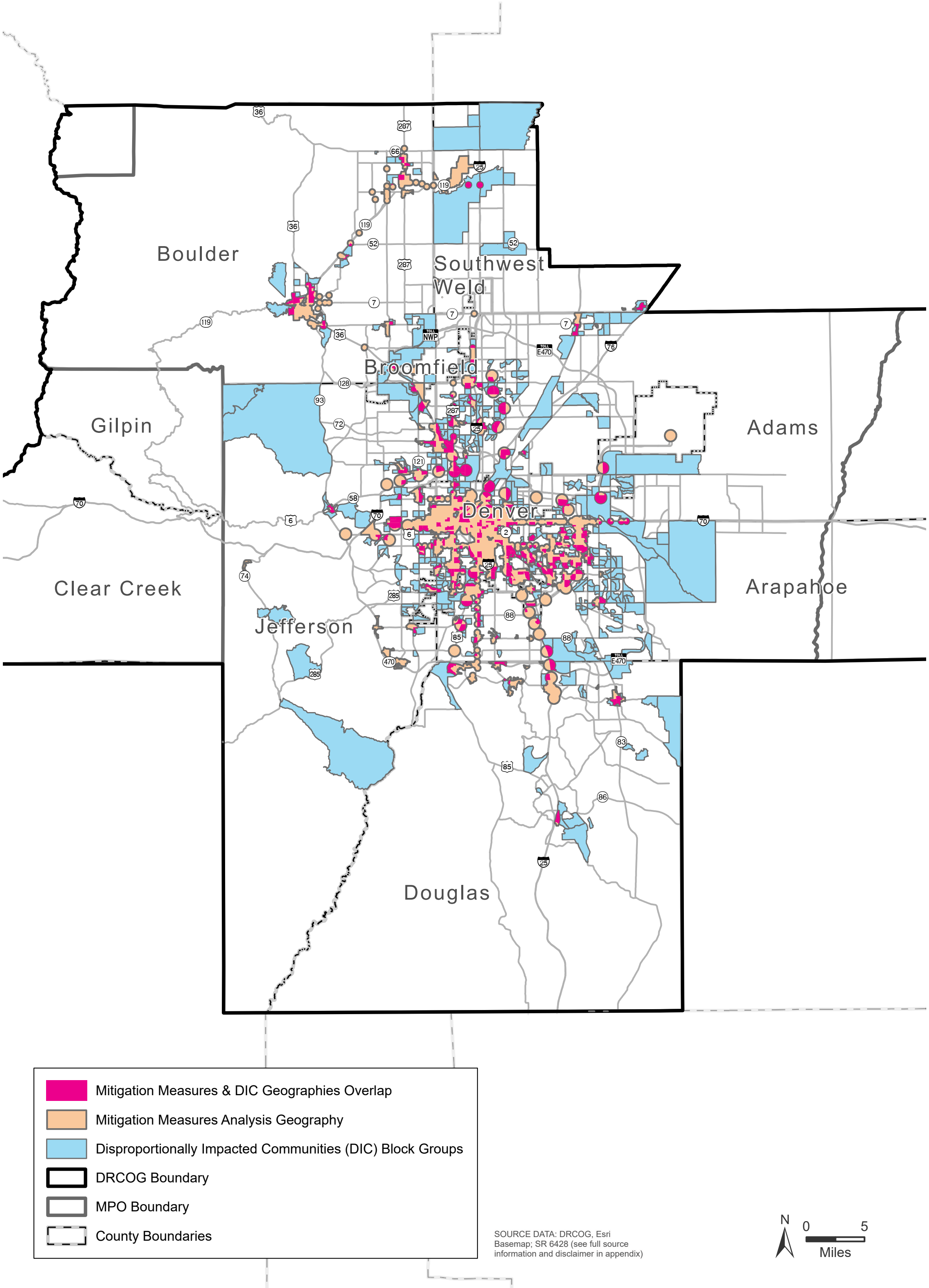


Figure 3: Mitigation measures and disproportionally impacted communities geographies overlay



Measure origin and history

While the mitigation measure profiles describe their general origin and how they are "additive" (going beyond what the region is already doing), Policy Directive 1610 also requires information about the role of the metropolitan planning organization or Colorado Department of Transportation in the proposed mitigation measures. As indicated throughout this report, DRCOG staff selected mitigation measures to expand the region's existing efforts related to integrated land use and transportation planning in applicable areas, particularly around rail stations, urban centers, and in strategic development and redevelopment areas. Similarly, many jurisdictions (as well as DRCOG) have adopted Complete Streets standards or toolkits. These activities are primarily undertaken and led by local governments within the region, with support from DRCOG.

The analysis geographies draw on DRCOG's planning framework. For example, urban centers are identified by local governments and then regionally designated through DRCOG's Metro Vision plan. Similarly, the pedestrian focus areas are a geography defined in DRCOG's Regional Active Transportation Plan. And the bus rapid transit network is an implementation priority of DRCOG's 2050 Metro Vision Regional Transportation Plan. The geographies selected for analyzing the mitigation measures were chosen because they closely relate to the concepts embodied in the mitigation measures.

Going forward, DRCOG will work with local jurisdictions to develop tracking and support mechanisms related to required annual reporting associated with the Mitigation Action Plan.

Funding, resources and partnerships

For this section, Policy Directive 1610 specifies describing confirmed funding sources, partnerships, or in-kind or other matching funds associated with the proposed mitigation measures. Given the policy-oriented nature of the mitigation measures as noted in previous sections, there is not dedicated funding to implement the measures. That said, DRCOG has a legacy of funding the types of planning activities encompassed by the mitigation measures. For example, DRCOG has allocated funding for several cycles through its Transportation Improvement Program Community Mobility Planning and Implementation Set-Aside to encourage visioning, planning and implementation around transit stations and other applicable areas. Through the 2024-2027 Transportation Improvement Program, DRCOG will implement the Community Mobility Planning and Innovation Set-Aside, which will dedicate $12 million for transportation corridor planning, community mobility planning and innovative mobility. There is the potential within these eligible activities for local governments to apply for funding to support the planning and policy development activities underpinning several of the mitigation measures.

In addition to potential funding, partnerships will play a pivotal role in implementing the Mitigation Action Plan. One primary example, discussed in the previous section, will be DRCOG staff developing tracking and support mechanisms for the required annual reporting associated with the plan. As part of that work, DRCOG has offered its local governments the availability of its staff and resources to help explore the feasibility and implementation of specific mitigation measures at the time, location and purview of each interested local government. Examples of DRCOG staff and resource support could include developing and making available to local jurisdictions model code language, best practices, training, research, data and analysis as needed to help their staff establish and implement the mitigation measures most applicable for that jurisdiction.

Appendix B: Public and stakeholder engagement for the 2022 Updated 2050 RTP

Introduction

During the 2050 Metro Vision Regional Transportation Plan technical analysis and update process (approximately December 2021 through July 2022), Denver Regional Council of Governments staff focused on providing frequent updates on the fast-paced technical analysis process to DRCOG's committees, Board, county transportation forums and other stakeholders. DRCOG staff also reconvened the Civic Advisory Group to provide input throughout the plan update process.

This appendix summarizes the outreach and engagement efforts undertaken during the plan update process including the engagement activities conducted during the review period and the comments received during that period and at the public hearing.

General methods of public and stakeholder engagement used included:

- Notices and promotion.
- Civic Advisory Group.
- Online engagement site (Social Pinpoint).
- Stakeholder presentations.
- DRCOG committee and Board briefings.
- Partner agency review (Colorado Department of Transportation, Transportation Commission and Colorado Department of Public Health and Environment).
- Website and social media posts.

Committees, Board, forums and stakeholder outreach

DRCOG staff provided an average of five to 10 updates a month throughout the technical plan update process to DRCOG's committees, Board, county transportation forums and other stakeholders, including:

- DRCOG Transportation Advisory Committee (regular meetings and June work session).
- DRCOG Regional Transportation Committee.
- DRCOG Board (regular meetings and work sessions).
- County transportation forums (Adams County, Arapahoe County, Boulder County, City and County of Broomfield, City and County of Denver, Douglas County, Jefferson County and southwest Weld County).

For all briefings, the focus was on informing and seeking input on each step of the multifaceted and fast-paced technical analysis to respond to the requirements of the Greenhouse Gas Transportation Planning Standard. Because the technical analysis was so complex (as documented in Appendix T), there was new technical information to present and use for subsequent decision-making on a regular basis.

DRCOG staff also participated in CDOT's "4P" outreach process in spring 2022. While not specifically oriented toward this plan update process, it was still an valuable mechanism for both agencies to collaborate with and receive input from local governments regarding the planning process for DRCOG's 2050 RTP and CDOT's 10-Year Plan.

Finally, DRCOG staff also had regular dialogue with Board directors, local government staff, stakeholder groups and others who had questions or requested information about the technical analysis process to comply with the greenhouse gas rule.

Civic Advisory Group

To assist in determining the best strategies for complying with the greenhouse gas rule, DRCOG staff prioritized community engagement and input. DRCOG staff reinstated and met with the Civic Advisory Group four times throughout the greenhouse gas analysis process. The Civic Advisory Group was able to provide input at various stages of the analysis and assist DRCOG in determining the most meaningful mitigation strategies from a community lens. During the four meetings the Civic Advisory Group was able to:

- Discuss transportation investment preferences based on perceived greenhouse gas reduction benefits and community/personal benefits.
- Determine priorities surrounding greenhouse gas reduction strategies.
- Perform a “strengths, weaknesses, opportunities and challenges” analysis on various greenhouse gas mitigation measures.
- Comment on the final proposed amendment.

The Civic Advisory Group’s exercises and discussions highlighted its members’ preference for mitigation and reduction strategies that prioritize accessibility and personal choices. For instance, when asked what types of transportation investments they believed to be most beneficial to reducing greenhouse gases the group mentioned investments such as:

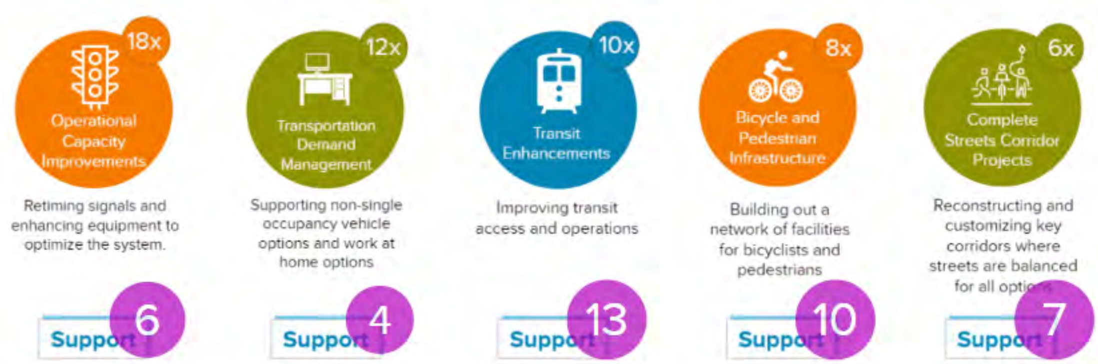
- Focusing on the integration of various transportation systems to allow for succinct trips for all users.
- Free and flexible rapid transit.
- More frequent transit.
- Better education of our transportation systems and travel etiquette.

Similarly, during the greenhouse gas reduction priority exercise the group prioritized reduction strategies that prioritized access to transit, bike and pedestrian options. The strategies provided in the exercise were operational capacity improvements, transportation demand management, transit enhancements, bicycle and pedestrian infrastructure and Complete Streets corridor projects. Group facilitators provided the Civic Advisory Group 10 votes and asked members to allocate them to the projects they considered to be of the highest priority. Facilitators held two voting sessions, the first was purely based on group members’ personal priorities for themselves and their communities. Before the second round of voting the group was given more context about each reduction strategy and its effects. Members were asked to spend no more than two votes on operational capacity improvements and transportation demand management. See exercise results below.

When given the chance to reflect on their choices, group members noted their unwavering support for transit, bike and pedestrian improvements and the need for balance between greenhouse gas impact and community benefit. The group felt that although the transit, bike and pedestrian-focused strategies did not create as significant of an impact in greenhouse gas emissions, such strategies prioritized people.

Figure 1. Voting session one result

Figure 1. Voting session two results

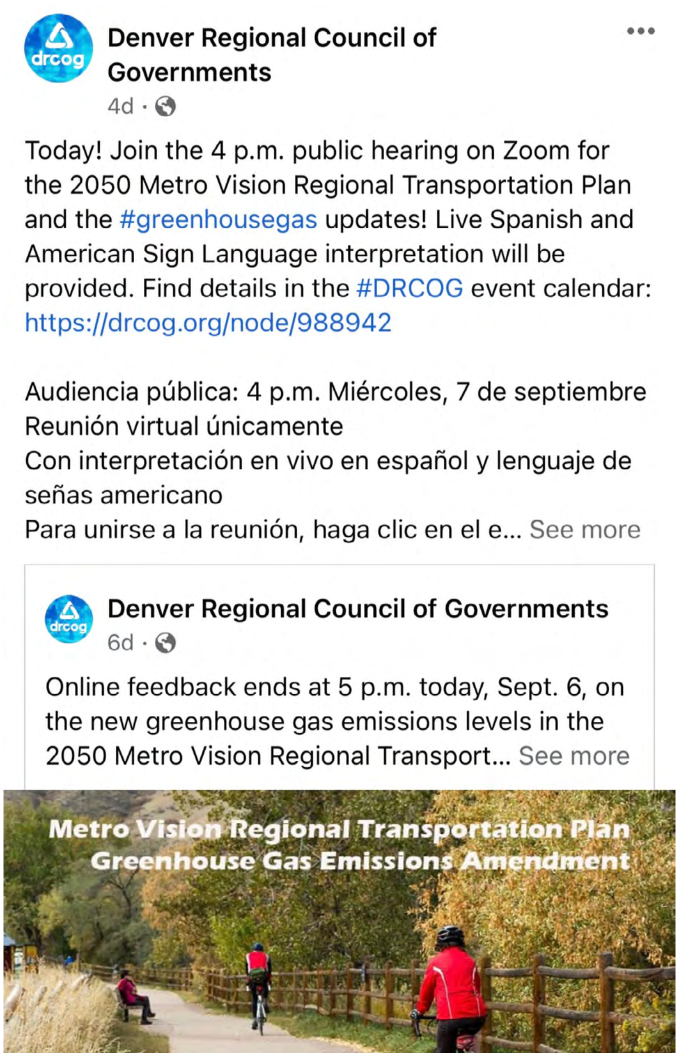


Public comment period outreach activities and comments received

DRCOG held a 31-day public comment review period from Aug. 7 through Sept. 6 to solicit review, engagement and input on the draft 2050 RTP documents. To do so, DRCOG staff updated the 2050 RTP Social Pinpoint project website to house the draft plan documents, announce public meetings and provide opportunities for feedback and discussion. DRCOG gave the public the option of sharing general comments and engaging in discussion through the site's idea wall and providing more specific comments on markable PDFs of the plan documents. Several eblasts and social media posts were made during the public review period to publicize the Social Pinpoint site and the virtual public meetings.

Public notice

DRCOG staff published a legal notice in the Sunday, Aug. 7, edition of The Denver Post officially announcing the public review period.



Denver Regional Council of Governments
4d ·

Today! Join the 4 p.m. public hearing on Zoom for the 2050 Metro Vision Regional Transportation Plan and the #greenhousegas updates! Live Spanish and American Sign Language interpretation will be provided. Find details in the #DRCOG event calendar: https://drcog.org/node/988942

Audiencia pública: 4 p.m. Miércoles, 7 de septiembre
Reunión virtual únicamente
Con interpretación en vivo en español y lenguaje de señas americano
Para unirse a la reunión, haga clic en el e... See more

Denver Regional Council of Governments
6d ·

Online feedback ends at 5 p.m. today, Sept. 6, on the new greenhouse gas emissions levels in the 2050 Metro Vision Regional Transport... See more

Virtual public meetings

During the public review period, DRCOG staff held five virtual public meetings to present the draft 2050 RTP, with a focus on the proposed updates to comply with the state Greenhouse Gas Planning Standard. Simultaneous Spanish interpretation was provided for two of the meetings. Each meeting included an introduction to DRCOG, an introduction to the Greenhouse Gas Planning Standard, an overview of DRCOG's proposed greenhouse gas compliance strategy, an explanation of overall changes to the 2050 RTP and information on how to participate in the process further. Over the five public meetings, there were 11 attendees.

Civic Advisory Group

DRCOG staff met twice with the Civic Advisory Group during the public comment review period. The first was a formal virtual meeting to provide an overview of the draft 2050 RTP, like the virtual public meetings described above. The second meeting was an informal in-person meeting to reflect on the group's work during this 2022 update process and to begin to look ahead toward potential future Civic Advisory Group topics, roles and structure.

Other presentations

DRCOG staff also made other presentations and updates during and after the public comment review period. These included presentations to the Colorado Communities for Climate Action, Denver South, Denver Inter-Neighborhood Cooperation, several county transportation forums, DRCOG committees and the state Transportation Commission.

Comments received

DRCOG received almost 350 comments from the general public and stakeholders during the public comment period. The majority of comments were received through the Social Pinpoint idea wall. Although previous invitations for public comment provided the capacity for participants to interact with each other's posts, the 2050 RTP represented the first time they took advantage of the opportunity. Comments were also received through marked-up PDF documents and via email. Comments generally fell into one of the following categories:

- Support for the proposed 2050 RTP updates to comply with the state Greenhouse Gas Planning Standard.
- Support for the proposed 2050 RTP updates, but with a desire to shift investment further from roadways and highways to transit and other multimodal travel options.
- Opposition to the proposed 2050 RTP updates and opposition to the Greenhouse Gas Planning Standard, with a preference for additional roadway- and highway-oriented investment.
- Neutral or technical comments that were not opinion-based.

Public hearing

DRCOG held a virtual public hearing on Sept. 7 as part of a special DRCOG Board meeting. For the first time, the public hearing and Board meeting included both simultaneous Spanish interpretation and American Sign Language interpretation using the Zoom platform. Eleven people testified during the public hearing, with comments generally in support of the proposed 2050 RTP updates and urging the DRCOG Board to adopt the updated plan. Commenters generally urged even greater investment in multimodal travel options and less in roadways and highways.

Comments matrix

All written comments that were received on the draft updated 2050 RTP during the public comment review period are listed in a matrix.

Document revisions based on public comment

DRCOG staff made the following revisions to plan documents after the public comment review period and public hearing:

- 2050 RTP document, Table 3.1: added references to transit to the project description and table for Arapahoe County projects as requested by county staff.
- Greenhouse Gas Transportation Report: corrected Table 1 to remove references to greenhouse gas reductions from mitigation measures for the 2025 analysis year (staff published an errata sheet on this issue during the public comment period).
- Greenhouse Gas Transportation Report: corrected a copy-editing error on page 11 (Additional Programmatic Investments section).
- Greenhouse Gas Transportation Report, Appendix C (Model Outputs): corrected a formula error in the table.

drcogorg

Liked by **mobilemesacounty**

drcogorg Final call to attend the last two public meetings for the 2050 #MetroVision Regional Transportation Plan #greenhousegas updates! #DRCOG staff will be on Zoom answering questions and fielding comments. The Thursday, Sept. 1 session from 3 to 4:30 p.m. includes live Spanish translation, and the Friday, Sept. 2 session will be held from 10 to 11:30 a.m. Click the link in our bio for more information and to register for the Q&As. Questions? Call Public Engagement Planner Kellsie Forfar-Jones at 303-480-5658. #2050MVRTP #OzoneAware #Transportation

We make life better!

drcog

DENVER REGIONAL COUNCIL OF GOVERNMENTS

Sort Comments ⦿ Recent ○ Popular

About

About you

socialpinpoint

Your comments | 6 days ago Like +1 Dislike

As someone who's been commuting in Denver for 15 years, I was so happy to see that the plan was updated to include more bus rapid transit (BRT) and no expansions to I-25! We know that adding lanes only induces more traffic. Just look at Houston, Vegas and LA. Adding lanes just doesn't work. Let's do BRT and do it right. If you want to spend money on highways, get rid of toll roads and improve the loop around the city. Instead of expanding a horrific freeway through the heart of the city!

Start a discussion

Your comments | 6 days ago Like +16 Dislike

Improve our roads... thus improving the quality of

We should not be widening I-270 as long as the region is in severe ozone non-attainment status. This will only make the problem worse. Redirect those funds to transit and bicycle infrastructure.

Start a discussion

Your comments | 6 days ago Like +5 Dislike

Please continue to invest in highway capacity improvements. The safe and efficient movement of people and goods on roads through metro Denver is critical to the quality of life for Denver residents. Also, moving traffic is much better for air quality.

Start a discussion

Your comments | 6 days ago Like +1 Dislike -4

Appendix C: Key model outputs

Table 1. Baseline and GHG Action Modeling Outputs for MPO Boundary

	2025		
	Base	Action	Base
Socioeconomic Data			
Population	3,579,146	3,581,763	3,785,097
Households	1,447,137	1,449,760	1,558,474
Employment	2,285,194	2,285,283	2,427,438
Vehicle and Transit Data – Typical Weekday			
Vehicle Miles Traveled (VMT)	89,682,621	84,413,140	96,297,646
VMT per capita	25.05	23.56	25.44
Person Miles Traveled (PMT)	125,490,607	118,738,780	135,151,753
PMT per capita	35.05	33.14	35.71
Average vehicle speed (mph)	35.97	37.12	35.48
Average vehicle trip length (mi)	8.84	8.94	8.92
Vehicle Hours Traveled (VHT)	2,494,574	2,274,771	2,714,228
Vehicle Hours Delay (VHD)	400,157	317,733	465,460
Transit boardings	373,096	339,157	476,948
Trip Mode Share			
Single occupancy vehicle	7,794,512	7,234,971	8,348,266
Shared ride trip	5,982,668	5,559,432	6,405,984
School Bus	245,348	222,625	243,538
Bicycle	220,888	358,675	232,257
Walk	1,347,359	1,938,258	1,463,460
Transit	265,239	267,462	321,376
Total Daily Trips	**15,856,014**	**15,581,423**	**17,014,881**
Lane Miles by Roadway Type			
Interstate	1,890	1,894	1,929
Expressway	476	476	482
Principal Arterial	4,206	4,205	4,445
Minor Arterial	2,693	2,693	2,732
Collector/Other (CC included)	8,712	8,712	8,727
Total Lane Miles	**17,978**	**17,979**	**18,315**
VMT by Roadway Type			
Interstate	34,343,430	32,878,504	36,671,282
Expressway	5,147,926	4,874,994	5,469,704
Principal Arterial	27,133,787	25,412,101	29,363,218
Minor Arterial	9,045,034	8,294,271	9,700,858
Collector/Other (CC included)	14,012,444	12,953,272	15,092,583
Total Lane Miles	**89,682,621**	**84,413,141**	**96,297,645**

2030	2040		2050	
Action	Base	Action	Base	Action
3,776,311	4,159,729	4,140,898	4,382,191	4,348,527
1,558,656	1,728,921	1,726,703	1,844,824	1,839,296
2,427,554	2,687,310	2,687,621	2,948,570	2,948,769
90,228,400	108,206,129	99,479,208	118,314,127	108,369,631
23.89	26.01	24.02	27.00	24.92
127,551,977	152,132,871	141,387,016	166,422,152	154,515,131
33.78	36.57	34.14	37.98	35.53
36.78	34.81	36.45	34.12	35.83
9.02	9.08	9.27	9.25	9.48
2,453,093	3,108,478	2,729,089	3,467,330	3,024,211
363,327	587,159	435,540	721,146	535,862
456,975	574,836	529,783	647,314	625,950
7,717,264	9,259,523	8,331,155	10,009,451	8,947,200
5,916,371	7,069,963	6,271,214	7,561,293	6,643,433
219,276	260,698	222,228	258,313	217,532
375,969	253,605	384,535	264,251	406,277
2,115,709	1,635,726	2,857,802	1,708,534	3,060,170
339,391	381,132	415,013	424,240	486,666
16,683,980	**18,860,647**	**18,481,947**	**20,226,082**	**19,761,278**
1,940	2,073	2,045	2,084	2,045
482	488	488	488	488
4,441	4,899	4,900	4,935	4,900
2,730	2,853	2,863	2,863	2,863
8,727	8,744	8,744	8,744	8,744
18,320	**19,057**	**19,040**	**19,114**	**19,040**
35,083,155	40,785,141	38,468,590	44,799,037	42,153,693
5,173,921	5,966,243	5,590,389	6,420,522	6,077,067
27,312,073	33,305,345	30,298,966	36,285,219	32,736,501
8,817,582	10,882,437	9,633,254	11,949,964	10,501,653
13,841,670	17,266,962	15,488,008	18,859,384	16,900,717
90,228,401	**108,206,128**	**99,479,207**	**118,314,126**	**108,369,631**

Appendix D: Focus model documentation

Introduction

The Denver Regional Council of Governments maintains the Regional UrbanSim Socio-economic Model and the Focus regional travel demand modeling system. Outputs from the Focus Model are used in the MOtor Vehicle Emission Simulator model by the Colorado Department of Public Health and Environment to calculate emissions of several pollutants:

- Greenhouse gas CO2
- Ozone precursors: Nitrogen oxides and volatile organic compounds
- Particulate matter 10 microns or less

The Focus Model simulates the millions of trips made throughout the region on a typical weekday. It considers virtually all the types decisions considered by people when making choices on where, when and how to travel, whether for a two-block walk to the store, or a cross-region drive to visit relatives. Currently, about 15 million trips made by individuals are made every weekday. The Focus Model sums all travel to forecast how many vehicles will be driven on major roads: travel speed and delay, 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, the Focus Model simulates the many choices each person makes through activity-based model components including:

1) Where to work.
2) Where to go to school.
3) How many automobiles are available in the person's household.
4) How many trips each person makes in a day, and for what purposes.
5) Which trips are chained together within 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 activity-based model components for household travel, the Focus model also incorporates three add-on gravity models for:

- Commercial vehicle trips by light, medium and heavy-duty vehicles. This model reflects non-household vehicles used for everything from the hauling of large goods, construction materials and small packages to the provision of business and household services (e.g., electrical, plumbing, health care, landscaping). An estimated 1.7 million commercial vehicle trips are made within the region every day.

- External station trips starting or ending outside the DRCOG modeling area. This model represents trips that pass through the region (such as on I-25 from Colorado Springs to Fort Collins) and trips between the inside of the Denver region and outside (such as between Denver and Summit County).

- Denver International Airport trips – for trips not fully captured by the activity-based model components. Denver International Airport is unique in terms of the types of trips and vehicles: drop-offs/pick-ups, rental cars, shuttle vehicles and employees.

An UrbanSim model is used to forecast household and employment levels by small-area transportation analysis zones. The Focus Model considers many characteristics of people, such as their age, gender, employment status and income, as well as how the region's demographics will change over time. It also considers characteristics of the built environment, such as transit stops and stations, household and employment density, bicycling facilities, shared-use paths, sidewalks and walkability. The Focus Model creates an origin and destination for each trip (15 million weekday trips in the 2020 base model). Specific groupings of origins and destinations were initially estimated based on detailed data from a 1998 survey called the Travel Behavior Inventory. In 2016, the Focus Model was recalibrated using more recent data sources including roadway counts, transit boardings, American Community Survey Census data and results from the following surveys:

- The Regional Transportation District's 2008 Regional On-Board Transit Survey – a questionnaire handed out to light rail and bus travelers to understand transit travel patterns and choice factors. 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 Denver region, using a format similar to the 1998 Travel Behavior Inventory described above.

In 2020 and 2022, 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. (See the Calibration Report at https://drcog.org/sites/default/files/resources/Focus%202.3.1%20Calibraton%20Report.pdf.)

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. (See the Validation Report at https://drcog.org/sites/default/files/resources/Focus%202.3.1%20Validation%20Report.pdf.)

Regional socioeconomic forecasts

DRCOG staff uses county-level forecasts of population, households and employment produced by the Colorado State Demography Office as the basis for future growth reflected in the Focus Model. Table 1 shows the population, household and employment forecasts by model staging years for the DRCOG full region and the metropolitan planning organization area.

Table 1: Population, household, and employment forecasts

	Model Area	DRCOG	MPO
2025			
Population	3,655,852	3,609,906	3,583,810
Households	1,513,712	1,497,432	1,486,067
Employment	2,343,134	2,320,916	2,308,241
2030			
Population	3,855,518	3,805,523	3,776,311
Households	1,588,772	1,570,673	1,558,656
Employment	2,467,276	2,440,736	2,427,554
2040			
Population	4,232,276	4,174,425	4,140,898
Households	1,761,980	1,740,370	1,726,703
Employment	2,733,137	2,702,026	2,687,621
2050			
Population	4,456,092	4,386,631	4,348,527
Households	1,882,036	1,854,938	1,839,296
Employment	3,000,648	2,964,774	2,948,769

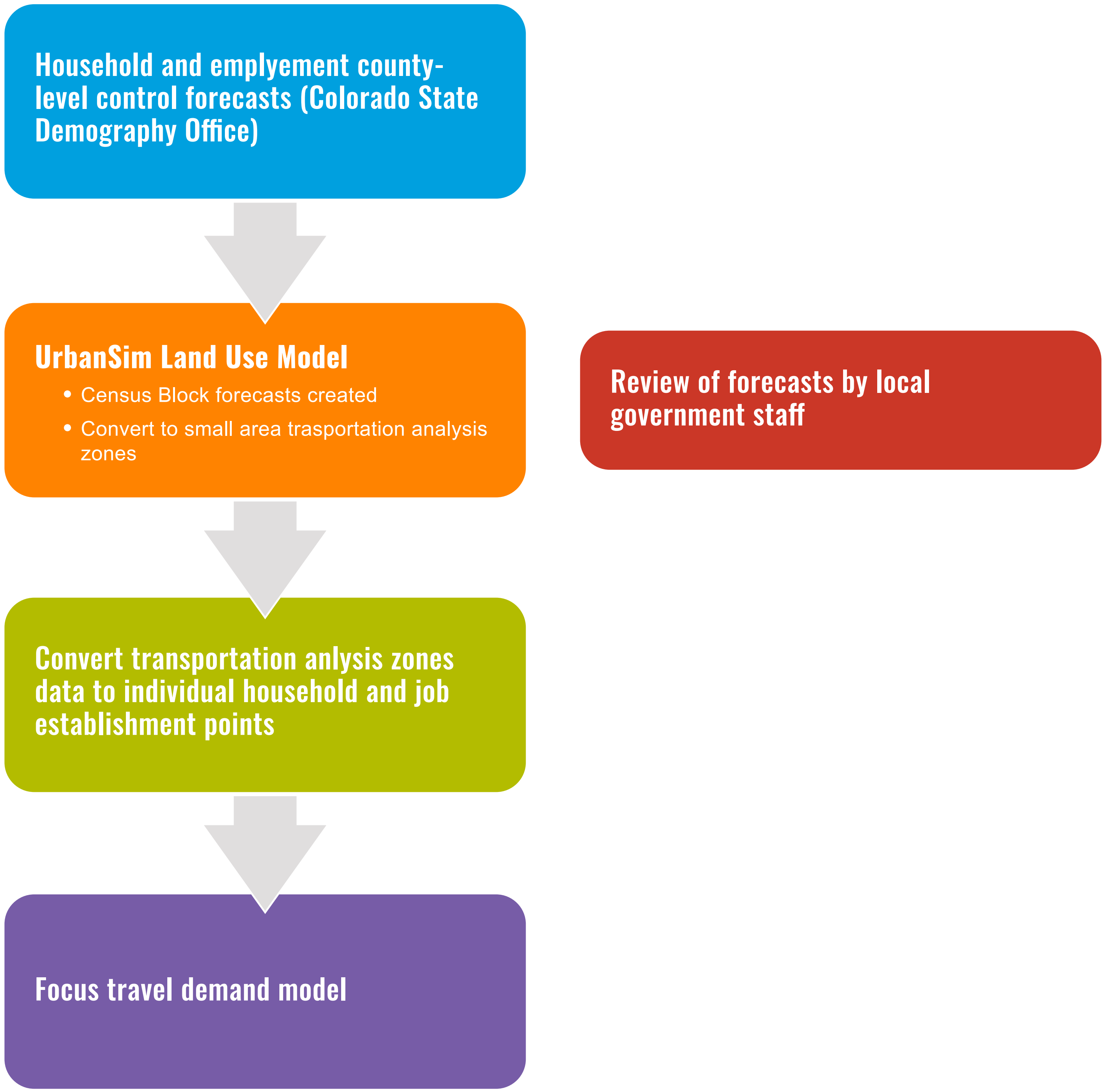
Small area development forecasts

To provide household and employment data at a level of detail necessary for the travel model, the regional socioeconomic forecasts are disaggregated into 2,800 transportation analysis zones, as shown in Figure 1. The allocation of households and employment to transportation analysis zones 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?
- What is the level of transportation accessibility?
- Where should a firm locate to conduct its business in accordance with zoning regulations, and with suitable transportation 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 1.4 million records for 2020) and each person (about 3.4 million records in 2020). Figure 2 shows a flowchart for the process of socioeconomic forecasting in the Denver region.

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.

A key use of the model is to estimate the travel patterns that result from before and after changes to model network facilities or inputs. Such changes can be made to population/employment, road/transit projects, cost of transportation fuels, fares, and services and many other model factors. The model is designed to estimate varying output values (e.g., traffic volume, delays and ridership) due to people in the model adjusting travel paths, travel modes, and travel demand due to the model changes mentioned above. This includes newly induced trips or trips to destinations further away. For a new transportation project(s) the model clearly depicts:

- Diversion of existing (assigned) trips between different roadway paths or transit routes.
- Mode shift of trips between driving, auto passenger, transit, walk and bicycle.
- Increase in traffic volume or transit ridership due to planned household and employment developments.
- Induced new trips or longer trips due to significant changes in travel time.
- Induced trips associated with changes in the location or timing of developments (new housing units or employment establishments), within the limits of state established demographic control totals.

Figure 3: Focus activity-based model elements

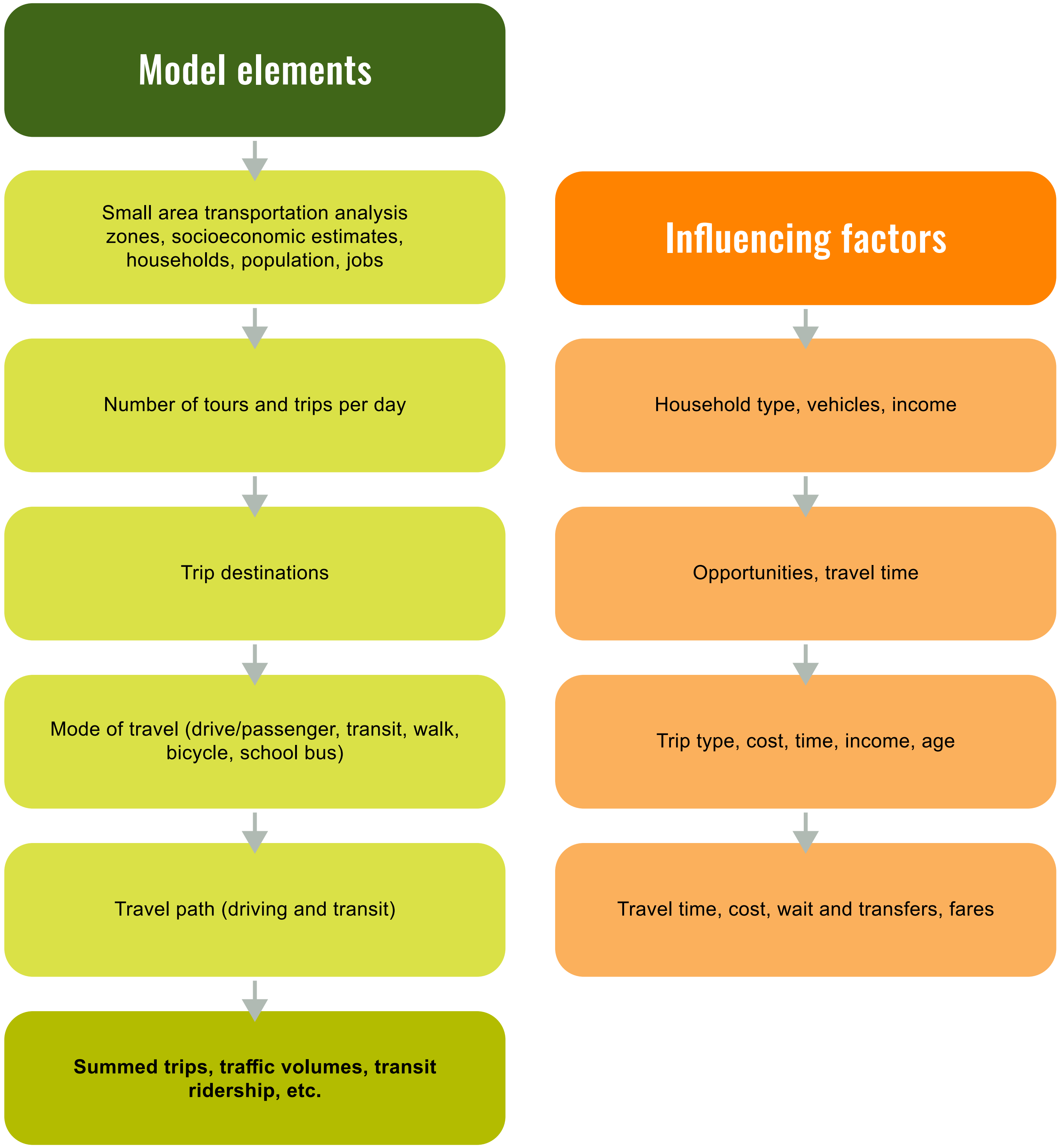
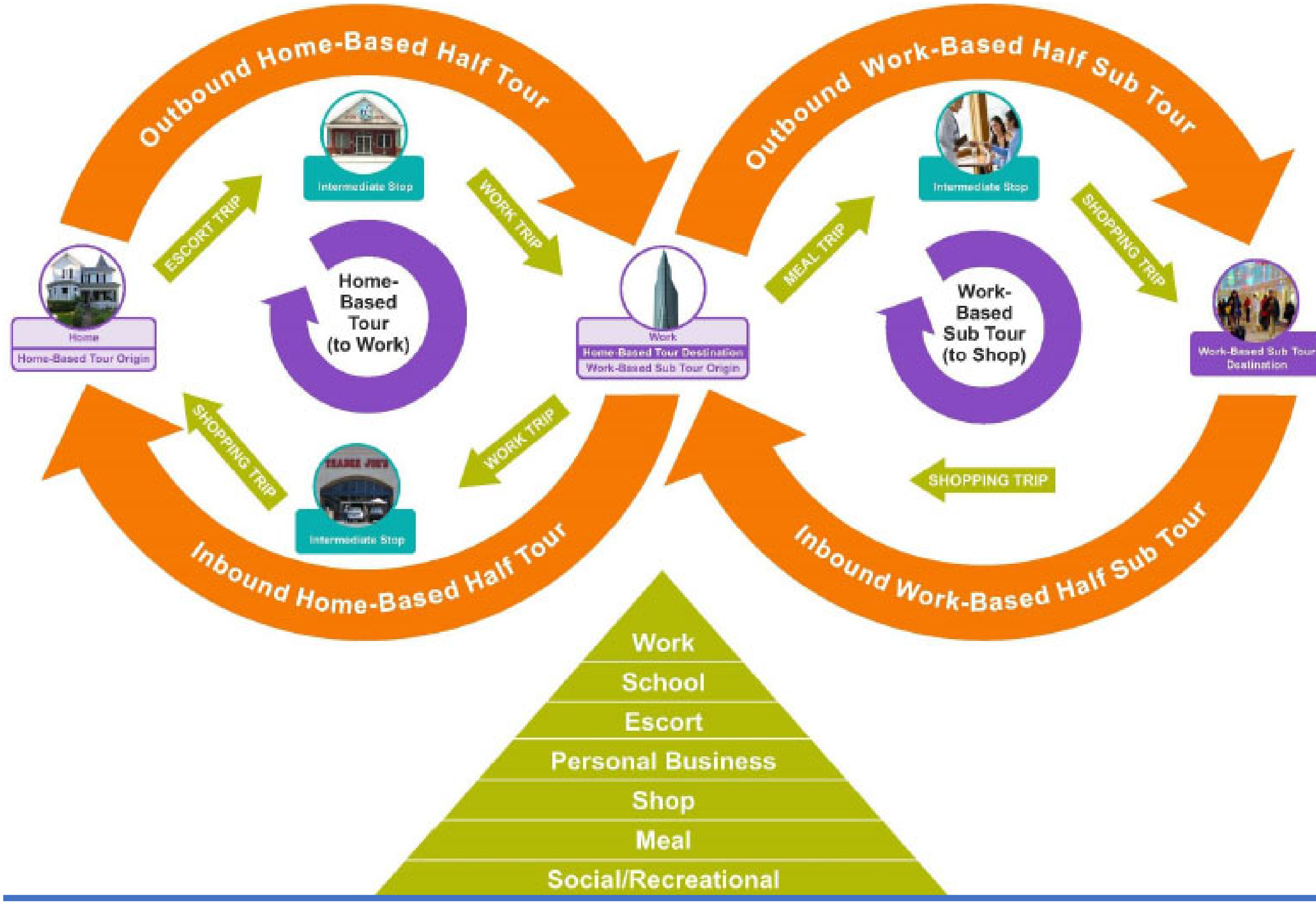


Figure 4: Sample tour diagram



Roadway and transit system

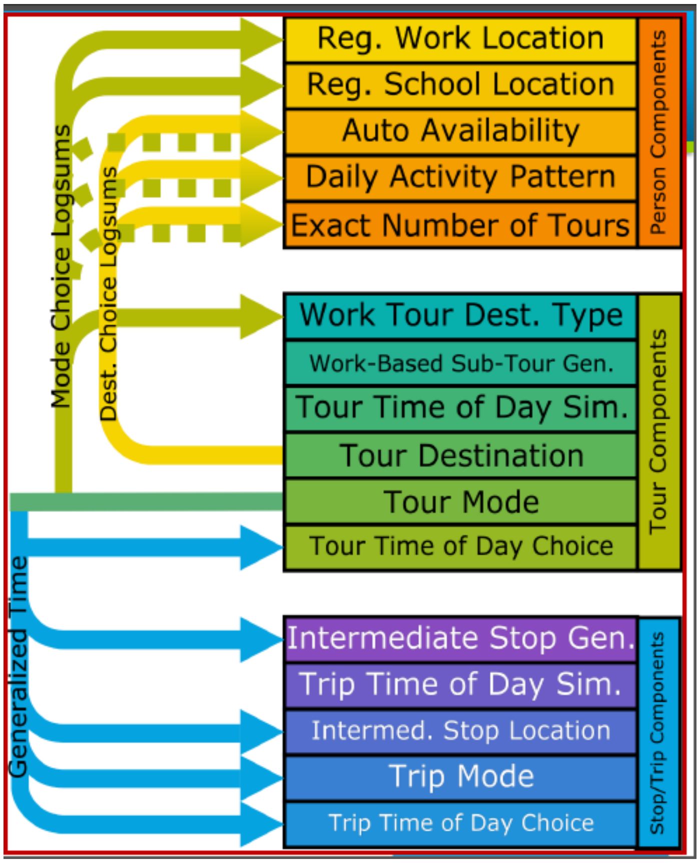
The most critical feature of the model is the representation of the transportation system. The roadway network is represented by over 25,000 directional road segments, described by location, length, number of lanes, functional classification and area type. High-occupancy vehicle and managed lanes also 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. Bus rapid transit facilities use a formula to reflect less delay time than general purpose lane auto travel. 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 travel paths are calculated using time, distance, fares, tolls and other operating costs.

Model components

The most important model components are briefly described in the sections below, and Figure 5 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.

Figure 5: Key focus model components (Activity Based Model components in red italics)

1) TransCAD model software initialization
2) Size sum variable calculator
3) TransCAD trip generation
4) TransCAD skimming (path selection)
5) TransCAD airport, commercial vehicle, and external travel distribution and mode choice
6) *Regular workplace location*
7) *Regular school location*
8) *Auto availability*
9) *Aggregate destination choice log sum generation*
10) *Daily activity pattern*
11) *Exact number of tours*
12) *Work tour destination type*
13) *Work-based subtour generation*
14) *Tour time of day simulation*
15) *Tour primary destination choice*
16) *Tour priority assignment*
17) *Tour main mode choice*
18) *Tour time of day choice*
19) *Intermediate stop generation choice*
20) *Trip time of day simulation*
21) *Intermediate stop location choice*
22) *Trip mode choice*
23) *Trip time of day*
24) Write trips to TransCAD
25) TransCADhighway and transit assignment



Roadway and transit skims (path selection)

Representative roadway and transit paths are initially used for all origin-destination transportation analysis zone pairs (2,800 zones by 2,800 zones) and each of the ten time-of-day periods. The paths consider travel time, travel cost and other factors. The time and cost 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 vehicle trips

After optimal paths are identified via the skims, three additional Compass Gravity Model components must be run to generate and assign:

1) Trips to and from Denver International Airport
2) External trips to, from and through the DRCOG region
3) Commercial vehicle trips.

Regular workplace and school location

The work location choice model assigns all regional workers a regular work location transportation analysis zone and point. Characteristics of the worker and their home location are used in combination with other characteristics to determine the relative attractiveness of each transportation analysis zone.

The regular school location choice model assigns each student a regular school location associated with a transportation analysis zone. The model uses information about the student, such as income and age and information such as total 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 the widely differing characteristics of school location decision making associated with each of the four grade ranges. 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 zero cars to 4-plus cars. The model uses information about households such as income, household size and household accessibility to work and school to determine how many autos are available to households.

Tour models

After the Focus Model has assigned the long-term decisions about work and school locations and auto availability, it forecasts daily activities of chained trips that start and end at home, known as tours.

The ***daily 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. For example, a person may be eating out, running errands or attending meetings. 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 (driving alone, shared ride of two individuals, shared ride of three or more individuals, 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.
- Which person made the trip.
- What household the person who made the trip belongs to.

The ***write trips to TransCAD*** component assembles the individual records for auto and transit trips into origin-destination trip tables (matrices) that Transportation Computer Assisted Design can use for assignment. These trip tables are then combined with those developed for DEN, 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 transportation analysis zone in such a way that, by the end of the process, no trip can reduce its travel time by changing its path. The process accounts for the congestion produced by all other trips in the region, each trip is following its minimum path. High-occupancy vehicles are loaded simultaneously with single-occupant vehicles. During this process, TransCAD keeps track of which vehicles are eligible to use high-occupancy vehicle facilities, and which might need to pay a toll to use high-occupancy/toll lanes, such as the reversible I-25 express lanes north of downtown Denver. The model also accounts for 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 account for 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.

Core model outputs

Final core model results for the base validation year and future reporting years are presented below. Detailed output results are shown in Appendix A. 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 3 and Table 4.

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 1% difference.

Table 3: Sum of 2020 weekday observed traffic counts and modeled volumes

	2019/2020 Observed counts (Sum of vehicle miles traveled)	2020 Model link volume (Sum of vehicle miles traveled)	Model variation
Colorado Department of Transportation roadways with counts	17,077,000	17,023,000	0.3%
Highway Performance Monitoring System roadways with counts	24,110,000	23,477,000	-2.6%
Highway Performance Monitoring System urbanized area network estimate	67,381,400	72,256,000	7.2%
All model links with counts	30,341,000	29,464,000	-2.9%

Table 4: Observed estimates and modeled 2020 transit weekday boardings

	2019 observed (est.)	2020 modeled	Model variation
RTD boardings	373,000	393,000	5.4%
RTD trips	261,000	264,000	1.1%

Air quality modeling

Formal air pollutant emissions modeling is conducted by the Colorado Air Pollution Control Division for transportation conformity purposes and by DRCOG for greenhouse gas emission analyses. DRCOG, the Air Pollution Control Division and other agencies work closely together in this effort, both in developing the modeling techniques, assumptions, and parameters and in executing the model runs. Modeled link speed and vehicle miles traveled results from the Focus Model are principal inputs to the MOtor Vehicle Emission Simulator air pollutant emissions model. The model produces estimates of the amount of emissions of greenhouse gases, carbon monoxide, volatile organic compounds, oxides of nitrogen and particulate matter 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 E: Methodology to calculate greenhouse gas emissions using the Motor Vehicle Emission Simulator

Introduction

This appendix summarizes the methodology used to calculate greenhouse gas emissions for the DRCOG metropolitan planning organization area, using emission rates from the Environmental Protection Agency's MOtor Vehicle Emission Simulator (MOVES).

MOVES is a state-of-the-science emissions modeling system that estimates air pollution emissions for criteria air pollutants, greenhouse gases and air toxics. MOVES estimates emissions from on-road vehicles such as cars, trucks and buses, accounting for the phase-in of federal emissions standards; vehicle and equipment activity; fuels; temperatures; humidity; and emission control activities such as inspection and maintenance programs.

In Colorado, the Air Pollution Control Division, a branch of the Colorado Department of Health and Environment, develops the locally defined inputs to MOVES, which is run to establish over 47,000 unique emission rates for each combination of month, hour, road type, speed and vehicle type. The emission rates are then multiplied by distances, total vehicle volumes, volumes per time period, and speeds per time period outputs from DRCOG's Focus travel demand model in a relational database, resulting in a greenhouse gas emissions inventory of surface transportation.

To develop baseline and compliance greenhouse gas emission inventories for the state's Greenhouse Gas Planning Standard, Air Pollution Control Division staff created versions of relational databases for each compliance year (2025, 2030, 2040 and 2050) and provided them to DRCOG. Air Pollution Control Division staff trained DRCOG staff on the methodology to perform the greenhouse gas emissions analysis on Feb. 23, 2022, and, per agreement, is authorized to perform the greenhouse gas emissions analysis for compliance with the rule. In the event of an update to the MOVES relational database, Air Pollution Control Division staff will notify DRCOG staff when there are updates to the MOVES relational database including input assumptions. DRCOG staff will be retrained as necessary to perform greenhouse gas emissions analysis.

The MOVES documentation that follows was developed by the consultant Felsburg Holt & Ullevig on behalf of the Colorado Department of Transportation and has not been modified by DRCOG staff. It describes the inputs and methodology used to create the MOVES relational databases.

MEMORANDUM

TO: Ms. Marissa Gaughan, CDOT Multimodal Planning Branch Manager

FROM: Dale Tischmak and Jake Fritz

DATE: January 21, 2022

SUBJECT: DRAFT MOVES3 Greenhouse Gas Modeling Methodology (117429-32)

Introduction

This document summarizes the methodology used to calculate greenhouse gas (GHG) emissions for the CDOT Statewide Travel Demand Model (TDM). Previous GHG modeling to support CDOT was conducted by APCD. This methodology replicates APCD's modeling process as best as possible.

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 linked to in the references (i.e., EPA 2016).

The process begins with generating emission rates using the EPA's Motor Vehicle Emission Simulator version 3.0.1 (MOVES3). The emission rates are multiplied by the vehicle miles traveled from the TDM. The result is an emissions inventory. A series of data engineering steps are required to prepare the rates and VMT into desirable and compatible formats.

MOVES3 Run Specifications

The run specification (RunSpec) parameters outlined below were used to calculate GHG emission rates with MOVES. They are consistent with APCD's process to calculate GHG emissions.

The four modeled years 2025, 2030, 2040, and 2050 used the same run specifications except for where specified (e.g., the year being modeled). Each of the four modeled years has six related run specifications to separate the emission rates by vehicle type, as described in the On-road Vehicles section.

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 SIPs and transportation conformity, either the County or National scale can be used for GHG inventories. EPA recommends using the

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County scale for GHG analysis. The County scale allows the user to enter county-specific data through the County Data Manager. Providing local data significantly improves the precision of the modeling results (EPA 2016).

The County scale was used.

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 must be post-processed to produce an inventory. Either may be used to develop emissions estimates for GHGs (EPA 2016).

The Emission Rates calculation type was used.

Time Span

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

When Emission Rates is chosen, 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 (EPA 2016).

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 (EPA 2016). However, the year, month, and day must still be specified and will affect the emission rates calculated.

The time span parameters specified below were also used because the TDM outputs represent an annual average weekday.

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 (EPA 2016).

The years used were 2025, 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 and their corresponding fuel efficiency.

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 (EPA 2016).

The months used were January and July to match the process described 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.

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 (EPA 2016).

The days used were weekdays to match the TDM output data. These represented the emission rates for an average weekday. The results were escalated later to approximate a full year.

Hours

The hours used were all 24 hours of the day (i.e., clock hours of 1 AM, 2 AM, 3 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. The county defines input parameters such as the meteorology data used to estimate emission rates.

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.). The [Panel] is used to specify the vehicle types included in the MOVES run (EPA 2016).

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 MOVES3 were used to calculate the emission rates. APCD's process, which was being followed, assigns TDM mileage based on a modified HPMS category. To calculate aggregate emission rates for each HPMS category (i.e., merging all of the relevant source types and fuel types), each of the six HPMS categories used a separate RunSpec. It is important to note that APCD's modified HPMS category does not match the MOVES HPMS types for source types 21, 31, and 32. When this methodology document refers to HPMS categories, it is generally referring to APCD's HPMS categories. The figure below illustrates the HPMS categories.

	A	B	C	D	E
1	sourceTyp	sourceTypeName	HPMSVtypeID	HPMSVtypeName	**HPMS from APCD**
2	11	Motorcycle	10	Motorcycles	**10**
3	21	Passenger Car	25	Light Duty Vehicles	**20**
4	31	Passenger Truck	25	Light Duty Vehicles	**30**
5	32	Light Commercial Truck	25	Light Duty Vehicles	**30**
6	41	Other Buses	40	Buses	**40**
7	42	Transit Bus	40	Buses	**40**
8	43	School Bus	40	Buses	**40**
9	51	Refuse Truck	50	Single Unit Trucks	**50**
10	52	Single Unit Short-haul Truck	50	Single Unit Trucks	**50**
11	53	Single Unit Long-haul Truck	50	Single Unit Trucks	**50**
12	54	Motor Home	50	Single Unit Trucks	**50**
13	61	Combination Short-haul Truck	60	Combination Trucks	**60**
14	62	Combination Long-haul Truck	60	Combination Trucks	**60**

Road Type

The Road Type Panel is used to define the types of roads that are included in the run. MOVES defines five different road types as shown in Table 3-1. Generally, all road types should be selected including Off-Network. Selection of road types in the Road Type Panel determines the road types that will be included in the MOVES run results (EPA 2016).

Table 3-1: MOVES Road Types

Roadtypeid	Road type	Description
1	Off-Network	Locations where the predominant activity is vehicle starts, parking and idling (parking lots, truck stops, rest areas, freight or bus terminals)
2	Rural Restricted Access	Rural highways that can be accessed only by an on-ramp
3	Rural Unrestricted Access	All other rural roads (arterials, connectors, and local streets)
4	Urban Restricted Access	Urban highways that can be accessed only by an on-ramp
5	Urban Unrestricted Access	All other urban roads (arterials, connectors, and local streets)

All road types available in MOVES3 were used.

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 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.

The CO2 Equivalent pollutant is the sum of the global warming potential of other greenhouse gases expressed as a unit of CO2 (EPA 2016) and CO2 Equivalents (CO2e) is the pollutant of interest for these GHG calculations. MOVES requires several other prerequisite pollutants for CO2e; however, only the emission rates for CO2e were needed for this project.

General Output

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

Output Database

Results from the six related HPMS RunSpecs for a single emissions year can be stored in a single output database for convenience. The RunSpecs must have the same units and aggregation (EPA 2016). A different output database is needed for each year of emission rate calculations. A consistent and informative naming convention for all output databases is very valuable.

One output database was used for each year modeled (i.e., 2025, 2030, 2040, and 2050). Each output database contained results for six RunSpecs, where each RunSpec represented a different APCD HPMS type. The naming convention FHU used was as follows:

[firm]_[pollutant]_[year][region]_[description]_[database type]

[firm] = The company or agency performing the analysis.

[pollutant] = The pollutant(s) of interest.

[year] = The year that emission rates were generated for.

[region] = The geographic area that emission rates were generated for.

[description] = An abbreviated description of relevant notes for the RunSpec.

[database type] = Whether the database was an input or output database.

For example, the database "fhu_ghg_2025sw_wev_in" represented an input database for greenhouse gases, the year 2025, the Statewide Transportation Plan, with electric vehicles, and was performed by FHU.

Units

Users are free to choose any of the mass unit selection options but should generally choose a unit whose magnitude is appropriate for the parameters of the RunSpec (EPA 2016).

The units used for models were grams for mass, joules for energy, and miles for distance.

Activity

MOVES allows the user to select multiple activity output options (e.g., distance traveled, population, etc.). For Emission Rate calculations, distance and population are reported automatically, but the values in the output are intermediate steps in the rate calculation and do not represent the true activity (EPA 2016).

When calculating emission rates (as opposed to emission inventories), MOVES selects the activities hoteling hours, population, and starts without the option of changing them.

Output Emissions Detail

This panel allows the user to select the amount of detail provided in the output database. Certain selections on this panel are made by the MOVES software and cannot be changed, based on selections made on earlier panels. The more boxes checked on this panel, the more detail and segregation provided in the MOVES output database. More detail generally is not helpful for this process so no optional selections should be checked on this panel. For example, if Source Use Type were selected on this panel, emission rates for each of the MOVES vehicle Source Use Type categories would be reported in the output database, which would defeat the purpose of performing MOVES calculations based on consolidated HPMS category.

No optional aggregation selections were made on this panel. Source type detail was captured via the six HPMS RunSpecs for each year modeled, as described in the On-road Vehicles section. Since multiple source types were used for HPMS 30, 40, 50, and 60, emission rates were aggregated for into HPMS categories. That is, emission rates for MOVES source types 31 and 32 were aggregated into the HPMS 30 RunSpec, etc.

Input Database/County Data Manager

After completing the RunSpec, the next step is to supply MOVES with data to create an input database that is the basis for the emission rate calculations. When using the County scale, the County Data Manager (CDM) is used to create an input database and populate it with local data. Modelers can either rely on MOVES default information or local data that the user inputs, as is appropriate for the goals of the MOVES modeling. The data contained in the MOVES default database are typically not the most current or best available for any specific county. Therefore, with the exception of fuels, EPA recommends using local data for MOVES for GHG analyses when available to improve the accuracy of GHG emissions estimates. However, the MOVES default data (county level) may be the only or best source of that data readily available. Also consider that data consistency may be more important than data perfection for some GHG analyses. At a minimum, EPA strongly encourages the use of local VMT and vehicle population data. EPA believes these inputs have the greatest impact on the quality of results. However, if local data are not available, MOVES default data may be useful for some inputs without affecting the quality of the results (EPA 2016).

In Emissions Rates mode, a full gamut of input data must be provided, described below, for MOVES to run. Some of these inputs actually do not affect the ultimate emission rates (they would affect inventory mode output) but reasonable inputs in the CDM should be used for general data integrity. As a general rule, users should input accurate activity for the scenario being modeled regardless of whether MOVES is being used in Inventory or Emissions Rates mode (EPA 2016).

The "Create Input Database" parameters define the region-specific inputs such as distributions of road types, vehicle age distributions, and meteorology data. The parameters specified in RunSpecs pre-populate the input database with default data for some of the parameters. However, region-specific data should be used when available and not all parameters have default data.

One comprehensive input database was created for each year modeled. Each of the six HPMS RunSpecs for that year used that single input database and were saved to a single output database. The input data were entered with the MOVES County Data Manager window, as specified below.

Age Distribution

A typical vehicle fleet includes a mix of vehicles of different ages, referred to as Age Distribution in MOVES. MOVES covers a 31 year range of vehicle ages, with vehicles 30 years and older grouped together. MOVES allows the user to specify the fraction of vehicles in each of 30 vehicle ages for each of the 13 source types in the model. For estimating on-road GHG emissions, EPA recommends and encourages states to develop age distributions that are applicable to the area being analyzed (EPA 2016).

APCD has developed a vehicle age distribution, and it was used for each year modeled.

Average Speed Distribution

This input is more important for Inventory than Emission Rates. Vehicle power, speed, and acceleration have a significant effect on vehicle emissions, including GHG emissions. MOVES models those emission effects by assigning activity to specific drive cycles. The Average Speed Distribution Importer in MOVES calls for a speed distribution in VHT in 16 speed bins, by each road type, source type, and hour of the day included in the analysis. EPA urges users to develop the most detailed local speed information that is reasonable to obtain. However, EPA acknowledges that average speed distribution information may not be available at the level of detail that MOVES needs (EPA 2016).

The Emission Rates option in MOVES will produce a table of emission rates by road type for each speed bin. Total running emissions are then quantified outside of MOVES by multiplying the emission rates by the VMT for each source type in each vehicle speed category. Users should supply an appropriate speed distribution to produce the necessary emission rates (EPA 2016).

APCD uses MOVES default data for all years in emission rate mode for their GHG models. This was used for each year modeled. Since emission rates were calculated (as opposed to emission inventories), the average speed distribution used in MOVES will not change the emission rates calculated. The speeds are accounted for in the TDM data.

Fuel

Entering this input data into MOVES involves four tables – called FuelFormulation, FuelSupply, FuelUsageFraction, and AVFT (alternative vehicle fuels and technology) – that interact to define the fuels used in the area being modeled.

- The FuelSupply Table identifies the fuel formulations used in a region (the regionCounty Table defines which specific counties are included in these regions) and each formulation's respective market share;
- The FuelFormulation Table defines the properties (such as RVP, sulfur level, ethanol volume, etc.) of each fuel;
- The FuelUsageFraction Table defines the frequency at which E-85 capable (flex fuel) vehicles use E-85 vs. conventional gasoline; and
- The AVFT Table is used to specify the fraction (other than the default included in the sampleVehiclePopulation Table) of fuel types capable of being used (such as flex fuel vehicles) by model year and source type.

In general, users should review/use the default fuel formulation and fuel supply data provided in MOVES, with important exceptions noted below. EPA strongly recommends using the default fuel properties for a region unless a full local fuel property study exists.

The GHG effects of changes in the fuel mix used by vehicles can be modeled in MOVES. AVFT can be used to change the fraction of future vehicles using gasoline, diesel, CNG and electricity. These changes will be reflected in MOVES GHG emission rates.

The FuelUsageFraction Table allows the user to change the frequency at which E-85 capable vehicles use E-85 fuel vs. conventional fuel, when appropriate. MOVES contains default estimates of E-85 fuel usage for each county in the U.S. In most cases, users should rely on the default information.

The AVFT Table allows users to modify the fraction of vehicles using different fuels and technologies in each model year. In other words, the Fuel Tab allows users to define the split between diesel, gasoline, ethanol, CNG, and electricity, for each vehicle type and model year. For transit buses, the default table assumes that gasoline, diesel, and CNG buses are present in the fleet for most model years. If the user has information about the fuel used by the transit bus fleet in the county modeled, the user should be sure it is reflected in the AVFT Table (EPA 2016). ***NOTE: This tab can be critically important in CDOT's GHG calculations. This is where electric vehicle percentages, etc. are defined. This tab may vary among CDOT's scenarios and should not be overlooked.***

APCD uses MOVES default data for fuel supply, fuel formulation, and fuel usage fraction for all years in their GHG models. For AVFT, APCD uses custom inputs that includes electric vehicles for all years. These were used for each year modeled.

Meteorology

Ambient temperature and relative humidity data are important inputs for estimating on-road GHG emissions with MOVES. Ambient temperature and relative humidity are important for estimating GHG emissions from motor vehicles as these affect air conditioner use. MOVES requires a temperature (in degrees Fahrenheit) and relative humidity (in terms of a percentage, on a scale from 0 to 100) for each hour selected in the RunSpec. EPA recommends that users input the average daily temperature profile for each month if they are modeling all 12 months. Temperature assumptions used for estimating on-road GHG emissions should be based on the latest available information. The MOVES database includes default monthly temperature and humidity data for every county in the country. These default data are based on average monthly temperatures for each county from the National Climatic Data Center for the period from 2001 to 2011. These national defaults can be used for a GHG inventory, or more recent data can be used (EPA 2016).

If the Emission Rate calculation type is chosen in the RunSpec, users can enter a different temperature and humidity for each hour of the day to create an emission rate table that varies by temperature for running emissions processes. Emission rates for all running processes that vary by temperature can be post-processed outside of MOVES to calculate emissions for any mix of temperatures that can occur during a day. This creates the potential to create a lookup table of emission rates by temperature for the range of temperatures that can occur over a longer period of time such as a month or year from a single MOVES run (EPA 2016).

MOVES default meteorology data was used for all years. The county used was Adams County, Colorado for the months of January and July. Emission rates were post-processed to average winter and summer emission rates.

Road Type Distribution

MOVES does not have default data for this input, so it must be developed. The fraction of VMT by road type varies from area to area and can have a significant effect on GHG emissions from on-road mobile sources. EPA expects states to develop and use their own specific estimates of VMT by road type (EPA 2016).

If the Emission Rates option is used, MOVES will automatically produce a table of running emission rates by road type. Running emissions would then be quantified outside of MOVES by multiplying the emission rates by the VMT on each road type for each source type in each speed bin. In that case, data entered using the Road Type Distribution Importer is still required, but is not used by MOVES to calculate the rate. However, road type distribution inputs are important for Emission Rates runs involving non-running processes, because they are used by MOVES to calculate the relative amounts of running and non-running activity, which in turn affects the rates for the non-running processes (EPA 2016).

APCD uses a custom road type distribution for all years in their GHG models. This was used for each year modeled. Since emission rates were calculated (as opposed to emission inventories), the road type distribution used in MOVES will not change the emission rates calculated. The road types are accounted for in the TDM.

Source Type Population

MOVES does not have default data for this input, so it must be developed. APCD uses a custom source type distribution for all years in their GHG models. These data were used for each year modeled. The source type populations used in MOVES will not change the emission rates calculated. However, source population data are still needed as inputs for an emission rates MOVES run.

Vehicle Type VMT

MOVES does not have default data for this input, so it must be developed. EPA believes VMT inputs have the greatest impact on the results of a state or local GHG or energy consumption analysis. Regardless of calculation type, MOVES requires VMT as an input. MOVES can accommodate whatever VMT data is available: annual or average daily VMT, by HPMS class or MOVES source type. Therefore, there are four possible ways to enter VMT, allowing users the flexibility to enter VMT data in whatever form they have. EPA recommends that the same approach be used in any analysis that compares two or more cases (e.g., the base year and a future year) in a GHG analysis (EPA 2016).

The Output Emission Detail panel determines the detail with which MOVES will produce emission rates for running emissions, such as by source type and/or road type in terms of grams per mile. Total emissions are quantified outside of MOVES by multiplying the emission rates by the VMT for each source type and road type. However, users will still need to enter data using the Vehicle Type VMT Importer that reflects the VMT in the total area where the lookup table results will be applied. This is necessary because MOVES uses the relationship between source type population and VMT to determine the relative amount of time vehicles spend parked vs. running (EPA 2016).

APCD uses HPMS as the source type and annual as the time span for their GHG models. This was used for each year modeled. Since emission rates were calculated (as opposed to emission inventories), the VMT used in MOVES will not change the emission rates calculated. The VMT values are in the TDM data. However, VMT data are still needed as inputs for an emissions rate MOVES run.

Inspection/Maintenance Program

If a model is examining any nonattainment/maintenance areas, an inspection and maintenance (I/M) program may apply. I/M program inputs should be those used for SIP and conformity analyses and are generally available as defaults within MOVES. However, if a user is modeling CO2, N2O, and/or elemental carbon emissions only, or modeling area where no I/M program applies, the user should check the box on this tab (EPA 2016).

APCD uses the check box for "No I/M Program" for the Statewide Transportation Plan, since there is not a statewide emissions program that applies in these areas. This was used for each year modeled.

Others

APCD assumes MOVES default values for the starts, hoteling, idle, retrofit data, and generic tabs. This was left as is for each modeled year.

Output Database

When a RunSpec is executed in MOVES, the results are stored in the output database specified in the "General Output" parameters. HeidiSQL (or equivalent software) can be used to view and export the calculated emission rates.

MOVES Rate per Distance Table

The critical table in the output database with the calculated emission rates was the "rateperdistance" table. It contained emission rates for each combination of month, hour, pollutant, road type, speed bin, and vehicle type as specified in the RunSpec. The MOVESScenarioID field was the mechanism used by FHU to identify the HPMS source type.

The table was filtered to include only CO2e (i.e., pollutant ID 98) emission rates and exported to a comma-separated value (CSV) file. Because the table included emission rates for both January and July, and MOVES speed bins are not discrete speeds in miles per hour, post-processing of the emission rates was required to calculate emission inventories.

Processed Emission Rates

APCD provided several Access databases with calculation tools for processing the MOVES and TDM data. These Access databases are the basis for the post-MOVES data processing. The instructions contained below provide a narrative of what occurs, but these actions are already built into the Access databases.

The MOVES rate per distance output table needed to be manipulated to produce emission rates that could be related to the calculated vehicle speeds for road links in the TDM data. The emission rates for January and July needed to be averaged to create composite emission rates. The emission rates for the 16 speed bins (which cover 5 MPH ranges) in MOVES were linearly interpolated to provide emission rates for every mile per hour speed from 1 to 75, which is how speed data are presented in the TDM data.

The resulting table includes a total of 43,776 unique emission rates. That is, an emission rate for each combination of:

- MOVES Road Types 2-5
- HPMS Types 10/20/30/40/50/60
- Hours 1-24
- Speeds 1-75

Processing Annual Average Emission Rates

For each year/rate per distance table (i.e., this process must be repeated for 2025, 2030, 2040, and 2050):

- Filter to include only CO2e (pollutant ID 98) emission rates
- There were unique emission rates for each combination of:
  - Road type
  - HPMS type
  - Speed Bin
  - Hour
  - Month
- To get the average emission rates per year, each combination of road type, HPMS type, average speed bin, and hour were summed and divided by two (to average the corresponding emission rates for January and July)
- Seasonally averaged emission rate = (Winter Rate + Summer Rate)/2

Interpolating Emission Rates from Speed Bin to Integer Speeds

After seasonally averaging the emission rates, these rates were used to interpolate (linearly) between speed bins to get an emission of rate for every mile per hour for the speeds of 1 to 75 miles per hour. In general, the process used was:

- For adjacent speed bins, subtract the lower bin number emission rate from the higher bin number emission rate and divide by five to calculate a per mile per hour change in the emission rate (NOTE: emission rates generally decrease with increased speed)
- Add the appropriate emission rate change to the lower bin avgBinSpeed value to interpolate each mile per hour emission rate between the avgBinSpeed values
- For reference, the table below illustrates the MOVES speed bins
- Example for interpolating emission rate of 11 mph:
  - Speed per mph = 11 mph
  - Speed of Lower Speed Bin = 10 mph
  - Number of Speeds per Speed Bin = 5 (= 2.5 for speed bin 1; = 5 for all other speed bins)
  - ER of Lower Speed Bin = 4055 g/m (dummy data)
  - ER of Upper Speed Bin = 3421 g/m (dummy data)
  - 4055 + (3421 – 4055) * (11 – 10)/5 = 3928

avgSpeedBinID	avgBinSpeed	avgSpeedBinDesc
1	2.5	speed < 2.5mph
2	5	2.5mph <= speed < 7.5mph
3	10	7.5mph <= speed < 12.5mph
4	15	12.5mph <= speed < 17.5mph
5	20	17.5mph <= speed <22.5mph
6	25	22.5mph <= speed < 27.5mph
7	30	27.5mph <= speed < 32.5mph
8	35	32.5mph <= speed < 37.5mph
9	40	37.5mph <= speed < 42.5mph
10	45	42.5mph <= speed < 47.5mph
11	50	47.5mph <= speed < 52.5mph
12	55	52.5mph <= speed < 57.5mph
13	60	57.5mph <= speed < 62.5mph
14	65	62.5mph <= speed < 67.5mph
15	70	67.5mph <= speed < 72.5mph
16	75	72.5mph <= speed

Processed TDM

The TDM data are usually presented as an ESRI polyline shapefile format with each traffic link represented as one record (feature) and attributed with distances, total volumes, volumes per time period, and speeds per time period. A series of post-processing steps were performed to relate the relevant TDM data with the appropriate MOVES emission rates, as described below. The first step described below was done using ArcGIS. The other steps were done using the tools in the Access databases.

The resulting table includes aggregated VMT for each combination of:

- MOVES Road Types 2-5
- HPMS Types 10/20/30/40/50/60
- Hours 1-24
- Speeds 2.5-75

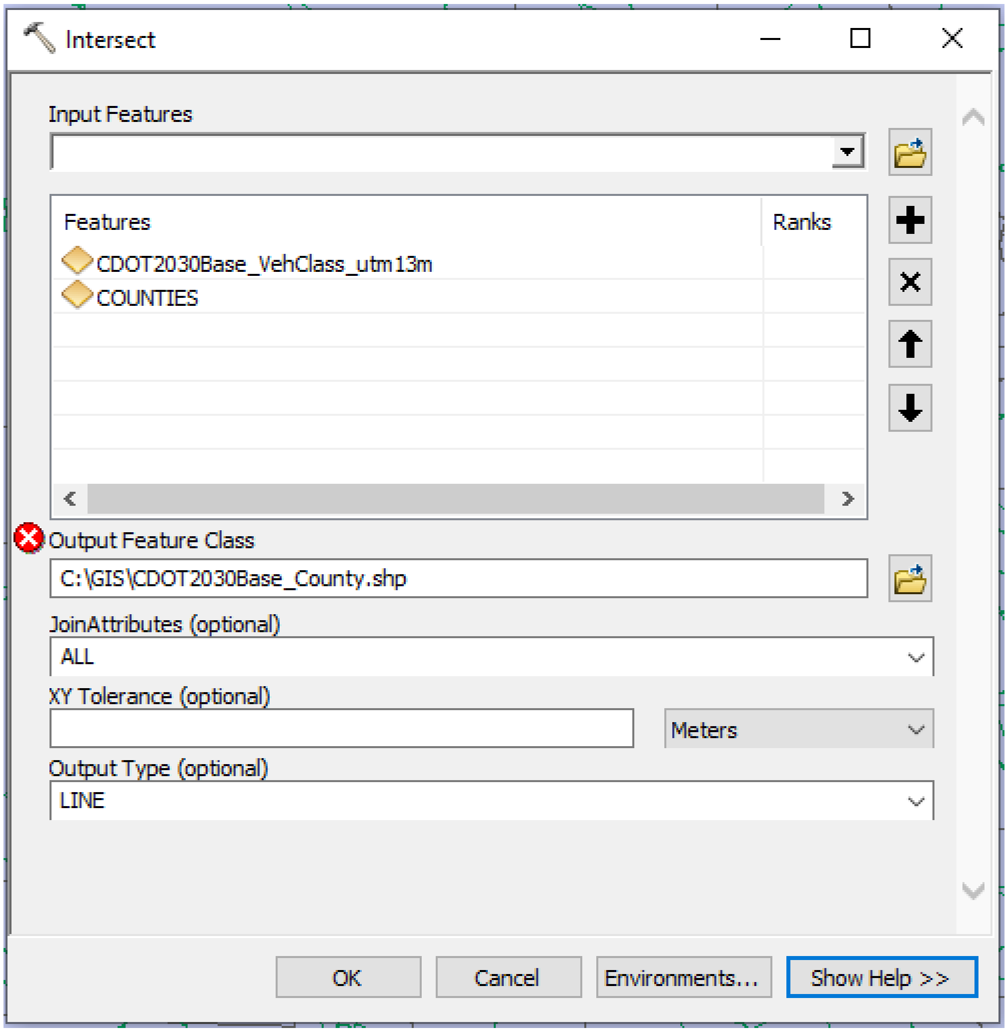
This process provides respective county names for each link to aggregate VMT by geography/region.

Attribute TDM with County Name

The first step was to attribute each link with the county name. The county information was necessary because it was used later in the process to filter VMT (and thus, on-road emissions inventory) by geography/region (e.g., MPO or non-MPO traffic). Performing this step later in the process would require significant modifications to the process.

The ArcGIS geoprocessing tool "Intersect" was used to attribute the TDM shapefile with county names for each roadway link (feature). The Input Features were the TDM shapefile and CDOT's "COUNTIES" shapefile that can be downloaded from OTIS. Unnecessary fields in the counties shapefile were deleted, so that the fields remaining were FID, Shape*, COUNTY, and CO_FIPS. The Output Feature Class name and file path could change, depending on the user's preference. The Join Attributes parameter was set to "ALL" which kept attributes from both input features. The Output Type parameter was set to "LINE" which set the output feature class to be the geometry of the TDM shapefile. The Environment was defaults except for the Output

Coordinate System. That was set to the projected coordinate system, "GRS_1980_UTM_Zone_13N" which matched the TDM shapefile's coordinate system.



The resulting output feature class had the same geometry and attributes as the TDM shapefile except for the following changes:

- Each link was attributed with the county name and FIPS number.
- Links within multiple counties were split (divided) into separate features at the county line(s). In these cases:
    - Both features still had the same attributes except for the county name and FIPS.
    - The distance attribute in the "DIST" field was now invalid since the feature was split.

To account for changes in distances for links that were in multiple counties, a new field "cntyMiles" was added to the output feature class. The geoprocessing tool "Calculate Geometry" was used on the "cntyMiles" field to calculate the distance of each link in miles. The "cntyMiles" field, rather than the "DIST" field, was used later in Access to calculate VMT.

The resulting attribute table was saved as a CSV file and used in the following steps.

Access Database

The TDM CSV file from the step above was imported into an Access database. The remaining post-processing steps were performed in this Access database, as described below.

Speeds

The TDM speeds were in floating decimal format and rounded to the nearest integer. Speeds less than 2.75 mph were rounded to 2.5 mph. This was because emission rates for speeds of 2.5 mph or less were the same, as described in the Processed Emission Rates section.

Time Periods

The TDM model provides aggregated data for 10 blocks of time for a day, not hour by hour—see the "name" column below. The data for these TDM periods were recategorized/interpolated into data for discrete clock hours 1-24 based on methodology from APCD.

The PeriodHour24 table below was used to split the TDM data for different time periods (AM1, PM2, OP1, etc.) into 24 clock hour time periods. VMT was calculated for each combination of integer speed (2.5 – 75mph), interstate (yes or no), road functional class (1-8), rural (yes or no), periodCog (1-10), and county.

The periodCog 1-10 were related to hours 1-24 as shown in the “hour” column. That provided a VMT per clock hour for each combination of speed and functional class. This was used to relate the VMT to fractions of VMT by HPMS per functional class and hour.

The cVMT was divided by the number of “periods” corresponding with each clock hour to calculate the VMT.

PeriodHour24

Interval	periodCog	name	hour	hrsT	periods
11:00 PM - 6:30AM	7	Op1.bin	1	7.5	7
11:00 PM - 6:30AM	7	Op1.bin	2	7.5	7
11:00 PM - 6:30AM	7	Op1.bin	3	7.5	7
11:00 PM - 6:30AM	7	Op1.bin	4	7.5	7
11:00 PM - 6:30AM	7	Op1.bin	5	7.5	7
11:00 PM - 6:30AM	7	Op1.bin	6	15	7
6:30-7:00 AM	1	Am1.bin	7	1	1
7:00-8:00 AM	2	Am2.bin	8	1	1
8:00-9:00 AM	3	Am3.bin	9	1	1
9:00 AM - 11:30 AM	8	Op2.bin	10	2.5	2.5
9:00 AM - 11:30 AM	8	Op2.bin	11	2.5	2.5
	9	Op3.bin	12	3.5	7
	8	Op2.bin	12	2.5	5
11:30 AM - 3:00 PM	9	Op3.bin	13	3.5	3.5
	9	Op3.bin	14	3.5	3.5
	9	Op3.bin	15	3.5	3.5
3:00-5:00 PM	4	Pm1.bin	16	2	2
3:00-5:00 PM	4	Pm1.bin	17	2	2
5:00-6:00 PM	5	Pm2.bin	18	1	1
6:00-7:00 PM	6	Pm3.bin	19	1	1
7:00-11:00 PM	10	Op4.bin	20	4	4
7:00-11:00 PM	10	Op4.bin	21	4	4
7:00-11:00 PM	10	Op4.bin	22	4	4
7:00-11:00 PM	10	Op4.bin	23	4	4
11:00 PM - 6:30AM	7	Op1.bin	24	7.5	7

Fraction of VMT by HPMS

Once VMT was calculated for each road functional class and clock hour, the fractions of VMT by HPMS for each corresponding functional class and clock hour were applied. This calculated the VMT for HPMS 10-60. The fractions used were from APCD and were consistent with their methodology.

FractionsByHourHPMSnaaT

NAA?	Weld?	Rural?	FC	Hr	10f	20f	30f	40f	50f	60f
-1	W	R	1	1	1.12494375281236E-03	0.442984079764564	0.408981870287873	8.24958752062397E-04	3.60606876834793E-03	0.14247807867434
-1	W	R	1	2	6.50325162581291E-04	0.418107821883677	0.388118179039889	1.40070035017509E-03	5.57032759041272E-03	0.186152645973265
-1	W	R	1	3	1.1907462009526E-03	0.402448608970853	0.376594285267901	1.9278748015423E-03	8.86488378110699E-03	0.208973600977645
-1	W	R	1	4	1.88772529102432E-03	0.400795540811441	0.375296865809669	3.5956672209987E-03	8.74568726325532E-03	0.209678513603612
-1	W	R	1	5	1.27600843728028E-03	0.438002933384539	0.406922735865401	8.59352621025494E-04	5.91653137282429E-03	0.14702243831893
-1	W	R	1	6	9.86892049192773E-04	0.462978652961131	0.429325812630245	1.88521686320158E-03	5.20852159466524E-03	9.96149039015637E-02
-1	W	R	1	7	8.56477631797771E-04	0.47063947538398	0.437825973989187	1.19740562115417E-03	7.50554404406707E-03	8.19751233298142E-02

Road Types

The TDM used roadway functional classes that were recategorized to MOVES road types. That allowed the road types from the TDM to be related to the emission rates.

RTt

DRCOG Facil	FHWA facility type	rural?	FHWA	Urban	MOVESrt	fhwaRT	fcCode	Intestate
1	Principal Arterial - Interstate	-1	R	R	2	1	1	1
1	Principal Arterial - Interstate	-1	R	R	2	1	1	0
1	Principal Arterial - Interstate	0	N	U	4	11	1	0
1	Principal Arterial - Interstate	0	N	U	4	11	1	1
2	Principal Arterial - Other	-1	N	R	3	2	2	0
2	Principal Arterial - Other Freeways or Expresswa	0	N	U	4	12	2	0
3	Principal Arterial - Other	-1	N	R	3	2	3	0
3	Principal Arterial - Other	0	N	U	5	14	3	0
4	Minor Arterial	-1	N	R	3	6	4	0
4	Minor Arterial	0	N	U	5	16	4	0
5	Major Collector	-1	N	R	3	7	5	0
5	Collector	0	N	U	5	17	5	0
6	Principal Arterial	-1	R	R	2	1	1	0
6	Principal Arterial	0	N	U	4	11	1	0
8	Local System	-1	N	R	3	9	7	0
8	Local System	0	N	U	5	19	7	0

Filter by Geography/Region

The statewide GHG inventory was filtered to contain VMT for all counties in Colorado except for the nine-county region in the ozone non-attainment area. The nine counties excluded were Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, Jefferson, Larimer, and Weld. The statewide results were subdivided further into Pikes Peak area and the rest of the state.

Emissions Inventory

The processed emission rates table and the processed VMT table were related by road type, HPMS type, hour, and speed. This relate was used to multiply the emission rate (g/mi) by the VMT (mi) to get a total in grams of CO2e for an average weekday. The formula used was:

- CO2e (g/day) = SUM(Emission Rate (g/mi) * VMT (mi))
- CO2e (MMt/day) = CO2e (g/day) * 1 (MMt) / 1e+12 (g)
- CO2e (MMt/year) = CO2e (MMt/day) * 338 (TDM weekdays/calendar year)

The calculated emissions inventory was for on-road emissions. Non-road emissions were not included in this calculation.

References

EPA. 2016. *Using MOVES for Estimating State and Local Inventories of On-road Greenhouse Gas Emissions and Energy Consumption*. June. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100OW0B.pdf

Appendix F: Methodology to represent programmatic funding for the 2022 Updated 2050 RTP

Summary

In a typical Regional Transportation Plan update, there are often network changes to regionally significant projects. These are reflected in the Denver Regional Council of Governments Focus Model for each staging year. For the 2022 Updated 2050 RTP staff also proposed making further updates to model inputs and factors to better reflect observed, real-world changes and future categories of “programmatic investments” included in the adopted 2022 Updated 2050 RTP.

As adopted in April 2021, DRCOG’s fiscally constrained 2050 RTP contains over $15 billion in programmatic funding. These programmatic investments are shown as a lump sum and individual projects are not yet identified in these programs. Specific projects within these programmatic investments will be determined through the Transportation Improvement Program process as regional and local priorities evolve over the 30-year life of the plan.

Programmatic funding categories include transit investments, active transportation, safety/Vision Zero, transportation demand management and intelligent transportation system investments, all of which are key strategic investments in improving the region’s multimodal transportation system while also reducing emissions. Despite representing a significant portion of the total investments in the fiscally constrained 2050 RTP, DRCOG has not historically reflected how the programmatic funding may influence future travel behavior in the Focus travel model.

In the context of the Colorado Department of Transportation’s Regulation Governing Statewide Transportation Planning Process and Transportation Planning Regions, DRCOG is now evaluating methodologies to represent these programmatic funds in the travel model in coordination with the North Front Range Metropolitan Planning Organization and CDOT. Through this coordinated effort, we hope to achieve a transparent and consistent methodology to reflect the effects these types of investments could make in future travel within the DRCOG region. DRCOG staff believe that reflecting these programmatic funds in the modeling will result in a more complete and accurate depiction of the total investments included in the 2050 RTP.

The details of model outputs, such as bicycle and pedestrian trips at localized and regional levels, better reflect future increased investments supporting those travel modes in relation to recent observed land use changes. This document details the methodology used to estimate available funding, the specific adjustments made to the model and the reasoning behind those adjustments.

Methodology

DRCOG staff evaluated the categorical and programmatic 2050 RTP funding and estimated the approximate percentage of total funds in each pool associated with additional projects and investments not yet reflected in the travel model. The results are shown in Table 1, which has been reviewed by DRCOG's Transportation Advisory Committee, Regional Transportation Committee and Board workshop committees.

The percentage of the total funds, by category, was estimated by evaluating historic and intended uses of funding for infrastructure and services with the potential to reduce greenhouse gas emissions. The intention was to determine funding and/or enhancements in the use of funds for new infrastructure investments, services or components of projects that were not reflected in the previous 2050 RTP model, such as bicycle/pedestrian infrastructure supporting a bus rapid transit corridor.

The resulting funding estimates will be used along with an estimated cost per unit to approximate the quantity of infrastructure (i.e., new multi-use paths) or service levels (i.e., increased transit service) to be reflected or mimicked in the travel model.

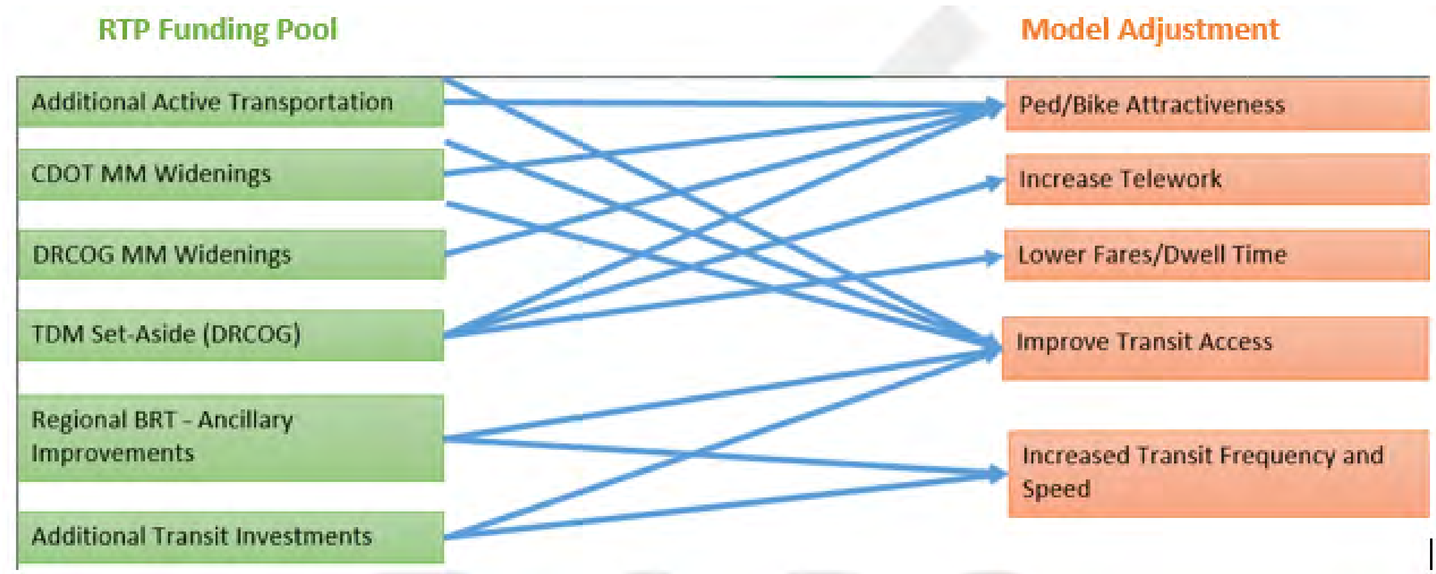
Table 1: 2050 RTP Funding associated with additional greenhouse gas reduction

2050 RTP Investment Categories	Total Investment 2020 Dollars ($Millions)			
	2021-2030	2031-2040	2041-2050	RTP Total Funds
Additional Transit Investments	$62	$379	$261	$702
Regional BRT - Ancillary Improvements	$629	$256	$298	$1,183
Additional Active Transportation	$52	$36	$92	$180
Multimodal Components of DRCOG Funded Widening Projects	$221	$748	$630	$1,599
Multimodal components of CDOT Funded Widening Projects	$3,144	$1,360	$1,550	$6,054
DRCOG TDM Set-Aside	$34	$34	$34	$102
TOTAL:	**$4,143**	**$2,813**	**$2,865**	**$9,821**

Next, DRCOG staff evaluated how to represent these pools of funds, either in the focus travel model, or through an off-model evaluation. DRCOG staff leaned heavily on the methodologies used during a scenario planning exercise from early 2020, as well as methodologies used by CDOT in defining the greenhouse gas targets. DRCOG staff linked each type of 2050 RTP categorical funding with the types of model factors that could be adjusted based on the intended use of the funds. Figure 1 shows how several of the 2050 RTP funding pools are associated with various adjustments in the model.

Estimated % of total funds associated with GHG benefits	Investments Associated with GHG Benefits 2020 Dollars ($Millions)			
	2021-2030	2031-2040	2041-2050	Total Funds Associated with GHG Benefits
90%	$56	$341	$235	$632
5%	$31	$13	$15	$59
100%	$52	$36	$92	$180
10%	$22	$75	$63	$160
5%	$157	$68	$78	$303
10%	$3	$3	$3	$10
	$322	**$536**	**$486**	**$1,344**

Figure 1: Model adjustments associated with programmatic funding pools



For funding pools that are associated with multiple types of model adjustments, total funds were divided evenly between model adjustment categories. The total funding available, by model adjustment category, by staging year, is shown in Table 2.

Table 2. Total programmatic funding available by model category

Model Adjustment	2021-2030 Funds	2031-2040 Funds	2041-2050 Funds	Total Funds
Ped/Bike Attractiveness	$ 159.5	$ 266.2	$ 241.2	$ 666.9
Increase Telework	$ 1.1	$ 1.1	$ 1.1	$ 3.4
Lower Fares/ Reduced Dwell Time	$ 43.7	$ 177.0	$ 124.9	$ 345.6
Improve Transit Access	$ 1.2	$ 1.2	$ 1.2	$ 3.5
Increased Transit Frequency and Speed	$ 116.9	$ 90.3	$ 117.4	$ 324.6
Grand Total	**$ 322.4**	**$ 535.8**	**$ 485.8**	**$ 1,343.9**

2020 Dollars ($M)

DRCOG staff then estimated the level of adjustment to each model component, based on the funding available, scaled in proportion to estimates used in DRCOG's scenario costing work as well as the methodologies used in CDOT's cost/benefit document developed in relation to the state's greenhouse gas rulemaking.

Model adjustments

The model adjustments, reasoning and funding summaries that support the adjustments are documented below. DRCOG staff will continue to perform research and monitor travel trends to ensure the model adjustments reflect real world conditions into the future.

Share of work at home

Table 3: Model adjustments associated with work at home

Increase telework	2030	2040	2050
Work at home rate for workers	25%	25%	25%
Funding per staging period	$1.1 million	$1.1 million	$1.1 million

- Multiple factors influence work location choice and work trips. Previously, DRCOG targeted 20% of workers working at home on a given day. Current conditions lead DRCOG staff to believe 20% is now an underestimate. An increase to 25% is warranted because of the new way of work we are seeing in the world changed by the pandemic along with increased efforts in travel demand management programs and interest in policies to encourage more working from home at the state and local level.
- It is important to know what “work at home” encompasses. It does not just include telework, or office workers working remotely. Work from home also includes part time workers, self-employed small businesses, home offices, flexible/hybrid working schedules and people who work alternative schedules such as three 12-hour shifts a week, could be doing on a sample day.
- It is also important to note that people that work from home may still take trips, whether it’s for personal reasons or work-related.
- Following the pandemic, there has been an increase in businesses, schools, agencies or other communities turning towards a four-day week compressed work week model.
- Before the pandemic, observed data demonstrated a significant increase in people working from home in the Denver region. Post-pandemic we continue to observe elevated levels of remote working or working at home some days of the week.

Bicycle and pedestrian attractiveness

The regional travel model does not have a bicycle and pedestrian network and, thus, specific identified projects cannot be coded. To reflect the programmatic investments in the model, bicycle and pedestrian attractiveness factors are used to represent the additional investments.

Table 4: Model adjustments associated with bicycle and pedestrian attractiveness

Bicycle and pedestrian attractiveness model component	2030	2040	2050
Increase sidewalk density by the following factor	8%	16%	25%
Increase walk and bicycle operating speeds	4 mph / 11 mph	5 mph / 12 mph	5 mph / 12 mph

Increase sidewalk density

- One of many factors correlated with the attractiveness of active transportation modes is "sidewalk density." As a pre-process to running the travel model, each transportation analysis zone is assigned a sidewalk density value based on the quantity of sidewalks and shared use paths within that zone, divided by the area. Sidewalk density is one factor which represents the ease and comfort of active transportation modes in specific geographic areas.
- To reflect the funds dedicated to active transportation infrastructure in each staging period, DRCOG is proposing to incrementally increase the sidewalk density values for urban and suburban area types over the life of the plan.
- The increased values do not represent an absolute increase in sidewalks, but rather represents select, strategic projects effectively increasing the density by focusing on key gaps and missing links. Through planimetric data and local government data collection and sharing efforts, we can optimize the addition of new sidewalk mileage to create more complete, connected networks.
- The value increases over the staging period because these infrastructure investments are additive over the years.

Increase walking and bicycle operating speeds

- When the walk or bike modes are assigned in the model, they are given an operational travel speed which reflects the average speed for the trip, including, for example, wait time at intersections. Walk speeds were 3 mph and bike speeds 8 mph.
- DRCOG is proposing to increase walk and bicycle speeds incrementally in future staging years, as described in the table above.
- The increase in speed for walk and bicycle modes represent:

  - The electrification of active modes through the adoption of e-bikes[1] and e-scooters[2]. Not only does electrification increase the speed of these modes, but it may make the mode more attractive.
  - The speed increase also represents additional priority being provided to active modes through legislation and infrastructure such as: cyclists given their own right of way and priority signal treatments; legal permissions for traversing intersections; improved sidewalk conditions; new key connections completed; and the perception of faster travel time that occurs when a walking journey is comfortable and on a well-connected network.

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[1] https://denverite.com/2022/05/06/denvers-e-bike-rebates-are-already-gaining-traction-with-residents/

[2] https://www.9news.com/article/news/local/next/scooter-bike-share-denver-released-public/73-1d0e03e1-43fa-4ea7-bc3c-f024ec8db6b4

Modify person-specific negative attractiveness factors for bike and pedestrian mode choice

- In both real life and in the model, an individual's propensity to walk or bike is influenced by their age and their gender. Based on travel survey data from 2010, the model was calibrated to make walking and bicycling less attractive for women and older adults to reflect the observed data.
- To reflect the buildout of, and enhancements to the region's active transportation system, observed cultural changes, and electrification providing additional mobility to older adults, DRCOG staff removed the negative factors applied to individuals in the model based on gender and adjusted the age where negative factors as described in the table above.This is motivated by the belief that the enhanced multimodal facilities will reduce some barriers for cycling for older people and women.
- Examples of enhancements that might affect the attractiveness of biking and walking include lighting on paths, safe crossings with appropriate time to cross, all new paths having appropriate widths – and added space at potential conflict points. DRCOG staff also know local governments are working to build bike facilities based on comfort for all ages and abilities and targeting key connections to make high comfort complete routes.
- There is research[3] to show the perception of increased safety in numbers. For example, knowing other cyclists and walkers will be on a path can help it feel safer for some users or knowing drivers are used to seeing cyclists aids in comfort and sense of safety.

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[3] https://www.sciencedirect.com/journal/safety-science/vol/92/suppl/C ;

https://www.normalizecycling.com/safety-in-numbers/#:~:text=There%20is%20strong%20evidence%20of%20an%20association%20between,causes%20%28confounding%20factors%29%20that%20are%20not%20being%20measured

Transit

Table 5- Model adjustments associated with transit

Transit	2030	2040	2050
Reduce fares	20%	20%	20%
Reduce dwell time	20%	20%	20%
Reduce headways	5%	5%	5%
Cap on waiting time	Maximum 15 minutes	Maximum 15 minutes	Maximum 15 minutes
Reduce transit walk-access time	Remove penalties	Remove penalties	Remove penalties
Increase speed on transit walk links	100%	100%	100%
Transit access improvements funding	$1.2 million	$1.2 million	$1.2 million
Improve transit frequency and speed funding	$117 million	$90 million	$117 million
Funds used for lower fares/reduced dwell time	$44 million	$177 million	$125 million
Total additional transit funding	**$162 million**	**$268 million**	**$243 million**

Reduce transit fares

- In the travel model, the cost of a trip influences people's mode choice, as it does in real life. In the model, the cost of transit fare is a single value that represents what, in reality, is a complex pricing system including people with EcoPasses, discounted fares, monthly passes, fare zones and more.
- DRCOG is proposing to reduce this value by 20% for all staging years. This is not suggesting there will be a blanket reduction of 20% in fares, hitting Regional Transportation District revenues in the fare box, but rather it is intended to reflect the experience of users having a perception of lower fare through programmatic investments and strategic partnership, including:

  - Through transportation demand management efforts, more people in the region will be able to use transit at a free or reduced cost, through commuter benefits like EcoPass or other programs.
  - Ongoing efforts to increase eligibility for discounted fares, and this is intended to reflect that.
  - RTD's fare-revenue study is reviewing how to simplify the fare structure, which could reduce fares for some trips or psychologically reduce the cost for people by reducing confusion.[4]
  - SB22-180[5] will pilot free transit for one month a year, which could influence future transit fare decisions.

Reduce transit dwell time

- In the travel model, transit buses have a dwell time based on the type of route. To reflect some of the ancillary benefits of enhanced transit investments, the dwell time was reduced by 20%.
- In general, this change is to reflect transit investments that enhance the travel time competitiveness of transit. The primary reason for this change is streamlined payment and faster boardings.
- It also reflects investment in transit signal prioritization equipment, that allows for a bus to travel through an intersection before or after a stop or more quickly re-enter the flow of traffic, which users can experience as additional dwell time.

Reduce headways

- The frequency of each transit route is included in the model. The time between buses or trains at a particular stop is considered the headway.
- The 5% decrease in headway for all staging years is to reflect an increase in vehicle revenue miles across the region. Because these model adjustments represent programmatic investments, DRCOG staff cannot model specific route changes because this is adaptable based on future needs of the region.

Cap waiting time for longer headway routes

- In the travel model, travelers are assigned a "wait time" equal to half of the transit route's headway for that time period. For all routes, the total wait time was capped at 15 minutes.

[4] https://www.rtd-denver.com/farestudy

[5] https://leg.colorado.gov/bills/sb22-180

- Previously, the model assumed some people would arrive 30 minutes before their bus arrived. This significantly increased the travel time for some transit trips and did not reflect how most people use transit for long headway routes. This adjustment accounts for how smart phones and the investment in real time transit service information have changed how people will plan for their transit trip. Bus tracking specifically also allows people to plan to reduce wait time.

Reduce transit walk-access time

- The model includes information on how people get to transit. For trips where people access transit though active transportation modes the access time penalties were removed.
- This reflects the significant investment being made in active transportation access across the region and DRCOG's prioritization of pedestrian projects near transit. More direct walk routes and pedestrian infrastructure improvements increase the ease of accessing transit.

Increase speed on transit walk links

- The specific pedestrian links that have a distinct connection to transit have a defined user travel speed. Because of the investments in active transportation and the pedestrian environment near transit, this speed needed to be readjusted. The speed was doubled for these short links to reflect the enhancements in infrastructure, including things like sidewalks, lighting, and more.
- The idea is that more comfortable and direct infrastructure, such as pedestrian bridges over high volume roadways, allows people to travel faster and has a psychological impact on how people experience the length of a journey.

Appendix G: Intergovernmental Agreement

INTERGOVERNMENTAL AGREEMENT BETWEEN THE COLORADO DEPARTMENT OF TRANSPORTATION, COLORADO DEPARTMENT OF PUBLIC HEALTH & ENVIRONMENT, AND THE DENVER REGIONAL COUNCIL OF GOVERNMENTS REGARDING THE EXECUTION OF MPO TRAVEL DEMAND MODEL AND MOVES EMISSIONS MODEL

5/26/2023

THIS AGREEMENT is made effective and entered into this ___ day of _____, 2023, by and between the Denver Regional Council of Governments[1] (DRCOG) and the Colorado Department of Transportation (CDOT) and the Colorado Department of Public Health & Environment (CDPHE).

I. APPLICABILITY

This intergovernmental agreement (IGA) applies to the continuing, cooperative, and comprehensive transportation planning and emissions modeling processes required to be carried out pursuant to 2 CCR 601-22, the Rules Governing Statewide Transportation Planning Process and Transportation Planning Regions, as implemented by CDOT and the state's Metropolitan Planning Organizations (MPOs) in order to meet state transportation planning requirements and ensure progress towards reducing greenhouse gas (GHG) emissions from the transportation sector.

II. DEFINITIONS

All defined terms provided in 2 CCR 601-22 have the same definition in this Intergovernmental Agreement.

"Modeling Requirements to Estimate Greenhouse Gas Emissions" - a living document summarizing the most appropriate model structure and design standards for modeling GHG emissions and the transportation system as it relates to the requirements of 2 CCR 601-22. This document is developed and periodically updated through the Statewide Modeling Coordination Group.

"Statewide Modeling Coordination Group (SMCG)" - composed of travel and air pollutant modeling professionals designated by the State Interagency Consultation Team (IACT), with representatives from all the state's MPOs, CDOT, and the APCD.

[1] The Greater Denver TPR, which includes the Denver Regional Council of Governments' planning area, comprises the counties of Adams, Arapahoe, Boulder, Broomfield, Clear Creek, Denver, Douglas, Gilpin, Jefferson, and parts of Weld.

III. PURPOSE

This IGA is established to define the roles and responsibilities of the Air Pollution Control Division of the CDPHE (APCD), the Division of Transportation Development of CDOT, and DRCOG (hereafter referred to as "parties") related to the development and execution of DRCOG's MPO Model and the MOVES Model to address the requirements of the GHG Planning Standard in 2 CCR 601-22. Further, this IGA ensures coordination between all parties in carrying out these responsibilities and sets common and shared standards, assumptions, and verification procedures for GHG analysis.

IV. COORDINATION AND COMMUNICATION

Staff from each party will work in partnership to ensure the successful implementation of 2 CCR 601-22 - Rules Governing Statewide Transportation Planning Process ("GHG Planning Rules"). Staff will communicate frequently and make every attempt to resolve differences at the lowest staff level possible and in a timely manner.

Each party will provide one or more representatives to serve on the following committees established by CDOT.

- The State Interagency Consultation Team (IACT), and
- The Statewide Modeling Coordination Group (SMCG).

The IACT works collaboratively and consults appropriately to approve modifications to Regionally Significant definitions, address classification of projects as Regionally Significant, review modeling assumptions and address other issues raised by the parties.

The SMCG works collaboratively to discuss, advise, and agree on analysis approaches and the inputs, content, and timing of work products and outputs related to travel demand modeling, MOVES modeling, and the interrelationships between these tools. The SMCG will make every attempt to resolve technical issues among the parties and to do so in a timeframe that does not delay submission of DRCOG's GHG Transportation Report. Disagreements among the SMCG will be elevated to the IACT.

It is expected that all parties will actively participate in the IACT and the SMCG along with any other groups as determined by the IACT.

Any protracted disagreements between parties shall be elevated to the Executive Director of each party.

V. ANALYSIS, DOCUMENTATION, REVIEW & VERIFICATION RESPONSIBILITIES

DRCOG RESPONSIBILITIES - two (2) areas of responsibility are identified:

1-Modeling and Analysis

1. Notify CDOT's Director of Transportation Development and APCD's Director via email when initiating a transportation planning process that requires a GHG analysis under the GHG Planning Rules to ensure early coordination on MOVES analysis and other relevant technical issues. Such coordination will include developing a milestone schedule identifying an anticipated timeline and the type and format of data and reporting information to be shared between the DRCOG, APCD, and CDOT.
2. Conduct travel modeling for the DRCOG MPO area. Develop and report results of DRCOG's Travel Demand Model and the MOVES Model to the standard described in the "*Modeling Requirements to Estimate Greenhouse Gas Emissions"* document. Operate these models as described in each submitted DRCOG GHG Transportation Report.
3. Ensure that results contained within the GHG Transportation Report submitted to APCD and CDOT are complete and comprehensive enough to allow for review and verification.

2-Documentation

1. Prepare the GHG Transportation Report in compliance with the requirements of 2 CCR 601-22, 8.02.6. Per the requirements of section 8.04.1, the GHG Transportation Report constitutes the technical data supporting DRCOG's compliance demonstration. The GHG Transportation Report will also include, if applicable, a GHG Mitigation Action Plan.
2. Prepare a calibration and validation report per the requirements of 2 CCR 601-22, 8.02.2.1. This report may be included in the GHG Transportation Report.
3. Document any substantial changes or modifications made to the technical data provided by APCD, for review during the APCD verification process.
4. When appropriate, provide documentation as described in Section VI of this Agreement.

APCD RESPONSIBILITIES - two (2) areas of responsibility are identified:

1-Modeling and Documentation

1. Prepare, and provide to the SMCG and DRCOG's Transportation Planning Division Director, documentation of the MOVES modeling process, assumptions and inputs utilized by APCD for the DRCOG MPO area, for inclusion in the GHG Transportation Report. Unless otherwise agreed to by the parties to this Intergovernmental Agreement, this modeling process and documentation will be considered final for the duration of a given compliance period which begins when a GHG analysis is initiated as determined through SMCG consultation and concludes when the Transportation Commission has approved a DRCOG GHG Report for a plan update or amendment.
2. Provide DRCOG with GHG emission factor outputs from the MOVES model and any necessary tools for GHG emissions analysis for each of the required compliance years. Changes to GHG emission methodology that become available after a GHG emission analysis is initiated will only be used if agreed to by the parties to this Intergovernmental Agreement.

2-Review and Verification

1. Perform an overall review of the technical data provided in the draft GHG Transportation Report for obvious calculation errors, and/or results that appear inaccurate, unreasonable, inconsistent, or unsubstantiated; and assess the methods used to estimate future emissions projections.
2. Provide timely feedback via a letter or email to DRCOG's Transportation Planning Division Director on the submitted draft GHG Transportation Report recognizing that Reports will be considered acceptable if no written comments are received by DRCOG within 30 days of submission. APCD will notify DRCOG as early as possible of any potential issues to allow time for consultation and consideration of adjustments.

CDOT RESPONSIBILITIES - two (2) areas of responsibility are identified:

1-SMCG and IACT Coordination and Management

1. Convene, organize, and provide non-financial support the IACT. Schedule a minimum of (3) meetings per year, with additional meetings as needed.
2. Convene, organize, and provide non-financial support the SMCG. Schedule a minimum of (3) meetings per year, with additional meetings as needed, to evaluate the state of modeling

throughout the duration of the rule and cooperatively review at least annually, the need for specific updates to the "*Modeling Requirements to Estimate Greenhouse Gas Emissions*".

3. Ensure that the *"Modeling Requirements to Estimate Greenhouse Gas Emissions"* document is updated to reflect new information and decisions made by the SMCG and that all changes receive concurrence from the SMCG before finalizing. Serve as document custodian and ensure all parties have access to the most recent version.
4. As a member of the SMCG, CDOT will provide technical support and advice on modeling issues as needed, including defining assumptions regarding zero emission vehicles by vehicle class and staging year to be used in the MOVES model.

2-GHG Transportation Reports - Facilitation and Review

1. Ensure timely exchanges of the tools, data inputs and outputs, and documentation between parties to this IGA.
2. Facilitate coordination of parties during the review process by helping to schedule meetings as needed and provide technical assistance as needed.
3. Support the Transportation Commission's review of each submitted GHG Transportation Report and prepare filing of all necessary information.

VI. RELIANCE ON PREVIOUS GHG EMISSIONS ANALYSIS

Applicable planning documents, as defined in 2 CCR 601-22, may rely on the previous GHG emissions analysis if the criteria listed below can be demonstrated. This demonstration must be described in writing and presented to the IACT and SMCG for their concurrence.

1. The new applicable planning document contains all projects which must be completed in the document's covered timeframe to achieve the transportation system as defined by the applicable planning document for which the previous GHG emissions analysis was conducted;
2. The scope of each project in the new applicable planning document is not significantly different from that described in the previous applicable planning document; and
3. The previous GHG emissions analysis and Mitigation Action Plan, if any, demonstrates compliance with all applicable GHG Reduction Levels required in 2 CCR 601-22.

VII. AMENDMENT, TERMINATION, AND SUPERSESSION OF AGREEMENT

This IGA will be reviewed at least every four (4) years from its effective date. It may be amended, whenever deemed appropriate, by written agreement of all parties.

Any party to this IGA may terminate it by a 60-day written notice to the other parties. If this occurs, the parties agree to consult further to determine whether the issues can be resolved, and the agreement re-implemented in an amended form.

THE COLORADO DEPARTMENT OF TRANSPORTATION

By: DocuSigned by: Darius Pakbaz C00E7F883BFF4BD...

Name: Darius Pakbaz

Title: Director, Division of Transportation Development

Date: 5/26/2023

THE COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT

By: DocuSigned by: 63436B5866C649D...

Name: Michael Ogletree

Title: APCD Director

Date: 5/26/2023

THE DENVER REGIONAL COUNCIL OF GOVERNMENTS

By: DocuSigned by: Ron Papsdorf 5FA43B8A681A4C2...

Name: Ron Papsdorf

Title: Transportation Planning and Operations Director

Date: 5/26/2023