CMAQ Emissions Calculator Toolkit

Documentation of Tool Methodology and Emissions Data for the Adaptive Traffic Control Systems (ATCS) Tool

This document supplements the User Guide for the Adaptive Traffic Control Systems (ATCS) Tool in the Congestion Mitigation and Air Quality Improvement Program Emissions Calculator Toolkit (CMAQ Toolkit). It discusses the primary data sources used for this tool and how the emission datasets were derived. In addition, it discusses the methodology used to calculate the delay reduction used to estimate emissions benefits and how this methodology was developed. Emission estimates from the CMAQ Toolkit are not intended to meet specific requirements for State Implementation Plans (SIPs) or transportation conformity analyses.

The document highlights the emissions data obtained from the US Environmental Protection Agency's (EPA) Motor Vehicle Emissions Simulator (MOVES).[1] The MOVES Methodology section describes the specific inputs and outputs, pre-processing, and post-processing that were used to generate the default-scale emission rates used within the tool.

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[1] US Environmental Protection Agency, Office of Transportation and Air Quality, https://www.epa.gov/moves

EMISSION RATE DATA SUMMARY

Emission rates for the Adaptive Traffic Control Systems (ATCS) tool were derived from the US Environmental Protection Agency's (EPA) Motor Vehicle Emissions Simulator (MOVES) version 3, with default input database "movesdb20220105." MOVES emission rates data rely on default age distributions, fuels, I/M programs, and meteorology. Roadway grade is also not accounted for by default in the tool. Users in areas that differ significantly from the default parameters that wish to obtain more accurate estimates of emissions benefits should consider running moves separately for their specific locality and using the emissions rates post processing steps outlined in User-Supplied Emission Rates section of this guide.

MOVES METHODOLOGY

MOVES3 project-level runs were used to determine running rates at different speeds and idling emission rates across varying road types for this tool. MOVES runs for the ATCS Tool include speeds of 0 to 75 miles per hour (mph) in 1-mph intervals. Project-level links were created to correspond to the road type and speed. Note that each MOVES 3-digit linkID was formed by concatenating roadTypeID (first digit) and speed in mph (subsequent two digits). For example, 335 indicates roadType 3 (urban unrestricted) and 35 mph.

MOVES Parameters

In order to run MOVES at the project level, some default-scale runs, described in Table 1, were completed first. The default data could be used as inputs for the project-scale runs, which are laid out in Table 2a, to differentiate emission rates by average speed. The national defaults used as inputs for the Project Data Manager are documented in Table 2b.

Table 1: Default-Scale Run Specifications

Category	Variable	Input
Description	-----	<blank>
Scale	Model	ONROAD
	Domain/Scale	Default
	Calculation Type	Inventory
Time Spans	Years	[2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040]
	Months	All Selected
	Days	All Selected
	Hours	All Selected
Geographic Bounds	-----	No Selection Needed
Vehicles/Equipment	On-Road Vehicle Equipment	All Selected
Road Type	Road Types	All Selected
Pollutants and Processes (selected)	Total Gaseous Hydrocarbons	All Selected
	Non-methane Hydrocarbons	All Selected
	Volatile Organic Compounds	All Selected
	Carbon Monoxide (CO)	All Selected
	Oxides of Nitrogen (NOx)	All Selected

Category	Variable	Input
	Primary Exhaust PM2.5 – Total	All Selected
	Primary Exhaust PM2.5 – Species	Running Exhaust, Start Exhaust, Extended Idle Exhaust, Auxiliary Power Exhaust
	Primary PM2.5 – Brakewear Particulate	All Selected
	Primary PM2.5 – Tirewear Particulate	All Selected
	Primary Exhaust PM10 – Total	All Selected
	Primary Exhaust PM10 – Species	All Selected
	Primary PM10 – Brakewear Particulate	All Selected
	Primary PM10 – Tirewear Particulate	All Selected
	Carbon Dioxide Equivalent (CO_2e)	All Selected
	Total Energy Consumption (TEC)	All Selected
	Atmospheric CO_2	All Selected
	Select Prerequisites	All Selected
General Output	Units	Mass: Kilograms, Energy: Million BTU, Distance: Miles
	Activity	All Selected
Output Emissions Detail	Output Aggregation	Year, Nation
	On Road	Road Type, Source Use Type
	For All Vehicle/Equipment Combinations	Model Year, Fuel Type, Emission Processes
Advanced Features	Time Aggregation	Hour
	Region Aggregation	Nation

Users that are importing their own emission rates do not need to complete default-scale runs if they have all the local data necessary for project-level analysis (see the section below on user-provided emission rates for more details). The generic parameters used in project-scale runs can be found in Table 2a. Further guidance on developing local rates is available in the User-Supplied Emission Rates section contained in this document.

Table 2a: Project-Scale Run Specifications

Category	Variable	Input
Description	-----	<blank>
Scale	Model	Onroad
	Domain/Scale	Project
	Calculation Type	Inventory

Category	Variable	Input
Time Spans	Time Aggregation Level	Year
	Years[2]	2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040
	Months	January
	Days	Weekday
	Hours	00:00 – 00:59
Geographic Bounds	Selections:	Middlesex County, MA (25017)
Vehicles/Equipment	On-Road Vehicle Equipment	All Vehicle Source Types
Fuel Type	-----	All Combinations
Road Type	Road Types	All Road Types
Pollutants and Processes (selected)	Total Gaseous Hydrocarbons	Running Exhaust, Crankcase Running Exhaust, Start Exhaust, Crankcase Start Exhaust, Evap Permeation, Evap Fuel Leaks, Refueling Displacement Vapor Loss, Refueling Spillage Loss
	Non-methane Hydrocarbons	Running Exhaust, Crankcase Running Exhaust, Start Exhaust, Crankcase Start Exhaust, Evap Permeation, Evap Fuel Leaks, Refueling Displacement Vapor Loss, Refueling Spillage Loss
	Volatile Organic Compounds	Running Exhaust, Crankcase Running Exhaust, Start Exhaust, Crankcase Start Exhaust, Evap Permeation, Evap Fuel Leaks, Refueling Displacement Vapor Loss, Refueling Spillage Loss
	Methane (CH4)	Running Exhaust, Crankcase Running Exhaust, Start Exhaust, Crankcase Start Exhaust
	Carbon Monoxide (CO)	Running Exhaust, Crankcase Running Exhaust, Start Exhaust, Crankcase Start Exhaust
	Oxides of Nitrogen (NOx)	Running Exhaust, Crankcase Running Exhaust, Start Exhaust, Crankcase Start Exhaust
	Nitrous Oxide (N2O)	Running Exhaust, Crankcase Running Exhaust, Start Exhaust, Crankcase Start Exhaust

[2] To avoid an excessively large output database, each evaluation year was run individually and results were placed in separate output databases.

Category	Variable	Input
	Primary Exhaust PM2.5 – Total	Running Exhaust, Crankcase Running Exhaust, Start Exhaust, Crankcase Start Exhaust
	Primary Exhaust PM2.5 – Species	Running Exhaust, Crankcase Running Exhaust, Start Exhaust, Crankcase Start Exhaust
	Primary PM2.5 – Brakewear Particulate	Brakewear
	Primary PM2.5 – Tirewear Particulate	Tirewear
	Primary Exhaust PM10 – Total	Running Exhaust, Crankcase Running Exhaust, Start Exhaust, Crankcase Start Exhaust
	Primary PM10 – Brakewear Particulate	Brakewear
	Primary PM10 – Tirewear Particulate	Tirewear
	Total Energy Consumption	Running Exhaust, Start Exhaust
	Atmospheric CO2	Running Exhaust, Start Exhaust
	CO2 Equivalent	Running Exhaust, Start Exhaust
General Output	Units	Mass: kilograms, Energy: million BTU, Distance: miles
	Activity	All Selected
Output Emissions Detail	Output Aggregation	<blank>
	For All Vehicle/Equipment Categories	Model Year, Fuel Type, Emission Process
	Onroad	Road Type, Source Use Type, Regulatory Class
	Nonroad	<blank>
Advanced Performance Features	-----	<blank>

Considering that the MOVES project-scale runs utilized a series of inputs from the default-scale runs outlined above and from the MOVES default database, the data entered into each Project Data Manager tab have been recorded in Table 2b.

Table 2b. Project Data Manager – Inputs by Tab

Data	Source
Age Distribution	Adopted MOVES3 age distributions for all evaluation years from 2018 through 2040 (taken from sourcetypeagedistribution table in movesdb20210726 database)
AVFT	Used default tables for each run
Fuel Formulation	Used default tables for each run
Fuel Supply	Used default tables for each run
Fuel Usage Fraction	Used default tables for each run
Generic	---

Hotelling	---
I/M Programs[3]	Used imcoverage table from movesexecution database in default-scale inventory run for all evaluation years (2018 through 2040)
Links	Customized input with the following data: • linkID: roadTypeID concatenated with linkAvgSpeed (i.e., 200, 201, 202… 275) • countyID: 25017 • zoneID: 1 • roadTypeID: 2, 3, 4, 5 • linkLength: equal to linkAvgSpeed (except when 0 mph, then equal to 1 mile) • linkVolume: 1000 • linkAvgSpeed: 0 through 75 mph (repeated for all four road types) • linkDescription: --- • linkAvgGrade: 0
Link Source Type	Customized input with the following data: • linkID: 200-275, 300-375, 400-475, 500-575 • sourceTypeID: all 13 types • sourceTypeHourFraction: normalized values from movesactivityoutput table in default-scale inventory run for all years 2018-2040 of vehicle miles traveled by source type over the total vehicle miles traveled on a given road type (source type fractions sum to 1 by road type)
Meteorological Data	Used default tables for each run
Off-Network	For all source types: • Vehicle Population: 4 • Start Fraction: 0.5 • Extended Idle Fraction: 0 • Parked Vehicle Fraction: 0.5
Operating Mode Distribution	Data from default-scale inventory run described previously
Retrofit Data	---
Tools	---

Users supplying their own emission rates do not need to follow the default inputs used in the Project Data Manager above and can develop the necessary project-level inputs from an analysis of local data. Guidance for developing local rates follows.

Post-MOVES Run Data Processing

Results from the project-level MOVES runs described above were used to obtain different categories of data for use in the ATCS Tool. The following section describes how MOVES activity and emissions inventory data were used to develop the tool's emissions rates.

[3] Inspection and Maintenance Programs. Note that default-scale MOVES runs were used to populate the I/M Program table, as it is not populated in the MOVES default database. If needed, please follow the parameters in Table 1 for the default-scale runs.

Light- and heavy-duty vehicle emission rates were calculated separately using otherwise identical procedures: light-duty rate aggregate output for passenger vehicles and light commercial trucks (sourceTypeID 21, 31, and 32); heavy-duty rate aggregate output for the various types of buses, single unit trucks, and combination trucks (all sourceTypeIDs greater than 40). Brake and tire wear were aggregated into the particulate matter (PM) results for both sets of rates.

1. **Activity rates** – To obtain project-level activity rates, the distance travelled (activityTypeID 1) was extracted from the results for all vehicles. Hours operating was also extracted from the results for all vehicles.
2. **Hourly emissions** – Emission rates were generated on a per-mile basis. This involved joining emission inventories from the movesoutput table and activity from the movesactivityoutput. To determine emission rates, emissions (aggregated across all processes) were divided by distance travelled. In order to determine an idling emission rate, the emissions inventory was divided by the hours operating activity rate, as the distance travelled was zero in the case of vehicles going 0 miles per hour.

Emission rates are based on project evaluation year, speed, pollutant, and road type.

Once the MOVES project-level run completed for a given project year, the 'movesactivityoutput' table was retrieved to obtain the source hours operating activity. The emissions quantity found in the 'movesoutput' table of the output database was divided by the value of source hours operating for a given vehicle, pollutant, on a given road type, to determine idling emission rates in kg/hr. These idling emission rates serve as the emission rates used in the ATCS Tool.

EMISSIONS METHODOLOGY

The following sections provide a description of the delay reduction equation, emission rate equation, and default input parameters.

Data Collection

The underlying methodology for this tool is based on a meta-analysis of delay reduction data collected from before-and-after studies of corridors where an adaptive signal timing system was deployed in place of a time-of-day (TOD) signaling plan. This meta-analysis was performed on a specific brand of system (InSync) due to the breadth of the studies that exist for this system and the quality of the data reported in those studies. A decision was made to focus the meta-analysis on this system, because the studies reported the descriptive metrics on their respective corridors of study more consistently than studies of other ATCS systems. The system that was studied in depth is considered to represent the current and future state of the practice in Adaptive Traffic Control, and therefore the results can be used to estimate the delay reduction and subsequent emissions benefits from a variety of adaptive systems. Overall, data from 13 studies were collected for this analysis (see Appendix).

Four specific metrics describing a corridor with signalized intersections were chosen to study regression analyses on the resulting datasets. These metrics and their descriptions are shown in the table below. The letters within the parentheses associated with each metric are the corresponding variables in the equations that follow.

Table 3. Metrics Used to Describe a Corridor with Signalized Intersections

Metric	Description
Corridor Length (L)	The length of the corridor in the study measured as the distance along the roadway from the first signalized intersection to the last signalized intersection.
Number of Signalized Intersections (I)	The number of signalized intersections at which an adaptive system is to be deployed.
Traffic Volume (V)	The average hourly volume of traffic in both directions in all lanes of the roadway that pass by any one point along the corridor. Averaging the traffic volume along the entire corridor gives a convenient descriptor for the amount of vehicles that use the roadway and the signalized intersections on the roadway.
Existing Delay per Vehicle (D)	The delay that vehicles experience as they progress from the first signalized intersection to the last which increases the potential travel time above free-flow travel time through the entire corridor. This can be calculated as the sum of the average delay per vehicle experienced at each intersection in the corridor.

The dependent variable was chosen to be the absolute delay reduction per vehicle in the corridor. Overall, 48 data points from specific hour-long periods described in the studies were collected. Descriptive statistics for the data collected from the various studies are presented in Table 4.

Table 4: Overall Metrics of Meta-Analysis Data

Overall Metrics	**Corridor Length (miles)**	**Number of Intersections**	**Hourly Volume (vehicles)**	**Existing Delay (seconds/vehicle)**	**Absolute Delay Reduction (seconds/vehicle)**	**Delay Reduction (%)**
Average	3.36	12.09	2490.90	188.44	133.44	0.64
Min	0.55	4.00	575.33	28.70	2.08	0.18
Max	7.50	26.00	4849.81	1058.07	947.85	1.23
Standard Deviation	2.27	5.96	904.30	190.57	170.50	0.24

Relationships between the dependent and independent variables were deemed non-linear. As such, various transformations and combinations of the descriptor variables were tested in an effort to fit these variables into a linear modeling framework (i.e., multi-variate linear regression). The final model used to predict the delay reduction per vehicle was determined by finding the highest coefficient of determination (R2) using these transformed/combined descriptor variables (hereafter referred to as nonlinear expressions) as independent variables in the regression analysis. The nonlinear expressions providing the most accurate prediction of delay reduction are shown in the table below. These nonlinear expressions are given names for convenience of discussion of the regressions analysis.

Table 5. Nonlinear Expressions

Nonlinear Expression	Name of Expression
$\log(VI)^2$	Log vehicles managed per hour squared
VI	Vehicles managed per hour
$\frac{D}{I}$	Existing delay per intersection per vehicle

Corridor length and average intersection spacing along the corridor was considered initially as a potential descriptor in this model. However, results from preliminary regression analyses showed that fits to this parameter had a p-value much higher than 0.1, indicating that inclusion of this parameter did not statistically improve the model's performance. Considering that the output of the model is the absolute reduction in delay along the corridor, it is reasonable that intersection spacing overall would not greatly affect the ability of the adaptive system to reduce delay. This parameter was therefore not included in the final model used in the tool.

Thus, the basic form of the linear regression equation that predicts absolute reduction in delay per vehicle as a result of deployment of ATCS on a corridor is as follows:

$$\Delta_{delay} = \beta_0 + \left(\beta_1 \log(V \cdot I)^2 + \beta_2 (V \cdot I)\right) + \beta_3 \frac{D}{I} + \varepsilon \quad (1)$$

Where

Δ_{delay}: Delay reduction per vehicle in seconds
β_n: Coefficients of regression
V: Hourly vehicle volume
I: Number of intersections
D: Existing delay in seconds
ε: Error of regression

Table 6: Coefficients of Regression Statistics

Expression	Symbol	Coefficient	Standard Error	t Statistic	P-value
Intercept	B_0	-480	76	-6.3	<0.001
Log vehicles managed per hour squared	$\log(V \cdot I)^2$	30	4.8	6.3	<0.001
Vehicles managed per hour	$V \cdot I$	-3.7×10^{-3}	6.3	-5.8	<0.001
Existing delay per intersection per vehicle	D/I	4.4	0.48	9.1	<0.001

Table 7: Regression Statistics

Regression Statistics	
Adjusted R^2	0.71
Standard Error	24
Observations	48

The final relationship used to estimate the delay reduction in this tool is given by Equation 2:

$$\Delta_{delay} = -480 + \left(30\log(V \cdot I)^2 - (3.7 \times 10^{-3})(V \cdot I)\right) + 4.4\frac{D}{I} \quad (2)$$

While this regression equation works well for situations where most of the delay per vehicle is caused by traffic lights, it may overestimate benefits where vehicle volumes approach roadway capacity. In practice, adaptive systems are not as effective in reducing delay on overly congested corridors.

Emission Reduction

Emissions reductions are estimated by computing an increase in average speed as a result of the overall delay reduction on the corridor. The emissions data obtained from the MOVES model are based on average speeds across the fleet of vehicles on the modelled links of roadway. Thus the emissions rates at different average speeds most closely aligns with the emissions data available in the tool.

To estimate the change in emissions from average speed increase, the average speed before ATCS deployment is calculated from user input free flow travel speed and existing delay values. The travel time after deployment is calculated by subtracting the predicted delay reduction from calculated travel time before deployment to obtain a resultant travel time after deployment. Then, the average speed after deployment is calculated by dividing the corridor length by the travel time after deployment. These calculations are shown in Equations 5 through 7:

$$\text{Speed Before} = \frac{\text{L}}{\text{T Before}} \quad (3)$$

$$\text{T After} = \text{T Before} - \Delta_{delay} \quad (4)$$

$$\text{Speed After} = \frac{\text{L}}{\text{T After}} \quad (5)$$

where:

Speed Before: The average speed before deployment in miles per hour
L: The length of the corridor in miles
T Before: The average time to traverse the corridor before deployment in hours
T After: The average time to traverse the corridor after deployment in hours
Speed After: The average speed after deployment in miles per hour

Once the average speeds before and after deployment are calculated, the emissions benefit can be calculated using Equation 8, in which the emissions factors per distance traveled at the speeds before and after the ATCS deployment are subtracted and multiplied by the length of the corridor and the volume of vehicles traveling in both directions along the corridor.

$$\begin{aligned}\Delta Emissions = {} & Emission\ Rate(Speed\ Before) \times Volume\ per\ hour \times L \\ & - Emission\ Rate(Speed\ After) \times Volume\ per\ hour \times L\end{aligned} \quad (6)$$

The change in emissions is computed separately for heavy and light duty vehicles, and separately for peak and non-peak hours of the day. Final daily emissions benefits are then calculated by multiplying the change in emissions per hour for the peak and non-peak hours by the number of hours per day of those periods.

USER-SUPPLIED EMISSION RATES

Some users may wish to incorporate local data into the tool's emission rates. For those unfamiliar with developing local MOVES runs, please refer to EPA's mobile-source emissions modeling guidance and documentation for highway vehicles.[4] Take the following steps to replace default emission rates in the ATCS Tool:

1. The MOVES output data need to be reformatted so that they can be used in the tool. The details on post processing these output data are described below:
    - Unhide the 'emissionsRates' tab in Excel and ensure that the MOVES output has the following parameters: yearID, pollutantID, linkID, speed, and roadTypeID. As noted earlier, the linkID is concatenated from the roadTypeID (one digit) and speed (2 digits) ranging between 0 and 75 miles per hour. For light-duty emission rates, post-processed data should include only passenger cars (sourceTypeID 21), passenger trucks (sourceTypeID 31), and light commercial trucks (sourceTypeID 32). For heavy-duty emission rates, post-processed data should include all buses (sourceTypeID, 41, 42, and 43), single unit trucks (sourceTypeID 51, 52, 53, and 54), and combination trucks (sourceTypeID 61 and 62).

      Note that light-duty and heavy-duty rates are separated by 'classID', where classID 1 denotes light-duty and classID 2 denotes heavy-duty. These values are assigned during the post-processing of emissions rates. Assign heavy and light duty rates to the appropriate classifications.
    - From a local MOVES run, aggregate the emission quantities in the movesoutput table by year, pollutant, speed, and road type. To include emissions from evaporative emissions, include processIDs 11, 13, 18, and 19 on roadTypeID 1, 2, 3, 4, and 5.
    - Incorporate brakewear and tirewear PM emissions in total PM emissions. For PM10 emissions, change pollutantIDs 106 and 107 to 100. For PM2.5, change pollutantIDs 116 and 117 to 110.
    - After these pollutantIDs have been changed, sum the emission quantities again to ensure a unique combination of fields exist in the post-processed data.
    - Extract vehicle miles traveled (VMT) from the movesactivityoutput table (activityTypeID 1) by year, speed, and road type.
    - Separately merge the emission inventories from the movesoutput table and the VMT estimates from the movesactivityoutput table using year and link for light-duty and heavy-duty vehicles by the source type filters indicated in the table.
    - Include a column in the post-processed data for each emission rate. Emission rates are calculated by dividing emission quantity by VMT or by source hours operating for each unique combination of year, pollutant, and link.
    - Be sure to define unit columns where appropriate, namely massUnits (kg), time units (hr), distanceUnits (mi), and rateUnits (kg/mi, kg/hr).

    The local MOVES output data should now be structured and labeled in exactly the same way as the national default output data initially used in the tool. Export the post-processed local emission rates in .csv or .xlsx file format, one for light-duty vehicles and another for heavy-duty vehicles.

2. Delete any data (keep the title of the columns the same) in the tool's existing rates tab and then copy and paste the appropriate exported local emission rates into the existing worksheet with the same table

[4] EPA, https://www.epa.gov/moves/tools-develop-or-convert-moves-inputs

format. Save the ATCS Tool under a different name and verify that it produces expected results with local emission rates.

Appendix

References

The following list cites the studies used in the development of the regression model to predict delay reduction in this tool.

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13. TJKM. (2016). *Shoreline Adaptive Signal System Final Corridor Performance and Evaluation Report City of Mountain View*. https://trafficbot.rhythmtraffic.com/wp-content/uploads/MountainView-CA-TJKM.pdf.

Data Used in Regression Analysis

City or County	Data point Description	Corridor Length (miles)	Number of Intersections	Hourly Volume	Existing Delay (s/veh)	Log Vehicle Service Rate Squared	Vehicle Service Rate	Delay Per Intersection	Intersection Density	Delay Reduction - Absolute (s/veh)
Maricopa County AZ	Segment 1 AM	7.40	21	2396	76.92	22.11	50324.73	3.66	0.35	19.10
Maricopa County AZ	Segment 1 MD	7.40	21	3347	240.87	23.49	70290.39	11.47	0.35	57.75
Maricopa County AZ	Segment 1 Weekend	7.40	21	3327	202.97	23.47	69869.07	9.67	0.35	14.88
Maricopa County AZ	Segment 1 Event	7.40	21	3023	86.78	23.07	63489.68	4.13	0.35	19.19
Maricopa County AZ	Segment 2 AM	3.14	13	2998	77.04	21.07	38968.48	5.93	0.24	40.52
Maricopa County AZ	Segment 2 MD	3.14	13	3599	219.37	21.81	46784.70	16.87	0.24	81.04
Maricopa County AZ	Segment 2 Weekend	3.14	13	3630	181.88	21.84	47188.29	13.99	0.24	26.36
Miami-Dade County FL	AM	7.50	26	2954	878.82	23.87	76791.00	33.80	0.29	121.89
Miami-Dade County FL	MD	7.50	26	3043	688.53	23.99	79118.00	26.48	0.29	36.67
Longmont CO 1	AM	6.50	13	1814	208.10	19.12	23579.73	16.01	0.50	91.15
Longmont CO 1	MD	6.50	13	1851	239.50	19.20	24059.60	18.42	0.50	129.45
Longmont CO 1	PM	6.50	13	2263	309.00	19.97	29416.58	23.77	0.50	141.35
Longmont CO 2	AM	5.00	21	1549	230.40	20.36	32524.30	10.97	0.24	60.90
Longmont CO 2	MD	5.00	21	1742	280.65	20.82	36581.62	13.36	0.24	42.65
Longmont CO 2	PM	5.00	21	2090	309.95	21.55	43883.62	14.76	0.24	24.90
Pinellas FL 66St	AM	5.00	12	2600	310.96	20.20	31200.00	25.91	0.42	154.90
Pinellas FL 66St	MD	5.00	12	2671	332.84	20.30	32055.00	27.74	0.42	145.61
Pinellas FL 66St	PM	5.00	12	2823	342.36	20.52	33870.00	28.53	0.42	140.30
San Ramon CA	Segment Bollinger Canyon AM	0.55	5	2555.125	48.65	16.86	12775.63	9.73	0.11	29.5
San Ramon CA	Segment Bollinger Canyon OP	0.55	5	1950.125	28.7	15.91	9750.63	5.74	0.11	3.85
San Ramon CA	Segment Bollinger Canyon MD	0.55	5	2097.375	59.2	16.17	10486.88	11.84	0.11	35.05
San Ramon CA	Segment Bollinger Canyon PM	0.55	5	2854.5	63.30	17.26	14272.50	12.66	0.11	33.45
San Ramon CA	Segment Crow Canyon AM	0.59	5	2413.75	44.7	16.66	12068.75	8.94	0.12	31.15

City or County	Data point Description	Corridor Length (miles)	Number of Intersections	Hourly Volume	Existing Delay (s/veh)	Log Vehicle Service Rate Squared	Vehicle Service Rate	Delay Per Intersection	Intersection Density	Delay Reduction - Absolute (s/veh)
San Ramon CA	Segment Crow Canyon OP	0.59	5	2047.875	43.5	16.08	10239.38	8.70	0.12	23.05
San Ramon CA	Segment Crow Canyon MD	0.59	5	2229.125	72.6	16.38	11145.63	14.52	0.12	41.3
San Ramon CA	Segment Crow Canyon PM	0.59	5	2861.25	77.35	17.27	14306.25	15.47	0.12	27.65
Lees Summit MO	AM peak	2.5	12	1550	102.65	18.23	18604.00	8.55	0.21	50.35
Lees Summit MO	AM off peak	2.5	12	1454	115.65	17.99	17444.00	9.64	0.21	72.25
Lees Summit MO	noon peak	2.5	12	1801	163.10	18.79	21612.00	13.59	0.21	101.95
Lees Summit MO	PM peak	2.5	12	2124	127.35	19.42	25484.00	10.61	0.21	49.7
Mt Pleasant SC	PM Peak	1.7	6	3500	44.00	18.68	21000.00	7.33	0.28	31.50
Greeley CO	AM	3.2	11	1472	77.75	17.72	16187.11	7.07	0.29	25.6
Greeley CO	AM off peak	3.2	11	1553	84.25	17.91	17079.33	7.66	0.29	7.45
Greeley CO	MD	3.2	11	1937	120.75	18.74	21310.67	10.98	0.29	48.6
Greeley CO	PM off peak 1	3.2	11	1985	152	18.83	21833.17	13.82	0.29	60.2
Greeley CO	PM	3.2	11	2123	106.75	19.08	23348.11	9.70	0.29	9.95
Greeley CO	PM off peak 2	3.2	11	1155	96.75	16.84	12703.17	8.80	0.29	20.45
Teays Vally WV	AM	0.64	4	1786.5	84.50	14.85	7146.00	21.13	0.16	42.00
Teays Vally WV	PM	0.64	4	2107.666667	87.00	15.41	8430.67	21.75	0.16	52.00
Teays Vally WV	MD	0.64	4	2444.5	106.50	15.92	9778.00	26.63	0.16	65.50
Wauwatosa WI	AM	1.5	6	1399.2	48.5	15.40	8395.20	8.08	0.25	14
Wauwatosa WI	MD	1.5	6	1496.018462	61	15.63	8976.11	10.17	0.25	16.5
Wauwatosa WI	PM	1.5	6	2045.673846	126.5	16.72	12274.04	21.08	0.25	43
SanJuan NM	AM	2.3	11	2272.5	51.00	19.34	24997.50	4.64	0.21	42.00
SanJuan NM	PM	2.3	11	3829.5	115.50	21.39	42124.50	10.50	0.21	86.50
SanJuan NM	Sat	2.3	11	4033.5	102.00	21.60	44368.50	9.27	0.21	68.50
Mountain View CA	AM	2.5	15	1956.5	327.50	19.96	29347.50	21.83	0.17	146.00
Mountain View CA	PM	2.5	15	2476.5	289.50	20.88	37147.50	19.30	0.17	154.00