CMAQ EMISSIONS CALCULATOR TOOLKIT

The purpose of the Congestion Mitigation and Air Quality Improvement Program Emissions Calculator Toolkit (CMAQ Toolkit) is to provide users a standardized approach for estimating emission reductions from the implementation of a CMAQ-funded project. The CMAQ Toolkit uses emission rates for highway vehicles based on a series of project-scale and default-scale runs of the Motor Vehicle Emission Simulator (MOVES[1]) as well as other data sources. For each tool in the Toolkit, the inputs and methodology are described in user guides along with some example cases. Emission estimates from the CMAQ Toolkit are not intended to meet specific requirements for State Implementation Plans (SIPs) or transportation conformity analyses. Information regarding the development of default emission rates and guidance on building regressions to predict relationships between traffic conditions and emissions can be found in the accompanying documentation of emissions modeling details.

Travel Advisories Tool

This tool provides estimates of emission reductions for CMAQ-funded projects that reduce emissions due to implementation of travel advisories and the corresponding change in driving behavior.[2]

Travel advisories are comprised of signage that provides traveler information messages. Travel advisories can take many shapes ranging from signage, to radio messages, to in-app alerts, and serve the purpose of alerting drivers of upcoming roadway conditions. The specific travel advisory types this tool currently accommodates are variable message signs (VMS) and variable speed limits (VSL). VMS often provide warnings about temporary road events such as congestion, construction, or inclement weather, while VSL adjust the permitted speed to make travel conditions safer in response to roadway conditions.

Travel advisories can contribute to reduced emissions by modifying driving behavior and tend to smooth the driving cycle. VMS and VSL prepare drivers for upcoming roadway conditions which provides drivers with time to prepare for hazards or slow-downs, resulting in reduced hard breaking and acceleration patterns. While these two travel advisories take different approaches, their effect is quite similar. Both generally result in fewer speed variations.[3]

This document is organized into four sections—User Guide, Tool Methodology, Examples, and Resources—to aid the user in selecting inputs and interpreting results from the emissions calculator tool. The User Guide provides definitions of user inputs and tool outputs as well as direction on how to properly input values into the tool. The Tool Methodology section outlines how the tool calculates emission reductions, as well as any associated assumptions. The Examples section provides instructive examples of how to use the tool for project analysis. The Resources section provides information on references used to develop the Travel Advisories Tool and other tools that may be helpful to users.

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[1] https://www.epa.gov/moves

[2] The current version of the Travel Advisories Tool is dated April 2022.

[3] Lee, C., Abdel-Aty, M., 2008. Testing Effects of Warning Messages and Variable Speed Limits on Driver Behavior Using Driving Simulator: Transportation Research Record. https://doi.org/10.3141/2069-08

Please note that the current version of the Travel Advisories Tool is not intended to be used to estimate reductions in vehicle miles traveled (VMT) resulting from mode shift, for example due to air quality alerts. This feature may be added in a future version of the Tool.

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USER GUIDE

This section describes each user input and tool output as well as error messages and key assumptions present in the tool.

User Inputs

The Travel Advisories Tool contains a series of questions to guide the user in properly inputting information for emission reductions calculations in a step-by-step process. The user-defined inputs are described in Table 1. All volume inputs should encompass the traffic experienced across all lanes for one direction of traffic.

Table 1: User Inputs

Item	User Input	Units	Description
(1)	Project evaluation year	-----	Use the drop-down menu to choose a year between 2018 and 2040.
(2)	Period of activity	-----	Use the drop-down menu to select either "Only Peak Hours" or "Peak and Non-Peak Hours".
(3)	Hours of activity (peak hours)	hrs/day	Enter the average number of peak hours that the travel advisory is active per day.
	Hours of activity (non-peak hours)*	hrs/day	**Optional**: Enter the average number of non-peak hours that the travel advisory is active per day. By default, this tool will only provide smoothing benefits for up to 6 hours of non-peak hour tool operation, although users can enter a higher number. A description of this design decision can be found following this table. **Note**: The default value of 6 hours can be modified through the *Optional Adjust Defaults* selection.
(4)	Before TA – peak traffic volume	veh/hr	Enter the average hourly throughput before conversion during peak hours (for the hours of active travel advisories only). **Note**: Total volume for all lanes should be entered. However, Example 2 provides details on how to conduct a per lane evaluation.
	Before TA – non-peak traffic volume	veh/hr	Enter the average hourly throughput before conversion during non-peak hours (for the hours of active travel advisories only). **Note**: Total volume for all lanes should be entered. However, Example 2 provides details on how to conduct a per lane evaluation.

Item	User Input	Units	Description
	Before TA – peak speed	mph	Enter the average speed during peak hours that is currently experienced across the stretch of roadway that will be impacted by travel advisories (for the hours of active travel advisories only).
	Before TA – non-peak speed*	mph	**Optional**: Enter the average speed during non-peak hours that are currently experienced across the stretch of roadway that will be impacted by travel advisories (for the hours of active travel advisories only).
	After TA – peak traffic volume*	veh/hr	**Optional**: Enter the average hourly throughput after conversion during peak hours if anticipated to be significantly different from existing conditions (for the hours of active travel advisories only). **Note**: Total volume for all lanes should be entered. However, Example 2 provides details on how to conduct a per lane evaluation.
	After TA – non-peak traffic volume*	veh/hr	**Optional**: Enter the average hourly throughput after conversion during non-peak hours if anticipated to be significantly different from existing conditions (for the hours of active travel advisories only). **Note**: Total volume for all lanes should be entered. However, Example 2 provides details on how to conduct a per lane evaluation.
	After TA – peak speed*	mph	**Optional**: Enter the average speed expected during peak hours across the stretch of roadway that will be impacted by travel advisories if it is anticipated to be significantly different from existing conditions (for the hours of active travel advisories only).
	After TA – non-peak speed*	mph	**Optional**: Enter the average speed expected during non-peak hours across the stretch of roadway that will be impacted by travel advisories if it is anticipated to be significantly different from existing conditions (for the hours of active travel advisories only).
(5)	Corridor length	mi	Enter the total number of miles that Travel Advisories impact the roadway.
(6)	Heavy duty traffic	%	Enter the average percentage of heavy-duty traffic out of total hourly throughput for the hours of active travel advisories in the area impacted by the travel advisories.

Item	User Input	Units	Description
(7) **Optional:** Adjust Defaults	Adjust defaults	-----	Select from the drop-down menu whether you choose to "Use Defaults" or "Adjust Defaults" for the variables of Smoothing Factor and Number of Non-Peak Smoothing Hours.
	Smoothing factor*	-----	Standard MOVES drive cycles were smoothed using a smoothing spline function with a lambda value of 0.22999. More details on how the default value was selected is available in the *Drive Cycle Smoothing* Section. Currently, the tool will not accept smoothing values greater than the default; however, if you have reason to believe that traffic on your corridor would be smoothed less than the default, a lower lambda value can be entered instead.
	Number of non-peak smoothing hours*	hrs/day	As a default, the tool limits the benefits gained from travel advisories during non-peak hours to 6 hours. This was selected on the basis that a common daily traffic pattern involves a morning and afternoon peak, with several hours of non-peak during the midday. Although not peak, this midday period receives a high enough traffic volume that travel advisories may still have smoothing effects. If you have reason to believe that your corridor benefits from greater or fewer non-peak smoothing hours, a different value between 0 and 12 (inclusive) can be entered instead.

*Optional user inputs

Volume and average speed data may be either modeled or measured. If available, measurements from traffic counters, video footage, or other roadside sensors provide the most accurate traffic condition estimates. When measurements are not readily available, traffic conditions can be estimated using travel demand models or traffic microsimulations. Average speeds can be obtained from traffic sensors, or if necessary, assumed to be the posted speed limit. Reasonable traffic volumes and speeds can be found in the Highway Capacity Manual.[4]

This tool incorporates smoothing benefits for all peak hours (based on the number of peak hours entered by the user) and for up to six hours of non-peak hours. The six hours of non-peak conditions represent smoothing benefits that may be gained from midday operation of travel advisories, or non-peak hours outside of morning/even peak hours. The tool limits the non-peak smoothing benefits gained from overnight operation of travel advisories since these benefits are expected to be negligible. This six-hour default can be adjusted using the *Optional: Adjust Defaults* item.

[4] Highway Capacity Manual 6th Edition: A Guide for Multimodal Mobility Analysis. Washington, DC: The National Academies Press. https://doi.org/10.17226/24798.

Drive Cycle Smoothing

In the case of this tool, *smoothing* refers to a smoothing spline function (Equation 1) that has been applied to default MOVES drive cycles. This function moderately reduces variations in the speed profile. The lambda (λ) value, which could theoretically range from 0 to 1, determines the magnitude of smoothing which has been applied to the drive cycle, with smaller values representing less impact. The default lambda value used in this tool is 0.22999 based on research conducted by Liu et al. regarding the smoothing impacts of connected and autonomous vehicles.[5] Since this research centered around a mixed fleet of connected and autonomous vehicles, lambda values greater than 0.22999 are not accepted in the *Optional: Adjust Defaults* item; however, the default can be adjusted to be lower if the user anticipates a smaller amount of smoothing as a result of their travel advisory implementation.

$$\sum_{i=1}^{n}(y_i - f(x))^2 + \lambda \int f''(x)^2 dx \quad \textbf{(1)}$$

While mathematically a lambda of zero would still result in some smoothing according to Equation 1, it should be noted that this tool interprets a user input of lambda equal to zero as no smoothing.

Tool Outputs

Outputs of this tool include emissions reductions and changes to network performance (network performance changes are only measured if the optional 'After' inputs are used). The output fields will not automatically update when inputs are changed. Users must click the 'Calculate Output' button to recalculate results. To return to default settings and clear all inputs, the user must click on the 'Reset to Default Values' button located at the top right of the interface.

For emissions outputs, the tool calculates reductions for five pollutants—carbon monoxide (CO), nitrogen oxides (NO_X), particulate matter with diameters ≤ 2.5 µm ($PM_{2.5}$), particulate matter with diameters ≤ 10 µm (PM_{10}), and volatile organic compounds (VOC) —in kilograms per day (kg/day) for CMAQ reporting. Reductions in carbon dioxide equivalents (CO_2e) and total energy consumption are also provided in in kg/day and millions of British Thermal Units per day (MMBTU/day), respectively. Emissions reductions represent the change in emissions resulting from the implementation of travel advisories. For all pollutants, a positive emission reduction can be interpreted as a decrease in emissions (or a benefit) whereas a negative emissions reduction can be interpreted as an increase in emissions (or a disbenefit) resulting from the travel advisories.

For network performance outputs, the tool calculates the average speed improvement, total estimated travel time savings, total traffic throughput increases, and traffic density reduction for the hours of

[5] Liu, J., Kockelman, K., Nichols, A., 2017. Anticipating the Emissions Impacts of Smoother Driving by Connected and Autonomous Vehicles, Using the MOVES Model. Presented at the Transportation Research Board 96th Annual Meeting.

active travel advisories resulting from the implementation of travel advisories. Equations for changes in network performance and emissions reductions are described in detail in the Tool Methodology section.

Error Messages

Table 2 below lists error messages that the user may encounter in this tool and the solution. Once an error is corrected, the user must click 'Calculate Output' again to recalculate the results. Note that the 'After' fields in Question 4 are optional. Users who do not wish to enter data for 'After' conditions should ensure that the checkbox below the data entry box is unchecked.

Table 2: Error Messages

Error Message	Solution
Please enter a valid evaluation year.	Select a project evaluation year from the drop-down menu.
Please select an activity period in Question 2.	Select 'Only Peak Hours' or 'Peak and Non-Peak Hours' from the drop-down menu.
Please enter the number of hours the Travel Advisory is active.	Enter the number of hours that the Travel Advisory is active. Note: Peak and non-peak hours must add up to 24 or less.
The total value for Peak and Non-Peak hours must be 24 hours or less.	The sum of values entered for peak hours and non-peak hours when the travel advisory is active must be 24 or less.
Please enter the peak traffic volume for before Travel Advisories implementation.	Enter the average number of vehicles per hour. The tool accepts values between 1 and 20,000 veh/hr (inclusive).
Please enter the average peak speed before Travel Advisories implementation.	Enter the average speed across all lanes in mph. The tool accepts values between 30 and 85 mph (inclusive).
Please enter the non-peak traffic volume for before Travel Advisories implementation.	Enter the average number of vehicles per hour. The tool accepts values between 1 and 20,000 veh/hr (inclusive).
Please enter the average non-peak speed before Travel Advisories implementation.	Enter the average speed across all lanes in mph. The tool accepts values between 30 and 85 mph (inclusive).
Please enter the peak traffic volume for after Travel Advisories implementation.	Enter the average number of vehicles per hour. The tool accepts values between 1 and 20,000 veh/hr (inclusive).
Please enter the peak average speed for after Travel Advisories implementation.	Enter the average speed across all lanes in mph. The tool accepts values between 30 and 85 mph (inclusive).
Please enter the average non-peak volume for after Travel Advisories implementation.	Enter the average number of vehicles per hour. The tool accepts values between 1 and 20,000 veh/hr (inclusive).
Please enter the average non-peak speed for after Travel Advisories implementation.	Enter the average speed across all lanes in mph. The tool accepts values between 30 and 85 mph (inclusive).
Please enter the length of the facility.	Enter the length for which the travel advisory(ies) is expected to impact travel behavior. The tool accepts values between 0.1 and 1,000 miles (inclusive).

Error Message	Solution
Please enter the percentage of heavy-duty traffic.	Enter the percentage of heavy-duty traffic in terms of total throughput. The tool accepts values between 0 and 25 percent (inclusive).
ERROR: Please select a year from the drop-down menu.	Select a project year from the drop-down menu.
ERROR: Please enter a valid number of peak hours between 0 and 24.	The number of hours cannot exceed 24.
ERROR: Please enter a non-zero value for hours active during non-peak hours or select only peak hours in question 2.	If "Peak and Non-Peak Hours" is selected in Question 2, then both boxes in Question 3 must contain a value greater than zero.
ERROR: This tool only accepts traffic volumes between 1 and 20,000 veh/hr.	Enter a traffic volume between 1 and 20,000 veh/hr (inclusive).
ERROR: This tool only accepts speeds between 30 and 85 mph.	Enter a speed between 30 and 85 mph (inclusive).
ERROR: This tool only accepts distances between 0.1 and 1000 miles.	Enter a distance between 0.1 and 1000 miles (inclusive).
ERROR: This tool only accepts heavy-duty percentages between 0 and 25 percent.	Enter a percentage between 0 and 25 percent (inclusive).
ERROR: This tool does not accept negative values.	Change any negative input values to positive values.
ERROR: Please select an option from the drop-down menu.	Please select "Only Peak Hours" or "Peak and Non-Peak Hours" from the drop-down menu.
ERROR: This tool only accepts smoothing factors between 0 and 0.22999	Enter a value between 0 and 0.22999 (inclusive).
ERROR: This tool only allows a smoothing benefit to apply to a number of Non-Peak Hours between 0 and 12.	Smoothing benefits will apply to a maximum of 12 non-peak hours. For an explanation of the reasoning behind this decision, please see the User Inputs section.
NOTE: You have entered a value greater than 6 for Non-Peak hours of operation. Default settings only allow smoothing benefits for up to 6 hours of non-peak Travel Advisory activity. You can modify this default setting in Question 7.	This is just an alert, and the calculations will complete once the user clicks "OK".

TOOL METHODOLOGY

This section explains the tool methodology, while the accompanying *Emissions Data Document* includes further details on building the MOVES models, the multivariable linear regressions (MLR), and any pre- or post-processing formulas used.

Emissions Reductions

MOVES3 was used for default-scale runs to generate the necessary input data for project-level runs using different drive cycles. The default-scale runs were used to differentiate between the emissions rates from the different drive cycles used in this tool.

A smoothing spline function, described previously in Equation 1 in the User Guide section, was applied to the drive cycles using different values of lambda to allow users the option to modify the default value. The lambda values used in development were 0.22999, 0.115, and 0.

These newly smoothed drive cycles were used as inputs to project-level MOVES runs along with values generated by the default-scale MOVES runs. MOVES outputs were aggregated to generate emission rates by project evaluation year, speed, and pollutant. The difference between the default emission rates and the smoothed emission rates were calculated and an MLR approach was used to estimate the emission benefit rate by pollutant based on the evaluation year, smoothing value (i.e., lambda), and average speed.

The Travel Advisories tool uses the results of the MLR to estimate the emission benefit rate for given user inputs to the tool. For each pollutant, the change in emissions (kg/day) reported in the CMAQ tool is the difference between the emissions rate before (pre-) and after (post-) implementation of the travel advisories project. There are two different calculation sets within the tool: the first calculation set addresses a simple scenario where traffic volume and speed to not change between the pre- and post-travel advisories conditions, while the second calculation set addresses a scenario where pre- and post-conditions differ. The methodology applied in the tool is explained by the series of equations below.

Emissions Benefits Due to Smoothing

$$E_{i,j} = e_{smoothed,pol} \cdot l \cdot v \cdot t \quad \textbf{(2)}$$

$$E_{Benefits,Peak,\lambda} = (E_{Benefits,HD,peak,\lambda} \times HD\%) + (E_{Benefits,LD,peak,\lambda} \times LD\%) \quad \textbf{(3)}$$

$$E_{Benefits,Non-Peak,\lambda} = (E_{Benefits,HD,Non-Peak,\lambda} \times HD\%) + (E_{Benefits,LD,Non-Peak,\lambda} \times LD\%) \quad \textbf{(4)}$$

$$E_{\ Benefits\ due\ to\ smoothing} = (E_{Benefits,Peak,\lambda} \times Peak\%) + (E_{Benefits\ ,Non-Peak,\lambda} \times Nonpeak\%) \quad \textbf{(5)}$$

Emissions Benefits Due to Changes in Traffic Conditions[6]

$$E_{i,j,k} = e_{traffic,pol} \cdot l \cdot v \cdot t \quad \textbf{(6)}$$

$$E_{pre,Peak} = (E_{pre,HD,Peak} \times HD\%) + (E_{pre,LD,Peak} \times LD\%) \quad \textbf{(7)}$$

$$E_{pre,Non-Peak} = (E_{pre,HD,Non-Peak} \times HD\%) + (E_{pre,LD,Non-Peak} \times LD\%) \quad \textbf{(8)}$$

[6] Equations only used when the user enters different traffic volumes or speeds for before and after travel advisory implementation.

$$E_{pre,Total} = (E_{pre,Peak} \times Peak\%) + (E_{pre\ ,Non-Peak} \times Nonpeak\%) \quad \textbf{(9)}$$

$$E_{post,Peak} = (E_{post,HD,Peak} \times HD\%) + (E_{post,LD,Peak} \times LD\%) \quad \textbf{(10)}$$

$$E_{post,Non-Peak} = (E_{post,HD,Non-Peak} \times HD\%) + (E_{post,LD,Non-Peak} \times LD\%) \quad \textbf{(11)}$$

$$E_{post,Total} = (E_{post,Peak} \times Peak\%) + (E_{post,Non-Peak} \times Nonpeak\%) \quad \textbf{(12)}$$

$$E_{Benefits\ due\ to\ traffic\ conditions} = E_{pre} - E_{post} \quad \textbf{(13)}$$

Total Value of Emissions Benefits

$$E_{Benefits,total} = E_{Benefits\ due\ to\ smoothing} + E_{Benefits\ due\ to\ traffic\ conditions} \quad \textbf{(14)}$$

where:

E = emission inventory (kg/day).
i = Light-duty or heavy-duty traffic
j = Peak or non-peak hours
k = Pre or Post implementation of travel advisories
e = emission rate from MLR $\left(\frac{kg}{mi} \cdot veh\right)$
l = length of roadway impacted by travel advisories (*mi*)
v = volume (*veh/hr*)
t = hours operated (*hr*)
HD% = Percent of heavy-duty vehicles
LD% = Percent of light-duty vehicles
Peak% = Percent peak hours per day $(\frac{No.\ Peak\ Hours}{24\ Hours} \times 100)$
Nonpeak% = Percent non-peak hours per day $(\frac{No.\ Non-peak\ Hours}{24\ Hours} \times 100)$
Emission benefits = The output provided by the tool (*kg/day*) where a positive result represents an emissions reduction, and a negative result represents an emissions increase

Network Performance

The change in average speed in miles per hour (mph) is the difference in the user-input values for average speed before versus after implementation of the travel advisory project.

$$\begin{aligned} &average\ daily\ speed \\ &\quad = [(average\ peak\ hour\ speed\ \times no.of\ peak\ hours\ per\ day) \\ &\quad + (average\ nonpeak\ hour\ speed \times no.of\ nonpeak\ hours\ per\ day)] \\ &\quad \div no.of\ active\ travel\ advisory\ hours\ per\ day \end{aligned} \quad \textbf{(15)}$$

$$average\ speed\ improvement = average\ daily\ speed_{after} - average\ daily\ speed_{before} \quad \textbf{(16)}$$

Total travel time in minutes is calculated from the user inputs by dividing the travel advisories impact length (in miles) by the average speed (in mph) and applying the appropriate conversion factor.

$$\begin{aligned} &\Delta\ peak\ total\ travel\ time \\ &\quad = traffic\ volume_{after}\left(\frac{facility\ length}{average\ speed_{after}} \times 60\frac{min}{hr}\right) \\ &\quad - traffic\ volume_{before}\left(\frac{facility\ length}{average\ speed_{before}} \times 60\frac{min}{hr}\right) \end{aligned} \quad \textbf{(17)}$$

$$\begin{aligned} &\Delta\ nonpeak\ total\ travel\ time \\ &\quad = traffic\ volume_{after}\left(\frac{facility\ length}{average\ speed_{after}} \times 60\frac{min}{hr}\right) \\ &\quad - traffic\ volume_{before}\left(\frac{facility\ length}{average\ speed_{before}} \times 60\frac{min}{hr}\right) \end{aligned} \quad \textbf{(18)}$$

$$\begin{aligned} &Total\ Daily\ Travel\ Time\ Savings \\ &\quad = (\Delta\ peak\ total\ travel\ time\ \times no.peak\ hours) \\ &\quad + (\Delta\ nonpeak\ total\ travel\ time\ \times no.nonpeak\ hours) \end{aligned} \quad \textbf{(19)}$$

Total traffic hourly throughput in vehicles per hour (veh/day) is calculated by subtracting the traffic volume after implementation of travel advisories from the volume before.

$$\Delta\ peak\ throughput = peak\ throughput_{after} - peak\ throughput_{before} \quad \textbf{(20)}$$

$$\Delta\ nonpeak\ throughput = nonpeak\ throughput_{after} - nonpeak\ throughput_{before} \quad \textbf{(21)}$$

$$\begin{aligned} &Total\ Traffic\ Throughput\ Increase \\ &\quad = (\Delta\ throughput_{peak} \times no.peak\ hours) \\ &\quad + (\Delta\ throughput_{non-peak} \times no.nonpeak\ hours) \end{aligned} \quad \textbf{(22)}$$

Lastly, traffic density in vehicles per mile (veh/mi) is calculated from the user-supplied average speed (in mph) and total hourly traffic throughput (in veh/hr) that is calculated within the tool and described above. Traffic density is the total hourly traffic throughput divided by the average speed.

$$\Delta\ peak\ traffic\ density = \left(\frac{\Delta\ peak\ throughput}{average\ peak\ speed_{after}}\right) - \left(\frac{\Delta\ peak\ throughput}{average\ peak\ speed_{before}}\right) \quad \textbf{(23)}$$

$$\begin{aligned} &\Delta\ nonpeak\ traffic\ density \\ &\quad = \left(\frac{\Delta\ nonpeak\ throughput}{average\ nonpeak\ speed_{after}}\right) - \left(\frac{\Delta\ nonpeak\ throughput}{average\ nonpeak\ speed_{before}}\right) \end{aligned} \quad \textbf{(24)}$$

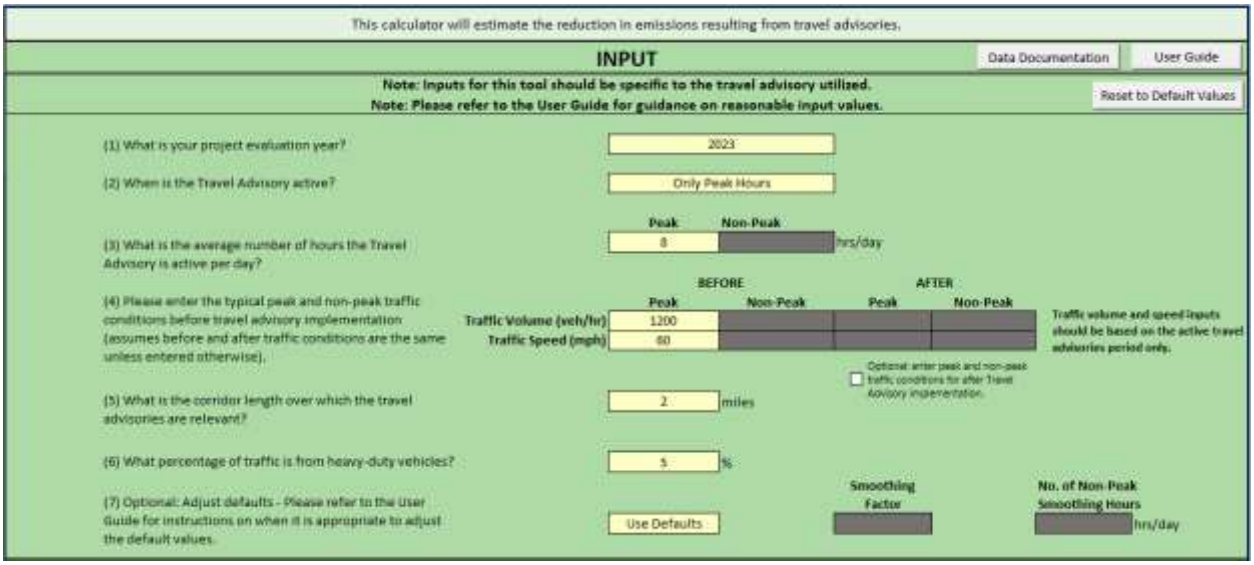
$$\begin{aligned} &Traffic\ density\ reduction \\ &\quad = (\Delta\ peak\ traffic\ density\ \times no.peak\ hours) \\ &\quad + (\Delta\ nonpeak\ traffic\ density\ \times no.\ nonpeak\ hours) \end{aligned} \quad \textbf{(25)}$$

EXAMPLES

Example 1: Peak Hour Operation Only

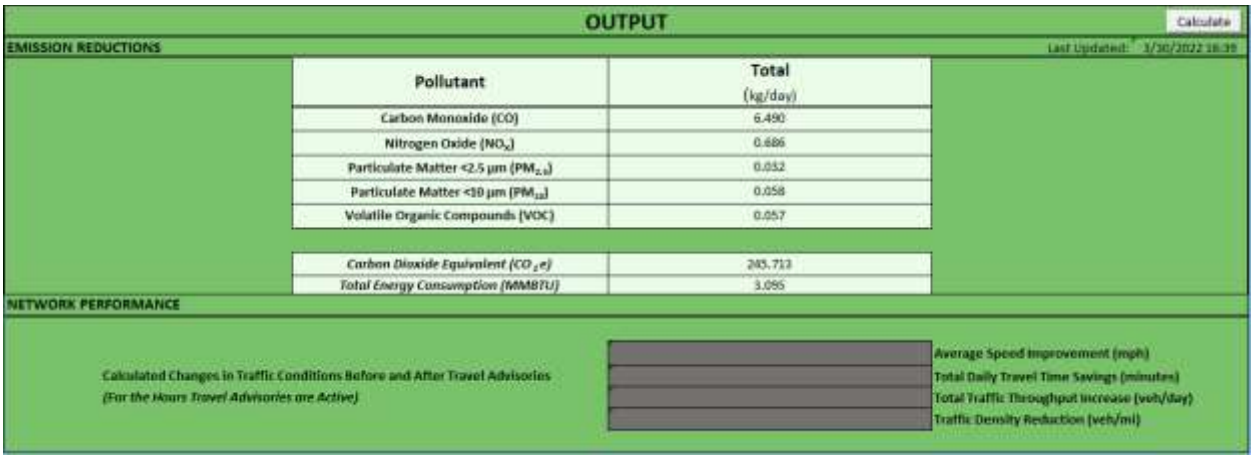
A highway agency plans to install a VMS in 2023 which will be used to warn traffic of upcoming congestion, incidents, or significant weather events. It is expected that the sign will influence traffic for a two-mile section of the highway. The agency knows that this section of roadway experiences approximately 1,200 veh/hr across all lanes with an average speed of 60 mph during peak hours. The roadway typically experiences peak hour conditions for 8 hours per day with 5% heavy-duty traffic. The addition of a VMS is not expected to modify traffic volume or speed, but it is expected to cause drive cycle smoothing.

Based on this proposed project description, the user would enter the following inputs:



Project Evaluation Year: 2023
Activity Period: Only Peak Hours
Active Hours (Peak): 8
Peak Traffic Volume (veh/hr): 1,200
Peak Traffic Speed (mph): 60
Length of Corridor (mi): 2
Percent of heavy-duty vehicles: 5
Optional: Use Defaults

Once inputs are entered, clicking the 'Calculate' button generates the following emission reductions and network performance results:



Emission Reductions (kg/day)

CO: 6.490
NO_X: 0.686
$PM_{2.5}$: 0.032
PM_{10}: 0.058
VOC: 0.057
CO_2e: 245.713
Total Energy Consumption (MMBTU/day): 3.095

Changes in Network Performance

Average Speed Improvement (mph): 0.00
Total Daily Travel Time Savings (min): 0.00
Total Traffic Throughput Increase (veh/hr): 0.00
Total Traffic Density Reduction (veh/mi): 0.00

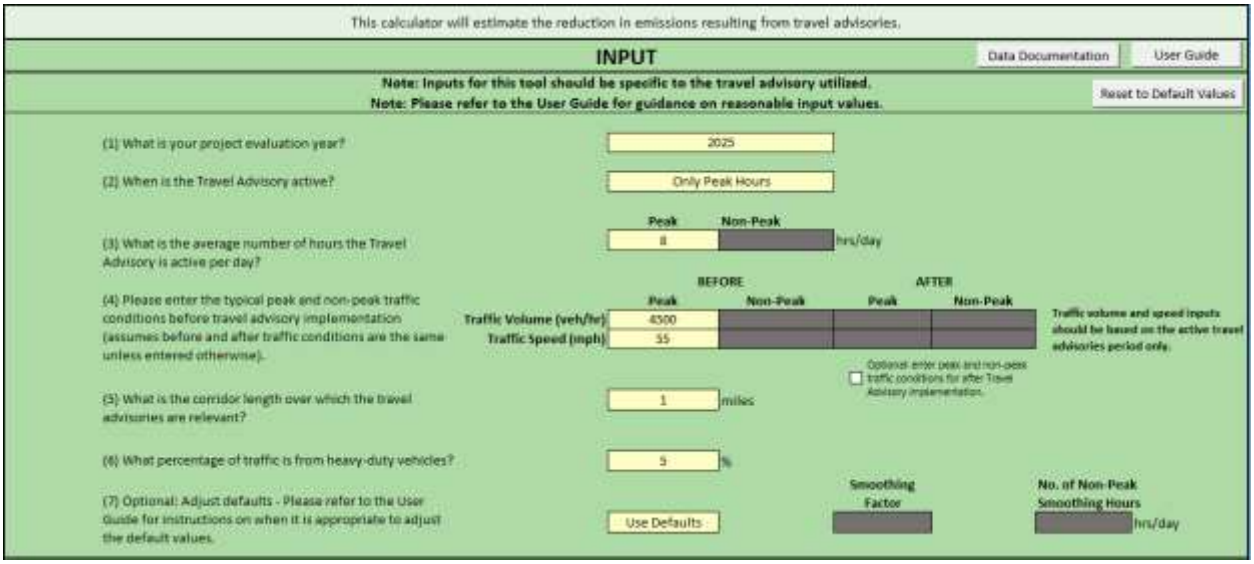
There are no benefits (or disbenefits) in network performance since there was no change in traffic volume or speed in this example.

Example 2: Lane Volume Variations

A highway agency will be implementing a VMS across a four-lane highway in 2025. Three of the lanes are general purpose lanes while the fourth lane is a high-occupancy vehicle (HOV) lane with a different average volume and speed. The general purpose lanes have an average volume of 1,500 veh/hr/ln and average speed of 55 mph with 5% heavy duty vehicle traffic. The HOV lane does not permit heavy duty vehicles and has an average volume of 800 veh/hr and average speed of 60 mph. The travel advisories will only be active for 8 hours per day in peak hour times. They will impact travel over a one mile stretch of road.

This evaluation will require two separate calculations with the tool. Based on this proposed project description, the user would enter the following inputs:

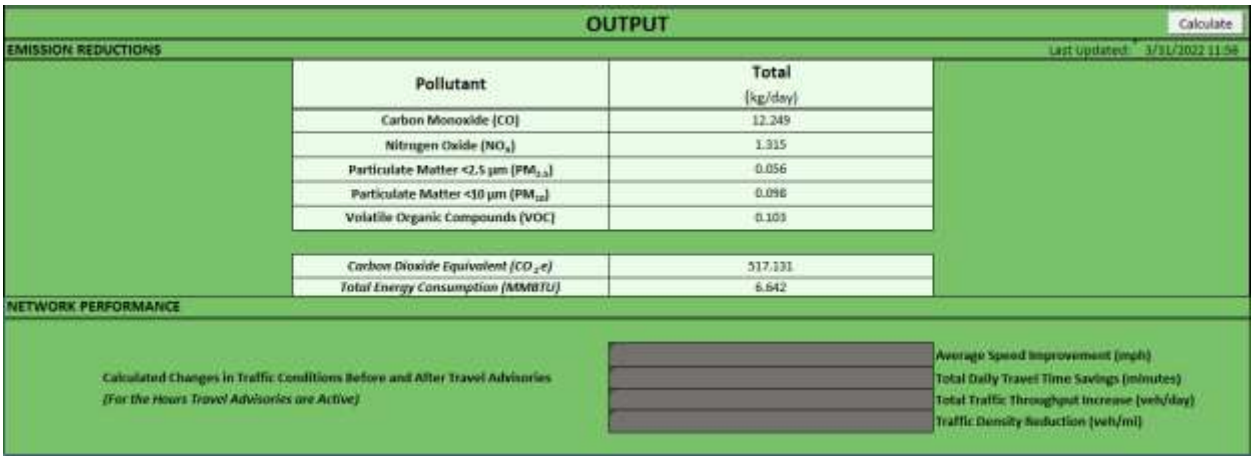
General Purpose Lanes Run



Project Evaluation Year: 2025
Activity Period: Only Peak Hours
Active Hours (Peak): 8
Peak Traffic Volume (veh/hr): 4,500
$(1500 \frac{veh}{hr} / \text{ln} \times 3 = 4500\ veh/hr)$

Peak Traffic Speed (mph): 55
Length of Corridor (mi): 1
Percent of heavy-duty vehicles: 5
Optional: Use Defaults

Once inputs are entered, clicking the 'Calculate Output' button generates the following emission reductions and network performance results:



Emission Reductions (kg/day)

CO: 12.249
NO_X: 1.315
$PM_{2.5}$: 0.056
PM_{10}: 0.098
VOC: 0.103

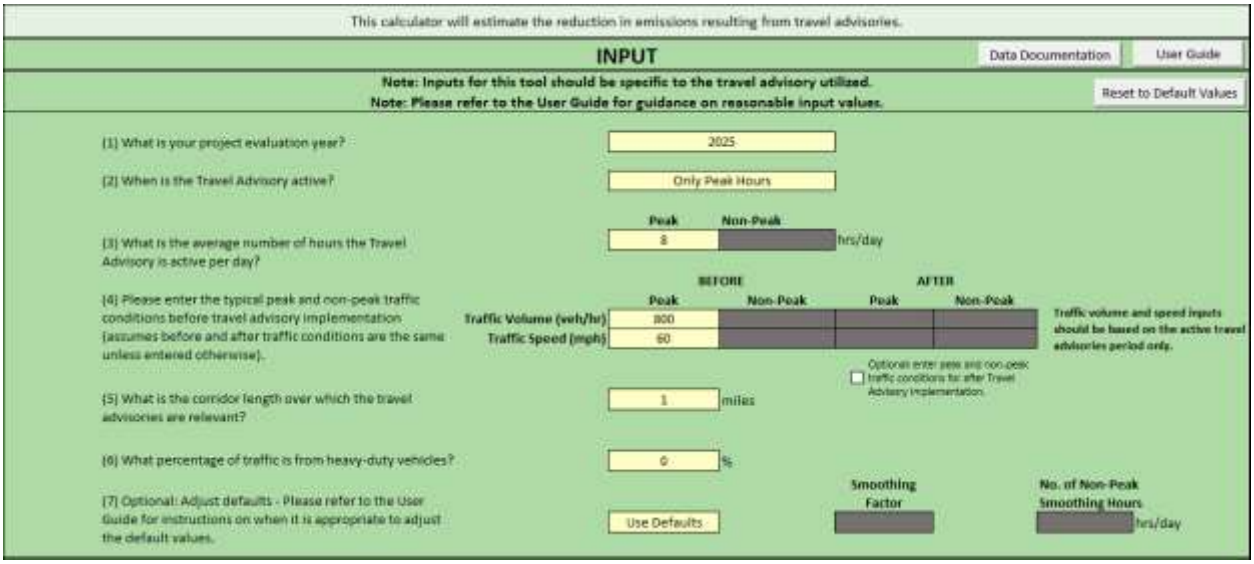
CO_2e: 517.131
Total Energy Consumption (MMBTU/day): 6.642

Changes in Network Performance

Average Speed Improvement (mph): 0.00
Total Daily Travel Time Savings (min): 0.00
Total Traffic Throughput Increase (veh/hr): 0.00
Total Traffic Density Reduction (veh/mi): 0.00

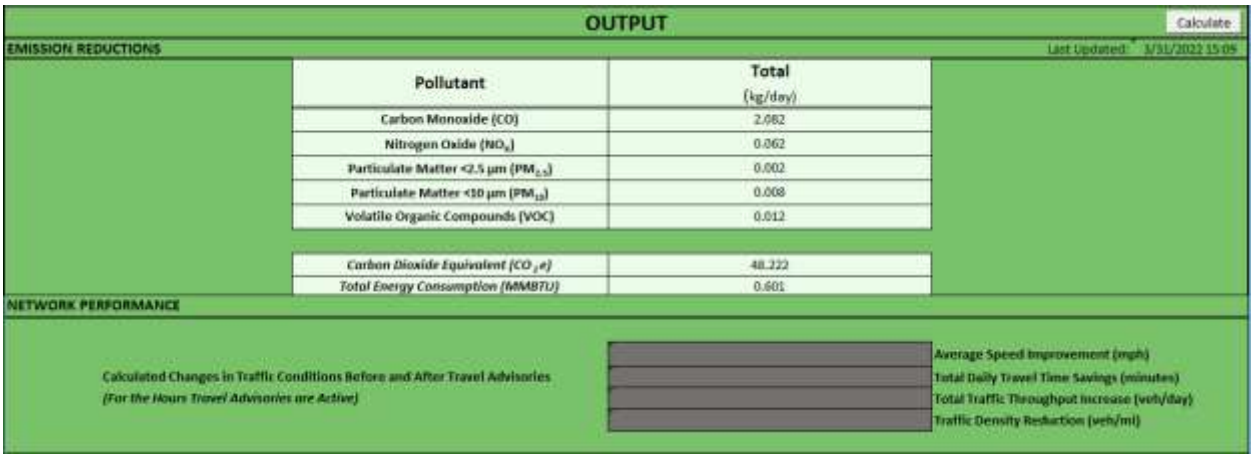
There are no benefits (or disbenefits) in network performance since there was no change in traffic volume or speed in this example.

HOV Lane Run



Project Evaluation Year: 2025
Activity Period: Only Peak Hours
Active Hours (Peak): 8
Peak Traffic Volume (veh/hr): 800
Peak Traffic Speed (mph): 60
Length of Corridor (mi): 1
Percent of heavy-duty vehicles: 0
Optional: Use Defaults

Once inputs are entered, clicking the 'Calculate Output' button generates the following emission reductions and network performance results:



Emission Reductions (kg/day)

CO: 2.082
NO_X: 0.062
$PM_{2.5}$: 0.002
PM_{10}: 0.008
VOC: 0.012
CO_2e: 48.222
Total Energy Consumption (MMBTU/day): 0.601

Changes in Network Performance

Average Speed Improvement (mph): 0.00
Total Daily Travel Time Savings (min): 0.00
Total Traffic Throughput Increase (veh/hr): 0.00
Total Traffic Density Reduction (veh/mi): 0.00

There are no benefits (or disbenefits) in network performance since there was no change in traffic volume or speed in this example.

In order to find the total emissions benefit from this scenario, the benefit from the general purpose lanes and the HOV lane were summed.

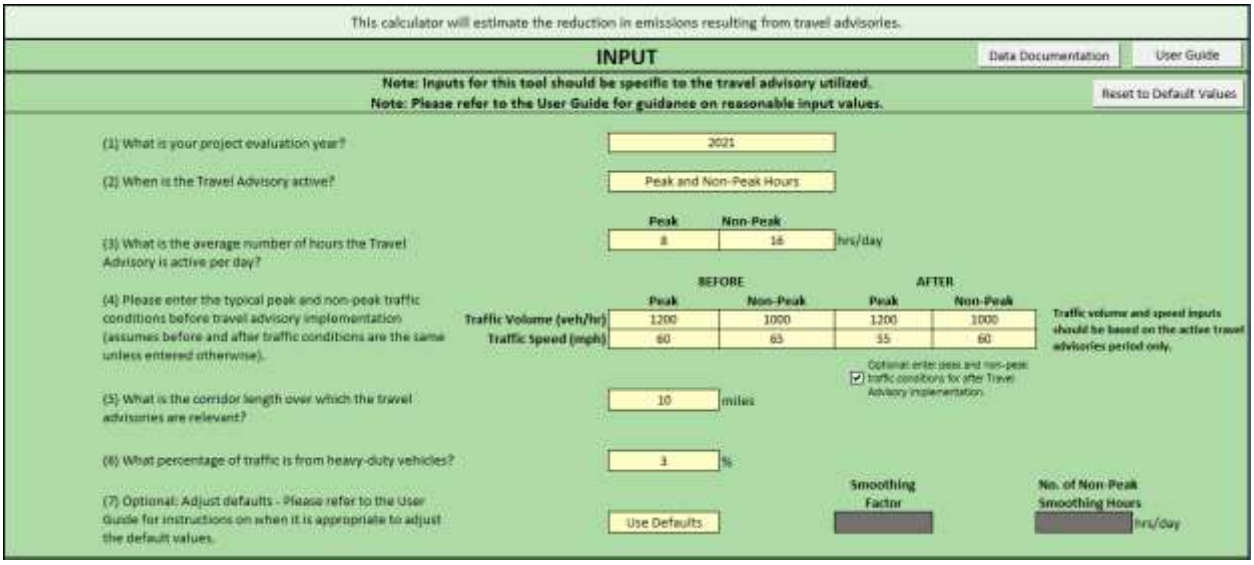
Sample Calculation: $Total\ CO\ Benefits = 12.249 \frac{kg}{day} + 2.082 \frac{kg}{day} = 14.331 \frac{kg}{day}$

Pollutant	Units	General Purpose Lanes	HOV Lane	Sum
CO	(kg/day)	12.249	2.082	14.331
NOx	(kg/day)	1.315	0.062	1.377
PM2.5	(kg/day)	0.056	0.002	0.058
PM10	(kg/day)	0.098	0.008	0.106
VOC	(kg/day)	0.103	0.012	0.115
CO2e	(kg/day)	517.131	48.222	565.353
Total Energy Consumption	(MMBTU/day)	6.642	0.601	7.243

Example 3: Different Pre- and Post-Conversion Traffic Conditions

A highway agency plans to implement a series of VSL signs over a 10-mile corridor in 2021. The VSL will not impact the traffic volume, which should remain at 1,200 veh/hr for peak hours and 1,000 veh/hr for non-peak hours. However, the average speed on the corridor is expected to decrease from 60 mph to 55 mph for peak periods and 65 to 60 mph for non-peak periods. The VSL is active 24 hours per day, but 8 of those hours are at peak conditions. There is 3% heavy-duty traffic.

Based on this proposed project description, the user would enter the following inputs:



Project Evaluation Year: 2021
Activity Period: Peak and Non-Peak Hours
Active Hours:
- Peak: 8
- Non-peak: 16

Before Traffic Volume (veh/hr):
- Peak: 1,200
- Non-Peak: 1,000

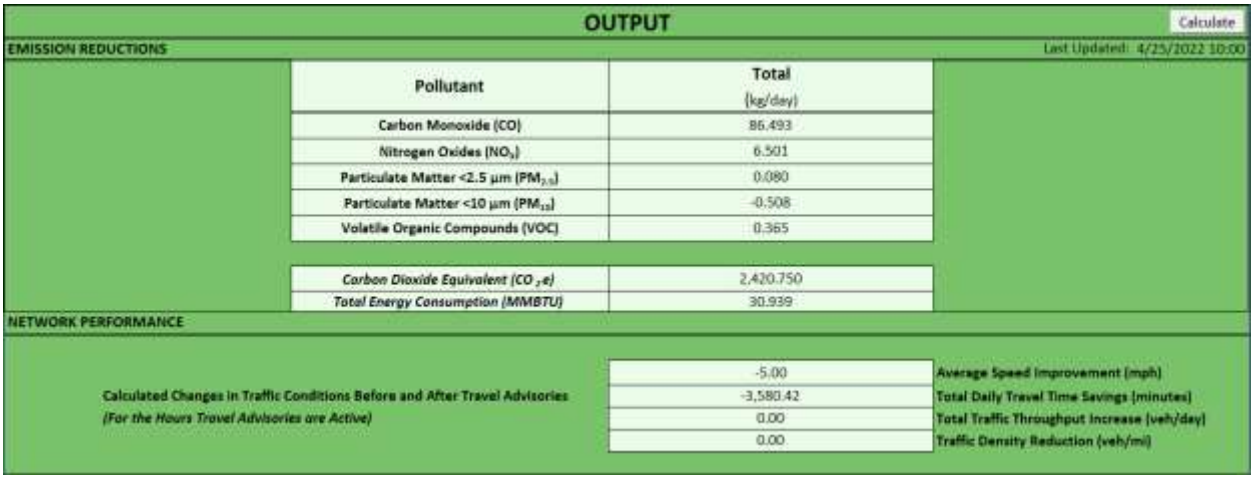
Before Traffic Speed (mph):
- Peak: 60
- Non-Peak: 65

After Traffic Volume (veh/hr):
- Peak: 1,200
- Non-Peak: 1,000

After Traffic Speed (mph):
- Peak: 55
- Non-Peak: 60

Length of Corridor (mi): 10
Percent of heavy-duty vehicles: 3
Optional: Use Defaults

Once inputs are entered, clicking the 'Calculate Output' button generates the following emission reductions and network performance results:



Emission Reductions (kg/day)

CO: 86.493
NO_X: 6.501
$PM_{2.5}$: 0.080
PM_{10}: -0.508
VOC: 0.365

CO_2e: 2,420.750
Total Energy Consumption (MMBTU/day): 30.939

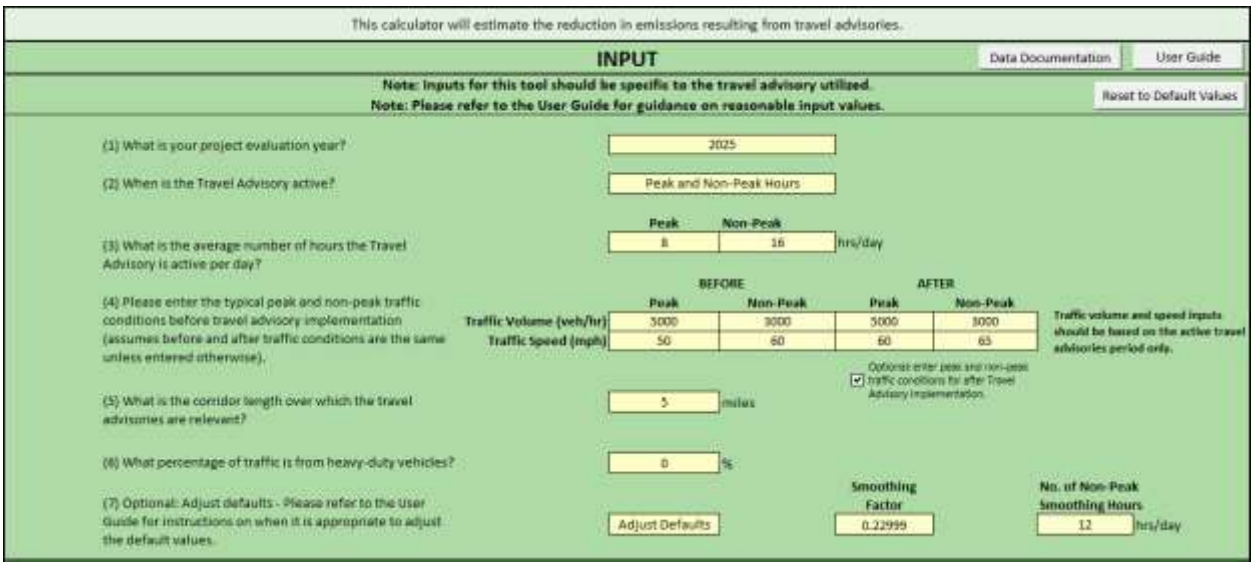
Changes in Network Performance

Average Speed Improvement (mph): -5.00
Total Daily Travel Time Savings (min): -3,580.42
Total Traffic Throughput Increase (veh/hr): 0.00
Total Traffic Density Reduction (veh/mi): 0.00

The 'Average Speed Improvement' output is negative because the VSL caused a reduction in average speed along the corridor. Additionally, this reduction resulted in a negative impact on the 'Daily Travel Time Savings' output which means that, on average, it now takes vehicles a longer time to pass through the corridor. There is no change in 'Total Traffic Throughput Increase' or 'Traffic Density Reductions' since there was no change in the traffic volume before and after implementation of the VSL.

Example 4: Adjusting Default Conditions

A VMS project to be completed in 2025 will operate during Peak and Non-Peak hours near an airport. Due to the nature of the roadway, the project is expected to smooth traffic during most hours of the day. Traffic volume before the implementation is 5,000 veh/hr during peak hours and 3,000 veh/hr during non-peak hours. The average speed during peak hours is 50 mph and during non-peak hours is 60 mph. Although the volume is not expected to change after implementation, the speed is expected to increase to 60 mph during peak hours and 65 mph during non-peak hours. The travel advisories impact a 5-mile stretch of roadway where heavy duty vehicles are not permitted.



Project Evaluation Year: 2025
Activity Period: Peak and Non-Peak Hours
Active Hours:
- Peak: 8
- Non-peak: 16

Before Traffic Volume (veh/hr):
- Peak: 5,000
- Non-Peak: 3,000

Before Traffic Speed (mph):
- Peak: 50
- Non-Peak: 60

After Traffic Volume (veh/hr):
- Peak: 5,000
- Non-Peak: 3,000

After Traffic Speed (mph):
- Peak: 60
- Non-Peak:65

Length of Corridor (mi): 5
Percent of heavy-duty vehicles: 0
Optional: Adjust Defaults
- Smoothing Factor: No change
- No. of Non-Peak Smoothing Hours: 12

Once inputs are entered, clicking the 'Calculate Output' button generates the following emission reductions and network performance results:

OUTPUT Calculate

EMISSION REDUCTIONS — Last Updated: 4/25/2022 11:43

Pollutant	Total (kg/day)
Carbon Monoxide (CO)	73.920
Nitrogen Oxides (NO_x)	0.183
Particulate Matter <2.5 µm ($PM_{2.5}$)	0.383
Particulate Matter <10 µm (PM_{10})	2.752
Volatile Organic Compounds (VOC)	1.064
Carbon Dioxide Equivalent (CO_2e)	2,597.154
Total Energy Consumption (MMBTU)	31.516

NETWORK PERFORMANCE

Calculated Changes in Traffic Conditions Before and After Travel Advisories (For the Hours Travel Advisories are Active)	
6.67	Average Speed Improvement (mph)
-21,538.46	Total Daily Travel Time Savings (minutes)
0.00	Total Traffic Throughput Increase (veh/day)
0.00	Traffic Density Reduction (veh/mi)

Emission Reductions (kg/day)

CO: 73.920
NO_X: 0.183
$PM_{2.5}$: 0.383
PM_{10}: 2.752
VOC: 1.064
CO_2e: 2,597.154
Total Energy Consumption (MMBTU/day): 31.516

Changes in Network Performance

Average Speed Improvement (mph): 6.67
Total Daily Travel Time Savings (min): -21,538.46
Total Traffic Throughput Increase (veh/hr): 0.00
Total Traffic Density Reduction (veh/mi): 0.00

RESOURCES

Data Dictionary

The CMAQ Data Dictionary, which can be found here, is a resource available to the public to help understand terms that may be used in this tool. On the Data Dictionary webpage, select "Congestion Reduction and Traffic Flow Improvements" and for strategy type select "Intelligent Transportation Systems", "Traffic Operations", or "Incident Management". If you are searching for a particular term, you can use the "Find in results" button. After clicking submit you will be shown a list of results, an example is included below.

Annual Average Daily Traffic (AADT), both directions

Definition	The annual average daily traffic (AADT) volume of traffic across all lanes of travel, in both approach directions along the length of the corridor.
Units	Vehicles per day
Input Category	Activity
CMAQ Project and Program Type	Congestion Reduction and Traffic Flow Improvements
Strategy Type	Roundabouts, Intersection Improvements
Values	None given
Uncertainty	Lack of current data; Forecasting techniques and data (e.g., travel demand model)
Common Errors	Use of old or otherwise inadequate traffic data
Resources	Travel demand model; Local and/or State DOT traffic counts

MOVES

General information about the MOVES model can be found on the EPA's website. MOVES is free to download and allows users to model mobile source emissions at different scales ranging from project to national (called default). The website includes subpages to download the latest version, watch webinars and training sessions, and contact the developers for help.