California Freight Investment Program: Discussion Draft Quantification Methodology for Air Pollutants

This draft quantification methodology is for applicants of the California Freight Investment Program to quantify the carbon dioxide (CO2), particulate matter (PM), and nitrogen oxide (NOx) emission impacts from proposed projects.

The methodology is intentionally simplified and relies on widely available inputs and tools. The results are not intended to replace environmental review and quantification of environmental impacts for the purposes of the California Environmental Quality Act or National Environmental Policy Act.

For project inputs, applicants are expected to rely on existing project level data and tools. Project applicants using this methodology will be required to submit documentation supporting calculations and key assumptions. Web links to supporting data/documents will be accepted.

Project Types

The methodology focuses on four project types—interchange improvement, highway widening, grade separation, and operational improvement—and must be utilized for projects falling under these categories.

Table 1 – Project Type Definition

Project Type	Definition
Interchange Improvement	To improve a junction, including on- and off-ramps, to permit traffic on at least one highway to pass through the junction without directly crossing another traffic stream.
Highway Widening	To widen a highway in order to improve its capacity.
Grade Separation	To improve a junction by using grade separation to permit traffic on at least one highway to pass through the junction without directly crossing another traffic stream.
Operational Improvement	Any project (other than an interchange upgrade, highway widening, or grade separation) expected to result in a decrease in vehicle or locomotive congestion.

Quantification Methodology for CO2, NOx, and PM Emissions

The general steps of the quantification methodology are:

- Quantify the pre- and post-project CO2, NOx, and PM emissions for an interchange upgrade, highway widening, grade separation, or operational improvement project using the equations provided below.
- Quantify the emissions for passenger vehicles, heavy-duty vehicles, and locomotives (grade separation or operational improvement projects only) separately, and then sum the categories to calculate total emissions.
- Subtract the pre-project emissions from the post-project emissions to determine the emission impact of the project.
- For projects with construction occurring on more than one route (interchange improvements, grade separations), calculations should be done for each route separately and then summed.

See Appendix A for a general example of the application of this methodology.

Passenger Vehicle Methodology:

$$Emissions = (Emission\ Factor) * (Passenger\ Vehicle\ Throughput) * (Impacted\ Distance) * (20\ Year\ Project\ Life)$$

Emission Factor:
Select the appropriate emission factor (grams/vehicle-mile) in Table 2 based on average vehicle speed at the location of the project and the estimated post-project average speed. The statewide passenger vehicle emission factors, provided in Table 2, were downloaded from EMFAC 2014 with the following parameters:

- Annual average for 2030 (estimated mid-project life)
- 2007 vehicle categories LDA, LDT1, LDT2, MDV, and MCY.
- Aggregated model year
- Gasoline fuel

Table 2 – 2030 Annual Average Passenger Vehicle Emission Factors (Per Vehicle)

Speed	g NOx/mile	g PM10/mile	g CO2/mile
5	0.0969	0.00946	806
10	0.0761	0.00591	595
15	0.0678	0.00394	460
20	0.0603	0.00276	367
25	0.0538	0.00204	304
30	0.0496	0.00158	260
35	0.0483	0.00131	233
40	0.0472	0.00114	217
45	0.0473	0.00104	209
50	0.0478	0.00101	209

Speed	g NOx/mile	g PM10/mile	g CO2/mile
55	0.0484	0.00102	217
60	0.0467	0.00109	231
65	0.0517	0.00123	255
70	0.0512	0.00134	281

Passenger Vehicle Throughput:
Use total vehicle throughput per year and the proportion of passenger vehicles at the project site to calculate the passenger vehicle throughput. If post-project throughput is not available, keep it consistent with the pre-project throughput. Assume a passenger fleet mix factor of 0.91 for all projects[1].

$$Passenger\ Vehicle\ Throughput = \left(\frac{total\ vehicle\ throughput}{year}\right) * (0.91)$$

Project Life:
Assume a 20 year project life for pre- and post-project calculations[2].

Impacted Distance:
Using documented data (project study report, environmental document), provide the impacted distance of the project in centerline miles. If documented impacted distance data is not available, provide the length of the project area in centerline miles. Use the same value for pre- and post-project calculations.

Heavy-Duty Vehicle Methodology:

$$Emissions = (Emission\ Factor) * (Heavy - Duty\ Vehicle\ Throughput) * (Impacted\ Distance) * (20\ Year\ Project\ Life)$$

Emission Factor:
Select the appropriate emission factor (grams/vehicle-mile) in Table 3 based on annual average vehicle speed at the location of the project and the estimated post-project annual average speed. The statewide heavy-duty vehicle emission factors, provided in Table 3, were downloaded from EMFAC 2014 with the following parameters:

- Annual average for 2030 (estimated mid-project life)
- 2007 vehicle categories LHDT1, LHDT2, MH, MHDT, HHDT, SBUS, UBUS, and OBUS.
- Aggregated model year
- Diesel fuel

[1] ARB, "EMFAC 2014 Web Database," 2014, https://www.arb.ca.gov/emfac/, accessed on April 17, 2017.
[2] Caltrans, "Life-Cycle Benefit-Cost Analysis Model," 2007, http://www.dot.ca.gov/hq/tpp/offices/eab/LCBC_Analysis_Model.html, accessed on April 17, 2017.

Table 3 – 2030 Annual Average Heavy-Duty Vehicle Emission Factors (Per Vehicle)

Speed	g NOx/mile	g PM10/mile	g CO2/mile
5	12.18	0.0264	2501
10	9.05	0.0209	2127
15	5.00	0.0188	1498
20	3.74	0.0204	1510
25	2.01	0.0095	1269
30	1.46	0.0077	1274
35	1.15	0.0064	1337
40	0.86	0.0057	1288
45	0.70	0.0054	1264
50	0.63	0.0056	1157
55	0.51	0.0051	1164
60	0.42	0.0048	1091
65	0.45	0.0052	1106
70	0.45	0.0052	1187

Heavy-Duty Vehicle Throughput:
Use total vehicle throughput per year and the proportion of heavy-duty vehicles at the project site to calculate the heavy-duty vehicle throughput. If post-project throughput is not available, keep it consistent with the pre-project throughput. Assume a heavy-duty fleet mix factor of 0.09 for all projects[3].

$$Heavy-Duty\ Vehicle\ Throughput = \left(\frac{total\ vehicle\ throughput}{year}\right) * (0.09)$$

Project Life:
Assume a 20 year project life for pre- and post-project calculations[4].

Impacted Distance:
Using documented data (project study report, environmental document), provide the impacted distance of the project in centerline miles. If documented impacted distance data is not available, provide the length of the project area in centerline miles. Use the same value for pre- and post-project calculations.

Locomotive Methodology:

$$Emissions = (Emission\ Factor) * (Fuel\ Usage\ Factor) * (Locomotive\ Throughput) * (Impacted\ Distance) * (20\ Year\ Project\ Life)$$

[3] ARB, "EMFAC 2014 Web Database," 2014, https://www.arb.ca.gov/emfac/, accessed on April 17, 2017.
[4] Caltrans, "Life-Cycle Benefit-Cost Analysis Model," 2007, http://www.dot.ca.gov/hq/tpp/offices/eab/LCBC_Analysis_Model.html, accessed on April 17, 2017.

Emission Factor:
Select the appropriate emission factor in Table 4. The g/gal is calculated using Tier 2, Tier2+/Tier3, and Tier 4 line-haul emission factors from U.S. EPA[5] and a train conversion factor of 20.8 bhp-hr/gallon[6]. The 2030 Train Mix is based on U.S. EPA emission factors and ARB 2016 Line Haul Locomotive Model projection of Tier distribution.

Table 4 – Locomotive Emission Factors

	NOx (g/gallon)	PM10 (g/gallon)	CO2 (g/gallon)
2030 Train Mix	66	1.4	10,206

Fuel Usage Factor:
The fuel usage factor shall be provided in gallons of fuel/gross ton-miles. The pre-project fuel usage factor should be based on recent regional data. The post-project fuel usage factor could improve compared to the pre-project factor if the project is expected to result in locomotives operating in more efficient notch profiles. Estimate the post-project fuel usage factor based on the projected notch profile through the grade change. Work with the locomotive operators, as appropriate, to estimate the fuel usage factor.

Locomotive Throughput:
Provide locomotive throughput in gross tons moved per year. If post-project throughput is not available, keep it consistent with the pre-project throughput. Work with the locomotive operators, as appropriate, to estimate the locomotive throughput.

$$Locomotive\ Throughput = \frac{gross\ tons}{year}$$

Project Life:
Assume a 20 year project life for pre- and post-project calculations[7].

Impacted Distance:
Using documented data (project study report, environmental document), provide the impacted distance of the project area in track miles (of only one track if there are multiple tracks. If documented impacted distance data is not available, provide the length of the project area in track miles (of only one track if there are multiple tracks). Use the same value for pre- and post-project calculations.

[5] EPA, "Emission Standards Reference Guide for On-road and Nonroad Vehicles and Engines," December 13, 2016, http://www3.epa.gov/otaq/standards/nonroad/locomotives.htm, accessed on April 17, 2017
[6] EPA, "Emission Factors for Locomotives Table 3," https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100500B.TXT, accessed April 17, 2017
[7] Caltrans, "Life-Cycle Benefit-Cost Analysis Model"

Appendix A: Example of Methodology Application

Project Emission Quantification

Example Scenario: An applicant is proposing a grade separation project at a junction between rail tracks and a road in Sacramento. Pre-project average vehicle speed is 20mph and is expected to increase to 30mph post project. Vehicle throughput is 100,000 vehicles/year and locomotive throughput is 1,000,000 gross tons/year and throughput is expected to be the same post-project. The impacted road distance is one mile and the impacted rail distance is two miles. The pre- and post- project fuel usage factors are 1gallon/550 gross ton-miles and 1gallon/600 gross-ton miles (expected), respectively.

Pre-Project Passenger Vehicle:

$$Emissions = (Emission\ Factor) * (Passenger\ Vehicle\ Throughput) * (Impacted\ Distance) * (Project\ Life)$$

Inputs:

Emission Factor (per vehicle):

Speed	g NOx/mile	g PM10/mile	g CO2/mile
20	0.0603	0.00276	367

Passenger Vehicle Throughput:

$$Passenger\ Vehicle\ Throughput = \left(\frac{total\ vehicle\ throughput}{year}\right) * (passenger: fleet\ mix\ factor)$$

$$Passenger\ Vehicle\ Throughput = \left(\frac{100{,}000\ vehicles}{year}\right) * (.91)$$

$$Passenger\ Vehicle\ Throughput = 91{,}000\ passenger\ vehicles/year$$

Project Life: 20 years

Impacted Distance: 1 mile

Quantification:

$$NOx\ Emissions = (.0603 g/vehicle - mile) * (91{,}000\ vehicles/year) * (1\ mile) * (20\ years)$$

$$NOx\ Emissions = 109{,}746\ grams$$

$PM10\ Emissions = (.00276g/vehicle - mile) * (91{,}000\ vehicles/year) * (1\ mile) * (20\ years)$

$PM10\ Emissions = 5{,}023\ grams$

$CO2\ Emissions = (367g/vehicle - mile) * (91{,}000\ vehicles/year) * (1\ mile) * (20\ years)$

$CO2\ Emissions = 667{,}940{,}000\ grams$

Pre-Project Heavy-Duty Vehicle:

$$Emissions = (Emission\ Factor) * (HD\ Vehicle\ Throughput) * (Impacted\ Distance) * (Project\ Life)$$

Inputs:

Emission Factor:

Speed	g NOx/mile	g PM10/mile	g CO2/mile
20	3.74	0.0204	1510

Heavy-Duty Vehicle Throughput:

$$Heavy - Duty\ Vehicle\ Throughput = \left(\frac{total\ vehicle\ throughput}{year}\right) * (heavy - duty: fleet\ mix\ factor)$$

$$Heavy - Duty\ \ Vehicle\ Throughput = \left(\frac{100{,}000\ vehicles}{year}\right) * (.09)$$

$$Heavy - Duty\ \ Vehicle\ Throughput = 9{,}000\ vehicles$$

Project Life: 20 years

Impacted Distance: 1 mile

Quantification:

$NOx\ Emissions = (3.74g/vehicle - mile) * (9{,}000\ vehicles/year) * (1\ mile) * (20\ years)$

$NOx\ Emissions = 673{,}200\ grams$

$PM10\ Emissions = (.0204g/vehicle - mile) * (9{,}000\ vehicles/year) * (1\ mile) * (20\ years)$

$PM10\ Emissions = 3{,}672\ grams$

$$CO2\ Emissions = (1{,}510 g/vehicle - mile) * (9{,}000\ vehicles/year) * (1\ mile) * (20\ years)$$

$$CO2\ Emissions = 271{,}800{,}000\ grams$$

Pre-Project Locomotive

$$Emissions = (Emission\ Factor) * (Fuel\ Usage\ Factor) * (Locomotive\ Throughput) * (Impacted\ Distance) * (Project\ Life)$$

Inputs:

Emission Factor:

	NOx (g/gallon)	PM10 (g/gallon)	CO2 (g/gallon)
2030 Train Mix	66	1.4	10,206

Fuel Usage Factor: 1 gallon/550 gross ton-miles

Locomotive Throughput:

$$Locomotive\ Throughput = \frac{1{,}000{,}000\ gross\ tons}{year}$$

Project Life: 20 years

Impacted Distance: 2 miles

Quantification:

$$NOx\ Emissions = (66\ g/gallon) * (1\ gallon/550\ gross\ ton - mile) * (1{,}000{,}000\ gross\ tons/year) * (2\ mile) * (20\ years)$$

$$NOx\ Emissions = 4{,}800{,}000\ grams$$

$$PM10\ Emissions = (1.4\ g/gallon) * (1\ gallon/550\ gross\ ton - mile) * (1{,}000{,}000\ gross\ tons/year) * (2\ mile) * (20\ years)$$

$$PM10\ Emissions = 101{,}818\ grams$$

$$CO2\ Emissions = (10{,}206\ g/gallon) * (1\ gallon/550\ gross\ ton - mile) * (1{,}000{,}000\ gross\ tons/year) * (2\ mile) * (20\ years)$$

$$CO2\ Emissions = 742{,}254{,}545\ grams$$

Total Pre-Project Emissions:

$$NOx(passenger\ vehicle + heavy - duty\ vehicle + locomotive) = 109{,}746\ g + 673{,}200\ g + 4{,}800{,}000\ g$$

$$\boldsymbol{NOx = 5{,}582{,}946\ grams}$$

$$PM10(passenger\ vehicle + heavy - duty\ vehicle + locomotive) = 5{,}023\ g + 3{,}672\ g + 101{,}818\ g$$

$$\boldsymbol{PM10 = 110{,}513\ grams}$$

$$CO2(passenger\ vehicle + heavy - duty\ vehicle + locomotive) = 667{,}940{,}000\ g + 271{,}800{,}000\ g + 742{,}254{,}545\ g$$

$$\boldsymbol{CO2 = 1{,}681{,}994{,}545\ grams}$$

Post-Project Passenger Vehicle:

$$Emissions = (Emission\ Factor) * (Passenger\ Vehicle\ Throughput) * (Impacted\ Distance) * (Project\ Life)$$

Inputs:

Emission Factor (per vehicle):

Speed	g NOx/mile	g PM10/mile	g CO2/mile
30	0.0496	0.00158	260

Passenger Vehicle Throughput:

$$Passenger\ Vehicle\ Throughput = \left(\frac{total\ vehicle\ throughput}{year}\right) * (passenger{:}\ fleet\ mix\ factor)$$

$$Passenger\ Vehicle\ Throughput = \left(\frac{100{,}000\ vehicles}{year}\right) * (.91)$$

$$Passenger\ Vehicle\ Throughput = 91{,}000\ passenger\ vehicles/year$$

Project Life: 20 years

Impacted Distance: 1 mile

Quantification:

$$NOx\ Emissions = (.0496 g/vehicle - mile) * (91{,}000\ vehicles/year) * (1\ mile) * (20\ years)$$

$$NOx\ Emissions = 90{,}272\ grams$$

$$PM10\ Emissions = (.00158 g/vehicle - mile) * (91{,}000\ vehicles/year) * (1\ mile) * (20\ years)$$

$$PM10\ Emissions = 2{,}876\ grams$$

$$CO2\ Emissions = (260 g/vehicle - mile) * (91{,}000\ vehicles/year) * (1\ mile) * (20\ years)$$

$$CO2\ Emissions = 473{,}200{,}000\ grams$$

Post-Project Heavy-Duty Vehicle

$$Emissions = (Emission\ Factor) * (Heavy - Duty\ Vehicle\ Throughput) * (Impacted\ Distance) * (Project\ Life)$$

Inputs:

Emission Factor:

Speed	g NOx/mile	g PM10/mile	g CO2/mile
30	1.46	0.0077	1274

Heavy-Duty Vehicle Throughput:

$$Heavy - Duty\ Vehicle\ Throughput = \left(\frac{total\ vehicle\ throughput}{year}\right) * (heavy - duty{:}\ fleet\ mix\ factor)$$

$$Heavy - Duty\ Vehicle\ Throughput = \left(\frac{100{,}000\ vehicles}{year}\right) * (.09)$$

$$Heavy - Duty\ Vehicle\ Throughput = 9{,}000\ vehicles$$

Project Life: 20 years

Impacted Distance: 1 mile

Quantification:

$$NOx\ Emissions = (1.46 g/vehicle - mile) * (9{,}000\ vehicles/year) * (1\ mile) * (20\ years)$$

$$NOx\ Emissions = 262{,}800\ grams$$

$PM10\ Emissions = (.0077 g/vehicle - mile) * (9{,}000\ vehicles/year) * (1\ mile) * (20\ years)$

$PM10\ Emissions = 1{,}386\ grams$

$CO2\ Emissions = (1{,}274 g/vehicle - mile) * (9{,}000\ vehicles/year) * (1\ mile) * (20\ years)$

$CO2\ Emissions = 229{,}320{,}000\ grams$

Post-Project Locomotive

$$Emissions = (Emissin\ Factor) * (Fuel\ Usage\ Factor) * (Locomotive\ Throughput) * (Impacted\ Distance) * (Project\ Life)$$

Inputs:

Emission Factor:

	NOx (g/gallon)	PM10 (g/gallon)	CO2 (g/gallon)
2030 Train Mix	66	1.4	10,206

Fuel Usage Factor: 1gallon/600 gross ton-miles

Locomotive Throughput:

$$Locomotive\ Throughput = \frac{1{,}000{,}000\ gross\ tons}{year}$$

Project Life: 20 years

Impacted Distance: 2 miles

Quantification:

$$NOx\ Emissions = (66\ g/gallon) * (1\ gallon/600\ gross\ ton - mile) * (1{,}000{,}000\ gross\ tons/year) * (2\ mile) * (20\ years)$$

$NOx\ Emissions = 4{,}400{,}000\ grams$

$$PM10\ Emissions = (1.4\ g/gallon) * (1\ gallon/600\ gross\ ton - mile) * (1{,}000{,}000\ gross\ tons/year) * (2\ mile) * (20\ years)$$

$PM10\ Emissions = 93{,}333\ grams$

$$CO2\ Emissions = (10{,}206\ g/gallon) * (1\ gallon/600\ gross\ ton - mile) * (1{,}000{,}000\ gross\ tons/year) * (2\ mile) * (20\ years)$$

$$CO2\ Emissions = 680{,}400{,}000\ grams$$

Total Post-Project Emissions:

$$NOx(passenger\ vehicle + heavy - duty\ \ vehicle + locomotive) = 90{,}272\ g + 262{,}800\ g + \ 4{,}400{,}000\ g$$

$$\boldsymbol{NOx = 4{,}753{,}072\ grams}$$

$$PM10(passenger\ vehicle + Heavy - Duty\ \ vehicle + locomotive) = 2{,}876\ g + 1{,}386\ g + \ 93{,}333\ g$$

$$\boldsymbol{PM10 = 97{,}595\ grams}$$

$$CO2(passenger\ vehicle + heavy - duty\ \ vehicle + locomotive) = 473{,}200{,}000\ g + 229{,}320{,}000 + \ 680{,}400{,}000\ g$$

$$\boldsymbol{CO2 = 1{,}382{,}920{,}000\ grams}$$

Emissions Impact of the Project:

$$Emission\ Impact = (Post - Project\ Emissions) - (Pre - Project\ Emissions)$$

$$NOx = 4{,}753{,}072\ g - \ 5{,}582{,}946\ g = \boldsymbol{-829{,}874\ grams\ \ NOx}$$

$$PM10 = 97{,}595\ g - 110{,}513\ g = \boldsymbol{-12{,}918\ grams\ \ PM10}$$

$$CO2 = 1{,}382{,}920{,}000\ g - 1{,}681{,}994{,}545\ g = \boldsymbol{-299{,}074{,}545\ grams\ CO2}$$