ARIZONA DEPARTMENT OF TRANSPORTATION

DRAFT CMAQ GUIDELINES AND PROCEDURES

PM2.5 Nonattainment Areas

8/31/2017

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ADOT *Draft* Congestion Mitigation and Air Quality (CMAQ) Methodologies and Procedures

Overview

The CMAQ program was created under the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 and continued under the subsequent transportation funding bills, Transportation Equity Act for the 21st Century (TEA-21), Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), Moving Ahead for Progress in the 21st Century (MAP-21), and currently reauthorized under the Fixing America's Surface Transportation Act (FAST) Act, December 4, 2105.

The purpose of the CMAQ program is to fund transportation projects or programs that will contribute to the attainment and maintenance of the national ambient air quality standards (NAAQS) for ozone, carbon monoxide, and particulate matter (both PM_{10} and $PM_{2.5}$).[1] The CMAQ program supports two important goals of the U.S. Department of Transportation (Department): improving air quality and relieving congestion. CMAQ funding is calculated using a weighted population formula for ozone and carbon monoxide nonattainment areas. While Arizona is under no statutory obligation to allocate CMAQ funds in the same way they are apportioned, ADOT has traditionally distributed all CMAQ funding to Maricopa Associations of Governments (MAG). The MAP-21 legislation set priorities for use of CMAQ funding in particulate matter with an aerodynamic diameter of 2.5 microns or less ($PM_{2.5}$) nonattainment areas.

> "For any State that has a nonattainment or maintenance area for particulate matter, an amount equal to 25 percent of the funds apportioned to each State under section 104(b)(4) for a nonattainment or maintenance area that are based all or in part of the weighted population of such area in fine particulate matter nonattainment shall be obligated to projects that reduce such fine particulate matter emissions in such area, including diesel retrofits."[2]

The FAST Act amended the eligible uses of CMAQ funds set aside for PM2.5 nonattainment and maintenance areas. PM2.5 set-aside funds may be used to reduce fine particulate matter emissions in a PM2.5 nonattainment or maintenance area, including:
- diesel retrofits;
- installation of diesel emission control technology on nonroad diesel equipment or on-road diesel equipment that is operated on a highway construction projects ; and
- the most cost-effective projects to reduce emissions from port-related landside nonroad or on-road equipment that is operated within the boundaries of the area.

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[1] Federal Highway Administration, *The Congestion Mitigation and Air Quality (CMAQ) Improvement Program under the Moving Ahead for Progress in the 21st Century Act INTERIM PROGRAM GUIDANCE.* November 12, 2013. (https://www.fhwa.dot.gov/environment/air_quality/cmaq/policy_and_guidance/2013_guidance/cmaq2013.pdf)

[2] Federal Highway Administration, *MAP-21 Moving Ahead for Progress in 21st Century, Section 1113 Congestion Mitigation and Air Quality Improvement Program (CMAQ) Questions & Answers*," September 27, 2012 (https://www.fhwa.dot.gov/map21/qandas/qacmaq.cfm)

Arizona has two $PM_{2.5}$ nonattainment areas in which MAP-21 priority funding would apply, Santa Cruz County (Nogales) and Pinal County (Maricopa). ADOT will administer the CMAQ program for the Nogales nonattainment and any other nonattainment area that is outside of MAG jurisdiction.

CMAQ Program Requirements

To be eligible for CMAQ funds a project must first be included in ADOT's current Statewide Transportation Improvement Plan (STIP), meet transportation conformity provisions in section 176(c) of the Clean Air Act Amendments and complete National Environmental Policy Act (NEPA) as required for funding under Titles 23 and 49 of the United States Code. The CMAQ program also requires that a CMAQ project must be a transportation project, it must generate an emissions reduction, and it must be located in or benefit a nonattainment or maintenance area. Eligible projects listed in the FHWA Interim Program Guidance Under MAP-21 include:

1. Diesel Engine Retrofits & Other Advanced Truck Technologies
2. Idle Reduction
3. Congestion Reduction & Traffic Flow Improvements
4. Freight/Intermodal
5. Transportation Control Measures (TCM)
6. Transit Improvements
7. Bicycle and Pedestrian Facilities and Programs
8. Travel Demand Management
9. Public Education and Outreach Activities
10. Transportation Management Associations
11. Carpooling and Vanpooling
12. Carsharing
13. Extreme Low-Temperature Cold Start Programs
14. Training
15. Inspection and Maintenance (I/M) Programs
16. Innovative Projects
17. Alternative Fuels and Vehicles

The FAST Act added eligibility for verified technologies for non-road vehicles and non-road engines that are used in port-related freight operations located in ozone, PM10, or PM2.5 nonattainment or maintenance areas funded in whole or in part under 23 U.S.C. or chapter 53 of 49 U.S.C, specifically makes eligible the installation of vehicle-to-infrastructure communications equipment, and continues eligibility for electric vehicle and natural gas vehicle infrastructure and adds priority for infrastructure located on the corridors designated under 23 U.S.C. 151. [3]

[3] Federal Highway Administration, *Congestion Mitigation & Air Quality Improvement Program (CMAQ) Fact Sheet,* March 2016. (https://www.fhwa.dot.gov/fastact/factsheets/cmaqfs.cfm)

Project Selection

Existing guidance states that the CMAQ project selection process should be transparent, in writing, and publically available and that proposals for funding should include a precise description of the project size, scope, location and an assessment of the expected emission reduction benefits. The project selection process should identify agencies involved in rating proposals, clarify how projects are rated, and name the committee or group responsible for making the recommendation to approving body. The process should also clearly identify the basis for rating the projects, including emissions benefits, cost effectiveness, and any other ancillary selection factors such as congestion relief, greenhouse gas reduction, safety, system preservation, sustainable development and freight, reduced SOV reliance, and others.

Suggested CMAQ Evaluation Process

Application: ADOT will solicit CMAQ projects through a formal letter from the Multimodal Planning Division Director that will include a copy of this document, application, and date the application is due. Interested applicants will complete an application and include the appropriate project type emissions calculation spreadsheets and return the completed application as instructed.

It is expected that the first round of CMAQ funding will include the following project types. Any additional CMAQ eligible projects will be evaluated on a case by case basis as necessary.

Dust Mitigation Projects:

- Dust Suppression
- Road Paving/Chip Sealing
- Paving Shoulders

Equipment Purchases:

- Street sweepers
- Water Trucks

Other Projects:

- Bike/Pedestrian
- Diesel Retrofits

Project Selection Team: ADOT Air Quality staff, MPD Regional Planning Staff assigned to region, COG representative, ADEQ representative, MPD Programming staff, (optional members TBD).

Scoring: ADOT MPD Air Quality staff will calculate expected emissions reduction for each project application received and include a cost benefit estimate (cost per emissions reduced) in a table and provide this information to the project selection team. Each member of the project team will score each project as described in Figure 2.

Figure 2: Suggested CMAQ Scoring Matrix

Factor Evaluated	Total Points Available = 50			
Air Quality Benefit	Unknown (5)	Low (10)	Medium (15)	High (20)
Cost-Effectiveness	Unknown (1)	Low (5)	Medium (10)	High (15)
Project is a measure, plan, or program from ADEQ submitted SIP	No (0)	Yes (5)		
Projects that Implement FHWA National Goals	No (0)	Yes (10)		

Project Programming: The CMAQ program is a cost-reimbursable program and project costs must be initially borne by the sponsors prior to requesting reimbursement from ADOT. Any and all costs incurred by the sponsor prior to the: (1) execution of an agreement with the ADOT, (2) completion of federal environmental process documentation and/or (3) federal funding authorization for the project and/or the phase of work are not eligible for reimbursement.

The federal funding share for most projects is 80% of the proposed cost of eligible projects (The federal funding share for eligible projects on the interstate highway system is 90% or 100%) it is presumed that ADOT can also use the sliding scale federal share of 93.7% for most projects. Sponsors must provide local matching funds that cannot be in the form of in-kind services or federal funds. Sponsors are responsible for project cost overruns. The sponsor must provide a resolution declaring the sponsor's commitment to provide the required local funding match and to assume responsibility for maintaining the project during its useful life and follow Arizona Department of Transportation Local Public Agency Projects Manual.[4]

CMAQ Emissions Calculation Procedures

Introduction

The suggested CMAQ emissions calculations procedures in this document are based on available and existing methodologies from other MPO's and DOT's in PM_{10} nonattainment areas. ADOT has an ongoing a planning study to update transportation conformity processes and develop an air quality management guidebook for use by transportation professionals. This study includes a task to identify control measures directly and indirectly related to on-road sources and develop emissions estimation techniques for CMAQ eligible types of projects. As this study is not expected to be completed until late 2013, ADOT staff will continue to review the state of the practice control measures and identify any additional CMAQ emissions estimation techniques.

[4] ADOT, *Arizona Department of Transportation Local Public Agency Projects Manual,* February, 2013.

General Notes on Analysis Methods

The EPA guidance "Emissions Factors & AP 42, Compilation of Air Pollutant Emission Factors" commonly referred to as "AP-42" or "AP-42 methods" is the source of many of the highlighted analysis techniques. In particular "Chapter 13-Other Sources" covers baseline emissions and several control measures relevant to these methodologies.

Throughout AP-42 all emission reductions are calculated using the following formulation:

E = A x EF x (1-ER/100)

Where:
E = emissions;
A = activity rate (Generally VMT)
EF = emission factor, and
ER =overall emission reduction efficiency, %

ADOT used references found in AP-42 and provided suggested inputs to help applicants complete the emissions analysis required for CMAQ funding. These guidelines include examples of common assumptions and values used in calculation PM_{10} and $PM_{2.5}$ emissions. Some assumptions may change after further discussions with the Arizona Department of Environmental Quality (ADEQ). As an example, the number of days with measurable rainfall in the Nogales PM10 nonattainment plan used a value of 45, while other sources suggest using a value of 60.[5] ADOT also used the Maricopa Association of Governments (MAG) *Methodologies for Evaluating Congestion Mitigation and Air Quality Improvement Projects*[6] as a guide for analyzing paving projects and the Idaho Department of Transportation CMAQ calculation methods as a guide for dust mitigation projects.

In using these approaches in cases where only PM_{10} reductions are available than an adjustment factor will be applied as a course estimate of $PM_{2.5}$ from PM_{10} impacts. AP-42 provides different emissions factors for various fugitive dust sources which varies based on silt content, climate, and other factors. AP-42 provides an estimate that 25% of PM_{10} fugitive dust by weight is $PM_{2.5}$ and uses this factor to represent particle size multiplier for paved road dust.[7] AP-42 provides a different estimate for unpaved roads referencing a study that suggests that a $PM_{2.5}$ particle size adjustment factor of .15 be used for unpaved roads.[8] The California Air Resources Board also provides emissions factors for $PM_{2.5}$ contributions of .208 for construction emissions, .212 for unpaved road dust, and .169 for paved road dust.[9]

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[5] United States Environmental Protection Agency, *AP-42, Background Documentation, Figure 13.2.1-2*, January 2011.
[6] http://www.azmag.gov/Documents/CMAQ_2011-04-05_Final-CMAQ-Methodologies_3-31-2011.pdf
[7] United States Environmental Protection Agency, *AP-42, Background Documentation, Section 13.2.1.5*, January 2011.
[8] Midwest Research Institute, "Fugitive Particulate Matter Emissions," for U.S. EPA, April, 1997.
[9] Houck, J., 1989. *Determination of Particle Size Distribution and Chemical Composition of Particulate Matter from Selected Sources in California*, Final Report, OMNI Environmental Services, Inc., June 30.

Given this wide range of estimates of $PM_{2.5}$ emissions reductions from traditional PM_{10} emission reduction programs, ADOT will be using the following adjustment factors until further information is available.

- Dust Suppression on unpaved roads a $PM_{2.5}$ factor of .15
- Dust Suppression on construction sites a $PM_{2.5}$ factor of .20
- Sweeping Pave Roads a $PM_{2.5}$ factor of .25 if certified as PM_{10} efficient
- Paving Roads and other paving projects will apply a $PM_{2.5}$ factor of .25
- All other projects will conservatively use a $PM_{2.5}$ factor of .21

ADOT will calculate both PM_{10} and $PM_{2.5}$ emissions reduction estimates and provide these results to the project selection team to aide in evaluating a project's effectiveness in reducing particulate matter. ADOT will report both $PM_{2.5}$ and PM_{10} emissions reductions in the CMAQ Annual Report that is submitted to FHWA.

CMAQ Application Process

Applicants interested in receiving CMAQ funding for projects will be asked to fill out the application form included in Appendix A and include the necessary self-calculating excel spreadsheets for the project type. A detailed description of the calculation methodologies and example of using spreadsheet analysis tools is provided by project category in Appendix E.

Dust Mitigation Projects

Dust Suppression for Road Construction Projects and/or Unpaved Roads:

ADOT tested two surface treatments for unpaved roads as part of the project entitled "*Identification of Emissions Sources for Pinal County*". Field measurements of PM10 emission rates were made on two different state highways, routes, SR88 and SR288. The segment of state route 88 between mile point 220.1 and mile point 227.5 was treated with Envirotac II Acrylic copolymer at a rate of 1 gallon per 36 square feet, after 5 months the PM10 emissions were reduce by a factor of five. The segment of SR 288 between mile points 274.7 and 280.5 was treated by milling 6in of the base material that was treated with a 1:1 ratio of SS1 followed by an application of CRS II Emulsified liquid at a rate of 0.5 gallon per square yard and then 28 pounds per square yard of 3/8 in chips, after one year PM10 emissions were reduce by a factor of sixty. This study also looked as typical cost effectiveness results from other dust palliative applications as illustrated by Table 1.

Table 1: Dust Control Method Costs and Effectiveness ($ per mile of road treated)

Dust Control Category	Specific Product	Control Cost ($ per mile of road treated)	Control Effectiveness Range	Control Duration
Moisture Increase	Watering	$31	0% - 50%*	0.5-1 hours
	Calcium Chloride	$18,000	0% - 70%**	6 months
Particle Agglomeration	EK-35	$16,000	0% - 99%***	1 year
	Lignosulfonate	$12,000	0% - 90%*	2 months
	Soil Sement	$18,000	0% - 84%****	1 year
Soil Coverage	Gravel	$16,000	0% - 30%*	1 year
	Asphalt Paving	$311,000	90% - 99%	20 years

* Orlemann, 1983
** Morgan, 2005
*** MRI, 2002
**** California ARB, 2002

Given the wide range of effectiveness for dust palliatives, ADOT is including an example of emissions reduction control efficiency for water at 50% and chemical stabilizers at 70% this amount will change based on manufacturer specification and frequency of application. ADOT is also reviewing the appropriateness of the emissions factors assumption for unpaved roads and construction fugitive dust emissions as these factors may change in the future.

Example A: The City of Nogales requests $200,000 CMAQ funds to purchase chemical dust palliatives to be applied 2 times a year to stabilize 4 miles of a rural unpaved road with an ADT of 200. The product specifications state that one application will be effective for 180 days and the City is purchasing a one year supply of dust palliative. The applicant provides information for green sections of the "Dust Suppressant Calculation Sheet" in Figure 3 and the emissions benefits are calculated. This project produces an annual PM_{10} emissions reduction of 51,488.64 kilograms an adjustment factor of .15 used to estimate the associated $PM_{2.5}$ emissions reduction of 7,723.3 kilograms. The cost effectiveness is calculated for only PM_{10} as the $PM_{2.5}$ is an assumed percentage of the PM_{10} emissions reductions. The cost effectiveness of this project is estimated by dividing the total emissions by the total CMAQ funding to produce a cost effectiveness of $ 3.88 per Kg of PM_{10} emissions reduced.

Note: This example is for dust mitigation for unpaved road, there is another emissions calculation sheet for dust mitigation for a construction project, see Appendix E.

Figure 3: Dust Suppression Calculation Sheet

Unpaved Road Dust Suppression

	PM10 Emissions Factor (kg/mile)
High Value	0.2554
Low Value	0.0984
Mid Value	0.1769

	Control Efficiency	Number of Days Effective
Water	50%	
Chemical Stabilizers	70%	180

Daily Emissions Reductions

Road Name	Emissions Factor (kg/Mile)	X	Control Efficiency	X	Average Daily Traffic	X	Length of segment (miles)	=	Daily PM10 Emissions Reductions (kg/day)
Example A	0.2554	X	0.7	X	200	X	4.00	=	143.02

Number of Days with Emissions Reductions

Number of Days Effective per Application	X	Number of Applications per Year	=	Number of Days with Emissions Reductions (days/year)
180	X	2	=	360

Annual Emissions Reductions

Daily PM10 Emissions Reductions (kg/day)	X	Number of Days with Emissions Reductions (days/year)	=	Annual PM10 Emissions Reductions (Kg/Year)	X	Emission Factor Used for PM2.5 Contribution	=	Annual PM2.5 Emissions Reductions (Kg/Year)
143.02	X	360	=	51,488.64	X	0.15	=	7,723.30

Cost/Benefit Analysis

Total Project Cost ($)	÷	Life of Project (year)	÷	Annual Emissions Reductions (kg/year)	=	Cost Effectiveness ($/kg)
$ 200,000	÷	1	÷	51,488.64	=	3.88

Surface Improvement (Unpaved Roads)

Surface improvement control options alter the road surface. As opposed to "surface treatments", improvements are relatively permanent and do not require periodic retreatment. The most obvious surface improvement is paving an unpaved road. This option is quite expensive and is probably most applicable to relatively short stretches of unpaved road with at least several hundred vehicle passes per day. Furthermore, if the newly paved road is located near unpaved areas or is used to transport material, it is essential that the control plan address routine cleaning of the newly paved road surface. The control efficiencies achievable by paving can be estimated by comparing emission factors for unpaved and paved road conditions.

Other surface improvement methods involve covering the road surface with another material that has a lower silt content. Examples include placing gravel or slag on a dirt road. The control efficiency can be estimated by comparing the emission factors obtained using the silt content before and after improvement. The silt content of the road surface should be determined after 3 to 6 months rather than immediately following placement. Control plans should address regular maintenance practices, such as grading, to retain larger aggregate on the traveled portion of the road. The paving of unpaved roads and unpaved parking areas can result in a control efficiency of 99 percent based on the comparison of paved road and unpaved road emissions factors.[10]

Road Paving:

Paved Road Baseline Emissions

For the paved roadway improvements the calculation begins with the calculation of the base emissions on the roadway from re-entrained dust:

Emissions Factor is $E_{ext} = [\, k\,(sL)^{0.91} \times (W)^{1.02}\,]\,(1 - P/4N)$
Annual Emissions Reduction = Roadway $VMT_{Annual} * E_{ext}$

Where:
E_{ext} = annual or other long-term average emission factor in the same units as *k*,
k = particle size multiplier for particle size range and units of interest – PM_{10} 1 g/VMT, $PM_{2.5}$ .25 g/VMT[11]
sL = road surface silt loading – 0.105 g/m^2 ADEQ Nogales PM10 SIP[12]
W = average weight (tons) of the vehicles traveling the road – 3 tons
P = number of "wet" days with at least 0.254 mm (0.01 in) of precipitation during the averaging period
For precipitation a value of 60 days/365 days per year is the value presented in the AP-42 references for the region containing Nogales, ADEQ used 45 days in nonattainment plan.
N = number of days in the averaging period (e.g., 365 for annual)

Example B (part 1): The City of Nogales is interested in applying for $650,000 in CMAQ funds to pave a 1 mile section of unpaved road that accesses an existing paved road, curb and gutter will also be added on both sides of the roadway. This road has an annual VMT of 200,000 with an ADT of 550 the City will also be providing curb and gutter on both sides of a road with paved shoulders, the paving has an expected lifecycle of 15 years. The City will fill out the green portion of the "Paved Road Baseline Emissions " Calculation Sheet in Figure 4, this baseline will be used to calculate the PM_{10} emissions factors for use in both the "Paving Unpaved Roads or Alleys" Calculation Sheet in Figure 5 for part 2 and the "Paving Unpaved Shoulders and/or Providing Curb and Gutter (C&G)" Calculation Sheet in Figure 6 for part 3 of this example.

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[10] Western Regional Air Partnership (WRAP), *Fugitive Dust Handbook*, September 7, 2006 (http://www.wrapair.org/forums/dejf/fdh/content/FDHandbook_Rev_06.pdf)
[11] United States Environmental Protection Agency, *AP-42, Background Documentation, Table 13.2.1-1*, January 2011.
[12] ADEQ, *State Implementation Plan Nogales PM10 Nonattainment Area* , July 2012 http://www.azdeq.gov/environ/air/plan/download/sip_npm10na.pdf

Figure 4: Baseline Calculation Sheet

Paved Road Baseline Emissions

Emissions Factor: Eext = [k (sL)0.91 x (W)1.02] (1 – P/4N)

Particle Size	Particle Size Multiplier (k) (g/VMT)	Road Surface Silt Loading (sL) (g/m^3)	Average Weight of Vehicles (W) (ton)	Number of Wet Days (P) (>=0.254 mm)	Number of Days in Averaging Period (N)	Emission Factor (E_{ext})
PM10	1	0.105	3	45	365	0.382251788

Annual PM10 Emissions Reduction

Road Name	Roadway VMT_{Annual}	X	Emission Factor (E_{ext})	=	Annual Emissions Reduction (kg/year)
Example B	200,000	X	0.382251788	=	76.45035769
			Total Daily Emissions Reductions		76.45035769

For Paving Unpaved Roads or Alleys:

Daily Emission Reductions = (BEF – AEF) * Miles * 0.93 * ADT * 1 /1000 (Kg/day)

Where:
BEF = the PM_{10} emission factor for vehicles traveling on unpaved roads or alleys (PM10 emissions factor – high value for roads/mid value for alleys)
AEF = the PM_{10} emission factor for vehicles traveling on paved roads or alleys (baseline emissions factor)
Miles = the length of the project (in centerline miles)
ADT = the average weekday traffic on the unpaved road or alley
0.93 = the factor to convert from weekday to annual average daily traffic on arterials.

Example B (part 2): After the "Paved Road Baseline Emissions" Calculation Sheet is completed in Figure 4, the City will continue entering data in the green sections of the "Paving Unpaved Roads or Alleys" Calculation Sheet in Figure 5. The grey portions of the spreadsheet automatically calculate the emissions and cost effectiveness of the project. This project produces an annual PM_{10} emissions reduction of 47,608.6 Kg with the estimated PM2.5 emissions reduction of 11,901.5 Kg, the cost effectiveness of $ 0.91 per Kg of PM_{10} reduced.

Figure 5: Paved Road or Alley Calculation Sheet

Paving Unpaved Roads or Alleys

	PM10 Emissions Factor (kg/mile)
High Value	0.2554
Low Value	0.0984
Mid Value	0.1769

Difference in Emissions Factors

	Emissions Factor Unpaved (g/mile)	-	Emissions Factor Paved (g/mile)	=	Difference in Emissions Factors (g/mile)
Road	255.37	-	0.3823	=	254.99
Alley	176.90	-	0.3823	=	176.52

Daily PM10 Emissions Reductions

Road Name	Difference in Emissions Factors (g/Mile)	X	Length of segment (miles)	X	Average Daily Traffic	X	Factor to convert from weekday to AADT on arterials	=	Emissions Reductions (kg/day)
Example B	254.99	X	1	X	550	X	0.93	=	130.427385
		X		X		X	0.93	=	0
		X		X		X	0.93	=	0
		X		X		X	0.93	=	0
		X		X		X	0.93	=	0
		X		X		X	0.93	=	0
							Total Daily Emissions Reductions		130.427385

Annual Emissions Reductions

Daily PM10 Emissions Reductions (kg/day)	X	Number of Days per Year (days/year)	=	Annual PM10 Emissions Reductions (kg/year)	X	Emission Factor Used for PM2.5 Contribution	=	Annual PM2.5 Emissions Reductions (kg/year)
130.43	X	365	=	47,606.00	X	0.25	=	11,901.50

Cost/Benefit Analysis

Total Project Cost ($)	÷	Life of Project (year)	÷	Annual Emissions Reductions (kg/year)	=	Cost Effectiveness ($/kg)
$ 650,000	÷	15	÷	47,606.00	=	0.91

Paving Shoulders and/or Curb and Gutter:

Paved road dust also depends on whether the road shoulder is paved and whether there is a source of dust fallout present. This measure reduces the generation of dust from vehicle excursion onto unpaved shoulders. For example, facilities with dust-generating storage piles, and truck traffic moving between these piles, are likely to have high particulate emission rates. This is particularly true for facilities with unpaved road shoulders.[13] Generally, roads with average daily traffic (ADT) of 500 to 3,000 should have an average shoulder width of at least four feet. Roads with an ADT that is greater than 3,000 require an average shoulder width of at least 8 feet. The reduction of road dust associated with paved shoulders depends on site-specific variables, including silt loading and traffic volumes.

The following approach was taken from the MAG Methodologies for Evaluating Congestion Mitigation and Air Quality Improvement Projects and provides a basic framework for analyzing these projects:

For Paving Unpaved Shoulders and/or Providing Curb and Gutter (C&G):
Daily Emission Reductions = Miles * ADT * 0.93 * RF * 1 /1000 (Kg/day)

Where:
Miles = the length of the project (in centerline miles)
ADT = the average weekday traffic on the road adjacent to the unpaved shoulders
0.93 = the factor to convert from weekday to annual average daily traffic
RF = Emission reduction factor in grams per vehicle mile of travel (vmt) for PM_{10}:

- Low volume arterials (<10,000 ADT)
  - 0.76 g/vmt, if paving shoulders and providing C&G on both sides of the road;
  - 0.57 g/mvt, if paving shoulders on both sides of the road without C&G;
  - 0.38 g/vmt, if paving shoulder and providing C&G on one side of the road;
  - 0.29 g/vmt, if paving shoulder on one side of the road without C&G;
  - 0.19 g/vmt, if providing C&G on both sides of a road with paved shoulders; or
  - 0.10 g/vmt, if providing C&G on one side of a road with a paved shoulder.
- High volume arterials (> 10,000 ADT)
  - 0.53 g/vmt, if paving shoulders and providing C&G on both sides of the road;
  - 0.40 g/mvt, if paving shoulders on both sides of the road without C&G;
  - 0.27 g/vmt, if paving shoulder and providing C&G on one side of the road;
  - 0.20 g/vmt, if paving shoulder on one side of the road without C&G;
  - 0.14 g/vmt, if providing C&G on both sides of a road with paved shoulders; or
  - 0.07 g/vmt, if providing C&G on one side of a road with a paved shoulder.

Example B (part 3): Continuing with the example of a 2 mile road paving project that adds shoulders, curb and gutter the emission calculation sheet is provided in Figure 6. The City will input the Reduction Factor (RF) of .19 for a low volume road, the ADT of 550, the cost of $650,000, the number of days in year, and the life of project estimated at 15 years. The spreadsheet will calculate the cost effectiveness and emissions PM_{10} where the $PM_{2.5}$ emissions reduction is calculated by assuming the 25% of total PM_{10} is attributed to $PM_{2.5}$. This example produces an annual PM_{10} emissions reduction of 70.95 Kg with a cost effectiveness of $610.80 per Kg of PM_{10} reduced and an estimate of an annual $PM_{2.5}$ emissions reduction of 17.74 Kg.

[13] United States Environmental Protection Agency, *AP-42, Background Documentation to Chapter 13.2.1*, January 2011.

Figure 6: Pave Shoulder and Curb & Gutter Calculation Sheet

Paving Unpaved Shoulders and/or Providing Curb and Gutter (C&G)

Reduction Factor (RF) (g/vmt)

	Low volume arterials (<10,000 ADT)		High volume arterials (>=10,000 ADT)
If paving shoulders and providing C&G on both sides of the road	0.76		0.53
If paving shoulders on both sides of the road without C&G	0.57		0.4
If paving shoulders and providing C&G on one side of the road	0.38		0.27
If paving shoulders on one side of the road without C&G	0.29		0.2
If providing C&G on both sides of a road with paved shoulders	0.19		0.14
If providing C&G on one side of a road with paved shoulders	0.1		0.07

PM10 Daily Emissions Reductions

Project Name	RF	X	Average Daily Traffic	X	Length of segment (miles)	X	Factor to convert from weekday to AADT on arterials	=	Emissions Reductions (kg/day)
Example B	0.19	X	550	X	2	X	0.93	=	0.19437
							Total Daily Emissions Reductions		0.19437

Annual Emissions Reductions

Daily PM10 Emissions Reductions (kg/day)	X	Number of Days per Year (days/year)	=	Annual PM10 Emissions Reductions (Kg/Year)	X	Emission Factor Used for PM2.5 Contribution	=	Annual PM2.5 Emissions Reductions (kg/year)
0.19	X	365	=	70.95	X	0.25	=	17.74

Cost/Benefit Analysis

Total Project Cost ($)	÷	Life of Project (year)	÷	Annual Emissions Reductions (kg/year)	=	Cost Effectiveness ($/kg)
$ 650,000	÷	15	÷	70.95	=	610.8013643

For Chip Sealing Unpaved Roads or Alleys:

Daily Emission Reductions = BEF * CCE * Miles * 0.93 * ADT * 1 /1000 (Kg/day)

Where:

BEF = the PM_{10} emission factor for vehicles traveling on unpaved roads or alleys (PM10 emissions factor – high value for roads/mid value for alleys)

CCE = the chip sealing control efficiency (90% from Nogales PM10 SIP)

Miles = the length of the project (in centerline miles)

ADT = the average weekday traffic on the unpaved road or alley

0.93 = the factor to convert from weekday to annual average daily traffic on arterials.

Example B-1: The City of Nogales is interested in applying for $650,000 in CMAQ funds to chip seal a 1 mile section of unpaved road. This road has an annual VMT of 200,000 with an ADT of 550. The chip sealing has an expected lifecycle of 6 years. The City will fill out the green portion of the "Chip Sealing Unpaved Roads or Alleys" Calculation Sheet in Figure 7. This project produces an annual PM_{10} emissions reduction of 42,910.55 Kg with the estimated PM2.5 emissions reduction of 10,727.64 Kg, the cost effectiveness of $ 2.52 per Kg of PM_{10} reduced.

Figure 7: Chip Sealing Unpaved Roads or Alleys Calculation Sheet

Chip Sealing Unpaved Roads or Alleys

	PM10 Emissions Factor (kg/mile)
High Value	0.2554
Low Value	0.0984
Mid Value	0.1769

Chip Seaing Control Efficiency
90%

Difference in Emissions Factors

	Emissions Factor Unpaved (g/mile)	X	Control Efficiency	=	Chip Sealing Emissions Factor (g/mile)
Road	255.37	X	0.9	=	229.84
Alley	176.90	X	0.9	=	159.21

Daily PM10 Emissions Reductions

Road Name	Chip Sealing Emissions Factor (g/mile)	X	Length of segment (miles)	X	Average Daily Traffic	X	Factor to convert from weekday to AADT on arterials	=	Emissions Reductions (kg/day)
Example B	229.84	X	1	X	550	X	0.93	=	117.56316
		X		X		X	0.93	=	0
		X		X		X	0.93	=	0
		X		X		X	0.93	=	0
		X		X		X	0.93	=	0
		X		X		X	0.93	=	0
								Total Daily Emissions Reductions	117.56316

Annual Emissions Reductions

Daily PM10 Emissions Reductions (kg/day)	X	Number of Days per Year (days/year)	=	Annual PM10 Emissions Reductions (kg/year)	X	Emission Factor Used for PM2.5 Contribution	=	Annual PM2.5 Emissions Reductions (kg/year)
117.56	X	365	=	42,910.55	X	*0.25*	=	10,727.64

Cost/Benefit Analysis

Total Project Cost ($)	÷	Life of Project (year)	÷	Annual Emissions Reductions (kg/year)	=	Cost Effectiveness ($/kg)
$ 650,000	÷	6	÷	42,910.55	=	2.52

Equipment Purchases

Road Street Sweepers:

Paved road dust is fugitive dust that is deposited on a paved roadway and then re-entrained into the air by passing vehicles. Dust is deposited on the roadway by being blown from disturbed areas, tracked from unpaved shoulders or vehicles traveling on connecting unpaved roads, stirred up from unpaved shoulders by wind currents created from traffic movement, spilled by haul trucks, and deposited by water runoff or erosion. Vehicles cause dust from paved and unpaved roads to be re-entrained or re-suspended in the atmosphere. The forces created by the rolling wheels of vehicles remove fine particles from the road bed and also pulverize aggregates lying on the surface. Emissions of paved road dust are generally proportional to vehicle miles traveled. Re-entrained road dust emission rates are primarily affected by the silt loading on the road and amount of vehicle travel. Emission rates are lower per mile traveled on more trafficked roads.[14]

The Western Regional Air Partnership (WRAP) has compiled tested road dust control reductions. According to the WRAP *Fugitive Dust Handbook*, 86 percent efficient sweeping and a 14-day frequency can result in a control efficiency of 16 percent for local streets and a control efficiency of 26 percent for arterial/collector streets.[15]

Table 2 illustrates the anticipated emissions effectiveness of paved road dust reduction control measures based on research compiled within the AP-42 background documentation. It is important to note that not all sweepers are certified to reduce PM$_{2.5}$, which is necessary if the quoted reductions are to be achieved. Percent reduction will depend on the specifications of the equipment purchased.

Table 2: Emissions Effectiveness of Paved Road Dust Reduction Control Measures

Control Measure: Paved Roadway Sweeping	Effectiveness
Sweeping Alone	**16-50%**
Water Flushing	**30-70%**
Sweeping and Water Flushing	**35-90%**

These PM$_{10}$ emissions factors calculated in Figure 7 can then be used to estimate the PM$_{2.5}$ emissions using the 25% PM$_{10}$ to PM$_{2.5}$ factor found in AP-42. A list of South Coast Air Quality Air Quality Management District (SCAQMD) Certified Street Sweepers under SCAQMD Rule 1186 as of June 1, 2016 found in Appendix D.

Example C: The County of Santa Cruz is requesting $320,000 in CMAQ funding for a purchase of a PM10 Certified street sweeper. The County has 4 roads with a total of 65 miles that will be swept twice a month, the County provided a listing of each road name, length, and ADT as provided in green sections of worksheet. The control efficiency of this sweeper was determined to be 40% due to the limited sweeping schedule. It is expected that this sweeper will be used for 18 years . The "Paved Road Sweeping" Calculation Sheet in Figure 8 is used to calculate emission reductions and cost effectiveness for PM$_{10}$. This example produces an annual PM$_{10}$ emission reduction of 115,381.23 Kg with a cost effectiveness of $0.15 per Kg of PM$_{10}$ reduced and an annual PM$_{2.5}$ emission reduction of 24,230.061 Kg.

Note: This example is for purchasing a Street Sweeper another emissions calculation sheet is available for purchasing a water truck based on palliative use, see Appendix F.

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[14] United States Environmental Protection Agency, *EPA's Technical Support Document for the San Joaquin Valley, California, 2003 PM$_{10}$ Plan and 2003 PM$_{10}$ Plan Amendments*, January 27, 2004.

[15] Western Regional Air Partnership (WRAP), *Fugitive Dust Handbook*, September 7, 2006 (http://www.wrapair.org/forums/dejf/fdh/content/FDHandbook_Rev_06.pdf).

Figure 8: Sweeping Calculation Sheet

Paved Road Sweeping

Particle Size	Emission Factor (E_{ext})
PM10	0.382251788

Control Measure	
Sweeping Alone	16 - 50%
Flusher Truck	30 - 70%
Combined	35 - 90%

PM10 Emissions Reductions Over Entire Network

Road Name	Emissions Factor (kg/mile)	X	Control Efficiency	X	Average Daily Traffic	X	Lane Miles to be Cleaned (miles)	=	Emissions Reductions (kg/day)
Example C Road 1	0.000382252	X	30	X	100,000	X	20.00	=	22,935.11
Example C Road 2	0.000382252	X	30	X	75,000	X	20.00	=	17,201.33
Example C Road 3	0.000382252	X	30	X	120,000	X	10.00	=	13,761.06
Example C Road 4	0.000382252	X	30	X	50,000	X	15.00	=	8,600.67
								Emissions Reductions Over Entire Network	62,498.17
						Total Lane Miles to be Cleaned	65.00		

Percent of Total Lane Miles to Be Cleaned per Day

Lane Miles Cleaned per Day	÷	Total Lane Miles to Be Cleaned	=	Percent of Total Lane Miles to Be Cleaned per Day
5	÷	65.00	=	8%

Daily Emissions Reductions

PM10 Emissions Reductions Over Entire Network (kg)	X	Percent of Total Lane Miles to Be Cleaned per Day	=	Daily PM10 Emissions Reductions (kg/day)
62,498.17	X	8%	=	4,807.55

Annual Emissions Reductions

Daily PM10 Emissions Reductions (kg/day)	X	Number of Days per Year that Roads are Cleaned (days/year)	=	Annual PM10 Emissions Reductions (kg/year)	X	Emission Factor Used for PM2.5 Contribution	=	Annual PM2.5 Emissions Reductions (kg/year)
4807.55	X	24	=	115,381.23	X	0.21	=	24,230.06

Cost/Benefit Analysis

Total Project Cost ($)	÷	Life of Project (year)	÷	Annual Emissions Reductions (Kg/Year)	=	Cost Effectiveness ($/Kg)
$ 320,000	÷	18	÷	115,381.23	=	$ 0.15

Water Trucks:

The purchase of water trucks may also be eligible for CMAQ funding. This option is being considered by ADOT pending further guidance from Federal Highway Administration (FHWA) on eligible expenses. It is expected that the emissions calculation methodologies will mirror what was developed for dust palliatives in that it is expected that a commitment to stabilize dirt surfaces will be a condition of reimbursement for purchase of a water truck.

Other Projects

Bicycle and Pedestrian Projects (PM only):

The methodology for calculating improvements emissions from a bike or pedestrian project assumes that a dirt surface will be paved requiring the "Baseline Calculation Sheet "(Figure 4) to be included. The project must also demonstrate that there will be a reduction in auto travel to be eligible for CMAQ funding. At this time this calculation will only determine an emissions reduction for PM_{10} and $PM_{2.5}$ attributed to removing an unpaved surface.

> Example D: The City of Nogales wants to provide a bicycle path along an arterial with VMT of 200,000, it is assumed that 15 bikes a day will use this trail, the CMAQ funds requested in $200,000. The "Baseline Calculation Sheet" in Figure 4 and the "Bicycle and Pedestrian" Calculation Sheet in Figure 8 will be used. This example produces an annual PM_{10} emissions reduction of 8.05022 Kg with a cost effectiveness of $4,347.71 per Kg of PM_{10} reduced. A $PM_{2.5}$ emissions factor of .21 is used with an estimated annual $PM_{2.5}$ emission reduction of 1.69 Kg.

Figure 8: Bicycle and Pedestrian Calculation Sheet

Bicycle and Pedestrian

Particle Size	Emission Factor (E_{ext})
PM10	0.382251788

Single Occupancy Vehicle (SOV) Miles Replaced ** NOTE: For Average Trip Length use local data, or 1.8 as default

Expected Average Daily Bike Traffic	÷	Average Auto Occupancy	X	Average Trip Length (miles/trip)	=	Daily SOV Miles Replaced (miles/day)
15	÷	1.8	X	3	=	81

Daily Emissions Reductions (SOV Vehicle Emissions Saved)

Daily SOV Miles Replaced (miles/day)	X	PM10 Emissions Factor (kg/mile)	=	Daily PM10 Emissions Reductions (kg/day)
81	X	0.000382252	=	0.030962395

Annual Emissions Reductions

Daily PM10 Emissions Reductions (kg/day)	X	Number of Days per Year (days/year)	=	Annual PM10 Emissions Reductions (kg/year)	X	Emission Factor Used for PM2.5 Contribution	=	Annual PM2.5 Emissions Reductions (kg/year)
0.030962395	X	365	=	8.050222665	X	0.21	=	1.69

Cost/Benefit Analysis

Total Project Cost ($)	÷	Life of Project (year)	÷	Annual Emissions Reductions (kg/year)	=	Cost Effectiveness ($/kg)
$ 700,000	÷	20	÷	8.050222665	=	4347.705828

Diesel Retrofits:

ADOT uses the Diesel Emissions Quantifier (DEQ) to estimate PM2.5 reduction from Diesel Retrofits programs. DEQ is an interactive tool developed by EPA and evaluates clean diesel projects and options for medium and heavy duty diesel vehicles. EPA recommended the DEQ for estimating benefits for the CMAQ program. DEQ results provide annual and lifetime estimates of baseline emission, estimates of emission reductions, cost effectiveness and health benefits, and comparison of emission reductions, cost effectiveness and health benefits for different emission control strategies. ADOT developed a blank spreadsheet with drop-down menus to prepare inputs for DEQ (see Appendix F). With these specific manufacturer details provided for the retrofit technology, ADOT staff can estimate PM2.5 emission reductions using DEQ tool at EPA website (https://www.epa.gov/cleandiesel/diesel-emissions-quantifier-deq). Any retrofit projects must use the technology on EPA's Verification list at (https://www.epa.gov/verified-diesel-tech/verified-technologies-list-clean-diesel) to be eligible for CMAQ funds.

Construction Equipment Related Emissions/ Exhaust

In 2009 ADOT conducted a yearlong study on emissions impacts of widening SR92 in Sierra Vista. One of the goals of this study was to determine the impact of a road construction project on $PM_{2.5}$ emissions.[16] A summary of the emission results from this study is in Table 3. While a large portion of $PM_{2.5}$ is generated from exhaust from diesel engines, fugitive dust still contributes a larger percent of emissions for a road construction project. ADOT is still researching ways to estimate road construction dust and emissions factors for potential CMAQ projects. The Sierra Vista study estimated the construction activity for a 4 mile road widening project that added 2 travel lanes and a center auxiliary lane. This project produced 29 kg of PM_{10}, 6 kg of $PM_{2.5}$, and 30 kg of NOx, assumptions could be made that similar types of projects would produce similar emissions.

Table 3: Emissions from SR92 Road Widening Year 2009

Emissions Source	PM10 kg	PM2.5 kg
Construction Equipment Exhaust	553 (8%)	537 (37%)
Fugitive Dust	6,490 (92%)	924 (63%)

16 ADOT, *Construction Activity, Emissions, and Air Quality Impacts: Real-World Observations from an Arizona Road-Widening Case Study* http://www.azdot.gov/mpd/PDF/2010-STI-ADOT-Construction-Study-Final-Report-10-25-10.pdf , October 2010.

Nogales $PM_{2.5}$ Congestions Mitigation and Air Quality

In addition to measuring emissions from a typical road construction project, this study looked at existing mitigation controls for $PM_{2.5}$ including retrofitting construction equipment as included in Table 4. A full literature review on construction equipment emissions can be found in Appendix A of the report.

Additional Projects for Next Round of CMAQ funding

To provide CMAQ funding to $PM_{2.5}$ areas as quickly as possible, ADOT only developed methodologies for those CMAQ eligible projects that were of greatest interest to stakeholders in the nonattainment area. These methodologies are based on reducing fugitive dust in which $PM_{2.5}$ is a subset of PM_{10} emissions. Both pollutants will be estimated for project evaluation and reporting. Several CMAQ projects that reduce congestion, improve traffic flow/speeds or reduce tailpipe emissions require the use of complex emissions model(s) that require additional resources and data before ADOT staff can adequately estimate emissions for these types of CMAQ projects. As previously mentioned, ADOT has included as part of their State Planning and Research (SPR) program a work element to review and revise ADOT's CMAQ process to expand eligible CMAQ projects requiring emissions modeling and a work element to develop mobile source emissions inventory methodologies to aide ADOT in delivering the CMAQ program.

Table 4: Emissions and Cost Effectiveness of Retrofitting Construction Equipment

Control	Implementation	Costs	Benefits	Sources
DOC	Installation required to add device to vehicle exhaust system (several hours)	Relatively inexpensive ($1000-$2000 per truck engine).	10% to 30% $PM_{2.5}$ reductions, 20% to 50% HC and CO reductions	(U.S. Environmental Protection Agency, 2003; STAPPA/ALAPCO, 2006; ICF International, 2007; Storey, 2009)
DPF (active or passive)	Installation to vehicle exhaust system (<5 hours)	More expensive than DOC ($5000-$10,000 per truck engine). Can increase the ratio of NO_2 to NO.	80% to 90% $PM_{2.5}$, 60% to 93% HC and CO reductions	(STAPPA/ALAPCO, 2006; ICF International, 2007; Storey, 2009)
SCR	Installs on most diesel engines; often requires urea tank, pump, injector, and pressure/temperature monitors.	SCR systems can cost $10,000-20,000 per truck engine plus additional parts and reductant (urea) supplies.	60% NOx reduction, potential HC, CO and $PM_{2.5}$ reductions in combination with DPF or DOC	(STAPPA/ALAPCO, 2006)
EGR	Install EGR system. May require installation of DPF and/or upgrades to engine cooling system.	Can cost $10,000-15,000 when DPF is also required. May require upgrades and increase maintenance costs.	30% to 40% NO_x reduction, potential HC, CO, and $PM_{2.5}$ reductions in combination with DPF or DOC	(STAPPA/ALAPCO, 2006)

APPENDIX A-E

Located under "Projects for Improving Air Quality" at:

https://azdot.gov/business/environmental-planning/air-quality/reports-and-guidance