Congestion Mitigation and Air Quality Improvement Program Scenario Development

Final Report

June 2020

U.S. Department of Transportation
Federal Highway Administration

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-	(Remove; Insert Information Here or leave blank)	(Remove; Insert Information Here or leave blank)

4. Title and Subtitle	5. Report Date
Congestion Mitigation and Air Quality Improvement Program Scenario Development	May 2020
	6. Performing Organization Code: (Remove; Insert Information Here or leave blank)

7. Author(s)	8. Performing Organization Report No.
Porter, C.D. and S. Indrakanti	(Remove; Insert Information Here or leave blank)

9. Performing Organization Name And Address	10. Work Unit No. (TRAIS)
Cambridge Systematics, Inc. 101 Station Landing Medford, MA–02155	(Remove; Insert Information
	11. Contract or Grant No.: (Remove; Insert Information

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Federal Highway Administration Office of Planning, Environment, and Realty 1200 New Jersey Avenue SE Washington, DC 20590	Draft Report
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This report examines the potential for synergistic emissions benefits for groups of projects funded by the Congestion Mitigation and Air Quality Improvement (CMAQ) program. The key issue being addressed is the extent to which multiple projects might have synergistic effects—i.e., the benefits of the whole set of projects being greater than the sum of the benefits of individual projects. The report: (1) provides information to support State and Metropolitan Planning Organization (MPO) investment and policy decisions involving multiple factors affecting transportation-related outcomes; (2) may be of value to State Departments of Transportation (DOT) and MPOs interested in conducting programmatic assessments of the set of CMAQ projects under review; and (3) lays a framework for testing suites of CMAQ projects for evaluating their combined or synergistic effects towards improving air quality and relieving congestion. The report describes benefits, challenges, and solutions in leveraging potential synergies among CMAQ projects. It provides grouping scenarios and sample menus of projects that might be expected to create synergies, for both metropolitan and statewide levels of application.

17. Key Words	18. Distribution Statement
Emissions, congestion, Congestion Mitigation and Air Quality Improvement Program, CMAQ program, CMAQ projects	No restrictions.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	90	N/A

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ADA	Americans with Disabilities Act
AFV	Alternative Fuel Vehicle
APU	Auxiliary Power Unit
CAMPO	Capital Area Metropolitan Planning Organization
CFAT	Clean Fuel Advanced Technology
CMAP	Chicago Metropolitan Agency for Planning
CMAQ	Congestion Mitigation and Air Quality Improvement (Program)
CNG	Compressed Natural Gas
CO	Carbon Monoxide
DOT	Department of Transportation
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
HOT	High-Occupancy Toll
HOV	High-Occupancy Vehicle
I&M	Inspection and Maintenance
ITS	Intelligent Transportation Systems
LPG	Liquid Propane Gas
MAG	Maricopa Association of Governments
MAP-21	Moving Ahead for Progress in the 21st Century Act
MOVES	Motor Vehicle Emission Simulator Model
MPO	Metropolitan Planning Organization
MTP	Metropolitan Transportation Plan
NAAQS	National Ambient Air Quality Standards
NCCETC	North Carolina Clean Energy Technology Center
NCDOT	North Carolina Department of Transportation
NCHRP	National Cooperative Highway Research Program
NCSU	North Carolina State University
NCTCOG	North Central Texas Council of Governments
NO_x	Oxides of Nitrogen
PM	Particulate Matter
$PM_{2.5}$	Particulate Matter with a diameter of 2.5 microns or less
RTA	Regional Transportation Authority
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SOV	Single-Occupancy Vehicle
STBG	Surface Transportation Block Grant
STP	Surface Transportation Program
TCM	Transportation Control Measure
TDM	Travel Demand Management
TEAM	Travel Efficiency Assessment Method
TIP	Transportation Improvement Program
TJCOG	Triangle J Council of Governments
TMA	Transportation Management Association
TOD	Transit-Oriented Development
VMT	Vehicle-Miles of Travel
VOC	Volatile Organic Compounds

Executive Summary

This report examines the potential for synergistic emissions benefits for groups of projects funded by the Congestion Mitigation and Air Quality Improvement (CMAQ) program. The key issue being addressed is the extent to which multiple projects might have synergistic effects—i.e., the benefits of the whole set of projects being greater than the sum of the benefits of individual projects. The report:

- Provides information to support State and Metropolitan Planning Organization (MPO) investment and policy decisions involving multiple factors affecting transportation-related outcomes. States and MPOs may consider this information when selecting projects for CMAQ funding with the goal of maximizing emission reductions and/or congestion relief.
- May be of value to State Departments of Transportation (DOT) and MPOs interested in conducting programmatic assessments of the set of CMAQ projects under review, as described in the Federal Highway Administration (FHWA) CMAQ Interim Program Guidance (FHWA, 2013).
- Lays a framework for testing suites of CMAQ projects for evaluating their combined or synergistic effects towards improving air quality and relieving congestion.

Synergies can be **geographic** in nature (e.g., improving a corridor or network); complementary in a **functional** way, for example, clean technology supported by demand-side measures to shift passenger or freight travel to the cleaner modes; or achieved through program **scope or scale** to leverage economies of scale, for example in purchasing clean fuel technology across multiple vehicle fleets or procurement of bikeshare infrastructure across municipalities.

States and MPOs face a number of challenges in leveraging potential synergies among CMAQ projects. These include:

- Understanding which types of CMAQ projects may produce synergistic emissions benefits and why, and determining how best to combine them.
- How to cover the geographic distribution of areas using CMAQ funds.
- How to address the numerous pollutants reduced by CMAQ projects.
- How to cover the size (e.g., population) of States and MPOs implementing CMAQ projects.

This report addresses potential solutions to these challenges. Information is presented on which types of projects are most likely to have synergies, why, for what pollutants, and in what geographic contexts.

The report also provides grouping scenarios and sample menus of projects that might be expected to create synergies. These groupings are formed around particular goals or objectives that States and regions are likely to have. They are framed around project types, such as implementing clean technology or reducing travel demand; geography, for example, reducing congestion and emissions in major corridors and activity centers; and pollutants of concern, including reducing ozone or particulate matter (PM) exceedances. For each of these groupings, sample project menus are developed for both metropolitan (MPO)-level application and for statewide (State DOT) application. Table 1 lists the sample project grouping scenarios and the corresponding types of CMAQ projects that might be included.

Table 1. Sample grouping of Congestion Mitigation and Air Quality Improvement project types into synergistic scenarios.

Scenario—If your goal is to:	These CMAQ project types can help:
1. Expand Commute Options	Travel demand management (TDM), transit improvements, carpooling and vanpooling, public education and outreach, Transportation Management Associations (TMA), training.
2. Increase Active/Nonmotorized Transportation	Bicycle and pedestrian facilities and programs, public education and outreach.
3. Provide Clean Public Transportation	Transit improvements, public education and outreach activities, training, alternative fuels and vehicles.
4. Reduce Emissions and Congestion from Freight/Goods Movement	Diesel engine retrofits/truck technologies, freight/intermodal, public education and outreach, idle reduction.
5. Reduce Congestion in Congested Urban Corridors or Activity Centers	Congestion reduction and traffic flow, transit improvements, bicycle and pedestrian, TDM, public education and outreach.
6. Manage Congestion on a Regional or Statewide Level	Congestion reduction and traffic flow, transit improvements, public education and outreach activities.
7. Reduce Particulate and Oxides of Nitrogen (NO_x) Emissions—Heavy-Duty Vehicle Focus	Diesel retrofit/truck technology, public education and outreach, training, inspection and maintenance (I&M) programs.
8. Reduce Emissions of Ozone Precursors and Prevent Ozone Exceedances	Diesel retrofits/truck technologies, idle reduction, transit improvements, public education and outreach, training, I&M programs, alternative fuels and vehicles.
9. Reduce Emissions in Rural Areas/Small Communities	Diesel retrofits/truck technologies, idle reduction, freight/intermodal, bicycle and pedestrian, carpooling and vanpooling, public education and outreach, I&M programs, alternative fuels and vehicles.

1.0 Introduction

The CMAQ Program was established to support surface transportation projects and other related efforts that contribute air quality improvements and provide congestion relief. The CMAQ program provides funding for a broad array of projects to accomplish the goals of improving air quality and relieving congestion.

This report examines the potential for synergistic emissions benefits for groups of projects funded by the CMAQ Program. The key issue being addressed is the extent to which multiple projects might have synergistic effects—i.e., the benefits of the whole set of projects being greater than the sum of the benefits of individual projects. The report provides information to support State and MPO investment and policy decisions involving multiple factors affecting transportation-related outcomes. The report lays a framework to test a suite of CMAQ projects for evaluating their combined or synergistic effects towards improving air quality and relieving congestion. States and MPOs may consider this information when selecting projects for CMAQ funding with the goal of maximizing emission reductions and/or congestion relief.

The report also may be of value to States and MPOs interested in conducting programmatic assessments of the program of CMAQ projects under review, as described in the FHWA CMAQ Interim Program Guidance (2013). A programmatic assessment would include an analysis of the collective emission reduction benefits of the program of projects rather than project-by-project analysis. A programmatic assessment would be a logical way of accounting for emissions benefits from groups of projects that have common objectives or synergies for achieving emission reductions.

The information on potential synergies included in this report is based on existing information regarding the effects of CMAQ projects and understanding of how different types of projects might interact. Future work may include the development and testing of analysis approaches to quantify synergies among projects.

The report is organized as follows:

- Section 2.0 discusses the potential benefits of considering synergies, challenges to leveraging synergies among CMAQ projects, and potential solutions to these challenges.

- Section 3.0 provides an overview of each of the eligible CMAQ project types listed in the FHWA CMAQ Program Interim Guidance, with information on each type of project to inform potential groupings to test synergistic effects. This section also provides a matrix illustrating potential synergies among project types.

- Section 4.0 proposes project groupings that might be expected to create synergies. These groupings are based on themes related to project types (e.g., clean technology, demand reduction), geography (e.g., corridor focus), and pollutants of concern (e.g., ozone, PM). Sample menus of projects are presented that might be expected to have synergies when implemented together. Menus are developed for both metropolitan (MPO)-level application and for statewide (State DOT) application.

- Section 5.0 provides conclusions.

- Appendix A describes existing resources on the CMAQ program and information from these resources relevant to potential groupings of projects to test synergies.
- Appendix B provides an example in which CMAQ projects funded in North Carolina (statewide) and Raleigh (MPO) during 2016 through 2018 are evaluated to assess the extent to which synergies might be present in past funded project lists, and if so, how.
- Appendix C provides a list of references.

While the report presents sample menus of CMAQ projects with potential synergies, it makes no claim regarding the eligibility of any project example under Title 23 section 149 of the U.S. Code. States and MPOs should consult with their FHWA Division office with any questions regarding project eligibility.

2.0 Benefits, Challenges, and Solutions for Leveraging Synergies Among Congestion Mitigation and Air Quality Improvement Projects

Benefits of Leveraging Synergies

States and MPOs are required to document that CMAQ-funded projects provide emission reduction benefits. Typical practice is to select and document projects individually based on their own merits. The CMAQ program, however, also provides opportunities to fund multiple projects that are related and may potentially have synergies—thus increasing overall benefits to congestion reduction and air quality. States and MPOs may, in fact, already be funding synergistic projects without accounting for additional benefits created by these synergies.

Examples of potential projects with synergies include:

- The effectiveness of projects to **improve public transit service** or provide **pedestrian and bicycle paths** could be increased if **public education and outreach programs** were in place to provide information to people about travel alternatives.

- Investments to support **intermodal freight movement** might be more effective at reducing emissions if combined with **idle reduction**, **diesel retrofit**, or other emission-reducing technologies on equipment that will see increased use.

- The effects of **bicycle investments** might increase if multiple projects are completed that contribute to a connected network of bicycle facilities.

- Programs to purchase **clean fuel transit vehicles** may achieve economies of scale in purchasing if implemented across multiple agencies, resulting in lower cost per unit of emissions reduced.

These examples illustrate that synergies can be **geographic** in nature (e.g., improving a corridor or network); complementary in a **functional** way, for example, clean technology supported by demand-side measures to shift passenger or freight travel to the cleaner modes; or achieved through program **scope or scale** to leverage economies of scale.

Figure 1 shows the number and dollar value of funded CMAQ projects between Federal Fiscal Years 2006 and 2012. Most projects fall within a small number of similar types of projects, such as traffic flow improvements, pedestrian/bicycle projects, or transit—illustrating the potential for synergies. By considering synergies among similar projects, or even among complementary projects of different types, in project programming, States and MPOs may be able to obtain greater emissions benefits than they would by accounting only for the individual emissions benefits of unrelated projects.

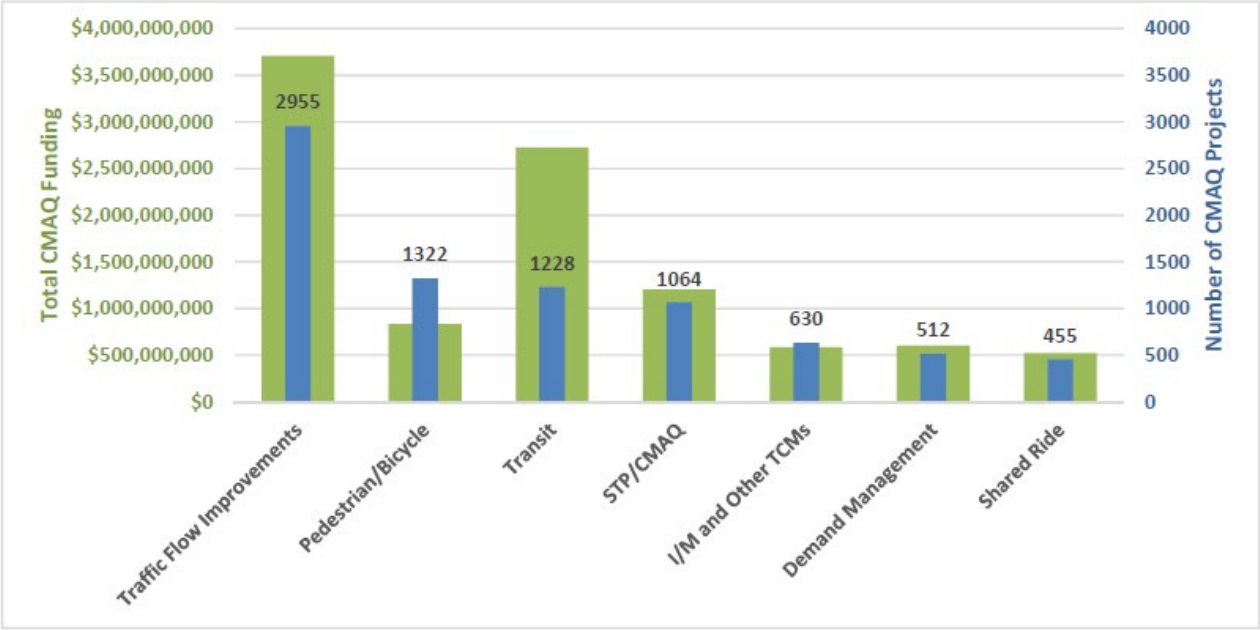


Figure 1. Chart. Distribution of Congestion Mitigation and Air Quality Improvement funding by project type, 2006–2012.

(Source: Battelle and TTI, 2014.)

Challenges and Solutions to Leveraging Synergies

As described in appendix A, a review of existing resources related to the CMAQ program found little information on potential synergies. A few synergies were hypothesized in resource documents. However, most current evaluation methods are focused on looking at project benefits and/or cost effectiveness individually rather than in combination. State and MPO CMAQ project prioritization practices were also reviewed, but very few examples were found of methods that explicitly considered synergies when programming projects. In one MPO example, a single evaluation was conducted for all phases of a multi-phase project.

States and MPOs face a number of challenges in leveraging potential synergies among CMAQ projects. These include:

- How to best combine the wide range of eligible projects.
- Understanding which types of CMAQ projects may produce synergistic emissions benefits and why.
- Reasonable and feasibility issues with combining project types.
- How to cover the geographic distribution of areas using CMAQ funds.
- How to address the numerous pollutants reduced by CMAQ projects.
- How to cover the size (e.g., population) of States and MPOs implementing CMAQ projects.

Understanding Synergies and Combining the Wide Range of Eligible Project Types

CMAQ funds may support a very diverse set of project types, ranging from clean vehicle technologies to traffic flow improvements to demand-side measures such as shared-use paths and enhanced transit service. Some project types are clearly related, whereas others are very different and are unlikely to have synergies with each other. The CMAQ program provides the flexibility for States and MPOs to focus on particular types of projects that meet local needs for emissions and congestion reduction and also support other transportation planning goals and objectives.

Section 3.0 of this report reviews each type of eligible CMAQ project, discusses potential synergies that may exist with other types of projects, and presents these synergies in the form of a matrix. States and MPOs may find it easier to create synergies if they direct funding towards specific types of projects that are clearly related, as illustrated in this section.

For many agencies, cost effectiveness—i.e., the emissions reduced per dollar spent—is an important consideration in selecting CMAQ projects for funding. The program's authorizing legislation places an emphasis on efficiency and cost effective project selection. FHWA has developed cost effectiveness tables that summarize available information on the cost-effectiveness of different types of projects (FHWA, n. d.). Other reports, as described in appendix A, also examine cost effectiveness. However, cost effectiveness has only been considered for individual types of projects, rather than for projects implemented in combination with other types of projects.

Reasonable and Feasibility Issues with Combining Project Types

Just because two projects are potentially synergistic (based on their typology) does not assure that there will be synergies. For example, they may be implemented in different geographic areas and therefore their effects may be unrelated. Or, they may affect different travel markets even in the same area (e.g., commuters versus visitor travel) and therefore not have any clear synergistic relationship. States and MPOs should carefully consider *why* synergies might be achieved when creating programs of synergistic projects.

When looking for synergies—opportunities to implement packages of CMAQ projects rather than individual projects—it helps to clearly identify the challenges that need to be addressed. For example, a State or MPO may wish to combine CMAQ projects to address a range of issues, such as needs that are:

- Community focused: "How do we reduce emissions near port facilities, especially from truck traffic, rail operations, and ports?"
- Rural area focused: "How can we reduce emissions contributing to regional ozone when we are a low-density, rural area not well suited to substantial transit use?"
- Electric vehicle fleet penetration focused: "How can our region use CMAQ projects to accelerate introduction of electric and other advanced technology vehicles to reduce energy use as well as urban-scale pollutants?"

- Transit-oriented development (TOD) focused: “How can our region use CMAQ funding to increase the ability of mixed-use, compact development to reduce single-occupant vehicle travel and encourage transit use and active transportation via walking and bicycling?”

Specifying the challenge or need helps refine understanding of the travel activities and emissions situations that need to be addressed, and helps direct which CMAQ projects are most likely to work synergistically, as described throughout this report.

Geographic Distribution

To ensure the needs of all their members or customers are being met, States and MPOs often consider the geographic distribution of project funding. Consideration of geographic distribution may sometimes conflict with the ability to fund projects that are synergistic due to their proximity. Some potential solutions include:

- Supporting projects that contribute to an **overall regional goal**, such as the completion of a bicycle network as specified in a regional bicycle plan, thus supporting longer-term synergistic benefits.

- **Rotating CMAQ funding** across geographic subareas, so that a cluster of synergistic projects are funded in one program period, and another cluster of synergistic projects (of a same or different type) is funded in a different geographic area in the next program period.

- Considering project synergies, as well as funding opportunities, **beyond just the CMAQ program**. For example, Surface Transportation Block Grant (STBG) funds also may be considered when selecting clusters of projects with synergistic effects, thus expanding the pool of funding that can be applied to support diverse geographies. The North Central Texas Council of Governments, profiled in appendix A, provides one example of combining CMAQ and STBG funds in practice.

If projects are selected thoughtfully, the CMAQ program provides an opportunity to leverage synergies across projects and a region or State.

Multiple Pollutant Types

The CMAQ Program provides flexibility for project sponsor agencies to focus on pollutants of local concern. Different types of CMAQ projects may have different effects on different pollutants. While many CMAQ project types reduce all pollutants by reducing vehicle-miles of travel (VMT) or improving traffic flow, some may be focused on specific pollutants. For example, diesel retrofit or heavy-duty alternative fuel technologies mainly reduce PM and/or NO_x from diesel vehicles. Projects that mainly reduce light-duty VMT may be more effective at reducing volatile organic compounds (VOCs), which may be more important in areas with ozone problems.

States and MPOs, especially those with nonattainment areas, are likely to consider local air quality needs when prioritizing CMAQ projects for funding. Considering synergies among project types can help to leverage greater reductions in pollutants that are of local air quality concern. For example, agencies covering a PM nonattainment area may want an enhanced focus on funding technologies, outreach, and training to maximize the implementation of PM-reducing clean vehicle technologies, with the objective of

growing the capability of truck and bus fleet operators in the area to acquire and implement the most cost effective PM-reducing technology.

A National Cooperative Highway Research Program (NCHRP) report (Cambridge Systematics, Inc., and Eastern Research Group, Inc., 2010) provides information on the effects of different transportation air quality control strategies on a full range of pollutants, and identifies methods for evaluating tradeoffs among different pollutants when selecting control strategies. Key findings of this study include:

- Projects that reduce travel generally reduce all pollutants in equal measure, although transit investments and expansion may reduce PM and NO_x less, or actually increase these pollutants.
- Most studies evaluating traffic flow improvements did not find tradeoffs among pollutants—i.e., all pollutants were consistently reduced. However, some projects did show increased NO_x levels as a result of higher traffic speeds.
- Vehicle and fuel technology strategies and their effects tend to be different for different classes of vehicles (e.g., light duty, buses, medium trucks, large trucks), for the specific technology and pollutant of interest, and depending upon the conditions under which the vehicle is operated.

Area Size

Geographic context, including metropolitan area size, population density, and the balance of population in urban versus rural areas, can have important implications for which types of CMAQ projects may be most beneficial or have the greatest synergies. For example, public transportation, carpool/vanpool, or TDM programs may have greater opportunities in larger or more densely populated metropolitan areas where congestion and parking costs are high and trips are more highly concentrated. In contrast, clean vehicle technology projects might have larger emission reduction benefits in rural areas where trip distances tend to be longer.

The selection of synergistic projects may be influenced by these contextual issues. For example, a largely rural State might determine that the greatest emissions benefits will be achieved by focusing on a cross-State freight corridor to leverage opportunities for freight modal shift and clean technology, or on an I&M program to ensure clean vehicles. Bicycle and pedestrian improvements may still be effective in small communities where trip densities are not great enough to support frequent transit service.

3.0 Summary of Congestion Mitigation and Air Quality Improvement Project Types to Inform Potential Scenario Groupings

Congestion Mitigation and Air Quality Improvement Project Type Overview

This section provides an overview of each of the eligible CMAQ project types listed in the 2013 Interim Program Guidance, to inform potential grouping to test synergistic effects. Appendix A presents a review of existing resources regarding the CMAQ program, including Federal legislation and guidance, program evaluation reports, other studies of emission reduction strategies and effectiveness, and examples of MPO prioritization methods that consider project groupings. Some of these resources discuss potential synergistic effects among different types of projects. These resources formed the foundation for identifying the various types of CMAQ projects and their potential effects.

The following information is presented for each project type:

- **Primary pollutants addressed—**i.e., the pollutants that are the main focus of the project type. Note that any type of project may affect all pollutants to at least some degree. Projects that are directed at heavy-duty vehicles, including buses, trucks, and rail vehicles, will mainly reduce PM and NO_x emissions, since these vehicles are usually diesel powered, and PM and NO_x are the most significant emissions from diesel vehicles. Projects that mainly reduce passenger travel will affect light-duty VMT. Direct (tailpipe) PM emissions are generally small from light-duty vehicles, but VOCs, NO_x, and carbon monoxide (CO) will be reduced, and there will be some PM benefits from reduced brake and tire wear as well as reduced secondary formation from NO_x emissions. Projects that increase transit service could increase PM and NO_x unless clean transit vehicles are used.

- **Potential synergies with other projects of the same type—**if more projects are implemented, will synergies be achieved through network effects or economies of scale?

- **Potential synergies with other projects of different types—**specifically, for what types of projects synergies might occur, and why.

- Potential effects of **location type** (urban, suburban, rural, corresponding to higher or lower levels of population density) on project effectiveness and synergies. Are synergies more or less likely to occur (for example) in an urban area versus a rural area?

- **Potential effects of area type/size** (large/medium/small metro, State) on project effectiveness and synergies. Are synergies more or less likely to occur (for example) in a large versus small metro area? Might they be achieved in the context of a statewide program?

While some generalizations can be made about effectiveness by location type or area type, there also will be differences in effectiveness related to factors such as density, traffic congestion, and parking costs that are loosely related to these area types, but not completely correlated.

The definitions for the project types are based on the CMAQ Interim Guidance but are intended to be illustrative rather than exhaustive.[1]

Diesel Engine Retrofits and Other Advanced Truck Technologies

These efforts are defined as vehicle replacement, repowering (replacing an engine with a cleaner diesel engine, alternative fuels, etc.), rebuilding an engine, or other technologies determined by the U.S. Environmental Protection Agency (EPA) as appropriate for reducing emissions from diesel engines. Pollutants, potential synergies, and geographic effects are shown in table 2.

Table 2. Diesel engine retrofits and other advanced truck technologies.

Issue	Discussion
Primary pollutants addressed.	All pollutants, but especially PM and NO_x.
Potential synergies with other projects of the same type.	Generally, effects will be additive across individual vehicles with no specific synergies noted. However, there could be synergies resulting from economies of scale if purchasing or technical assistance is coordinated across multiple fleet operators.
Potential synergies with other projects of a different type.	Could improve the effectiveness of freight and intermodal projects if freight traffic is shifted to cleaner vehicles. Public education and training activities, such as individual expert advice, webinars, or Web resources, could help ensure that operators of both public and private fleets select the most effective and appropriate technologies for their fleet applications and properly implement to these technologies to maximize emission reductions.
Effect of location type (urban, suburban, rural) on project effectiveness and synergies.	Likely more effective in urban environments where low-speed operating conditions lead to higher emission rates.
Effect of area type/size (large/ medium/small metro, State) on project effectiveness and synergies.	May be more effective in larger metro areas to the extent that speeds are lower and emission rates higher.

Idle Reduction

Idle reduction projects include onboard and other technologies to reduce emissions from idling from heavy-duty vehicles, such as auxiliary power units (APU), direct fired heaters, and truck stop electrification. Pollutants, potential synergies, and geographic effects are shown in table 3.

[1] Two types of projects identified in the Interim Guidance are not included: “Innovative projects”—These are defined as projects that show promise in reducing emissions, but do not yet have supporting data. Many types of projects may fall under this umbrella, so it is difficult to generalize about this category. Transportation Control Measures—Also known as TCMs, these are identified as emission reduction strategies in section 108 of the Clean Air Act. TCMs cover a wide variety of project types, most of which also are covered within other project types listed in the CMAQ Interim Guidance.

Table 3. Idle reduction.

Issue	Discussion
Primary pollutants addressed.	All pollutants, but especially PM and NO_x.
Potential synergies with other projects of the same type.	Generally, effects will be additive across individual projects/ vehicles, but in some cases, there may be synergistic effects, for example, if truck stop electrification across an entire corridor reduces the need for onboard APUs.
Potential synergies with other projects of a different type.	May amplify the benefits of intermodal and freight projects, for example, if idle reduction is applied to switching locomotives that are used more due to truck-rail mode shifts. Public education and training activities, such as individual expert advice, webinars, or Web resources, could help ensure that operators of both public and private fleets select the most effective and appropriate technologies for their fleet applications and properly implement to these technologies to maximize emission reductions.
Effect of location type (urban, suburban, rural) on project effectiveness and synergies.	Likely more effective in urban environments where low-speed operating conditions lead to more idling conditions.
Effect of area type/size (large/ medium/small metro, State) on project effectiveness and synergies.	No clear relationship.

Congestion Reduction and Traffic Flow Improvements

Traffic flow improvements may include geometric improvements, such as the construction of roundabouts, high-occupancy vehicle (HOV) lanes, left-turn or other managed lanes; Intelligent Transportation Systems (ITS) projects, such as traffic signal synchronization projects, traffic management projects, and traveler information systems; and value/congestion pricing encompassing a variety of market-based approaches to pricing travel. Pollutants, potential synergies, and geographic effects are shown in table 4.

Table 4. Congestion reduction and traffic flow improvements.

Issue	Discussion
Primary pollutants addressed.	All (specific effect/benefit may depend on speed range).
Potential synergies with other projects of the same type.	Corridor or areawide application could support shifts in traffic flow patterns to improve overall efficiency.
Potential synergies with other projects of a different type.	Could improve transit operations and ridership in corridor, especially with transit priority elements. Some types of projects in this category, such as HOV lanes, traveler information, and value pricing, could be more effective when combined with public education/outreach, and with transit improvements or carpool/vanpool programs to provide travel alternatives. However, projects that only improve traffic flow and reduce travel times might encourage more people to drive, having an effect on emissions that counteracts the benefits of improved traffic conditions.

Table 4. Congestion reduction and traffic flow improvements (continuation).

Issue	Discussion
Effect of location type (urban, suburban, rural) on project effectiveness and synergies.	Most effective in urban and suburban locations where traffic congestion is high; or at specific locations outside of urban areas that attract a large number of trips, such as entrances to sport and recreation venues and areas. Multimodal/mode shift benefits most likely in locations with high trip densities.
Effect of area type/size (large/ medium/small metro, State) on project effectiveness and synergies.	Congestion often related to metro area size, but this project scenario could be effective anywhere there is a concentration of traffic.

Freight/Intermodal

This category includes projects and programs targeting freight rolling stock or ground infrastructure, including new diesel engine technology or retrofits of vehicles or engines; as well as infrastructure modifications to encourage truck-rail or truck-shipping modal shift. Pollutants, potential synergies, and geographic effects are shown in table 5.

Table 5. Freight/intermodal.

Issue	Discussion
Primary pollutants addressed.	All pollutants, but especially PM and NO_x.
Potential synergies with other projects of the same type.	A series of infrastructure modifications in the same corridor is likely to support or encourage greater mode shift than isolated improvements. For example, grade separation and siding improvements across a corridor might be needed in order to improve operations enough to encourage shippers to use rail instead of truck more extensively in the corridor. Infrastructure modifications to encourage mode shift will be more effective when implemented in conjunction with clean vehicle technology on the modes where usage is increased.
Potential synergies with other projects of a different type.	Improvements to encourage mode shift will reduce emissions more if clean technologies (diesel retrofits, idle reduction, alternative fuels) are implemented on the modes where traffic is increased.
Effect of location type (urban, suburban, rural) on project effectiveness and synergies.	No clear relationship.
Effect of area type/size (large/ medium/small metro, State) on project effectiveness and synergies.	Larger metro areas are more likely to handle large amounts of freight and therefore realize greater benefits from mode shifting; however, to support mode shift, improvements may be needed across entire shipping corridors, making this a logical project scenario for statewide application.

Transit Improvements

Eligible transit improvements generally increase transit capacity and would likely result in an increase in transit ridership and a potential reduction in congestion. Projects may include new facilities; new vehicles; operating assistance and fuel costs for new or expanded services; and transit fare subsidies under certain conditions. Pollutants, potential synergies, and geographic effects are shown in table 6.

Table 6. Transit improvements.

Issue	Discussion
Primary pollutants addressed.	All pollutants. Specific effect/benefit may depend on mode shift, improved speeds, and fuel and emissions characteristics of replaced or newly added vehicles, among others.
Potential synergies with other projects of the same type.	Corridor (transit route) or areawide (service area) application could support larger mode shifts by expanding transit accessibility. Network effects may be realized with multiple projects.
Potential synergies with other projects of a different type.	The emissions benefits of mode shifting to transit will be increased if the transit vehicles are clean (alternative fuels and/or idle reduction technologies). TDM and public education programs can increase the use of new or enhanced transit services by providing information and/or incentives to use these services. Bicycle and pedestrian improvements can increase transit ridership if implemented at locations that support first-/last-mile access to transit. Carsharing, bicycle and pedestrian improvements, and carpool/ vanpool programs could increase transit use by providing more options for travelers who want to give up their car, even though they also might compete with transit for specific trips. Transit improvements are likely to attract more riders if transit-focused traffic flow improvements (such as transit priority signals) are implemented.
Effect of location type (urban, suburban, rural) on project effectiveness and synergies.	Transit improvements are typically more effective in high population density areas (urban and suburban place types) where trip densities are greater.
Effect of area type/size (large/ medium/small metro, State) on project effectiveness and synergies.	As larger metros and cities typically have a higher population density, the effectiveness of transit improvements is typically higher in these areas, although dense, transit-supportive development also is found in some smaller metro areas and communities.

Bicycle and Pedestrian Facilities and Programs

Eligible projects include constructing bicycle and pedestrian facilities that are not exclusively recreational; non-construction outreach related to safe bicycle use; and State bicycle/pedestrian coordinator positions. Pollutants, potential synergies, and geographic effects are shown in table 7.

Table 7. Bicycle and pedestrian facilities and programs.

Issue	Discussion
Primary pollutants addressed.	All pollutants, but mainly those from gasoline powered vehicles.
Potential synergies with other projects of the same type.	Corridor or areawide application of multiple projects is likely to support larger mode shifts by providing connected networks that allow travelers to access more places, as compared to isolated improvements.
Potential synergies with other projects of a different type.	TDM and public education programs can increase the use of bicycle and pedestrian facilities by providing information and/or incentives to use these facilities. Carsharing and transit improvements could increase walking and bicycling by providing more options for travelers who want to give up their car, even though they also might compete with walking and biking for specific trips.
Effect of location type (urban, suburban, rural) on project effectiveness and synergies.	Project effectiveness is typically greater in urban and suburban location types (specifically in areas of dense land use) where trip origins and destinations are close enough to walk or bike and vehicular congestion and/or parking difficulties discourage auto travel.
Effect of area type/size (large/ medium/small metro, State) on project effectiveness and synergies.	No clear linkage to area type, except for extent to which density and auto disincentives (congestion, parking costs, etc.) are correlated to metro size.

Travel Demand Management

TDM encompasses a diverse set of activities that focus on physical assets and services that provide real-time information on network performance and support better decision making for travelers choosing modes, times, routes, and locations. TDM projects often include public education/outreach (to the public, employers, and/or other trip generating institutions); incentives to use non-Single-Occupancy Vehicle (SOV) modes for commuting or school travel; institutional approaches to coordinate travel alternatives; carpool and vanpool services (such as guaranteed ride home programs), and efforts to encourage alternative work schedules. While TDM projects overlap with other types of CMAQ projects, they are typically distinguished by applying multiple approaches, e.g., by funding an organization that works with employers to implement a wide variety of SOV travel reduction strategies. Pollutants, potential synergies, and geographic effects are shown in table 8.

Table 8. Travel demand management.

Issue	Discussion
Primary pollutants addressed.	All pollutants, mainly from gasoline powered vehicles.
Potential synergies with other projects of the same type.	TDM programs could have synergies within a region as resources could be pooled across TDM service providers to maximize the value and benefit of services provided.
Potential synergies with other projects of a different type.	TDM programs will be more effective if good travel alternatives are available. Transit improvements, carpool and vanpool, TMAs, bicycle and pedestrian improvements, other TCMs, and education/ outreach projects should all create synergies with TDM programs.

Table 8. Travel demand management (continuation).

Issue	Discussion
Effect of location type (urban, suburban, rural) on project effectiveness and synergies.	Most effective in urban and suburban (central business district and other employment center) locations where there are high densities of trips, especially for commuting, so that more travelers can be reached and more effective alternatives provided.
Effect of area type/size (large/ medium/small metro, State) on project effectiveness and synergies.	Effective where there are prospects for work-trip consolidation (metro areas of all sizes) and availability of alternative means of transportation (transit/carpool/vanpool).

Public Education and Outreach Activities

The goal of CMAQ-funded public education and outreach activities is to educate the public, community leaders, and potential project sponsors about connections among trip making and transportation mode choices, traffic congestion, and air quality. This project is not necessarily a stand-alone project category (although education-only projects can be undertaken), but rather can be included as part of other projects to enhance their effectiveness. Pollutants, potential synergies, and geographic effects are shown in table 9.

Table 9. Public education and outreach activities.

Issue	Discussion
Primary pollutants addressed.	All pollutants, mainly from gasoline powered vehicles.
Potential synergies with other projects of the same type.	People often need to be reached in multiple ways before they change their behavior, so more expansive projects (or combined projects) could have synergies, although it may be best to combine them into one coordinated outreach campaign.
Potential synergies with other projects of a different type.	Education and outreach are likely to enhance the effectiveness of other project types, such as transit improvements, carpool and vanpool, TMAs, bicycle and pedestrian improvements, carsharing, and other TCMs, by providing more information to travelers about these travel options. It also can enhance the effectiveness of technology-focused projects, such as advanced truck technology, idle reduction, and alternative fuel vehicles (AFV), by educating consumers and fleet operators about the most appropriate technologies and their proper use to maximize emission reductions.
Effect of location type (urban, suburban, rural) on project effectiveness and synergies.	Most effective in urban and suburban locations where more alternatives to driving alone are likely to exist.
Effect of area type/size (large/ medium/small metro, State) on project effectiveness and synergies.	While outreach and education costs can be tailored for any area type, bigger metros have greater effectiveness for some outreach programs given the scale of potential enrollment or reach and their return on cost of campaigns.

Transportation Management Associations

TMAs are groups of citizens, firms, or employers that organize to address the transportation issues in their immediate locale by promoting rideshare programs, transit, shuttles, or other measures. TDM programs are often implemented with TMAs as lead agencies or partners. Pollutants, potential synergies, and geographic effects are shown in table 10.

Table 10. Transportation Management Associations.

Issue	Discussion
Primary pollutants addressed.	All pollutants, mainly from gasoline powered vehicles.
Potential synergies with other projects of the same type.	Multiple TMAs in the same region could provide synergies as resources could be pooled across TMAs to maximize the value and benefit of services provided (e.g., to share resource materials, technologies, or service contracting).
Potential synergies with other projects of a different type.	TDM programs will be more effective if good travel alternatives are available. Transit improvements, carpool and vanpool, TDM programs, bicycle and pedestrian improvements, other TCMs, and education/outreach projects should all create synergies with TMAs. Training can help increase the effectiveness of TMA staff.
Effect of location type (urban, suburban, rural) on project effectiveness and synergies.	Most effective in urban and suburban locations where more alternatives to driving alone are likely to exist.
Effect of area type/size (large/ medium/small metro, State) on project effectiveness and synergies.	Effective where there are prospects for work-trip consolidation (metro areas of all sizes) and availability of alternative means of transportation (transit/carpool/vanpool).

Carpooling and Vanpooling

Eligible activities include marketing for carpools and vanpools, and vehicle costs for vanpools. Pollutants, potential synergies, and geographic effects are shown in table 11.

Table 11. Carpooling and vanpooling.

Issue	Discussion
Primary pollutants addressed.	All pollutants, mainly from gasoline powered vehicles.
Potential synergies with other projects of the same type.	An expanded program may leverage economies of scale (e.g., larger markets for carpool/vanpool matching, procurement of vanpool services), although it may be best to operate a single set of regional or statewide services instead of operating multiple independent projects.
Potential synergies with other projects of a different type.	TMAs, TDM programs, and public education and outreach all play an important role in supporting carpooling/vanpooling programs and leveraging the benefits of these services. TCMs such as HOV/managed lanes and parking management can increase the incentives to carpool or vanpool.

Table 11. Carpooling and vanpooling (continuation).

Issue	Discussion
Effect of location type (urban, suburban, rural) on project effectiveness and synergies.	Most effective in urban and suburban locations with high concentrations of trip ends and high levels of congestion and/or parking costs.
Effect of area type/size (large/ medium/small metro, State) on project effectiveness and synergies.	Effective where there are prospects for work-trip consolidation/ chaining (metro areas of all sizes, but especially large ones).

Carsharing

Carsharing includes the pooling of efficient, low-emission vehicles, provided to travelers who have occasional need for a vehicle but not the constant, daily necessity that demands ownership. Pollutants, potential synergies, and geographic effects are shown in table 12.

Table 12. Carsharing.

Issue	Discussion
Primary pollutants addressed.	All pollutants, mainly from gasoline powered vehicles.
Potential synergies with other projects of the same type.	Carsharing is a service that benefits from economies of scale, as more vehicles are available to a greater number of people, and as program startup and administration costs can be spread over a larger member base.
Potential synergies with other projects of a different type.	TMAs, TDM programs, and public education and outreach can all play an important role in supporting carsharing programs and leveraging the benefits of these services. Carsharing services may benefit from AFV projects, including refueling infrastructure as well as incremental purchase costs compared to conventional fuel vehicles. Given the high utilization of carshare services, alternative fuels may be particularly cost effective in this application.
Effect of location type (urban, suburban, rural) on project effectiveness and synergies.	Most effective in urban locations with high trip densities, where parking is more difficult, transit is readily available, and vehicle ownership rates are lower than suburban or rural areas.
Effect of area type/size (large/ medium/small metro, State) on project effectiveness and synergies.	Larger and medium metros have higher effectiveness due to the incidence of sharing economies and use of carsharing apps and technology compared to smaller metros or rural areas.

Extreme Low-Temperature Cold Start Programs

These projects may include retrofitting vehicles and fleets with water and oil heaters and installing electrical outlets and equipment in publicly owned garages or fleet storage facilities, with the objective of reducing emissions from cold starts. Pollutants, potential synergies, and geographic effects are shown in table 13.

Table 13. Extreme low-temperature cold start programs.

Issue	Discussion
Primary pollutants addressed.	CO and other pollutants.
Potential synergies with other projects of the same type.	No clear synergies; benefits would scale with the number of installations and amount of use.
Potential synergies with other projects of a different type.	These projects may be more effective if applied with idle reduction technology, which would increase the number of starts. On the other hand, they may be of less value when they are applied with alternative fuels and vehicles or other advanced emission reducing vehicle technology that reduces cold-start emissions. Public education can be important for maximizing the benefits of these projects.
Effect of location type (urban, suburban, rural) on project effectiveness and synergies.	No clear relationship to location type.
Effect of area type/size (large/ medium/small metro, State) on project effectiveness and synergies.	No clear relationship to area type/size.

Training

This category includes training and educational development for the transportation workforce. Such training should be related to air quality improvements. Pollutants, potential synergies, and geographic effects are shown in table 14.

Table 14. Training.

Issue	Discussion
Primary pollutants addressed.	All pollutants.
Potential synergies with other projects of the same type.	It may be most effective to combine training-focused projects into a single program to leverage and coordinate resources.
Potential synergies with other projects of a different type.	Training can potentially help to increase the benefits of almost any other type of CMAQ projects by ensuring that project funds are spent in the most effective way. For example, for technology-focused projects such as diesel retrofits, idle reduction, and alternative fuels, training could focus on helping fleet managers select and implement the most appropriate and cost effective technologies. For behaviorally focused projects such as TDM programs, TMAs, and public and education and outreach, training can help to build skills of staff charged with program implementation (e.g., outreach to employers or public education campaigns).
Effect of location type (urban, suburban, rural) on project effectiveness and synergies.	No clear relationship to location type.
Effect of area type/size (large/ medium/small metro, State) on project effectiveness and synergies.	No clear relationship to area type/size.

Inspection and Maintenance Programs

I&M programs are programs to enforce compliance with vehicle in-use emissions standards by identifying high-emitting vehicles and/or vehicles with malfunctioning pollution control equipment. Eligible CMAQ-funded activities include construction of facilities, purchase of equipment, I&M program development, and one-time start-up activities. Pollutants, potential synergies, and geographic effects are shown in table 15.

Table 15. Inspection and maintenance programs.

Issue	Discussion
Primary pollutants addressed.	All pollutants (specific effect/benefit may depend on vehicle types covered and pollutants or equipment types tested by the program).
Potential synergies with other projects of the same type.	Typically a single I&M program would be implemented on a regional or statewide basis.
Potential synergies with other projects of a different type.	Public education and outreach activities could increase the effectiveness of an I&M program by emphasizing the importance and benefits of complying with the program. Training activities could increase the ability of I&M program staff to carry out their responsibilities.
Effect of location type (urban, suburban, rural) on project effectiveness and synergies.	No clear relationship to location type.
Effect of area type/size (large/medium/ small metro, State) on project effectiveness and synergies.	No clear relationship to area type/size.

Alternative Fuels and Vehicles

Program funds may be used to support projects involving the alternative or renewable fuels defined in the Energy Policy Act of 1992 or the Energy Independence and Security Act of 2007. Eligible expenses include certain types of fueling facilities and other infrastructure needed to fuel AFVs; purchasing publicly owned AFVs or converting fleets to alternative fuel; and purchase of certain hybrid vehicles. Pollutants, potential synergies, and geographic effects are shown in table 16.

Table 16. Alternative fuels and vehicles.

Issue	Discussion
Primary pollutants addressed.	All pollutants (specific effect/benefit may depend on vehicle and fuel types).
Potential synergies with other projects of the same type.	Emission reductions should scale proportionate to the number of vehicles; however, economies of scale in refueling infrastructure and/or vehicle purchasing may lead to cost savings on a per-unit basis (i.e., more emission reductions per program dollar) for larger projects or multiple projects in the same area.

Table 16. Alternative fuels and vehicles (continuation).

Issue	Discussion
Potential synergies with other projects of a different type.	Transit improvements, vanpooling, and freight/intermodal projects could have greater emission reductions per unit of mode shift if expanded services make use of AFVs. Education/outreach activities and training could help to maximize the effectiveness of these programs.
Effect of location type (urban, suburban, rural) on project effectiveness and synergies.	Emission reductions per vehicle might be higher in urban or sub-urban areas with more congested traffic conditions, although this will depend on the relationship between speed and emissions for a specific vehicle/fuel technology.
Effect of area type/size (large/ medium/small metro, State) on project effectiveness and synergies.	Adoption of alternative vehicles and fuels was found to be more likely in transit agencies in larger urban areas compared to the rural areas (Mattson, 2012).

Synergies Among Project Types

Figure 2 provides a matrix illustrating potential synergies between project types. A check mark in the row for a project type indicates a relationship (and therefore potential synergy) between that project type and the corresponding project type indicated in the column heading. For example:

- The emissions benefits of freight/intermodal or transit improvement projects may be greater if diesel retrofit or advanced technologies are deployed on freight and transit vehicles to reduce emissions from these vehicles, in addition to any mode-shifting effects of these projects (e.g., truck to rail, driving to transit).

- Projects such as transit improvements, carpooling and vanpooling, and bicycle and pedestrian facilities may show greater benefits if they are accompanied by public education and outreach to inform people of modal options and encourage their use.

Figure 2 also indicates those project types that show synergies with the same type of project. Examples might include bicycle projects that add to a connected network, or idle reduction projects that achieve economies of scale in purchasing or deployment. These same-project-type relationships are shown with the gold boxes running diagonally from upper left to lower right.

The project types showing synergies are the same as those described in the above discussion, which provides more details on how the synergies might be achieved. Just because there is a check mark in a cell does not mean a synergy necessarily exists; it just means that there is a good possibility of synergies if the projects are designed and coordinated appropriately. Some categories cover a broad range of project types, some of which may achieve synergies and some of which may not. In some cases, projects may even work at cross purposes, e.g., transit and vanpool projects competing for the same travel market.

A project of this type…	… could have synergies with a project of this type:														
	Diesel Retrofit and Advanced Truck Tech	Idle Reduction	Congestion Reduction and Traffic Flow	Freight/ Intermodal	Transit Improve-ments	Bike and Ped Facilities and Programs	TDM	Public Education and Outreach	TMAs	Carpooling and Vanpooling	Car-sharing	Extreme Low-Temp. Cold Start	Training	I&M Programs	Alt. Fuels and Vehicles
Diesel Engine Retrofits/ Advanced Truck Tech				✓				✓					✓		
Idle Reduction				✓				✓				✓	✓		
Congestion Reduction and Traffic Flow			✓		✓			✓		✓			✓		
Freight/Intermodal	✓	✓		✓									✓		✓
Transit Improvements		✓	✓		✓	✓	✓	✓	✓	✓	✓		✓		
Bike and Ped Facilities and Programs					✓	✓	✓	✓	✓		✓		✓		
TDM					✓	✓	✓	✓	✓	✓	✓		✓		
Public Education and Outreach Activities	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
TMAs					✓	✓	✓	✓	✓	✓	✓		✓		
Carpooling and Vanpooling			✓		✓		✓	✓	✓	✓	✓		✓		✓
Carsharing					✓	✓	✓	✓	✓	✓	✓				
Extreme Low-Temperature Cold Start		✓						✓							
Training	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					✓
I&M Programs								✓							
Alternative Fuels and Vehicles				✓	✓			✓		✓			✓		✓

Figure 2. Matrix. Synergy among Congestion Mitigation and Air Quality Improvement project types.

(Source: Federal Highway Administration.)

4.0 Illustrative Project Groupings

Potential Illustrative Scenarios

The information provided above is used in this section to propose and evaluate potential groupings of projects for testing of synergistic effects. Table 17 provides a qualitative assessment of how various issues are addressed by each grouping. A total of nine sample grouping scenarios are proposed here, built around the project types identified in the CMAQ Interim Program Guidance. The groupings are formed around particular goals or objectives that States and regions are likely to have, such as implementing clean technology or preventing air quality National Ambient Air Quality Standards (NAAQS) exceedances. They include scenarios formed around the following concepts:

- Similar mechanisms for reducing emissions or modal focus—e.g., commute/workplace focus, active transportation, public transportation, or freight and goods movement.
- A focus on congestion at different geographic scales, including corridor/subarea and regional.
- A focus on specific air quality problems for the pollutants of most common concern in the United States today, including pollutants with localized health impacts (PM and NO_x) as well as precursors to ozone formation at a regional scale.

Table 17 includes:

- The types of projects that might be included in the scenario.
- A brief description of potential synergistic benefits in this scenario.
- The extent to which the scenario addresses multiple pollutants.
- The extent to which the scenario is suitable for projects grouped at different project scales, including statewide and metropolitan.

Table 17. Grouping of Congestion Mitigation and Air Quality Improvement project types into synergistic scenarios.

Scenario—If your goal is to:	Helpful CMAQ Project Types	Potential Synergistic Benefits	Examples	Addresses Multiple Pollutants	Geographic Suitability/ Area Types
1. Expand Commute Options	TDM, transit improvements, carpooling and vanpooling, public education and outreach, TMAs, training.	More multimodal options can increase likelihood of non-SOV use by providing travelers with multiple options, such as carpooling to work, with the option of taking transit home if the carpool is missed. Public education and institutional work (TMAs) can support other project types.	Regionally coordinated TDM projects and programs that include formation of TMAs, enhanced transit service to activity centers, a regional vanpooling and carpool matching program and incentives, and public education activities.	Most/all pollutants affected in same proportion through VMT reductions. Possible exceptions for increased transit.	Most relevant in urban and suburban areas with more density and travel options. Statewide programs can support project implementation across the State.
2. Increase Active/ Nonmotorized Transportation	Bike/ped facilities and programs, public education and outreach.	Multiple projects or types of projects can assist in building out a regional or statewide network, leveraging network connectivity benefits, and also complement infrastructure with education and enforcement.	Shared-use paths and bicycle lanes that are part of a regional network; bicycle parking in high-demand areas; wayfinding.	Most/all pollutants affected in same proportion through VMT reductions.	Most relevant in urban and suburban areas with more density and travel options. Statewide programs can support bike/ped networks in communities across the State.
3. Provide Clean Public Transportation	Transit improvements, public education and outreach activities, training, alternative fuels and vehicles.	Synergies may be achieved by jointly deploying projects to increase/improve transit service, encourage greater use of transit, and implement clean transit vehicle technologies so that increased transit VMT does not offset benefits of reduced auto VMT.	Electric buses and recharging infrastructure serving a new transit center, combined with marketing and free fares on high ozone days.	Mode shift to transit will especially benefit VOC and NO_x, while clean transit technology will especially benefit NO_x and PM.	Most relevant in urban and suburban areas with higher trip densities. Statewide programs can support clean transit in multiple communities.

Table 17. Grouping of Congestion Mitigation and Air Quality Improvement project types into synergistic scenarios (continuation).

Scenario—If your goal is to:	Helpful CMAQ Project Types	Potential Synergistic Benefits	Examples	Addresses Multiple Pollutants	Geographic Suitability/ Area Types
4. Reduce Emissions and Congestion from Freight/ Goods Movement	Diesel engine retrofits/truck technologies, freight/intermodal, public education and outreach, idle reduction.	Multiple projects of this type could leverage economies of scale in purchasing, infrastructure, and maintenance, as well as ensuring the benefits of truck-rail mode shift are maximized with clean technology.	Regionwide or statewide collaboration to purchase AFVs for similar fleet types and/ or establish a network of refueling/recharging stations.	Primary focus on PM and NO_x from diesel vehicles.	Most relevant in areas of freight generators, e.g., ports, intermodal facilities, manufacturing and warehousing districts. Statewide programs can leverage synergies across multiple freight generator areas and interregional freight corridors.
5. Reduce Congestion in Congested Urban Corridors or Activity Centers	Congestion reduction and traffic flow, transit improvements, bicycle and pedes-trian, TDM, public education and outreach.	Synergies may be achieved through coordination of pro-jects across a corridor or subarea to improve traffic flow, provide multiple travel options, design infrastructure for all modes, and coordi-nate multimodal traveler information and operations, thus encouraging greater mode shift.	A set of mobility pro-jects that include traffic signal and other oper-ations improvements, enhanced transit service, and bike/ped improvements, focused on a highly congested corridor.	Generally, all pollu-tants reduced, but may be exceptions depending on speed range and operating conditions, or with provision of new transit service.	Most relevant in urban and suburban areas with travel-intensive corridors. Statewide programs might focus on corridors of statewide significance or high trip generators such as recreational areas and venues.
6. Manage Congestion on a Regional or Statewide Level	Congestion reduction and traffic flow, transit improvements, public education and outreach activities.	Synergies may be achieved through coordination of projects across the region or State to optimize traffic flow, manage demand through pricing, and coordinate transit with traffic operational projects.	Traffic operations center to manage adaptive signal control systems and high-occupancy toll (HOT) lanes with dynamic pricing.	Generally, all pollutants reduced, but may be exceptions depending on speed range and operating conditions.	Most relevant in larger or more densely populated metro areas with higher levels of congestion, or in areas with high levels of seasonal travel demand.

Table 17. Grouping of Congestion Mitigation and Air Quality Improvement project types into synergistic scenarios (continuation).

Scenario—If your goal is to:	Helpful CMAQ Project Types	Potential Synergistic Benefits	Examples	Addresses Multiple Pollutants	Geographic Suitability/Area Types
7. Reduce Particulate and NO_x Emissions—Heavy-Duty Vehicle Focus	Diesel retrofit/truck tech, idle reduction, public education and outreach, training, I&M programs.	Synergies may be achieved through coordination of purchasing and growth of institutional knowledge on the most effective technologies for a specific use case and operating conditions.	Diesel retrofit, idle reduction, and heavy-duty AFV projects that meet local cost effectiveness thresholds for PM for equipment used in heavily populated areas.	May reduce all pollutants, but targeted especially to PM and/or NO_x reduction through technology and heavy-duty vehicle focus.	May be applicable at any geographic scale, but especially for PM nonattainment areas, and in vicinity of communities where health concerns are expressed.
8. Reduce Emissions of Ozone Precursors and Prevent NAAQS Ozone Exceedances	Diesel retrofits/truck technologies, idle reduction, transit improvements, public education and outreach, training, I&M programs, alternative fuels and vehicles.	Projects that might receive primary consideration in an area where emissions of ozone precursors (VOC and/or NO_x) are of key concern, especially under weather conditions conducive to ozone formation. Synergies may be achieved by coordinating efforts focused on reducing emissions specifically during ozone-conducive conditions.	Car/vanpooling programs, bike improvements and incentives, and public education focused on reducing auto travel on high ozone days.	Yes, but targeted especially to VOC and/or NO_x reduction.	May be applicable at any geographic scale, but especially for ozone nonattainment areas.
9. Reduce Emissions in Rural Areas/ Small Communities	Diesel retrofits/truck technologies, idle reduction, freight/ intermodal, bicycle and pedestrian, carpooling and vanpooling, public education and outreach, I&M programs, alternative fuels and vehicles.	Synergies may be achieved through economies of scale with assisting multiple small communities in implementing similar programs, as well as focusing on emissions generating activities that are concentrated in rural areas (e.g., truck idling).	Truck electrification throughout a corridor that reduces the need for APUs and extended idling. Funding and technical assistance for small communities to plan and implement local walk and bike networks.	Generally, all pollutants reduced, but will depend on specific projects and emissions sources targeted.	Project types may be effective everywhere, including rural communities.

Sample Project Menus

This section provides a set of sample menus of projects that are likely to have synergies. The purpose of these menus is to illustrate examples of CMAQ projects that might have synergies when implemented together (i.e., benefits of the whole greater than the sum of individual projects)—and therefore might be considered for collective implementation to increase the overall benefits of a metropolitan or statewide CMAQ program. These menus of projects also might serve as a basis for quantifying synergies using appropriate analysis methods. Each menu includes a list of sample CMAQ projects and identifies the associated project type (from the Interim Program Guidance) for each project.

The menus are created with thematic groupings aligned with the "scenario descriptions" in the previous sections. These themes include sets of projects that reduce emissions through related mechanisms (e.g., employee commute options), as well as those that address specific problems that might be of concern in a particular region or State, such as ozone or PM. Two sets of menus are provided—one for metropolitan application, such as an MPO might include in their Transportation Improvement Program (TIP); and one for statewide application, such as a State DOT might include in their State TIP. The metropolitan and statewide menus are generally parallel, covering the same themes, but customized for the scale of application.

In addition to the sample menus provided here, which are built from hypothetical projects, appendix B provides an example in which CMAQ projects funded in North Carolina (statewide) and Raleigh (MPO) during 2016 through 2018 are evaluated to assess the extent to which synergies might be present in past funded project lists, and if so, how.

While this section presents sample menus of CMAQ projects with potential synergies, it makes no claim regarding the eligibility of any project example under Title 23 section 149 of the U.S. Code. States and MPOs should consult with their FHWA Division office with any questions regarding project eligibility.[2]

Metropolitan Sample Menus

Expand Commute Options

This sample project menu (table 18) is focused on reducing congestion and emissions by providing a broad range of alternatives to single occupancy vehicle commuting.

More multimodal options can increase the likelihood of non-SOV use by providing travelers with multiple options, such as carpooling to work, with the option of taking transit home if the carpool is missed. Public education and institutional arrangements, such as TMAs and TDM programs, can support projects to improve infrastructure or services for specific modes.

[2] As noted in the FHWA Interim Program Guidance, the Federal Transit Administration (FTA) determines the eligibility of transit projects, and the FHWA determines the eligibility of all other projects. The FHWA, FTA, and EPA field offices should establish and maintain a consultation and coordination process to review CMAQ funding proposals. The FHWA and FTA headquarters offices are available to consult with their field offices on eligibility determinations.

This set of projects will reduce emissions by reducing light-duty VMT, affecting all pollutants from passenger vehicles in roughly equal proportion. They are most likely to be effective in urban and suburban areas with higher trip densities and more travel options.

Table 18. Sample project menu: expand commute options—metropolitan.

Sample Projects	CMAQ Project Type
Regional TDM program support (staffing for regional coordinator).	Travel Demand Management
Regional guaranteed ride home program.	Travel Demand Management
Regional telework resource center.	Travel Demand Management
Assistance to administer employer-based cash-out pilot.	Travel Demand Management
Redesignate general purpose to HOV lane in high-transit corridors serving downtown.	Transportation Control Measures
Implement statewide trip reduction ordinance.	Transportation Control Measures
Capital and initial operating expenses for pilot reverse-commute shuttle program connecting urban neighborhoods to suburban office parks.	Transit Improvements
Regional carpool and vanpool matching program.	Carpooling and Vanpooling
Vanpool capital subsidy.	
Regional TDM outreach and education program.	Public Education and Outreach Activities
Staffing for TMAs serving downtown and suburban activity centers.	Transportation Management Associations
Training for regional TDM and TMA staff.	Training

Increase Active/Nonmotorized Transportation

This sample project menu (table 19) is focused on reducing congestion and emissions by encouraging people of all ages to walk and/or bicycle to work, school, and other activities.

Multiple projects in one geographic area can assist in building out a local or regional bicycle or pedestrian network, thereby leveraging network connectivity benefits. Programs such as bikesharing and bicycle parking will work in combination with network improvements to increase bicycling. Infrastructure projects also can complement education projects such as safe bicycling, wayfinding, or other public information campaigns.

This set of projects will reduce emissions by reducing light-duty VMT, affecting all pollutants from passenger vehicles in roughly equal proportion. They are most likely to be effective in large or small communities with higher trip densities, where more destinations are within walking or biking distance, or where first- and last-mile access to transit is needed.

Table 19. Sample project menu: increase active/nonmotorized transportation—metropolitan.

Sample Projects	CMAQ Project Type
Procure and install secure bicycle parking at neighborhood hubs and activity centers.	Transportation Control Measures
Bicycle lane projects adding to the network proposed in the regional bike plan.	Bicycle and Pedestrian Facilities and Programs
Capital funding for bikeshare program—bikeshare facilities in neighborhood hubs.	Bicycle and Pedestrian Facilities and Programs
New sidewalks and bike paths serving neighborhood hubs.	Bicycle and Pedestrian Facilities and Programs
Bicycle safety education classes and outreach materials.	Bicycle and Pedestrian Facilities and Programs
Bicycle and pedestrian wayfinding (signage and route mapping).	Public Education and Outreach Activities
Workshops and outreach materials providing introduction to year-round bicycle commuting.	Public Education and Outreach Activities

Provide Clean Public Transportation

This sample project menu (table 20) is focused on reducing congestion and emissions by enhancing public transportation services, encouraging their use, and using clean vehicles and fuels to provide new and expanded services.

Synergies in this group of projects may be achieved by jointly deploying projects to expand or improve transit service, encourage greater use of transit through public education, and implement clean transit vehicle technologies so that increased transit VMT does not offset the emissions benefits of reduced automobile VMT.

The pollutants that are most reduced with these projects will depend on the vehicle/fuel and emissions characteristics of any new transit service introduced. Reducing automobile VMT will reduce all pollutants, but especially VOC, NO_x, and CO. However, new diesel transit vehicles could have the potential to increase NO_x and PM emissions if ridership levels are not high enough. The use of electric or other clean fuel transit technology is more likely to provide a net reduction in emissions.

These projects will be most effective at reducing emissions and congestion in urban and suburban areas with higher trip densities where public transportation can serve more trips.

Table 20. Sample project menu: provide clean public transportation—metropolitan.

Sample Projects	CMAQ Project Type
Transit center at a regional transit hub/transfer point (docking facilities and building with protected waiting area, restrooms, and information).	Transit Improvements
Pilot operating funding for neighborhood circulator service.	Transit Improvements
Free fares on high ozone days.	Transit Improvements
Campaign to market new and expanded transit services.	Public Education and Outreach Activities
Training for transit agency staff on procurement and installation of electric bus charging equipment.	Training
Capital cost for new electric buses, and purchase and installation of supporting charging equipment.	Alternative Fuels and Vehicles

Reduce Emissions and Congestion from Freight/Goods Movement

This sample project menu (table 21) is focused on reducing congestion and emissions caused by trucks by shifting freight moving into and out of the region from truck to rail, while introducing cleaner technology on truck and rail vehicles that will see increased use.

While the effects of emission reductions will generally be additive based on the number of vehicles affected, multiple projects of the same type could leverage economies of scale in purchasing, infrastructure, and maintenance. Combining projects that encourage freight mode shift with clean technology will ensure that the emissions benefits of truck-rail mode shifting are maximized.

Freight is primarily moved by diesel vehicles, meaning that the greatest emissions benefits will be to PM and NO_x. These types of projects are most relevant and most likely to achieve synergies in areas of freight generators, such as ports, intermodal facilities, and manufacturing and warehousing districts, where there is a concentration of truck traffic.

Table 21. Sample project menu: reduce emissions and congestion from freight/goods movement—metropolitan.

Sample Projects	CMAQ Project Type
Diesel retrofit assistance: Approved emission reducing retrofit technology, prioritized towards locomotives and drayage trucks serving intermodal facilities in the region.	Diesel Engine Retrofits and Other Advanced Truck Technologies
Intermodal facility improvements: Expand capacity and throughput of intermodal container terminal.	Freight/Intermodal

Table 21. Sample project menu: reduce emissions and congestion from freight/goods movement—metropolitan (continuation).

Sample Projects	CMAQ Project Type
Survey freight shippers to understand shipping requirements and what rail/intermodal improvements might encourage them to shift from truck to rail serving the regional market.	Public Education and Outreach Activities
Purchase/install electric hook-ups at a truck parking/staging area serving a warehousing district.	Idle Reduction
Purchase hybrid electric switcher locomotive for a rail yard located near an environmental justice population area.	Idle Reduction

Reduce Congestion in Congested Urban Corridors or Activity Centers

This sample project menu (table 22) is focused on reducing congestion and emissions in one or more highly congested urban or suburban roadway corridors, through both traffic flow improvements and demand reduction. A similar menu of projects could be applied to suburban activity centers.

Synergies within this group may be achieved through coordination of projects across a corridor or sub-area to improve traffic flow, provide multiple travel options, design infrastructure for all modes, and coordinate multimodal traveler information and operations, thus encouraging greater mode shift.

These project types will generally reduce all pollutants as a result of improved traffic flow and reduced VMT. However, there may be exceptions depending on the speed range and operating conditions, or with the provision of new transit service that is powered by conventional fuels. These projects are most relevant in urban and suburban areas with travel-intensive corridors.

Table 22. Sample project menu: reduce congestion in congested urban corridors or activity centers.

Sample Projects	CMAQ Project Type
Implement advanced traffic control systems, including fiber optic lines, traffic sensors, new signal equipment, adaptive control system, and transit signal priority.	Congestion Reduction and Traffic Flow Improvements
Designate queue jump lanes for transit buses at major intersections.	Congestion Reduction and Traffic Flow Improvements
Purchase vehicles, install stops, and provide initial operating assistance for a new transit shuttle serving major employers, residential developments, and other destinations corridor.	Transit Improvements
Create separated bike lanes along corridor.	Bicycle and Pedestrian Facilities and Programs
Construct new sidewalks (including pedestrian signals, crosswalks, and curb cuts at intersections) linking transit stops with commercial and residential buildings.	Bicycle and Pedestrian Facilities and Programs

Table 22. Sample project menu: reduce congestion in congested urban corridors or activity centers (continuation).

Sample Projects	CMAQ Project Type
Form TMA of businesses in corridor and assist with staffing.	Travel Demand Management
Conduct outreach campaign to inform businesses/workers along corridor of improved travel options, incentives, and regional connections via transit.	Public Education and Outreach Activities

Implement/Expand Regional Congestion Management

This sample project menu (table 23) is focused on reducing congestion and emissions across the region by managing traffic flow on major corridors and managing travel demand during congested times. In contrast to the previous menu, which focused on specific corridors or activity centers, this menu includes projects that affect traffic flow across the entire region.

Synergies in this project group may be achieved through coordination of projects across the region to optimize traffic flow, manage demand through pricing, and coordinate transit with traffic operational projects.

Projects in this menu will generally reduce all pollutants as a result of improved traffic flow and reduced VMT. However, there may be exceptions depending on the speed range and operating conditions, since some pollutant emissions can increase at high speeds. These projects are most relevant in larger or more densely populated metropolitan areas with travel-intensive corridors.

Table 23. Sample project menu: implement/expand regional congestion management.

Sample Projects	CMAQ Project Type
Implement advanced traffic control systems, including fiber optic lines, traffic sensors, new signal equipment, adaptive control system, and transit signal priority.	Congestion Reduction and Traffic Flow Improvements
Provide funding to municipalities to regularly evaluate and update signal timing on corridors of regional significance.	Congestion Reduction and Traffic Flow Improvements
Convert freeway general purpose to HOT lanes or build new managed lanes with tolls varying by time of day/congestion level.	Congestion Reduction and Traffic Flow Improvements
Vary tolls by time of day on existing regional tolled facilities.	Congestion Reduction and Traffic Flow Improvements
Develop and implement advanced traffic management algorithms through existing traffic operations center designed to maximize emission reductions.	Congestion Reduction and Traffic Flow Improvements
Implement bus priority lanes on key regional routes.	Transit Improvements
Conduct outreach campaign to inform travelers of new pricing applications and the benefits of managing congestion through these measures.	Public Education and Outreach Activities

Reduce Particulate and NO_x Emissions—Heavy-Duty Vehicle Focus

This sample project menu (table 24) is focused on reducing emissions of hazardous air pollutants from diesel exhaust.

While the effects of emission reductions will generally be additive based on the number of vehicles affected, synergies within this project group may be achieved through coordination of purchasing and growth of institutional knowledge on the most effective technologies for a specific use case and operating conditions (e.g., climate conditions that affect the emissions benefits of a particular technology). This can help to direct technologies to their most effective applications and maximize the cost effectiveness of CMAQ funds.

These projects may affect all pollutants, but are targeted especially to PM and/or NO_x reduction through their focus on clean heavy-duty vehicle technologies. They may be applicable at any geographic scale, but especially for PM nonattainment areas, and in the vicinity of communities where health concerns are expressed.

Table 24. Sample project menu: reduce particulate and NO_x emissions—heavy-duty vehicle focus—metropolitan.

Sample Projects	CMAQ Project Type
Diesel retrofit assistance: Approved emission reducing retrofit technology, prioritized towards drayage and other short-haul trucks serving urban areas.	Diesel Engine Retrofits and Other Advanced Truck Technologies
Purchase of a hybrid electric switcher locomotive for a rail yard near a densely populated community.	Idle Reduction
Clean Air Assistance Program: staff and technical resources to help heavy-duty vehicle fleet managers and individual owner/operators match appropriate clean technology with their vehicles and operating requirements.	Public Education and Outreach Activities
Training for Clean Air Assistance and Heavy-Duty I&M Program staff.	Training
Heavy-duty I&M program: purchase equipment for roadside enforcement in densely populated + high truck traffic areas to identify high-emitting vehicles and target these vehicles for repair.	I&M Programs

Reduce Emissions of Ozone Precursors and Prevent National Ambient Air Quality Standards Ozone Exceedances

This sample project menu (table 25) is focused on reducing emissions of ozone precursors, especially VOC and NO_x, and especially under conditions most conducive to ozone formation, with the goal or reducing NAAQS exceedances in a nonattainment area.

Synergies within this project group may be achieved by coordinating efforts focused on reducing emissions specifically during ozone-conducive conditions, and by complementing clean technology and demand reduction with public education.

Projects in this group may reduce all pollutants, but the MPO may especially target VOC and/or NO_x reduction depending upon local air quality needs. They may be applicable at any geographic scale, but are especially intended for ozone nonattainment areas.

Table 25. Sample project menu: reduce emissions of ozone precursors and prevent National Ambient Air Quality Standards ozone exceedances—metropolitan.

Sample Projects	CMAQ Project Type
Diesel retrofit assistance: Approved emission reducing retrofit technology, prioritized towards technologies/applications with greatest NO_x cost effectiveness.	Diesel Engine Retrofits and Other Advanced Truck Technologies
Clean construction equipment program to retrofit older State and contractor equipment with NO_x reducing technology.	Diesel Engine Retrofits and Other Advanced Truck Technologies
Truck stop electrification equipment at truck stops in ozone nonattainment area.	Idle Reduction
Onboard APU equipment for trucks placed in drayage service for the regional port.	Idle Reduction
Purchase of hybrid electric switcher locomotive for a rail yard in the nonattainment area.	Idle Reduction
Free transit fares on high ozone days.	Transit Improvements
Outreach to businesses and shippers on technologies and incentives available for NO_x reducing medium and heavy-duty vehicle purchases and retrofits.	Public Education and Outreach Activities
Ozone Action Days—Outreach campaigns to inform public of importance of reducing travel and alternative travel modes available on high ozone days.	Public Education and Outreach Activities
Training for I&M Program staff.	Training
Light-duty I&M program requiring annual inspection, targeted at identifying and repairing high-emitting vehicles.	I&M Programs
Heavy-duty I&M program using roadside enforcement to identify high-emitting vehicles and target these vehicles for repair.	I&M Programs
Propane refueling infrastructure and purchase costs for new propane buses to replace diesel buses for the municipal transit agency.	Alternative Fuels and Vehicles
Clean school bus program to purchase electric school buses and support equipment and retrofit older buses with NO_x reducing technology.	Alternative Fuels and Vehicles

Statewide Sample Menus

Expand Commute Options

This sample project menu (table 26) is focused on reducing congestion and emissions by providing a broad range of alternatives to SOV commuting.

More multimodal options can increase the likelihood of non-SOV use by providing travelers with multiple options, such as carpooling to work, with the option of taking transit home if the carpool is missed. Public education and institutional arrangements, such as TMAs and TDM programs, can support projects to improve infrastructure or services for specific modes.

This set of projects will reduce emissions by reducing light-duty VMT, affecting all pollutants from passenger vehicles in roughly equal proportion. They are most likely to be effective in urban and suburban areas with higher trip densities and more travel options. Statewide programs can support the provision of commute options across multiple metro areas.

Table 26. Sample project menu: expand commute options—State.

Sample Projects	CMAQ Project Type
Statewide TDM program support (staffing for statewide coordinator).	Travel Demand Management
Statewide guaranteed ride home program.	Travel Demand Management
Statewide telework resource center (Web information and technical support staff) to assist employers with establishing telework programs.	Travel Demand Management
Capital and initial operating expenses for pilot reverse-commute shuttle program serving suburban office parks in the State's metro areas.	Travel Demand Management
Statewide employer parking cash-out pilot.	Travel Demand Management
Redesignate general purpose to HOV lane in high-transit corridors serving downtowns.	Transportation Control Measures
Implement statewide trip reduction ordinance.	Transportation Control Measures
Statewide carpool and vanpool matching program.	Carpooling and Vanpooling
Vanpool capital subsidy—for interurban commuting.	Carpooling and Vanpooling
Statewide TDM outreach and education program.	Public Education and Outreach Activities
Staffing for TMAs serving major activity centers in the State's metro areas.	Transportation Management Associations
Training for regional TDM and TMA staff.	Training

Increase Active/Nonmotorized Transportation

This sample project menu (table 27) is focused on reducing congestion and emissions by encouraging people of all ages to walk and/or bicycle to work, school, and other activities.

Multiple projects in one geographic area can assist in building out a local or regional bicycle or pedestrian network, thereby leveraging network connectivity benefits. Programs such as bikesharing and bicycle parking will work in combination with network improvements to increase bicycling. Infrastructure projects also can complement education projects such as safe bicycling, wayfinding, or other public information campaigns.

This set of projects will reduce emissions by reducing light-duty VMT, affecting all pollutants from passenger vehicles in roughly equal proportion. They are most likely to be effective in large or small communities with higher trip densities, where more destinations are within walking or biking distance, or where first- and last-mile access to transit is needed. Statewide programs can provide resources that are shared across multiple metro areas and communities.

Table 27. Sample project menu: increase active/nonmotorized transportation—State.

Sample Projects	CMAQ Project Type
Provide municipalities with financing to procure and install secure bicycle parking at neighborhood hubs and activity centers identified in statewide bicycle plan.	Transportation Control Measures
Bicycle lane projects adding to the network along State highways serving commuter corridors identified in the statewide bike plan.	Bicycle and Pedestrian Facilities and Programs
Capital funding for single-operator bikeshare program serving State's metro areas.	Bicycle and Pedestrian Facilities and Programs
Construct new sidewalks along State roads identified in high pedestrian demand areas per the State's pedestrian plan.	Bicycle and Pedestrian Facilities and Programs
Bicycle safety education classes and outreach materials.	Bicycle and Pedestrian Facilities and Programs
State bicycle/pedestrian coordinator position.	Bicycle and Pedestrian Facilities and Programs
Bicycle and pedestrian wayfinding (signage and route mapping) in high-demand areas identified in statewide bike plan.	Public Education and Outreach Activities
Workshops and outreach materials providing introduction to year-round bicycle commuting.	Public Education and Outreach Activities

Provide Clean Public Transportation

This sample project menu (table 28) is focused on reducing congestion and emissions by enhancing public transportation services, encouraging their use, and using clean vehicles and fuels to provide new and expanded services.

Synergies in this group of projects may be achieved by jointly deploying projects to expand or improve transit service, encourage greater use of transit through public education, and implement clean transit

vehicle technologies so that increased transit VMT does not offset the emissions benefits of reduced automobile VMT.

The pollutants that are most reduced with these projects will depend on the vehicle/fuel and emissions characteristics of any new transit service introduced. Reducing automobile VMT will reduce all pollutants, but especially VOC, NO_x, and CO. However, new diesel transit vehicles could have the potential to increase NO_x and PM emissions if ridership levels are not high enough. The use of electric or other clean fuel transit technology is more likely to provide a net reduction in emissions.

These projects will be most effective at reducing emissions and congestion in urban and suburban areas with higher trip densities where public transportation can serve more trips. Statewide programs can provide resources that are shared across multiple transit agencies (or implemented by a single statewide transit agency) and can coordinate longer-distance services that connect metro areas and rural communities.

Table 28. Sample project menu: provide clean public transportation—State.

Sample Projects	CMAQ Project Type
Transit center at an interregional transit hub/transfer point (docking facilities and building with protected waiting area, restrooms, and information).	Transit Improvements
Capital and pilot operating funding for new long-distance/interregional commuter transit service.	Transit Improvements
Campaign to market new and expanded transit services.	Public Education and Outreach Activities
Training for transit agency staff on purchase and installation of electric bus charging equipment.	Training
Purchase cost for new electric buses for the State's transit agency or regional transit agencies, and purchase and installation of supporting charging equipment.	Alternative Fuels and Vehicles

Reduce Emissions and Congestion from Freight/Goods Movement

This sample project menu (table 29) is focused on reducing congestion and emissions caused by trucks by shifting freight moving into and out of the region from truck to rail, while introducing cleaner technology on truck and rail vehicles that will see increased use.

While the effects of emission reductions will generally be additive based on the number of vehicles affected, multiple projects of the same type could leverage economies of scale in purchasing, infrastructure, and maintenance. Combining projects that encourage freight mode shift with clean technology will ensure that the emissions benefits of truck-rail mode shifting are maximized.

Freight is primarily moved by diesel vehicles, meaning that the greatest emissions benefits will be to PM and NO_x. These types of projects are most relevant and most likely to achieve synergies in areas of freight generators, such as ports, intermodal facilities, and manufacturing and warehousing districts, where there is a concentration of truck traffic. Statewide programs can coordinate projects on intercity freight corridors and also leverage resources across multiple local operators.

Table 29. Sample project menu: reduce emissions and congestion from freight/goods movement—State.

Sample Projects	CMAQ Project Type
Diesel retrofit assistance: Approved emission reducing retrofit technology, prioritized towards locomotives and drayage trucks serving intermodal facilities.	Diesel Engine Retrofits and Other Advanced Truck Technologies
Intermodal facility improvements: Expand capacity and throughput of intermodal container terminal.	Freight/Intermodal
Construct sidings to increase capacity and speed of service on a shared passenger/freight rail line.	Freight/Intermodal
Survey freight shippers to understand shipping requirements and what rail/intermodal improvements might encourage them to shift from truck to rail.	Public Education and Outreach Activities
Purchase and installation of truck stop electrification equipment along major truck traffic corridors.	Idle Reduction
Purchase hybrid electric switcher locomotive for a rail yard located near an environmental justice population area.	Idle Reduction

Reduce Congestion in Congested Corridors of Statewide Significance

This sample project menu (table 30) is focused on reducing congestion and emissions in one or highly congested roadways on the State's highway system, through both traffic flow improvements and demand reduction.

Synergies within this group may be achieved through coordination of projects across a corridor to improve traffic flow, provide multiple travel options, design infrastructure for all modes, and coordinate multimodal traveler information and operations, thus encouraging greater mode shift.

Projects in this menu will generally reduce all pollutants as a result of improved traffic flow and reduced VMT. However, there may be exceptions depending on the speed range and operating conditions, or with the provision of new transit service that is powered by conventional fuels. These projects are most relevant in urban and suburban areas with travel-intensive corridors, as well as rural areas with high levels of seasonal recreation/visitor traffic.

Table 30. Sample project menu: reduce congestion in congested corridors of statewide significance.

Sample Projects	CMAQ Project Type
Implement advanced traffic control systems, including fiber optic lines, traffic sensors, new signal equipment, adaptive control system, and transit signal priority.	Congestion Reduction and Traffic Flow
Designate queue jump lanes for transit buses at major intersections.	Congestion Reduction and Traffic Flow

Table 30. Sample project menu: reduce congestion in congested corridors of statewide significance (continuation).

Sample Projects	CMAQ Project Type
Create separated bike lanes along corridor.	Bicycle and Pedestrian Facilities and Programs
Construct new sidewalks connecting destinations and transit stops within activity centers located along corridors.	Bicycle and Pedestrian Facilities and Programs
Form TMA of businesses in corridor and assist with staffing.	Travel Demand Management
Establish guaranteed ride home program available to employers across the State.	Travel Demand Management
Provide capital support to assist formation of vanpools serving major employers in statewide corridors.	Travel Demand Management
Conduct outreach campaign to inform businesses/workers along corridor of improved travel options, incentives, and regional connections via transit.	Public Education and Outreach Activities

Implement/Expand Statewide Congestion Management

This sample project menu is focused on reducing congestion and emissions on congested roadways on the State's highway system by managing traffic flow on major corridors and managing travel demand during congested times.

This sample project menu (table 31) is focused on reducing congestion and emissions on congested roadways on the State's highway system by managing traffic flow on major corridors and managing travel demand during congested times. In contrast to the previous menu, which focused on specific corridors, this menu includes projects that affect traffic flow across the entire State.

Synergies in this project group may be achieved through coordination of projects across the State to optimize traffic flow, manage demand through pricing, and coordinate transit with traffic operational projects.

Projects in this menu will generally reduce all pollutants as a result of improved traffic flow and reduced VMT. However, there may be exceptions depending on the speed range and operating conditions, since some pollutant emissions can increase at high speeds. These projects are most relevant in larger or more densely populated metropolitan areas with travel-intensive corridors. Statewide projects or programs (such as congestion pricing) may be able to leverage resources across multiple metro areas and complement local and regional congestion management projects.

Table 31. Sample project menu: implement/expand statewide congestion management.

Sample Projects	CMAQ Project Type
Implement advanced traffic control systems, including fiber optic lines, traffic sensors, new signal equipment, adaptive control system, and transit signal priority.	Congestion Reduction and Traffic Flow
Provide funding to municipalities to regularly evaluate and update signal timing on corridors of regional significance.	Congestion Reduction and Traffic Flow
Convert freeway general purpose to HOT lanes or build new managed lanes with tolls varying by time of day/congestion level.	Congestion Reduction and Traffic Flow
Undertake statewide mileage-based pricing pilot program.	Congestion Reduction and Traffic Flow
Develop and implement advanced traffic management algorithms through existing traffic operations center designed to maximize emission reductions.	Congestion Reduction and Traffic Flow
Conduct outreach campaign to inform businesses/workers along corridor of improved travel options, incentives, and regional connections via transit.	Public Education and Outreach Activities

Reduce Particulate and NO_x Emissions—Heavy-Duty Vehicle Focus

This sample project menu (table 32) is focused on reducing emissions of hazardous air pollutants from diesel exhaust.

While the effects of emission reductions will generally be additive based on the number of vehicles affected, synergies within this project group may be achieved through coordination of purchasing and growth of institutional knowledge on the most effective technologies for a specific use case and operating conditions (e.g., climate conditions that affect the emissions benefits of a particular technology). This can help to direct technologies to their most effective applications and maximize the cost effectiveness of CMAQ funds.

These projects may affect all pollutants, but are targeted especially to PM and/or NO_x reduction through their focus on clean heavy-duty vehicle technologies. They may be applicable at any geographic scale, but especially for PM nonattainment areas within a State, and in the vicinity of communities where health concerns are expressed.

Table 32. Sample project menu: reduce particulate and NO_x emissions—heavy-duty vehicle focus—State.

Sample Projects	CMAQ Project Type
Diesel retrofit assistance: Approved emission reducing retrofit technology, prioritized towards drayage and other short-haul trucks serving urban areas.	Diesel Engine Retrofits and Other Advanced Truck Technologies
Purchase of a hybrid electric switcher locomotive for a rail yard near a densely populated community.	Idle Reduction
Clean Air Assistance Program: staff and technical resources to help heavy-duty vehicle fleet managers and individual owner/operators match appropriate clean technology with their vehicles and operating requirements.	Public Education and Outreach Activities
Training for Clean Air Assistance and heavy-duty I&M program staff.	Training
Heavy-duty I&M program: roadside enforcement in densely populated + high truck traffic areas to identify high-emitting vehicles and target these vehicles for repair.	I&M Programs

Reduce Emissions of Ozone Precursors and Prevent National Ambient Air Quality Standards Ozone Exceedances

This sample project menu (table 33) is focused on reducing emissions of ozone precursors, especially VOC and NO_x, and especially under conditions most conducive to ozone formation, with the goal or reducing NAAQS exceedances in nonattainment areas.

Synergies within this project group may be achieved by coordinating efforts focused on reducing emissions specifically during ozone-conducive conditions, and by complementing clean technology and demand reduction with public education.

Projects in this group may reduce all pollutants, but the State may especially target VOC and/or NO_x reduction depending upon local air quality needs. They may be applicable at any geographic scale, but are especially intended for ozone nonattainment areas within a State.

Table 33. Sample project menu: reduce emissions of ozone precursors and prevent National Ambient Air Quality Standards ozone exceedances—State.

Sample Projects	CMAQ Project Type
Diesel retrofit assistance: Approved emission reducing retrofit technology, prioritized towards technologies/applications with greatest NO_x cost effectiveness.	Diesel Engine Retrofits and Other Advanced Truck Technologies
Clean construction equipment program to retrofit older State and contractor equipment with NO_x reducing technology.	Diesel Engine Retrofits and Other Advanced Truck Technologies
Truck stop electrification equipment at truck stops in ozone nonattainment area.	Idle Reduction
Onboard APU equipment for trucks placed in drayage service for the regional port.	Idle Reduction
Purchase of hybrid electric switcher locomotive for a rail yard in the nonattainment area.	Idle Reduction
Free transit fares on high ozone days.	Transit Improvements
Outreach to businesses and shippers on technologies and incentives available for NO_x reducing medium and heavy-duty vehicle purchases and retrofits.	Public Education and Outreach Activities
Ozone Action Days—Outreach campaigns to inform public of importance of reducing travel and alternative travel modes available on high ozone days.	Public Education and Outreach Activities
Training for I&M program staff.	Training
Light-duty I&M program requiring annual inspection, targeted at identifying and repairing high-emitting vehicles.	I&M Programs
Heavy-duty I&M program using roadside enforcement to identify high-emitting vehicles and target these vehicles for repair.	I&M Programs
Propane refueling infrastructure and purchase costs for new propane buses to replace diesel buses for local transit agencies.	Alternative Fuels and Vehicles
Clean school bus program to purchase electric school buses and support equipment and retrofit older buses with NO_x reducing technology.	Alternative Fuels and Vehicles

Reduce Emissions in Rural Areas/Small Communities

This sample project menu (table 34) is focused on project types that may be most likely to be effective in rural areas and small communities.

Synergies in this group of projects may be achieved through economies of scale with assisting multiple small communities in implementing similar programs, as well as focusing on emissions generating activities that are concentrated in rural areas, such as extended truck idling.

Most projects in this group will reduce all pollutants, but the specific reductions will depend on the projects and emissions sources targeted. Some technology-focused projects may primarily target NO_x and/or PM emissions.

Table 34. Sample project menu: reduce emissions in rural areas/small communities.

Sample Projects	CMAQ Project Type
Diesel retrofit assistance: Approved emission reducing retrofit technology, focused on rural/small community school bus and utility fleets.	Diesel Engine Retrofits and Other Advanced Truck Technologies
Clean maintenance equipment program to retrofit older State and contractor equipment with PM or NO_x reducing technology.	Diesel Engine Retrofits and Other Advanced Truck Technologies
Truck stop electrification equipment at truck stops in ozone nonattainment area.	Idle Reduction
Purchase of hybrid electric switcher locomotive for a rail yard in the nonattainment area.	Idle Reduction
Intermodal facility improvements: Expand capacity and throughput of intermodal container terminal.	Freight/Intermodal
Construct sidings to increase freight capacity along heavily used rail corridor.	Freight/Intermodal
Implement pedestrian and bicycle improvements in small community town centers.	Bicycle and Pedestrian
Provide carpool matching services for commuters to major employers or centers in a small city or metropolitan area about one hour distant.	Carpooling and Vanpooling
Survey freight shippers to understand shipping requirements and what rail/intermodal improvements might encourage them to shift from truck to rail.	Public Education and Outreach Activities
Light-duty I&M program requiring annual inspection, targeted at identifying and repairing high-emitting vehicles.	I&M Programs
Propane refueling infrastructure and purchase costs for new buses to replace diesel buses for local school districts.	Alternative Fuels and Vehicles

5.0 Conclusion

This report has taken a first step in hypothesizing groupings of CMAQ projects that are likely to provide synergies with respect to congestion and/or emissions reduction. Potential synergistic effects are identified based on geography (e.g., network connectivity benefits), functional complementarity, and economies of scale. Challenges to achieving synergies are identified and solutions proposed. The CMAQ project types listed in the FHWA Interim Program Guidance are evaluated to consider which types of projects are likely to have synergistic effects. The possible variation of these effects across geographies (e.g., urban, suburban, rural, statewide) is considered, as is the extent to which synergies might affect different pollutants. Sample menus of projects are created for consideration at both the metropolitan and statewide scales of application.

A review of existing resources related to the CMAQ program found little information on potential synergies. A few synergies were hypothesized in resource documents. However, most current evaluation methods are focused on looking at project benefits individually rather than in combination. Very few examples were found of MPO or State project prioritization or evaluation methods that explicitly considered synergies when programming projects.

The extent to which synergies might actually be achieved in practice, and the best methods for measuring these synergies, require further consideration and testing. Existing data sources and analytical tools may be able to capture synergies to varying degrees. Next steps to build on this initial research might include developing analytical approaches to measure synergistic benefits of projects. These might include the use of existing models and tools, such as FHWA's CMAQ Emissions Calculator Toolkit, regional travel demand models, sketch models, and the Motor Vehicle Emission Simulator Model (MOVES) emission factor model; as well as the evaluation of multiple real-world projects implemented in different contexts to look for potential synergistic effects.

Appendix A. Existing Resources

FHWA and other organizations have developed a number of documents related to the CMAQ Program. The purpose of these documents varies, covering topics related to legislation, performance measures, to detailed analysis. While a handful of reports reference the possible synergistic relationships between projects, they do not further explore how to package project types for synergistic benefits or estimate the combined emission benefits of multiple projects that may interact with each other. This section provides an overview of relevant CMAQ research on synergistic relationships.

Congestion Mitigation and Air Quality Improvement Program Legislation (23 USC § 149)

The CMAQ program is most recently authorized through the Federal Government's Fixing America's Surface Transportation Act Transportation Bill, with detailed requirements, eligibility, and other rules outlined in the U.S. Code (23 USC § 149). Relevant highlights in the legislation as it relates to this project are listed in table 35.

Table 35. Congestion Mitigation and Air Quality Improvement program (23 USC § 149) summary.

Contents	Potential Relevance
Describes projects eligible for funding (section (b)).	Identifies possible (high-level) project types (see below).
Describes geographic eligibility requirements based on air quality nonattainment status (section (b), (d)).	Provides information that may be helpful in selecting MPOs and State DOTs for testing the roll-out project plan as well as grouping projects geographically, Funds must be spent in areas that are nonattainment or maintenance status for ozone, CO, or PM, with the exception of flexibility provisions outlined in section (d).
Includes a section describing optional programmatic eligibility (section (j)).	The programmatic eligibility section allows an MPO to conduct an emissions reduction assessment of a group of projects rather than individually. While the statute does not explicitly mention synergies, such a programmatic approach could include modeling of synergistic effects.
Priority consideration (section (g)(3); section (k)).	Specifies that States should give priority to PM of 2.5 microns or less ($PM_{2.5}$) reduction projects, including diesel retrofits, in $PM_{2.5}$ nonattainment or maintenance areas. This may inform groupings of projects.

(Source: 23 USC § 149.)

The text of the legislation does not explicitly set out to define project types, but it does discuss different types of projects in separate paragraphs as follows:

- Paragraph (b)(4): Traffic monitoring, management, and control facility or programs, including advanced truck stop electrification systems.
- Paragraph (b)(5): Traffic flow improvements.

- Paragraph (b)(6): Purchase of integrated, interoperable emergency communications equipment.
- Paragraph (b)(7): Projects that shift traffic demand to nonpeak hours or other transportation modes, increase vehicle occupancy rates, or otherwise reduce demand for roads.
- Paragraph (b)(8): Purchase, or conduct of outreach regarding, diesel retrofits.
- Paragraph (b)(9): Installation of vehicle-to-infrastructure communication equipment.
- Paragraph (c)(2): Establishment of electric vehicle charging stations or natural gas vehicle refueling stations.
- Paragraph (c)(3): HOV facilities.

The above list does not preclude other types of projects that are determined to reduce emissions in a nonattainment or maintenance area, as described under the section (b)(1) eligibility criteria. Also, paragraph (b)(2) notes as eligible "a project or program included in a State implementation plan that has been approved pursuant to the Clean Air Act and that has air quality benefits."

Congestion Mitigation and Air Quality Improvement Interim Program Guidance (2013)

FHWA released interim guidance for the CMAQ Program in 2013, explaining program changes as result of the Moving Ahead for Progress in the 21st Century Act (MAP-21). This document revised and expanded upon the CMAQ Program Guidance previously issued in 2008. Relevant highlights for this project are listed in table 36.

Table 36. Congestion Mitigation and Air Quality Improvement program guidance summary.

Contents	Potential Relevance
Identifies eligible and ineligible project types.	Establishes the categories for the basis of the study.
Sets requirements for quantitative and qualitative emissions benefits assessment.	Part VIII(A)(3) specifically discusses "Analyzing Groups of Projects" and could be a reference for ideas for synergistic effects (see verbiage below).
Sets requirements for program administrating, reporting, and performance plans.	Reference for continued compliance.

(Source: FHWA, 2013.)

The guidance identifies 17 eligible project categories, but also states that "Not all possible requests for CMAQ funding are covered—this section provides examples of general project types that may be eligible for CMAQ funds."

The guidance includes a specific section on "Analyzing Groups of Projects," providing support on combining synergistic projects, where appropriate:

> *In some situations, it may be more appropriate to examine the impacts of comprehensive strategies to improve air quality by grouping projects. For example, transit improvements coupled with demand management to reduce SOV use in a corridor might best be analyzed together. Other examples include linked signalization projects, transit improvements, marketing and outreach programs, and ridesharing programs that affect an entire region or corridor. (FHWA, 2013, p. 31)*

Air Quality and Congestion Mitigation Measure Outcomes Assessment Study: Final Technical Report (2014)

This report examines the results of the CMAQ program since the enactment of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), including the impact to emissions, traffic congestion, and health as well as findings on how to improve the accuracy of these estimations. This document can serve as the basis for selection of project types and calculation of benefits. While some projects were grouped by type (e.g., traffic flow improvements), the synergistic effects of projects were not investigated. Relevant highlights in the Outcomes Assessment Study are listed in table 37.

Table 37. Outcomes Assessment Study summary.

Contents	Potential Relevance
Distribution of obligations by location, subcategory, costs; trends.	Table 1 summarizes project types eligible for funding (descriptions in appendix A of the report). Further establishes the categories for the basis of the study. Figure 1 and table 5 identify most commonly funded project types. These could be considered priorities for the study.
Case studies: Detailed benefits, methods and assumptions, and impacts reported for 72 projects.	Provides baseline information on magnitude of expected traffic and emissions impacts by individual project type and pollutant.
Emissions estimation and modeling techniques assessed for 10 models.	Consider each method's potential to assess any synergistic impacts.
Tables of equation variables for many project types in section 5.4.	Consider which variable(s) impact multiple projects.
Review and findings of 10 before-and-after studies.	Provides "real-world" and detailed methodology and results.

(Source: Battelle & Texas A&M Transportation Institute, 2014.)

This study also grouped CMAQ projects into major types and subcategories. This grouping is reproduced in table 38 and may be considered when developing the grouping of similar project types into scenario packages.

Table 38. 2014 Congestion Mitigation and Air Quality Improvement study major project types and subcategories.

Major Project Types	Subcategories
Vehicle/Fuel Technology	AFVs/Fueling Facilities Conventional Bus and Paratransit Replacements Diesel Engine Retrofits
Vehicle Activity Programs	Idle Reduction Extreme Low-Temperature Cold Start Programs
Traffic Flow Improvements	Traffic Signalization Traffic Engineering (Roadway Improvements) Intersection Improvements HOV and Managed Lanes Roundabouts
Intelligent Transportation Systems	General ITS Freeway Management Systems Traveler Information Systems
Improved Public Transit	Transit Facilities, Systems, and Services New Bus Services New Rail Services
Transportation Demand Management	Public Education/Outreach (Information/Marketing) TDM Park and Ride Facilities Car Sharing Value/Congestion Pricing
Other	Pedestrian/Bicycle Other Dust Mitigation Freight/Intermodal Innovative Projects

(Source: Battelle & Texas A&M Transportation Institute, 2014.)

Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users 1808: Congestion Mitigation and Air Quality Improvement Program Evaluation and Assessment, Phase 1 Final Report (2008)

This study (Grant et al., 2008) investigated the impacts of CMAQ-funded projects on air quality and traffic congestion. Relevant highlights in the CMAQ Evaluation and Assessment Study are listed in table 39. Note that many of the findings of this assessment may be updated or superseded by findings of the more recent 2014 program assessment.

Table 39. Congestion Mitigation and Air Quality Improvement Program Evaluation and Assessment summary.

Contents	Potential Relevance
Distribution of funding and projects by category.	Establishes project categories for the basis of the study, although more recent studies have used different categories.
Discussion of direct and indirect effects on congestion and mobility and on air quality, including potential combined effects (pages 13 to 14).	May provide some insights into synergistic effects (see text following table).
Representative sample of projects selected for evaluation, including methodology assumptions, results, description, and costs.	Provides information on magnitude of expected traffic and emissions impacts by individual project type and pollutant.
Review of cost effectiveness' role in project selection; estimate of cost effectiveness ranges by project type and pollutant.	May provide insights into how projects addressing different pollutants might collectively lead to overall cost effectiveness outcomes.
Review of existing methods for estimating emission reductions and cost effectiveness.	May provide insights into each method's potential to assess any synergistic impacts.

(Source: Grant et al., 2008.)

Some relevant findings from the section on "impacts of projects on air quality and congestion" include:

> *Individual projects [that reduce vehicle travel] often have limited impacts on travel demand in specific corridors or on a regionwide basis…. Reductions of this level of trips may not have measurable effects on traffic congestion…. As a result, the magnitude of congestion relief due to VMT reduction projects is difficult to predict or assess…. There also are no standardized and simple methodologies to assess these effects.—pages 13–14*

This may imply challenges for assessing the synergistic effects of multiple projects, unless the combined effects are large enough to model or measure and appropriate methods can be identified.

> *Although estimated reductions [of emissions from small scale and localized projects] are generally quite small, the combined effect of many small projects and those that are more regional in nature may help in achieving regional air quality goals. In fact, a number of regions take emissions reduction credit for regional demand management programs and other CMAQ-funded projects as part of their regional conformity analyses.—p. 14*

This may suggest grouping of similar projects, such as individual TDM projects that are collectively part of a regional TDM program.

> *Moreover, the combined effect of many similar projects may help to achieve longer-term and more substantial indirect benefits to air quality. For instance, by contributing to development of a more multimodal transportation system, by supporting access to transit, and by focusing attention to operational strategies, CMAQ projects can help support longer-term changes in travel behavior, land use, and attitudes toward transportation that support air quality goals and other related planning goals. These effects are very difficult to assess, and are not quantified for purposes of reporting to FHWA.—p. 14*

This points to the potential for synergistic benefits but also observes the challenge of estimating these benefits.

Multi-Pollutant Emissions Benefits of Transportation Strategies (2006)

This report provides a high-level overview of how different transportation strategies or projects could impact specific emissions. Included are sets of tables detailing if a specific strategy is likely to decrease, not impact, or possibly increase seven specific pollutants. Also included are a series of sample projects and calculations for select strategies. Relevant highlights are listed in table 40.

Table 40. Multi-pollutant emissions benefits of transportation strategies summary.

Contents	Potential Relevance
Overview of project impacts on emissions (tables 2-1 through 2-4).	Baseline information on expected project impacts.
Discussion on interactions between project types and impacts (page 2-9).	May provide some insights into synergistic effects.
Various sample equation variables for many project types.	Consider which variable(s) impact multiple projects (similar information is provided in the 2014 program assessment).
Overview of possible project types (appendix A).	Establishes project categories for the basis of the study, although more recent studies have used different categories.

(Source: ICF International, 2006.)

The report briefly discusses “Interactions between Strategies and Effects,” providing support on evaluating synergistic projects together, where appropriate:

> *While strategies are classified independently, it is important to recognize that many strategies are not typically implemented in isolation, and consequently should not be evaluated as such. Specifically:*
>
> - *Many strategies are commonly implemented in combination and separating out the impacts of individual program elements is often difficult. Consequently, strategies should often be evaluated together as integrated packages. For example, an expanded bus service strategy may include additional transit service provision, using new compressed natural gas (CNG) vehicles, combined with enhanced marketing and new bus shelters. Analyzing this project as an integrated package of strategies helps both to avoid double-counting and to account for effects that are not additive, due to synergies between strategies or competition.*
> - *Some strategies can have both positive and negative affects on emissions. For example, employer flex-time policies tend to discourage co-worker carpooling, but encourage family carpool arrangements. Park-and-ride lots can encourage transit use, but also increase auto access to transit, thus creating a cold start. Strategies that increase transit ridership may not only reduce personal motor vehicle travel, but may also require additional transit services.*

Transportation Research Board Special Report 264: Congestion Mitigation and Air Quality Improvement Program: Assessing 10 Years of Experience (2002)

This report evaluates the CMAQ program, assessing if the program is meeting its primary goals and providing recommendations for future iterations of the program. Included is an evaluation of the program's policies and operations as well as the impacts and assessments of the projects. Relevant highlights are listed in table 41. Note that many of the findings of this assessment may be updated or superseded by findings of the more recent program assessments and cost effectiveness tables.

Table 41. Transportation Research Board Special Report 264 summary.

Contents	Potential Relevance
Classification of projects and spending trends.	Establishes project categories for the basis of the study, although more recent studies have used different categories.
Cost effectiveness ranges by project type and pollutant.	Possible support for combining projects to improve cost effectiveness, especially smaller, lower costing projects.
Case studies/success stories describing impacts of select projects.	Provides information on magnitude of expected traffic and emissions impacts by individual project type and pollutant.
Big-picture discussion of opportunities and challenges associated with CMAQ project and program assessment.	Possible connection of how introducing synergistic impacts could address these opportunities and challenges.
Review of selected agencies' project selection and evaluation procedures.	Possible look into how combining projects could influence project selection and evaluation procedures.
Identification of ex-post studies.	Possible projects to obtain more comprehensive impact evaluations.

(Source: Transportation Research Board, 2002.)

Federal Highway Administration Cost Effectiveness Tables Summary and Development and Methodology

MAP-21 requires the development of cost effectiveness tables to assist MPOs and State DOTs with selecting and giving funding priority to cost effective transportation projects. FHWA developed summary tables and a corresponding methodology document, which detail the cost effectiveness of select project types by five pollutants. Relevant highlights are listed in table 42.

Table 42. Cost effectiveness tables summary.

Contents	Potential Relevance
Classification of common projects.	Another potential basis for project categories for this study.
Summary of cost effectiveness of projects by pollutant.	Baseline information on expected project impacts by pollutant, which may suggest project groupings based on cost effectiveness at reducing specific pollutants of concern.
Description of methods and assumptions in determining cost effectiveness.	Methods give insights into how projects effect emissions, which could be considered when developing methods to examine synergies. Key assumptions supporting cost effectiveness for individual projects (project lifetimes, discounting, emissions rate assumptions, etc.) could be applied when evaluating cost effectiveness for groups of projects.

(Source: FHWA, n.d.; Volpe National Transportation Systems Center (2015).)

The methodology document (Volpe, 2015) notes that the project types listed in the 2013 Interim Guidance were supplemented with additional project types. Some of these project types could be subsets of project types listed in the Interim Guidance. Project types that are not specifically called out in the Interim Guidance include:

- Employee transit benefits.
- Bikesharing.
- Electric vehicle charging stations.
- Transit amenity improvements.
- Intersection improvements.
- Dust mitigation.
- Natural gas refueling infrastructure.

Federal Highway Administration Congestion Mitigation and Air Quality Improvement Program Public Access System

FHWA developed the CMAQ Public Access System to serve as a database of all CMAQ-funded projects since 1992. Relevant to this work is the grouping all of the projects into the following 11 major project reporting categories:

- TDM.
- I&M Programs.
- Bicycle and Pedestrian Facilities and Programs.
- Ride Sharing.
- Congestion Reduction and Traffic Flow Improvements.
- Transit Improvements.
- Surface Transportation Program (STP)/CMAQ.
- Advanced Diesel Truck/Engine Technologies.
- Freight/Intermodal.
- Alternative Fuels and Vehicles.
- Other.

National Cooperative Highway Research Program 25-25 Task 59: Evaluate the Interactions between Transportation-Related Particulate Matter, Ozone, Air Toxics, Climate Change, and Other Air-Pollutant Control Strategies

This 2010 NCHRP report (Cambridge Systematics, Inc., and Eastern Research Group, Inc., 2010) provides information on the effects of different transportation air quality control strategies on a full range of pollutants, and identifies methods for evaluating tradeoffs among different pollutants when selecting control strategies. The study first assesses the effectiveness and cost effectiveness of a variety of transportation emission control strategies at reducing emissions of various pollutants. It also includes a review of different pollutant weighting systems; a survey of how State and regional transportation and air quality agencies have evaluated cost effectiveness, considering multiple pollutants, and made tradeoffs among these pollutants when prioritizing control strategies; and information gaps and research needs to assist agencies in selecting the most cost effective control strategies, considering their potential impact on multiple pollutants. The study leverages existing data on the cost effectiveness of CMAQ projects to compare cost effectiveness of different project types across multiple pollutants.

Key findings relevant to this study of CMAQ scenarios include:

- Projects that reduce travel generally reduce all pollutants in equal measure, although transit investments and expansion may reduce PM and NO_x less, or actually increase these pollutants. The cost effectiveness (emission reductions per dollar) varies widely across project types, with some clear trends, but there also is substantial variation within a given set of project types—suggesting that their cost effectiveness depends strongly upon the specific context of the project and how effectively it is implemented.

- Most studies evaluating traffic flow improvements did not find tradeoffs among pollutants—i.e., all pollutants were consistently reduced. However, some projects did show increased NO_x levels as a result of higher traffic speeds. The effects of projects such as HOV lanes can be complex and very context specific.

- Vehicle and fuel technology strategies and their effects tend to be different for different classes of vehicles (e.g., light duty, buses, medium trucks, large trucks). The effects and cost effectiveness of individual strategies vary widely by the specific technology and pollutant of interest, and also can vary significantly depending upon the conditions under which the vehicle is operated. Most control strategies provide emission reductions for one or more pollutants, without notably increasing other pollutants, although some diesel retrofits can increase fuel consumption.

- Except for MPOs in California that use the California Air Resources Board cost effectiveness database tool, the Phoenix, AZ MPO was found to be the only agency using a quantitative method of combining cost effectiveness for multiple pollutants. The New York State DOT also planned to release CMAQ guidance with weighting among multiple pollutants. Several other agencies have a qualitative method of combining cost effectiveness for multiple pollutants.

U.S. Environmental Protection Agency Travel Efficiency Assessment Method

Starting in 2011 and continuing through the present, the EPA Office of Transportation and Air Quality has provided a program of Travel Efficiency Assessment Method (TEAM) technical assistance to metropolitan and regional planning agencies and developed case studies on these analyses. The TEAM approach uses travel activity data for the analysis area, transportation sketch modeling techniques, and EPA's MOVES emission model to estimate emissions with and without travel efficiency strategies chosen by the partner agency.

The TEAM case studies examined various combinations of regional travel reduction and efficiency strategies, including:

- Expanded TDM programs, including employer-based incentives and transit incentives.

- Bicycle and pedestrian network improvements.

- Enhanced transit (expansion, frequency improvements).

- Road and parking pricing.

- HOV lanes.

- Land use, including TOD and workforce housing.

The case studies evaluated the regional percent change in light-duty VMT, greenhouse gas emissions, $PM_{2.5}$, NO_x, and VOC. Various combinations of strategies were bundled into scenarios and compared. The analysis tools for travel impacts included regional travel demand model base data; Trip Reduction Impacts of Mobility Management Strategies for sketch modeling of TDM and pricing; and other "off-model"

approaches based on data from the literature for land use, bicycle, and pedestrian strategies. Subgeographies and subpopulations were used to target individual strategies. The latest version of MOVES was used to develop emission rates, which were applied to changes in VMT.

The TEAM case studies are relevant to this CMAQ study in that there is overlap in the types of projects (TDM, bike/ped, transit, HOV), and the TEAM studies looked at combined as well as individual strategy impacts. They therefore provide some insight into bundling of synergistic strategies as well as analysis methods to test for synergistic effects. The TEAM case studies could potentially represent combinations of multiple CMAQ and non-CMAQ projects. However, they differ from this project in that the strategies analyzed are described in the abstract, at a regional or subregional scale of application, rather than through concrete individual CMAQ projects. The TEAM case studies also do not cover some types of CMAQ projects such as traffic flow improvements or clean vehicle technology.

Table 43 lists the scenarios modeled in the 2016 TEAM case studies and table 44 lists the scenarios modeled in the 2014 TEAM case studies.

Table 43. Scenarios modeled in 2016 Travel Efficiency Assessment Method case studies.

Agency and Scenario
MetroPlan Orlando
Scenario 1: Expanded TDM
Scenario 2: Scenario 1 + Enhanced Transit
Scenario 3: Scenario 2 + Road Pricing
Scenario 4: Scenario 3 + University Transit Pass
Atlanta Regional Commission
Scenario 1: Expanded TDM
Scenario 2: Scenario 1 + Transit Frequency Improvement
Scenario 3: Scenario 2 + Parking Pricing
Scenario 4: Scenario 3 + Land Use
East-West Gateway Coordinating Council (St. Louis, MO)
Scenario 1: Regional TOD
Scenario 2: Scenario 1 + Workforce Housing Balance
Scenario 3: Scenario 2 + Bike/Ped Network
Scenario 4: Scenario 3 + Transit Expansion

(Source: U.S. EPA (2016).)

Table 44. Scenarios modeled in 2014 Travel Efficiency Assessment Method case studies.

Agency and Scenario
Pima Association of Governments (Tucson, AZ)
Scenario 1: SunTran All-Access Pass
Scenario 2: Expanded Employer-based Incentives
Scenario 3: Bus Rapid Transit (BRT) on 2 Corridors
Scenario 4: Parking Pricing in Downtown

Table 44. Scenarios modeled in 2014 Travel Efficiency Assessment Method case studies (continuation).

Agency and Scenario
EPA Scenario: Land Use changes with all other scenarios
Massachusetts Department of Transportation
Scenario 1: Expanded Healthy Modes Program
Scenario 2: Scenario 1 + Land Use
Scenario 3: Scenario 2 + HOV Lanes
Scenario 4: Scenario 3 + Expanded Transit
Mid-America Regional Council (Kansas City, MO)
Scenario 1: Expanded TDM
Scenario 2: Scenario 1 + Enhanced Transit
Scenario 3: Scenario 2 + Land Use
Scenario 4: Scenario 3 + Pricing

(Source: U.S. EPA (2014).)

Association of Metropolitan Planning Organizations—Congestion Mitigation and Air Quality Improvement Program White Paper

This paper (Siwek & Associates, 2019) summarizes a 2019 survey of MPOs on the CMAQ Program and to provide examples of different practices and approaches in four key CMAQ program areas: intrastate distribution of funds; CMAQ project selection processes and criteria; emissions reduction estimating methodologies for CMAQ-funded projects; and CMAQ performance measures and target setting. The survey findings are based on responses from 62 MPOs in 32 States.

Some of the information on distribution of funds and project selection processes is potentially relevant to how synergies might be considered. For example, some States reserve funds for ongoing programs such as transit, traffic operations centers, commuter choice programs or public education and outreach. Some of these State-led programs might be considered complementary to other specific State- or MPO-funded projects.

Three project selection approaches were identified:

- State DOT conducts selection process.
- MPO conducts a stand-alone CMAQ selection process based on CMAQ-specific criteria.
- MPO selects projects using the same criteria for all project types.

This third approach could potentially suggest the inclusion of more than just CMAQ projects when considering synergies among projects. Examples of project selection criteria also were listed. Criteria

such as inclusion in or consistency with the regional plan, or multimodal and multiagency projects, might indirectly relate to achievement of synergistic effects. However, no sample criteria were listed that directly addressed synergies.

The survey also asked about analysis methods used, and about approaches to setting targets for performance measures. No particular information related to consideration of synergistic effects was included.

Metropolitan Planning Organization Programs

The project team reviewed CMAQ prioritization methods used by MPOs to look for examples that considered the synergistic or combined effects of multiple projects when evaluating potential benefits and/or making funding decisions. Only three potentially relevant examples were identified; these are described below.

Maricopa Association of Governments—Phoenix, AZ

The Maricopa Association of Governments (MAG) has developed robust methodologies for quantifying emission benefits and disbenefits and calculating the cost effectiveness of proposed CMAQ projects. MAG is responsible for programming available CMAQ funds annually in the Phoenix region. As part of the programming process, jurisdictions are asked to submit requests for federally funded projects. After the receipt of project requests, MAG evaluates CMAQ projects for possible inclusion in the MPO's TIP. Among MAG's recommended methodologies is an approach to include grouping of individual projects in the MAG TIP that, when combined in a common geographic area, lead to implementation of a larger project that reduces emissions. Project elements are typically implemented over a number of years in the TIP. Rather than estimating benefits for each element, elements are analyzed as one project with benefits assigned to a geographic area (i.e., city, town, or regionwide). This approach is applied for projects within one category (e.g., ITS projects). MAG documentation includes actual project groupings from their TIP. The projects are not all CMAQ funded.

While this approach does not represent grouping across different CMAQ project types, it does provide an example of looking at synergies between separate CMAQ projects, specifically based on geographic synergies for multiple projects of the same type implemented over time in the same geographic area.

Documentation: Methodologies for Evaluating Congestion Mitigation and Air Quality Improvement Projects. MAG. September 30, 2011.

North Central Texas Council of Governments—Dallas-Ft. Worth, TX

The North Central Texas Council of Governments (NCTCOG) has a program to combine projects eligible for STBG and CMAQ funding into one pool when requesting project submittals and selecting projects for funding.

STBG is a Federal-aid source of transportation funds provided to States and suballocated to larger urbanized areas. MPOs typically have programming authority for STBG funds, and develop a process to solicit project applications from local jurisdictions, and criteria to evaluate and select projects that will receive funding. FHWA defines eligible project types for STBG funding. MPOs typically follow a similar

process for programming CMAQ funds. However, the two processes are often conducted separately. NCTCOG selection criteria include emission reductions when evaluating many project categories.

While this approach also does not explicitly group CMAQ projects of different types, it does group CMAQ projects with projects submitted for STBG funding, which have different eligibility requirements that are broader than CMAQ funding. It also appears that CMAQ projects are grouped most frequently with management and operations projects, although air quality is a consideration in evaluating other project types that would not be typical CMAQ projects.

Chicago Metropolitan Agency for Planning—Chicago, IL

The Chicago Metropolitan Agency for Planning (CMAP) and its partners developed a program to help jurisdictions in the region meet goals for infill development and TOD.

The Regional Transportation Authority (RTA) created the Access to Transit Improvement program for projects that implement TOD plans. Under the program, RTA solicits applications for small-scale transit access projects from communities where RTA already has funded TOD plans. Selected projects are then bundled into a single joint CMAQ application for submittal to CMAP. CMAP also created new criteria for transit projects that benefit communities already zoned for TOD. CMAP has received project applications with numerous improvements identified in an RTA-funded TOD plan, including many bundled within the Access to Transit program, and has awarded CMAQ funding to several of them.

This example is interesting in that the approach ties CMAQ funding to other transportation and community goals an agency has established, and bundles CMAQ projects to achieve a greater benefit beyond only air quality and congestion mitigation.

Appendix B. Example Synergies Using Actual Funded Congestion Mitigation and Air Quality Improvement Projects

To consider an example of the extent to which actual funded programs of projects might contain synergies, North Carolina CMAQ project data for the years 2016, 2017, and 2018 was downloaded from the Public Access System. Two sample extracts from the downloaded list of projects were used to test example scenarios for the following groupings:

- North Carolina Capital Area Metropolitan Planning Organization (CAMPO) projects focused on travel demand reduction at a metropolitan area level, for the Raleigh metro area.
- North Carolina statewide projects mainly with a freight and technology focus.

These funded projects would not necessarily have been chosen with the objective of selecting projects with synergies, but they are used to illustrate the extent to which synergies might be observed in existing programs of funded projects.

Capital Area Metropolitan Planning Organization Congestion Mitigation and Air Quality Improvement Project List

A total of 32 CMAQ projects were funded between 2016 and 2018 by CAMPO (see table 52 for a complete list of projects). Table 45 identifies the number of projects by project type and year.

Table 45. Capital Area Metropolitan Planning Organization-funded Congestion Mitigation and Air Quality Improvement projects, 2016–2018.

Project Type	2016	2017	2018	All Years
Bicycle and Pedestrian Facilities and Programs	7	7	7	**21**
Congestion Reduction and Traffic Flow Improvements	2	2	3	**7**
STP/CMAQ	0	1	0	**1**
Transit Improvements	1	0	0	**1**
TDM	1	1	0	**2**
All Project Types	**11**	**11**	**10**	**32**

The following three grouping approaches were used for testing sample scenarios for the list of CMAQ projects in the CAMPO region:

- Typological grouping of projects.
- Geographical proximity of projects.
- Phased project elements that are part of a larger project.

Typological Grouping of Projects

Projects in the list that can be grouped on the basis of their description and general location (jurisdiction level) were tentatively grouped as shown in table 46, with potential synergies considered as follows:

- Bikeshare capital funding and Raleigh citywide bicycle improvements (increasing bicycle lanes from 4.2 miles to 31.5 miles) are projects that are aligned towards demand reduction by providing capital infrastructure. Several bicycle and pedestrian improvement projects in the Raleigh City area could be included in the grouping, although synergies among these projects might depend on their proximity, and several of them are geographically dispersed.

- TDM projects include a program to promote flexible work schedules for employers. It is not clear what synergies this project might have with the bicycle/pedestrian or transit signal priority projects.

- The transit signal priority project also supports demand reduction by making transit more attractive. However, it is not clear what synergies this project might have with the bicycle/pedestrian or TDM projects on this list, unless the project includes improved bicycle or pedestrian accommodations.

Table 46. Capital Area Metropolitan Planning Organization Congestion Mitigation and Air Quality Improvement-funded demand reduction projects, 2016–2018.

Project Description	Project Type
Raleigh Citywide Bicycle Improvements	Bicycle and Pedestrian Facilities and Programs
Raleigh Bike Share—Capital Equipment	Congestion Reduction and Traffic Flow Improvements
New Bern Avenue Pedestrian and Transit Improvements	Bicycle and Pedestrian Facilities and Programs
Raleigh-Coleridge Drive to Wake Forest Road	Bicycle and Pedestrian Facilities and Programs
Gorman Street Connector-bike facility connect Richland Creek Greenway to Rocky Branch Trail	Bicycle and Pedestrian Facilities and Programs
I-40 Overpass Pedestrian Accessibility Retrofits	Bicycle and Pedestrian Facilities and Programs
Transit Signal Priority Project	Congestion Reduction and Traffic Flow Improvements
Triangle J Council of Governments (TJCOG)-CAMPO Org-Flexible work schedule for employers-Triangle Ozone NA Area	TDM

Geographical Proximity of Projects

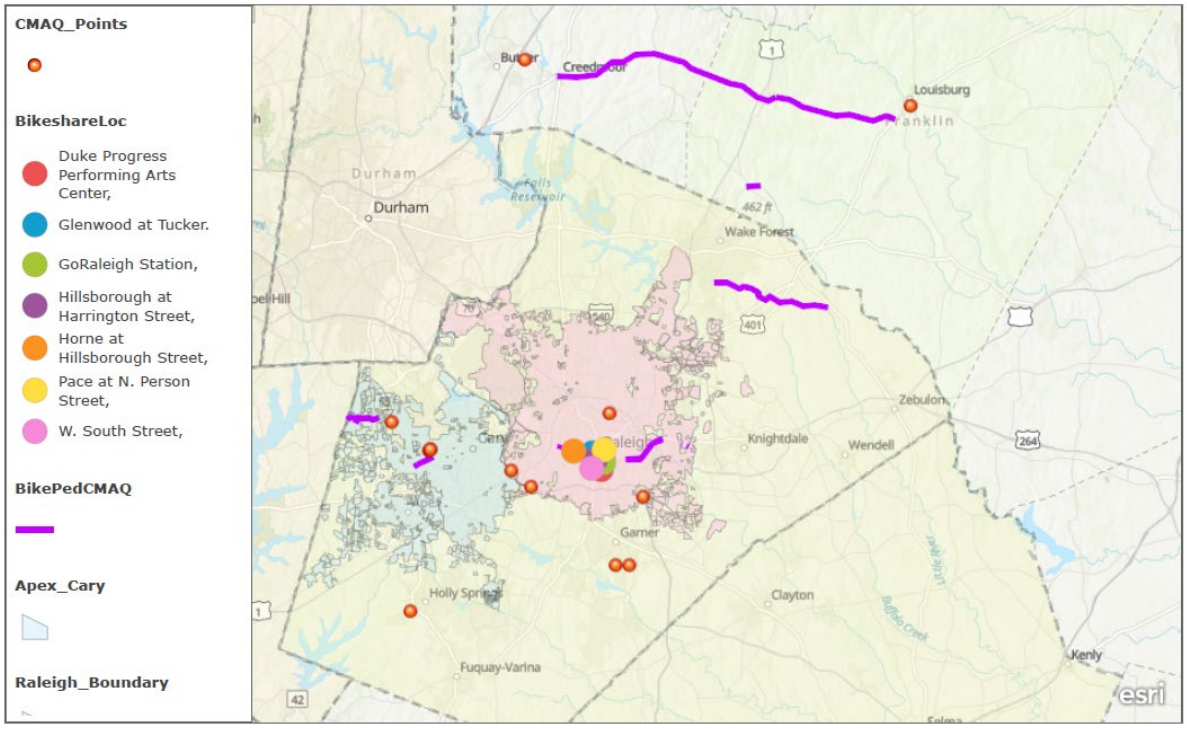
One major gap in understanding whether a given project can be grouped with another was the lack of enough information in the CMAQ data to specifically locate the projects. The necessary information that is needed to identify the geographic location of a CMAQ project was only partially available in the CMAQ

project details report table. Based on project description and attributes like the "TIP project ID," projects were mapped to the best possible extent.[3]

Some basic rules of thumb were used in plotting project locations:

- Systemwide projects were denoted using jurisdictional boundaries.
- Projects whose extents were not clear were denoted as point locations to provide a general idea of project location for consideration in grouping projects with other projects in a subarea or along a corridor.
- Project extents of TIP and Metropolitan Transportation Plan (MTP) projects were used as CMAQ project extents where available. While this may not be entirely an accurate assumption, it was helpful in identifying project extents that are eventually planned to be included in plans and programs.

A CMAQ project data viewer was created to view and interactively analyze project locations for grouping purposes. A screenshot is shown in figure 3.



Esri, CGIAR, USGS | NCDOT GIS Unit, NCDOT STIP Unit | Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, EPA, NPS, USDA

Figure 3. Map. Congestion Mitigation and Air Quality Improvement project viewer—Capital Area Metropolitan Planning Organization projects 2016–2018.

(Source: FHWA CMAQ Public Access System.)

[3] Some linear projects along roadways had to be denoted as points as there was not enough information about the extent of the project to map it accordingly. In some cases, project extents have been extracted from the State TIP and CAMPO MTP project extents and may not be exactly reflective of the CMAQ project extents. However, effort was made to locate projects based on publicly available information.

Considering project groupings based only on geographic proximity may provide a limited view of synergistic effects. For a better understanding of grouping potential, other contextual information like transit route information, the existing bicycle and pedestrian network, and other planned projects may be helpful.

Based on plotting the locations of projects, certain groups of projects appear to have potential synergies based on proximity and connectivity:

- GoRaleigh Station Bikeshare capital funding and New Bern Avenue bike lane improvements are one such grouping that can be made given that the bikeshare station is located at the western end of the New Bern Avenue bike lane improvement, which has the potential to increase bike trips along New Bern Avenue due to the confluence of the bikeshare station and provision of bike lane improvements along the corridor.

- There may be other such groupings that could be identified based on exact locations of the Raleigh citywide bicycle improvements as the City increases the bicycle lanes from 4.2 miles to 31.5 miles.

In the absence of specific location and project information, it can only be established that there may be some potential synergy between bike and pedestrian projects based on the fact that there is an increased network density of bicycle lanes in the City, which have the potential to increase bicycle trip making due to improving connectivity.

Another byproduct of geographical plotting projects is the ability to uncover other potential grouping scenarios; for example, the “Subarea/Activity Center Focus.” A cluster of projects is observed in the Bond Park vicinity, including access improvements at Cary Parkway and High House road as well as improvements to greenways and trails that link Bond Park with other parks, including McArthur Park through White Oak Creek Greenway connection. Table 47 shows two bicycle/pedestrian projects and one traffic flow improvement project in the same vicinity. In this case, it might be expected that the bike/ped projects have synergies by increasing network connectivity. However, it is not obvious what synergies might be achieved between the traffic flow and bike/ped projects, unless the intersection improvements also improve bicycle and pedestrian access across the intersection.[4] The project description references “turn lanes” as part of this project. Additional project details would be required to determine if bicycle and/or pedestrian improvements also are included.

Table 47. Cluster of projects in vicinity of Bond Park.

Project Description	Project Type
Crabtree Creek Greenway	Bicycle and Pedestrian Facilities and Programs
White Oak Creek Greenway	Bicycle and Pedestrian Facilities and Programs
Intersection Improvements at Cary Parkway and High House Road	Congestion Reduction and Traffic Flow Improvements

[4] This grouping could potentially also include Apex/Cary ITS improvements. However, not enough information was available to pinpoint the specific location of ITS improvements in this subarea.

Phased Project Elements That are Part of a Larger Project

Projects implemented in stages over time could have synergistic effects in the sense of providing benefits once completed that are greater than the sum of benefits of each phase of the project implemented and evaluated individually. The "CMAQ details report data" has an attribute for continuing projects, which is helpful to understand the timeline of implementation of some of these grouped projects and how they were implemented. Several projects in the sample group of 2016–2018 projects are continuing projects and phased implementation over the years. Sample projects that have been implemented in a continued or phased manner are shown in table 48. Note that it is possible that project sponsor estimates of emissions benefits already are based on the cumulative benefits of the project rather than individual phases.

Table 48. Projects implemented over multiple years.

Project Name	Years Implemented
Crabtree Creek Greenway	2016, 2017
NC 56 East Greenway Connector	2017, 2018
New Bern Avenue Pedestrian and Transit Improvements	2017, 2018
Intersection Improvements at Cary Parkway and High House Road	2016, 2017, 2018
ITS Project Cary/Apex	2016, 2017
TJCOG-CAMPO Dev of Flex Work Schedule for Employers & Orgs in the Triangle	2016, 2017

North Carolina Statewide Projects

Statewide projects are funded by the State DOT (NCDOT). Projects funded through a statewide program could potentially achieve synergies through mechanisms such as:

- Administering and management of projects by a single coordinating agency or organization, achieving economies of scale in purchasing, implementation cost savings, leveraging common knowledge, etc.
- Funding of projects improving service along an intercity/cross-State corridor, such as a passenger of freight rail corridor, thus supporting modal shifts.

Two broad groupings are clearly evident from the North Carolina statewide projects list (the complete list is shown in table 53):

- Clean Fuel Advanced Technology (CFAT) project grants.
- Passenger rail improvement and outreach programs.

Other projects on the statewide list include:

- Statewide Transportation Demand Management Program.
- Two ITS projects: I-85 Integrated Corridor Management System and ITS Deployment for R-2123CE.

- Two freight rail and congestion reduction projects: CSX Transportation NC Service Improvement and grade separation project—Dixie Storage, and Dixie Storage Track—Improve Siding Union County.

Clean Fuel Advanced Technology Projects

NCDOT supports the CFAT program by funding projects and providing grants to reduce transportation-related emissions in eligible counties. The program is administered by the North Carolina Clean Energy Technology Center (NCCETC) at North Carolina State University (NCSU). Several statewide projects in the list potentially experience implementation synergies through central coordination of the projects and by supporting specific projects with outreach and awareness. Table 49 shows CFAT projects listed in the statewide project list.

Table 49. North Carolina Clean Fuel Advanced Technology Congestion Mitigation and Air Quality Improvement projects, 2016–2018.

Project Description	Project Type
CFAT-Retrofit 1 diesel locomotive operating on Piedmont Passenger Rail	Advanced Diesel Truck/Engine Technologies
CFAT-Durham-Buildsense lease of 3 AFVs	Alternative Fuels and Vehicles
CFAT-Charlotte-7 vehicle convert to bi-fuel liquid propane gas (LPG)	Alternative Fuels and Vehicles
CFAT-Winston Salem-convert 31 vehicles to LPG	Alternative Fuels and Vehicles
CFAT-Convert 10 vehicles from gas to bi-fuel LPG	Alternative Fuels and Vehicles
CFAT-Convert 24 service vehicles from gas to LPG	Alternative Fuels and Vehicles
CFAT-MDI will replace 38 diesel powered refrigeration units w/electric units	Other
CFAT-Retrofit 12 utility bucket trucks	Other
CFAT III-2013-2017 clean fuel advanced tech outreach and awareness program	Other
NCSU-NC Solar Center Clean Transportation Program[1]	STP/CMAQ

[1] This project is not labeled as a CFAT project, but it appears to support the same objectives and be administered by the same entity. “The Clean Transportation program propels the development, awareness and use of alternative fuels and advanced transportation technologies.”—https://nccleantech.ncsu.edu/our-work/clean-transportation/.

Passenger Rail Projects

Several statewide projects support passenger rail services through infrastructure, service improvements, and outreach/awareness campaigns, as shown in table 50.

Table 50. North Carolina Congestion Mitigation and Air Quality Improvement projects supporting passenger rail.

Project Description	Project Type
NCDOT Piedmont and Carolinian Passenger Rail Services Public Outreach Program	STP/CMAQ
Rebuild 2 Cab Control Units for Piedmont Passenger Rail Service	Transit Improvements
CFAT—retrofit one diesel locomotive operating on Piedmont Passenger Rail	Advanced Diesel Truck/Engine Technologies
Refurbish Passenger Rail Car	Other
Statewide Rail Marketing Public Outreach Piedmont Rail Service	Other
Passenger Rail Promotion Linking Triangle, Triad, and Charlotte Regions	Other

Other Projects

Other statewide projects, as listed in table 51, do not fit as neatly into similar categories.

Table 51. Other North Carolina statewide Congestion Mitigation and Air Quality Improvement projects.

Project Description	Project Type
I-85 Integrated Corridor Management System	Congestion Reduction and Traffic Flow Improvements
ITS Deployment for R-2123CE *(note—this project is related to a major interchange modification at the I-85/I-485 interchange in the Charlotte area)*	Congestion Reduction and Traffic Flow Improvements
CSX Transportation NC Service Improvement and grade separation project—Dixie Storage	Congestion Reduction and Traffic Flow Improvements
Dixie Storage Track—Improve Siding Union County	Freight/Intermodal
Statewide Transportation Demand Management Program	TDM

Potential Synergies

Considering the 2016–2018 statewide projects listed above, the following potential synergies might be achieved:

- The CFAT projects would mostly be additive in their emissions benefits. However, synergies might be achieved in the form of economies of scale and knowledge leveraging through the administration of the program by a single entity (NCCETC). It is possible that the outreach and awareness program, along with the demonstration of technologies directly funded by CFAT, might be encouraging additional clean technology adoption beyond that directly funded by the program. Further evaluation

would be required to determine whether these benefits are real and what specific synergies (if any) are being achieved.

- The passenger rail projects might have synergies in the sense that multiple projects might be needed to achieve the service upgrades that would leverage mode shift. The public outreach, marketing, and promotion programs also should increase the benefits made possible by capital investments. Note that one passenger rail project also is a CFAT project.

- Two projects relate to a siding improvement (Dixie Storage Track) to increase freight rail efficiency and capacity. (Two other siding improvements along the same corridor are noted in project documents funded by CMAQ, but those projects are not listed in the 2016–2018 project sample.)

- In the "other projects" category, it is possible that the statewide TDM program also could help support mode shifting to passenger rail, although this would depend on what specific activities the program is funding. The statewide TDM program also might help to leverage demand management projects from the sample in the CAMPO region.

Summary of Observations from North Carolina Project Sample

Based on a sample of MPO and statewide projects from North Carolina funded between 2016 and 2018, the following observations regarding potential groupings to test synergies can be made:

- A three-pronged approach considering typological, geographical, and temporal synergies was helpful in considering potential synergistic groupings at a metropolitan scale. Projects also were grouped typologically at a statewide scale.

- The project information provided in the CMAQ public access system is not enough to geolocate a project with a fair degree of accuracy, making it harder to assess potential geographic synergies just based on the information in this system. Additional research on project details is often needed.

- Additional project information also may need to be researched to determine the likelihood that other synergies might exist—for example, if an intersection improvement project includes transit, pedestrian, and/or bicycle improvements that might have synergies with other nearby projects, or if it is solely directed at improving traffic flow.

- Projects often receive funding across multiple years, or otherwise in multiple pieces (e.g., railroad improvements at multiple locations along a corridor). In such cases, consideration should be given to the extent to which project sponsors estimate benefits associated with completion of the entire project, as compared with individually funded pieces of the project. There may be cases where individual project elements would produce no benefits on their own and there is some minimum set of improvements needed to provide benefits.

- For any given State or metro area, and especially for areas receiving smaller funding amounts, observations of multiple projects over longer timeframes (e.g., five to 10 years) might be needed in order to maximize the likelihood of observing synergistic effects. There may only be a few projects of a given type in a given timeframe. Furthermore, funding agencies often tend to disperse funding geographically to distribute benefits across multiple communities.

- There may be projects funded through means other than CMAQ that create synergistic effects with CMAQ projects. This would be difficult to infer without a detailed examination of regional or statewide transportation funding programs over time. In the example of pedestrian and bicycle projects, a large collection of improvements might be needed in order to achieve the full benefits of network connectivity.

- Different MPOs or States might have different logical project groupings based on the types of projects that the MPO or DOT chooses to fund, and thus might support different scenarios. In the 2016–2018 project sample, CAMPO funded mainly demand management projects. At a statewide level in North Carolina, most projects related to clean technology, which also could relate to a specific pollutant focus such as PM or ozone). A few projects were stand-alone and did not create obvious synergies with other projects.

Table 52. Capital Area Metropolitan Planning Organization 2016–2018 Congestion Mitigation and Air Quality Improvement project list.

CMAQ Project ID	Project Type	Project Title	Year	TIP Project ID	Continuing Project	Total Project Amount
NC20060019	TDM	TJCOG-CAMPO Org-Flexible work schedule for employers-Triangle Ozone NA Area	2016	C-4924A	Yes	$1,287,000
NC20090020	Bicycle and Pedestrian Facilities and Programs	Greenway Project-Spur of Hike and Bike Project	2016	C-5114	Yes	$47,336
NC20130007	Bicycle and Pedestrian Facilities and Programs	Crabtree Creek Greenway	2017	C-5163	Yes	$4,538,000
NC20130008	Bicycle and Pedestrian Facilities and Programs	NC 56 East Greenway Connector	2017	C-5166A	Yes	$20,000
NC20130008	Bicycle and Pedestrian Facilities and Programs	NC 56 East Greenway Connector	2018	C-5166A	Yes	$900,379
NC20130009	Bicycle and Pedestrian Facilities and Programs	NC 56 West Greenway Connector	2018	C-5166B	Yes	$730,968
NC20130011	Bicycle and Pedestrian Facilities and Programs	Crabtree Creek Greenway	2016	C-5168	Yes	$3,840,668
NC20130016	Congestion Reduction and Traffic Flow Improvements	Intersection Improvements at Cary Parkway and High House Road	2017	C-5165	Yes	$2,185,000
NC20130016	Congestion Reduction and Traffic Flow Improvements	Intersection Improvements at Cary Parkway and High House Road	2018	C-5165	Yes	$1,650,000
NC20130016	Congestion Reduction and Traffic Flow Improvements	Intersection Improvements at Cary Parkway and High House Road	2016	C-5165	Yes	$1,175,000
NC20130030	Transit Improvements	Hybrid Buses	2016	TA-4903A	Yes	$575,000
NC20130040	Bicycle and Pedestrian Facilities and Programs	Wake Forest-Smith and Sanford Creek Greenway and Sidewalks	2016	C-5164	Yes	$2,656,233
NC20140012	Bicycle and Pedestrian Facilities and Programs	I40 Overpass Pedestrian Accessibility Retrofits	2016	C-5504	Yes	$376,183

Table 52. Capital Area Metropolitan Planning Organization 2016–2018 Congestion Mitigation and Air Quality Improvement project list (continuation).

CMAQ Project ID	Project Type	Project Title	Year	TIP Project ID	Continuing Project	Total Project Amount
NC20150003	STP/CMAQ	Morrisville Parkway Grade Separation	2017	P 5201	Yes	$625 [sic]
NC20150009	Bicycle and Pedestrian Facilities and Programs	Johnson Street. Wade Avenue Sidewalk	2017	C 5568	Yes	$185,000
NC20150019	TDM	TJCOG-CAMPO Dev of Flex Work Schedule for Employers & Orgs in the Triangle	2017	C-4924B	Yes	$1,334,000
NC20160006	Bicycle and Pedestrian Facilities and Programs	Raleigh-Coleridge Drive to Wake Forest Road	2016	C-5172	No	$242,466
NC20160017	Congestion Reduction and Traffic Flow Improvements	ITS Project Cary/Apex	2017	C-5600I	Yes	$118,600
NC20160017	Congestion Reduction and Traffic Flow Improvements	ITS Project Cary/Apex	2016	C-5600I	No	$1,230,000
NC20160019	Bicycle and Pedestrian Facilities and Programs	Utley Creek Greenway Connection-Town of Holly Springs	2016	C-5604JA	No	$89,000
NC20160020	Bicycle and Pedestrian Facilities and Programs	Main St. Improvements-Sidewalks-Town of Youngsville	2016	C-5604QA	No	$82,500
NC20170014	Bicycle and Pedestrian Facilities and Programs	Crabtree Creek W Greenway	2017	C-5604OD	No	$5,000
NC20170016	Bicycle and Pedestrian Facilities and Programs	Panther Creek Greenway	2017	C-5604IA	No	$1,267,300
NC20170026	Bicycle and Pedestrian Facilities and Programs	New Bern Avenue Pedestrian and Transit Improvements	2018	C-5604OA	Yes	$81,462
NC20170026	Bicycle and Pedestrian Facilities and Programs	New Bern Avenue Pedestrian and Transit Improvements	2017	C-5604OA	No	$10,000
NC20170027	Bicycle and Pedestrian Facilities and Programs	White Oak Creek Greenway—MacArthur Section	2018	C-5604IB	Yes	$4,530,000

Table 52. Capital Area Metropolitan Planning Organization 2016–2018 Congestion Mitigation and Air Quality Improvement project list (continuation).

CMAQ Project ID	Project Type	Project Title	Year	TIP Project ID	Continuing Project	Total Project Amount
NC20170030	Bicycle and Pedestrian Facilities and Programs	Raleigh Citywide Bicycle Improvements	2017	C-5170	No	$468,871
NC20180008	Bicycle and Pedestrian Facilities and Programs	Gorman Street Connector-bike facility connect Richland Creek Greenway to Rocky Branch Trail	2018	C-5604OE	No	$12,500
NC20180009	Bicycle and Pedestrian Facilities and Programs	Wake County-Timber Drive Sidewalk	2018	C-5604RA	No	$62,400
NC20180011	Bicycle and Pedestrian Facilities and Programs	Bike Ped Facilities Salisbury U.S. 29 Main Street from D Avenue to SR 1526 (Rowan Mill)	2018	C-4908H	No	$134,000
NC20180018	Congestion Reduction and Traffic Flow Improvements	Raleigh Bike Share—Capital Equipment	2018	C-5604OB	No	$1,838,613
NC20180054	Congestion Reduction and Traffic Flow Improvements	Transit Signal Priority Project	2018	TT-6108	No	$1,250,000

Table 53. North Carolina statewide 2016–2018 Congestion Mitigation and Air Quality Improvement project list.

CMAQ Project ID	Project Type	Project Title	Year	TIP Project ID	Continuing Project	Total Project Amount
NC20090002	STP/CMAQ	North Carolina Air Awareness Program	2017	C-4903	Yes	$400,000
NC20100006	STP/CMAQ	3rd Frequency Passenger Rail Service	2017	P-2918	Yes	$4,091,000
NC20100006	STP/CMAQ	3rd Frequency Passenger Rail Service	2018	P-2918	Yes	$6,140,100
NC20130001	STP/CMAQ	NCSU-NC Solar Center Clean Transportation Program	2016	C-4902A	Yes	$2,235,275
NC20150010	STP/CMAQ	NCDOT Piedmont and Carolinian Passenger Rail Services Public Outreach Program	2017	C 5571	Yes	$819,000
NC20160013	Other	Refurbish Passenger Rail Car	2016	C-5600A	No	$6,025,000
NC20160014	TDM	Statewide Transportation Demand Management Program	2018	C-5600C	Yes	$1,500,000
NC20160014	TDM	Statewide Transportation Demand Management Program	2016	C-5600C	No	$1,500,000
NC20160018	Transit Improvements	Rebuild 2 Cab Control Units for Piedmont Passenger Rail Service	2016	C-5600J	No	$2,293,414
NC20170001	Congestion Reduction and Traffic Flow Improvements	CSX Transportation NC Service Improvement and grade separation project- Dixie Storage	2017	C-5600B	No	$3,635,200
NC20170023	Congestion Reduction and Traffic Flow Improvements	ITS Deployment for R-2123CE	2017	R-2123CG	No	$497,108
NC20170028	Congestion Reduction and Traffic Flow Improvements	I-85 Integrated Corridor Management System	2017	C-5600K	No	$800,000
NC20170032	Other	CFAT III-2013-2017 clean fuel advanced Tech outreach & awareness program	2018	C-5702A	Yes	$905,993
NC20170032	Other	CFAT III-2013-2017 clean fuel advanced Tech outreach & awareness program	2017	C-5702A	No	$905,993
NC20180003	Freight/Intermodal	Dixie Storage Track-Improve Siding Union County	2018	C-5600BA	No	$36,000

Table 53. North Carolina statewide 2016–2018 Congestion Mitigation and Air Quality Improvement project list (continuation).

CMAQ Project ID	Project Type	Project Title	Year	TIP Project ID	Continuing Project	Total Project Amount
NC20180014	Other	Statewide Rail Marketing Public Outreach Piedmont Rail Service	2018	C-5600M	No	$448,745
NC20180015	Other	North Carolina Division of Air Quality Statewide Air Awareness Program	2018	C-5601C	No	$688,564
NC20180016	Other	Passenger Rail Promotion Linking Triangle, Triad, and Charlotte Regions	2018	C-5601D	No	$622,790
NC20180036	Alternative Fuels and Vehicles	CFAT-Durham-Buildsense lease of 3 AFVs	2018	C-5702BA	No	$48,102
NC20180037	Alternative Fuels and Vehicles	CFAT-Charlotte-7 vehicle convert to bi-fuel LPG	2018	C-5702BB	No	$43,000
NC20180038	Alternative Fuels and Vehicles	CFAT-Winston Salem-convert 31 vehicles to LPG	2018	C-5702BC	No	$202,100
NC20180039	Other	CFAT-MDI will replace 38 diesel powered refrigeration units w/electric units	2018	C-5702BD	No	$1,227,014
NC20180040	Alternative Fuels and Vehicles	CFAT-Convert 10 vehicles from gas to bi-fuel LPG	2018	C-5702BE	No	$70,000
NC20180041	Advanced Diesel Truck/ Engine Technologies	CFAT -retrofit one diesel locomotive operating on Piedmont Passenger Rail	2018	C-5702BF	No	$387,143
NC20180042	Alternative Fuels and Vehicles	CFAT-Convert 24 service vehicles from gas to LPG	2018	C-5702BG	No	$231,079
NC20180043	Other	CFAT-Retrofit 12 utility bucket trucks	2018	C-5702BH	No	$328,620
NC20130001	STP/CMAQ	NCSU-NC Solar Center Clean Transportation Program	2017	C-4902A	Yes	$359,725

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U.S. Department of Transportation
Federal Highway Administration
Office of Planning, Environment, & Realty
1200 New Jersey Avenue, SE
Washington, DC 20590

https://www.fhwa.dot.gov/hep/

Publication Number

June 2020