Air Quality

Congestion Mitigation and Air Quality Improvement (CMAQ) Program

SAFETEA-LU Evaluation and Assessment Phase I

3. Impacts of Projects on Air Quality and Congestion

This section describes the reported impacts of the selected CMAQ projects on transportation emissions and congestion levels. The data reported in this section are based on the materials reported by the sponsors of CMAQ-funded projects, or by the State DOT or MPO responsible for reporting to FHWA. These estimates of project effects reflect project-specific factors and local conditions, such as typical vehicle trips lengths and factors that affect vehicle emissions rates (such as temperatures, vehicle fleet mix, and vehicle speeds and operating conditions). They often utilize data from past local studies reflecting local factors (e.g., park-and-ride lot utilization rates, transit ridership levels on new services).

While these data are generally the best estimates of expected emissions benefits available to the project sponsors, the data have some limitations that that should be noted. Specifically, the reported effects are forecasts of expected effects, typically based on sketch planning analysis methods. In most cases, the effects have not been validated based on before-and-after studies or other post-project evaluations. For some types of projects, such as bicycle and pedestrian projects and transit service amenities, it is difficult to predict effects, given limited scientific studies, analysis tools, and established approaches for estimating travel and emissions impacts. As a result, there is a fairly high degree of uncertainty in some of the results. Another limitation is that in many cases, State DOTs or MPOs reported emissions benefits only for pollutants of concern in the local area, such as ozone-precursors. Consequently, effects on emissions of carbon monoxide and particulate matter were not reported for many projects, even in cases where the projects would be expected to reduce emissions of these pollutants.

Overall findings are summarized below, followed by a brief discussion of the project impacts organized in major project category and subcategory groupings. For each project type, a table summarizing quantitative findings is accompanied by a commentary on findings and trends.

General Observations

Direct and Indirect Effects on Congestion and Mobility

Some CMAQ projects are designed to reduce traffic congestion and to minimize delay experienced by drivers. Traffic flow improvement projects - such as traffic signalization improvements, incident management programs, and intersection improvements - reduce recurring and/or nonrecurring traffic delay on the transportation system. Project sponsors used a range of different techniques, from simulation modeling to simplified sketch planning, to estimate changes in travel delay or speeds.

Although many traffic flow improvement projects are small in scope (e.g., an individual intersection improvement), targeted investments can yield significant improvements in roadway level of service and intersection performance in specific locations. Consequently, these projects can have a large impact on the daily travel conditions experienced by individual drivers in the area where the project is implemented. Moreover, on highly-traveled corridors, even small changes in travel speeds can result in substantial travel time savings when multiplied over thousands of vehicles. For instance, an intersection improvement project in Louisiana estimated that travel conditions would improve from Level of Service (LOS) F, reflecting heavy congestion, to LOS C, and would yield a reduction of 1,459.2 vehicle-hours of delay per weekday.

Projects that reduce vehicle travel may also have impacts on congestion, but these effects are generally not quantified, and the primary travel benefit of these projects is generally enhanced mobility and multimodal choices. Projects such as bike and pedestrian facilities, shared ride programs, travel demand management (TDM) programs, and transit improvements may reduce vehicle miles traveled (VMT) by passenger vehicles, particularly during peak periods, and, therefore, may contribute to reduced traffic congestion. Freight/intermodal projects are often designed to shift goods movement from trucks to rail, and thereby reduce congestion associated with truck traffic on corresponding freight corridors.

These individual projects, however, often have limited impacts on travel demand in specific corridors or on a region-wide basis. For instance, several projects examined (including vanpool projects, park and ride lots, bicycle and pedestrian projects, and transit service improvements) were estimated to reduce less than 200 vehicle trips each day. Reductions of this level of trips may not have measurable effects on traffic congestion. Moreover, changes in travel speeds and delay depend on the volume of traffic by time of day, and impacts are non-linear (i.e., a reduction in 1,000 cars will not necessarily have twice the effect of a reduction in 500 cars on travel speeds). 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. Given the lack of a specific funding for this type of analysis, and other demands placed on the program, it is perhaps not surprising that quantitative data on congestion benefits are very limited.

A primary purpose of bicycle and pedestrian projects, share ride programs, TDM programs, and transit service improvements is to enhance mobility by allowing greater travel choices. Over the long term and in combination other projects, projects such as bicycle paths and transit shuttles may improve mobility further by supporting transit-oriented development, an improved pedestrian environment, and enhanced multi-modal choices.

Some eligible CMAQ projects will not have any effects on traffic congestion or mobility. For instance, diesel engine retrofits and bus replacements are designed to reduce emissions rates from on-road vehicles without changing travel patterns. Similarly, dust mitigation projects are designed to reduce wind-blown dust on roadways without any changes in traffic congestion or mobility.

Direct and Indirect Effects on Air Quality

Overall, the analysis of selected projects suggests that emissions reductions have been achieved across the wide range of projects funded through the CMAQ Program, and that ultimately, each project helped contribute to some extent toward air quality goals. CMAQ projects can help reduce emissions through:

1. improving traffic flow, thereby reducing vehicle idling and stop-and-start driving conditions that are associated with higher levels of emissions;
2. encouraging changes in travel behavior that reduce motor vehicle miles traveled (such as shifts to ridesharing, transit, bicycling, or walking); and
3. using technologies to reduce the rate of emissions (such as through purchases of cleaner buses, or retrofits of diesel vehicles).

Given the small scale and localized nature of many CMAQ projects (e.g., a park-and-ride lot, a bicycle path, a transit shuttle), many CMAQ projects only yield small direct reductions in motor vehicle pollution. Among the projects reviewed in this study, the majority had emissions reduction estimates of less than 50 kg per day of both VOC and NOx, and less than 500 kg per day of CO. Although these estimated reductions 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.

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 multi-modal 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.

Additional Considerations on Air Quality Impacts

It should be noted that although project sponsors reported estimates of emissions benefits in the CMAQ database, and a consistent metric of kg per day is used, there are limitations associated with reporting a single emissions figure for each pollutant for each project. In considering the overall benefits of CMAQ projects on air quality, it is important to consider the following factors:

- **Days of Effectiveness** Some projects have impacts every day of the year, while others only have effects on weekdays (such as projects that affect peak period traffic), and others have effects on even fewer days. For instance, bicycle projects might only be effective in encouraging shifts from driving during days when the weather is mild (for instance, the analysis of a bike path in Indiana assumed use 132 days per year), and analysis of a dust mitigation project that involved use of de-icing chemicals rather than sand would only be effective during winter months. The analysis of an ozone action days program in Rhode Island reported emissions effects based on changes in transit ridership due to a free transit program, and noted that the free transit days occurred on 4 days in 2005. Consequently, the reported emissions benefits in the CMAQ database are not sufficient to compare the impacts of projects at a national level. Many project sponsors estimate emissions benefits on an annual basis, in addition to daily effects, and this is particularly important to States and MPOs that rank projects on the basis of effects or cost-effectiveness as part of their selection process.

- **Duration of Benefits** Some project benefits are expected to occur in the short-term, such as operational programs, like a ridesharing program or travel demand management incentives program. Other project benefits may have longer lasting impacts, notably infrastructure projects, like park -and-ride lots, transit rail, and bicycle and pedestrian facilities, which would be expected to last for perhaps more than 10 years and continue to generate emissions benefits over this time period.
- **Changes in Effectiveness over Time** Since the CMAQ database only requires reporting of one emissions figure for each pollutant, emissions benefits were typically calculated or reported for one year in time. However, in reality, the stream of emissions benefits for a project is not likely to be constant over time. Overall, emissions rates from motor vehicles are declining, and so a project that produces a near constant travel impact, such as a park-and-ride lot or transit shuttle service (which are capacity constrained), is likely to have declining emissions benefits over time. On the other hand, some projects, such as regional employer trip reduction programs, might achieve increasing benefits over time as population and congestion in a region grow. Although not reported to the FHWA CMAQ database, some project sponsors estimated a stream of benefits over time, which is useful for purposes of project ranking and selection.

The following sections summarize congestion and emissions benefit findings for the projects reviewed in this study by project category.

Traffic Flow Improvements

Traffic flow improvements are designed specifically to meet the dual goals of the CMAQ program: decreasing congestion and reducing air pollution. In this report, traffic flow improvements are broken into three subcategories:

- Traffic Signalization and Intersection Improvements;
- Freeway Management; and
- High-Occupancy Vehicle Lanes.

Examining the emissions impacts of these strategies typically involves estimating travel speeds with and without the improvement in order to develop two different emissions factors for each situation. These emissions factors are then applied to VMT along the facility. In some cases, emissions benefits are calculated by estimating the reduction in vehicle delay and applying an idle emissions factor (grams per hour).[22] Some of these project analyses also account for changes in vehicle volumes associated with the improvements.

Traffic Signalization and Intersection Improvements

Seven CMAQ-funded traffic signalization and intersection improvement projects were reviewed in this analysis; quantitative cost and emissions findings are summarized in the table below.

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	$PM_{2.5}$ (kg/day
Michigan	$660,000	$660,000	Signal Timing	2002	-40.1	NR	NR	NR	NR

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	$PM_{2.5}$ (kg/day
			along Ryan Rd.						
Louisiana	$4,400,000	$5,500,000	Continuous Flow Intersection at Airline and Sherwood Forest	2004	- 20.1	NR	- 5.2	NR	NR
Kentucky	$320,000	$400,000	Fiber Optic Cable Installation for Traffic Signal Optimization	2005	- 33.5	- 378.0	- 9.1	NR	NR
Ohio	$355,302	$639,543	Signal Timing along West Main Street	2005	- 5.1	-90.7	- 3.9	NR	NR
Tennessee	$33,000	$33,000	Signal Timing on SR-169 from Cedar Bluff to College St.	2005	- 15.0	NR	+ 2.2	NR	NR
Kentucky	$400,000	$500,000	Installation of Reversible Lanes on Nicholasville Road (US 27)	2006	- 2.9	-45.0	-1.1	NR	NR
New York	$2,000,000	$4,870,000	Construction of a two lane roundabout at Fuller St. and Washington St.	2007	-24.2	-24.2	-1.9	NR	NR

NR Values were not reported by the local project sponsor or State DOT in the CMAQ database or other materials for the project.

Congestion / Mobility Benefits

Traffic signalization and intersection improvement projects are typically designed to reduce traffic congestion, increase travel speeds, and/or reduce delay.

Congestion benefits were reported for each of the signalization and intersection improvement projects in the study, as described briefly below:

- Interconnection and modernization of 15 traffic signals along an urban minor arterial (Ryan Road) in Macomb County, Michigan, which borders the City of Detroit to the South and Lake St. Clair to the east, was estimated to improve travel speeds by 4 mph in both peak and off-peak periods, due to reduced delay at intersections.
- A modification to two intersections in East Baton Rouge Parish (Airline Highway US 61 and Siegen Lane/Sherwood Forest Boulevard) was undertaken to increase traffic flow and reduce congestion and delay. The intersections were operating at level of service F during peak hours, and a new design called a Continuous Flow Intersection would improve traffic operations at the intersection to acceptable levels of service. Simulations conducted using the VISSIM Microscopic Simulation Model, which estimates average delay in seconds per vehicle for each approach to the intersections, showed that the proposed improvements would enhance the throughput at the intersection for two hours during the morning peak period and two hours during the evening peak period while reducing delay time. For instance, in the evening peak at the intersection of Siegen/Sherwood and Airline, existing conditions were 6,200 vehicles per hour each experiencing an average of 178.3 seconds of delay, for a total of 368.5 vehicle hours of delay per peak hour; with the improvements, it was estimated that 6,700 vehicles per hour would experience an average of 34.4 seconds of delay, for a total of 64.0 vehicle-hours of delay per peak hour. In total, the two components of the intersection would reduce delay by 299.3 vehicle-hours in each morning peak hour and 429.9 vehicle hours in each evening peak hour, for a total of 1,459.2 vehicle hours saved per weekday.
- In Lexington, Kentucky, the installation of fiber optic cable for traffic signal optimization for the arterial highway network was estimated to reduce delay by 4 minutes per vehicle (determined by using an average reduction for a sample of 18 intersections), resulting in an estimated 6,360 vehicle hours of delay per day saved throughout the entire network.[23]
- Installation of coordinated signalized intersections to replace stop control at several intersections along Main Street in the City of Newark, Ohio was estimated to reduce delay by 702 vehicle hours per day at four of the main intersections involved in the project, based on analysis using a traffic simulation model.
- Tennessee DOT estimated an increase in average speed of 34 mph to 38 mph after traffic signal timing synchronization for a roadway in Knoxville, affecting 25,935 average daily vehicle trips.
- Installation of reversible lanes along Nicholsonville Road (US 27) in Fayette County, Kentucky, to allow three northbound lanes during the morning peak period was estimated to result in a 17 percent reduction in delay, or 63 vehicle hours saved during the morning and evening peak hour each day. According to the region's Congestion Management System report, for approximately 1.5 hours each morning, a queue of traffic bound for Lexington extended for a distance of nearly one-half mile, and often further due to incidents or inclement weather. The project would take advantage of unutilized median space and low early morning left turning volumes to create a third northbound traffic lane in the morning peak period by reassigning one of the left turn lanes on each side of an intersection as a through lane during this period.

- In Albany, New York, conversion of a signalized intersection into a roundabout was estimated to increase average speeds from 15 mph to 29 mph, and affect 48,670 vehicles over a quarter mile. These figures were calculated based on changes in vehicle delay, which were estimated to fall from an average of 31 to 47 seconds per vehicle at each approach to an average of 6 to 16 seconds.

Emissions Benefits

In general, traffic signalization and intersection projects that reduce vehicle delay will reduce emissions across all types of pollutants. However, traffic flow projects that increase travel speeds may have different effects on different pollutants. VOC emissions generally decline with increasing speeds, while CO and NOx emissions can begin to increase at speeds beyond 32 to 35 mph. As a result, some projects that increase speeds around certain ranges may actually increase CO and NOx emissions.

For the selected projects, the project sponsors estimated daily emissions reductions ranging from 2.9 kg to 40.1 kg of VOC. Daily NOx emissions reductions associated with each project show a smaller effect (from 1.1 kg to 9.1 kg reduced), with one project exhibiting a 2.2 kg increase in NOx emissions due to speed increases beyond 35 mph. CO reductions reported by sponsors indicate 24.2 kg to 378.0 kg emissions reductions each day.

None of the sponsors reported reductions in PM for these projects. Since EPA's MOBILE6 model does not account for the effects of changes in vehicle operating speeds on PM emissions, one would expect no reportable change in PM emissions for projects that alter vehicle operating speeds. Several project sponsors, however, calculated emissions benefits based on reduced vehicle idling time (e.g., calculating reduction in delay time due to the project and multiplying by idle emissions factors), in which case, PM emissions reductions could be calculated.

Costs

The total project costs for the signalization and intersection improvement projects ranged in magnitude from $33,000 to $5.5 million. The non-CMAQ share of project funding ranged from 0 to 20 percent of the total project cost. The total cost of signal timing projects will vary greatly depending on a number of local and project-specific factors, including the methods for coordinating signals, the number of signals included in the project, and the length of the roadway. The most expensive two projects both involved capital projects to redesign intersections. At $4.87 million and $5.5 million, respectively, the development of a continuous flow intersection in Louisiana and the construction of a roundabout in New York required substantially more funding than the signal timing projects. Although the capital costs are relatively expensive, the infrastructure and emissions benefits, associated with these types of projects could be long lasting.

Freeway Management

Four CMAQ-funded freeway management projects were documented in this analysis; quantitative findings are summarized in the table below.

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	$PM_{2.5}$ (kg/da
Louisiana	$2,712,940	$2,712,940	ITS on I-10 from Acadian St. to Highland Blvd.	2003	-189.6	NR	-489.0	NR	NR
Washington	$998,037	$2,000,000	Duwamish ITS System	2004	-76.0	-939.0	-4.0	NR	NR
Connecticut	$1,279,246	$1,421,384	Incident Management System on I -95	2005	-6.1	NR	-3.00	NR	-0.004
Alabama	$240,000	$800,000	Alabama Service Patrols Program	2007	-31.3	NR	-11.9	NR	-0.12

NR Values were not reported by the local project sponsor or State DOT in the CMAQ database or other materials for the project.

Freeway management projects improve traffic flow along major highways and often target travel impacts during peak periods when delays most often occur. These projects include service patrols that assist or remove disabled vehicles from blocking travel lanes, computer systems that control traffic flow onto freeways, monitoring devices that scan for incidents and provide motorist assistance or reroute traffic around the incident, and other Intelligent Transportation System (ITS) components. In most metropolitan areas, traffic incident-related delay (not including other non-recurring delay caused by weather, work zones, etc.) is estimated to account for between 25 and 30 percent of total congestion delay.[24] When vehicles are cleared from the motorway and/or other vehicles are alerted to incidents ahead, idling is reduced and traffic speeds along freeways can return to more optimal levels.

Congestion / Mobility Benefits

Freeway management projects can reduce recurring and/or nonrecurring delay associated with incidents. For example, an ITS system project in Seattle, Washington included interconnection of traffic signals and controller equipment upgrading, installation of variable message signs and other driver information systems, and implementation of traffic control strategies to monitor traffic conditions and accidents. This project was designed to minimize the conflicts among freight movement, transit travel, commuter traffic, and ferry access, while enhancing safety and mobility for people and goods. The project sponsors estimated a 10 percent increase, or 2 mph, in both peak and off peak speeds due to the program.

In Connecticut, development of a 13.94 mile portion of an incident management system on I-95 included the installation of a fiber-optic communication system, video surveillance, traffic flow monitors, and a link to the Bridgeport Operations Center. The incident management project was designed to allow operational problems to be identified sooner and enable faster dispatch of the proper response equipment and medical services to a site. Based on data from the "Connecticut

Freeway Management System" report, which reported effects for a 65 mile length corridor, it is estimated that this type of system will result in annual delay savings of 368,000 vehicle hours, assuming proportional benefits for the 13.94 mile corridor (based on an assumption of a congested incident speed of 5 mph, and a free flow speed of 55 mph).

The Alabama Service and Assistance Patrol (ASAP) Program, an incident management program of the Alabama DOT and Alabama State Troopers, offers services to disabled motorists to reduce response time and to minimize major disruption of interstate traffic flow. This program was estimated to result in a savings of 3,849 vehicle hours of delay per incident for an estimated 111 incidents per year, resulting in a savings of over 427,000 vehicle hours per year. An advanced traffic management center in the Baton Rouge metropolitan area, including incident detection and response, motorist assistance, and surveillance components along I-10, also was designed to reduce incident-based delay, but did not report hours of delay reduced.

Emissions Benefits

As with other traffic flow improvements, freeway management projects that cause an increase in travel speeds may have varying effects on different pollutants, depending on the magnitude of the overall speed change. Emissions reductions reported by project sponsors for the four projects indicated daily VOC emissions reductions ranging from 6.1 kg to 189.6 kg per day, and daily NOx emissions reductions ranging from 4.0 kg to 489.0 kg per day. One project sponsor estimated a 939.0 kg CO emissions reduction; the three other projects did not report CO reductions. Two projects reported $PM_{2.5}$ emissions benefits of 0.004 and 0.12 kg per day. Due to reduced vehicle idling, one would expect reductions of CO and PM for each project.

It should be noted that the Louisiana project, which reported the highest emissions reductions, assumed that the incident detection and response, motorist assistance, and surveillance components of the ITS project along I-10 would result in a 4.41 percent reduction in total emissions for traffic along the I-10. This assumption appears to be somewhat high in comparison to the other analyses, and is based on data showing that 4.9 percent of freeway emissions are associated with nonrecurring congestion, and an assumed 90 percent reduction in incident-based emissions. The 90 percent effectiveness factor is based on an effectiveness rate of 50 percent for incident detection and response, 25 percent for motorist assistance, and 15 percent for surveillance.

Costs

The total project costs of the selected projects ranged in magnitude from $800,000 to $2,712,940. In general, most freeway management projects involve major corridors or a network of roadways and so have substantial capital and/or operating costs. The non-CMAQ share of project funding ranged from 0 percent to about 50 percent of the total project cost.

High-Occupancy Vehicle (HOV) Lanes

Although the CMAQ program has helped to fund a number of HOV projects throughout the history of the program, only a small number of HOV projects have used CMAQ funding since FY 2000, which is the focus of this representative analysis. Consequently, only one project was identified for analysis in this study construction of an HOV interchange in Dallas. Quantitative findings are summarized in the table below.

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	$PM_{2.5}$ (kg/day)
Texas	$17,152,000	$254,570,093	Dallas HOV Interchange	2002	-68.8	NR	-135.3	NR	NR

NR Values were not reported by the local project sponsor or State DOT in the CMAQ database or other materials for the project.

An HOV lane is a travel lane usually reserved for use by vehicles with more than one occupant, such as carpools, vanpools and buses, during peak periods or longer periods. They are often located next to the regular or general purpose lanes. Most users of HOV facilities can expect a substantial savings in travel time, as well as a commute time that is more reliable and predictable on a daily basis. Because HOV lanes carry vehicles with a higher number of occupants, the amount of vehicles needed to transport those occupants is reduced, resulting in fewer vehicle trips and lower overall VMT.

There are approximately 126 HOV freeway projects in 27 metropolitan areas in the U.S. These HOV facilities include over 1,000 miles of roadway, most often on interstate freeways. HOV lanes have also been implemented on arterial roads, especially those related to bus-only applications.[25]

Congestion/Mobility Benefits

HOV lanes improve mobility for people who choose to rideshare and for transit users by allowing a faster trip compared to being in general purpose lanes. HOV lanes also offer congestion benefits primarily by encouraging more passengers to travel in fewer vehicles, and can provide more person throughput on a fixed amount of transportation infrastructure. Additionally, some States open HOV lanes to unrestricted traffic during non-peak hours, increasing the overall capacity for vehicle movement.

In Dallas, the HOV interchange project sponsors estimated that 2,929 daily vehicle trips would be reduced due to the HOV facility, based on an estimate that 56 percent of transit and rideshare users on the facility previously drove alone. Effects on overall congestion levels and speeds on the highway were not quantified, although the calculation of emissions effects took into account the differences in speeds between the general purpose lanes and HOV lane.

Emissions Benefits

HOV lanes affect air pollution emissions in several ways. First, restricting the lanes to certain vehicles encourages ridesharing among commuters and results in fewer vehicle trips and an overall reduction in emissions of all pollutants. HOV lanes also increase travel speeds for HOV traffic, and sometimes along the entire roadway. Increases in travel speeds, as noted previously, will have different effects for different pollutants depending on the magnitude of the increase.

The Dallas HOV interchange project was estimated to reduce 68.8 kg of VOC and 135.3 kg of NOx per day. CO and PM reductions were not reported for this project, but might occur due to the reduction in vehicle travel. The calculation accounted for both a reduction in VMT due to people shifting to transit and ridesharing, and an increase in vehicle speeds for the traffic shifting from general purpose lanes to the HOV lane. The analysis did not take into account the potential speed changes that occur for the vehicles remaining in the general purpose lanes.

Costs

The construction of a new HOV lane and the ramps and other infrastructure required for an HOV system can be expensive. The total public cost of the reviewed project was $254,570,093, but the CMAQ program only paid for approximately 7 percent of the total project cost. The bulk of funding came from National Highway System (NHS) funding, along with a lesser amount from State and local sources. Although HOV projects incur large capital costs upfront, the infrastructure and corresponding emissions benefits, may be long-lasting.

Shared Ride Programs

Shared ride programs encompass a wide variety of projects that focus on changing travel behavior to reduce air pollutant emissions from light-duty vehicles. These programs offer services that encourage single-occupant vehicle travelers to group rides with other travelers, generally in carpools or vanpools, thus increasing the average number of occupants per vehicle trip and reducing total vehicle trips and VMT. Projects analyzed include:

- Regional Ridesharing Programs;
- Vanpool Programs; and
- Construction of Park and Ride Lots.

Regional Ridesharing

Three CMAQ-funded regional ridesharing programs were documented in this analysis.

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	$PM_{2.5}$ (kg/d
Maryland	$956,000	$956,000	11 County Ridesharing Program Operations	2002	-35.0	NR	-110.0	NR	NR
Pennsylvania	$480,000	$600,000	University of Pittsburgh TDM Program	2005	-26.2	-187.4	-30.9	NR	NR
Alabama	$700,000	$700,000	CommuteSmart Commuter Services Program Operations	2007	-10.2	NR	-12.0	NR	-0.1

NR Values were not reported by the local project sponsor or State DOT in the CMAQ database or other materials for the project.

Regional ridesharing programs provide ride-matching services, employer outreach, and incentives to commute by carpool or vanpool. These incentives can include free gas cards, award programs, and travel subsidies. Ride-matching may encourage people to establish regular carpool routines or can be dynamic and create systems to match individuals who want to travel to/from similar locations in real-time. These programs largely serve a supportive or facilitative role, and help to optimize use of existing transportation infrastructure and services. Their success depends, in part, on the commute options existing in the community, such as HOV lanes and transit services.

Congestion / Mobility Benefits

Regional ridesharing programs can improve mobility by giving people greater options in meeting their travel needs, and can reduce travel costs for people who choose to rideshare. The congestion benefits of a regional ridesharing program will depend on the number of new carpools and vanpools that are formed and the extent to which participants previously drove alone. It should be noted, however, that if some of the persons who choose to rideshare previously rode transit, this mode switch would not necessarily be beneficial to congestion or emissions. Reductions in VMT are also dependant on the length of the trips, and the length of the carpool trip to pick up riders.

The Birmingham MPO estimated that its regional CommuteSmart Commuter Services Program which includes a ridesharing database, a vanpool program with 34 vans in 2007, and a carpool program would result in a reduction of about 312 vehicle trips per weekday. The primary users of these services have longer-than average commutes. At an average one-way trip length of 39.5 miles, the program reduces a total of 9,470 vehicle miles of travel per weekday.

The TDM program in the Oakland area of Pittsburgh, Pennsylvania surrounding the University of Pittsburgh, offers ridesharing coordination, employer-sponsored vanpools, and carpool programs. This program was estimated to reduce 2,024 vehicle trips per day at an average one-way trip distance of 5.45 mile, for a total of 22,062 vehicle miles reduced per day.

The Maryland program - which funds a ridesharing program in eleven counties in the Baltimore and Washington, DC metropolitan areas - was estimated to reduce about 3,000 vehicle trips per weekday, based on data showing 12,360 rideshare applicants in the programs and an estimate that 24 percent will take part in ridesharing each day. At an average one-way trip distance of 14 miles, this program results in about 84,000 vehicle miles reduced per day.

None of the project sponsors for the three projects submitted information on delay reductions or travel speed improvements anticipated with the projects.

Emissions Benefits

By encouraging people who would normally drive alone to share trips, ridesharing programs reduce motor vehicle travel and associated emissions. Daily emissions reductions associated with the selected projects range from 10.2 kg to 35.0 kg of VOC and from 12.0 kg to 110.0 kg of NOx. One project was estimated to result in a CO emissions reduction of 187.4 kg per day. $PM_{2.5}$ emissions effects were reported in the analysis of one project, showing a reduction of 0.1 kg per day. However, since these projects reduce VMT, all three projects would likely reduce emissions of all pollutants.

Costs

The CMAQ program is a key funding source for many regional ridesharing programs, with grants used to cover operating expenses, such as advertisements, outreach materials, and commute incentive purchases. The total public cost of these projects ranged in magnitude from $600,000, for two years of the Pittsburgh program ($300,000 per year) to $956,000 for the annual costs of the eleven-county Maryland program. The non-CMAQ share of project funding ranged from 0 to 20 percent of the total project cost.

VANPOOL PROGRAMS

Three CMAQ-funded vanpool programs were reviewed in this analysis. Findings are summarized in the table below.

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	$PM_{2.5}$ (kg/day)
Utah	$448,000	$448,000	15 new vans for vanpool leasing program	2002	-12.2	-136.9	-14.9	NR	NR
Utah	$148,866	$180,866	5 new vans for vanpool leasing program	2005	-3.2	-37.2	-4.0	NR	NR
Kentucky	$96,000	$120,000	6 new vans for LexTran Vanpool	2006	-10.4	-80.2	-5.3	NR	NR

NR Values were not reported by the local project sponsor or State DOT in the CMAQ database or other materials for the project.

Vanpool programs provide vehicles that are owned by an organization or public agency to commuters who live in a common geographic area and who share an employment destination. Each vanpool carries between seven and fifteen passengers on a van or bus, operates on weekdays, and typically travels between one or two common pick-up locations and the place of work. The vehicles may be operated by a paid driver or by the commuters themselves, depending on local or program preferences. Employers or institutions frequently enable vanpool operations in any of a variety of supportive or financial ways.

Each of the selected projects involved the purchase of passenger vans: 15 new 8-passenger vans for the Utah Transit Authority (UTA) Vanpool Leading Program in 2002 to be used in the Salt Lake City and Ogden areas; five new 8-passenger vans for the UTA Vanpool Leasing Program in 2005 to be used in the Ogden and Layton area; and six new 12-passenger vans for LexVan, a commuter vanpool program managed by the Lexington Bluegrass Mobility Office in Kentucky.

Congestion / Mobility Benefits

Vanpool projects can improve mobility by giving people an option to meet their commuting needs at lower cost than driving alone. The congestion benefits of vanpool programs will vary depending on the number of vanpools established through the program, the number of passengers, and the length of a trip. Typically, vanpools are successful in areas with longer commutes and where they utilize established park and ride lots as the common pick up location. For small vanpool programs serving a limited number of passengers, the net reduction in vehicle trips is small: the three reviewed projects were estimated to remove from 40 to 120 drivers from the road each day, and reduce overall VMT by 3,000 to 6,600 vehicle miles traveled per day. Consequently, congestion benefits would be too difficult to quantify. These projects, however, can result in important benefits to individual passengers, including reduced fuel and vehicle maintenance costs, and improved quality of life due to reduced commuting stress and time that can be spent reading or in other activities during the vanpool trip.

Emissions Benefits

Vanpools reduce VMT on the roads, and therefore should reduce emission of all pollutants. Although the vanpool vehicle may produce more emissions than an individual automobile, the emissions are considerably less than the total of the seven to fifteen individual vehicle trips that are typically replaced. Among the three projects, estimated daily VOC emissions reductions associated with each project ranged from 3.2 kg to 12.2 kg, daily NOx emissions reductions ranged from 4.0 kg to 14.9 kg, and daily CO reductions ranged from 37.2 kg to 136.9 kg.

Costs

CMAQ funding for vanpool programs may be used for capital costs, such as purchase of new or replacement vans, or for operating expenses, such as paid advertisements and printing outreach materials. For these three projects, CMAQ funding was used for the purchase of additional vans and does not include any operating costs. The total public cost of the selected projects ranged in magnitude from $120,000 to $448,000. The non-CMAQ share of funding ranged from 0 percent to 20 percent of the total project cost, and in some cases, included the vanpool fares.

Park and Ride Lots

Five CMAQ-funded park and ride lot projects were reviewed in this analysis.

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	$PM_{2.5}$ (kg/c
Maryland	$132,817	$132,817	Two new 25 space lots	2000	- 0.01	NR	-0.06	NR	NR
Wisconsin	$48,000	$48,000	Lake Geneva and Root Creek Lots	2000	- 1.5	NR	- 3.8	NR	NR
Maryland	$1,218,831	$1,218,831	MD 210 and MD 373 500 space lot	2002	- 1.4	NR	- 5.9	NR	NR

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	$PM_{2.5}$ (kg/c
Kentucky	$844,800	$1,056,000	Walton/Union Lot with 200 spaces	2005	-0.9	- 33.8	- 3.2	NR	-0.1
Washington	$4,150,000	$20,000,000	Expansion of Terrace Station Transfer Lot to 880 spaces	2005	- 18.0	- 145.0	- 9.0	NR	NR

NR Values were not reported by the local project sponsor or State DOT in the CMAQ database or other materials for the project.

Park and ride lots are transportation facilities that provide people a secure location to park their vehicles before joining a carpool, vanpool, or transit service. Typically located in suburban areas, these projects provide commuters the flexibility of driving to a central location near their home and then completing the majority of their commute using transit or ridesharing. The selected projects range widely in size and include:

- Construction of two new 25-space lots in Cecil County, Maryland;
- Construction of 300 spaces at two lots in Southeastern Wisconsin;
- Addition of 500 spaces at an existing lot in suburban Maryland;
- Development of a new 200-space lot, along with improvements to existing lots, including improving signage, adding bicycle parking racks, and providing information kiosks in Kentucky; and
- Construction of a new multi-level parking structure over an existing park-and-ride lot in Seattle, Washington, increasing capacity from 388 to 880 spaces.

Congestion / Mobility Benefits

The congestion benefits of park and ride lots are associated with reductions in freeway and arterial VMT during peak periods when commuters use the park and ride lots. The reductions are dependent on the number of spaces that will be created as part of the project, and the utilization of the available spaces.

The projects generally reported 126 to 738 vehicle trips reduced per day (the exception is the small park and ride project in Cecil County, Maryland). More precisely, vehicle trips are not eliminated since users still drive to the lot; these trips are shorter in length since commuters drive to the park and ride facilities. Since carpool trips, however, tend to be longer than average regional vehicle trip lengths, VMT reduction typically is larger than for other types of programs affecting a similar number of trips (e.g., bicycle projects, bus services).

Emissions Benefits

These projects improve air quality by reducing the number of vehicle miles traveled each day. Because motorists are required to drive to the park and ride lots, these projects will not reduce the number of vehicle cold starts, when the highest levels of CO, NOx, and VOCs are emitted.

Estimates of daily VOC emissions reductions associated with each project ranged from 0.01 kg to 18.0 kg. Daily NOx emissions reductions associated with each project ranged from 0.06 kg to 9.0 kg.

It should be noted that the project with the smallest impacts (two park and ride lots in Maryland funded in 2000) only involved the addition of 50 parking spaces, and assumed a very low utilization rate (15 percent) and a low percentage of users who are new riders (15 percent). The 2002 Maryland park and ride project used more typical assumptions, estimating that 56 percent of spaces would be utilized and 45 percent would be new riders; using similar assumptions for the 2000 park and ride project would result in emissions estimates approximately 11 times larger (e.g., -0.13 kg/day VOC, -0.65 kg/day NOx). Park and ride lot projects would be expected to reduce emissions of all motor vehicle-related pollutants. CO reductions reported by two projects indicate 33.8 kg to 145.0 kg emissions reductions each day, and $PM_{2.5}$ emissions reductions were reported by one project in Kentucky to be 0.1 kg each day.

Costs

CMAQ funding is usually provided as a portion of the total cost of construction of new facilities or the expansion and/or resurfacing of park and ride lots. The total public cost of these projects ranged widely, from $48,000 for two park and ride lots in Wisconsin to $20 million for construction of a multi-level parking garage in the Seattle region. In the case of the $20 million project, $4.15 million in capital costs were funded through CMAQ over two different funding years.

Travel Demand Management

Travel demand management (TDM) programs typically focus on reducing the number of vehicle trips by commuters during peak hours. TDM strategies are often linked to employer-based strategies and include encouragement of alternative work schedules, telework programs, guaranteed ride home initiatives, and Ozone Alert Days. They also may involve regional marketing efforts to support transit, ridesharing, and other travel options.

Four CMAQ-funded TDM projects were reviewed in this analysis, two of which are part of the Metropolitan Washington Council of Governments' (MWCOG) Commuter Connections Program.

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	$PM_{2.5}$ (kg/day)
Colorado	$73,000	$91,250	Coordinate Telework Program	2001	-2.0	-14.0	-2.0	NR	NR
DC, Maryland, Virginia	$9,000	$15,000	Regional Employer Outreach, Bicycles	2002	-1.0	NR	-1.0	NR	NR
DC, Maryland, Virginia	$772,110	$1,678,500	Regional Guaranteed Ride Home Program	2005	-95.2	NR	-216.8	NR	NR

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	$PM_{2.5}$ (kg/day)
Rhode Island	$168,000	$168,000	Ozone Alert Days	2005	-23.0	-251.3	-26.5	NR	NR

NR Values were not reported by the local project sponsor or State DOT in the CMAQ database or other materials for the project.

TDM strategies often are implemented through directing marketing, services, and informational tools to encourage the use of available travel options. Commuters frequently are the focus of TDM actions because of their regular, predictable driving patterns, the possibilities of employer partnerships, and expanded opportunities for ridesharing programs.

Congestion / Mobility Benefits

Travel demand management programs improve mobility by supporting a range of travel options, including not only choices of alternatives modes to driving alone, but also telecommuting and changes in work schedules to avoid travel during peak period hours. The congestion benefits of TDM strategies can be attributed to shortened vehicle trips, the shifting of peak-period trips to non-peak hours, and the elimination of trips altogether. For the four selected projects, estimated vehicle trip reductions ranged from 125 vehicle trips per day for the Washington, DC-area bicycle outreach effort to 12,350 vehicle trips per day for the region's Guaranteed Ride Home Program. Since these programs are part of an integrated TDM program involving multiple elements, and credit is being taken for this program as a Transportation Emissions Reduction Measure (TERM) as part of the region's conformity determination, the regional MPO (MWCOG) has taken care to analyze the impacts utilizing surveys and other tracking data. As with other types of VMT reduction programs, impacts on travel speeds are generally difficult to assess and were not quantified by the project sponsors.

Emissions Benefits

Emissions reductions estimated by project sponsors were generally small for the selected projects, with the exception of the Washington, DC region's Guaranteed Ride Home program. Daily VOC and NOx emissions reductions associated with two of the projects were at or under 2.0 kg/day; in the case of the DC region's Guaranteed Ride Home program, emissions reductions were estimated at 95.2 kg/day of VOC and 216.8 kg/day of NOx reduced. The Rhode Island program is an example of an "episodic" type program which is not in effect every day, but only on occasions when an ozone alert day is called. Hence, its benefits associated with a fare free transit program on ozone alert days only accrue on those few days a year when these events occur.

Costs

CMAQ funding is usually provided as an operating subsidy for TDM strategies. The total public cost of these projects ranged from $15,000 for the Washington, DC regional outreach on bicycling to more than $1.67 million programmed for the regional Guaranteed Ride Home program, including the costs of marketing, payment for rides, and staff labor. Total funding for the Commuter Connections program has ranged from $4.28 million to $5.11 million annually over the period FY 2002 to FY 2008, and includes seven related TDM program elements:

Metropolitan Washington Telework Resource Center (TRC), Expanded Telecommuting, Guaranteed Ride Home, Integrated Rideshare, Employer Outreach, Employer Outreach for Bicycling, and Mass Marketing (a large-scale, comprehensive media campaign). Funding comes from Maryland, Virginia, and the District of Columbia, of which CMAQ funding makes up at least half.

Bicycle / Pedestrian Facilities

Bicycle and pedestrian projects and programs include a wide range of investments and strategies to facilitate and encourage non-motorized travel. Some examples of these projects include bicycle paths and lanes, sidewalks, bicycle racks or lockers, pedestrian urban design enhancements, bicycle/pedestrian marketing materials, and bicycle sharing projects.

Four CMAQ-funded bicycle and pedestrian projects were reviewed in this analysis.

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg / day)	CO (kg / day)	NOx (kg / day)	PM_{10} (kg / day)	$PM_{2.5}$ (kg /
Massachusetts	$639,008	$1,300,000	8.3 mile Swansea Bikeway Facility	2002	-0.5	-3.0	-1.1	NR	NR
Indiana	$1,600,000	$2,000,000	4.3 mile Bike Path to Pinhook Park	2005	-0.4	-2.7	-0.5	NR	NR
Colorado	$63,910	$600,000	Construction of a Transit Bike Depot	2006	-0.9	-6.7	-0.9	NR	NR
New York	$2,400,000	$3,000,000	NYC CyclistNET Marketing Program	2007	-2.4	-38.4	-2.0	-0.9	-0.04

NR Values were not reported by the local project sponsor or State DOT in the CMAQ database or other materials for the project.

Bicycle and pedestrian projects often serve multiple goals, including improving mobility and safety. By providing bicycle and pedestrian access across barriers such as arterial roads, freeways, and/or train tracks, these projects can not only substitute for driving trips but also can improve mobility and access for non-drivers. Projects can also improve the safety of walkers and bicyclers by filling in gaps on existing, planned, or proposed routes and addressing potential hazards in existing facilities. Non-motorized forms of transportation require no fossil fuels, and are often considered in the context of goals such as sustainability, reducing energy consumption, and reducing greenhouse gas emissions.

Congestion / Mobility Benefits

Bicycle and pedestrian projects can contribute to improvements in mobility by providing additional options for people who might choose walking or biking. These projects improve the ability to reach desired goods, services, activities and destinations using non-motorized forms of transportation and may help diminish the need for automobile travel.

Bicycle and pedestrian projects may reduce congestion to the extent they shift mode choice from single occupancy vehicles to bikes and walking, and often are more successful in reducing VMT in locations where short driving trips, such as trips to local shopping areas, schools, or commercial districts, are common. While bicycle and pedestrian projects can reduce vehicle trips during both peak and off-peak times, congestion benefits are usually limited due to the relatively short distances of trips and to seasonal limitations on bicycling in some areas. The four projects reviewed had estimated reductions of 83 to 902 vehicle trips per day, with the largest figure reported for the New York bicycling program. Given the relatively small impacts at reducing vehicle travel, the bicycle and pedestrian projects assessed for this study did not provide estimates for changes in speed or delay times on the system.

Emissions Benefits

Bicycle and pedestrian projects generally have modest effects on emissions. Typically, pedestrian trips have a maximum distance of 1 mile and bicycle trips a limit of 5 miles, which reduces the ability of these projects to substitutes for driving for many commuters. Bicycle and pedestrian projects may be more effective when designed to enhance access to transit, so that longer trip lengths may be reduced.

Project sponsors generally estimated small reductions in motor vehicle emissions typically under 1.0 kg/day for VOC and NOx. CO reductions reported by sponsors indicate a range of benefits from 2.7 kg to 38.4 kg emissions reductions each day. PM_{10} emissions reductions were reported by one project to be 0.9 kg each day. The same project reported daily $PM_{2.5}$ emissions reductions of 0.04 kg. All of the projects, however, would be expected to reduce PM_{10} and $PM_{2.5}$ from motor vehicle exhaust.

Costs

CMAQ funding is usually provided for capital improvements, but can also be an operating subsidy for the operation of marketing or bike sharing programs. The total public cost of these projects range in magnitude from $600,000 to $3 million. The non-CMAQ share of project funding ranged from 0 percent to 89 percent of the total project cost in the case of the Colorado bike depot (CMAQ costs reported were for architectural design and engineering documents to create the site design).

Transit Service Improvements

CMAQ funds may be used to support projects that increase the use of public transportation systems. Generally, there are three broad categories of transit service-related projects or programs: provision of new or expanded bus services, provision of new or expanded rail services, and service upgrades and rider amenities on existing transit services. Routine maintenance and rehabilitation of existing transit facilities are not eligible for CMAQ funding. However, substantial changes to transit stations or facilities that are likely to increase ridership and reduce emissions are eligible. [26]

New Bus Services

These strategies include the establishment of new routes, increased frequency of vehicles, expanded hours of operation, or increased coverage of routes. Three CMAQ-funded projects that provide new bus services were analyzed.

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	$PM_{2.5}$ (kg/day)
Wisconsin	$157,382	$196,727	City of Racine New Sunday Bus Service	2001	-2.9	NR	-3.2	NR	NR
New York	$264,000	$420,000	Expanded S92 Bus Route	2005	-6.7	-153.4	+7.2	+1.0	+1.0
Rhode Island	$440,000	$550,000	Expanded Route 30 and New Route 12	2005	-6.7	-191.0	-11.1	NR	NR

NR Values were not reported by the local project sponsor or State DOT in the CMAQ database or other materials for the project.

Bus service improvement projects improve both air quality and congestion levels in the local community by increasing the use of transit services and reducing the number of auto trips. New bus routes make transit a more convenient transportation option and may reach areas of the community that were previously underserved or not served at all. Reductions in wait times for transit vehicles may lead to a faster overall trip for passengers, further increasing the number of transit users. Finally, increasing the hours of transit service along certain routes allows people to use the transit system at hours that were not previously available, thus allowing them more latitude in scheduling their trips and allowing for unforeseen changes in itinerary.

Congestion/Mobility Benefits

New bus service can reduce congestion by reducing vehicle trips and VMT. The extent of benefits will depend on several factors, including the extent to which new transit users drive to bus stops, the length of the new service, and the number of additional buses in operation in mixed-traffic. New bus services provide mobility improvements, to the extent that the services provide additional transportation options for users to choose. Mobility benefits will likely be greatest when land-use patterns and other supporting strategies, such as bicycle/pedestrian connections and rider amenities, are already in place. The projects selected for this study reduced between 72 to 358 vehicle trips per day, and project sponsors did not assess impacts on delay and travel speeds.

Emissions Benefits

Bus service improvements can reduce emissions of all pollutants by reducing the number of trips by single-occupancy vehicles and VMT. However, the new bus services also produce emissions, which may offset some of the emissions reductions from personal vehicles and in some cases, NOx and PM emissions could increase due to emissions from the diesel engines in buses if the new services do not attract a sufficient number of new riders who previously drove. Emissions reductions reported by project sponsors indicate a range of anticipated benefits from implementation of these projects. Daily VOC emissions reductions associated with each project ranged from 2.9 kg to 6.7 kg. Daily NOx emissions reductions associated with each project ranged from 3.2 kg to 11.1 kg. Due to increased emissions from the new bus services, the New York project estimated a NOx emissions increase of 7.2 kg per day and PM_{10} and $PM_{2.5}$ increase of 1.0 kg/day. The other two projects did not account for the increase in emissions due to the new bus services, only the reduced emissions from personal vehicles.

Costs

CMAQ funding is usually provided for the operating costs associated with new bus services, but can also be available as a portion of the capital costs to purchase new buses. Only one of the projects, the S92 bus route on Long Island, included estimates of transit fares in determining project costs. The project sponsors estimated a total project cost of $420,000 and farebox revenues equal to $90,000, resulting in a net public cost of $330,000. The total public costs of the selected projects, without consideration for farebox revenues, ranged in magnitude from $196,727 to $550,000.

New Rail Services

New passenger rail services include establishing new routes, increasing the frequency of service, expanding the hours of operation, or the overall coverage of transit corridors. Three CMAQ-funded rail service projects were reviewed in this analysis.

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	$PM_{2.5}$ (kg/da
Utah	$4,000,000	$4,000,000	Purchase of 5 New Light Rail Vehicles	2002	-27.0	-305.0	-33.0	NR	NR
Texas	$36,253,821	$70,472,342	TRE Double Tracking of Segments	2003	-67.2	NR	-110.0	NR	NR
Connecticut	$2,400,000	$3,000,000	Construct Rail Station Platforms and Bridge	2005	-6.0	NR	-6.0	NR	-1.0

NR Values were not reported by the local project sponsor or State DOT in the CMAQ database or other materials for the project.

Projects to expand rail services can improve both air quality and congestion levels by reducing the number of auto trips, as well as bus transit trips, which may contribute to congestion and emissions. The projects include purchase of new light rail vehicles for the TRAX North/South line in Salt Lake City to enable additional services; double tracking segments of the Trinity Railway Express (TRE) commuter rail line between Dallas and Fort Worth to enable expanded capacity; and construction of a new commuter rail station along the Metro-North commuter rail line to serve Fairfield, Connecticut, including students of Fairfield University and nearby areas within the city of Bridgeport.

Congestion / Mobility Benefits

New and expanded rail services may provide mobility improvements in the form of increased transportation mode options for users in the community, and often will provide faster travel times than existing bus services. Improvements in mobility will likely be greatest when land-use patterns, inter-modal connections, and other supporting strategies, such as bicycle/pedestrian connections and rider amenities, are already in place. New or expanded rail services also may reduce congestion by attracting riders who previously drove their own vehicles. The congestion benefits will depend on several factors, including the extent to which new transit riders drive to the station, the length of vehicle trips reduced, and the existence of supporting land use patterns and bicycle, pedestrian, and parking access to stations. The three selected projects were estimated to reduce from 400 (Connecticut) to 5,400 (Dallas) vehicle trips per day. The project sponsors did not assess impacts on delay and travel speeds.

Emissions Benefits

New rail services and routes may reduce emissions of all pollutants by reducing VMT. These types of projects are often most effective when implemented in areas that have a large, established transit network. Daily VOC emissions reductions estimated by project sponsors ranged from 6.0 kg to 67.2 kg. Daily NOx emissions reductions ranged from 6.0 kg to 110.0 kg. CO emissions reductions were reported by one project sponsor as 305.0 kg per day. $PM_{2.5}$ emissions reductions were reported by one project sponsor to be 1.0 kg per day. These emissions effects only take into account the reduction in personal vehicle travel.

The emissions benefits of projects to provide new diesel rail services should include consideration of the increase in off-road emissions from operating locomotives. In the case of the Utah and Connecticut reviewed projects, there were no new diesel emissions, since these involved light rail and construction of a new rail station but no new service. The documentation for the Dallas project noted that there will not be any new emissions of NOx and VOC from diesel locomotives due to the double-tracking project; however, presumably the calculation of emissions benefits accounts for new ridership associated with higher service levels.

Costs

All three of the projects had costs that were several million dollars, reflecting the high capital costs of transit rail cars, track, and stations. The Texas project, which was the largest at $70.4 million, received substantial funding from other sources. This is often the case for large capital investment projects which receive funding from multiple sources, including Federal, State, and local programs.

Service Upgrades/Amenities

This category of CMAQ projects includes strategies to increase transit marketing, provide more widely accessible transit information, improve transit passenger amenities, and create new intermodal connections at transit stations (e.g., improved bus circulation, parking, and interface between bus and rail). Five CMAQ-funded service upgrades/amenities were reviewed in this analysis.

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	PM_2 (kg
Massachusetts	$388,000	$625,000	Fitchburg Intermodal Trans. Center Parking Garage	2002	-14.0	-143.0	-27.0	NR	NR
Missouri	$960,000	$1,200,000	Operation Welcome Aboard Infrastructure (bus shelters)	2004 - 2006	-2.5	NR	-3.4	NR	NR
New York	$160,000	$200,000	Suffolk County Transit Marketing Program	2004	-2.4	-40.7	-2.2	-0.07	-0.0
Ohio	$2,800,000	$3,500,000	Laketran AVL -MDT System	2005	-4.0	-47.0	-13.0	NR	NR
Connecticut	$89,000	$111,000	Rail Utility Construction & Parking Spaces	2007	-6.0	NR	-6.0	NR	-1.0

NR Values were not reported by the local project sponsor or State DOT in the CMAQ database or other materials for the project.

Increased marketing, provision of more widely accessible transit information, additional customer service, and availability of parking may increase the number of people using public transportation. For instance, Operation Welcome Aboard in Missouri is a passenger amenity project to construct bus shelters at 100 highly utilized stops throughout the Kansas City transit service area. The new facilities will have a coordinated look and feel with the bus fleet and feature valuable route and schedule information. While the project will not expand existing bus routes or create new transit services, the project sponsors estimate that an additional 450 individuals will ride transit each day as a result. The installation of Automatic Vehicle Location (AVL) and Mobile Data Terminal (MDT) systems on Laketran transit vehicles in Ohio is designed to improve the system's paratransit operations, by improving schedule adherence, improving route planning and scheduling, and reducing operating costs; it is estimated to result in a 17.5 percent increase in paratransit ridership.

Congestion / Mobility Benefits

Transit service upgrades and amenities may improve mobility if they make it easier for the public to use public transportation and rely less on their personal vehicles. Since these projects focus on increasing the number of transit riders, they potentially can reduce traffic congestion by reducing the number of personal vehicle trips taken each day. Travel behavior studies have long shown that transit riders respond positively to service improvements that reduce travel or waiting time. Adding more vehicles so as to reduce headways and wait time, or providing routing improvements that reduce travel time or increase reliability are all strategies that can increase ridership. Providing riders with a seat or less crowding can also make the trip more enjoyable, comfortable, and safe, helping to increase the number of transit trips (and reduce the use of SOVs) by encouraging more frequent use by existing riders and attracting individuals who would otherwise drive private vehicles.

Project sponsors for the selected projects reported reductions in vehicle trips ranging from 176 per day (for the Suffolk County Transit Marketing) to 490 per day (for the Fitchburg parking garage at the MART intermodal transportation center). However, since benefits from service upgrades are typically indirect, the projects selected for this study did not assess impacts on delay and speed.

Emissions Benefits

Emissions reduction estimates reported by project sponsors were generally small to moderate. Daily VOC emissions reductions associated with each project range from 2.4 kg to 14.0 kg. Daily NOx emissions reductions associated with each project range from 2.2 kg to 27.0 kg. CO reductions reported by sponsors indicate a range of benefits from 40.7 kg to 143.0 kg emissions reductions each day. CO, PM_{10}, and $PM_{2.5}$ emissions were not reported for some of the projects, but would be expected to drop for each of the selected projects.

Costs

The total public cost of these projects ranged in magnitude from $200,000 to $3,500,000. The non-CMAQ share of project funding ranged from 20 percent to 38 percent of the total project cost.

Transit Vehicle Replacements and Related Infrastructure

Vehicle replacements are designed to reduce the emissions rates of vehicles due to improved technologies or switching to cleaner alternative fuels. While this category is primarily dominated by transit bus purchases, it can also include other public vehicles, such as school buses or government fleets, and related infrastructure, such as fueling stations. Generally, these strategies do not affect congestion levels; instead, they focus primarily on emissions reductions.

Alternative Fuel Vehicles / Fueling Facilities

Projects to purchase alternative fuel vehicles or construct refueling facilities and related other infrastructure are included in this category. Four CMAQ-funded alternative fuel projects were reviewed in this analysis.

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	$PM_{2.5}$ (kg/da
Maine	$150,000	$1,305,903	Compressed Natural Gas Fueling Station	2002	-2.8	NR	-2.1	NR	NR
Pennsylvania	$5,608,000	$7,010,000	Purchase 12 Alternative Fuel Buses	2002	-3.0	-12.0	-91.0	NR	NR
Connecticut	$688,800	$861,000	CT Clean Fuels Program	2005	-6.8	NR	-12.5	NR	NR
New York	$1,000,000	$1,250,000	Purchase 3 CNG Transit Buses	2007	-1.5	-7.6	-4.3	NR	-1.4

NR Values were not reported by the local project sponsor or State DOT in the CMAQ database or other materials for the project.

Vehicles that use non-conventional fuels, such as CNG, LNG, electric, or hybrid electric, will reduce emissions while generally having little to no impact on overall VMT. Vehicles that operate using these fuels generally emit fewer pollutants than similar vehicles which run using gasoline or diesel. Other projects provide funding to construct facilities to service, fuel, or provide maintenance for the vehicles in order to encourage their continued use. Alternative fuel vehicle projects provide States and MPOs the opportunity to use high-profile fleets, such as public transit and school districts, to increase public awareness and approval of alternative fuels. This may lead to interest in other fleet operators in switching to alternative fuels.

To encourage alternative fuel vehicle projects to be undertaken in partnership with the private sector, the Transportation Equity Act for the 21st Century contained special provisions for alternative fuel projects that are part of a public-private partnership. For purchase of privately owned vehicles or fleets using alternative fuels, CMAQ funds may be used for only the incremental cost of an alternative fuel vehicle compared to a conventionally-fueled vehicle. Furthermore, if other Federal funds are used for vehicle purchase, such funds should be applied to the incremental cost before CMAQ funds are applied.[27]

Congestion / Mobility Benefits

These strategies are unlikely to reduce congestion since they are not changing transit service in a manner that would be expected to affect ridership. However, bus replacements may increase transit ridership to a small degree by improving the ease and comfort of transit or improving the reliability of service. These effects are very difficult to determine, and none of the sponsors of the selected projects estimated this effect.

Emissions Benefits

Emissions reductions estimates associated with the replacement of transit vehicles are attributable solely to the lower emissions rates of the new vehicles, not to any effects on transit ridership and diversion of trips from private vehicles. An important consideration with these types of projects is the service life of urban transit buses, which is generally at least 12 years. According to FTA regulation, Federal funds cannot be used to replace vehicles before the end of their useful service life.[28] However, according to EPA guidance for taking credit for emissions reductions, credit can only be taken for the remaining years of service of the older vehicle, not the entire service life of the new vehicle.[29] Consequently, transit vehicle replacement projects will have an immediate emissions benefit when the older vehicle is replaced; however, they likely only have a few years of emissions benefits, over the period of time when the vehicle has reached the end of its service life but might still be continuing in service. The emissions benefits calculations presented in the selected examples only reflect the first year of benefit, and probably should only be assumed for a maximum of a few additional years.

Emissions reductions reported by project sponsors for this set of projects generally indicate the largest emissions reductions from NOx. Daily VOC emissions reductions associated with each project range from 1.5 kg to 6.8 kg. Daily NOx emissions reductions associated with each project range from 2.1 kg to 91.0 kg. CO reductions reported by sponsors indicate a range of benefits from 7.6 kg to 12.0 kg emissions reductions each day. Two project sponsors did not report any CO emissions benefits. $PM_{2.5}$ emissions reductions were reported by one project to be 1.4 kg each day.

Costs

The total public cost of these reviewed projects ranged in magnitude from $861,000 to $7,010,000. The non-CMAQ share of project funding was 20 percent of total project cost for most of the analyzed projects. A natural gas fueling station for public and private fleets operating in the Greater Portland area, Maine, received most of its funding from sources other than CMAQ.

Conventional Bus Replacements

Conventional bus replacement projects replace older diesel buses with new diesel vehicles that emit fewer pollutants. Two bus replacement projects were reviewed in this analysis.

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	$PM_{2.5}$ (kg/day
Maryland	$5,000,000	$26,500,000	100 Replacement Local Buses	2002	-17.0	NR	-188.9	NR	NR
Ohio	$4,864,440	$6,949,200	61 Replacement Local Buses	2003	-9.6	-35.5	-11.6	NR	NR

NR Values were not reported by the local project sponsor or State DOT in the CMAQ database or other materials for the project.

The projects included in this category take advantage of improvements in heavy duty diesel technology. Diesel engines today are cleaner and emit fewer pollutants than similar engines more than 10 years ago, so in principle, retiring the older, more-polluting buses will reduce emissions. The new, less polluting vehicles run along existing routes and do not change overall vehicle mileage or service levels, so have no claimed effect on transit ridership. Conventional bus replacement projects have historically comprised a large share of CMAQ funding requests; however, in recent years States and MPOs have opted to replace aging bus fleets with CNG or other alternative fueled vehicles whose emissions rates are even lower than current generation diesel buses.[30] These projects were captured in the Alternative Fuel Vehicles/Fueling Facilities project category.

Congestion / Mobility Benefits

These strategies are unlikely to have congestion or mobility benefits since they are not changing transit service in a manner that would be expected to affect ridership. However, conventional bus replacements may increase transit ridership to a small degree by improving the ease and comfort of transit or improving the reliability of service. These effects are very difficult to determine, and neither of the sponsors of the selected projects estimated this effect.

Emissions Benefits

The emissions benefits from these strategies would be subject to the same caveats applied to alternative fuel vehicle projects. Specifically, if replacement buses are purchased for the purpose of replacing buses that have remaining service life, the emissions credit can only extend to the period of remaining service life of the vehicle being replaced, and with the presumption that the older vehicle will not still be operated.

With these caveats in mind, emissions reported by the sponsors of the example projects indicated daily VOC emissions reductions from 9.6 kg to 17.0 kg. Daily NOx emissions reductions associated with the projects ranged from 11.5 kg to 188.9 kg. CO reductions reported by one project indicated a benefit of 35.5 kg emissions reductions each day.

Costs

CMAQ funding is provided for the capital investment in the new transit vehicles. The total public cost of these projects ranged in magnitude from $6,949,200 to $26,500,000. However, given the expense of bus purchases, CMAQ funds are often used only to supplement FTA funding and are a small share of the overall funding. In the case of the Maryland bus replacement project, more than 80 percent of funding came from sources other than CMAQ.

Dust Mitigation Projects

Road dust reduction strategies are designed to reduce the amount of fugitive dust (PM_{10} and $PM_{2.5}$) that is suspended into the air by tires on roadways. Three CMAQ-funded dust mitigation projects were reviewed in this analysis.

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	$PM_{2.5}$ (kg/day)
California	$174,360	$197,360	Graaf Avenue Paving Project	2004	NR	NR	NR	-143.0	NR
Idaho	$319,600	$319,600	Lincoln Ave	2004	NR	NR	NR	-175.5	NR

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	$PM_{2.5}$ (kg/day)
Idaho	$152,889	$165,000	Paving Project Purchase of a Liquid De-Icer Truck	2005	NR	NR	NR	-6,292.0	NR

NR Values were not reported by the local project sponsor or State DOT in the CMAQ database or other materials for the project.

Particles suspended by vehicular movement on paved and unpaved roads are a major contributor to fugitive dust emissions. The origins of this particulate matter differ from the particulate matter that is emitted from vehicles' tailpipes. Exhaust particulate emissions are created from engine combustion while dust mitigation projects control particulate matter originating from the roadway. When vehicles travel along roads, the force of the wheels on the road surface causes the pulverization of surface material. The particles are lifted and dropped from the rolling wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The air disturbance behind the vehicle continues to act on the road surface after the vehicle has passed.[31]

Typical dust mitigation projects include paving shoulders, curbs and gutters, roads, and access points. When paving is not feasible, such as for industrial roads with heavy vehicles and/or spillage of material in transport, watering or chemical suppressants may be used. Other CMAQ projects to address the amount of particulate matter released into the air include adding street sweepers, replacing non-certified sweepers with newer vehicles, using new vehicles to increase the frequency of sweeping in existing areas, or using new vehicles to expand the area that is regularly swept. Regular street sweeping on paved roads removes sand and/or other de-icing materials, and other deposition of dirt on roads, reducing the level of road dust.

Congestion/Mobility Benefits

These strategies will have limited, indirect impact on congestion levels, though some benefits may be observed through speed improvements on previously unpaved or icy roads. Since dust mitigation projects are not intended to improve congestion, the sponsors for projects selected for this study did not assess travel impacts.

Emissions Benefits

The quantity of dust emissions from a given segment of road depends on various factors such as whether it is paved or unpaved, precipitation levels, and traffic volumes. Emissions reductions reported by project sponsors at the local level indicated a range of daily PM_{10} emissions reductions from 143.0 to 6,292.2 kg.

Costs

CMAQ funding is usually provided for capital improvements, such as the paving of a road shoulder or purchase of a new street sweeper. The total public cost of the selected projects ranged in magnitude from $165,000 to $319,600. The non-CMAQ share of funding ranged from 0 percent to 11 percent of the total cost.

Freight / Intermodal Projects

An intermodal system includes both origins and destinations (for example, ports railheads and warehouses), as well as the links between them (such as roads or rail).[32] Strategies that reduce emissions from the movement of freight and cargo through air quality nonattainment areas are grouped together in the category of freight/intermodal projects. Six CMAQ-funded freight/intermodal projects were reviewed in this analysis.

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	PM (k
Maine	$283,941	$355,180	South Portland Truck to Rail Intermodal Facility	2000	-0.7	NR	-4.2	NR	NR
Maine	$128,501	$494,098	South Portland Rail Line Rehab for Freight Shipping	2002	-0.2	NR	-2.0	NR	NR
Pennsylvania	$7,600,000	$9,500,000	Westmoreland Intermodal Freight Facility	2002-2003	NR	-1.9	-13.3	NR	NR
New York	$1,700,000	$9,000,000	Arlington Intermodal Yard	2004	-209.0	-1,712.2	-1,008.8	-37.0	-3
Pennsylvania	$10,000,000	$12,500,000	Norfolk Southern Rail Extension and Rehabilitation	2004	-11.5	-64.7	-53.5	NR	NR
Connecticut	$1,409,600	$1,762,000	Freight Rail Construction along Waterfront Street.	2006	-0.5	NR	-18.4	NR	-0.

NR Values were not reported by the local project sponsor or State DOT in the CMAQ database or other materials for the project.

Emissions from heavy-duty trucks and large-scale freight facilities can contribute significantly to the overall air pollution in urban areas. Projects that shift movement to a more efficient mode of transport or improve the efficiency of freight transfers between modes will reduce emissions. Some strategies will shift trips from road to rail, reducing emissions and congestion caused by heavy duty vehicles. Other intermodal projects improve the efficiency of transfers between water-borne, truck, and/or rail vehicles. By reducing the amount of time vehicles are required to wait at these transfer stations, idling emissions will be reduced.

Congestion / Mobility Benefits

Reducing the movement of freight by heavy-duty trucks through urban areas can result in congestion relief benefits. Each of the sample projects was designed to reduce truck vehicle travel by shifting freight movement to rail. For instance:

- The sponsors of the Maine projects estimated reductions of up to 2,250 trucks per year by 2006 due to construction of two projects: rail siding as part of an intermodal transfer and rehabilitation and/or replacement of tracks.
- The Westmoreland Intermodal Freight Facility, a project to reduce the amount of freight cargo traveling through downtown Pittsburgh, was estimated to reduce 14 miles of travel for 20,000 truck loads.
- In New York, capacity improvements to a rail yard were expected to increase rail efficiencies and reduce the movement of freight shipments by truck though the metropolitan New York area. The project sponsors estimated that 10,268 truck trips per day would reduce 6 miles of travel for one segment (Visy Paper Mill Bayonne Bridge and Transfer Station), and 15,786 truck trips per day would reduce 5 miles for the other segment.
- The Norfolk Southern rail extension and rehabilitation project in Pennsylvania was designed to fund the construction of 5.25 miles and rehabilitation of 7 miles of train track in Indiana County to create a more direct route for delivery of coal. The sponsors estimated the project would reduce 43,478 truck trips per year.
- In Connecticut, the installation of additional railroad track and the associated utility relocations was expected to reduce congestion by shifting an estimated 4,000 truck shipments per year to rail.

The effects on roadway congestion and speeds, however, were not quantified in the analyses provided to the study team.

Emissions Benefits

Emissions reduction estimates reported by project sponsors vary, depending on the modes of transportation affected by the project and the amount of freight that is moved. The Arlington Intermodal Yard in New York, in particular, reported very large emissions reductions, based on assumptions of significant diversions of truck traffic to rail. Most of the calculations do not account for increased railroad diesel emissions, or any congestion or idling associated with transfers between truck and rail.

Costs

Funding under CMAQ has been used to improve efficiency of truck, rail and marine operations, as well as intermodal freight facilities where air quality benefits can be shown. Capital improvements that increase the efficiency of freight movement between truck and rail, for example, as well as up to three years operating assistance for these types of projects, are appropriate for CMAQ funding if emissions reduction can be demonstrated.[33] The total public cost of these projects ranged from $355,180 to $12,500,000. The non-CMAQ share of project funding ranged from 20 percent to 81 percent of the total project cost.

Diesel Emissions Reduction

Diesel emissions reduction strategies are designed to reduce emissions from on-road and off-road diesel engines (e.g., those used in construction equipment, locomotives, marine vessels), and include use of retrofit technologies and idle reduction technologies.

Diesel Engine Retrofits

The term "retrofit" is broadly defined by EPA to include any technology, device, fuel or system that, when applied to an existing diesel vehicle or engine, achieves emissions reductions beyond that required by EPA regulations at the time of a vehicle or engine's certification. Retrofit technologies may include EPA verified emissions control technologies and fuels and CARB-verified emissions control technologies.[34] Seven CMAQ-funded diesel engine retrofit projects were reviewed in this analysis.

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	$PM_{2.5}$ (kg/d
Maryland	$5,458,000	$23,036,000	142 Bus Engine Upgrades	2001	NR	NR	NR	NR	-34.8
New York	$1,200,000	$1,500,000	WCDOT Diesel Engine Retrofit of 177 Transit Buses	2004	-3.0	-45.9	+14.6[1]	NR	-2.3[2]
Pennsylvania	$1,793,520	$2,242,520	Install 235 Emissions Reduction Devices on Local Buses	2004	-7.3	-111.2	0	NR	NR
Oregon	$49,692	$62,115	Install filters on 9 trash collection vehicles	2005	-1.4	-2.5	0	-0.3	NR
Michigan	$3,360,000	$4,200,000	3 Locomotive Diesel Engine Retrofits	2007	-10.0	NR	-132.1	NR	-3.7
New York	$424,000	$530,000	Diesel Engine Retrofits of	2007	-0.4	-1.7	0	-0.2	-0.1

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	$PM_{2.5}$ (kg/d
			53 County Vehicles						
New York	$1,368,000	$1,710,000	Rockland County retrofit of on-road diesel vehicles	2007	-140.3	-969.9	0	-138.4	-125.9

NR Values were not reported by the local project sponsor or State DOT in the CMAQ database or other materials for the project.
[1] Project sponsor calculated an increase in NOx emissions based on data from retrofits and existing emissions from tailpipe testing. The project sponsors noted that the increase in NOx emissions is highly unusual and it is widely accepted that these retrofits have no impact on NOx.
[2] Project sponsor did not report PM reductions in CMAQ database but included information on emissions rates in project backup information to enable calculation.

Diesel engine retrofits are typically aimed especially at reducing particulate matter from heavy-duty diesel engines, as well as other pollutants. Verified technologies purchased and installed through these projects included the Englehard DPX soot filter and bus engine overhauls. As with all CMAQ projects, retrofitted vehicles must operate predominantly within or in close proximity to nonattainment or maintenance areas.[35]

CMAQ-funded diesel retrofit projects include a wide range of measures to reduce diesel emissions by retrofitting vehicles/equipment with new or improved emissions control equipment, upgrading engines, replacing older engines with newer/cleaner engines, and using cleaner fuels. The selected projects included installation of retrofit devices on transit buses, trash collection vehicles, a range of county-owned vehicles, and locomotives.

Congestion/Mobility Benefits

Diesel engine retrofits are not designed to provide congestion benefits and do not affect travel.

Emissions Benefits

Project sponsors reported that daily VOC emissions reductions ranged from 0.4 kg to 140.3 kg. One project sponsor did not report any VOC emissions effects. Most of the selected projects were not expected to reduce NOx (i.e., particulate filters, such as the Englehard DPX soot filter, reduce emissions of PM, VOC, and CO, but not NOx), according to EPA's Diesel Retrofit Technology Verification.[36] However, the Michigan locomotive repowering project was estimated to reduce a substantial amount of NOx, due to lower fuel use and an 86 percent estimated reduction in ozone precursors. A reported increase in NOx emissions from a diesel engine retrofit project is highly unusual. The project sponsor for the New York project that reported noted that it is widely accepted that these retrofits have no impact on NOx; however, an increase was reported based on data from the retrofit manufacturers and emissions from tailpipe testing of the subject vehicles.

PM reductions of 0.1 to 138.4 kg/day were reported for the sample retrofit projects. In the case of the Pennsylvania bus retrofit project, no PM emissions reductions were reported; however, EPA reports a 60 percent reduction in PM emissions associated with the Englehard DPX soot filter. The CO reductions reported by sponsors indicate a range of benefits from 1.7 kg to 969.9 kg emissions reductions each day. Two projects did not report any CO emissions benefits.

Costs

CMAQ funding is usually provided for equipment such as new diesel engines, truck stop electrification infrastructure, or purchase of retrofit devices. Funding may also be provided to offset a portion of the cost of installation or operation of a regional retrofit program. The total public cost of these projects range in magnitude from $530,000 to $23,036,000, depending on the number of vehicles to be retrofitted and the type of device used. The non-CMAQ share of project funding ranged from 20 percent to 76 percent of the total project cost.

Truck Idle Reduction

Unnecessary idling often occurs when trucks wait for extended periods of time to load or unload materials or supplies, or when equipment is left on overnight when it is not being used. Idle reduction strategies eliminate this unnecessary idling by heavy duty vehicles which can save fuel, prolong engine life, and reduce emissions. There are several technologies available to address idling. Some of these technologies are mobile and attach onto the truck (mobile Auxiliary Power Units (APUs)), and provide air conditioning, heat, and electrical power to operate auxiliaries such as a microwave. Another technology involves electrifying truck parking spaces (stationary Truck Stop Electrification (TSE)) with or without modifying the truck. This involves power from the electrical grid providing energy to operate stationary equipment or on-board truck equipment to provide cab heating, cooling, and other needs.[37] Three truck idling reduction projects were reviewed in this analysis.

STATE	CMAQ FUNDING	TOTAL COST	PROJECT TITLE	YEAR Funded	VOC (kg/day)	CO (kg/day)	NOx (kg/day)	PM_{10} (kg/day)	$PM_{2.5}$ (kg/day)
Tennessee	$1,000,000	$1,000,000	100 Auxiliary Power Units	2003	-4.5	NR	-60.4	NR	NR
Kentucky	$500,000	$835,000	50 Auxiliary Power Units	2005	-6.7	-46.7	-110.2	NR	NR
Tennessee	$788,240	$985,300	59 Auxiliary Power Units	2006	NR	NR	-79.7	NR	2.2

NR Values were not reported by the local project sponsor or State DOT in the CMAQ database or other materials for the project.

For long haul trucks, the truck driver must have l0 hours off duty after driving 11 hours.[38] Surveys have found that 70 to 80 percent of truck drivers say the need for heating or air conditioning is the main reason they idle their trucks while off duty. They also cite the need to operate on-board electrical appliances, such as a television or refrigerator, and to ensure the engine block, fuel, and oil remain warm. Long duration truck idling occurs at truck stops, travel centers, distribution hubs, airports, borders, ports, and roadsides.[39]

Congestion / Mobility Benefits

Truck stop idle reduction projects are not designed to provide congestion benefits and do not affect travel.

Emissions Benefits

Truck stop idle reduction projects are designed primarily to reduce NOx and PM emissions. While some project sponsors in the past estimated reductions in VOC and CO using MOBILE idle emissions factors, EPA's "Guidance for Quantifying and Using Long Duration Truck Idling Emission Reductions in State Implementation Plans and Transportation Conformity" (January 2004) provides long-duration idling emissions factors only for NOx and PM. At the time the emissions calculations were conducted for the 2003 Tennessee project and the 2005 Kentucky project, this guidance had not yet been available or used.

The three projects reported NOx emissions reductions estimates of 60.4 to 110.2 kg/day.[40] Only the 2006 Tennessee projects have estimated $PM_{2.5}$ emissions reductions of 2.2 kg/day. Using long-duration truck idling emissions factors currently available from EPA, the 2003 Tennessee and 2005 Kentucky projects would have had PM emissions reductions of 3.7 kg/day and 1.8 kg/day, respectively.

Costs

CMAQ funding is usually provided for truck stop electrification infrastructure and equipment. The total public cost of these projects ranged in magnitude from $835,000 to $1,000,000.

1. [22] Calculated based on the emissions factor (in grams per mile) at 2.5 miles per hour, the slowest speed in MOBILE6, multiplied by 2.5 miles per hour, to generate an idle emissions factor in grams per hour.
2. [23] Hours of delay was not reported directly by the project sponsors, but was calculated by the study team based on information provided in the project sponsor's emissions analysis.
3. [24] FHWA. 2003. Freeway Management and Operations Handbook. http://ops.fhwa.dot.gov/freewaymgmt/publications/frwy_mgmt_handbook/toc.htm.
4. [25] FHWA. "Frequently Asked HOV Questions" http://ops.fhwa.dot.gov/freewaymgmt/faq.cfm#faq7.
5. [26] FHWA "Guidance on the Congestion Mitigation and Air Quality Improvement (CMAQ) Program Under the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users." Page 11.

6. [27] See Federal Highway Administration Guidance. *CMAQ and Alternative Fuel Vehicle Projects*. (2005) http://www.fhwa.dot.gov/environment/air_quality/cmaq/reference/alternative_fuel/index.cfm.
7. [28] See 49 USC 5309.
8. [29] This approach is consistent with EPA guidance on diesel engine retrofits ("Diesel Retrofits: Quantifying and Using Their Benefits in SIPs and Conformity - Guidance for State and Local Air and Transportation Agencies", June 2006) and on early retirement of vehicles ("Guidance for the Implementation of Accelerated Retirement of Vehicles Programs", February 1993).
9. [30] Transportation Research Board. *Special Report 264: The CMAQ Program: Assessing 10 Years of Experience*. 2002.
10. [31] See U.S. EPA. AP 42, *Fifth Edition*, Volume I, Chapter 13: Miscellaneous Sources. Unpaved Roads. http://www.epa.gov/ttn/chief/ap42/ch13/index.html#13.2.1.
11. [32] See Federal Highway Administration Guidance. *CMAQ and Intermodal Freight Transportation*. (2005) http://www.fhwa.dot.gov/environment/air_quality/cmaq/reference/intermodal_freight_transportation
12. [33] 23 USC 149(b)(1), (3). See FHWA Factsheet. "CMAQ and Intermodal Freight Transportation" Available at: http://www.fhwa.dot.gov/environment/air_quality/cmaq/reference/intermodal_freight_transportation
13. [34] A list of the EPA verified technologies can be accessed at: http://www.epa.gov/otaq/retrofit/verif-list.htm.
14. [35] 23 USC 149(b)-(c). See FHWA, 2003. "Eligibility of Freight Projects and Diesel Engine Retrofit Programs" Memorandum. http://www.fhwa.dot.gov/environment/air_quality/cmaq/policy_and_guidance/freightdiesel.cfm.
15. [36] For a listing of verified retrofit technologies and their emissions reductions, see: http://www.epa.gov/otaq/retrofit/verif-list.htm.
16. [37] See Federal Highway Administration Guidance. *CMAQ and Idle Reduction Technologies*. (2005) http://www.fhwa.dot.gov/environment/air_quality/reference/idle_reduction/index.cfm.
17. [38] See 49 CFR, Part 395. For additional information: http://www.fmcsa.dot.gov/rules-regulations/administration/fmcsr/fmcsrguidedetails.aspx?reg=r49CFR395.
18. [39] See Federal Highway Administration Guidance. *CMAQ and Idle Reduction Technologies*. (2005).
19. [40] The 2003 Tennessee project had an estimated 60.4 kg/day in NOx based on MOBILE emissions factors; using long-duration idle emissions factors available from the EPA guidance, released in 2004, the project would reduce 135.0 kg/day.