Development of Cost-Effectiveness Estimates for Mobile Source Emission Control Measures: The CMAQ Program under MAP-21

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Extended Abstract

Background

The Moving Ahead for Progress in the 21st Century Act (MAP-21) continues and expands the project selection focus on efficiency and cost-effectiveness established under the Safe, Accountable, Flexible, Efficient Transportation Act – A Legacy for Users (SAFETEA-LU). The MAP-21 also calls for the development of cost-effectiveness tables (Tables) for a range of eligible project types under the Congestion Mitigation and Air Quality (CMAQ) Program. The Tables are intended to assist States, MPOs and other project sponsors as they make the most efficient use of their CMAQ dollars in reducing on-road vehicle emissions and traffic congestion.

This paper provides information regarding the development of estimates of cost-effectiveness for a range of representative project types previously funded under the CMAQ Program, for concurrence with the MAP-21. The range of cost-effectiveness estimates includes separate analyses of the criteria pollutants and applicable precursors controlled through the CMAQ program (listed in order of appearance in the summary Tables): fine particulate matter (PM$_{2.5}$), nitrogen oxides (NOx), volatile organic compounds (VOCs), carbon monoxide (CO), and particulate matter (PM$_{10}$).

Cost-effectiveness is defined in the Tables as the cost per short ton of pollutant reduced. This specification enables a simple scaled value that can be compared both within project type (and across project size), and across pollutants (and either within or across project types). Previous studies have focused on a smaller subset of pollutants (chiefly VOCs and NOx), and also tended to combine estimated emission impacts of projects into a composite measure (e.g., tons of VOC equivalents). The analysis presented in this paper focuses on individual estimates of cost-effectiveness by pollutant, to avoid combining impacts on multiple pollutants within a given project type. For example, a composite measure of cost-effectiveness for a project that has strong impacts on VOCs but minimal impacts on PM$_{2.5}$ may indicate high cost-effectiveness in reducing pollutants overall, despite being weakly cost-effective in reducing PM$_{2.5}$. Rather than generating a composite measure, the analysis involved the generation of separate estimates, which would yield distinct estimates for VOCs (indicating high cost-effectiveness for VOC reductions in this example) and PM$_{2.5}$ (indicating low cost-effectiveness for PM$_{2.5}$ reductions in this example).

Full project costs are specified within the calculation of cost-effectiveness, rather than the subset of project costs covered by CMAQ funds within the projects analyzed. This approach was selected to generate a meaningful comparison of cost-effectiveness across project types, independent of the particular
funding opportunities and constraints present in any given setting. The results are presented in descending order of cost-effectiveness (i.e., in increasing order of dollars per ton of pollutant reduced).

The values in the tables center on the median estimates for each project type within the analysis. The primary advantages of using the median rather than the mean or best-case scenarios are that: (1) the median is not distorted by poorly-performing outliers; (2) the median offers an intuitive marker of a cost with equally as many high-cost effective as low-cost effective values for the same project type; (3) the median (among reasonable project proposals) is likely to be more representative within project types than an absolute best-case scenario; and (4) the median (among reasonable project proposals) is likely to be more comparable across project types than an absolute best-case scenario.

For comparison purposes, best-case (i.e., lowest cost per ton reduced) estimates are also presented for each project type. These estimates present insight into the range of outcomes that could be achieved for each project type, but are not likely to be representative of general cost-effectiveness.

Topics addressed in the development of these Tables include: key limitations of the cost–effectiveness analysis process; utilization of EPA’s MOVES2010b (Motor Vehicle Emission Simulator 2010, Version B) model in determining emissions rates by criteria pollutant; and the selection of specific project types for analysis. The results of the cost-effectiveness analysis of CMAQ projects are displayed in bar charts by pollutant type in increasing order of median cost-effectiveness. An aggregate table of summary findings displays a color-coded display for all pollutants and all project types. The Tables are supplemented with detailed information about the analyses conducted in the study that yielded the findings summarized within the Tables. The discussion also includes a review of estimated congestion impacts for project types with identifiable reductions on vehicle delay.
Project Types in the Study

The November 2013 CMAQ Interim Program Guidance identifies the eligibility of 17 types of projects under the MAP-21. Following consultation with stakeholders and a review of relevant content in MAP-21, the range of project types represented in the summary of CMAQ funding was supplemented with additional project types in the analysis, including:

- Traffic flow improvements (intersection improvements, roundabouts)
- Incident management
- Shared vehicle (ridesharing, carsharing, bikesharing)
- Transit (park and ride, employee transit benefits, transit service expansion, transit amenity improvements)
- Alternative fuel technologies (electric vehicle charging stations, natural gas re-fueling infrastructure)
- Heavy vehicle diesel technologies (diesel retrofits, truck stop electrification, intermodal freight facilities, diesel engine replacements)
- Pedestrian and bicycle infrastructure
- Extreme-temperature cold-start technologies
- Dust Mitigation

The selection of project types in the analysis was conducted following a review of CMAQ funded projects and consultation with USDOT, EPA and state-level stakeholders. A summary of CMAQ funded projects is useful in gaining an understanding of the prevalence of various project types. According to the CMAQ Public Access System, in 2013 (the most recent fiscal year for which data was available at the time of the analysis), 2023 projects received CMAQ funding; additional funding was applied to joint Surface Transportation Program (STP) and CMAQ projects with different eligibility criteria (around 14 percent of the total).

In terms of shares of overall CMAQ obligations in FY2013, traffic flow improvements and transit projects received the largest, and approximately equal, shares, at 36 percent and 33 percent, respectively. The remaining project types received similar shares of total CMAQ funding, including around four percent for traffic control measures and travel demand management projects, about five percent for shared ride projects, and about seven percent for pedestrian and bicycle projects.
Summary Findings

Figure 1 below offers a comparison of the median cost-effectiveness estimates for each project type and pollutant in the analysis:

![Figure 1. Median Cost-Effectiveness Estimates (Dollars per Ton of Pollutant Reduced).](image)

The analysis yielded a broad range of cost-effectiveness estimates, represented in terms of dollars per ton of pollutant reduced. The most critical findings relate to project types that indicate particularly strong or weak cost-effectiveness, for either individual pollutants or across the range of pollutants.

Table 1 summarizes the best-performing project types by pollutant, based upon the distributions of cost-effectiveness measures evaluated at the median:

<table>
<thead>
<tr>
<th>Project Type</th>
<th>Pollutants with Most Cost-Effective Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck Stop Electrification</td>
<td>All pollutants</td>
</tr>
<tr>
<td>Heavy-Duty Vehicle Engine Replacements</td>
<td>NOx, VOCs, PM$<em>{10}$, PM$</em>{2.5}$</td>
</tr>
<tr>
<td>Diesel Retrofits (DOCs, DPFs)</td>
<td>CO, PM$<em>{10}$, PM$</em>{2.5}$, and VOCs</td>
</tr>
<tr>
<td>Transit Service Expansion</td>
<td>NOx, VOCs, CO</td>
</tr>
<tr>
<td>Park and Ride</td>
<td>NOx, VOCs, CO</td>
</tr>
<tr>
<td>Extreme-Temperature Cold Start</td>
<td>CO and VOCs</td>
</tr>
<tr>
<td>Incident Management</td>
<td>CO and VOCs</td>
</tr>
<tr>
<td>Intermodal Freight</td>
<td>NOx</td>
</tr>
<tr>
<td>Dust Mitigation</td>
<td>PM$_{10}$</td>
</tr>
</tbody>
</table>
The analysis indicates that idle reduction projects can be as cost-effective as diesel retrofits for CO, PM$_{2.5}$ and PM$_{10}$ emission reduction. Idle reduction also demonstrates strong cost-effectiveness for reducing NOx and VOC emissions.

Diesel retrofits demonstrate strong cost-effectiveness for CO, VOCs, PM$_{2.5}$ and PM$_{10}$. Heavy-duty vehicle diesel engine replacements demonstrate strong cost-effectiveness for all pollutants in the study with the exception of CO, which indicated moderate cost-effectiveness.

Transit service expansion and park and ride projects appear to provide strong cost-effectiveness in reducing CO, NOx and VOC emissions. In addition, transit service expansion demonstrates moderate cost-effectiveness with respect to PM$_{2.5}$ and PM$_{10}$.

Extreme-temperature cold start technologies are limited in applicability (i.e., to areas with unusually cold winter weather), but reveal strong cost-effectiveness with respect to CO and VOCs. Furthermore, these projects appear competitive with respect to cost-effective mitigation of NOx, PM$_{2.5}$ and PM$_{10}$.

Intermodal freight projects revealed strong cost-effectiveness with respect to NOx. Dust mitigation projects were clearly the most cost-effective alternative for reducing PM$_{10}$, which is the only pollutant that these projects are expected to affect. This relationship held for both street sweeping and dirt road paving projects, the two types of dust mitigation projects evaluated in the analysis.

Conversely, several project types demonstrated overall weak cost-effectiveness across the pollutants in the study. These project types include:

- Roundabouts,
- Bikesharing,
- Electric vehicle charging infrastructure, and
- Subsidized transit fares.

Roundabouts did not demonstrate strong cost-effectiveness for any of the pollutants in the study. Consequently, roundabouts generally perform less effectively than other intersection improvements.

Bikesharing did not demonstrate strong cost-effectiveness for any pollutant in the study. This was driven chiefly by a relatively small impact on VMT compared to the costs of implementing bikesharing projects. That is, while bikesharing projects are capable of leading to mode shift from light-duty vehicle to bicycle, the types of trips likely to be influenced involve relatively short distances or low frequencies of use.

Electric vehicle charging infrastructure tended to be one of the least cost-effective project types in the study for all pollutants in the study. It is worth noting that this should change if electric vehicle use increases in future years.

Subsidized transit fares are also among the least cost-effective projects. This result is limited by the available estimates of marginal operating costs per passenger mile to assign to these projects; transit services with the capability of assigning low marginal costs to passengers receiving subsidized fares (e.g., services with high demand) may be able to achieve stronger cost-effectiveness in emission reduction associated with light-duty vehicle travel.