

Learning from Experiments: An Evaluation Plan for CMAQ Projects

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Abstract

The Congestion Mitigation/Air Quality Program (CMAQ), established in 1991 by the Intermodal Surface Transportation Efficiency Act (ISTEA) to provide about \$1 billion per year to fund transportation projects that improve air quality, is intended both to support traditional transportation control measures and to encourage innovation in developing new strategies and technologies for controlling emissions from transportation sources. While the program has indeed encouraged some innovative approaches to local transportation and air quality problems, critics see it as a diversion of funds that could more usefully be devoted to conventional highway improvement projects. The current debate in Congress over the reauthorization of ISTEA and, specifically, the CMAQ provisions, is hampered by the lack of detailed information about the achievements of previous CMAQ projects and a plan for evaluating future projects.

Resolution of this debate could be aided by emphasizing the role of CMAQ projects as natural experiments and developing a plan to conduct them. The purpose of this paper is to outline a strategy of analysis and data collection that will facilitate evaluation of CMAQ projects. This paper argues that the lack of emphasis (in all but the largest projects) on project evaluation can be explained by the public goods nature of information. Because local implementing agencies bear the costs of evaluation, while the benefits are enjoyed primarily by other jurisdictions in planning their transportation and environment projects, too little evaluation is conducted. At present, much of the potential usefulness of CMAQ projects to planners is dissipated because there is little systematic learning. Indeed, a project could succeed as an experiment if learning took place, even if it failed to improve air quality.

This paper examines the kinds of data collected now in CMAQ programs in comparison with the kinds of data that would permit more effective program evaluation, particularly *ex post* evaluation, i.e., analysis of what actually resulted from the implementation of the individual project. In many cases, data-gathering should concentrate on observable outcomes that can clearly be attributed to the project and yet bear some relationship to air quality or congestion, either established by previous empirical study or by model results. A method is proposed for collecting the requisite data for each of several important types of CMAQ projects. To assure that the data are collected and evaluated will also require changes in the way in which CMAQ is administered, including the dedication of some portion of CMAQ funds for evaluating completed projects. The biggest change may be the need to develop measures of "success" and identify "control cases" against which to judge the success of the experiment.

Key Words: project evaluation, transportation and environment

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Table of Contents

Acknowledgments	iii
Introduction	1
Overview of CMAQ	3
Types of CMAQ Projects	5
How Projects Are Evaluated	6
<i>Ex ante</i> Analysis	6
<i>Ex post</i> Analysis	8
Elements of an evaluation protocol	9
Example Evaluations	12
Ride Instead of Drive, It's Easy (RIDE) — Nashville, TN Ride Share	12
Red Hook Barge — New York, NY — Transportation Demand Management	13
Freeway Service Patrol — San Francisco, CA — Traffic Flow	13
US1 Busway — Dade County Florida — HOV / Transit	14
Walkway to Gateway — Cleveland, OH — Pedestrian / Bicycle	15
Employee Trip Reduction — Maricopa County, AZ — TDM	15
Encouraging Project Evaluations	16
Conclusions and Policy Considerations	17
Appendix: Discussion of Six CMAQ Project Evaluations	20

List of Tables and Figures

Table 1. CMAQ Project Types by Percent of Total Funds Obligated in FY95	5
Table 2. FY 1995 Summary of Projects Funded	6
Table 3. CMAQ Evaluations Analyzed	12
Table 4. Freeway Service Patrol Effectiveness Summary	14
Figure 1. Headings of Tables Summarizing Effects of Project Options: US1 Busway	25

LEARNING FROM EXPERIMENTS: AN EVALUATION PLAN FOR CMAQ PROJECTS

Deirdre Farrell, Winston Harrington, and Alan J. Krupnick¹

INTRODUCTION

The Congestion Mitigation/Air Quality Program (CMAQ) was established in 1991 by the Intermodal Surface Transportation Efficiency Act (ISTEA) to provide funding to transportation projects that improve air quality. CMAQ is intended both to support traditional transportation control measures and to provide a flexible source of funding that encourages innovation in developing new strategies and technologies for controlling emissions from transportation sources. Since 1992 CMAQ has had an authorized spending level of approximately \$1.0 billion each year, although actual outlays fell short of that figure. In the Administration's reauthorization package currently before Congress, CMAQ is retained as a set aside program and its authorized funding level is expanded by 30 percent to \$1.3 billion per year until 2003.

Our review of selected CMAQ projects suggests that the program has indeed encouraged some innovative approaches to local transportation and air quality problems, thus earning the support it now enjoys from environmentalists and supporters of alternative transportation systems. However, CMAQ also has critics, who see the program as a diversion of funds that could more usefully be devoted to conventional highway improvement projects. The debate is hampered by the lack of detailed information about what individually funded CMAQ projects have actually achieved in terms of emission reductions and what might potentially be achieved in the future.²

This paper argues that much more systematic project evaluation is needed if the promise of CMAQ is to be realized. More specifically, Congress and transportation/air quality agencies should take more seriously the opportunity that CMAQ provides for conducting natural experiments. Viewing these projects as natural experiments would require some changes in the approach to project selection and funding, including the dedication of some portion of CMAQ funds to the purpose of evaluation of completed projects. But the biggest change may be the need to develop measures of "success" and identify "control cases" against which to judge the success of the experiment. While some analysis of this sort is done now, it appears frequently to be inadequate and in any case limited to a few of the biggest projects.

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² See K. Adler, M. Grant, and W. Schroerer. 1998. "The Emissions Reduction Potential of the CMAQ Program: A Preliminary Assessment," paper presented at the 77th Annual Meeting of the Transportation Research Board, January 11-15, Washington, D.C. They find that CMAQ is "playing a significant role in U.S. emissions reductions. . . ." (p. 6).

The principal cause of these inadequacies appears to be the fact that analysis from which supportable generalizations can be made can be expensive, and the fact that the agencies doing project evaluation (usually the agency in charge of the project) are often not the same as those who would benefit from it. The main beneficiaries, of course, are those who have something to learn and something to gain from better information: other state and local transportation agencies planning similar projects. At present, much of the potential usefulness of CMAQ projects to planners is dissipated because there is little systematic learning.

Better evaluation would not only lead to improvements in transportation project selection, but could lead to better information about the value of CMAQ itself. Assuming that the CMAQ program remains in the current bill, the issue of its usefulness will arise in several years when CMAQ next comes up for Congressional reauthorization. Unless some action is taken now, however, Congress will again find itself asked to continue funding a program for which data on program effectiveness is sparse. The purpose of this paper is to outline a strategy of analysis and data collection that will facilitate evaluation of the CMAQ program.

Below is an examination of the kinds of data collected now in CMAQ programs in comparison with the kinds of data that would permit more effective program evaluation. Fundamental to this analysis is a distinction between *ex ante* and *ex post* analysis. *Ex ante* analysis is completed before the project is started and in fact is used to help decide whether to proceed with the project. Necessarily it is based on projected rather than actual outcomes and relies heavily on models and argument by analogy to other projects. In contrast, *ex post* analysis can only be completed after the project itself is completed via monitoring of effects, and is concerned with what actually resulted from the implementation of the individual project.

Ex ante analyses are required now for most categories of CMAQ projects, however guidance on how to perform the analysis is provided locally, and varies by state and even by Metropolitan Planning Organization (MPO). The *ex ante* analysis is, of course, important to local decision-makers, but for project evaluation what is needed are data describing actual project effects. That has implications not only for when data are collected (it must be collected after the fact, obviously), but what data are collected, and how. For example, it is probably fruitless to attempt to measure changes in ambient air quality resulting from many CMAQ projects, since these projects may be too small to separate signal from noise. In these cases, the data-gathering should concentrate on observable outcomes that can clearly be attributed to the project and yet bear some relationship to air quality or congestion, either established by previous empirical study or by model results. *Ex post* analysis does not allow one to avoid using models and projections, but it puts them on a firmer footing based on empirical data. Most projects receive this type of analysis only in the context of a conformity demonstration.

A method is proposed for collecting the requisite data for each of several important types of CMAQ projects. To assure that the data are collected will also require changes in the way in which CMAQ is administered; these changes are outlined as well.

OVERVIEW OF CMAQ

Evaluation of CMAQ must take into account several particular features of the program.

Criteria for funding decisions. CMAQ funding allocations are made on the basis of an area's ozone, carbon monoxide, or PM10 nonattainment status, according to a statute-based formula. CMAQ projects must be part of a conforming transportation plan and transportation improvement program (TIP), and must comply with the relevant conformity provisions of the Clean Air Act. Additionally, detailed eligibility requirements are listed in ISTEA, and in subsequently issued Federal Register notices. States without nonattainment areas are allocated 0.5 percent of total CMAQ funding, with higher allocations provided for states with nonattainment areas. Importantly, project selection occurs at that state, local, or MPO level. No federal guidance is provided on how to select among proposed projects that meet the eligibility requirements if there is competition for limited funds, on ensuring uniformity of project evaluation criteria, or in other activities that might alter the funding formula based on project quality.

At the state level, allocations to MPOs are made in a variety of ways. Some states simply apply the federal apportionment formula to the nonattainment areas in the state. Others allocate only some of the money to MPOs, reserving the rest for particular state projects. MPOs likewise allocate funds in a variety of ways. A few hold formal grant competitions. In most cases, MPOs distribute guidance to eligible agencies describing the CMAQ program and the requirements for CMAQ eligibility, and solicit project proposals. Most projects compete against a very limited set of alternatives, and therefore tend to receive relatively little *ex ante* scrutiny. In this environment *ex post* evaluation is all the more important.³

Diversity of project types. The range of projects for which CMAQ funds have been used is quite diverse and affects air quality in a wide variety of ways, including improving traffic flow (traffic signalization projects and emergency response projects), increasing vehicle occupancy (vanpool and other employee trip reduction programs), and encouraging use of bicycles and transit. The diversity of projects makes it difficult to develop a general evaluation method applicable to all projects.

³ The extent to which states choose to exercise their authority over funding allocation raises an interesting question. Take for example the case of Virginia and Maryland, two neighboring states with highly divergent funding policies. In Maryland, CMAQ funds are lumped with all other transportation-related funding in a general account from which all projects, including CMAQ-eligible projects, are funded. The overall picture in Maryland is of a state with a centralized transportation planning process that uses CMAQ funding to support projects, which, albeit CMAQ-eligible, might well have been included in the transportation budget had CMAQ funding not been available. The situation in Virginia is quite different. There, CMAQ funds are devolved to local transportation planning officials where they are typically used to support smaller projects which might not have received funding at all had it not been for funds made available through CMAQ. The picture here is of a state with a highly decentralized transportation planning process in which the funds provided through CMAQ to local transportation planners are used to fund projects that are local priorities. These different funding policies at the state level may influence the effectiveness of the projects selected in accomplishing the goals of the CMAQ program, and the performance of the transportation system as a whole.

Multiple objectives. The explicit goals of CMAQ include: (i) to contribute to meeting Clean Air Act requirements for reasonable further progress towards attaining National Ambient Air Quality Standards, and (ii) to reduce congestion. In addition, CMAQ plays an informal role in demonstrating and testing innovative new ideas for reducing emissions and congestion.

These goals are neither mutually exclusive nor fully overlapping. A project may be judged a success that has a large air quality benefit but only a small congestion benefit (relative to cost), or vice-versa. For some projects such as public education and outreach activities, measurement difficulties may make it impossible to discern air quality or even emission reduction benefits, rendering a strict benefit-cost or cost-effectiveness evaluation on environmental grounds impossible as well. As for the goal of testing new ideas, it is the knowledge that is gained from the project, i.e., the value of the information to future projects, that is of primary interest. In this vein, a project may be deemed a success even if it does very little to improve air quality or congestion, say because of its small scale, if it succeeds as an experiment, or by advancing the idea to a larger scale of implementation. Indeed, a project may fail to deliver any discernible benefits or even meet the most narrowly defined objectives, but be judged a success if it conveys information on policies that fail to achieve discernable benefits, or fail to do so at an acceptable cost. In this case, scarce project resources can be redirected where they have higher benefits or higher information value.

Multiple funding sources. For most CMAQ projects, the federal cost share can reach 80 percent (90 percent, if used on certain activities on the Interstate System). Signalization and carpooling and vanpooling can be funded at as much as 100 percent.⁴ Frequently CMAQ funds are used in on-going projects or programs to strengthen or extend their scope. For example, CMAQ funds have been used to assist in the development of state I/M programs in Rhode Island and Illinois. CMAQ funds are frequently used to enhance a project, such as adding tow trucks to a road accident patrol program. This co-mingling of funds suggests that sometimes it will be fruitless to examine the effectiveness of the CMAQ portion of the project. In other cases, and especially when the CMAQ project is an add-on to an existing project (CMAQ-funded or otherwise), the *ex ante* analysis will often be based on the interim results of the existing project; that is, on the *ex post* analysis of the preceding project. In either case, the focus of analysis should be on the effectiveness of the entire project, or of a component that has separable costs and effects.

Ancillary benefits. Although the primary focus of most CMAQ projects is to improve air quality and the secondary focus is to reduce congestion in urban areas, they also can promote a variety of other objectives that deserve attention in a project evaluation. For example, construction of bikeways or other alternative transportation facilities can make urban areas more pedestrian-friendly. Rapid-response emergency vehicles can reduce the time required for medical personnel as well as tow trucks to reach the scene of an accident, thereby improving survival probabilities of accident victims. Improvements in transit availability can improve access of handicapped and low-income people to employment

⁴ Federal Register: September 27, 1996 (Volume 61, Number 189), Notices, pp. 50890-50900.

opportunities. Projects with multiple outcomes are more difficult to evaluate and compare to other projects.

In particular, multiple outcome measures present problems for cost-effectiveness analysis because this technique is only with difficulty able to handle more than one physical effectiveness measure at a time. Therefore, if more than one measure of effectiveness is being affected, some weighting of the various physical effects is needed -- which is one justification for converting the physical effects into monetary measures of benefits, i.e., using the willingness-to-pay for reductions in various effects measures as weights. Then, the resulting analysis would be defined as a benefit-cost analysis.⁵ For example, the University of California, Berkeley's, Partners for Advanced Highways and Transit (PATH) analysis of the Freeway Service Patrol (FSP) program in San Francisco (described below) estimated the congestion benefits by valuing time saved at \$10/hour and gasoline saved at its net of tax price. Emission reductions were not estimated.

Encouragement of experimental and innovative ideas. One of the goals of CMAQ is to encourage states and MPOs to address their air quality needs creatively, and to experiment with innovative approaches to reduce emissions through transportation programs. The federal government also has an interest in encouraging this sort of policy experimentation because ideas that work in one area can often be transferred to another.

Types of CMAQ Projects

CMAQ expenditures are classified into six major categories. Funds obligated in states with no nonattainment areas are lumped into a seventh category, STP/CMAQ. The relative share of total funds allocated to each category is given in Table 1. Table 2 gives a breakdown of the actual amounts allocated to each project type, and the cost to CMAQ of the median project in each category.

Table 1. CMAQ Project Types by Percent of Total Funds Obligated in FY95

Project Type	Percent of Total Funds
Transit	50.4
Traffic Flow	29.2
Other TCMs	5.6
Shared Ride	4.9
Demand Management	4.6
Pedestrian / Bicycle	1.5
STP / CMAQ	3.8

⁵ Sometimes it is possible to monetize all types of physical effects but one. In this case, one can perform a *net* cost-effectiveness analysis, which involves subtracting the monetized effects from the costs and dividing by the unmonetized physical effect.

Table 2. FY 1995 Summary of Projects Funded

Project Type	Number of Projects Funded	Cost of Median Project	Total Funding (\$Million)
Transit	223	\$385,000	\$500
Traffic Flow	435	\$181,350	\$290
Shared Ride	66	\$79,500	\$49
Demand Management	122	\$190,000	\$46
STP/CMAQ **	74	\$144,858	\$37
Pedestrian / Bicycle	70	\$74,000	\$15
Other TCMs (Including I&M)	82	\$220,000	\$56
Total	1072	N/A	\$992
** NOTE: STP/CMAQ funds are obligated to states with no nonattainment areas. Source: The Congestion Mitigation and Air Quality Improvement Program: A Summary of Fourth Year Activities, Appendix. (FY 1995: October 1994 - September 1995)			

In FY 95, transit related programs made up the majority of all funds obligated. Traffic flow improvements, such as Intelligent Transportation Systems, improved signalization, and construction of HOV lanes, made up the second largest share. Other funding categories made up only around 20 percent of all funds obligated.

As there is no uniform procedure for designating individual CMAQ projects, in some cases it was difficult to accurately categorize projects. For example, there were cases in which states grouped multiple small projects into a single proposal.

HOW PROJECTS ARE EVALUATED

Ex ante Analysis

Proposals for CMAQ projects typically contain a quantitative estimate of the air quality benefits expected to result from their implementation. In FY95, 75 percent of CMAQ proposals were accompanied by quantitative estimates of their emission benefits. Estimated volatile organic compound (VOC) reductions were most frequently quantified (in 97 percent of proposals quantifying estimated pollutant reductions), followed by oxides of nitrogen (NOx) (77 percent) and carbon monoxide (CO) (57 percent). Emission reductions are estimated the least frequently for particulates (in only 12 percent of projects),⁶ a fact which FHWA attributes in part to "a lack of available modeling tools and expertise to actually estimate reductions of particulate matter for CMAQ-funded proposals."⁷

⁶ The Congestion Mitigation and Air Quality Improvement Program A Summary of Fourth Year Activities (FY 1995: October 1994 - September 1995).

⁷ Ibid.

The primary factors complicating *ex ante* estimation of annual reductions are (1) the need to guess at the project's utilization rate and effectiveness, (2) uncertainty or bias in the transportation models on which estimates are based, and (3) in the case of particulates, lack of available modeling tools on which to base estimates. *Ex ante* estimates of lifetime program effectiveness are further complicated by the fact that some projects have both fixed and variable operating cost components, or have variable effectiveness over time.

Currently *ex ante* estimates of air quality effects are generated either during a region's transportation conformity demonstration or according to guidance developed at the state level. CMAQ projects that involve HOV-lane construction, signalization, or other roadway improvements that require inclusion in an area's transportation improvement program (TIP) are evaluated for conformity with the requirements of the Clean Air Act Amendments using motor vehicle emission models provided or endorsed by EPA.

For projects that are not evaluated during the conformity modeling exercise, but which are amenable to quantitative analysis, states have developed protocols or guidance documents for estimating emission reductions. This guidance typically provides information such as emission factors for a variety of vehicle types under a range of operating conditions, estimates of the life span of different types of projects, and in some cases explanations of how to estimate changes in mode choice that will result from improvements to transit service. The emission factors provided are usually taken from EPA's MOBILE model or similar sources. Less detailed guidance may indicate, for example, the estimated effectiveness of a generically defined "regional vanpool" at removing single occupancy vehicles from the road, with no specific reference to the parameters of the project under consideration.

One attribute of an *ex ante* analysis that is often overlooked is the need to conduct a thorough literature review designed to determine whether the project proposed has been tried, or is underway, elsewhere. For instance, if the proposed project is intended to serve as a demonstration, it might be counterproductive to fund the startup of a new experiment if a more developed version exists. Other things equal, the funding should go to evaluation of the more developed project rather than to the startup of a new project.

Some projects slip through the cracks and are not amenable to any type of quantitative analysis of their benefits, in which case a logical explanation of their expected benefits is sufficient for meeting program requirements. Stronger *ex post* analyses (see below) would go a long way to improving the data available to those wishing to perform solid *ex ante* analyses.

There is, however, no federal guidance detailing procedures for estimating emission reductions, *ex ante* (or *ex post*, for that matter, as discussed below). As a result, the *ex ante* analyses as reported in CMAQ project proposals are of uneven quality. Producing such guidance would be useful not only to improve the quality of the proposals, an important end in itself, but also for providing incentives to proposers to think more carefully about the structure of their project and its desired outcomes and, perhaps, for making it easier to discriminate among the proposals for funding decisions. The appropriate levels of governance and the process for running such a program are discussed further below.

***Ex post* Analysis**

An *ex ante* study seeks to project the benefits of an action that has been proposed but not implemented yet. In contrast, an *ex post* study quantifies the actual effectiveness of a program, comparing conditions before and after implementation. Once the physical effects have been estimated, they may need to be linked via modeling and other analyses to the policy relevant variable.

For example a project that increased the size of the parking lot at a suburban stop of the Washington Metro could use a customer interview to link parking lot utilization to vehicle miles reduced, and modeling to link vehicle miles reduced to annual emissions reduced.

Adding significantly to the complexity of conducting an *ex post* study is the need to isolate the physical changes resulting from implementation of the action from those that would have taken place for other reasons, such as a pre-existing trend, or changes that took place during the same time period but which were not attributable to the project.

Ex post analysis of program effectiveness is not required under federal CMAQ guidelines for most project categories, and where it is, guidelines on how to conduct the analysis are meager.⁸ Despite this, many projects go to significant lengths to evaluate their effectiveness, either through the implementing agency or in collaboration with academic institutions. In some cases these evaluations are exemplary.

In other cases, attempts at evaluation are thwarted by poor planning, failure to take into account indirect effects of the program, or failure to consider the effect of the program within a sufficiently large context. Poor planning at the outset may involve failure either (i) to adequately establish a baseline scenario that determines initial conditions or predicts the trend over time in emissions in the absence of the project or (ii) to collect appropriate performance data over the project's lifetime. Evaluations that fail to take into account indirect effects of the project run the risk of over- or underestimating project performance.

In what follows, an ideal set of evaluation protocols is presented. Next, a brief section outlines the evaluation protocols used in six "exemplary" CMAQ projects identified by the Federal Highway Administration. An appendix contains detailed recommendations on how these evaluations could be expanded to meet the criteria described below.

Lessons learned about the effectiveness of CMAQ would be most effectively conveyed to federal authorities through thoughtful and thorough reports prepared at the project level. While it would be neither feasible nor necessary to evaluate every project, a wide range of projects, large and small, should be subject to thorough evaluation. Funding for collection of baseline data on a large number of projects, possibly all projects, should be allocated along with actual project money, thereby leaving to the later discretion of DOT the

⁸ A March 7, 1996, Federal Register notice states that projects in the "Experimental Pilot Projects / Innovative Financing" category must conduct "before and after studies" to "determine the actual project impacts on the transportation network (measured in VMT or trips reduced, or other appropriate measure) and on air quality (emissions reduced)." These assessments must be forwarded to FHWA or FTA.

choice of which evaluation completions to fund. Issues such as these are discussed in the concluding sections.

Elements of an evaluation protocol

To conduct an evaluation of a CMAQ project, each should be treated as a scientific experiment. This encourages the kind of careful project design and analytical rigor that is required to produce a useful project investigation. Nonetheless, project evaluations take place in the real world, not the laboratory, therefore it will be difficult to maintain a stringent observance of the requirements of the scientific method. Instead of changing a single variable, as required in a scientific experiment, CMAQ projects are often complex and many-faceted affairs that are designed to be integrated into ongoing projects. It will frequently be difficult to link observed outcomes to the CMAQ project itself, and even more difficult to isolate the effects of particular features of the CMAQ project.

This problem has no easy solution, but it is encountered in most areas of empirical social science research (and often natural science as well), not just the CMAQ program. Studies that appear inconclusive or incomplete in isolation often acquire more weight when part of a group of studies with broadly similar results. And so it is with policy evaluation. Despite researchers' best efforts, drawing conclusions about the meaning or significance of individual CMAQ projects will be highly tentative. But if a variety of CMAQ projects, undertaken in different parts of the country, under widely different economic and social conditions, reach similar conclusions, more is suggested than would be by a single project.

Ideally, the collection of information for the project evaluation will begin before the project is ever implemented. Preparing for the *ex post* evaluation, therefore, is an indispensable part of the original project plan. The evaluation requirement does not necessarily alter the plan, but it does make it more important to be clear about what is being done, why it is being done, and how progress is to be measured. In particular, the plan should include the following:

(1) *Description of the project.* If the project is an addition to an existing project or expansion of an existing service, the description should make clear precisely what is being added. The *ex post* evaluation will have to distinguish between the accomplishments of the new from those of the already existing.

For example, suppose the project expands the size of a parking lot at a suburban stop of the Washington Metro. The description should make clear the number of parking spaces currently, the number to be added, plus any additional nonstructural changes, such as would be the case if the parking addition were accompanied by a change in the pricing policy.

(2) *Literature review.* The purpose of the literature review prior to conducting an *ex post* analysis (as opposed to the case with an *ex ante* analysis as described above) is to find out whether any *ex post* analyses of similar projects have been conducted in the past, and to learn from them, if possible. The choice of evaluation criteria, data collection techniques and interpretation will be informed by this literature review.

(3) *Determination of evaluation criteria.* The ultimate goals of the CMAQ program are to help meet reasonable further progress requirements of the CAA, improve air quality, reduce congestion, and provide new knowledge about the design of cost-effective approaches to air quality improvements and congestion mitigation. Typically, individual projects are too small to affect air quality measurably, and furthermore, air quality is affected by so many variables that it would be impossible to prove that the measured improvements were the result of a particular project. For example, the ultimate goal of providing increased parking at a suburban Metro station is to reduce congestion and thereby improve air quality, but no one would think of evaluating the effectiveness of such a project by measuring air quality directly. On the other hand, the physical outputs of the project -- the number of parking spaces added in the case of the Metro parking addition -- is likewise not a very meaningful outcome for *ex post* policy evaluation.

To be useful as evaluation criteria, more meaningful outcome measures should have the following properties. First, they should bear a previously-established, defensible and quantifiable relationship to the congestion and air-quality goals of CMAQ. Second, their relationship to the physical outputs of the project must be observable. Measurement of the changes in these observable effects constitutes the main task of the *ex post* analysis. The main examples of such outcome measures are (i) the reduction in average vehicle emission rates and emissions, (ii) the reduction in vehicle miles traveled (VMT), (iii) the reduction in the number of cold starts, or (iv) the reduction in the number of vehicles on the roads. These outcome measures can be related to air quality and congestion goals by a variety of air quality and transport models, and they can be empirically observed before and after project implementation.

For the Metro parking lot expansion example, the project objective is to increase the number of parking spaces in the lot. It would be tempting to evaluate the project based on the increased number of vehicles using the lot. However, this would be a poor indicator of the number of vehicles removed from the road if some vehicles belong to commuters who previously used feeder buses to get to the Metro station or who previously drove to other Metro stations. In this case, it would be necessary to interview users of the park-and-ride facility to determine what they did before the facility was expanded, in order to finally measure the reduction in VMTs achieved through the expansion.

(4) *Identification and measurement of costs.* While an estimate of the costs incurred is of course an element of the *ex ante* analysis, costs need to be revisited during the *ex post* analysis to replace estimated costs with actual costs. Also, there may be elements of project costs that are not well captured by direct expenditures.

It will often be difficult to determine even the direct expenditures associated with individual CMAQ-supported projects, since many function as components of existing projects.

(5) *Data identification.* Having identified the evaluation criteria described above, it is necessary to determine the metric by which progress toward achieving the criteria is to be assessed. This metric should reflect the intermediate output measures described in (2). These

data may be routinely collected, such as Metro utilization or fare box revenues, or a special data collection activity may be required.

(6) *Establishment of baselines.* From a policy perspective, identifying both how the world looked before the policy, and how it would have evolved over time in the absence of the policy, in other words establishing a baseline scenario, is one of the most important elements of analysis. Unfortunately this is often not done until well after the fact, when it is difficult to reconstruct the situation. In order to measure the effectiveness of a CMAQ program, the evaluation protocol must be established before the program is put into effect to insure that a baseline is established, and must be designed so that the data collected are interpreted correctly. Often the data collection for this purpose will be far from trivial: a project intended to change commuter behavior, for example, would in most instances require a survey of the affected consumers to determine their pre-project behavior.

(7) *Identification of a control.* The "correct" measure of project effectiveness requires a "with-and-without" analysis. An *ex post* evaluation that only looks at the actual scenario and does not either (1) model a control scenario or (2) provide for one to compare against, is likely to find it difficult to distinguish the effect of the program from confounding information.

In the parking lot example, evaluation might be clouded by another event, say, a large increase in gasoline prices, that coincided with the completion of the project. Therefore, if possible it is useful to identify a "control" facility or situation that is not receiving the treatment but is subject to the same confounding events.

(8) *Dedication of resources to ex post evaluation.* While many projects receive a thorough *ex post* evaluation, in the cases where they are not done, one of the primary reasons is that resource-strapped local project administrators believe that there are better things to do with their limited program funds, or don't have the technical expertise to perform a rigorous evaluation in-house. From their point of view they are probably correct in that the benefits of a careful evaluation will be realized for the most part in jurisdictions that imitate or extend their project. Therefore, it makes sense for some portion of the CMAQ grants to be dedicated, before the project commences, to the *ex post* evaluation effort. If not, local investments in good analysis will be less than optimal.

(9) *Post-mortem examination.* If CMAQ is to have an experimental function, then after the project is concluded there should be an inquiry into what was learned about project design and how future projects of the same type could be made more cost-effective. In particular, viewing the project as an experiment to set the stage for replication or institutionalization throughout the nation, the plan should describe any local conditions -- such as other state or local initiatives, tax policies, public information programs -- that may affect the outcome of the project or its transferability to jurisdictions with different local conditions.

This set of criteria is demanding; it will be the uncommon project that fulfills them all. The need for a control is likely to be the most difficult to satisfy. Even without it, the *ex post* analysis will still be quite useful, even if not quite so definitive on the effects of the given project.

EXAMPLE EVALUATIONS

This section examines six CMAQ projects identified by FHWA as exemplary.⁹ Table 3 lists the projects, their locations, and the ratio of CMAQ to total funding. For each of these projects, the project administrators were contacted, and information on the effectiveness analyses conducted for each project was obtained. These are described below. An appendix at the end of this report contains more detailed information on the evaluations, and describes how the evaluations could have been improved relative to the criteria listed above, including data that might have been collected and how it should have been interpreted.

Table 3. CMAQ Evaluations Analyzed

Project Name	State	Project Type	CMAQ / Total Cost (\$Million)
1. RIDE	TN	Ride Share	0.5 / 1.1
2. Red Hook	NY	Traffic Flow	3.1 / 13.6
3. PATH	CA	Traffic Flow	1.9 / 6.4
4. US1 Bus Route	FL	Transit	14.8 / 36.7
5. Walkway to Gateway	OH	Ped. /Bike	7.3 / 13.7
6. Education and Outreach	AZ	Ride Share	0.9 / 1.9

The *ex ante* analyses that were performed were, in many cases, preambles to requests for additional funds for existing CMAQ projects. In these cases, the analyses were typically not truly *ex ante*, but rather were based on the performance of the previously existing CMAQ project. These analyses are included in the *ex post* project descriptions, since they have more in common with an *ex post* analysis. In one case (the US1 Bus Lane), only an *ex ante* analysis was available because the project was not yet complete. In this case, the *ex ante* analysis was driven by federal conformity requirements; in other cases, the analyses, where they existed, were driven by the rather minimal requirements of the CMAQ program itself, as interpreted by the states or MPOs.

In the case of nearly every project an attempt was made by project administrators to perform an *ex post* evaluation, even though there is no federal obligation to do so. In some cases, the requirement to evaluate the program came from the states, at least to the extent that project administrators were required to describe the "before and after" study that would be conducted to estimate the effectiveness of the program.

Ride Instead of Drive, It's Easy (RIDE) Nashville, TN Ride Share

This project received CMAQ funding of \$0.5 million out of a total budget of \$1.1 million to add features to a rideshare program in Nashville, TN. Sponsored by a coalition of

⁹ See "Innovations in Transportation & Air Quality: Twelve Exemplary Projects," U.S. Department of Transportation, FHWA, FTA. Publication No. FHWA-PD-96-016.

transportation agencies, it is administered by the Middle Tennessee Regional Transportation Authority (RTA). CMAQ funding was requested (1) to provide outreach to encourage utilization of the existing rideshare service, (2) to offer financial incentives for starting vanpools, (3) to provide a "guaranteed ride home" service, (4) to build the area's twelve park and ride lots, and, (5) under the terms of a CMAQ demonstration project (3 years of funding), to support the development of a commuter bus system.

Ex ante analysis: No *ex ante* analysis for this project was conducted that isolated the effects of the public education and guaranteed ride home program. The only *ex ante* estimate of project effectiveness estimated the effectiveness of the total Nashville regional rideshare program.

Ex post analysis: The *ex post* analysis consists of quarterly reports describing the activities of the various outreach components, utilization of the guaranteed ride home program, the number of vanpools established, the number of calls received expressing interest in the vanpool service, and the number of people assigned to a waiting list. The cost of these components was not provided in the reports. No attempt was made to formally analyze the data.

Red Hook Barge New York, NY Transportation Demand Management

New York State, New York City and the Port Authority of New York and New Jersey received \$3.1 million in CMAQ funding for a \$13.6 million project to relieve congestion on the Gowanus Expressway, one of only two arteries (the other being the Verrazano Narrows Bridge) connecting the Red Hook Containerpoint in Brooklyn, NY, with the Bay Avenue Terminal in Port Elizabeth, NJ. When the Gowanus was scheduled for a lengthy maintenance period, it was decided that container truck traffic would cause unacceptable congestion on the limited traffic lanes that would remain open once maintenance began. In order to head off this problem, the Port Authority of New York and New Jersey and the New York State Urban Development Corporation decided to move the containers by barge rather than overland between the two points. CMAQ funds will be used to replace existing, rented, equipment with more cost effective roll on, roll off barges.

Ex ante analysis: The Port Authority of New York and New Jersey had to submit an application in order to receive CMAQ funding for the project. This application contained, in essence, the *ex ante* analysis of the project. Quantitative estimates of project cost and effectiveness were derived from analyses completed by a private contractor, based on the functioning of a temporary barge service operating between the same points (funded in part through an earlier CMAQ grant). The contractor's report was not forthcoming from project officers.

Ex post analysis: Since the project is not complete, there is no *ex post* analysis. The reader is referred to the appendix for a discussion of some of the issues that may arise in this analysis.

Freeway Service Patrol San Francisco Bay, CA Traffic Flow

This project enhances an existing freeway service patrol (FSP) that reduces delays on California highways by providing for roving tow truck patrols equipped to assist stranded motorists by jump-starting cars, changing flat tires, providing gasoline, or towing vehicles that

are not immediately repairable. CMAQ funding in the amount of \$1.9 million contributes to this \$6.4 million program by paying for enhancements to its communication systems, and for operating costs for the first two years.¹⁰

Ex ante analysis: The *ex ante* analysis for this project is contained in the proposal for CMAQ funding to expand the program. Estimated congestion relief benefits were based on previous experience with the program, hence had more characteristics of an *ex post* than a true *ex ante* analysis.

Ex post analysis: An extremely thorough *ex post* analysis was conducted by UC Berkeley's PATH program at the Institute for Transportation Studies. The study estimates the cost savings resulting from avoided travel delays and fuel consumption caused by congestion before and after implementation of the program. This is accomplished through a sophisticated system by which highway speeds, flows and occupancies are collected at 1-second intervals from loop detectors spaced approximately 1/3 mile apart on the freeway mainline and all the ramps. Baseline data were collected before the FSP program was expanded. These "before" data were gathered on 24 weekdays in the spring of 1993. The "after" study took place in the fall of 1993 on 22 weekdays. Incident specific delay was estimated by comparing average travel speeds under normal and incident conditions. Among the many strengths of this analysis is the fact that congestion reduction estimates are monetized, as Table 4 illustrates, making it possible to estimate a benefit-cost ratio, and also to seek further improvements in the efficiency of the program from an economic standpoint.

Table 4. Freeway Service Patrol Effectiveness Summary

FSP Impact Estimates ¹¹									
System Information				Annual Savings					
Location	Miles	No. of Trucks	Truck-Hours/Yr.	Veh.-Hrs of Delay	Fuel Consumption (000 gal.)	Dollars (\$000)	Hydrocarbons (Tons)	Carbon Monoxide (Tons)	Nitrous Oxide (Tons)
PATH Study Results									
Beat 3	9	2	4,000	91	67	989	7.56	77.19	19.06
Extrapolated Results									
Bay Area	218	50	94,736	2,161	1,581	23,425	179	1828	451

US1 Busway Dade County Florida HOV / Transit

With this program, Florida's Department of Transportation plans to build exclusive bus lanes along a section of US1 using an abandoned railroad right-of-way. Costing \$36.7 million,

¹⁰ This description is based on the report, "Freeway Service Patrol Evaluation," by Alexander Skabardonis et al., California PATH Research Report UCB-ITS-PRR-95-5.

¹¹ The monetary value of an hour of delay per vehicle was assumed to be \$10, and the cost of a gallon of gas set at \$1.15 (excluding state and local taxes) for calculating the dollar savings. Table based on an article, "If FSP Reduces Congestion, why Aren't State Funds Growing?" provided by the Bay Area's Metropolitan Transportation Commission.

\$14.8 million of that from CMAQ, the plan includes the provision of a bike path running parallel to the bus route, a park and ride lot, sheltered bus stops at major cross streets, and an interface with the county's light rail system. Operationally, the project calls for changes to many bus routes, a modification that the report's authors conclude will not significantly affect air quality, and other changes to reduce delay at intersections, with the effect of improving air quality.

Ex ante analysis: The US1 Busway has not been completed, but modeling was used to estimate the benefits of the program, *ex ante*, as part of the conformity requirement for this major transportation project. The report, entitled "Air Quality Report: US1 Exclusive Bus Lanes," is concise (13 pages), yet contains most of the elements of a thoughtful *ex ante* program evaluation.

In the first of three sections, a thorough physical description of the project is provided, including descriptions of all optional elements, and describing the operational aspects of the program such as changes to bus route patterns. In the second section, the air quality impacts are described, starting with a summary of the pollutant burden analysis, which was based on a separate "traffic report" component of the study. The final section states that FHWA has determined that the transportation plan and the transportation improvement plan (which contain this project) conform to the SIP.

Ex post analysis: Not applicable since the project has not been completed.

Walkway to Gateway Cleveland, OH Pedestrian/Bicycle

"Walkway to Gateway" is an enclosed, climate controlled, pedestrian sidewalk connecting Cleveland's main transit station, which links two rapid transit lines to most downtown area bus service, to a new sport and entertainment complex containing the new home stadiums of the Cleveland Indians and the Cleveland Cavaliers sports teams.¹² The project was constructed by the Greater Cleveland Regional Transit Authority (RTA).

Ex ante analysis: No *ex ante* study on the effectiveness of this project was available.

Ex post analysis: The only evaluation conducted of the walkway's effectiveness in shifting sports fans from automobiles to transit use was a count of 940,000 people who used the walkway during the first 16 months of its opening. From this number it was estimated that 625,000 fewer vehicle trips were made, and 5 million fewer vehicle miles were traveled.

Employee Trip Reduction Maricopa County, AZ TDM

Maricopa County, AZ, used \$0.9 million in CMAQ funding out of a \$1.9 million total budget, to help implement two programs, both required by Arizona state law: a mandatory Trip Reduction Program (TRP) and a voluntary "Clean the Air Rideshare" campaign. The TRP requires employers with more than 50 employees to participate in a program involving the distribution of information on alternative modes of transportation, surveying employees and students annually, and writing and implementing a trip reduction plan, all under the

¹² Mentioned in "Innovations in Transportation & Air Quality: Twelve Exemplary Projects," US Department of Transportation, FHWA. Publication No. FHWA-PD-96-016.

supervision of an on-site transportation coordinator. The staffs of the TRP and the Regional Public Transportation Authority coordinate efforts to implement this program. The program consists in large part of providing training programs and presentations to major employers. In addition, the regional public transportation authority assists area employers in forming carpool / vanpool systems and in providing networking opportunities. This program has been in existence for six years.

Ex ante analysis: While no information was available on an *ex ante* analysis of this program's effectiveness, it is significant for more than one reason that mandatory annual surveys of employees of participating employers were required under the law in order to track progress. On the one hand, it would appear that this reflects a commitment to accuracy and information gathering; on the other hand, if the surveys are used to enforce compliance with the program, employers would have strong incentive to falsify survey results.

Ex post analysis: Evaluation of this program was based on surveys conducted annually at the offices of each of the employers participating in the TRP. The key questions on the surveys are mode choice and trip distance. Two indices, the single occupancy vehicle (SOV) trip rate and the SOV miles traveled rate, are used to assess the performance of the program. Adjustments are made to include credit for employers who allow compressed work weeks. Air pollution benefits of the program are based on the data collected from these employee site surveys.

ENCOURAGING PROJECT EVALUATIONS

The above review of this handful of "exemplary" CMAQ projects indicates that CMAQ projects are frequently not subject to very serious evaluation, either before or after the fact. From a national perspective, the lack of *ex ante* analysis is not a serious flaw, given the way CMAQ is funded. With grant allocations to each state fixed according to a formula taking into account population and air quality status, *ex ante* evaluation is something that may best be left to the state and perhaps local governments receiving the grants. That is where decisions about project allocations have to be made, and hence where there is an incentive to provide a mechanism for estimating future benefits and costs. Of course there is room for DOT to provide suggestions to state and local agencies on appropriate ways to analyze various kinds of projects.

Ex post analysis is another matter altogether. It is of major interest and importance to the federal agencies involved, even in some cases where it may be of little enough concern to states and localities that they resist taking funds away from the project itself to do project evaluation. In these cases if Congress -- or DOT -- are interested in proper project evaluation, they should dedicate a small portion of the CMAQ funds for purposes of *ex post* analysis. Whether this is possible without a change in the legislation is an open question.

This obviously raises a lot of questions, of which the most important perhaps are the following:

- How will projects be selected for *ex post* evaluation?
- What portion of the total CMAQ budget should be devoted to evaluation?

The first question is motivated by the large number of CMAQ projects. Since the *ex post* evaluation is designed to assist federal authorities, it seems appropriate to leave the project selection decision to authorities at DOT. This assigns the research decision to the parties that are most interested in the outcomes. The federal authorities are also well positioned to take advantage of any economies of scale that may come with standardization. For example, for particular types of projects, DOT officials could designate the outcomes of interest and perhaps even design data collection instruments.

However, if the selectors are unlucky, they could commit to an analysis of projects that, after the fact, turn out not to be very interesting. Since no one knows for sure which projects will yield the greatest benefits, the authorities are almost certain to make mistakes if they pick interesting projects for analysis before the projects are implemented. And yet, the analysis must commence before implementation, since it is necessary to establish a baseline.

The solution is to separate the funding of the baseline determination from the funding of the evaluation itself. This has the potential to permit the funding of a great many preliminary projects to establish baselines and develop evaluation criteria, leaving until later -- perhaps even years later -- the decision on which projects to analyze further.¹³

As for the funding levels themselves, arithmetic suggests that if two percent of CMAQ funds each year were set aside for evaluation, \$26 million would be available for project evaluations (assuming outlays equal to the proposed budget authorization). Two percent does not seem like an exorbitant amount to pay to find out how well federal dollars have been spent, but it can generate a substantial amount of analysis, especially if researchers are able to take advantage of standardized data collection instruments.

CONCLUSIONS AND POLICY CONSIDERATIONS

The CMAQ program is worthwhile on a number of counts and should be retained. By providing federal block grants for transportation projects that do not involve new highway construction, it encourages innovation on the part of state and local governments in meeting general transportation air quality needs, and flexibility in designing solutions to specific local problems. Given the strong national interest in generating creative and potentially cost saving ideas that may enhance the productivity of existing capital and foster the emergence of alternative transportation modes, it is imperative to retain a source of funding for projects such as these.

¹³ On the other hand, baseline determination itself may be a costly exercise in many cases. It will be important to restrict the scope of the baseline estimation by ensuring that the baseline is defined on a project-specific basis. Even this attempt at narrowing the scope of the baseline estimation may not be sufficient to control costs. If this is found to be the case, project categories could be defined. A limited number of evaluations within each category could receive a thorough baseline estimation, and thereby become candidates for a thorough *ex post* analysis.

However worthwhile it is to foster innovation over the short term, over the long term experience and institutional learning should emerge. All CMAQ projects can yield useful information, succeeding as experiments even if they fail as transportation air quality projects. Insights from failing projects can provide lessons on what to avoid, while experiments that were successful and transferable show what should be encouraged and supported, perhaps through more permanent provisions in federal and state transportation budgets. Only through the process of information feedback can institutional learning take place.

This informational purpose of CMAQ has two components. First, since CMAQ funding is provided as essentially a block grant, states and regional governments have day-to-day responsibility for coming up with project ideas and implementing them. Therefore the first stage of information distribution should take place laterally, between project implementation teams. One way to facilitate this sharing of ideas is through the Internet, perhaps on a page attached to the DOT website, where local project implementation teams would be encouraged to post information on their projects. The primary purpose of this site would be to establish a line of communication through which MPOs can share ideas and information.

Second, in order for the CMAQ program itself to evolve, quantitative information on project effectiveness needs to be fed back to the federal level. Project evaluation has a "public good" aspect to it, in that the information generated benefits not only the project being evaluated but also similar projects yet to be initiated. This suggests a strong federal interest in CMAQ evaluation. Therefore the CMAQ program would be well served by setting aside funds to be used for *ex post* project evaluation. The goal of this evaluation would be to determine the actual effects of selected projects, estimate associated congestion and environmental benefits, and then combine these with cost information to determine actual cost effectiveness. While cost effectiveness should not be the only consideration, it is certainly an important one. This investigative effort may bring to the attention of federal transportation (and environmental) officials a group of programs that are effective, and cost effective enough to be promoted at a national level.

Some CMAQ projects already receive some sort of *ex post* evaluation, including most of the projects examined above. While these analyses could be improved in a number of ways, notably by having greater attention paid to establishment of baseline conditions, they certainly demonstrate the possibilities of *ex post* analysis. The projects receiving analysis were the projects held up by DOT as exemplary and tended to be much larger than average. It is natural that large projects would be more likely to be evaluated than small ones. When considered as experiments, however, all projects are on the same footing.

The very large number (and small average size) of CMAQ projects funded in any given year precludes analysis of all of them. This reality poses questions of how to select projects for *ex post* analysis and who should do the selecting. In making these decisions it should be kept in mind that project size is not necessarily an indicator of the value of a good *ex post* analysis, or of the cost of a good analysis, for that matter. Thus, there is value in evaluating small projects, even though there may be cases in which the cost of evaluation will exceed the project budget. As for who should select projects for further analysis, DOT is in

the best position to do that. However, the fact that some projects (usually the larger ones) already engage in *ex post* evaluation implies that sometimes the local benefits exceed the cost of analysis. This suggests that in selecting projects for further analysis, there should be provision for local-federal cost-sharing arrangements to pay for project evaluation.

Some small projects may be implemented by groups that are ill equipped to either design or carry out an effective *ex post* analysis. In this case, design and execution of the project's evaluation should be carried out at the MPO level. In no case should the evaluation requirement present, in itself, a barrier to funding small projects.

APPENDIX: DISCUSSION OF SIX CMAQ PROJECT EVALUATIONS

This section supplements the brief project and evaluation descriptions provided in the body of the paper by illustrating some of the issues that arise in practical project evaluation. It is important to note that the evaluations described below are provided for illustrative purposes only; descriptions of evaluations are based on conversations and analyses received, which may not include all of the analyses that have been performed on these projects.

While in comparison to the evaluation protocols described above many of the evaluations described below appear lacking, it should be understood that this is only with respect to the criteria outlined in this report. The criticisms that appear here are not intended to suggest that these evaluations inadequately fulfill the statutory requirements of either the CMAQ program or any of the other institutions to which project administrators are accountable. Indeed, many appear to exceed the standards that have been set for them.

Ride Instead of Drive, It's Easy (RIDE) Nashville, TN Ride Share

This project adds features to a rideshare program in Nashville, TN, by providing outreach, offering incentives for starting vanpools, providing a "guaranteed ride home" service, building area park and ride lots, and supporting the development of a commuter bus system. The discussion that follows focuses on the public outreach and the guaranteed ride home service.

Because of the conglomerate nature of this program, its evaluation raised the question: to what degree can or should the independent effects of individual CMAQ projects be isolated? Even if all of the CMAQ-funded components of this project were considered together, it still significantly supplements an existing vanpool program and relies to some degree on a pre existing HOV lane funded by the interstate highway system.

It is important to devote some effort to establishing procedures for measuring the effectiveness of interstitial projects, such as this one, that enhance and improve the functioning of existing systems. The focus here is on how best to evaluate the effectiveness of the outreach components of this project alone. While such an analysis would not be sufficient to qualify as a total *ex post* analysis of this project, without it the *ex post* analysis could not be considered complete. The question of how to evaluate the total performance of a ride share program is dealt with in greater detail in the Employee Trip Reduction Program for Maricopa County, described below.

Ex ante analysis: As with most CMAQ projects, the goal is to reduce air pollution or congestion, so the first task is to figure out which intermediate metric should be used to gauge performance. As always, this metric must be observable, attributable backwards to the project in question, and forward, via modeling, to reductions in air pollutant emissions. At first blush VMTs would seem to be a likely candidate. However, the direct goal of the project is to increase public awareness of the rideshare options available and to provide a guaranteed ride home, and thereby to indirectly bring about increased utilization of the rideshare program. One way to evaluate such a project would be through exploring a two-stage link, the first

linking the outreach activity with public awareness, the second linking awareness to utilization of the resource.

For the *ex ante* analysis, by definition no data will be available for the project in question. However, data may be available for comparable projects undertaken in other areas, quantifying the effectiveness of similar outreach campaigns. These may provide information on the fraction of the population aware of a message before and after such a campaign. If such data are available, they can be used as a basis for *ex ante* estimates. It will be important, however to pay attention to any caveats in the report describing the comparison project, as they may indicate that the other outreach campaign was performed under more favorable or less favorable conditions than the one proposed.

The next link in the chain is to estimate the behavior changes associated with outreach efforts. In this case it will be more important than before to identify a very similar project because the link between awareness and behavior change may be more fragile than that between an outreach campaign and awareness.

Ex post analysis: While no thorough *ex post* evaluation appears to have been completed for this project, some analytical work may be possible based on data that program officers did collect. Data was collected on the number of calls received per quarter in reference to the program, the number signing up for the guaranteed ride home service, and the utilization of the guaranteed ride home service. The data could be used in an "event series" statistical analysis to determine the extent to which outreach efforts correlate with increases in the number of inquiries into the program. In the absence of baseline data, such an analysis would constitute an adequate *ex post* analysis on its own. However, a more thorough *ex post* analysis would focus, like the *ex ante* analysis, on the two stage linkage: outreach effort to public awareness, public awareness to behavioral change; and the importance of the guaranteed ride home in attracting people to the program.

Public awareness is typically gauged by survey methods. One model would question commuters through telephone surveys administered (1) before implementing the activities, (2) immediately after an outreach effort is completed, and (3) periodically thereafter. The surveys might ask commuters for demographic information and the types of media they are exposed to, commute origins, destinations and modes, whether they have ever used an alternative mode, and the cost of their commute in time and money. It might ask whether they know of any other means of getting from their origin to their destination, and why they choose their current mode over the alternatives.

A similar survey following each outreach effort, asking the same background questions as above, might elaborate on what the respondent knows about the specific program in question, and where the message was obtained. This survey might conclude by asking whether commuters are more or less likely to consider using the service since they have seen the ad, and whether they have changed their commuting behavior in response to the ad.

A second survey, directed at those who call to inquire into the program or to be matched up with a vanpool, would elicit peoples' impressions as to whether the advertisement

influenced their decision about whether to participate. At this point, the respondents' impression of the guaranteed ride home service may be assessed.

A final survey of people using the vanpool service, focusing on their former mode of transportation, trip distance, access trip distance, and trip cost in time and money before versus after switching to vanpool, would provide reliable estimates of the number of SOV miles reduced area wide by use of the vanpool, and resulting from each phase of the public outreach campaign.

At a minimum, survey data can provide the information needed to determine the fraction of the population that was reached by the campaign, and the fraction that changed their behavior as a result of the campaign.

In addition to the value of such survey work to the CMAQ program overall, valuable marketing information can be obtained from such survey results. Looking at the responses by demographic group, location trip origin and destination, etc., the project managers would be able to identify the population segments that provide the biggest behavior change or reduction in SOV travel for the promotional dollar. Furthermore, advertising dollars per SOV trip or mile reduced could be calculated based on these surveys.

A concluding section of the *ex post* report would describe, in detail, the basic rideshare program that formed the foundation of the project, since all results are predicated on a certain level of vanpool accessibility. Specifically, the number of park and ride lots, the presence or absence of a guaranteed ride home program, the cost of the service to commuters, and the presence or absence, and utilization rate, of HOV lanes, need to be described to make clear the conditions under which the results described in the body of the report can reasonably be anticipated to be replicated elsewhere.

Red Hook Barge New York, NY Transportation Demand Management

This project enhances a system of barges operating between New York and New Jersey shipping ports.

Ex ante analysis: On paper it would appear that the form provided by the states of New York and New Jersey for applying for CMAQ funding meets many of the guidelines listed in the evaluation protocol above. Notably it requires a project description and details on the project's goals with respect to air quality; it requires costs to be identified, and specifically requires "backup data" supporting claimed emissions reductions and a summary of the congestion reduced in terms of the VMT reduced and the number of automobile trips eliminated. Finally, and significantly, it requires that project administrators develop methodology for conducting a "before and after study."

One way to improve this form would be to require (1) that baseline data be collected at the outset and (2) that funds be set aside for conducting an *ex post* analysis of the project once implemented.

It is important to keep in mind, however, that the headings on the form and the quality of the responses are two completely separate things. It is apparent that in the case of some of these questions, only a superficial response was required. In the case of the projected

emissions benefits, however, the brief summary table that appears in the application reflects the outcome of a substantial study undertaken by a private consulting firm.¹⁴

Ex post analysis: If estimates of these emission reductions are based, as suggested in the brief description of the "before and after" study, entirely on the number of containers transported by the barge service, a number of concerns arise with respect to methodology, since in essence this would be equivalent to counting the number of cars using the hypothetical Metro parking lot expansion described above.

First, is a baseline established? Counting the number of containers transported by barge does not take into account the possibility that the total number of containers transported between the two points, by truck and by barge, is not the same after the barge system is implemented as before. There are a number of plausible scenarios under which this result may occur. If the barge service were free, for example (as it is), containers shipping between other points might find it more economical to use the barge system than their previous system, leading to an increase in the total number of containers shipped after implementation than before. On the other hand, if the barge service were slow, it might be less economical to ship between these points, and if alternative shipping points were available, they might be used instead, leading to a reduction in the total number of containers shipped between these points. Thus, failure to establish a baseline would make it difficult to compare the "with service" scenario to the "without."

This issue begs the potentially more important question: is the use of the number of containers as numeraire the closest that project evaluators can come to the goal of measuring emissions and congestion improvements directly? That is, is the number of barges transported the best, or just the simplest, criterion on which to base evaluation of the congestion and emission reductions resulting from the project?

For purposes of estimating the congestion relief caused by this reduction in truck traffic, it is assumed that each truck is equivalent to two automobiles. In the end, the number of automobile trip equivalents across the bridges is the final metric used to estimate reductions in congestion. This analysis falls short in a number of respects:

First, in estimating reduced congestion on the highways, it ignores time of day effects. For estimating reductions in congestion, one possible numeraire might be vehicle speeds and volumes across the system at peak and off peak hours (compare this with the FSP example). These quantities can be measured with modern automated equipment. Vehicle speeds and volumes measured before implementation, on a number of days and times, would establish the congestion baseline. Barge shipments, including number of containers and time of shipment, may also be counted and used as baseline information. This would permit a check for consistency between effectiveness estimates obtained based on utilization of the service, and observations of congestion on the roadways.

Continuing this line of reasoning, at each phase of project implementation, speeds and volumes, and the number and time of days that containers are shipped, would be measured

¹⁴ Unfortunately a copy of this study has not yet been made available to us.

again. It may be that no effect on traffic volumes and speeds is observed. If this is the case, then project evaluators could fall back on the original technique of counting containers. It would also indicate that there had been no effect on congestion, either because the effect was within the sampling error of the survey, or because there was latent demand for travel across the system, and that therefore the project had the effect of increasing system capacity without reducing congestion. Finally, a model could be developed to predict the flow of traffic before and after construction begins on the Gowanus. This model would be used to estimate the reductions below the predicted congestion that could be attributed to the implementation of the barge service, in effect serving as the baseline against which changes are measured.

Estimates of pollutant reductions could be based on the vehicle count data, if they showed a change "before and after," with attention given to vehicle type (car versus container truck) and speed. Thus emissions could be estimated as a function of congestion, as they should be, since vehicles operating in congested conditions travel more slowly. At slower speeds vehicles spend more time in the system, generally burning fuel less efficiently. At slower speeds, however, NO_x emissions may be reduced.

Calculations used by project evaluators to estimate emission reductions are not detailed in the proposal; rather, the consultant's study is referenced and totals presented. With respect to the emission estimate, one unanswered methodological question is: were barge emissions netted out of any reduction in emissions attributed to this project?

Finally, the completed report should detail pitfalls to implementing the program, such as institutional barriers or favorable conditions, such as preexisting capital stock at the ports. Recommendations as to how to improve the cost effectiveness of the program, plans for cost recovery, etc., may be included in the report at this point.

Freeway Service Patrol San Francisco Bay, CA Traffic Flow

This project enhances an existing freeway service patrol that reduces delays on California highways by providing for roving tow truck patrols equipped to assist stranded motorists by jump-starting cars, changing flat tires, providing gasoline, or towing vehicles that are not immediately repairable.

Ex ante analysis: As in the Red Hook case, the *ex ante* analysis consisted of filling out a form provided by the state to apply for CMAQ funding. While the physical description of the project was complete, its most noteworthy attribute was the specific request for CMAQ funding for further program evaluation. Because the proposal is for enhancement to an already existing program, the *ex ante* emissions and congestion reduction estimates were based on actual data on program effectiveness. The proposal contained the crude estimate (based on prior experience) that FSP could arrive at an incident within an average of seven minutes of its occurrence, whereas regular service would arrive within an average of 20 minutes, and over 60 minutes for stalled vehicles on the shoulder. A more complete evaluation than the one in the proposal would have provided estimates of the total hours of congestion delay and pollution emissions avoided. While this information was not contained in the request for additional funding, this analysis has been performed and used for other purposes.

Ex post analysis: The *ex post* analysis of this project was excellent, and left little room for improvement. The metric used to measure congestion relieved, which included traffic counts and vehicle speeds at various times based on the results of loop detectors, could profitably be emulated by other congestion mitigation projects.

US1 Busway Dade County Florida HOV / Transit

With this program, Florida's Department of Transportation will build exclusive bus lanes along a section of US1 using an abandoned railroad right-of-way.

Ex ante analysis: The *ex ante* analysis for this project was quite good, but it should be kept in mind that it was intended for use in a conformity demonstration. Given the requirement that transportation improvements meet conformity requirements, there is the possibility that transportation - air quality models may be biased in favor of transportation projects.

This evaluation was notable for the careful baseline analysis that was completed, allowing comparison between the status quo and the modeled effects of implementing the busway. The results for this project showed that the pollutant burden from buses would increase under the Proposed Action; but that this increase would be offset by the reduced burden from cars, compared with No Action. Furthermore, they found the Proposed Action superior to No build Modified Bus Operations due to the higher bus speeds under the Proposed Action. Figure 1 shows the headings for three tables that appeared in the report. These tables provide a good example of a summary that includes baseline data, and that considers the effect of the project on both peak and non peak congestion patterns.

One of many aspects of the analysis that are not elaborated on this summary report is how bus ridership and highway usage by automobiles are projected to change over time.

Figure 1. Headings of Tables Summarizing Effects of Project Options: US1 Busway

No Action Alternative														
Route	Two-way Dist.	Speed	Buses Hour		# of Hours		Daily Total		Emission Factors (grams per mile)			Total Bus Burden (lbs. Per day)		
			Peak	Off	Peak	Off	Buses	Miles	HC	CO	NOx	HC	CO	NOx

No Build Modified Bus Operations														
Route	Two-way Dist.	Speed	Buses Hour		# of Hours		Daily Total		Emission Factors (grams per mile)			Total Bus Burden (lbs. Per day)		
			Peak	Off	Peak	Off	Buses	Miles	HC	CO	NOx	HC	CO	NOx

Proposed Action														
Route	Two-way Dist.	Speed	Buses Hour		# of Hours		Daily Total		Emission Factors (grams per mile)			Total Bus Burden (lbs. Per day)		
			Peak	Off	Peak	Off	Buses	Miles	HC	CO	NOx	HC	CO	NOx

The final section states that FHWA has determined that the transportation plan and the transportation improvement plan (which contain this project) conform to the SIP.

"Softer" aspects of the busway, including effects of the park and ride lot and the provision of covered bus shelters, were not included in the evaluation. While these attributes were not a primary concern for those conducting the evaluation, since they were concerned primarily with the conformity requirement, they should not be neglected. One question that CMAQ evaluations should attempt to answer is the degree to which increasing the comfort, safety and convenience of public transportation has the potential to encourage its use.

Among the caveats that might be mentioned with respect to this project is the availability of an abandoned railway right of way, which was made available to the highway service at little or no cost.

Ex post analysis: Not applicable since the project has not been completed.

Walkway to Gateway Cleveland, OH Pedestrian/Bicycle

"Walkway to Gateway" is an enclosed, climate controlled, pedestrian sidewalk connecting Cleveland's main transit station to a new sport and entertainment complex.

Ex ante analysis: No *ex ante* study on the effectiveness of this project was available. An *ex ante* analysis would have been difficult in this case, since it would have had to predict the attendance of the new stadium and the rate at which sports fans would choose public transportation. Rather than predicting marginal changes, it would have had to predict utilization of an entirely new venue.

Ex post analysis: The only evaluation conducted of the walkway's effectiveness in shifting sports fans from automobiles to transit use was a count of 940,000 people who used the walkway during the first 16 months of its opening. From this number it was estimated that 625,000 fewer vehicle trips were made, and 5 million fewer vehicle miles were traveled.

This project in particular offered an opportunity for a careful *ex post* evaluation, had planning begun before the sports complex and walkway were constructed.

It would likely have been impossible, even with a well designed *ex post* study, to disentangle the effect of the climate controlled, covered walkway from the effect of placing a major sports arena at a pivotal transportation hub, in the absence of a fortuitous natural experiment. Thus this project is essentially an add-on to the larger project receiving funding primarily from non-CMAQ sources. For practical evaluation purposes, it would be acceptable to define the project as consisting of the relocation of the arena to a transportation hub.¹⁵

The questions one might ask to establish baselines include the following:

- (1) The average attendance at the old arena,
- (2) travel mode (or combination of modes) at the old arena,

¹⁵ With respect to transit, the question of bare access versus ease of use is an important one that should be explored further, since in relation to the cost of providing additional units of transit service, the cost of increasing the ease with which transit is used may potentially be extremely cost effective. See the RIDE case study for more on this issue.

- (3) average number of people per group,
- (4) average cost of the trip in money and time, for each mode,
- (5) trip distance,
- (6) demographic information : age, number in family, family income,
- (7) perceptual characteristics: convenience? congestion? sufficient parking?
- (8) frequency with which party attends sporting events.

Once the arena and walkway had been open for a while (preferably after a few sports seasons), one could proceed by giving a nearly identical survey to sports fans. To attempt, crudely, to get at the independent effect of the walkway, a final question could attempt to elicit whether, in the absence of a walkway, the respondent would likely have changed to another mode choice or visited the arena less frequently.

Regression analysis may reveal which of the factors, including presence or absence of the walkway, significantly influenced the answers. If successful, this survey has the potential to reveal the number of VMTs reduced (or added) by moving the arena, and to a lesser degree, by implementing the walkway. It is, however, information on the effectiveness, or the perceived effectiveness, of the walkway at attracting people to transit that is of the greatest importance in this evaluation.

It would, of course, be impossible based on this survey to determine what the utilization of the new arena would have been in the absence of either the public transportation or the walkway, or what the congestion effects for the city would have been under these circumstances.

Finally, the postmortem would discuss factors, such a high availability of underutilized land near the transit center, that facilitated the project.

Employee Trip Reduction Maricopa County, AZ TDM

This project used CMAQ funding to help implement two programs, both required by Arizona state law: a mandatory Trip Reduction Program (TRP) and a voluntary "Clean the Air Rideshare" campaign. The TRP requires employers with more than 50 employees to participate in a program to meet trip reduction targets that involves distributing information on alternative modes of transportation, surveying employees and students annually, and writing and implementing a trip reduction plan.

Ex ante analysis: No information on an *ex ante* analysis of this program's effectiveness was available. In a case such as this, it may be acceptable to base predictions on the success of other similar projects in reducing congestion or emissions. If no similar projects are available for comparison, which may be the case given that this one involved mandatory measures, an *ex ante* analysis based on reasonable compliance targets would have been sufficient.

Ex post analysis: Surveys given annually to employees of participating employers are used to assess utilization of this service, and they appear to have adequately dealt with many important methodological issues. Minimum response rates are required. If response rates are

not achieved at a site, non respondents are counted as single occupant commutes. Screening ensured that responses "made sense."

Telecommuting and compressed work week schedules are accounted for in the final calculations. Each employment center is evaluated for performance based on the percent reduction in SOV rate in the current year as compared with the previous year. Aggregate analysis is used to look at the total picture over all employment sites. The number of employers participating in the program has grown steadily over the life of the program, as the law has been expanded to include employers with smaller work forces.

Given, however, that the program is mandatory, if survey responses are used for compliance monitoring, employers will have an incentive to falsify the results.

While the analysis soundly and consistently answers the questions it has posed, one major factor is omitted that is of particular interest with respect to projects like this one that impose requirements on private citizens or businesses: a thorough description of private program costs. A thorough report would attempt to calculate the private administrative costs imposed on the employers and employees participating in the program. These costs add to the direct costs of implementing the program.

A program such as this one would have afforded an excellent opportunity to set up a control group, had provision for one been made in the law for setting aside half of all eligible establishments as exempt from having to implement rideshare until a later date, but not exempting them from the survey requirement. Without a control group, it is not possible to state with certainty that the trends observed at the targeted employers are the result of the efforts of the MTA, or whether they would have occurred, to some degree, due to external factors such as increased traffic congestion.

The postmortem for this project would mention prominently the fact that participation in the project is mandatory, a situation that likely will not be replicated in many states.