Case Studies of Cost-Effectiveness of Transportation Measures to Improve Air Quality

JOHN H. SUHRBIER

Many transportation agencies claim that transportation systems management measures are not cost effective for purposes of air quality, although these same measures are used to accomplish other transportation objectives. This contention is examined by first discussing the issues that are important in performing a cost-effectiveness analysis and then presenting examples of the results of 31 separate analyses in 19 different urban areas. To develop consistent and comparable results in terms of the standard air-quality measure of dollars per ton of pollutant eliminated, it is necessary to examine the net present value of the time stream of all potential costs, benefits, and emissions reductions, because transportation measures normally contribute to the accomplishment of multiple objectives. The results indicate that the benefits of implementing transportation-type air-quality measures frequently exceed their associated costs and that transportation measures are comparable in terms of cost-effectiveness to vehicle inspection and maintenance and stationary-source controls. The implication of these findings is that transportation measures have a legitimate role to play not only in state implementation plans but also as part of the emissions-trading program of the U.S. Environmental Protection Agency.

An important question that has emerged from the work on transportation and air quality performed over the past few years by state and metropolitan planning organizations (MPOs) can be stated very simply: Are transportation measures cost-effective? Specifically, the statement frequently has been made at different levels of government--local, MPO, state, and federal--that transportation measures are not cost effective. Yet when the actions of these agencies are examined, it is found that these same measures are being widely implemented. How does one explain this apparent discrepancy between what agencies are saying and what they are actually doing? Rather than simply taking a position that transportation measures either are or are not cost effective, I will instead discuss some of the important issues that are involved in performing a cost-effectiveness analysis based on the results of roughly 31 separate analyses conducted in 19 different urban areas. Examples of these results are presented along with a statement of some of the important methodological findings.

The kinds of measures of concern are really those referred to as transportation systems management; a list is given below:

1. Public transit,
2. Preferential treatment for high-occupancy-vehicle (HOV) traffic,
3. Carpool and vanpool programs,
4. Automobile-restricted zones,
5. Parking management,
6. Park-and-ride areas,
7. Bicycling,
8. Alternative work schedules, and
9. Traffic-flow improvements.

The work being reported may be characterized as consisting of two basic steps. First is the definition of a consistent methodology for looking at the cost-effectiveness of transportation measures to improve air quality. How do you calculate a cost-effectiveness number that is reasonably comparable across measures or between different cities? Second is the application of that methodology to representative measures by using, where possible, implementation or design experience from different urban areas. In addition, the applications presented include combinations of actions, or program packages, and are not limited only to individual measures.

ISSUES IN APPLYING COST-EFFECTIVENESS TO AIR-QUALITY MEASURES

A few comments on the methodology of cost-effectiveness are appropriate as a start. The particular measure generally used for air-quality purposes is dollars per ton of pollutant eliminated. (To keep things simple, only hydrocarbon data are presented as part of the examples.) This is the measure that has emerged from stationary-source control and it makes sense in this context because it is reasonably consistent with the original Department of Defense cost-effectiveness analysis in which the objective was to determine the best way of accomplishing a given level of effectiveness. The major advantage in terms of air quality is that emissions do not have to be converted to air-quality levels, health, or dollars. These are controversial conversions, and it is nice to be able to avoid them.

There are, however, at least three main disadvantages when the cost-per-ton measure is used to evaluate air-quality projects involving transportation. First, direct application of this same measure to transportation simply does not reflect the multiple program benefits of transportation projects: economic development, mobility, fuel conservation. An important question, then, is the method by which these benefits are taken into consideration. Second, experience shows that it is difficult to consistently or even correctly apply cost-effectiveness analysis so that it is comparable with other economic analysis techniques such as the benefit/cost ratio or the net present value. The third problem is one of perspective. Do you calculate a cost-effectiveness number from the perspective of society at large, which is traditional for economic analysis, or from the perspective of the decision maker? The results can be very different.

EXISTING PRACTICE

Before case-study applications of cost-effectiveness analysis are developed, it is instructive to look first at existing practice. In examining state and MPO practice, the cost-effectiveness of transportation measures frequently is compared with that of vehicle inspection and maintenance and stationary sources. In general, and I recognize that there are always exceptions to generalizations, for transportation, the total implementation cost normally is simply divided by the tons of reduced hydrocarbon emissions. For stationary sources, however, it is common practice to subtract any process savings or process benefits from the implementation cost and then divide the result by the tons of reduced emissions. For some controls, the process savings exceed the control cost, and there is a resulting negative cost per ton; i.e., the benefits exceed the cost. This is a different approach than has been used in deriving some of the numbers commonly reported for transportation.

For vehicle inspection and maintenance, published U.S. Environmental Protection Agency (EPA) documents report that the cost is \$600/ton of hydrocarbon emissions reduced. This number is calculated by taking the cost of the program, subtracting the associated fuel benefits, and dividing by 2 (program benefits are being allocated equally to hydrocarbons and to carbon monoxide). There are, however, few examples in transportation where this same division by 2 is done. If you do not divide by 2, the cost-effectiveness for hydrocarbons is \$1,200/ton. Some analyses of vehicle inspection and maintenance also include the benefits of fuel savings from correct tire pressure, which has no direct linkage with emissions other than that the inspection can be designed to also include benefits from correctly inflated tires and other considerations related to vehicle safety.

In summary, it is important to examine the black boxes that are used to calculate the cost-effectiveness numbers being reported in public hearings and in technical reports. Different black boxes and different methodologies should not be used for each of these three basic kinds of emissions controls. If the results are going to be compared, it is essential that the calculation approaches be consistent.

CONCEPT OF NET COST

An approach to cost-effectiveness analysis of transportation measures to improve air quality is proposed that is economically sound and can be consistently applied. Equation 1 defines the net present value of cost (NPVC); Equation 2 defines the net present value of emissions (NPVE); and the dollars-per-ton calculation is given in Equation 3:

$$NPVC = \sum_{t=0}^{n} (cost_t - non\ air\ quality_t)/(1+r)^t \quad (1)$$

$$NPVE = \sum_{t=0}^{n} emissions\ reductions_t/(1+r)^t \quad (2)$$

$$Dollars/ton = NPVC/NPVE \quad (3)$$

There are two alternatives that have been proposed for calculating the cost-effectiveness of transportation measures to improve air quality that should be mentioned for purposes of comparison. The first is to allocate program costs over the different program objectives. This turns out to be difficult operationally; there simply is no easy way to do it. The second alternative is to use the marginal cost actually incurred for air-quality purposes. For measures such as ridesharing or bicycling, however, the marginal air-quality costs are probably zero, because air quality is seldom the major reason these kinds of programs are implemented. The result is that use of a marginal-cost approach ends with a cost per ton of pollutant eliminated of zero.

As anyone who has worked with economic analysis techniques realizes, there are a variety of interesting calculation issues. Although these are not dwelt on as a part of this paper, it is nonetheless important to acknowledge them. They are listed below:

1. Discount rate,
2. Time stream of emissions,
3. Discounting of future emission benefits,
4. Treatment of CO benefits,
5. Project life, and
6. Value of time saved and time increased.

With respect to discount rates, how do you discount a time stream of emission benefits? Are future emission reductions worth more or less than current emission reductions? The approach formulated does not really give any credit at all to CO emission reductions but implicitly assumes that a measure is being implemented for purposes of either HC or CO but not both. As will be seen in the examples, there are some interesting questions of project life to assign. For many measures, travel time is actually increased and the question is raised how this should be valued. In general in the analyses performed, the AASHTO guidelines have been used (1), as shown below:

Time Savings (min)	Percentage of Hourly Household Income
Low (0-5)	6.4
Medium (5-15)	32.2
High (>15)	52.3

These are nonlinear and assign a relatively small value to small time savings (0-5 min assumes 6.4 percent of the average household income) and a much larger value to larger time savings. For example, if time savings are greater than 15 min, the value of time is equal to 52.3 percent of average hourly household income. Many might argue that even this 50 percent value may be on the low side relative to the values derived from behavioral travel demand models.

EXAMPLES OF ANALYSES

New Orleans Transit Service Improvements

Table 1 illustrates the results of two possible bus-speed improvement measures that were analyzed for the city of New Orleans. The first is the traffic signal preemption for buses in four major corridors, and the second is a change in bus-stop spacing from an average of two blocks to an average of four blocks. Both measures produce improvements in bus travel time; the savings from the signal preemption, however, are not sufficient to actually cut out any bus runs or produce a saving in transit-agency operating costs. For the change in bus-stop spacing, a \$500,000 operating cost savings is estimated.

Benefits include user time savings resulting from the decreased travel time and savings in automobile operating costs resulting from reductions in vehicle miles of travel associated with the increased transit ridership. The net benefit from the signal preemption is \$105,000 and from the increase in bus-stop spacing is roughly \$1 million. Converting to a cost-effectiveness basis yields -\$19,000/hydrocarbon ton for the signal preemption and roughly -\$67,000/ton for the increase in bus-stop spacing.

The conclusion from this example is simple. If a reasonably correct economic analysis is employed, benefit/cost ratios in excess of 1 are possible for some short-range transit improvement measures. Converting the results to a dollar-per-ton basis yields cost-effectiveness numbers that are negative.

Houston North Freeway Contraflow Lane

The Houston North Freeway contraflow lane is illustrative of a program of actions where it is fairly difficult to separate out the effects of individual program components. This example also illustrates one of the problems of treating the value of time.

Table 1. Analysis of New Orleans bus-speed improvements.

Item	Signal Preemption	Bus-Stop Spacing
Costs ($)		
Capital	163,000	87,500
Operating	—	-500,000
Benefits ($)		
User time savings	-63,000	-300,000
Automobile operating cost savings	-205,000	-266,000
Net benefit ($)	-105,000	-979,000
Cost-effectiveness HC ($/ton)	-19,000	-66,600

Figure 1. Houston North Freeway contraflow lane.

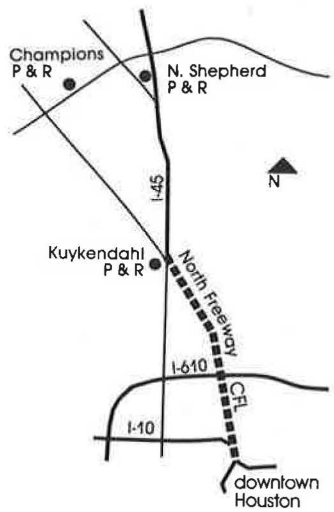


Table 2. Analysis of Houston North Freeway contraflow lane.

Item	Amount ($)
Costs	
Capital	4,413,000
Operating	9,369,000
Benefits	
User cost savings	-11,570,000
User time savings	-8,466,000
Net benefit	-6,254,000
Cost-effectiveness HC	-31,586/ton

The contraflow lane is 9.6 miles long and runs north from downtown Houston; it operates contraflow in both the morning and the afternoon peak periods (Figure 1). The lane is unique in that it allows authorized vanpools as well as buses. In addition to the high-occupancy-vehicle (HOV) lane, there are three park-and-ride facilities. There has been a major increase in transit service, and there is an active vanpool promotion program in the Houston area as well. In terms of use, the contraflow lane carried about 12,000 people per day in 1981; they were distributed in 180 buses carrying 7,000 people and 550 vanpools carrying about 4,900 people.

Table 2 summarizes the costs and benefits of the contraflow lane by using preliminary data developed from a series of UMTA Service and Methods Demonstration project evaluation surveys. In contrast to the New Orleans transit example, this is a fairly capital-intensive project involving certain construction costs and a very labor-intensive operation. Between the police and placement crews, there are approximately 20 people involved in setting up and taking down the lane each time period. The result is a $4.5 million net present value of capital cost and more than $9 million net present value in operating costs. The user cost savings, including just out-of-pocket fuel and operating cost savings, are $11.5 million. Combining these benefits with the capital and operating costs yields a net cost of $2.2 million. This, however, does not consider user time savings, which are estimated to be $8.5 million. Including these user benefits results in a total net benefit of the project, in an economic sense, of more than $6 million. If we convert this to a cost-effectiveness measure for hydrocarbons, -$32,000/ton is developed.

An interesting aspect of the contraflow-lane analysis is the method by which the value of time is calculated. In this particular application, there are both increases and decreases in travel time as well as three different kinds of users. These are the HOV-lane users, the automobile users in the off-peak direction from which the lane is being taken, and the automobile users in the peak-period direction. Each of these groups of people is affected in a different way. The lane itself is producing a 20-min time savings. The impact that is of importance, however, is really the change in door-to-door travel time, not just the 20-min savings from the lane. The evaluation surveys show that people spend time getting to the lane and using the park-and-ride facilities. For van passengers, the average travel-time change is a 10.1-min saving, roughly half the saving produced from the lane itself (Figure 2). Now if this average travel-time savings is used in the analysis as is normally done, the travel-time benefits do not offset the project costs because of the nonlinear manner in which user time savings are being valued. If instead the actual distribution of travel-time savings is used, where 32 percent of the van passengers are saving in excess of 15 min but also 4 percent have travel times that are increased by more than 15 min, the $6.3 million net benefit shown in Table 2 is derived.

The conclusion from this particular application is that both positive and negative results can be developed depending on the specific manner in which travel time is analyzed. An important observation, then, for those going through these kinds of analyses is that it is easy to manipulate the results to get almost any answer one wants.

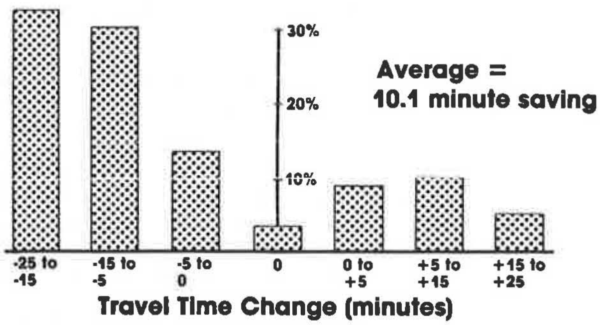
Boston's Downtown Crossing

Boston's Downtown Crossing project, which is generally regarded as having had a positive effect on the economic vitality of the downtown area, illustrates the problems of analysis perspective referred to earlier. A major downtown through street, Washington Street, has been closed to traffic and converted to a pedestrian zone, as have Winter and Summer Streets (Figure 3). Traffic restrictions have been imposed on five adjacent streets as well. Primary objectives of the project were to help in the economic revitalization of Boston's downtown area and to improve pedestrian space and facilities. Secondary objectives were to decrease noise and air pollution.

To summarize the major impacts of the project, pedestrian traffic has increased 11 percent; the modal utilization by visitors to the area has increased 34 percent for transit and decreased 35 percent for the automobile, and the demand for parking has decreased 20 percent. Retail sales have increased 16 percent over 2 yr in actual dollars, a rate about equal to the inflation rate for retail sales but in excess of the 5 percent annual rate of decline in real dollars before installation of the Downtown Crossing project. Traffic diversion also has occurred, although overall traffic volumes show a 5 percent decrease. There are some streets on which traffic congestion has increased, but there are more routes on which it has actually decreased, so overall no net change is assumed. Monitoring shows a decrease in both noise and emissions.

An important question is how these numbers are used to calculate a cost-effectiveness value. If one is an official of the city of Boston, there is a temptation to simply add up the benefits, which produces a net benefit per year of $15 million and a hydrocarbon cost-effectiveness ratio of -$104,000. This sounds very dramatic. (The capital cost was $4 million, and promotion and enforcement cost $1.1 million over 3 yr.) Critics will immediately point out, however, that this logic is incorrect. The major benefit is increased retail sales; the taxes represent a transfer from the consumer to the city, and at least some of the sales are a transfer from suburban shopping centers to the city. There is clearly a question of who benefits.

Figure 2. Distribution of van passenger travel-time changes on Houston North Freeway contraflow lane.



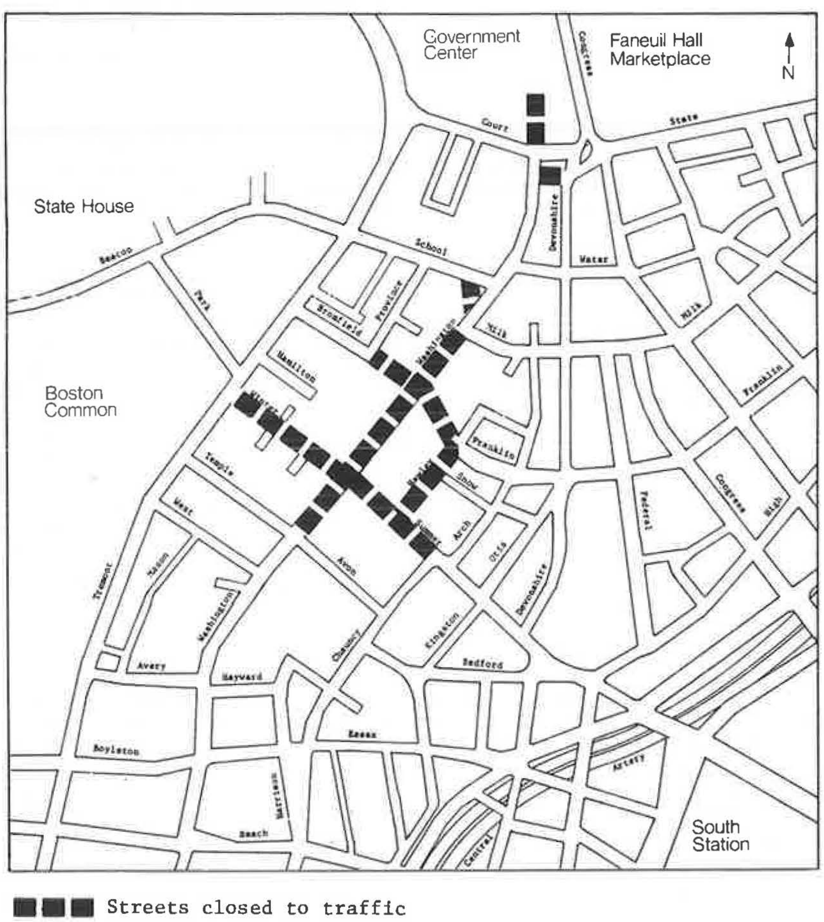
Detroit Park-and-Ride Lots

The final example is a park-and-ride lot program in the Detroit urban area, which illustrates both the difficulty in making required assumptions and the resulting sensitivity of the analysis to these assumptions. The first assumption involves the allocation of lot maintenance costs. Practically speaking, maintenance is not directly paid for in most park-and-ride programs. Snow plowing, cleaning, and other maintenance are performed as part of the routine maintenance operation that the state is doing anyway. If maintenance is not considered and a 12-yr lot life is assumed, a net cost of $2,900 results for the Detroit program. If, however, a maintenance cost of $40 per space is included, this cost increases dramatically to $45,600.

Lot life represents a second critical assumption. I am not sure that anyone knows what the realistic life of a park-and-ride lot is. An assumption of 12 yr produces a net cost of $2,900. Stretching this out to 25 yr, however, results in benefits that exceed costs by $37,500. There is just no reliable way of making some of these assumptions. In many cases, numbers are almost being pulled out of the air, yet there is a tendency to put a lot of confidence in the cost-effectiveness numbers being produced by the analysis even though some of the important input parameters have been almost guesses.

A third important assumption in this analysis

Figure 3. Boston Downtown Crossing project.



concerns the mode of access to the lot. The costs discussed above are based only on the number of cars parked in a lot. It is more correct to look at the actual number of users coming into a lot, and in fact the data show that at least 10 percent of the people are either being dropped off or walking to the lots. If this consideration is included, the $5,200 net cost figure for 25-yr lot life with maintenance changes to an $8,700 net benefit. Again, this is a dramatic shift.

CONCLUSIONS

Some of the methodological issues associated with the application of cost-effectiveness analysis to transportation measures to improve air quality have been briefly described, along with four examples. What can be concluded from both the material presented and the broader work from which this information has been drawn?

First, cost-effectiveness analysis, particularly in the area of transportation, frequently is incorrectly and inconsistently applied. Further, having gone through a number of these analyses, I must conclude that it is extraordinarily difficult to apply the methodology consistently in a way that produces truly comparable results. The kinds of measures are diverse and a sufficient amount of the required information is unknown, so that it is hard to be both comprehensive and correct. Few of us have sufficient internal discipline to be fully consistent in all the necessary assumptions.

Second, I do not find cost-effectiveness analysis to be particularly helpful for evaluating transportation air-quality improvement measures. It is difficult to interpret negative costs per ton. There are different levels of objectives being achieved and the absolute benefits being obtained from various transportation measures are both different and sometimes relatively small. In an economic sense, incremental analyses are not being developed as is routinely done with cost-benefit ratios. It is hard, then, to compare the results from different kinds of programs by looking only at the cost-effectiveness results.

Third, cost-effectiveness analysis does not tell anything about the distribution of impacts, so it is not really responsive to many of the political issues that are important to successful implementation. The overall results indicate, however, that many transportation measures can be comparable in terms of cost-effectiveness to vehicle inspection and maintenance and stationary-source controls. The statements being made that transportation measures are not cost effective are not supportable by the analyses performed.

It is appropriate to comment on the potential role of transportation measures in emissions trading. EPA has an emissions-trading program that involves the use of banking, offsets, netting, emission-reduction credits, and bubble analyses. Although originally developed for stationary-source controls, emission trading provides opportunities for the use of transportation that may be interesting in the coming years. Much more directly than in state implementation plans, the private sector is involved in deciding which controls to implement and attention is focused on the trade-offs among different types of measures. As a result of comparing the cost-effectiveness of transportation measures with stationary-source controls, there may be some interesting decisions in the next few years as firms are given a choice between implementing more stringent stationary-source controls or employee-based transportation programs.

REFERENCE

1. Manual on User Benefit Analysis of Highway and Bus-Transit Improvements. AASHTO, Washington, D.C., 1977.

Notice: The material presented is based on work performed for the U.S. Environmental Protection Agency. The findings and views presented are those of the author and do not necessarily represent those of EPA.

Publication of this paper sponsored by Committee on Transportation and Air Quality.

Methodology for Determining the Relative Cost-Effectiveness of Stationary- and Mobile-Source Controls

SALVATORE J. BELLOMO

A methodology for determining the relative cost-effectiveness of both stationary- and mobile-source controls (including transportation controls) is described and the results of applying this methodology to the Philadelphia Air Quality Control Region (AQCR) are discussed. First, the methodology is reviewed in terms of a five-step process: (a) adjustment of emission inventories, (b) determination of the initial list of controls, (c) determination of cost and emission reductions, (d) determination of other effects, and (e) evaluation of control strategies. Second, the methodology is illustrated through an application to the Philadelphia AQCR. Third, conclusions and implications of the relative cost-effectiveness of stationary- and mobile-source controls are presented.

The purpose of this paper is to describe a methodology for determining the relative cost-effectiveness of both stationary- and mobile-source controls, including transportation controls, and to discuss the results of an application of this particular methodology to the Philadelphia Air Quality Control Region (AQCR). The research was sponsored by the U.S. Department of Transportation and was undertaken with the cooperation of the U.S. Environmental Protection Agency (EPA) and several metropolitan planning organizations (MPOs) and states. The research objectives of the study were first to develop a methodology for determining the relative cost-effectiveness (economic, social, environmental, and political consequences) of both stationary-source and mobile-