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

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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.

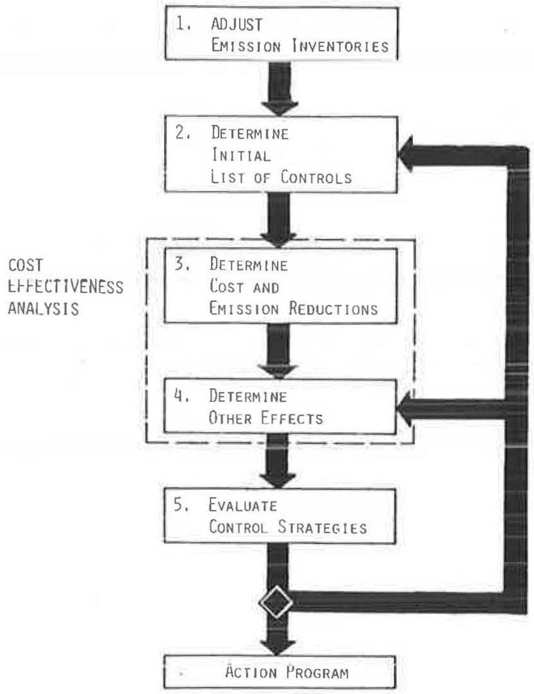
Methodology for Determining the Relative Cost-Effectiveness of Stationary- and Mobile-Source Controls

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-

Figure 1. Cost-effectiveness analysis framework.



source emission controls, including transportation, that could be incorporated into a typical state implementation plan (SIP). The second objective was to test the methodology by application to a major metropolitan area, in this case the Philadelphia AQCR, which was designated as a nonattainment area at the time of the study. The third objective was to develop practical guidelines for application of this methodology to other areas that are revising and updating their SIPs.

The first part of the paper will be an overview of the methodology in terms of a five-step process. In the second part the application and the results for the Philadelphia AQCR will be discussed. The last part will be an overview of some of the conclusions and implications of the work.

Before the methodology is presented, it should be noted that a key consideration in the research was to develop procedures that were sensitive to a wide range of potential users who are concerned with the decision-making process. A key principle used in the work is that evaluation criteria should be considered at greater levels of detail as the process moves toward the decision. Information generated by the methodology was developed by using data normally available to public agencies and the private sector; sketch-planning techniques were emphasized. The actions were structured into those for point, area, and mobile sources, which are categories usually developed by the public agencies concerned with air quality and other urban problems.

METHODOLOGY

Figure 1 shows the framework for the cost-effectiveness analysis. The methodology for assessing cost-effectiveness trade-offs between stationary and mobile sources is structured in five steps. The first step is to adjust the emission inventory for point, area, and mobile sources. The second step is to determine an initial list of controls for both mobile sources and stationary sources. Then the manner in which cost-effectiveness is defined in the broadest sense possible is included in step 3. The actual costs, both capital operating and maintenance, and the associated emission reduction for that pollutant are determined. In the case of this application, this was done for nonmethane hydrocarbons (NMHC), which are precursors for ozone. The fourth step was to determine other effects, such as those that are monetary in nature, those that are nonmonetary but quantifiable, or those that are just qualitatively expressed. The key in step 4 is to consider the whole gamut of socioeconomic and political factors related to the control measures being evaluated. Steps 3 and 4 are defined as the cost-effectiveness assessment. At this stage control strategies are evaluated by using the principle of increasing detail mentioned earlier. The fifth step is to evaluate these control strategies by sharing the results with the decision makers in the area who have to turn these projects into actions. At this point, feedback loops have been incorporated to step 2 in the process. I would like to note that when the research was done initially, the result, as usual, was a more complex process that had some 20 steps. But the realization of what users deal with in the various agencies and in the private sector caused the development of a more streamlined process that gave flexibility to the users in different metropolitan areas.

Regarding the first step in the process, it should be noted that this is basically a step to adjust normally available stationary- and mobile-source emission inventories. The data requirements include as a minimum the base-year inventory and the industrial growth and retirement rates, which could be obtained from regional forecasts made in the area or from state-level forecasting. In addition, data are needed on population growth rates for the area, growth rates on travel (including both trip purpose and vehicle miles of travel by trip purpose), and mobile-source emission factors. The output consists of future baseline emission inventories for point, area, and mobile sources.

The second step in the process is to determine the initial list of controls. Some of the transportation controls that are normally put into these SIP programs have been reviewed by Suhrbier in another paper in this Record; the list of measures that can be considered should be familiar. A comprehensive list based on the literature and metropolitan-area policies was compiled for this research. The transportation actions were screened by using criteria based on local goals and objectives. The measures for transportation are developed on a broader base than just air quality. Nevertheless, large lists can be reduced. The Washington Council of Governments started with a list of 55 control measures, and they are cutting it down to a list of 15 or 25.

The qualitative impacts could be determined based on the literature or actual experience in the area. The result of this step is to select controls for more-detailed analysis. For mobile sources or transportation sources, the screening process is much easier, but when complex stationary sources are involved, it is more difficult. For example, in Philadelphia there were 6,000 records reflecting different point sources in the region. This cannot be screened manually and a computerized approach is needed. It should be noted that for the stationary sources the various reasonable available control technologies (RACTs) and lowest achievable emission rates (LAERs) published by EPA were presented and these have been integrated into the stationary source analysis.

Step 3 was fairly important in that the annual capital, operating, and maintenance costs for mobile sources were often quite general in the literature

Figure 2. Philadelphia AQCR.

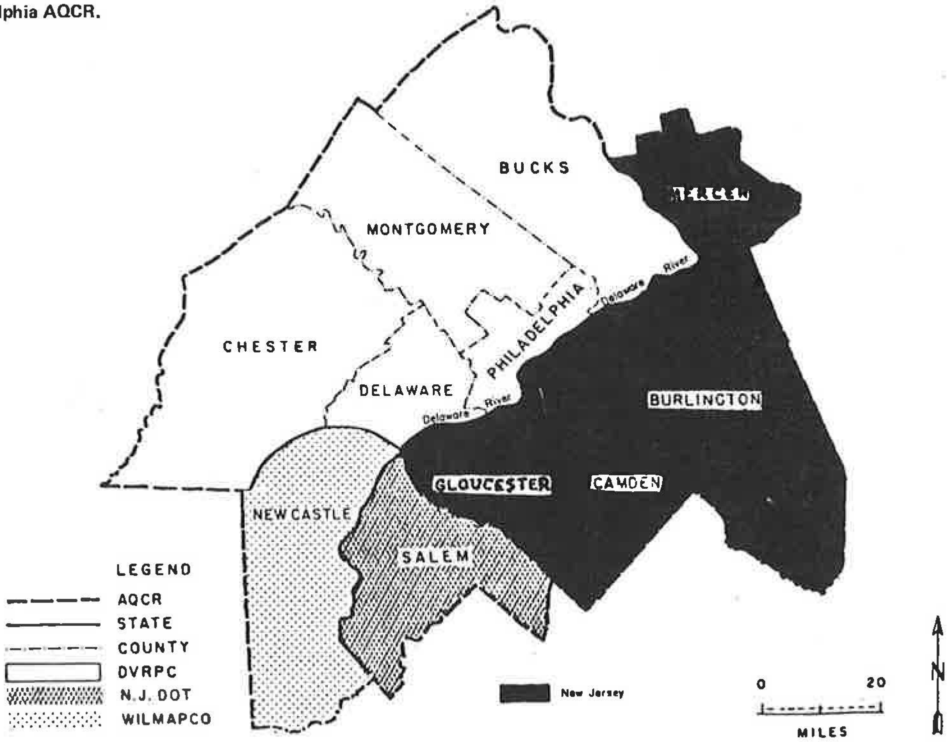
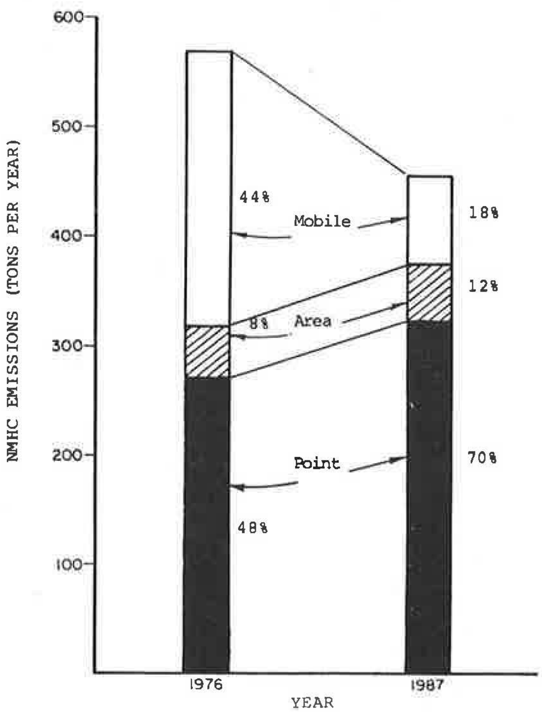


Figure 3. Baseline NMHC emissions for Philadelphia AQCR.



and often quite general when applied at the regional level. There is a need for more specific and consistent engineering estimates on projects that can be developed in the local areas. For stationary sources, the cost functions were developed from EPA data by specific industry types. Mobile-source cost function data available from the literature and from engineering studies were synthesized in the research work. Mobile-source control emissions reductions were obtained by using the literature and sketch-planning techniques. The cost data are annualized costs, including capital, operating, and maintenance.

Step 4 is to determine indirect costs and other effects. Indirect costs are important because transportation planners often consider direct capital and operating costs but exclude user costs. In this step the quantifiable indirect costs of users can be considered to offset transportation capital and operating costs. Other factors that can be considered include travel, mobility, land use, physical environment (other than air quality), energy, economic and fiscal factors, and social factors. The effects of these factors can be considered by using the case-study approach, sketch-planning methods, and traditional urban transportation planning systems technology. For economic factors (that is, how jobs are gained or lost by stationary-source and mobile-source controls), input-output models can be used. At the Rice Center in Houston, Texas, a promising approach to estimating these economic impacts has been developed. At the U.S. Department of Transportation, work is being done on an economic input-output model to quantify the number of jobs gained or lost through an application in the Baltimore region.

In the fifth step, again, preliminary screening is needed to eliminate controls with significant indirect costs or other effects. This screening can be done by using public agencies in an Adelphi panel approach or the approach can be broadened to include a base of local citizens to obtain different perspectives. At this point in the process, it is important not to waste time. If the measure cannot be used for one reason or another, it is really not worth subjecting it to further evaluation in the methodology. The measure should be screened out and the reasons why it was eliminated should be indicated. The Empirical Kinetic Modeling Approach (EKMA) can be used to estimate the needed hydrocarbon reduction. The least-cost model that was developed is a computerized model; it has been documented in the final report (1).

Figure 4. Least-cost model results without user cost considerations.

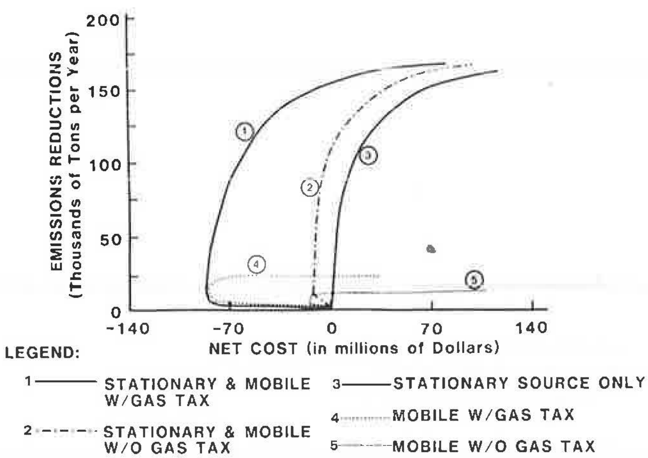


Figure 5. Least-cost model results with user cost considerations.

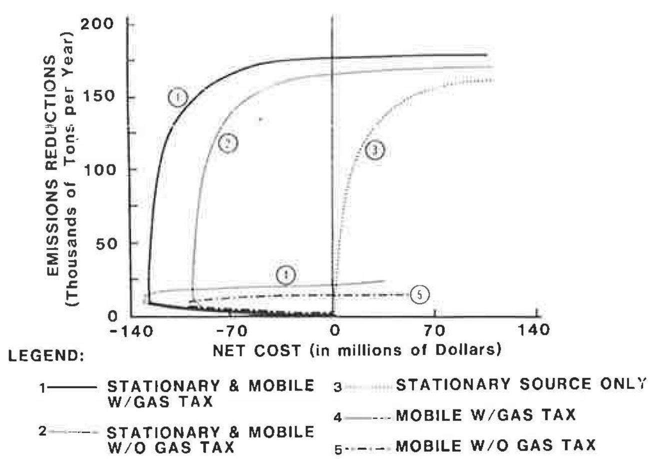
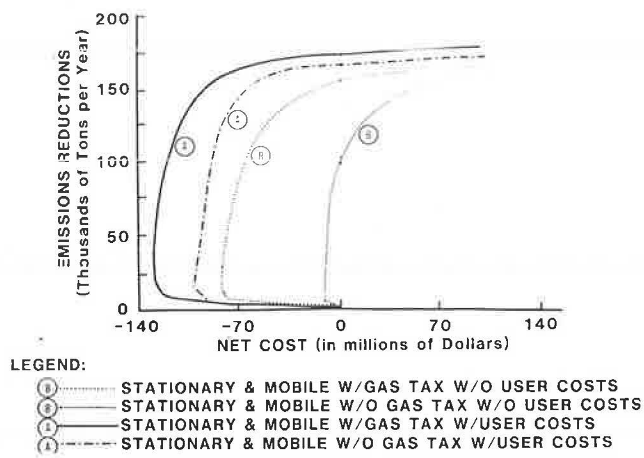


Figure 6. Comparison of least-cost model results with and without user cost considerations.



The output of the least-cost model includes the source classification code, the standard industrial code, the plant and point identification, emission reductions, the annualized direct cost of the control, the cumulative emission reduction, the cumulative annualized direct control costs, and the cost-effectiveness. The output is screened by using state and local agencies to select controls for implementation.

APPLICATION AND RESULTS

In this part of the paper the application of the five-step methodology to the Philadelphia AQCR (Figure 2) is discussed. As usual, when the beginning emission inventories are diverse (part of the state of New Jersey, part of the state of Pennsylvania, and part of the state of Delaware), a considerable amount of time is spent to obtain the best available emission inventory.

In Figure 3 the baseline NMHC emissions in the Philadelphia AQCR from the 1976 emission inventories and the 1987 estimates by Bellomo-McGee, Inc. (BMI), are shown in thousands of tons per year for point, area, and mobile sources. It should be noted that the data presented here were the best available at that time and are illustrative only. The industrial growth and retirement rates, the VMT, and the population growth rates that were used for the analysis are based on assumptions that have been made explicit in the final report (1). As noted, point sources are projected to increase from 48 to 70 percent of total emissions by 1987. Area sources are also due to increase from 8 percent to 12 percent. Nevertheless, due to the initiation of the Federal Motor Vehicle Emission Control Program, mobile sources dropped from 44 to 18 percent in 1987. This drop is consistent with reductions observed in the preparation of other SIPs.

Figure 4 shows the least-cost model results without user cost considerations. Hydrocarbon emission reductions versus net cost are shown for five different packages of actions. Negative costs represent savings. Because of the revenues from increases in the gas tax and vehicle registration fees, approximately 160,000 tons of emissions can be reduced with almost no direct costs. When the gas tax is excluded, however, the direct cost to achieve the same reduction is estimated at approximately $70 million. It should be noted that about 7 of the 25 transportation controls examined were selected in the least-cost model based on this application. For stationary sources only, 150,000 tons of emissions can be reduced from stationary sources at a direct cost of about $120 million; the first 22,000 tons are free because of the savings (primarily energy) on some of the controls. A maximum of approximately 15,000 tons of hydrocarbons can be reduced by mobile sources at a cost of about $28 million. However, when the two controls with large revenues are eliminated, the direct cost to achieve approximately the same emission reduction increased to $84 million.

Figure 5 shows the least-cost model results with user cost considerations.

Figure 6 was developed to show the impact of including user costs in the analysis. It shows the least-cost model results with and without user costs for two cases (with and without the gas tax). The difference between these two cases represents the effect of considered user costs in the analysis. For the case with the gas-tax increase, the cost difference between the scenarios with and without user costs is as high as $70 million. This difference increases to almost $100 million for the case with the gas-tax increase. These data underscore the importance of considering the costs in the analysis process.

CONCLUSIONS AND IMPLICATIONS

These findings have far-reaching implications for public and private efforts aimed at achieving air quality and other goals for metropolitan areas. The first conclusion is that stationary-source controls as a group were found to be more effective in directly reducing hydrocarbon emissions than mobile-source controls. Certain transportation controls that incorporated user costs were found generally to be more cost-effective than stationary-source controls even though their emission-reduction potential was not so great.

The incorporation of user cost considerations was found to reduce the net cost of emission reductions, and in the application in the Philadelphia region this amounted to $100 million annually. The methodology shown incorporates preliminary and more-detailed screening and a wide range of factors, some of which can be quantified and some of which cannot. It was found that by using this kind of methodology, looking at a number of alternatives, and making trade-offs between stationary and mobile sources, a timetable for the achievement of the ozone standard can be developed based on cost-effectiveness considerations. This gives a more realistic timetable for attainment of the standard.

A second finding is that integration of the results of both stationary and mobile sources is a better way to achieve air-quality goals. Since the Clean Air Act was passed, air-quality specialists have been divided into those who advocate control of stationary sources and those who advocate control of mobile sources. The methodology discussed here forces the two groups to get together to provide inputs on the costs and share with one another the impacts of the program, some of which can be quantified.

A third finding is that user cost considerations of transportation are needed in performing the cost-effectiveness analysis. Last, it is suggested that a cost-effectiveness rather than a cost-benefit framework be used by metropolitan areas in developing their SIPs.

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

Guidance from Disaggregate Emissions Inventory in Selection of Control Measures

KATHY BAILEY, MICHAEL CLIFFORD, AND PHILLIP SHAPIRO

A three-phase plan for development of an air-quality control program is discussed. The Council of Governments in Washington, D.C., has developed a plan in which phase 1 consists of development of a disaggregate emissions inventory, projection of emission levels for 1981, and sensitivity analyses. In phase 2 the control measures are defined and evaluated. Phase 3 involves seeking commitments by local governments and writing the plan.

The Council of Governments (COG) in Washington, D.C., has developed a three-phase plan for development of an air-quality control program in which phase 1 consists of development of disaggregate emissions inventory, projection of emission levels for 1987, and sensitivity analyses. In phase 2 the control measures are defined and evaluated. Phase 3 involves seeking commitments by local governments and writing the plan.

COG has been designated to do air-quality planning for a relatively large region, which covers three states (Maryland, Virginia, and the District of Columbia, if the District of Columbia is considered a state). Essentially all the work on the state implementation plans (SIPs) for the District and for portions of Maryland and Virginia is done by COG.

The work at COG is similar to the work states in other parts of the country are doing: developing the inventory for both stationary and mobile sources and examining and evaluating control measures. COG works with the states and the local jurisdictions, but the responsibility lies mainly with COG for the development of the plan that will form the basis for SIP revision. COG uses an interdisciplinary approach; several different departments work on the program. The Department of Environmental Programs has been given responsibility for overall coordination and management of the program as well as development of the stationary-source portion of the inventory (phase 1). The Department of Transportation Planning is responsible for development of the mobile-source portion of the inventory. In phase 2 the departments are working together to evaluate control measures; the Department of Community and Economic Resources is providing input to the evaluation of some measures. Also, the COG Computer Center has provided a programmer/analyst who worked on the inventory for almost a year.

COG started this program almost 2 yr ago. It was divided into three main parts. First, the problem had to be better defined. Previous work was inadequate for the level of detail that was needed. It would have been inconsistent to use data generated in earlier efforts to compare with the 1980 data. Phase 1 of the planning effort consisted of defining the problem and developing the detailed inventory that is the focus of this paper. Once the inventory had been developed, it showed emission levels that were too high to satisfy the ozone standard. Next came phase 2, the stage in which control measures were considered. More than 50 control measures were defined and are currently being evaluated. Phase 3 will involve seeking commitments and writing the plan.

Phase 1 also had three parts. First, emissions inventories for both 1980 and 1987 were developed.