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Cost-Effectiveness Model for the Analysis of Trade-Offs Between Stationary and Transportation Emission Controls in Baltimore

ARMANDO M. LAGO, SALVATORE BELLOMO, KEVIN HOLLENBECK, SAUD SIDDIQUE, and JOE MEHRA

ABSTRACT

The application of a cost-effectiveness model for the attainment of ozone standards in Baltimore is described. Cost-effectiveness programs for Baltimore are designed taking into account direct implementation costs and user costs. The mix of controls in the cost-effective solution varies when either direct implementation costs or social costs are considered. The economic and social impacts of the cost-effective solutions are discussed. Finally, the results of the Baltimore application are contrasted with the results of an earlier study in Philadelphia.

Under the provisions of the Clean Air Act (40 CFR 50, revised July 1, 1980) each state must prepare a state implementation plan (SIP) for meeting air quality goals. The SIP, which is usually prepared by a designated metropolitan planning organization (MPO), contains programs for control of mobile sources of air pollution [including transportation control measures (TCMs)] and stationary sources to meet the air quality emission goals. However, the plan may also consider other important socioeconomic, mobility, and environmental factors in the design and choice of pollution abatement and control strategies. A review of SIPs conducted by BKI Associates, Inc. (1) found that the SIP planning methodologies were applied separately to control of transportation sources and to stationary sources, a procedure that limited the opportunities for coordination and trade-off of mobile-source and stationary-source controls with the concomitant loss of information and opportunities for optimization of the strategies contained in the SIPs. The results of the development and application of a cost-effectiveness model for the analysis of trade-offs between controls of stationary sources and transportation sources for hydrocarbons in the Baltimore standard metropolitan statistical area (SMSA) are summarized.

BASIC COST-EFFECTIVENESS CONCEPTS

Cost-effectiveness analysis provides an efficient method for coordinating and trading off stationary-source and mobile-source control options. The method consists of defining a measure of effectiveness (MOE), in this case the reduction of hydrocarbon (HC) emissions, and then estimating costs of abatement control per unit of HC removed. Abatement strategies in specific pollutant-emitting industries are next ranked in terms of cost-effectiveness ratios (i.e., dollar costs divided by units of HC removed). Then, given an objective of total HC reductions derived from air quality standards for the region, the least-cost package of abatement strategies for meeting the standard is selected by picking those strategies with lowest cost per unit of HC removed and avoiding the higher-cost strategies and alternatives. Designing the least-cost package, sometimes called the cost-effective package, enables environmental planners to consider and trade off abatement strategies, such as those for stationary point sources versus those for mobile sources, an important feature sometimes lacking in the methodology used in developing the SIPs.

At the outset it should be noted that cost-effectiveness analysis per se is neutral with respect to the definition of the target level of emission reductions. In addition, cost-effectiveness analysis assumes that the effectiveness target is valuable in the sense that the benefits from its accomplishment exceed its costs. If the effectiveness target of HC reductions is not valuable, successively lower targets must be considered until one of these targets is deemed valuable. In this respect, cost-effectiveness analysis is a more restricted tool than benefit-cost analysis, which determines whether the benefits of the air quality standard are greater than its costs. However, although benefits from air pollution control have been quantified in terms of impacts on health (2), land values (3), and cleaning costs (4), among others, it is safe to state that controversy surrounds the estimation of these benefit impacts, so cost-effectiveness analysis is a more appropriate analysis technique.

Performing a cost-effectiveness analysis of air pollution control entails five major analytical operations, which are described in the following in the context of an application of the cost-effectiveness methodology to the planning of control of HC emissions in the Baltimore SMSA.

PROJECTION OF EMISSION INVENTORIES

The first step in the analysis is to project the emission inventories. The inventory of point sources (industrial processes and power plants) and area sources (residences, institutions, laundries, and gas stations) is usually contained in the National Emissions Data Systems (NEDS) (5) data base by type of pollutant. The point-source emissions inventories can be projected by assigned retirement rates to the existing sources and on the basis of new industrial growth rates expected by the industrial sectors. Value-added growth rates by industry sector provide the next most reasonable proxy if retirement rates are unavailable. Some area source emissions (e.g., dry cleaning and solvent evaporation) may be projected on the basis of general population growth rates, whereas others (e.g., fuel handling and asphalt paving) may be projected on the basis of vehicle miles of travel (VMT).

Mobile-source inventories, which include highway and off-highway vehicles, are developed by political jurisdiction, taking into account data on VMT, average speed, vehicle trip ends, and emission rates from the MOBILE I (6) and II (7) computer programs of the U.S. Environmental Protection Agency (EPA). The mobile-source inventories are projected on the basis of VMT growth rates and the effects of the Federal Motor Vehicle Emission Control Program. The projection data for mobile sources are available through the continuing, cooperative, and comprehensive (3c) transportation planning process. In the Baltimore SMSA application described here, projections of the emission inventories were available from local governmental sources. Projections of point and area HC emissions were available from the Maryland Department of Health and Mental Hygiene, and mobile-source emissions were available from the Baltimore Regional Planning Council (BRPC). These projections are presented in Table 1.

TABLE 1 1987 Projections of HC Emissions in the Baltimore SMSA

	Reactive HC Emission (short tons/yr)	
Source	1980	1987
Point	39,963	42,863
Area	38,842	40,667
Mobile	64,383	34,088
Total	143,188	117,618

Note: All the estimates come from BRPC and the Office of Environmental Programs of the Maryland Department of Health and Mental Hygiene.

DETERMINATION OF TARGET LEVEL OF EMISSION CONTROL REQUIREMENTS

The next analytical operation is to estimate the regionwide emission reductions needed to attain ambient air quality standards. The degree of HC emission control needed can be computed from an approved photochemical dispersion model, such as the Empirical Kinetic Modeling Approach (EKMA). The EKMA (city-specific level III) model produces a more realistic estimate of required emission reductions than the previously used rollback methods because (a) it is based on the chemical kinetics of O_3 production in smog chamber experiments and (b) it can be adjusted to reflect the existing mix of ambient HC and NO_x in the study region. EPA does not accept nonattainment plans for ozone that are based on linear or proportional rollback methods. There was no need for the researchers to apply the EKMA model to the Baltimore SMSA, because the target level of HC emission reductions had been estimated by the Maryland Department of Health and Mental Hygiene at 40,000 short tons per year of reactive HC by using similar methods to the one described earlier. The 40,000 short tons of reactive HC per year became then the target of the air pollution control efforts.

ESTIMATION OF COSTS AND EFFICIENCY OF AIR POLLUTION CONTROL OPTIONS

The control options for point sources of HC emission (8) include flares, thermal and catalytic incineration, carbon adsorption, Venturi scrubbers, floating roofs, and so on. As the regulatory agency, EPA has developed reasonably available control technologies (RACTs) for existing sources. For new sources, technologies corresponding to the lowest achievable emission rates (LAERs) are recommended. The area-source control technologies include carbon adsorption for dry cleaning, water coating for solvent evaporation, vapor balance and vacuum assist for fuel-handling sources, and emulsified asphalt for asphalt paving. Most of the area-source emission control options correspond to RACTs.

The estimation of costs of HC control options for point sources is complex because of the many industries involved and the wide variation in industrial processes. For point sources, the capital costs of controlling air emissions discharged through smokestacks are a function of the size (air flow) of the stack, whereas the operating and maintenance (O&M) costs are the product of control equipment size and operating time. Because data on the characteristics of air flow are not always available, a useful surrogate for estimating capital costs found in most emission inventories is the production or operating capacity (e.g., tons of fuel burned or chemical products) of the sources vented to the stack. Similarly, annual O&M costs can be estimated from information on the total amount of fuel used or output per year. The costs of each control operation include two functions, namely, one for capital costs and another for O&M costs. Total capital costs are defined as the sum of the cost of equipment, taxes and freight, installation, engineering, and contingencies. O&M costs include labor, parts, materials, utilities, waste disposal, energy penalties or credits, and by-product recovery credits, if any. In order to reflect economies of scale the HC emission control cost functions estimated are nonlinear functions of the following type:

Capital cost:

$$C_C = A(X_D)^{\alpha + 1} \tag{1}$$

O&M cost:

$$C_{OM} = B(X_0)^{\gamma + 1} \tag{2}$$

where

C_C = total capital costs in 1976 dollars;
X_D = maximum design rate for the point source in Source Classification Code (SSC) units per year;
A, α = empirical constants;
C_{OM} = annual O&M costs in 1976 dollars;
X_0 = annual operating rate, usually defined as amount of material produced (in some instances material consumed) in a given time, which may be used to compute emission factors, in SSC units per year; and
V, γ = empirical constants.

The design and operating rates of the foregoing cost functions are expressed in terms of the industrial units used in the NEDS system (the SCC units) (9). These SCC units may be tons, gallons, cubic feet, and other units appropriate to each industry. The cost functions were estimated by Energy and Environmental Analysis, Inc. (10), fitting a line to the costs for different scales of application reported in the literature. The capital costs are annualized by using capital recovery factors and added to the O&M costs to develop annual costs of abatement control for a given control option (RACT or LAER). The capital recovery factors used 10 percent discount rates and economic life of 10 years for the equipment.

For area sources the estimation of the costs and the HC emission reduction is accomplished on a more aggregate basis. The generalized cost functions are linear and the cost driving variable is now defined as annual tons of current emissions. Detail on the specifications of these functions has been presented by BKI Associates, Inc. (1) and Ecosometrics (11).

The methodology for estimating the TCMs is straightforward. Costs may be estimated for each of the TCMs by using unit costs in the literature or specific engineering estimates. Specific unit costs for TCMs are a function of the individual project, its location, and also the size of the urban area. However, generic unit costs can be developed (1,12) as a function of the size of the urban area, transit level of service, and the highway level of service. Annual recurring costs of operation, administration, maintenance, and enforcement make up the bulk of the costs incurred.

With respect to emission reduction estimates for mobile-source controls, these are obtained through sketch-planning techniques (13,14) or through the application of the Urban Transportation Planning System (UTPS). Essentially, mobile-source controls are translated into reductions in factors influencing emissions (vehicle trip ends, VMT, vehicle hours of travel, network speed). Once the transportation effects have been determined, the motor vehicle emissions can be estimated by using EPA's MOBILE I or II computer models.

With regard to the application of mobile controls for HC in the Baltimore SMSA, the analysis began with a list of initial transportation controls and their costs and impacts on HC reductions, developed by JHK and Associates (15) for BRPC. This study developed implementation costs and HC reduction impacts for the major corridors of the Baltimore metropolitan region.

The costs of the transportation control program for the Baltimore SMSA are presented in Table 2. These costs were developed by expanding to the metropolitan region the transportation control programs proposed by BRPC for the major corridors noted earlier (15). Economies of scale were assumed to be negligible. Equivalent annualized capital costs and operating costs were calculated by using a 10 percent discount rate (same as stationary sources) and reasonable assumptions of service life (for example, 10 years for traffic control systems, 15 years for buses, and 30 years for highway construction). Some of the TCMs were not expanded to the region because they involve spot improvements (such as SCC 954, 964, and 965). An important assumption made in developing costs of the inspection and maintenance program was that they would be borne by the users, who would pay through inspection fees for the costs incurred by the private sector (e.g., at gasoline stations and motor vehicle repair shops) and the program administration costs incurred by the Maryland Department of Motor Vehicles (DMV).

In addition to the direct implementation costs, user cost savings were also estimated for the TCMs. The user cost savings estimated included vehicle operating costs, travel time costs, and transit fares, whenever applicable. Accident costs were not estimated to correspond to the analytical procedures used by BRPC. The user unit cost estimates were derived by updating the 1975 AASHTO (16) estimates by using changes in the consumer price index (CPI). The demand projections used in the estimation of user cost savings made extensive use of the analysis of changes in VMT induced by the TCMs available from a previous study in Baltimore (15).

DESIGNING THE LEAST-COST POLLUTION CONTROL PROGRAM

The next analytical step is to select the mix of control options required to obtain air quality standards at minimum costs. Essentially the problem is one of selecting the least expensive set of control strategies that bring the total emissions in the region below a maximum emission level (E_{max}). The problem solution is formulated as an integer program as follows:

Minimize

$$\sum_{i=1}^{j} f_i(X_i)$$

Subject to

$$\sum_{i=1}^{j} g_i(X_i) \geq b \qquad X_i = 0, 1, \ldots, N_i$$

where

X_i = level of control on source category i,
$f_i(X)$ = cost of control level X on source category i,
$G_i(X)$ = tons reduced by control level X on source category i (this function is assumed to be an increasing function of X),
N_i = maximum level of control available for source category i, and
b = emission reduction needed ($b = E_{max}$) to obtain ozone standard.

TABLE 2 Direct and User Costs and Emission Reductions of Transportation Controls in the Baltimore SMSA

		Direct Costs ($ 1980)						
SCC	Action	Capital	Annual O&M	Annualized Capital	Total Annualized	Nonmethane HC Change (%)	Annual User Costs[a] ($ 1980)	Net Annual Costs (direct and user) ($ 1980)
950	Inspection and maintenance[b]	20,000,000	7,710,000	3,540,000	11,250,000	-23.460	787,500	12,037,500
951	Signal retiming, rephasing, and interconnection	427,200	21,600	76,660	98,260	-1.880	-2,019,410	-1,921,150
952	Remove signal or switch to flashing at nighttime	85,800	-61,800	14,760	-47,040	-0.227	-1,514,800	-1,561,840
953	Modify transit route, schedules, frequency, bus stops	3,666,000	-911,760	647,040	-264,720	-0.123	153,000	-111,720
954	Feeder service	1,713,000	371,500	293,200	664,700	-0.011	41,280	705,980
955	Improve transit marketing, information, amenities	2,444,580	166,460	430,390	596,850	-0.134	-229,270	367,580
956	Residential-based ridesharing	0	122,470[c]	0	122,470	-0.683	-15,756,620	-15,634,150
957	Employer-based ridesharing	0	1,597,240[c]	0	1,597,240	-3.116	-73,110,580	-71,513,340
958	Parking management	441,600	0	78,120	78,120	-0.010	-157,090	-78,970
959	Commuter park-and-ride lots[d]	17,794,800	116,640	3,070,920	3,187,560	-0.097	-2,185,270	1,002,290
960	Multiple use of parking facilities	489,600	47,400	86,660	134,060	-0.076	-684,300	-550,240
961	Improve bicycle facilities	4,657,200	52,800	822,600	875,400	-0.009	-296,390	579,010
962	Institute or extend turn lanes	12,638,400	2,400	2,241,480	2,243,880	-0.157	-2,966,940	-723,060
963	Improve roadways (geometrics and signing)	19,981,200	5,000	3,536,670	3,541,670	-0.183	-5,127,780	-1,586,110
964	Contraflow bus lanes	150,000	-24,000	27,000	3,000	-0.001	22,060	25,060
965	New signals[e]	312,000	36,000	55,200	91,200	+0.050	1,436,260[f]	1,527,460
966	One-way streets[e]	250,000	0	44,250	44,250	+0.001	58,680	102,930

[a]Negative figures denote savings or net benefits.

[b]These costs include $20 million of capital costs of investments by the private-sector operators, $1,875 million of annual administration costs by the Maryland Department of Motor Vehicles, $5.835 million of annual operation of the program by the private-sector operators, $11.25 million of inspections paid annually by the users, $5.25 million of annual repair costs of vehicles, and $4.462 million of annual fuel savings by the users.

[c]These figures refer to annual costs of a 6-year ridesharing program. To calculate the costs of the program in its entirety these costs must be multiplied by 6.

[d]The capital costs of commuter park-and-ride lots represent mostly right-of-way (35 percent) and construction (53 percent) expenses, the residual comprising shelters, signs, etc.

[e]These measures result in Increased nonmethane HC emissions.

[f]Excludes safety and accident cost savings.

The inputs to the least-cost model are the costs and emission reductions estimated in the previous steps and the estimated regionwide emission reductions needed to attain ambient air quality standards. Because the least-cost model has been described elsewhere (1) only its highlights are presented here. The workings of the least-cost model are as follows. Based on the available control options, the model selects sources for additional emission control by using the criteria of cost-effectiveness. Each control option is ranked according to its annualized cost per ton of emission reduction. The control option with the lowest cost per ton reduced is chosen first, the second-lowest cost per ton reduced next, and so on, up to the required emission reduction (specified by the user). The required emission reduction is based on the amount of HC emissions needed to attain a given annual ozone standard. If the available control options do not provide sufficient emission control to meet the specified HC reduction, the standard cannot be met and maximum control of all controllable sources in the inventory has been reached.

The least-cost model was then applied to design an HC pollution control program for the Baltimore SMSA. The control program selected was to be the one that achieved the target reduction of 40,000 tons per year at minimum social costs, which were defined to include the direct implementation costs plus the user costs with adjustments to remove double counting. A sensitivity analysis was also conducted to examine how the least-cost program would change if only direct implementation costs (no user costs) were considered. Of particular interest in the least-cost model simulations were the trade-offs between stationary-source and mobile-source controls in reaching the target level of emissions.

The application of all the control programs--stationary and mobile--results in controlling close to 840 HC pollution sources out of a possible total of 1,300 sources in the NEDS files. The sources subject to controls account for 81,700 reactive HC tons, and the emission control programs, if applied in their entirety, would result in reductions of 48,200 reactive HC tons, exceeding the 40,000-ton target. This results in opportunities for trading off strategies for control of stationary versus mobile sources.

As shown in Table 3, the transportation control options account for only 15 percent of the HC emission reductions in the cost-effective program package. Moreover, a large number of the transportation control options are cost effective if their user cost savings are considered. Inclusion of user cost considerations provides the correct basis for comparison because the sum of direct plus user costs renders the true social costs (public plus private) of each respective option. The stationary-source and area-source control options account for 86 percent of the HC reductions, but these reductions are achieved at the expense of greater costs. Not all the transportation control options are selected in the least-cost program. Some of them, such as SCC 965 (new signals) and SCC 966 (one-way streets) lead to increases in HC emissions and are therefore correctly excluded from the least-cost program package.

The results of the least-cost model considering only direct costs are presented in Table 4, in which the exclusion of user costs works to the disadvantage of the transportation control options whose cost-effectiveness ratios increase by the lack of consideration of the user cost savings. The relative small contribution of the TCMs in improving air quality and the political and institutional factors involved in selecting the TCMs often make cost effectiveness a secondary issue. Indeed, the TCMs will assume a smaller role in the future as new car control programs and vehicle inspection and maintenance programs continue to reduce vehicle emissions.

In this application of the cost-effectiveness model to the Baltimore SMSA, the HC emission control program achieves the target level of HC reductions and it is possible to trade off programs for stationary-source versus mobile-source control. However, this may not be typical of other areas. The reader should remember that the transportation control program postulated here has a broader metropolitan scope than the major corridor options developed by BRPC.

The total-cost curves of HC emission control in

TABLE 3 Summary of Cost-Effectiveness Model Results: Direct and User Costs

SCC Emission Source	Reactive HC Emission Reduction (tons/year)	Total Annualized Costs ($ 1987 000,000s)	Cost per Ton of HC Removed ($ 1987 000s)
Included in cost-effectiveness program package			
Mobile-source controls			
957 Employer-based ridesharing	608.0	-132.0	-217.0
956 Residential-based ridesharing	133.0	-28.90	-217.0
963 Improve roadways	35.7	-2.930	-82.1
958 Parking management	1.95	-0.146	-74.8
960 Multiple use of parking facilities	14.8	-1.020	-68.6
952 Remove signal or switch to flashing	44.3	-2.89	-65.2
962 Institute turn lanes	30.7	-1.34	-43.6
951 Signal retiming or rephasing	367.0	-3.55	-9.68
953 Modify transit routes and schedules	24.0	-0.207	-8.61
950 Inspection and maintenance	4,580.0	22.3	4.86
	5,839.45	-150.683	-25.80
Stationary-source controls (point and area)	34,160.55	41.68	1.22
Total	40,000.0	-109.00	-2.72
Not included in cost-effectiveness program package			
955 Improve transit marketing	26.20	0.680	26.0
959 Commuter park-and-ride lots	18.90	1.85	97.9
964 Contraflow bus lanes	0.195	0.046	237.0
954 Feeder service	2.15	0.31	608.0
961 Bicycle facilities	1.76	1.070	609.0
	49.205	4.956	100.721
All stationary-source controls (point and area)	8,150.795	5.63×10^6	690,730.2
Total	8,200.00	5.63×10^6	686,585.4

Note: Mobile-source controls SCC 965 (new signals) and SCC 966 (one-way streets) are not included because these measures result in increased nonmethane HC emissions.

TABLE 4 Summary of Cost-Effectiveness Model Results: Direct Costs Only

SCC Emission Source	Reactive HC Emission Reduction (tons/year)	Total Annualized Costs ($ 1987 000,000s)	Cost per Ton of HC Removed ($ 1987 000s)
Included in cost-effectiveness program package			
Mobile-source controls			
953 Modify transit routes and schedules	24.0	-0.490	-20.4
952 Remove signal or switch to flashing	44.3	-0.087	-2.0
951 Signal retiming or rephasing	367.0	0.182	0.495
956 Residential-based ridesharing	133.0	0.227	1.7
950 Inspection and maintenance	4,580.0	20.8	4.54
957 Employer-based ridesharing	608.0	2.95	4.86
	5,756.3	23.582	4.097
Stationary-source controls (point and area)	34,243.7	48.118	1.405
Total	40,000.0	71.70	1.793
Not included in cost-effectiveness program package			
960 Multiple use of parking facilities	14.8	0.248	16.7
964 Contraflow bus lanes	0.195	0.006	28.4
955 Improve transit marketing	26.2	1.10	42.2
958 Parking management	1.95	0.145	74.0
965 Institute turn lanes	30.7	4.15	135.0
963 Improve roadways	35.7	6.55	183.0
959 Commuter park-and-ride lots	18.9	5.90	311.0
954 Feeder service	2.15	1.23	572.0
961 Bicycle facilities	1.76	1.62	921.0
	132.355	20.949	158.279
All stationary-source controls (point and area)	8,067.645	5.63×10^6	697,849.2
Total	8,200.00	5.63×10^6	686,585.4

Note: Mobile-source controls SCC 965 (new signals) and SCC 966 (one-way streets) are not included because these measures result in increased nonmethane HC emissions.

Baltimore are presented in Figure 1. The total-cost curves with user costs (which represent the social costs) show that the user cost savings generated by the transportation control programs enable emission reductions of approximately 45,000 tons of reactive HC through stationary-source and mobile-source controls at negligible social costs. However, the distributional considerations cannot be ignored because the affected industrial plans would have to bear a huge control cost, whereas the transportation users enjoy significant benefits. Regarding solely the stationary-source controls, the total-cost curves show diminishing returns after reaching 33,000 short tons of reductions of reactive HC through stationary-source controls. Approximately 33,600 HC tons are reduced through stationary-source controls at an annual cost of $23 million of annualized total costs, and 37,700 tons cost $78 million, whereas 41,000 reactive HC tons from stationary sources cost $739 million in 1987 dollars. As may be seen from Table 4, the presence of user cost savings in the mobile-control options diminishes the social costs of HC reductions to negligible amounts.

Figure 1 also shows the direct costs of HC emission control in the Baltimore SMSA. As shown, it is possible to reduce as much as 24,000 short tons per

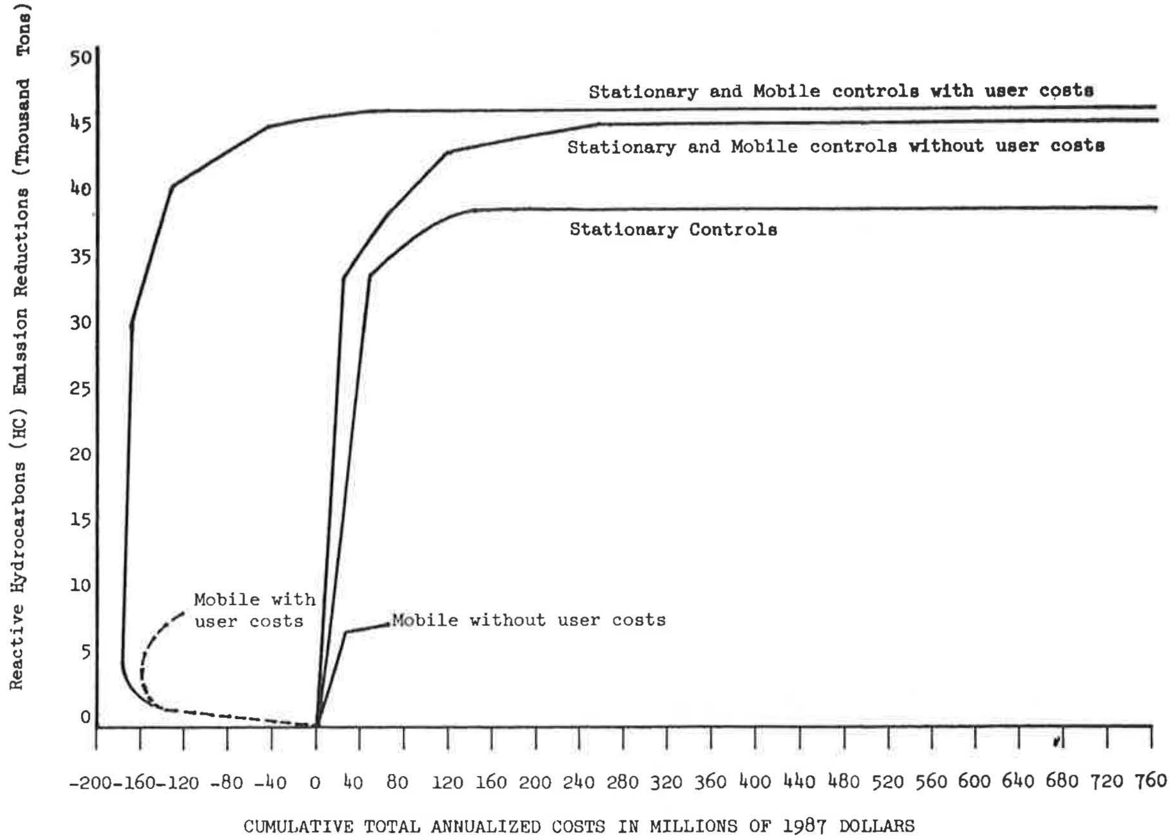

FIGURE 1 Cumulative total annualized costs of HC emission control in the Baltimore SMSA.

year of reactive HC at the moderate annual direct cost of $4.85 million in 1987 dollars. Reduction of 30,000 short tons costs $9.8 million in 1987 dollars every year. For the target of HC emission reductions in Baltimore of 40,000 short tons, the annual direct costs of implementation would be $71.7 million in 1987 dollars. However, it is costly to set the target level of emission reductions above 40,000 tons because reduction of reactive HC from 40,000 to 43,500 short tons costs an extra $32 million in direct costs annually. It may be concluded that reductions up to 40,000 tons of reactive HC are achieved at moderate costs, but that above this figure, the extra reductions are achieved at significantly higher costs.

The HC control cost functions of the Philadelphia Air Quality Control Region (AQCR) (1) and the Baltimore SMSA are contrasted in Figure 2. The direct-cost functions (which include the annual O&M costs and the annualized capital costs) are similar in shape in both areas except that the Baltimore cost curves become flatter much earlier than the Philadelphia curves, denoting that the costs per ton are cheaper in Philadelphia because of an economic base heavy with petrochemical concerns. In Baltimore the relatively lesser importance of petrochemicals affords less opportunities for point-source controls. As shown earlier, emission reductions greater than 40,000 tons are very expensive in Baltimore because less cost-effective methods must be employed after this level of emission reduction. Identical conclusions may be reached by focusing on the cost functions with user costs, except that in Baltimore large user cost savings accrue because of the transportation control program. With these considerations, the least-cost solutions differ in both areas, as follows:

Area	Least-Cost Solutions of Reductions in Reactive HC (short tons 000s): Stationary Source	Mobile Source
Baltimore SMSA (reactive HC)	34.2	5.8
Philadelphia AQCR (nonmethane HC)	150.0	15.0

In the Philadelphia AQCR stationary-source controls are relatively more cost effective; therefore its least-cost strategy concentrates less relative effort on mobile-source controls.

ECONOMIC AND SOCIAL CONSEQUENCES OF COST-EFFECTIVE PROGRAM

The final step in the analysis is to assess the economic, social, mobility, and environmental impacts of the control options in the least-cost set and their evaluations in the light of local preferences and policies. Because of their importance, only the economic and social impacts are discussed here. The reader is referred to the consultants' report (11) for a review of the mobility, energy, and other environmental impacts.

Economic Impacts

The estimation of economic and social effects is important because the costs of pollution abatement and control may adversely affect some of the industries in the region. This would be true partic-

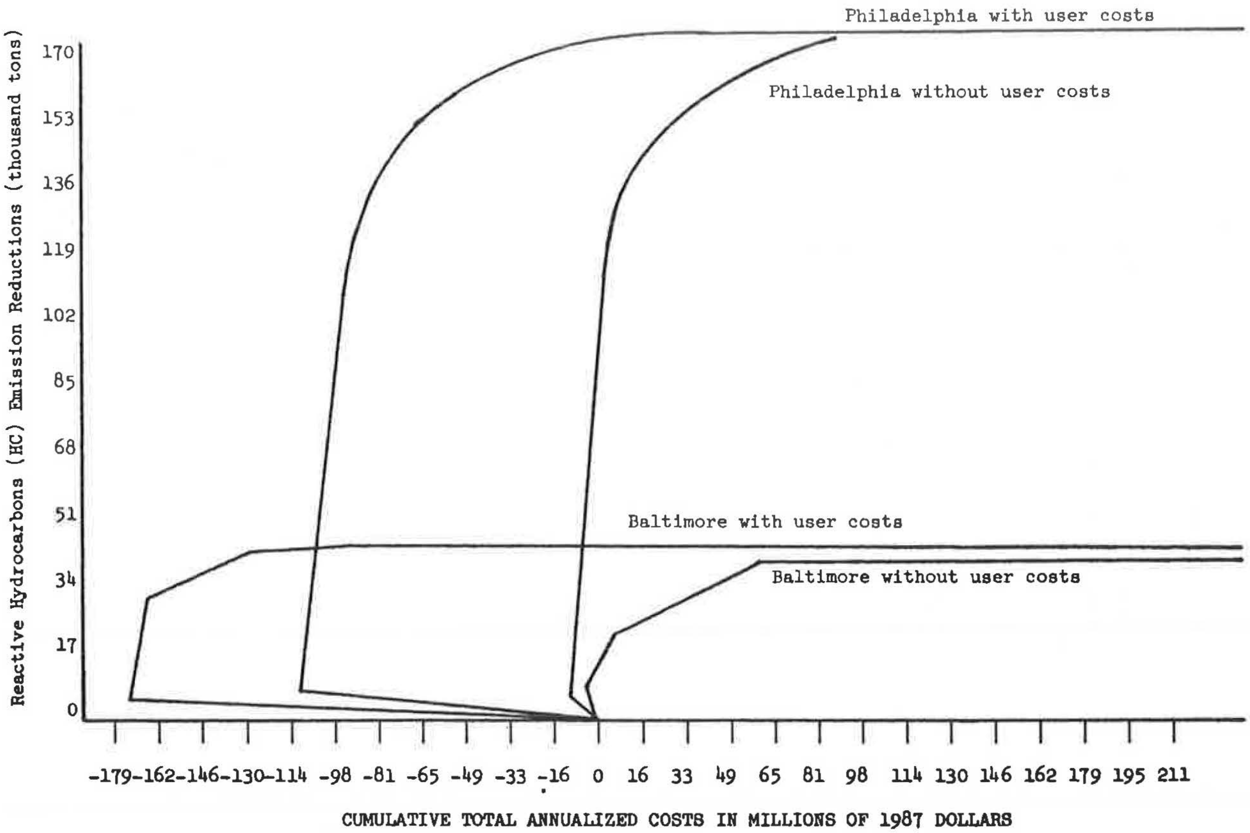

FIGURE 2 Comparison of annual costs of HC control in Baltimore SMSA and Philadephia AQCR.

ularly of regions without manufacturers that practice pollution abatement. In three case studies (Twin Cities, Ohio River Valley, and the New York metropolitan area) of impacts of air pollution control measures reviewed by the National Commission on Air Quality (17), relatively little impact of pollution control programs was noted. Depending on the industrial structure of the regional economy, pollution abatement expenditures need not result in regional losses in employment and output. Employment and output losses may not result if the regional economy possesses a manufacturing sector that practices pollution abatement or if the industries sensitive to economic dislocation are excluded from the control program. In some instances the pollution control technology results in more efficient processes that produce net cost savings. However, these cost savings in selected processes will not by themselves be large enough to offset cost increases in other sectors unless there is either a pollution-abatement manufacturing sector or an efficient set of transportation controls that generate enough employment through user benefits to offset job losses in other stationary sources.

The economic impacts of air pollution control in the Baltimore SMSA were researched by using the 1972 input-output matrix of the Baltimore SMSA economy, which was projected to 1987 for this study. The input-output impact analysis assumed that all air pollution control costs were shifted forward to consumers in the form of higher prices and that HC emission controls were uniformly implemented throughout the nation, so that competing plants in other regions were also subjected to controls. In addition, because of the peculiarities of the input-output approach, it was assumed that the household's user cost savings from the TCMs would be reallocated proportionally between increased consumer expenditures and other savings. The reader will recognize that the input-output approach followed in this study has elements in common with the input-output studies conducted by the Rice Center in Houston (18) and in St. Louis (19). The input-output analysis was complemented by a simple regional allocation model of population, employment, personal income, and fiscal impacts to distribute impacts on a county basis.

In Table 5 estimates of the economic and employment impact of HC emission control programs on the Baltimore SMSA economy are presented, assuming national implementation of ozone standards elsewhere in the United States. One advantage of using cost-effectiveness techniques for designing abatement strategies is that high-cost options are avoided and control programs result that have generally less adverse effects on the local economy. In the Baltimore case, the economic impact of control strategies is negligible. Slight increases in employment and regional income occur because of the employment increases generated by the transportation control programs, which exceed the reductions in employment due to the emission controls on stationary sources.

The negligible economic impacts of HC emission controls in Baltimore are due to the exclusion in the cost-effective or least-cost solution presented in Table 3 of some of the basic industries most sensitive to dislocation if subjected to HC control technologies. These industries include the Bethlehem Steel plant at Sparrows Point, some of the larger chemical plants, and some of the industrial processes at the General Motors plant in Baltimore City. The least-cost solution does not include these plants and facilities because their control options are more expensive in terms of cost per ton of HC

TABLE 5 Annual Changes in 1987 Baltimore SMSA Economy Induced by HC Emission Control Programs

Characteristic Changed	Area: Anne Arundel County	Baltimore County	Carroll County	Harford County	Howard County	Baltimore City	Total SMSA
Population (000,000s)	571	1,227	228	246	531	2,139	4,942
Employment (000,000s)	290	523	93	77	147	1,381	2,511
Personal income ($000,000s)	8.53	16.76	2.97	2.66	4.78	24.31	60.51
Regional output ($000,000s)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	113.51
Tax revenue	0.29	0.59	0.10	0.11	0.21	0.94	2.24
Income and sales taxes ($000,000s)	0.17	0.34	0.06	0.05	0.10	0.50	1.22
Property tax ($000,000s)	0.06	0.13	0.02	0.03	0.06	0.23	0.53
Miscellaneous charges ($000,000s)	0.06	0.12	0.02	0.03	0.05	0.21	0.49

Note: These impacts refer to the changes induced by HC emission control programs from the 1987 projection of the economic performance of the Baltimore SMSA economy without these emission controls, that is, comparisons of the Baltimore SMSA 1987 economy with versus without emission control programs.

removed; therefore this is an abatement program that does not place any burden on the regional and local economies of the counties in the SMSA. However, simulations of the economic impact conducted with the input-output model also revealed large adverse effects (i.e., employment losses of 10,000 and up) if these large basic industries were subjected to control programs.

Social Impacts

Two of the TCMs have a potential for adverse social effects. One-way streets (SCC 966), if located in the central business district and on retail strip locations, may have an adverse effect on some merchants (losses to some merchants compensated by gains to others) and although no net social impacts may occur over the metropolitan area, some redistribution effects may be present. The most important program in terms of its adverse effect on households is the vehicle inspection and maintenance program (SCC 950), which will generate as much as $11.25 million (in 1980 dollars) annually from inspection fees paid by households in addition to the $0.78 million in extra vehicle operating costs that the households must bear.

CONCLUSIONS

The results of the Baltimore application show the usefulness of the joint consideration and trade-off of stationary-source and mobile-source controls in the development of control strategies for attaining air quality and other goals. Separate consideration of stationary-source and mobile-source controls, such as those practiced in most SIPs, may not result in least-cost solutions with their concomitant less-adverse impact on local economies. This separate consideration of stationary-source and mobile-source controls should be abandoned in favor of the cost-effectiveness framework demonstrated in Philadelphia and Baltimore.

In summary, cost-effectiveness analysis provides a working methodology of relative easy application in other settings and an internally consistent framework for analyzing trade-offs between stationary-source and mobile-source controls. However, caution should be exercised in extending the results of the application to other sites. Not only are the TCM strategies and their costs sensitive to local conditions but also the costs of the stationary-source controls used in this study represent average generic costs, which may not properly reflect local features. However, it should also be recognized that there are areas that, in order to meet the air quality standards, require implementation of most of the pollution control programs, allowing little flexibility for selecting strategies and programs based on cost effectiveness. Each site should be encouraged to conduct its own application of cost-effectiveness analysis by using local costs and representing unique local conditions.

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The Feasibility of Using Computer Graphics in Environmental Evaluations

DANIEL D. McGEEHAN and DANIEL P. GAYK

ABSTRACT

The purpose of this study was to develop a procedure that could be used to distinguish quickly between proposed transportation projects that would have an effect on the environment, and thus require special approval, and those that would not. It is intended that this procedure be used as a basis for agreements between the Virginia Department of Highways and Transportation and other state and federal agencies to expedite evaluations of environmental impact. Data collection, program selection, and retrieval and update procedures are described.

The Environmental Quality Division of the Virginia Department of Highways and Transportation (VDHT) is directed to assess the probable benefits and damages that will result from the construction of all the department's proposed projects. For state-funded projects, these assessments result in informal reports used as decision-making tools within the department. For federally funded projects, they result in some form of environmental impact statement (EIS).

Revisions to the National Environmental Policy Act (NEPA) have been made by the federal government with the intent of shortening the overall EIS process; however, the effects have been realized more at the reporting phase than at the data-collection and analysis phase. For example, the scoping process (Section 1501.7 of the regulations of the Council on Environmental Quality) requires that an agency, as soon as possible after deciding to write an EIS on a proposed project, publish a notice of intent in the Federal Register. Among other objectives, this notice is aimed at assuring that all parties affected by or interested in the proposed action be invited to participate in determining the scope of the EIS, which includes establishing the significant issues to be studied, eliminating from study those issues considered insignificant, identifying and coordinating related EISs being written, and establishing the length of the final EIS. To prepare for and conduct the scoping process, initial data must be collected on all potentially significant variables, such as historic site locations, within the project area.

PROBLEM STATEMENT

Requests for environmental surveys needed to comply with federal regulations are sent to the Environmental Quality Division of VDHT from the Location and Design Division and from the district environmental coordinators. In response, the Environmental Quality Division staff either performs the survey or contacts federal agencies and other state agencies to obtain information to satisfy the request. In most cases the information is manually maintained or must be collected for the first time, and where the department is dependent on other agencies for information, it cannot expedite retrieval.

It would be extremely rare for a project to af-