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Cost-Effectiveness of Air-Quality Control Measures and Impact of the Environmental Review Process

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Contents

FOREWORD v

OVERVIEW OF TRANSPORTATION AND STATIONARY-SOURCE CONTROL OPTIONS
Brian J. McLean 1

CASE STUDIES OF COST-EFFECTIVENESS OF TRANSPORTATION MEASURES TO IMPROVE AIR QUALITY
John H. Suhrbier 5

METHODOLOGY FOR DETERMINING THE RELATIVE COST-EFFECTIVENESS OF STATIONARY- AND MOBILE-SOURCE CONTROLS
Salvatore J. Bellomo. 9

GUIDANCE FROM DISAGGREGATE EMISSIONS INVENTORY IN SELECTION OF CONTROL MEASURES
Kathy Bailey, Michael Clifford, and Phillip Shapiro 13

ENVIRONMENTAL IMPACT STATEMENT FOR DETROIT PEOPLE MOVER
Steve Beard and Thomas Rushfeldt 19

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Foreword

The first four papers in this Record were presented during the session entitled Cost-Effectiveness of Transportation and Stationary Source Control Measures for Air Quality at the 61st Annual Meeting of the Transportation Research Board in January 1982. These papers should interest those from air-quality control agencies, metropolitan planning organizations, or any other agency with some responsibility for developing the state implementation plan (SIP) for transportation. In attempting to obtain endorsement from state and local elected officials for air-quality measures, agencies must recognize that air quality is only one of the many concerns of these officials. Therefore, measures included in the SIP must meet multiple objectives.

The transportation element of the SIP should not be a single-purpose document directed only toward air quality and ignoring other urban priorities. The guidelines of the U.S. Environmental Protection Agency and the U.S. Department of Transportation emphasize the need to integrate transportation planning with the ongoing transportation planning process. To be successful, the process should identify those projects that improve air quality and at the same time meet other important needs. However, even if a comprehensive analysis of alternative measures and packages of measures has not been performed and effective public participation programs have not been implemented, the SIP might still be salvaged by looking at the cost-effectiveness of transportation measures that have been identified. All transportation measures have benefits that go beyond air quality. They may save users travel time or fuel; they may reduce accidents; they may increase real estate values or improve retail sales. Of course, they may also have detrimental effects. But all these benefits, and others, have been used traditionally by transportation planners to justify transportation projects. Why not, then, use similar measures to justify the same types of projects for air-quality purposes?

In this collection of papers that deal with the cost-effectiveness of transportation measures for air quality, the first is an overview of stationary and transportation control options. The purpose of this paper is to provide a context within which to consider transportation measures. In the second paper, the cost-effectiveness of transportation measures in several urban areas is examined. In the third paper, a methodology for addressing the cost-effectiveness of transportation and stationary-source measures is described. In the fourth, a description is given of how one metropolitan planning organization is using a disaggregate emission inventory to identify the most cost-effective means of reducing hydrocarbon emissions.

The fifth paper in this Record was not presented at the session on cost-effectiveness of air-quality control measures but is included to show the impact of the environmental review process on a transportation project, in this case the downtown people mover in Detroit.

Overview of Transportation and Stationary-Source Control Options

BRIAN J. McLEAN

An introduction to the subject of cost-effectiveness in selecting air-pollution control options is provided by offering an overview of control options for both stationary and mobile sources of air pollution and by identifying some historical obstacles to comparative analysis. After the traditional stationary-source control options presented in the U.S. Environmental Protection Agency guideline document Control Techniques for Volatile Organic Emissions from Stationary Sources are summarized, mobile-source control options, including transportation control measures, are described and grouped by applying the stationary-source categorization scheme. Some cost-effectiveness analysis problems common in evaluating both transportation and stationary-source controls are identified and the institutional obstacles that continue to inhibit effective comparative analysis and problem solving are noted.

In this paper, some background information on stationary-source and mobile-source control options is presented, and some of the historical problems--both institutional and analytical--that have impeded previous comparative assessments of these measures are addressed.

Although the costs and effects of transportation projects and programs are familiar, emission-reduction techniques for nontransportation sources are less well known. Therefore, this discussion will initially focus on stationary sources and their control and then relate these techniques to emission reduction from transportation measures.

The discussion will focus on emissions of volatile organic compounds, or VOC emissions. This term is similar to the description of the principal precursor to ozone but slightly more accurate than the term hydrocarbons. It should be remembered, however, that transportation sources are also the major source of carbon monoxide and nitrogen oxides in urban areas and at street level a major source of particulate matter. These facts become of interest when one discusses the multiple effects of a given control measure.

For the past 10 yr, the national amount of VOC emissions has not changed significantly; it has hovered around 30 million tons/yr. Nevertheless, mobile-source emissions have declined despite growth in travel because of the Federal Motor Vehicle Control Program, and stationary-source emissions have increased despite controls on some categories of sources (1). Major efforts by the U.S. Environmental Protection Agency (EPA), state and local air-pollution-control agencies, and industry over the past 3 yr should produce some decline in stationary emissions over the next few years.

When we look at national VOC emissions for 1977, for example, we find that highway vehicles contributed 10.3 million tons; total mobile sources, including highway, rail, ships, and aircraft, bring the total to 11.9 million tons out of a total of 30.1 million tons (2). From the transportation professional's point of view, contributing approximately one-third of the emissions is certainly significant, but should not the environmental agencies be focusing on the other two-thirds?

First of all, when we look at urban areas, the mobile-source contribution is slightly higher than one-third--typically 40-50 percent. Second, stationary sources are not homogeneous nor do they represent even a few homogeneous sources susceptible to one or even a few control techniques. There are dozens of major source categories (hundreds of smaller categories) and dozens of control techniques. It could be argued that there is more in common between a gasoline tank truck on the road (a mobile source) and the vapors emitted when it loads and unloads its gasoline (a stationary source) than there is between a dry cleaner and an oil refinery or between automobile painting and drug manufacturing, all of which are stationary sources.

I find the distinction between mobile and stationary somewhat arbitrary; but, more important, it can be misleading when used in a rationale for controlling air pollution. An emissions inventory serves two principal purposes: it tells us where emissions are coming from, and when multiplied by a control efficiency, it helps us determine potential emission reductions. By itself, an inventory does not tell us which sources to control. Control efficiency, cost-effectiveness, and political feasibility are far more important factors in making that decision.

STATIONARY-SOURCE CONTROL OPTIONS

Now let us look at the major approaches to stationary-source control and some of their applications (2). The three general methods employed commercially to control VOC emissions are

1. Installation of add-on control equipment to recover or destroy the organic vapors,
2. Substitution of less photochemically reactive materials in the process, and
3. Incorporation of process or material changes or both that reduce or eliminate vapor emissions.

Add-on Controls

The first general category can be further subdivided into five categories of techniques: incineration, adsorption, absorption, condensation, and flaring.

Incineration

Incineration is the technique most universally applicable to sources of volatile organics. Therefore, I will spend more time on this technique and discuss the others only briefly. There are two basic approaches to incineration--thermal afterburners and catalytic afterburners. Boilers can sometimes be used as thermal afterburners if the temperature, turbulence, and flame contact are adequate to burn the contaminate.

Thermal Afterburners

For the use of thermal afterburners, the concentrations of vapors and air must be within the limits of flammability--which, of course, vary by pollutant. Additional fuel, such as natural gas, liquid propane gas (LPG), distillate, or residual oil, is usually used. Heat recovery offers a way to reduce the afterburner energy requirements but at the expense of increased capital equipment costs.

Catalytic Afterburners

A catalytic afterburner initiates and promotes oxidation at a significantly lower temperature than a thermal afterburner. However, contact time is critical to ensure maximum oxidation, and a variety of substances in the pollutant stream can poison the catalyst and make it useless. Compared with those of thermal afterburners, fuel costs of catalytic afterburners are lower, but savings from heat recovery are lower also.

Applications

Incineration has been successfully applied to aluminum-chip dryers, petroleum processing and marketing operations, animal-blood dryers, automotive-brakeshoe debonding ovens, foundry-core ovens, meat smokehouses, paint-baking ovens, varnish cookers, paper printing and impregnating installations, pharmaceutical manufacturing plants, sewage-disposal plants, chemical-processing plants, and textile-finishing plants.

Efficiencies and Cost Factors

Control efficiencies have been more than 95 percent where applicable and when properly designed and operated. Capital costs and operating costs can vary widely, depending on

1. The nature of contaminants in the waste gas,
2. The concentration of organics in the gas,
3. The gas volume flow rate,
4. The fuel used for the afterburner,
5. Design problems, and
6. The degree of heat recovery.

Problems

In addition to the need of the thermal afterburner for energy, its use of fuel oil can be a source of pollution itself. If we assume that there is no sulfur in the off-gas, use of distillate oil in a typical afterburner can emit an SO_2 concentration of 50 ppm. In addition, nitrogen-containing compounds may be oxidized to NO_x, which increases those emissions. Due to the abundance of nitrogen in air, no nitrogen compounds need to be in the fuel or VOC stream to produce NO_x emissions. NO_x emissions will result from all combustion processes. The estimated NO_x concentration for effluent from noncatalytic afterburners fired with natural gas is 40-50 ppm. Incineration of any halogen-containing compound will cause acid formation; a scrubber following the incinerator may be required.

In catalytic incineration, the regeneration or replacement of the catalyst can present a secondary pollution problem. When the catalyst needs to be completely replaced, the used catalyst is treated as solid waste, and an acceptable means for disposal must be found. If the catalyst can be reused, the cleaning or reactivation process requires proper disposal of any waste material.

Adsorption

Adsorption is the process by which components of a gas are retained on the surface of granular solids. The adsorbent particles of the solids are highly porous and have a large surface-to-volume ratio. Gas molecules penetrate pores of the material and contact the large surface area available for adsorption. Organic vapors retained on the adsorbent are subsequently desorbed. Both the vapors and the adsorbent are recovered and may be reused.

Applications

Activated carbon is the most widely used adsorbent. It selectively adsorbs organic vapors from gases, even in the presence of water. Other adsorbents, such as silica gel and alumina, can remove organic solvents but are not widely used because of their affinity for water. Processes that can be controlled by adsorption include dry cleaning, degreasing, paint spraying, tank dipping, solvent extracting, metal-foil coating, fabric impregnation, and manufacturing of plastics, chemicals, pharmaceuticals, rubber, linoleum, and transparent wrap.

Efficiencies and Cost Factors

Initially, adsorption is rapid and removes essentially 100 percent of the VOC from the vapor. The efficiency declines as the adsorbent becomes saturated. Therefore, most systems are designed to require adsorbent regeneration or replacement as soon as the efficiency drops below 100 percent.

In addition to the characteristics of the particular operation affecting the capital and operating costs of this technique, if the absorbent is regenerated, there may be recovery costs. When recovered organics are credited at their market value, the adsorption operation can show a net return on investment. However, if more than one solvent is being recovered, product separation is usually not worth the cost. If cost recovery is not profitable, incineration of the recovered solvent is performed.

Problems

There is some air and water pollution from an adsorption system. Loss of organic solvent with wastewater, oxidation-product emissions with incineration, and solid-waste disposal are possible, depending on the system used.

Absorption

Absorption is the process in which certain constituents of a gas stream are selectively transferred to a liquid solvent. Absorption may be purely physical, in which the solute simply dissolves in the absorbent, or chemical, in which the solute chemically reacts with the absorbent or with reagents dissolved in the absorbent.

The generally low concentrations of exhausted organics require long contact times and large quantities of absorbent for adequate emission control. Absorption is therefore less desirable than adsorption or incineration, unless the absorbent is easily regenerated or the solution can be used as a process make-up stream. Absorption may be best suited for use in conjunction with other control methods such as incineration or adsorption to achieve the prescribed degree of emission removal.

Applications

Although absorption has been used primarily to control inorganic rather than organic vapors, it has been used to control organic vapors and particulate matter in surface-coating operations, waste handling and treatment plants, degreasing operations, asphalt-batch plants, ceramic-tile manufacturing plants, coffee roasters, chromium-plating units, petroleum coker units, fish-meal systems, smoke generators, and varnish and resin cookers.

Problems

Adverse environmental effects resulting from the operation of an absorber include improper disposal of the organic-laden liquid effluent, undesired emissions from the incineration of the regenerated waste gas, loss of absorbent to the atmosphere, and increased water use.

Condensation

Condensation is usually applied in combination with other air pollution control systems. Condensers located upstream of afterburners, carbon beds, or absorbers can reduce the total load entering the more expensive control equipment. When used alone as in gasoline vapor control in bulk terminals, refrigeration is the usual means of achieving the low temperatures necessary for condensation.

Applications

The predominant application of the condensation technique is with the recovery of gasoline vapors at bulk gasoline terminals. Removal efficiencies depend on the hydrocarbon concentration of the inlet vapors but are greater than 96 percent for the removal of saturated hydrocarbons.

Cost Factors

For the primary application of this technique, bulk gasoline terminals, high flow rates can offset both operating and capital costs, which results in a net savings through vapor recovery. In most other applications, however, condensation systems are uneconomical as the sole means of emission control unless the gas contains high concentrations of valuable and recoverable organic vapors.

Problems

A condenser will create few secondary environmental problems when the condensation process is considered by itself. However, condensation is rarely used alone as a control method.

Flaring

Flares are most commonly used as safety devices to incinerate waste gases from petroleum refining and petrochemical manufacturing operations. Flares are preferred when gas streams are disposed of that have sufficient heat value to attain the combustion temperature without the use of supplemental fuel. Flares are also preferred when gases that have little recovery value are disposed of or for gases containing contaminants that make recovery unprofitable.

Although capital and operating costs tend to be lower because the gas is sufficiently volatile to sustain combustion, there are costs and problems with flaring in addition to its limited application. Smokeless operation of a flare usually requires a supply of steam or air to ensure complete combustion. Also, the operation of a flare affects the environment in the following areas: chemical and oxidation emissions (including SO_x and NO_x emissions), particulate emissions, thermal and visible radiation, and noise.

SUBSTITUTION OF LESS-REACTIVE SUBSTANCES

The second general category of stationary VOC control is to substitute less photochemically reactive materials for highly reactive ones. This approach is not so popular today as it was several years ago for two reasons: first, even less-reactive materials react during a multiday stagnation and, second, of the small number of VOCs that have only negligible photochemical reactivity, all but one--benzaldehyde--are suspected carcinogens, teratogens, or mutagens.

PROCESS OPERATION AND MATERIAL CHANGES

Process operation and material changes are the most diverse options available for control of organic emissions. In general there are three types of possible changes: (a) material substitutions, in which alternative materials are used in the process or products of the process are reformulated; (b) process changes, in which certain operations of the process are modified; and (c) housekeeping and maintenance procedure changes.

Material substitutions are intended to reduce volatile organic emissions by replacing materials used in the process with less-volatile or nonreactive compounds. For example, organic emissions from surface-coating operations can be significantly reduced by replacing conventional organic solvent-borne coatings with water-borne high solids or powder coatings. Water-borne coatings can be applied with most of the same methods used for organic solvent-borne coatings. Water-borne spray-coating solvent does contain 20 to 30 percent organic solvent; thus, VOC emissions cannot be completely eliminated.

Process changes reduce organic vapor emissions by using raw materials more effectively. For example, organic emissions from surface coating can be reduced by adopting more efficient coating methods or by changing curing techniques. Electrostatic spray coating and ultraviolet curing reduce emissions by limiting solvent contact with air.

Finally, improved maintenance procedures and good housekeeping reduce volatile organic emissions by preventing leaks and spillage and by improving product yield.

MOBILE-SOURCE CONTROL OPTIONS

Interestingly, two of the three general categories of stationary-source control options can be related to mobile-source control. The first category, the installation of add-on control equipment, clearly describes the oxidizing catalyst and exhaust gas recirculation options used on automobiles.

The third category, incorporation of process and material changes that reduce or eliminate vapor emissions, may require some imagination, but I believe it is also analogous to mobile-source control. The use of diesel engines and the incorporation of computer control of engines can be seen as process changes that reduce VOC and CO emissions. What I find interesting about such process changes relative to the discussion of cost-effectiveness analysis is the difficulty in assigning that portion of the cost of the process change to one benefit, such as VOC emission reduction. Should the cost of a diesel engine (or the entire car) be related to the VOC reduction benefit? What about CO? And is not the primary reason for buying a diesel the savings in energy cost?

In advocating a relaxation in automobile emission standards, General Motors admitted that even though the new computer control technology would not be needed to meet the relaxed emissions standards, they might keep it on some cars to enhance performance (and sales). Should the entire cost of this technology, then, be assigned to air-quality improve-

ment? If not, what portion should be? What portion of the cost should be attributed to other effects?

These problems become more critical when one stretches the process-change analogy to other transportation measures. Encouraging modal shifts from automobile to transit by enhancing public transportation travel or increasing the costs of automobile travel can be seen as a process change. Under the right circumstances and properly planned, public transportation or ridesharing can be less-polluting alternatives (or travel processes) when compared with land use patterns, and right-of-way modifications can make pedestrian and bicycle travel a zero-polluting substitute for vehicular travel. The substitute for transportation traditionally offered is communications. I believe there are limits to the capability of communications to substitute for transportation and face-to-face interaction, but I also believe that more substitution is possible than we are currently exercising.

Specific transportation measures have been included in state air-quality plans or are under consideration by metropolitan planning organizations for inclusion in the 1982 air-quality plans. All nonattainment areas with populations greater than 200,000 submitted transportation measures in their 1979 state air-quality implementation plans. Of the 49 areas receiving an extension of the CO or ozone attainment date, 36 included transit improvements, 31 included carpool and vanpool programs, 27 included bicycle incentive measures, 25 included traffic-flow improvements, 18 included exclusive lanes for high-occupancy vehicles, 11 included work rescheduling, 10 included parking management programs, and 8 included automobile-restricted zones.

In addition to those measures that represent modal substitution, the above list of transportation control measures also includes what the stationary-source control engineer might term process-efficiency improvements and what the transportation planner refers to as transportation systems management, such as signalization and other measures designed to improve the efficiency of the existing transportation system.

THE TECHNICAL PROBLEM

The technical problem with analyzing the cost-effectiveness of process changes is relating specific costs to specific effects. All the transportation measures included in the 1979 air-quality plans were found acceptable because the transportation, energy, and perhaps political benefits outweighed the costs. None were determined to have only an air-quality benefit; most were not originally proposed for their air-quality benefits.

Should the entire cost of a measure be assigned to the effect of immediate analytical concern? Should the costs be allocated to each effect? If so, how? Or should all the effects (positive and negative) except the one of immediate concern be summed and then substracted from the costs and a net cost-effectiveness approach be used? Would this approach be meaningful if there were a net benefit assigned to the effect?

THE INSTITUTIONAL PROBLEM

In addition to the technical problem of analyzing cost-effectiveness, there is the institutional problem. This is an important problem, too, and I could spend considerable time on it; but for now, I will just highlight the issues. Until 1970, transportation planning and air pollution control were two separate worlds: there was little or no professional interaction, little sharing of analytical approaches, little in common in terms of institutional arrangements. When they were brought together during the 1970s, there was little understanding of these differences and a limited desire in both spheres to alter historical approaches and institutions.

Transportation decision making is far more complex institutionally than air pollution control, both in numbers of institutions and in their relationships to one another. In transportation, political costs can be more decisive than dollar costs, and thousands of people are routinely and directly affected by transportation decisions. Pollution control decisions generally have affected individual industries or groups of industries; the public is indirectly affected by these decisions. Transportation decisions have to be accepted or at least tolerated; they are not subject to enforcement actions, as are most pollution control decisions. Finally, the focus of pollution control has been by definition narrower than that of transportation. Of necessity, transportation has moved toward being multiobjective.

As a consequence of all these institutional factors, communication and mutual understanding between air pollution control and transportation decision makers have been limited. I believe that before agreement can be reached on applying analytical approaches and ultimately on the appropriate responsibilities for transportation and stationary sources in reducing air pollution, greater understanding is needed between the two professions and by responsible decision makers.

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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:

$$\text{NPVC} = \sum_{t=0}^{n} (\text{cost}_t - \text{non air quality}_t)/(1+r)^t \quad (1)$$

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

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

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.

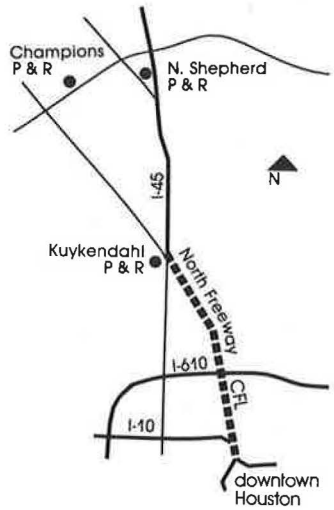


Table 2. Analysis of Houston North Freeway contraflow lane.

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

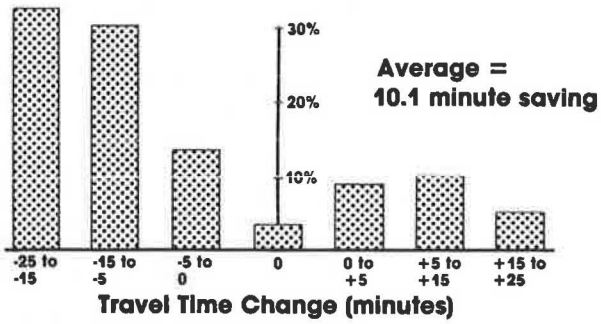
Boston's Downtown Crossing project, which is generally regarded as having had a positive effect on the economic vitality of the downtown area, illustrates the problems of analysis perspective referred to earlier. A major downtown through street, Washington Street, has been closed to traffic and converted 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.



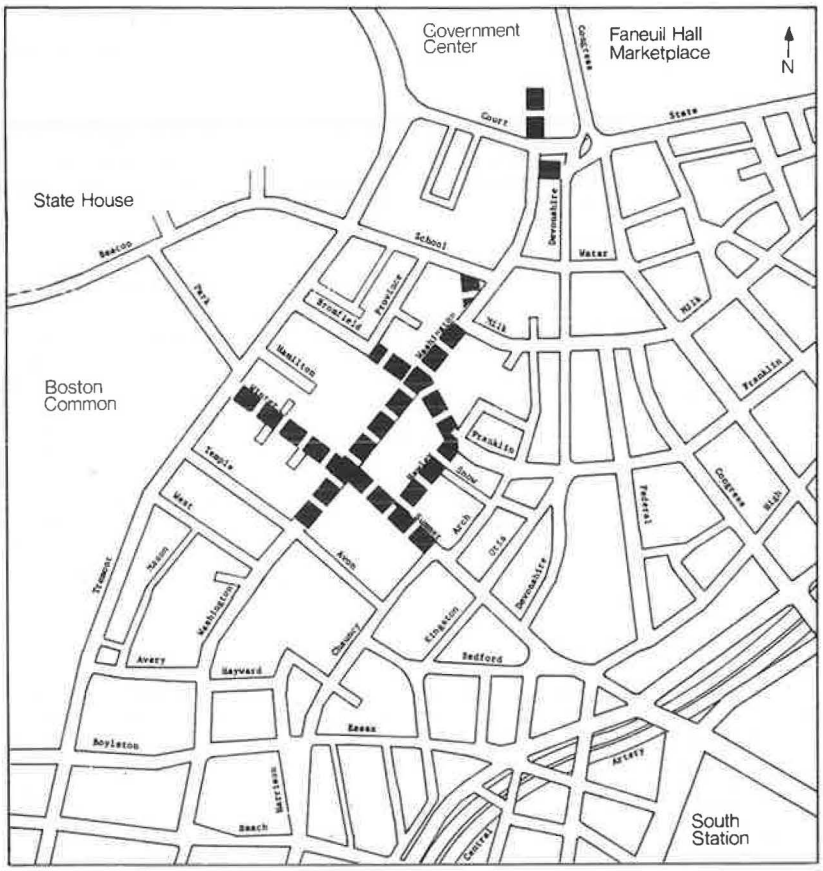
Detroit Park-and-Ride Lots

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.

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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.

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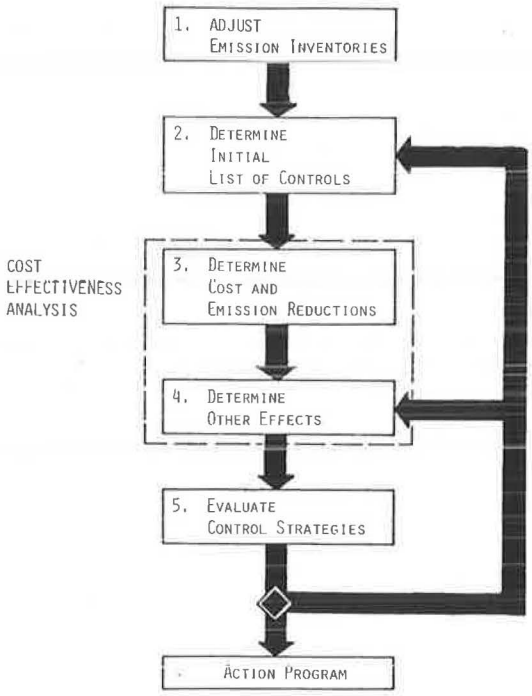
Methodology for Determining the Relative Cost-Effectiveness of Stationary- and Mobile-Source Controls

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.

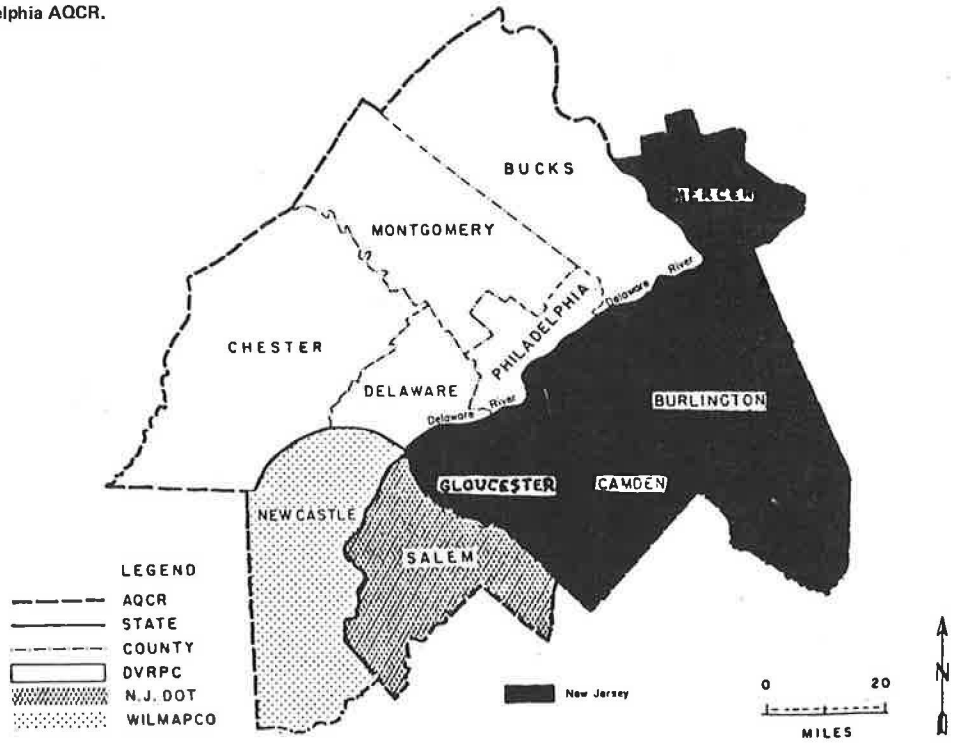
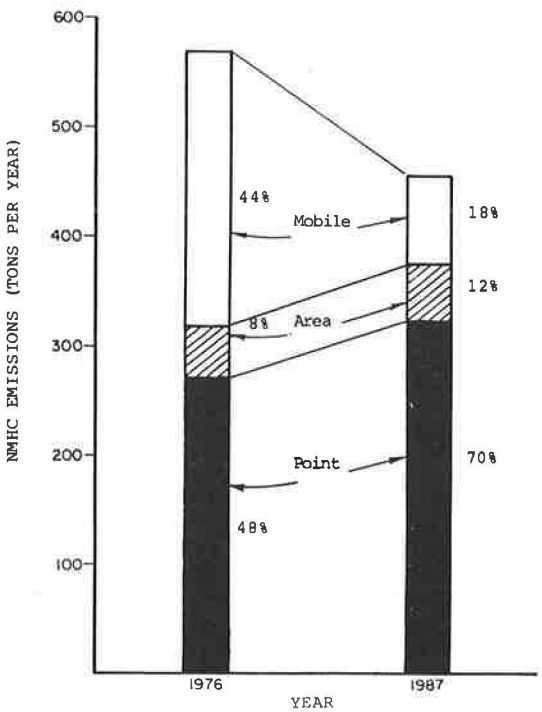


Figure 3. Baseline NMHC emissions for Philadelphia AQCR.



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.

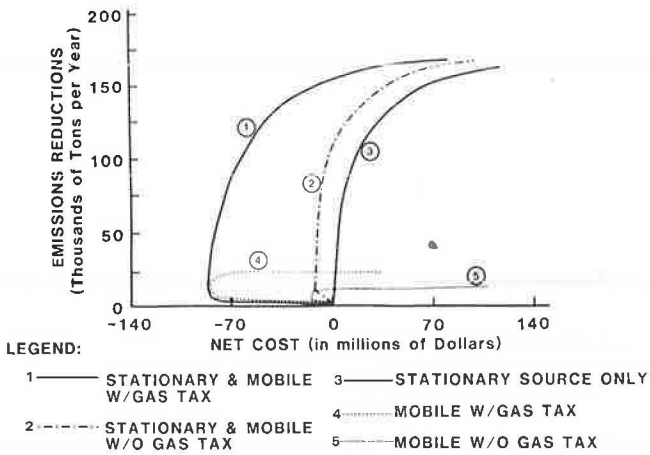
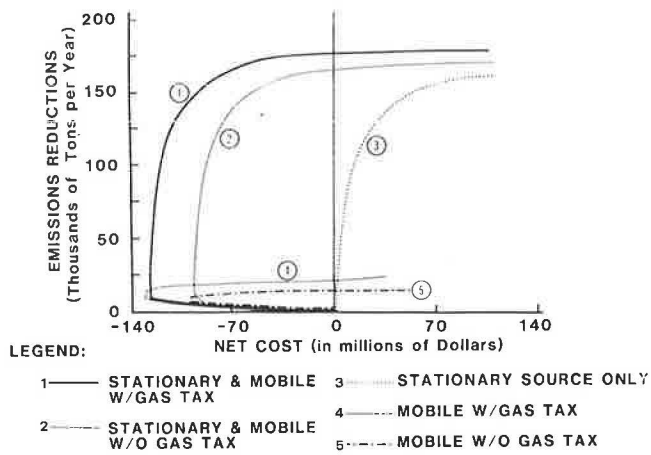


Figure 5. Least-cost model results with user cost considerations.



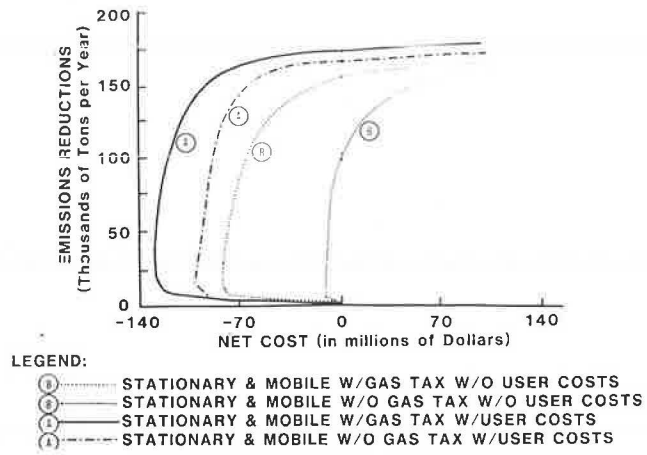
The output of the least-cost model includes the source classification code, the standard industrial code, the plant and point identification, emission reductions, the annualized direct cost of the control, the cumulative emission reduction, the cumulative annualized direct control costs, and the cost-effectiveness. 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

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



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.

Figure 1. Vehicle trips by mode and purpose: 1980 versus 1987.

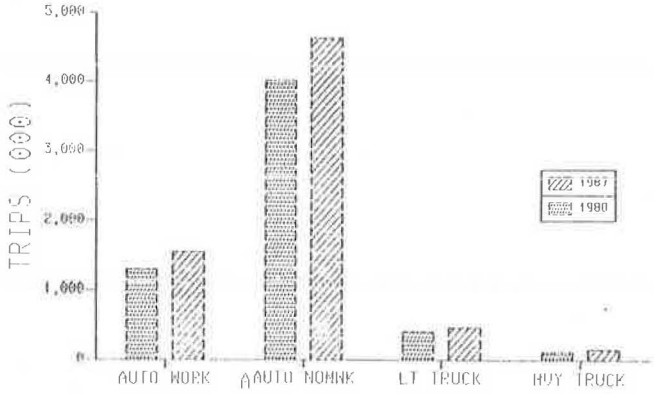


Figure 2. Daily VMT by mode and purpose: 1980 versus 1987.

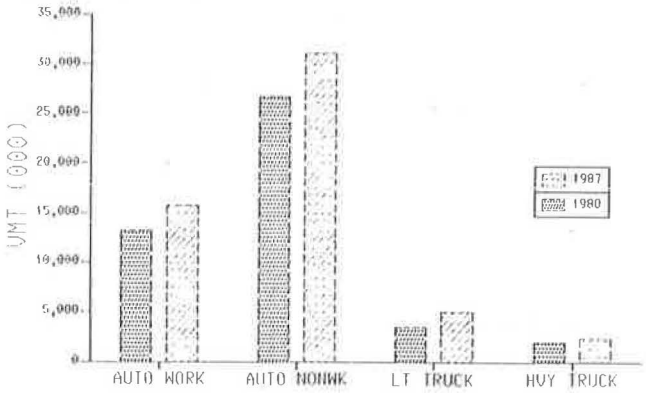


Figure 3. Automobile running emission rates for hydrocarbon and nitrogen oxide by model year.

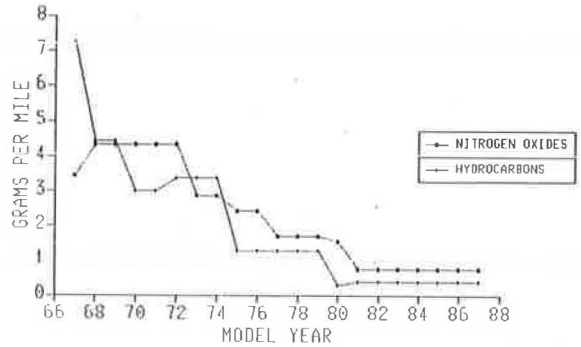


Figure 4. Automobile running emission rates for hydrocarbon and nitrogen oxide by calendar year.

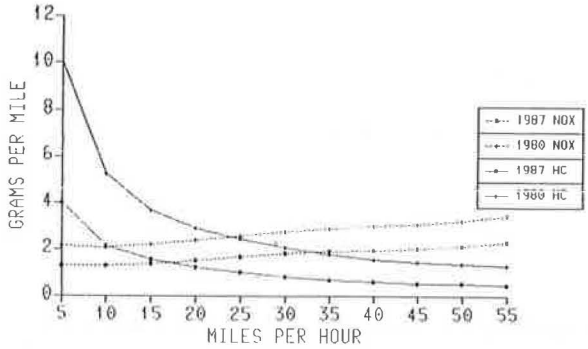
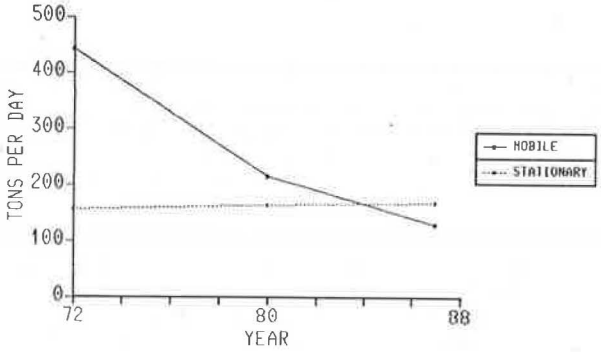


Figure 5. Hydrocarbon emissions by source.



Both the stationary-source and mobile-source portions of each inventory were broken down into several categories. One interesting result of this breakdown was the response received from the public. When, for example, the dry cleaner or the service station owner saw what portion of the total emissions was theirs, they could relate to that, and it turned out to be a good way to get public and industry involvement. The importance of each of the different categories to the overall total emissions became clear. Thus it was possible to obtain from different industry groups data that had not been available before, which in some cases replaced U.S. Environmental Protection Agency (EPA) default values. This helped to make the inventory Washington-specific as well as more detailed.

Another item to note is the point sources. There is virtually no industry in the region. If a limit of 100 tons/yr had been used for point sources, only about three sources in the entire Washington region would have qualified as being over the limit. Because each of the states keeps detailed records of emission rates for point sources to be used when permits are granted, it was decided to reduce the point-source limit to 25 tons/yr.

The second part of defining the problem, after these emissions data had been obtained, was to project what was going to happen by 1987. Were the data without the controls going to be too high? Was the ozone standard going to be met? To determine the answers, the city-specific empirical kinetic modeling approach was used, and it was found that hydro-carbon emissions would have to be reduced from 1980 levels by about 45 percent in order to meet the standard by 1987. That is a tremendous task in a region in which there is little industry to clean up.

The third part of defining the problem involved sensitivity analyses; a series of tests was performed to see what kind of changes would be required in various inputs, such as vehicle miles of travel (VMT) and so forth, before a change in the outputs could be seen. It took much bigger changes than had been expected to produce significant results.

TRAVEL ESTIMATES

The 1980 emissions inventory represents a simulation of existing conditions; the 1987 travel estimate is the base case for SIP development. It includes no controls other than 1987 emission factors; there is an inspection maintenance program in each state.

Figure 6. Hydrocarbon emissions by source: 1980 versus 1987.

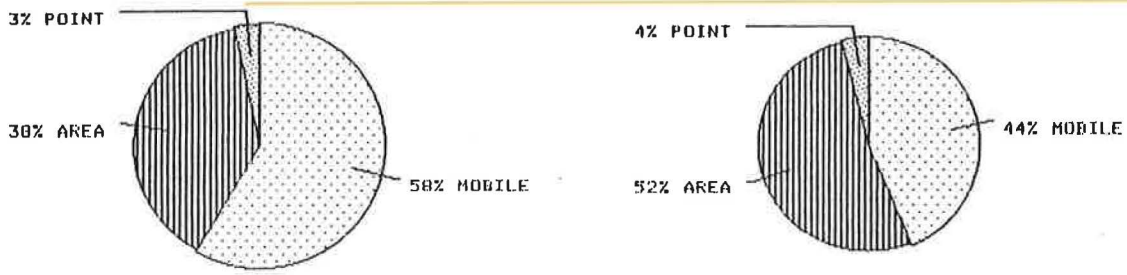
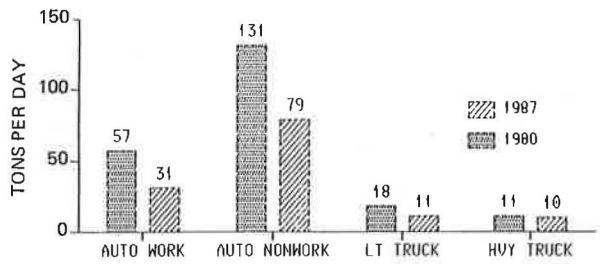


Figure 7. Mobile-source hydrocarbon emissions by mode and purpose.



The travel forecast was prepared in each case by using the traditional four-step modeling process; an additional step, generation of off-network travel, was used for later development of separate running and trip-end emissions. In the next step, travel-related data were used to prepare the average speed requirements, estimates of cold starts, and distributions of daily travel and travel by time of day. Transportation facility assumptions included, for highways, the best guess of what facilities will exist in 1987 made by the local and state operating agencies; for example, in Virginia I-66 and the Dulles toll road and in Maryland I-370 and Great Seneca Parkway. For transit, 1980 Metro rail was used in both the 1980 and 1987 inventories. Although a subway is under construction now and more of it will be in operation in 1987, Metro rail was evaluated separately because it was a control measure in the 1979 SIP.

Considering the results of the traffic simulations, Figure 1 shows that vehicle trips increase about 16 percent between 1980 and 1987, or about 2.2 percent per year. Figure 1 also shows that there are about three times as many automobile nonwork trips as automobile work trips. Figure 2 has been prepared to show VMT. There is roughly a 20 percent increase in VMT between 1980 and 1987, or about 2.5 percent increase per year. There is now twice as much nonwork VMT as work VMT because of longer trip lengths to work.

EMISSION FACTORS

Figure 3 shows how the allowable emission rates for hydrocarbons and nitrogen oxides have changed since motor vehicles were first controlled in 1968: Significant decreases in the factors may be seen. The curve is not a continuing decrease because the data points plotted are not for the legislated rates; rather, they are results of EPA's testing of new cars off the assembly line for each year. To show how the rates have changed, for example, the 1980 hydrocarbon rate is 5 percent of the rate under precontrol conditions, and the 1980 nitrogen oxide rate is about 22 percent of the precontrol rate. The rates taper down to the current model years, when automobiles are as clean as they are ever going to be, and are shown constant into the future.

The effect of new-car controls on a region's average mix of vehicles is shown in Figure 4, where the average vehicle mix in the Washington area is presented. Two sets of parallel lines may be seen, one for hydrocarbon emissions, which decrease with increasing speed, and one for nitrogen oxides, which increase at faster speeds. The influence of the new-car standards is shown because in each case the lower of the two lines represents 1987 emission factors. As older cars are replaced with new, cleaner vehicles, the average emission factor for the vehicle mix decreases. For example, at 40 mph the emission factor for hydrocarbons in 1980 was 1.6 gm/mile; by 1987 it drops to 0.6 gm/mile, or less than 40 percent of the 1980 rate. Note the shape of the hydrocarbon curves in Figure 4. For a given increase in average speed, the greatest impact will occur where it is needed the most, under the severely congested conditions in the range of 0 to 15 or 20 mph.

EMISSIONS

Hydrocarbon Emissions

An overview of what has been happening with hydrocarbon emissions in the Washington area is shown in Figure 5. Detailed inventories have been prepared for three data points--1972 as well as 1980 and 1987. Mobile sources are shown to be steadily decreasing, and stationary sources are increasing slightly over time. The lines cross in the middle 1980s, beyond which the mobile sources contribute less than half of the total daily hydrocarbon emissions. Figure 6 shows the hydrocarbon emissions by point, area, and mobile source for 1980 and 1987. Area sources are predicted to increase from 38 to 52 percent and mobile sources are predicted to drop from 58 to 44 percent. Figure 7 shows mobile-source hydrocarbon emissions by mode and purpose. First, the overall decrease in mobile-source emissions between 1980 and 1987 is about 40 percent--from 217 tons/day to 131 tons/day. The 1987 conditions show automobile nonwork emissions to be 79 tons, or 60 percent of the total. Work trips account for 25 percent of the total; the remaining 15 percent is due to light and heavy trucks. Finally, Figure 8 shows that four main categories of stationary sources for hydrocarbons--service stations, architectural coatings, solvents, and degreasing operations--account for two-thirds of the total emis-

Figure 8. Stationary-source hydrocarbon emissions by major type: 1980 versus 1987.

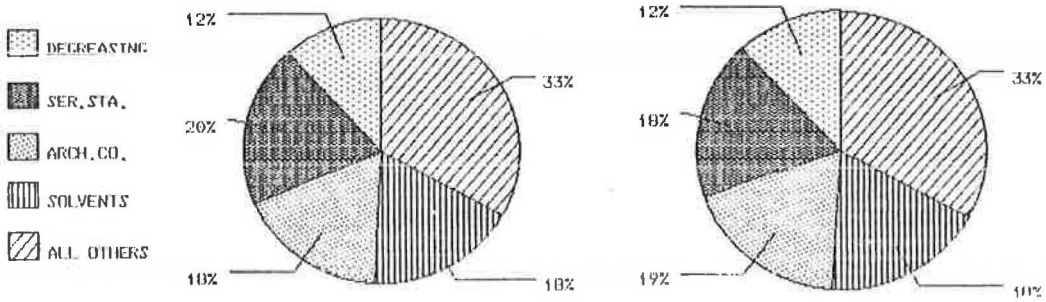
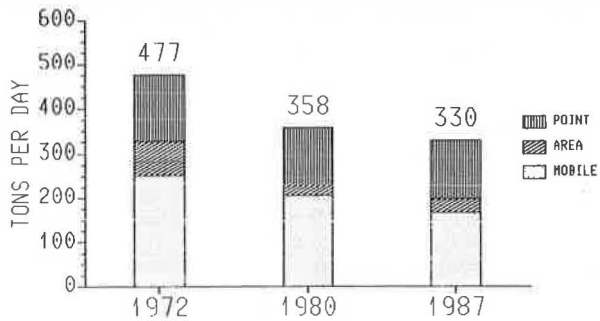


Figure 9. Nitrogen oxide emissions.



sions. The largest category, all others, accounts for 33 percent; it represents some seven or eight different sources grouped together.

Nitrogen Oxide Emissions

Figure 9 shows point, area, and mobile sources of nitrogen oxide emissions for 1972 to 1987; there is a drop of 10 percent between 1980 and 1987. This is due again mostly to the mobile-source emissions. Figure 10 shows mobile-source nitrogen oxide emissions by mode, and it indicates that trucks have a much greater effect on such emissions; they account for a third of total daily emissions in 1987. Finally, for stationary-source nitrogen oxide emissions (Figure 11), power plants are by far the largest source, accounting for more than three-fourths of the total daily stationary-source nitrogen oxide emissions.

HYDROCARBON REDUCTION REQUIREMENT

The hydrocarbon reduction requirement shown in Figure 12 is what COG has been trying to determine through the emission inventory work and what it wants to achieve in this SIP. In 1972 there was almost 600 tons/day of hydrocarbon emissions. In 1987 the level should be almost half that, or about 301 tons/day; the goal is a level of approximately 205 tons. Total emissions will be reduced from 1980 to 1987 by some 70 tons, primarily due to the reduction in the mobile-source contribution.

SENSITIVITY ANALYSES

A sensitivity analysis was performed as shown in Figure 13 to determine the effect on emissions of a 50 percent reduction in such variables as VMT; VMT and trips, because trips are so important; gasoline stations; solvents; and architectural coatings. Reduction of VMT by 50 percent causes a decrease of 22 tons in the total hydrocarbon emissions. For VMT and trips the amount decreases to 247 tons. Gasoline stations, solvents, and architectural coatings, the three primary stationary sources in the Washington area, yield a saving of 5 to 6 tons each when reduced by 50 percent. These reductions are probably more realistic attainments than those for VMT or VMT and trips. Figure 14 shows the effects of changes in travel characteristics on mobile sources. It is somewhat unrealistic to consider the effect on emissions of an increase of 5 mph in average speed regionwide, but the results are better than they were with the 50 percent reductions. A 10 percent reduction in VMT and trips and construction of the subway is probably unrealistic at this point too, but this was included as a potential action. All of these relatively modest changes in the variables reduce emissions no more than approximately 10 tons. This is an approximation of the approach that has to be taken, but the results are far lower than what is required.

MAJOR OBSERVATIONS

First, cleaner automobiles are reducing the total hydrocarbons for the 7-yr (1980-1987) period by approximately 20 percent (Figure 15). Mobile sources are decreasing by 40 percent. Mobile-source hydrocarbons shown in Figure 16 are 58 percent of the total in 1980 and only 44 percent in 1987. This is a major finding for the Washington area. Although it was noted earlier that no major polluting industry exists in this region, when the automobile contributes less than 50 percent, other sources are major contributors to the problem. Area sources increase from 38 percent to some 52 percent in the 7-yr period. Another important factor is nonwork trip emissions, which outnumber the work-trip emissions by more than 2 to 1. This means that all measures that have been considered for years that relate to the commuter trip may not be the most effective as far as reducing the total hydrocarbon and therefore the ozone. The work-trip emissions constitute about 25 percent of the total and the nonwork trip emissions, about 60 percent. The mobile-source nonwork trips are far more significant than any of the other mobile sources of hydrocarbon emissions.

Another finding that has been apparent for some time but has never been quantified is that trip-related emissions are more important than VMT emissions. It is estimated that the trip-end emissions will be approximately 48 percent, or half of the total, by 1987 and the running emissions will be

Figure 10. Mobile-source nitrogen oxide emissions by mode: 1980 versus 1987.

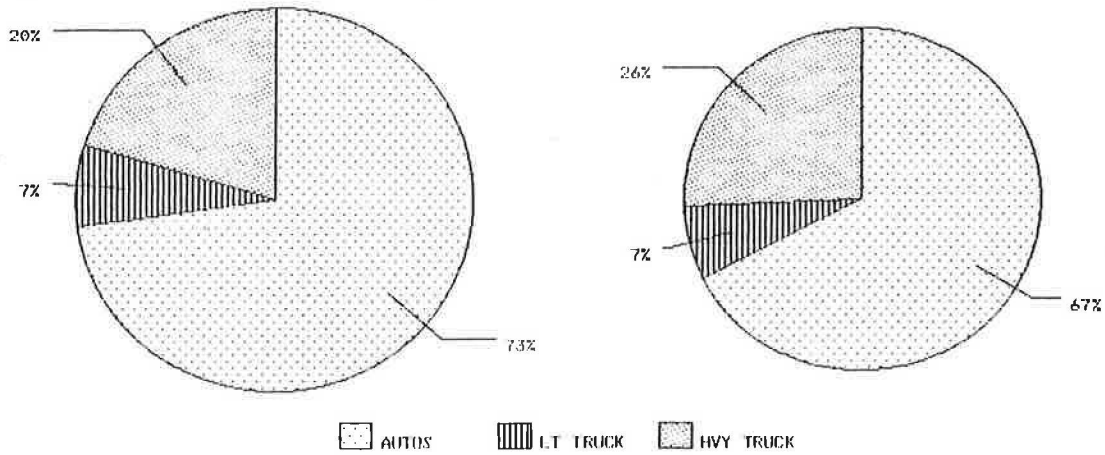


Figure 11. Stationary-source nitrogen oxide emissions by major type: 1980 versus 1987.

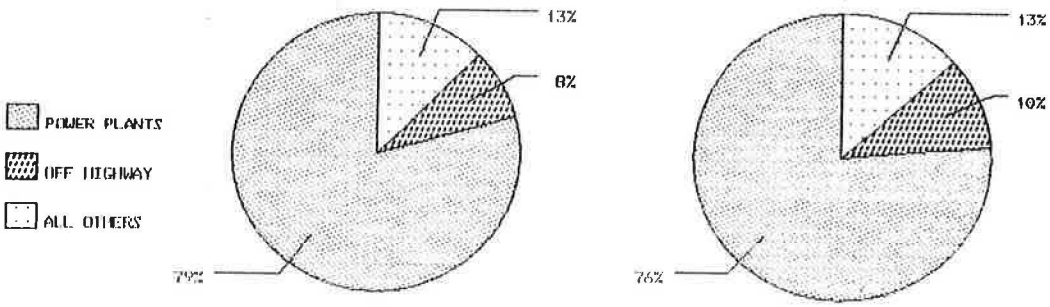


Figure 12. Hydrocarbon emission reduction required for attainment.

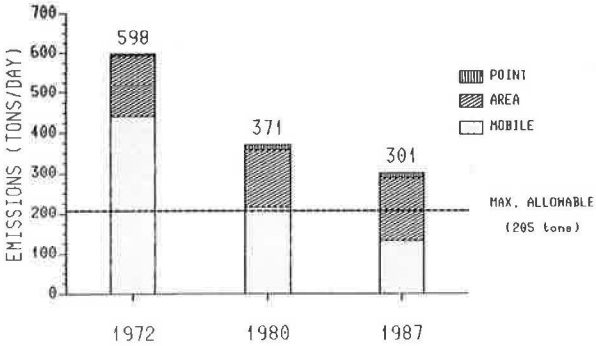


Figure 13. Sensitivity of hydrocarbon emissions to 50 percent reductions.

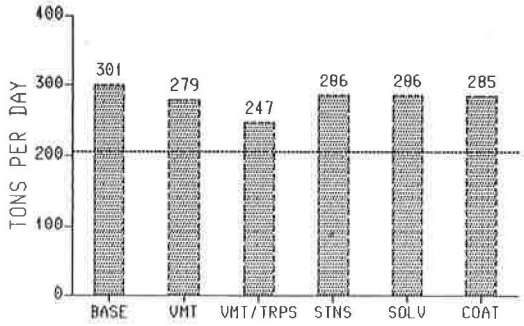


Figure 14. Sensitivity of hydrocarbon emissions to changes in travel characteristics.

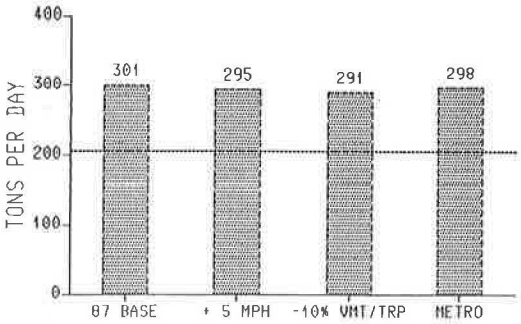


Figure 15. Hydrocarbon emissions.

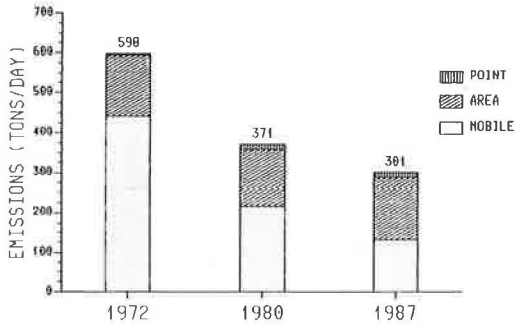


Figure 16. Hydrocarbon emissions by source: 1980 versus 1987.

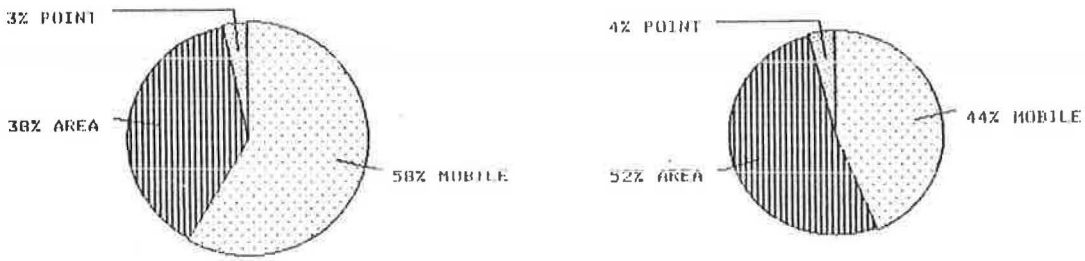
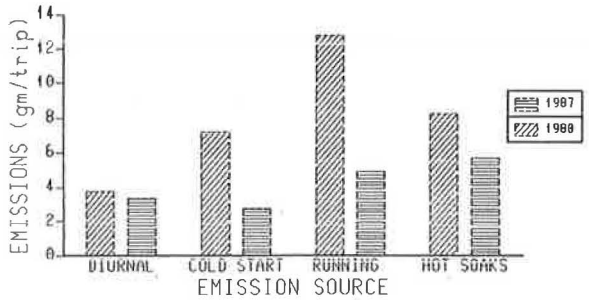


Figure 17. Automobile hydrocarbon emissions for average trip: 1980 versus 1987.



only 34 percent; these are the VMT-related emissions. There is also a category called diurnals, which are emissions that exist whether the car is started or left in the driveway. Also called the evaporative emissions, they represent about 18 percent of the total. The impact of hot soaks over time was an unexpected factor in this study. Cold starts have always been focused on as a primary source of the trip-end emissions, but hot soaks have not been studied in much detail. As can be seen in Figure 17, for the other categories of trip-related emissions--diurnal, cold start, and running--there is a significant decrease in the emissions from 1980 to 1987. There is a much less significant decrease in the proportion of hot soaks to the other categories. Thus, hot soaks represent a large percentage of total emissions. This suggests that there should be a reduction in the number of trips being made, not VMT. By doing so, a much greater reduction in total hydrocarbons and ozone can be achieved.

CONCLUSION

Once the reconnaissance-level impact analysis of the control measures had been completed, phase 2 of the program, screening the measures for implementation by the local governments, began. A more detailed impact assessment of these particular local measures is being performed, and in most cases the cost-effectiveness is being studied to determine the relative effectiveness of stationary sources versus mobile sources and to see how effective they would be on a per-ton basis. Then packages of measures are being evaluated and a final package for implementation that would be recommended to the states will be selected. Finally, in phase 3, local commitments will be obtained and the plan will be recommended.

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

Environmental Impact Statement for Detroit People Mover

STEVE BEARD AND THOMAS RUSHFELDT

Since 1968 studies in southeastern Michigan have addressed the feasibility of an automated people mover to serve the Detroit central business district (CBD). The two goals of such a system have been to facilitate travel and to improve the economic functioning of the CBD. In September 1978, preliminary engineering of the Detroit people mover began under a federal demonstration program. The draft environmental impact statement (EIS) was circulated in March 1980, and the final EIS followed in December 1980. Construction of the 3-mile, elevated, single-lane loop alignment around the Detroit CBD was proposed to begin in the spring of 1983; revenue service was scheduled to begin in 1985. The major environmental issues were both procedural and technical. A significant procedural issue was the desire to make the final EIS an all-purpose environmental document that satisfied all the state and federal environmental requirements. Waiting for clearance by Section 106 of the Historic Preservation Act and Section 4(f) of the Department of Transportation Act of 1966 delayed publication of the final EIS but facilitated the overall completion of environmental requirements. The key technical issue was the integration of an elevated guideway into a CBD containing numerous historic buildings and districts. Coordination with the State Historic Preservation Office was essential to developing an acceptable system. It was eventually possible to finalize plans for a system that would have an adverse effect on only three historic sites.

Since 1968 studies in southeastern Michigan have addressed the feasibility of an automated people mover to serve the Detroit central business district (CBD). The two goals of such a system have been to facilitate travel and to improve the economic functioning of the CBD. In August 1982, the Southeastern Michigan Transportation Authority (SEMTA), the project sponsor, notified the system supplier, the Urban Transportation Development Corporation (UTDC), to proceed. Final design is now under way; construction activities were to begin in the spring of 1983. Revenue service is scheduled for December 1985. The purpose of this paper is to present an overview of the planning and development of the system, emphasizing the environmental process.

PLANNING HISTORY

The planning history of the downtown people mover (DPM) can be divided into three periods: 1968 to 1978, 1978 through completion of the preliminary engineering, and after preliminary engineering. The first period was characterized by local and state planning efforts. Preliminary engineering work under a federal demonstration program began in 1978. Efforts after the completion of the preliminary engineering involved selecting a system supplier, securing federal and local funding, and initiating final design and construction.

First Period (1968 to 1978)

Although planning efforts had been undertaken as early as 1968, it was 1972 when SEMTA assumed responsibility for regional transit planning, including development of a DPM for Detroit. Planning for the DPM was initiated in November 1973 with a feasibility study sponsored by the Michigan Department of Transportation as part of the state's New Transportation Technology Demonstration Program. This study established a basic project plan for the Detroit DPM.

In May 1974, the Detroit DPM proposal was one of four selected by the state for more detailed study. This study culminated in June 1975 with the publication of several major documents, including an engineering report, preliminary systems specifications, and a draft environmental impact assessment report. The impact assessment was the first report to document the potential environmental effects of a DPM in the Detroit CBD, and it was used as the starting point for later environmental analyses.

In 1975, an automated guideway transit program for socioeconomic research was approved by Congress and initiated by UMTA. In April 1976, UMTA announced the establishment of a DPM demonstration program. To investigate their feasibility, DPMs were to be built in a number of cities. In December 1976, four cities were approved as demonstration cities for this program. Detroit's proposal, which was developed from the earlier work, was not selected by UMTA as one of the first demonstration projects, but SEMTA was told that it could proceed with the Detroit DPM provided that the following stipulations were met:

1. The system would form a part of the total regional transit improvements being developed by an ongoing transit-alternatives analysis,
2. The DPM would be funded from UMTA's previous commitment to Detroit for $600,000,000 in transit development funding, and
3. The funding project would be conducted in accordance with UMTA's DPM demonstration guidelines.

Second Period

UMTA approved funding for the preliminary engineering of the Detroit DPM, and work began in September 1978. The preliminary engineering program included engineering feasibility, travel demand modeling, economic analysis, and preparation of an environmental impact statement (EIS). The draft EIS was prepared and circulation began in March 1980. The final EIS was prepared to address the comments raised during circulation of the draft EIS and at the public hearing on the project. The final EIS was circulated on December 3, 1980.

Third Period

In the spring of 1981, the SEMTA board selected UTDC as the DPM system supplier. A contract between SEMTA and UTDC was signed April 23, 1982. A notice to proceed was issued in August 1982, and the work is currently under way. Construction of the fixed facilities should begin early in the spring of 1983, and the start-up of revenue service is planned for December 1985.

SYSTEM DESCRIPTION

The Detroit DPM as described in the EIS will be a single-lane, elevated-loop alignment 2.94 miles long. The system will have 13 elevated stations. The route follows existing city streets in circumscribing an area within the CBD of approximately 0.3 mile^2. The guideway will be constructed primarily within the street right-of-way, in the curb lanes, or on existing street medians. It will be elevated throughout its entire length. The average travel

speed for the automated vehicles, including stops, will be 12.6 mph. The entire loop will be traveled in approximately 14 min.

Of the 13 stations, 8 are planned to be free standing; the remaining 5 will be integrated into existing developments (Renaissance Center and Cobo Hall) or will be designed as an integral part of new developments (Cadillac Square, Millender Center, Joe Louis Arena). It is planned that two of the stations (Grand Circus Park and Renaissance Center) will connect directly to stations of the proposed regional light rail transit system. The total (escalated) cost of the DPM system is estimated to be $135 million.

ENVIRONMENTAL PROCESS OVERVIEW

The environmental analysis, including the preparation of the draft EIS and the final EIS, was undertaken under the framework of state and federal regulations. The city of Detroit had no comprehensive environmental review regulations, but the state of Michigan was actively involved in the environmental review through its agency, the Michigan Environmental Review Board. The environmental review process was structured by federal laws and regulations. The project was also subject to the dictates of the DPM demonstration program as well as the various federal environmental protection laws and regulations.

UMTA Demonstration Program Requirements

SEMTA was required to follow UMTA's federal DPM demonstration guidelines during the preliminary engineering phase of the project. The most significant of these guidelines required that the DPM cities develop performance specifications that would allow a number of different suppliers to compete for the system contract. To accomplish this, preliminary engineering was conducted for a generic design that accommodated the features of most of the currently available DPM systems. The technologies that were accommodated in the design ranged from bottom-supported vehicles to vehicles suspended from overhead; from vehicles with air-cushion suspension to rubber-tire suspension to steel-wheel on steel-rail suspension; and from vehicles with capacities of 20 to those that carried 130 passengers. This wide range of possible technologies and guideway configurations caused difficulties in precisely defining potential impacts. The system description of the DPM alternatives contained a discussion of the range of vehicle and guideway technologies and included many illustrations.

Michigan Environmental Review Board Requirements

In 1974 the governor of Michigan adopted a program of comprehensive review of the potential environmental impacts for all major projects in the state. The executive order created the Michigan Environmental Review Board (MERB). The membership of MERB is drawn from state agencies and from the private sector through appointments by the governor. MERB has a full-time executive director and has promulgated regulations requiring the preparation of environmental assessment reports for major projects within the state. The regulations closely follow the requirements of the National Environmental Policy Act (NEPA) and apply to local as well as federally funded projects. MERB has the power to review the environmental documents, request additional information if necessary, and ultimately report to the governor on the environmental consequences or merits of the projects under review.

For the DPM, MERB requirements resulted in another layer of regulations and another agency to meet with for approval of outlines, study plans, draft EIS, and final EIS. All formal submissions of documentation to UMTA were also supplied to MERB. MERB regulations did, however, provide for circulation of a single document to satisfy both state and federal requirements, provided that all state concerns were adequately addressed.

UMTA and Other Federal Requirements

The main requirements that guided the preparation of the environmental analysis of the DPM were the federal environmental regulations. These included

1. NEPA,
2. The regulations of the Council on Environmental Quality,
3. U.S. Department of Transportation (DOT) regulations, and
4. UMTA regulations and guidelines.

These legal and administrative provisions dictated that an EIS was required for the DPM project and specified the timing, organization, content, and processing of the documentation. Because the DPM will have impacts on cultural resources, the provisions of Section 106 of the Historic Preservation Act and Section 4(f) of the Department of Transportation Act of 1966 had to be considered. Both sections deal with additional documentation and processing requirements for projects affecting cultural resources, in this case, historic properties in the CBD.

In summary, it was necessary to complete an environmental document that met the requirements of the DPM demonstration program guidelines, the federal environmental regulations, and requirements promulgated to ensure the state a prominent role in environmental review. The expected impacts on cultural resources triggered parallel processes involving the U.S. Department of Interior (Section 106) and the Secretary of Transportation [Section 4(f)].

MAJOR ENVIRONMENTAL ISSUES

The EIS for the DPM was somewhat unique in that it dealt with the expected impacts of a generically defined technology operating in a densely urban setting where no such system had ever operated. The DPM program was a demonstration program to test the impacts of automated transit operations in a CBD. The program included provisions for a before-and-after study of operations of the DPM to determine precisely what impacts had occurred. The EIS, however, had to present the expected impacts with little empirical back-up data from operating systems. The DPM technology was defined only in general terms at the time of preparation of the EIS. In some cases this lack of specificity made it difficult to be precise in defining the impacts of the system. Each candidate DPM technology had its own noise, energy, and guideway specifications.

The issues that were selected for emphasis in the EIS were

1. Traffic and circulation,
2. Economics,
3. Noise,
4. Visual issues, and
5. Cultural resources.

The projected impacts of the DPM in each of these areas are summarized in the remainder of this section.

Traffic and Circulation

The DPM was conceived as a means to improve circulation in the CBD and to help alleviate traffic problems. It was estimated that the DPM would have a generally positive, but not overwhelming, impact on existing transportation systems. The capability of the downtown transportation system to move people would be increased, but benefits would not extend outside the CBD. The mobility of travelers with trip ends inside the DPM loop would be increased because of reduced congestion and direct use of the DPM. Persons traveling to the CBD would be more likely to park in fringe areas, an action that would reduce congestion in the CBD core and lower the cost of parking. Relocation of existing parking lots to the edges of the CBD would become an attractive alternative and would allow buildings to be constructed on vacated parking areas in the CBD core. The overall impact of the DPM would be to improve mobility within the CBD and improve access to the CBD core.

Predicted passenger volumes on the system are 71,000 passengers per weekday in 1990; 11,500 passengers are predicted in the noon peak hour. The average length of a trip is expected to be about 1.2 miles or slightly less than half the distance around the alignment. With vehicles traveling at 94-sec headways around the system, average passenger waiting times of about 47 sec could be expected under normal conditions. When combined with the average time passengers spend on a vehicle (5.4 min), the average station-to-station trip time for passengers is slightly more than 6 min.

Economics

A key issue in Detroit was the impact the DPM would have on the ongoing efforts to revitalize the central city. It was predicted that the DPM's major impact would be on land use and urban development. It was also predicted that construction of the DPM would increase investment in office, retail, hotel, and residential land uses within the CBD. Construction of a grade-separated transportation system would encourage all station areas to become activity centers due to their improved accessibility. Downtown employees and visitors would begin to make greater use of downtown retail and office businesses because of the convenient access afforded by the DPM.

Since 1966 the downtown area has been losing a substantial amount of office business. Projections indicate that the DPM system would decrease the rate at which the CBD has been losing its share of the office market. Between 1983 and 1990, it is expected that the DPM will increase total office space by 5 to 5.5 percent (compared with projected demand without the DPM). With the DPM system in operation, demand for additional downtown office space is expected to increase by 450,000 gross ft^2/yr.

Retail businesses would also benefit from construction of the DPM. Although development of the Renaissance Center and the Woodward and Washington Street Malls has stimulated retail development, retail sales still declined an average of 4.4 percent per year between 1972 and 1978. Construction of the DPM would connect the Renaissance Center with the older retail core, office buildings, and the convention area. All retail sales in the CBD are projected to increase from $295 million in 1978 to between $350 and $370 million in 1990, as measured in constant 1976 dollars.

For two other land use elements, residential housing and hotel and motel units, substantial increases are forecast. It is estimated that construction of a DPM would create demand for an additional 1,250 to 1,500 residential units in the CBD between 1985 and 1990. Furthermore, it is projected that the DPM will result in the demand for an additional 600 new hotel rooms by 1990--an increase of about 20 percent in the total number of hotel rooms in the CBD. With this expected growth in development, the DPM would create 2,900 additional jobs in the CBD. The projected growth in housing would increase the population of the CBD, benefitting the economy and enabling more efficient use of vacant land on the edges of the CBD.

Construction of the DPM is to be paid for by federal and state tax funds, benefitting southeastern Michigan by returning funds to the area. Operating costs would be met entirely by passenger fares, advertising income, and participation in joint development by private businesses. The employment and cost analyses clearly indicate a net benefit to be gained by the downtown business region from implementation of a DPM system.

When considered with the city of Detroit's proposed redevelopment plans, the DPM is an important element. Major downtown redevelopment or expansion projects sponsored or supported by the city have included phases 2 and 3 of the Renaissance Center, a new riverfront arena with housing and a major parking garage located nearby, rehabilitation and redevelopment of properties along Washington Boulevard, and smaller developments near Greektown and the financial district. All of these projects would have DPM stations on or near the site. It appears certain that each station would stimulate new development, which would support the city's objectives for downtown growth.

Noise

Noise was originally perceived to be a major environmental issue. However, this concern was not borne out by the analyses or by public comments. Ambient noise levels were monitored at 25 locations along the DPM alignment. Most locations were noise sensitive, such as auditoriums, churches, parks, offices, and residential areas. Maximum passby noise levels (L_{max}) were estimated for the DPM, and the impact of the system on ambient levels (L_{max} and L_{10}) was calculated. At 23 locations, it was predicted that L_{10} levels with the DPM in operation would increase over ambient levels but the judicious use of noise barriers would reduce noise to within acceptable levels all along the alignment.

Visual Issues

The compatibility of the DPM with the visual character of the CBD was addressed by the preparation of artist's renderings and photomontages. With these aids it was determined that the DPM would only have slight adverse effects on visual resources.

Guideway crossings in front of buildings along the route could detract from the building's appearance. Also, the views from the lower floors of some adjacent buildings would be altered. To mitigate this impact, the guideway and station facilities would be designed to harmonize with existing horizontal and vertical lines of buildings wherever feasible. Changes in vertical grade would be minimized to produce a smooth, flowing appearance. All storm drains, heating system components, and power-supply and train-control cables would be hidden. The drawings and photographs were invaluable in assessing impacts and in presenting the project to the public.

Cultural Resources

The Detroit CBD has a rich historical heritage; many fine buildings remain from its past. At the beginning of the DPM study, research led to compilation of a list of more than 120 places in the Detroit CBD that possessed some degree of historic significance. A major environmental issue was the DPM's potential impact on historic properties or other cultural resources in the CBD.

From the outset of the project, every effort was made to avoid impacts on historic resources. The State Historic Preservation Office (SHPO) was involved from the beginning to review preliminary alternatives and to adjust the final alignment to minimize impacts. It was eventually determined that 15 properties on, or eligible for, the National Register of Historic Places were located near the DPM alignment. By using the criteria of effect and adverse effect from the regulations of the Advisory Council on Historic Preservation, UMTA in consultation with SHPO determined that the DPM would have no effect on four of the properties. A finding of no adverse effect was made for eight of the properties. At the time of the final EIS, the DPM was judged to have an adverse effect on three properties:

1. Buckland-Van Wald Building,
2. Grand Circus Park Historic District, and
3. Detroit street plan.

The Buckland-Van Wald Building was designed and constructed in the 1880s and consists of two buildings with a common wall. This building is located on the site of the proposed maintenance facility. Following studies of alternative maintenance sites and the possibility of incorporating the existing buildings into the maintenance facility, demolition of the structure was determined to be the only feasible option. SEMTA agreed to record the building following the standards of the National Architectural and Engineering Record before demolition.

The DPM's adverse impact on the Grand Circus Park Historic District and the Detroit street plan would be less severe. The DPM would pass through the Grand Circus Park Historic District but would not require the demolition of any historic property or the taking of any part of the park. Members of the Grand Circus Park Development Association believe that any negative effects would be offset by economic benefits that would revitalize this historic area. The DPM would interrupt the broad avenues and views of open spaces originally designed as part of the Detroit street plan. An overhead structure such as the DPM would have some negative effect on the view of Grand Circus Park from Woodward Avenue and the Detroit River from Woodward Avenue. SHPO has noted that the location of a station across Woodward Avenue near Grand Circus Park could create the impression that the street terminates at the station. For both Woodward Avenue crossings, SEMTA planners and engineers have indicated that these locations are the best options. Alternative locations for the Grand Circus Park station would have more severe impacts than the location at the northern end of Woodward Avenue.

PROBLEMS ENCOUNTERED

Several problems were encountered during the environmental review process. The most significant of these were the problems in finalizing the outline of the EIS document; the resolution of the alternatives to be addressed in the document; the high turnover of UMTA staff, resulting in discontinuity of supervision; and the many difficulties in conforming with the overlapping Section 106 and 4(f) requirements. Each of these problems is discussed below.

EIS Outline

Considerable difficulty and frustration was caused by a number of changes to the basic outline of the EIS document. Early in the project SEMTA developed an outline for the EIS. UMTA approved the early outline but, later, during preparation of the individual chapters, made major changes that required fairly extensive rewrites. These major changes continued through the completion of the draft EIS. Some of these changes resulted from turnover in UMTA staff but many resulted from the review of submissions by UMTA supervisors late in the process. This review resulted in major changes and rewrites, which could have been minimized had these supervisors been involved earlier in the process. Because the changes occurred late in the draft EIS development process when the environmental work involved the DPM project's critical path, they caused considerable frustration and resulted in delays.

Analysis of Alternatives

Another of the initial problems in the EIS process was the treatment of alternatives to the DPM system. DPM demonstration program guidelines from UMTA did not discuss the development and analysis of alternatives other than the DPM. From the guiding environmental regulations, however, it was clear that the EIS would have to contain a discussion of alternatives. UMTA wanted consideration given to such alternatives as the CBD portion of the light rail system being planned in a parallel study, a light rail loop in the CBD, and the CBD component of a regional expansion in the surface bus system. Early work on the EIS included these alternatives, but there were major difficulties with each. The light rail loop in the CBD would have required considerable engineering work that was clearly outside the scope of the DPM demonstration program. All three of the alternatives did a poor job of circulating people within the CBD in a cost-effective manner, which was the intended purpose of the DPM. Because the alternatives did not serve the stated goals of the DPM, they were not viable alternatives within the intent of the National Environmental Policy Act.

Another problem concerning alternatives was that of a do-nothing or no-action alternative: an alternative or base condition against which the impacts of the preferred alternative are measured. The only existing circulator service in the CBD was a shuttle bus. Again, this was a poor alternative because it did not provide service comparable with that of the DPM.

After weeks of discussions, UMTA agreed that a single alternative to the DPM should be included in the EIS: a circulator bus. This alternative was designed to closely match the routing and level of service of the DPM. In this way a lower alternative capital cost could be analyzed. The compatibility of service made the circulator bus a more valid alternative base-line against which the DPM impacts could be measured.

The time that was lost choosing alternatives to include in the EIS did have a detrimental impact on the early stages of the project. It caused some floundering in finalizing the planning and engineering work programs, added to the cost of the project, and resulted in a one- to two-month delay in circulation of the draft EIS.

UMTA Staff Supervision

Another problem was turnover in the UMTA personnel responsible for reviewing the EIS. Four different UMTA staff members were responsible for guiding preparation of the EIS. Each change in personnel resulted in delays and changes in the document. This high rate of turnover of personnel also led to problems with internal communications at UMTA. After issues with staff members had been resolved and the instructions had been received and acted on, these instructions were often overturned or modified by the new project monitor or supervisor at a higher level, who had particular sensitivities in certain areas. This problem would have been greatly mitigated had there been more continuity of UMTA staff supervision.

Section 106 and 4(f) Compliance

There was much duplication of effort required to satisfy both the provisions of the DOT Act [Section 4(f)] and those of the National Historic Preservation Act (Section 106). With both acts, the issue was the adverse effects of the DPM on the three properties eligible for the National Register.

Section 106

Section 106 and the implementing regulations of the Advisory Council on Historic Preservation (ACHP) required the preparation of preliminary case reports on each of the three properties. Key elements required in the case reports were

1. Description and significance of affected property,
2. Application of the criteria of adverse effect,
3. Views of SHPO,
4. Views of others,
5. Alternatives that would avoid adverse effect,
6. Alternatives that would mitigate adverse effect, and
7. Determinations.

The case reports were completed and circulated to ACHP. Subsequently, a memorandum of agreement was negotiated with ACHP that allowed the adverse effects provided that certain mitigation measures were adopted. The measures included

1. Completing a feasibility study on alternative sites for the maintenance facility and on alternative designs that would preserve the Buckland-Van Wald Building;
2. Completing a feasibility study on moving the Buckland-Van Wald Building;
3. Recording the Buckland-Van Wald Building for the National Architectural and Engineering Record;
4. Preserving representative architectural elements of the Buckland-Van Wald Building for curatorial or other use in projects;
5. Allowing SHPO to review and comment on the final design of the alignment and station at Grand Circus Park Historic District;
6. Studying the Grand Circus Park station to investigate the possibility of using elevators instead of escalators to reduce the structural mass at street level, finding alternative locations for the vertical circulation system off Woodward Avenue, and reviewing the feasibility of incorporating the station into an existing building; and
7. Conducting an historic land use survey and limited subsurface testing program to identify potential archaeological resources.

Section 4(f)

Separate documentation was necessary to satisfy Section 4(f), which required that the Secretary of Transportation certify that there were no prudent or feasible alternatives to the adverse effects and that all possible planning had been undertaken to minimize the harm. The requirements for the Section 4(f) statements were almost identical to those for the preliminary case reports:

1. Description and significance of property,
2. Proposed use,
3. Alternatives,
4. Mitigation, and
5. Coordination.

Even though the requirements of both acts are similar, two separate sections had to be written for the final EIS and each section processed through different channels. Significant delay was experienced in the duplicative work. The greatest delay, however, came when DOT requested that additional work be done on alternatives to the demolition of the Buckland-Van Wald Building. At the time, the Section 106 process had been completed and a memorandum of agreement had been signed. The Office of the Secretary failed to accept the same detailed consideration of alternatives that had been accepted by ACHP. The additional work delayed completion of the final EIS by more than a month. In the end, the Secretary of Transportation finally approved demolition of the building as proposed by SEMTA.

It should be noted that revisions are under consideration that would reduce the duplication of effort now experienced in complying with Sections 106 and 4(f).

LESSONS LEARNED

What Was Right About the Process

In general the EIS process on UMTA projects is efficient. The UMTA regulations and guidelines were clear and were followed by the UMTA staff. Throughout the DPM project, the UMTA staff were accessible and prompt in their responses to inquiries. Submissions to UMTA were reviewed in a reasonable amount of time and comments were, for the most part, pertinent to the larger issues.

The element that had the greatest positive impact on the process was the early and continued involvement of SHPO in the project. All preliminary alternatives were reviewed by SHPO, and their comments were seriously weighed by SEMTA. The coordination with SHPO resulted in numerous alignment changes (e.g., guideway moved across the street from a National Register property) to minimize the impacts on cultural resources. When formal determinations were requested, few historic properties were affected and there were no surprises to SHPO or to SEMTA.

Where adverse effects did occur, SHPO had been sufficiently involved with the planning process to know that there were no feasible alternatives and that SEMTA would plan for appropriate mitigation. The Section 106 process for the DPM did not become an adversary relationship as so often happens. Rather, it was a joint effort of SEMTA and SHPO to preserve cultural resources and to improve mobility in the CBD. This relationship of trust and involvement with SHPO greatly minimized the impacts on historic properties and facilitated the entire EIS process.

The broad acceptance that the EIS has received is in large part due to the numerous, high-quality photomontages and drawings included in the document.

These were effective in providing a quick visual overview of the DPM project and its impacts without the necessity of reading the entire document. The readability of the document was also greatly enhanced by summarizing most of the technical and numerical data into tabular matter and graphs and addressing only the most significant points in the text.

What Was Wrong with the Process

The parts of the EIS process that resulted in the most difficulty and delay stemmed primarily from questions of form and management rather than strictly technical or environmental issues. The changing direction received about alternative actions and alignments to be presented in the EIS and the numerous structural changes to the EIS document caused the majority of the problems. These problems were further exacerbated by turnover and communication problems within the UMTA staff. The actual technical contents of the EIS were questioned in few instances. Thus, the most time-consuming part of the process was that of expediting the document through the approval process rather than concentrating on technical issues and the actual system impacts.

What We Would Do Differently

Although we were careful to maintain a close, ongoing relationship with the federal representative responsible for the EIS, next time we would expend even more effort early in the development process to develop a detailed outline for the EIS. After completing this outline, we would attempt to get a formal, written approval from the UMTA division chief or associate administrator responsible. Following this approval, we would attempt to stick as closely to this outline as possible and resist all changes from this basic structure. (These changes cost time and money.) In a similar way, we would identify the alternatives early and attempt to get an approval in writing. Action in these two areas, if carefully addressed early in the process, would have substantially reduced our problems.

Recommendations for Change

After having experienced the EIS process for the Detroit DPM, we would recommend changes to the EIS process in two areas: a better definition in the EIS guidelines of the alternatives to the proposed action that must be presented in the EIS and a consolidation of the overlapping Section 106 and Section 4(f) requirements relative to impacts on historical and archaeological resources.

The EIS development guidelines were quite vague on the type of alternative actions and level of detail to which these must be addressed in the EIS. These vague guidelines were subject to a variety of interpretations and resulted in considerable uncertainty. This in turn resulted in contradictory direction, rewriting, and delay. This situation was further clouded because during the development of the EIS for the DPM, many cities (including Detroit) were involved in alternatives analysis for regional systems. UMTA's involvement in these extensive analyses of alternatives led to further confusion over the type of alternatives that needed to be addressed and the level of detail required for this, a demonstration project. Many of these problems could be reduced or eliminated if further clarification of the alternatives that must be addressed were included in UMTA's guidelines for EIS development.

Finally, we believe that there is considerable overlap between Section 106 and Section 4(f) regulations; both place significant (and overlapping) requirements on projects that have an adverse impact on historic or archaeological resources. We realize that these are two different laws, but in our judgment, these two overlapping sets of regulations offer no additional protection for these resources and cause significant additional paperwork and potential delay to completing the process.

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