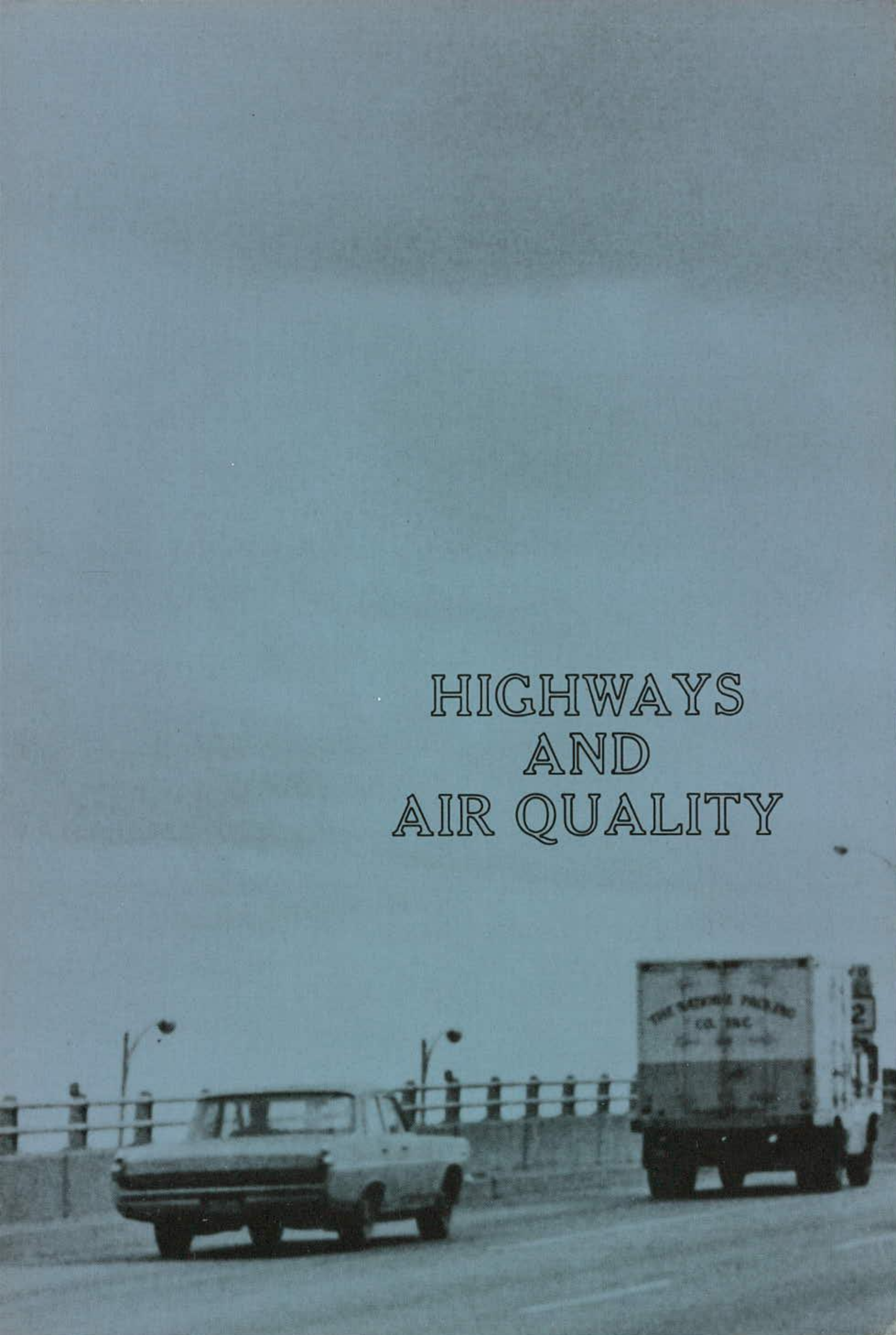


HIGHWAYS AND AIR QUALITY

HIGHWAY RESEARCH BOARD 1973

HIGHWAYS AND AIR QUALITY

Subject Areas

11 transportation administration
52 road user characteristics
53 traffic control and operations
70 legal studies
81 urban transportation administration
82 urban community values
83 urban land use
84 urban transportation systems

SPECIAL REPORT 141
Highway Research Board
Division of Engineering, National Research Council
National Academy of Sciences–National Academy of Engineering
Washington, D.C., 1973

NOTICE

The conference that is the subject of this report was approved by the Governing Board of the National Research Council acting in behalf of the National Academy of Sciences. Such approval reflects the Governing Board's judgment that the conference is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the committee selected to organize the conference and to supervise the preparation of this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project.

Responsibility for the selection of the participants in the conference and for any summaries or recommendations in this report rests with that committee. The views expressed in individual papers and attributed to the authors of those papers are those of the authors and do not necessarily reflect the view of the committee, the Highway Research Board, the National Academy of Sciences, or the sponsors of the project.

Each report issuing from such a conference of the National Research Council is reviewed by an independent group of qualified individuals according to procedures established and monitored by the Report Review Committee of the National Academy of Sciences. Distribution of the report is approved by the President of the Academy upon satisfactory completion of the review process.

ISBN 0-309-02165-0
Library of Congress Catalog Card No. 73-8482
Price: $2.80

Highway Research Board publications are available by ordering directly from the Board. They are also obtainable on a regular basis through organizational or individual supporting membership in the Board; members or library subscribers are eligible for substantial discounts. For further information, write to the Highway Research Board, National Academy of Sciences, 2101 Constitution Avenue N.W., Washington, D.C. 20418.

CONTENTS

advisory committee

INTRODUCTION

On March 16, 1972, representatives of the Federal Highway Administration and the U.S. Environmental Protection Agency met with staff members of the Highway Research Board to discuss the following activities:

1. The development of information on the relations between air pollution control and highway planning, construction, and operation that will be helpful to the Environmental Protection Agency, the Federal Highway Administration, and the states in discharging their respective responsibilities under the Clean Air Amendments of 1970, the Federal-Aid Highway Act of 1970, and the National Environmental Policy Act of 1969; and

2. The promotion of coordination between transportation development and air pollution control as provided in Section 136b of the Federal-Aid Highway Act of 1970 (23 U.S.C. 109j) and in the legislative history of the Clean Air Amendments of 1970 and as reiterated by the U.S. Senate Public Works Committee.

As a result of that meeting, the Highway Research Board agreed to undertake a program to carry out those activities, and EPA and FHWA agreed to provide financial support.

Drawing upon the resources of the Academy and the National Research Council, the Board created a 14-member Advisory Committee on Highways and Air Quality and charged it with the following responsibilities:

1. Assess the present situation with regard to the relation between highways and air quality in terms of present legislative and administrative requirements, the technical state of the art, and ongoing research;

2. Identify the primary issues and problem areas; and

3. Plan and conduct a 2- or 3-day workshop on highways and air quality in the fall of 1972 at which invited experts on transportation and on air pollution control can discuss and evaluate the issues and problem areas identified by the committee in terms of new administrative and planning requirements, available technology, and needed research.

During the spring and summer of 1972, the Advisory Committee on Highways and Air Quality met successively in Washington, D. C., Los Angeles, and Madison. At those meetings committee members were briefed by representatives from the District of Columbia Department of Highways and Traffic, the Department of Air Resources of New York City, the Environmental Quality Laboratory of the California Institute of Technology, the San Francisco Bay Metropolitan Transportation Commission, the Materials and Research Department of the California Division of Highways, and the Division of Air Pollution Control of the Illinois Environmental Protection Agency.

From September 11 through September 13, 1972, the Advisory Committee conducted an air quality workshop in Washington, D. C. Workshop participants were divided into 4 working groups to deal with the following specific subjects: highway air quality analysis and evaluation, short-term control strategies, implications for transportation planning, and institutional relations for implementing solutions. The reports of each of the 4 working groups are contained in this special report.

The Advisory Committee on Highways and Air Quality met again in Washington in December 1972 and March 1973 to review the results of the workshop and new information that developed after the workshop. This special report represents a culmination of the efforts of the advisory committee. The committee prepared the Summary of Findings and Observations and Comments, which appear in the following 2 sections. The Observations and Comments represent the general, though not necessarily the unanimous, consensus of the committee members concerning various aspects of the Summary of Findings.

Readers of this report should keep in mind that air quality, the subject of this study, is but one of a highly complex set of issues that must be considered in the planning of transportation systems or other public works. The Highway Research Board has been deeply involved through its committees, conferences, and workshops in all aspects of planning and land use, and Board publications are available that discuss the overall planning process and the issues involved. This report, then, concerns itself only with the air quality issue and considers air quality matters as input to the broader planning process.

SPECIAL NOTICE

After this special report had been completed and while it was being prepared for publication, William D. Ruckelshaus, the then Administrator of the U.S. Environmental Protection Agency, announced on April 11, 1973, that he was postponing until 1976 the application to new light-duty motor vehicles of carbon monoxide and hydrocarbon emission standards originally proposed for 1975. Mr. Ruckelshaus stated that EPA will adopt 2 sets of less restrictive interim emission standards for 1975, one set to be applied in the state of California and the other set to be applied in the rest of the states.

advisory committee

SUMMARY OF FINDINGS

Air pollution in the United States results from many activities including transportation, fuel combustion in stationary sources, industrial processes, and solid waste disposal. Recognizing the significant contribution of motor vehicles to air pollution in a number of urban areas, the Congress enacted the Clean Air Amendments of 1970 (84 Stat. 1676) that require substantial reductions in carbon monoxide and hydrocarbon emissions from light-duty motor vehicles beginning with the 1975 model year. [Hereafter in this report terms such as "light-duty motor vehicles" are intended to have the general meaning assigned to them by the U. S. Environmental Protection Agency. In this particular case, the term "light-duty motor vehicles" is intended to mean passenger vehicles, other than buses, traveling on highways. The general problem of light-duty trucks is discussed elsewhere (1).] Similar reductions will be required for nitrogen oxide emissions from light-duty motor vehicles beginning in 1976. Emissions from heavy-duty motor vehicles are subject to control under the 1970 Amendments. The Amendments, however, do not specify particular deadlines and emission levels but instead give the U. S. Environmental Protection Agency the responsibility for making those determinations.

Questions as to the technical feasibility of emission standards, particularly the 1975-76 standards, their economic impact, trade-offs with standards for stationary sources of air pollution, and so on are being explored in other studies and are not the subject of this report. This report instead deals primarily with changes that can be made and techniques that can be used in the planning and operation of transportation systems and facilities to minimize motor vehicle air pollution and its impact. (This report does not deal with transportation controls for air pollution emergency episodes that cause imminent and substantial danger to health not because of any intention to minimize the importance of emergency episode controls in maintaining air quality but because that subject did not fall within the scope of the present study.)

Short-Term Transportation Control Strategies

1. INSUFFICIENCY OF EMISSION REDUCTIONS IN SOME AREAS

The U.S. Environmental Protection Agency has concluded on the basis of data submitted to it by the states that in a number of U.S. urban areas emission reductions of new motor vehicles as required by the federal government will not by themselves be sufficient to permit those urban areas to meet national primary ambient air quality standards by 1975 as required by current federal law.

In addition to providing for emission controls for motor vehicles and for various types of industrial sources, the Clean Air Amendments of 1970 provide for the promulgation of "national primary and secondary ambient air quality standards." Those air pollution control standards are to be applied to ambient or surrounding air and must be uniform throughout the United States. Primary standards are designed to protect the public health, and secondary standards are designed to protect public welfare. [Effects of air pollutants on public welfare would include effects on soil, water, crops, vegetation, man-made materials, animals, wildlife, visibility, and climate; damage to and deterioration of property; hazards to transportation; and effects on economic values and on

CONDITIONS FOR EXTENDING TIME LIMIT

Under the Clean Air Amendments of 1970 to the Clean Air Act (42 U. S. C. 1857), the Administrator of the Environmental Protection Agency may grant a state an additional 2-year period (i.e., until May 31, 1977) before the state must be in full compliance with the state air quality implementation plan approved by EPA. The 2-year extension can be granted by the Administrator only under the conditions specified in the legislation. Under this provision, the Administrator has granted 2-year extensions to a number of states with respect to various portions of their implementation plans.

The U. S. Circuit Court of Appeals for the District of Columbia in Natural Resources Defense Council v. Environmental Protection Agency, No. 72-1522, January 31, 1973, ordered the Administrator to formally rescind all such extensions and to inform all affected states that any state that has not submitted an implementation plan that fully complies with the Clean Air Act, and in particular that provides for the attainment by May 31, 1975, of the national primary ambient air quality standards adopted by EPA on April 30, 1971, must submit such a plan by April 15, 1973. The court's decision was based on the failure of the Administrator in granting the 2-year extensions to fully comply with the provisions of the Clean Air Act. At a later date, the Administrator may grant 2-year extensions where in each case he can show full compliance with the standards set down in the Act.

The Clean Air Act (42 U. S. C. 1857c-5) also provides:

> Prior to the date on which any stationary source or class of moving sources is required to comply with any requirement of an applicable implementation plan the Governor of the State to which such plan applies may apply to the Administrator to postpone the applicability of such requirement to such source (or class) for not more than one year. If the Administrator determines that (a) good faith efforts have been made to comply with such requirement before such date, (b) such source (or class) is unable to comply with such requirement because the necessary technology or other alternative methods of control are not available or have not been available for a sufficient period of time, (c) any available alternative operating procedures and interim control measures have reduced or will reduce the impact of such source on public health, and (d) the continued operation of such source is essential to national security or to the public health or welfare, then the Administrator shall grant a postponement of such requirement.

personal comfort and well-being (42 U.S.C. 1867h).] The national primary and secondary ambient air quality standards that have been adopted to date by the U.S. Environmental Protection Agency are given in Table 1 (2).

The great significance of the national ambient air quality standards is that the Clean Air Amendments of 1970 provide that the air in all parts of the United States must meet the national primary ambient air quality standards given in Table 1 by May 31, 1975. Secondary standards must be achieved within a "reasonable time." In certain cases, the time limit for the primary standards may be extended to 1977. Each state has the responsibility for meeting the air quality standards within its borders, and each state must explain to the federal government in a detailed "implementation plan" how the state intends to do it. If a state prepares an inadequate implementation plan, or fails to carry out its implementation plan, the U.S. Environmental Protection Agency must step in and formulate its own air pollution cleanup program. By 1975, then, or 1977 at the latest, air quality in all areas of the United States should have improved sufficiently so that there will no longer be any danger to public health from the air pollutants given in Table 1.

The estimated relative contribution by weight of transportation to the nation's air pollution problem is given in Table 2 (3). It is apparent that transportation is a major source of carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NO_x). The impact varies from city to city as shown by data given in Table 3 (4). Transportation is also a comparatively small but nonetheless significant source of particulates, especially airborne lead, and a relatively insignificant source of sulfur oxides.

Lead is currently thought to be the most important particulate pollutant emitted in the exhausts of gasoline-powered motor vehicles.

Table 1. National primary and secondary ambient air quality standards.

Pollutant	Concentration Limit: Micrograms per Cubic Meter	Concentration Limit: Parts per Million	Averaging Time
Carbon monoxide	10,000	9	8 hours[a]
	40,000	35	1 hour[a]
Photochemical oxidants	160	0.08	1 hour[a]
Hydrocarbons (methane free)	160	0.24	3 hours[a]
Nitrogen oxides	100	0.05	1 year
Sulfur oxides	80	0.03	1 year
	365	0.14	24 hours[a]
	(60)	(0.02)	(1 year)
	(260)	(0.1)	(24 hours)[a]
	(1,300)	(0.5)	(3 hours)[a]
Particulate matter	75	—	1 year[b]
	260	—	24 hours[a]
	(60)	—	(1 year)[b]
	(150)	—	(24 hours)[a]

Note: Secondary standards are shown in parentheses; for some pollutants the secondary standards are the same as the primary standards.

[a]Not to be exceeded more than once a year.

[b]Geometric mean.

Table 2. Estimated nationwide emissions in 1970.

Source	Sulfur Oxides	Particulate Matter	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Transportation	1.0	0.7	111.0	19.5	11.7
Fuel combustion in stationary sources	26.5	6.8	0.8	0.6	10.0
Industrial processes	6.0	13.1	11.4	5.5	0.2
Solid waste disposal	0.1	1.4	7.2	2.0	0.4
Miscellaneous	0.3	3.4	16.8	7.1	0.4
Total	33.9	25.4	147.2	34.7	22.7

Note: Amounts are in millions of tons/year.

Table 3. Percentage of pollutants from mobile and stationary sources in large urban areas.

		Carbon Monoxide		Hydrocarbons		Nitrogen Oxides	
Region	Study Year	Mobile	Stationary	Mobile	Stationary	Mobile	Stationary
Chicago	1967	94	6	81	19	35	65
Denver	1967	93	7	78	22	48	52
Los Angeles	1966	95	5	72	28	73	27
New York	1965	96	4	84	16	38	62
Philadelphia	1967	70	30	47	53	27	73
Washington, D. C.	1966	96	4	86	14	44	56
Dallas	1967	97	3	93	7	80	20
Phoenix-Tucson	1967	94	6	87	13	71	29
Portland, Ore.	1968	72	28	64	36	79	21
Cincinnati	1967	85	15	83	17	34	66
Louisville	1967	75	25	83	17	35	65
Miami	1968	90	10	93	7	60	40
Atlanta	1968	89	11	86	14	71	29
Houston	1967	75	25	58	42	43	57
New Orleans	1968	47	53	49	51	56	44
Oklahoma City	1968	98	2	49	51	69	31
Pittsburgh	1967	80	20	70	30	29	71
St. Louis	1967	77	23	80	20	48	52
Charlotte	1968	92	8	86	14	28	72
Hartford	1967	95	5	82	18	52	48
Indianapolis	1967	85	15	86	14	52	48
Providence	1967	95	5	88	12	56	44

The U. S. Environmental Protection Agency has adopted regulations that provide for the general availability by July 1, 1974, of essentially lead-free and phosphorus-free gasolines of an octane quality suitable for 1975 and subsequent model year light-duty motor vehicles. Normal retail outlets will sell unleaded gasolines in addition to the leaded gasolines that are now available. The purpose of these regulations is to provide for the availability of gasoline that will be compatible with emission control devices that are expected to be incorporated in light-duty motor vehicles beginning with the 1975 model year. The U. S. Environmental Protection Agency is also considering the adoption of regulations that will produce a phased reduction in the lead content of leaded gasoline to protect the public health from possible adverse effects of airborne lead generated by motor vehicles (5).

Another important type of particulate emitted by motor vehicles is the smoke generated by improperly maintained heavy-duty diesel engines in trucks and buses. There are federal standards limiting smoke emissions from new diesel engines and some state standards limiting smoke emissions from diesel engines in use (40 CFR 85-I).

Table 4. 1975-76 federal emission standards for light-duty motor vehicles.

Pollutant	Controlled Emission Levels (grams/mile)	Beginning With Model Year
Hydrocarbons	0.41	1975
Carbon monoxide	3.4	1975
Nitrogen oxides	0.4	1976

Note: See special notice, p. 2.

In addition to their direct emissions (Table 2), motor vehicles are also a major source of photochemical "smog," which is formed in the atmosphere as the result of a series of complex chemical reactions involving nitrogen oxides, nonmethane hydrocarbons, and sunlight.

Table 4 (6) gives the CO and HC emission standards that will apply to new light-duty motor vehicles in 1975 and the NO_x emission standards that will apply in 1976. The CO and HC standards represent a 90 percent reduction from the 1970 level, and the NO_x standard represents a 90 percent reduction from the 1971 level.

There is no simple, straightforward way to relate those emission reductions to the amount of ambient air quality improvement that might be produced in a given region because the chemical and meteorological dynamics of air pollution are complex and not well understood. The U. S. Environmental Protection Agency, however, has for regulatory purposes adopted a simple "rollback" approach that ignores the chemical and meteorological dynamics and simply assumes that a proportional rollback in emissions from all sources in a particular region will produce an improvement in regional air quality in the same proportion. The EPA's rollback formula (7) is as follows:

$$\frac{A - C}{A - B} \times 100 = \text{percentage of reduction needed}$$

where

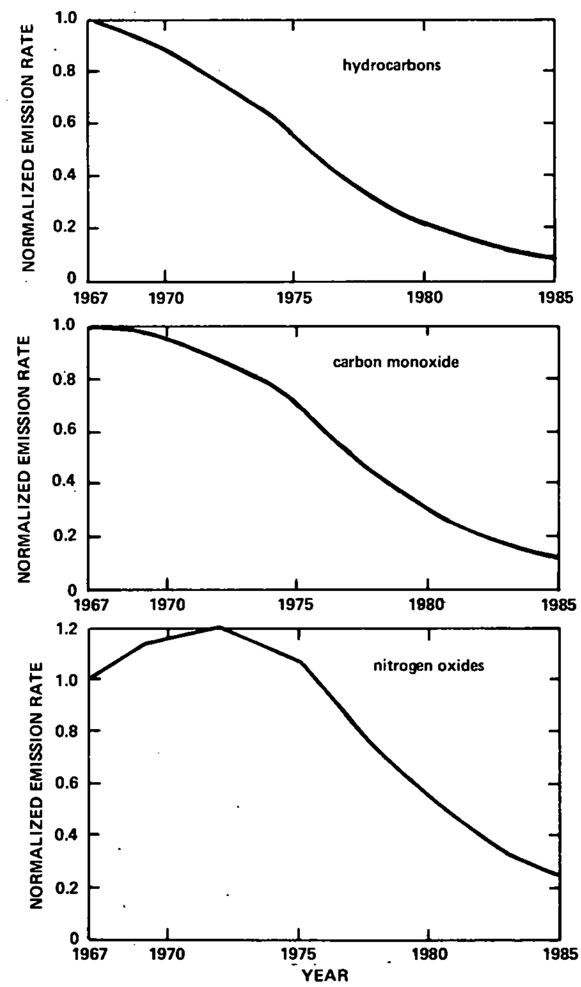
A = existing air quality at the location having the highest measured or estimated concentration in the region,
B = background concentration, and
C = national ambient air quality standard.

Application of this rollback approach might seem to indicate that when the light-duty motor vehicle emission standards (Table 4) go into effect in 1975 and 1976 the 90 percent reduction in emissions will produce a 90 percent improvement in air quality above background levels. That will not be the case. It will take at least 10 years following the application of the 1975-76 emission standards before pre-1975-76 motor vehicles with less effective emission controls are eliminated by age and attrition from the nation's streets and highways. Moreover, the emission control devices on post-1975-76 motor vehicles are expected to deteriorate to some extent with age. Even with a mandatory periodic motor vehicle inspection and maintenance program, emission control devices are expected to deteriorate between inspections so that average emissions during the period between inspections will exceed the emissions that would be generated if the emission standards were continuously maintained. And finally, urban vehicle-miles of travel are projected to continue increasing steadily, so that emission reductions resulting from vehicle emission controls will be offset to some extent by increases in emissions resulting from increases in vehicle travel.

Those points are illustrated by the normalized emission curves for CO, HC, and NO_x in Figure 1 (7). Those curves, developed by the U. S. Environmental Protection Agency, estimate the projected effect of all adopted and proposed federal motor vehicle emission standards on total urban vehicle emissions for each year from 1967 to 1985. The emission factors used in developing the curves were based on the New Federal Test Procedure (8). The curves were adjusted to account for deterioration of emission control devices with age, projected increases in urban vehicle-miles of travel, distribution of automobiles by age, and relative miles of travel for newer cars versus older cars. (More recent gasoline-powered motor vehicle emission factors are given in a later report, 9).

The curves shown in Figure 1 and the rollback equation, or an equivalent procedure, were used to determine the estimated impact of the 1975-76 light-duty motor vehicle emission standards

Figure 1. Urban vehicle emission rates.



for all urban areas of the United States. Based on those analyses, the U. S. Environmental Protection Agency concluded that 39 urban areas will not be able to achieve the national primary ambient air quality standards given in Table 1 within the deadlines required by federal law by relying solely on the motor vehicle emission reductions to be achieved through the 1975-76 federal standards. Those 39 urban areas are listed below:

Metropolitan Birmingham, intrastate
Mobile (Ala.)-Pensacola-Panama City (Fla.)-southern Mississippi, interstate
Northern Alaska, intrastate
Phoenix-Tucson, intrastate
Metropolitan Los Angeles, intrastate
San Francisco Bay Area, intrastate
Sacramento Valley, intrastate
San Diego, intrastate
San Joaquin Valley (Calif.), intrastate
Southeast Desert (Calif.), intrastate
Metropolitan Denver, intrastate
Hartford-New Haven (Conn.)-Springfield (Mass.), interstate
National Capital (D.C.-Md.-Va.), interstate
Metropolitan Chicago (Ill.-Ind.), interstate
Metropolitan Indianapolis, intrastate
Southern Louisiana-southeast Texas, interstate
Metropolitan Baltimore, intrastate
Metropolitan Boston, intrastate
Minneapolis-St. Paul, intrastate
Metropolitan Kansas City (Mo.-Kan.), interstate
Clark-Mohave (Nev.-Ariz.), interstate
El Paso (Texas)-Las Cruces-Alamogordo (N.M.), interstate
New Jersey-New York-Connecticut, interstate
Central New York, intrastate
Genesee-Finger Lakes (N.Y.), intrastate
Metropolitan Dayton, intrastate
Metropolitan Cincinnati (Ohio-Ky.-Ind.), interstate
Metropolitan Toledo (Ohio-Mich.), interstate
Portland (Ore.-Wash.), interstate
Metropolitan Philadelphia (Penn.-N.J.-Del.), interstate
Southwest Pennsylvania, intrastate
Corpus Christi-Victoria, intrastate
Austin-Waco, intrastate
Metropolitan Houston-Galveston, intrastate
Metropolitan Dallas-Fort Worth, intrastate
Metropolitan San Antonio, intrastate
Wasatch Front (Utah), intrastate
Puget Sound (Washington), intrastate
Eastern Washington-northern Idaho, interstate

2. SUPPLEMENTAL CONTROL STRATEGIES

The states are required by federal law to use land use and transportation controls as necessary to ensure that national ambient air quality standards are attained throughout the United States within the time limits specified by law and are maintained thereafter. To meet that requirement, attention is being given to various transportation control strategies designed to provide supplementary controls on motor vehicle emissions, to increase the efficiency of traffic flow, and to reduce vehicle-miles of travel.

The Congress recognized the possibility that reductions in motor vehicle emissions to meet the federal 1975-76 emission standards might not by themselves be sufficient to meet national ambient air quality standards. Therefore, Congress provided in the Clean Air Amendments of 1970 that states would, in their efforts to meet federal air pollution control standards, be required to adopt such measures "as may be necessary" to ensure the attainment and maintenance of the federal standards "including, but not limited to, land use and transportation controls." In its report on the legislation (10), the Senate Public Works Committee made the following comments on that provision:

> The Committee recognizes that during the next several years, the attainment of required ambient air quality in many of the metropolitan regions of this country will be impossible if the control of pollution from moving sources depends solely on emission controls. The Committee does not intend that these areas be exempt from meeting the standards. Some regions may have to establish new transportation programs and systems combined with traffic control regulations and restrictions in order to achieve ambient air quality standards for pollution agents associated with moving sources.
>
> The Committee realizes that changes or restrictions in transportation systems may impose severe hardship on municipalities and states, and it urges that agencies of the federal government make available any relevant program assistance to the states and regions to meet these obligations. The highway program, various housing and urban development programs, and other sources of assistance should be examined in this connection.

The Senate report mentions the relation between air pollution control and the federal-aid highway program. The Federal-Aid Highway Act of 1970 contains specific legislative requirements applying to that relation. It provides that the U. S. Department of Transportation, after consultation with the U. S. Environmental Protection Agency, shall promulgate guidelines to ensure that highways constructed under the federal-aid highway program are "consistent with" any approved plan for the implementation of any ambient air quality standard for any air quality control region designated pursuant to the Clean Air Act (84 Stat. 1735, 23 U. S. C. 109j).

The U. S. Environmental Protection Agency has adopted regulations under the authority of the foregoing provision of the Clean Air Amendments of 1970, which define the possible "control strategies" that states may use to develop their plans for achieving national ambient air quality standards. That definition (7) is given below.

> "Control strategy" means a combination of measures designed to achieve the aggregate reduction of emissions necessary for attainment and maintenance of a national standard, including, but not limited to, measures such as
>
> 1. Emission limitations;
> 2. Federal or state emission charges or taxes or other economic incentives or disincentives;
> 3. Closing or relocation of residential, commercial, or industrial facilities;
> 4. Changes in schedules or methods of operation of commercial or industrial facilities or transportation systems, including, but not limited to, short-term changes made in accordance with standby plans;
> 5. Periodic inspection and testing of motor vehicle emission control systems, at such time as the Administrator determines that such programs are feasible and practicable;
> 6. Emission control measures applicable to in-use motor vehicles, including, but not limited to, measures such as mandatory maintenance, installation of emission control devices, and conversion to gaseous fuels;
> 7. Measures to reduce motor vehicle traffic, including, but not limited to, mea-

sures such as commuter taxes, gasoline rationing, parking restrictions, or staggered working hours;

8. Expansion or promotion of the use of mass transportation facilities through measures such as increases in the frequency, convenience, and passenger-carrying capacity of mass transportation systems or providing for special bus lanes on major streets and highways;

9. Any land use or transportation control measures not specifically delineated herein; and

10. Any variation of, or alternative to, any measure delineated herein.

The following list gives in more detail the possible transportation control strategies:

I. Reduce motor vehicle-miles of travel
   A. Transit operations
      1. Bus lanes on city streets
      2. Bus lanes on freeways
      3. One-way streets with two-way buses
      4. Park-ride, kiss-ride (A situation in which a passenger is driven to a public transportation terminal and dropped off has come to be called kiss-ride.)
      5. Service improvements and cost reductions
   B. Regulation
      1. Parking bans
      2. Automobile-free zones
      3. Gasoline rationing
      4. Four-day, 40-hour week
      5. Congestion passes
   C. Pricing policy
      1. Parking tax
      2. Road-user tax
      3. Gasoline tax
      4. Car pool incentives
II. Increase efficiency of traffic flow
   A. Freeways
      1. Reverse-lane operations
      2. Driver advisory displays
      3. Ramp control
      4. Interchange design
   B. Arterials
      1. Alignment
      2. Intersection widening
      3. Parking restrictions
      4. Signal progression
      5. Reversible lanes
      6. Reversible one-way streets
      7. Helicopter reports
   C. Traffic improvements
      1. Traffic-responsive control
      2. One-way street operations
      3. Loading regulations
      4. Pedestrian control
      5. Traffic Operations Program to Increase Capacity and Safety (TOPICS)
   D. Staggered work hours
III. Apply supplementary motor vehicle emission controls
   A. Inspection and maintenance
   B. Idling restrictions
   C. Retrofit of emission control devices
   D. Conversion to gaseous fuels

The strategies are arranged in 3 groups according to the primary purpose intended to be achieved by each transportation control

strategy: (a) to apply supplementary motor vehicle emission controls; (b) to increase the efficiency of traffic flow; and (c) to reduce motor vehicle-miles of travel (VMT).

The effects of a reduction in VMT on air quality are fairly obvious. Ambient air pollution levels have a direct correlation to emission levels, and emission levels have a direct correlation to VMT. In the extreme case of zero VMT, there would be no emissions and no vehicle-related ambient air pollution. As VMT begins to increase, total vehicle emissions begin to increase and ambient air quality usually declines, depending on local meteorology, topography, and source location. Moving toward a reduction in VMT, therefore, means moving in the general direction of improved air quality although the exact relation might be rather difficult to define.

The effects of an increase in vehicle operating efficiency on air quality are less obvious. The results of a study performed by the U. S. Department of Health, Education and Welfare (11) and the results of a study conducted by the California Air Resources Board (12) both indicated that CO and HC emissions expressed as weight of contaminant emitted per vehicle-mile traveled decrease as average vehicle speed increases, where the average speed is determined during a cycle that includes idle, acceleration, cruise, and deceleration modes. NO_x, on the other hand, were found to increase with average vehicle speed in the California Air Resources Board study and to be independent of average vehicle speed in the HEW study. The general conclusion drawn from those data has been that increases in average vehicle speed during the normal operating cycle are desirable from an air pollution standpoint because they reduce CO and HC emissions, with the caveat that further research is required on the NO_x effects. (The limitations of the Department of Health, Education and Welfare study and the California Air Resources Board study should be noted. The HEW study was conducted 10 years ago and used 40 privately owned automobiles ranging in model year from 1955 through 1963 and 40 rental automobiles. The vehicles were tested for emissions while being operated under actual traffic conditions. The tests were conducted in Los Angeles and Cincinnati. The California Air Resources Board study was conducted in 1970-71 and used one 1964 automobile, one 1970 automobile, and three 1971 automobiles. The vehicles were tested on a dynamometer by a 7-mode procedure.)

One technique for applying supplementary emission controls to motor vehicles is regulatory control of vehicle idling. The concentration of CO in exhaust gases of an idling vehicle is nearly twice that of a cruising vehicle (14); therefore, any regulatory measures aimed at restricting extended vehicle idling time during traffic congestion, vehicle unloading, and so on would be a positive step toward cleaner air. Although such a program might be implemented by an active public information campaign, it would be extremely difficult to enforce.

Two other supplementary motor vehicle emission control techniques that have been considered are retrofit of emission control devices and conversion of motor vehicles to gaseous fuels.

A retrofit program involves 2 possibilities: the addition of emission control devices to automobiles that had no such devices when built (i.e., pre-1968 automobiles) and the addition of emission control devices to pre-1975 automobiles that had some form of emission control when built.

A study (12) conducted for the U. S. Environmental Protection

Agency found that a typical retrofit program applied to pre-1968 automobiles would probably produce a reduction of less than 5 percent in overall CO emissions in most cities in 1975. The study concluded that, unless more sophisticated emission control technology (e.g., catalytic converters, thermal reactors, or exhaust gas recirculation) can be applied, particularly to those post-1968 and pre-1975 automobiles that had no such devices when manufactured, retrofit did not warrant further examination as a transportation control strategy.

A program of conversion to gaseous fuels would take advantage of the fact that such fuels produce fewer of the heavy hydrocarbons that contribute to the formation of photochemical smog than gasoline because they have lower molecular weight and carbon content, they ignite more rapidly, and the combustion process proceeds more nearly to completion and leaves less unburned fuel in the exhaust system.

It is generally agreed that a program of conversion from gasoline to less polluting gaseous fuels should be considered only for large centrally maintained fleets, which account for a high proportion of total vehicle-miles of travel and operate in severely polluted areas (12). There is some confusion, however, as to whether adequate supplies of gaseous fuels are available, especially in view of the well-publicized shortage of natural gas. In areas like Los Angeles where both natural gas and propane are being used as boiler fuel and in industrial furnaces, gaseous fuels could be diverted to motor vehicles. That would be especially true for natural gas used by interruptible customers that have already installed equipment for burning fuel oil. The total petroleum consumption for the area would not be increased because the refineries would produce less gasoline for vehicles but more fuel oil. Some financial incentives to the vehicle owners to make the conversion would probably be required, but the reduction in maintenance requirements, the longer engine life, and the lower fuel costs (14) resulting from conversion to gaseous fuels would help. A California study (14) has demonstrated that as much as a third of the gasoline being used in the Los Angeles basin could be replaced by gaseous fuels.

Perhaps the most important supplementary motor vehicle emission control currently under consideration is the concept of mandatory motor vehicle inspection and maintenance for air pollution control. In those states or urban areas where it is adopted, such a program would help ensure that emission control devices are functioning properly and that the air pollution control benefits to be derived from a properly tuned and maintained car are being achieved. (Under the Clean Air Amendments of 1970, the responsibility for conducting a motor vehicle inspection and maintenance program for air pollution control rests with the states.)

3. SELECTION OF TRANSPORTATION CONTROL STRATEGIES

The improvements in air quality to be derived from transportation control strategies will vary from city to city, and specific strategies must be examined within the context of specific situations. Although significant improvements in traffic flow can produce reductions in air pollution, in general such traffic flow improvements in urban areas with present or potential air quality problems must be accompanied by other transportation control strategies that are designed to restrain vehicular volumes and by land use planning that decreases the need for vehicular travel. Otherwise, air *quality benefits may be canceled out by increased traffic volumes. Reduction of vehicle-miles of travel, for example, by the diversion of commuters from private vehicles to public transportation, can in certain circumstances produce a direct improvement in air quality. In some cases, restraints on vehicle travel in parts of an urban area may or may not reduce total motor vehicle travel in the urban area but may be necessary to make such a diversion possible. Where that is the case, the positive and negative social and economic effects may be serious and must be carefully considered when a decision is made to adopt such a program. Mandatory inspection and maintenance of in-use motor vehicles for air pollution control can make a significant contribution to maintaining air quality by ensuring that emission control devices are actually achieving substantial reductions in vehicle emissions.*

Improvements in vehicle operating efficiency can be achieved in a number of ways. Reverse-lane operations, freeway ramp controls, signal progression, intersection widening, on-street parking restrictions, and other transportation control strategies listed earlier can be used to improve vehicle flow and are well within existing technology. Other strategies that can be used to supplement those basic techniques include staggered work hours to spread the commuter rush over a longer period and reduce traffic congestion, elimination of on-street loading and unloading of trucks during rush hour, and better management of temporary traffic bottlenecks such as accidents and roadway maintenance.

Traffic flow improvements, however, have their greatest value from an air pollution control standpoint on streets and highways where average vehicle speeds (measured during a cycle that includes acceleration, cruise, deceleration, and idle) are quite low. A much greater improvement in air quality, in other words, would be obtained from increasing average vehicle speeds from 5 mph to 10 mph than would be obtained from increasing average vehicle speeds from 25 mph to 30 mph (11).

The Air Quality Workshop group that addressed the question of air quality benefits to be derived from improvements in traffic flow concluded that in general the overall effect on air quality would be comparatively low.

Most important, traffic flow improvements would normally result in reduced travel times within the affected transportation corridor, and they in turn might result in increased vehicle volumes within that corridor and longer trip lengths. That would produce increases in vehicle-miles of travel, which might in some cases generate air pollution levels that exceed the national ambient air quality standards. Therefore, significant improvements in traffic flow must be accompanied by other transportation control strategies that are designed to restrain vehicular volumes, or air quality benefits may be canceled out by increased traffic volumes.

In this connection, the following statement (15) recently issued by the U. S. Environmental Protection Agency should be noted:

> States preparing transportation control plans are also urged to give special consideration to sections 51.12 (a) and 51.14 (c)(1) [40 CFR 51] concerning the maintenance of the national ambient air quality standards and the offsetting of emissions increases due to growth in motor vehicle traffic and other factors. Consideration should be given to the possibility that certain improvements in transportation systems (e.g., traffic flow improvements, construction of fixed guide-way mass transit facilities) may stimulate gradual increases in motor vehicle traffic and, consequently, in emissions from transportation sources. Transportation control plans should include provisions as necessary to prevent such emissions increases from leading to pollutant concentrations that exceed the national ambient air quality standards.

In the short term (i.e., in the next 2 to 4 years), land use planning and control may have a substantial impact on improving air quality by halting or postponing the development of land uses that would generate increased traffic volumes in areas where transportation control strategies will be required to meet national ambient air quality standards. Halting the construction of new parking garages and postponing the development of major office complexes, shopping centers, and so on in such areas would reduce the emission growth factor for those areas in the critical period ahead when only a fraction of the motor vehicle population will consist of automobiles with 1975-76 emission controls. (The long-term significance of land use planning and control for maintaining air quality is discussed under finding 4.)

The U.S. Environmental Protection Agency is preparing regulations that will address this problem through the state air quality implementation plans (16). The regulations will apply to "complex sources" that include shopping centers; sports complexes; drive-in theaters; parking lots and garages; residential, commercial, industrial, or institutional developments; amusement parks and recreation areas; highways; sewer, water, power, and gas lines; and other such facilities that would result in increased emissions from motor vehicles or other stationary sources. Under the regulations, each state will be required to have procedures whereby, prior to construction or modification of complex sources, the state can determine whether the construction or modification of such sources will cause violations of the applicable portion of a state implementation plan control strategy or interfere with the attainment or maintenance of national ambient air quality standards. States will be required to have the authority to disapprove the construction or modification where there would be such a result.

Another short-term control strategy for reducing the effect of traffic volumes on air quality is the reduction of vehicle-miles of travel by increasing vehicle occupancy, particularly during commuter rush hours when the average occupancy is 1.4 people per vehicle (17). One approach would be to encourage car pooling through tax incentives, selective adjustment of parking rates and tunnel and bridge tolls, and reservation of preferential traffic lanes. The potential for car pooling is limited to the extent that car poolers must both live and work within reasonable proximity of each other and have common working hours.

Another way to increase vehicle occupancy is to move commuters out of automobiles into public transit vehicles where the load factor during the rush hour may be 35 to 40 people per vehicle. Methods that have been suggested for enhancing the attractiveness of public transit include increasing average transit speeds to make commuting travel times more competitive with private automobiles (perhaps through preferential and exclusive bus lanes, traffic signal controls, and unrestricted turning movements) and improving terminal facilities (by building sheltered bus stops, for example).

Moving commuters out of automobiles and into public transit vehicles to improve air quality, however, will not be an easy task. At the present time, just holding current levels of public transport traffic in many metropolitan areas requires an intensive marketing effort, variable scheduling, and great increases in express services. Many transit operations are in serious financial trouble because they cannot attract enough passengers to generate sufficient revenues to cover operating expenses. It appears that achieving a sufficient diversion of automobile trips to public transportation to attain desired improvements in air quality will require motor vehicle restraints in parts of the city to force drivers, particularly commuters, to use public transportation. Increases in the quantity and the quality of public transportation will be necessary to accommodate the displaced commuters for whom a reasonable alternative mode of travel is absolutely essential.

A number of possible motor vehicle restraint strategies have been proposed, ranging from commuter parking restrictions and traffic-free malls to "congestion passes," a pricing mechanism, and gasoline rationing. Particular attention has been focused on the restriction of commuter parking, either by direct regulation or through taxation. Parking restrictions have the advantage of not requiring the use of untested technology or unfamiliar enforcement programs, but they may be difficult to impose on noncommercial lots and garages maintained solely for employee parking. If imposed only in the core of a metropolitan area, parking restrictions will not reduce, and in fact may encourage, through traffic; and parking restrictions, especially parking taxes, when compared with other strategies, may be regressively costly for the poor.

If restraints on motor vehicle travel are imposed in particular cities, the positive and negative social and economic effects may be serious and must be very carefully considered. Wherever possible, transportation control strategies should be based not only on reducing air pollution but also on comprehensive urban planning that incorporates all social, economic, and environmental effects. In addition, provision must be made for the possibility that motor vehicle restraints may shift motor vehicle travel from particular transportation corridors but may not reduce total motor vehicle travel in an urban area.

Strong opposition to motor vehicle restraints can be expected from segments of the public, road users, automobile owners' associations, downtown businessmen, and parking garage owners. The problem will be made doubly difficult by the fact that the amount of air pollution reduction achieved through transportation controls will not be readily evident to the public. (That point is explored later in the discussion that follows the report of Working Group 2.) A major public information program will be required to explain the transportation control strategies that are being adopted, why they are needed, and what they will accomplish.

Another major transportation control strategy that is currently receiving considerable attention is mandatory air pollution control inspection and maintenance of in-use motor vehicles. Such a program could make a significant contribution to maintaining air quality by ensuring that emission control devices are actually achieving substantial reductions in vehicle emissions.

There are a number of potential problems to be overcome in the adoption of a mandatory motor vehicle inspection and maintenance program for air pollution control, but such a program appears to be highly desirable for several reasons. To meet 1975-76 federal emission standards, motor vehicles will contain new, highly complex equipment that will be subject to both tampering and failure. Because of the engine design changes that are being planned to accommodate the new emission control equipment, the possible deterioration of emission levels in the event of emission control device failure will be substantial. Deliberate interference with emission control equipment may also be a problem. Adjusting post-1975 vehicles for maximum performance rather than required pollution control, for example, could increase emissions of NO_x

to levels as high as those that now exist (18).

The Clean Air Amendments of 1970 (84 Stat. 1700, 42 U.S.C. 1857f-6b) provide that the U.S. Environmental Protection Agency may grant to states as much as two-thirds of the cost of developing and maintaining effective vehicle emission inspection and control programs. [In addition, Title 3 of the Motor Vehicle Information and Cost Savings Act provides the Secretary of Transportation, in consultation with the Administrator of the Environmental Protection Agency, with the authority to make grants for not less than 5 and not more than 10 state motor vehicle diagnostic inspection demonstration projects covering both motor vehicle safety and motor vehicle emissions (S. 976, Public Law 92-513, signed Oct. 20, 1972).] The Clean Air Amendments (84 Stat. 1696, 42 U.S.C. 1857f-5a) also provide that under certain circumstances the manufacturers of new motor vehicles must warrant to the ultimate purchaser and each subsequent purchaser that the emission control devices on the vehicle will perform properly for 5 years or 50,000 miles, but the law provides that such a warranty will be required only when the Administrator of the Environmental Protection Agency determines that adequate motor vehicle inspection procedures and facilities are available, only if the vehicle is properly maintained and operated, and only if the owner of the vehicle is subject to sanctions under state or federal law for failure of his vehicle to comply.

A relatively fast, simple, and inexpensive inspection procedure for measuring motor vehicle emissions has been developed and tested for carbon monoxide and hydrocarbons on pre-1972 light-duty motor vehicles (19). It is based on the fact that any vehicle, when operating properly, has a characteristic emission level for each mode of operation. The characteristic levels are the same for all vehicles of a particular make and model. A simple test that measures the emissions while the vehicle is being run on a dynamometer at 3 steady speeds and loads (including idle) is sufficient to determine whether the vehicle is operating and, therefore, emitting correctly. If the vehicle is not operating correctly, the excessive emissions and the conditions under which the excessive emissions occurred indicate the nature of the malfunction. [An EPA report (20) discusses the various approaches to motor vehicle air pollution control inspection and maintenance. Present EPA estimates of the average annual reductions in exhaust emissions per vehicle from an annual motor vehicle inspection and maintenance program where emissions are tested by exercising the vehicle under load on a dynamometer are as follows: HC, 12 percent; CO, 10 percent; and NO_x, 0 (15).]

In addition to the administrative problems inherent in setting up a motor vehicle inspection program for air pollution control, there is the problem of training the automotive service industry to make the necessary repairs and adjustments. It has been suggested that initially the emission levels at which inspected vehicles are rejected might be set too high so that only vehicles with gross malfunctions are rejected. As the automotive service industry gains experience, the pass-fail emission levels could be lowered.

4. URBAN PLANNING TO MAINTAIN AIR QUALITY

Transportation control strategies are a means for achieving particular air quality standards within specific legal deadlines. Federal law also requires maintenance of *air quality standards as well as attainment. Although transportation controls will continue to be important, in the long run urban growth and land use development will play a dominant role in maintaining air quality. A comprehensive urban planning process will be required to fit transportation goals and air quality standards into an overall framework that accounts for all community plans, needs, and goals and all of their social, economic, and environmental effects. Existing planning mechanisms can provide a basis for building such a comprehensive process.*

The distinction between short-term and long-term transportation controls for improving air quality arises from the deadlines specified in the Clean Air Amendments of 1970, which require that by 1975 or, in some circumstances, by 1977 particular levels of ambient air quality be achieved by using land use and transportation controls "as may be necessary." Within that limited time frame, changes in transportation systems and land use development to improve air quality can be expected to have an immediate impact. When the focus is changed from the short term to the long term, the importance of urban growth and land use development becomes more apparent. Growth and development policies create long-term economic, social, and political constraints on the urban planning process. Therefore, planning of urban growth and development within the context of achieving and maintaining air quality standards must begin at once in order to avoid further commitments that make it needlessly difficult to achieve environmental quality goals.

The growing significance of urban land use was underscored by the results of the 1970 census, which revealed that almost three-fourths of the American people live in urban areas and that those urban areas constitute less than 2 percent of the total land area of the United States. The pronounced concentration of population in urban areas has, from the viewpoint of transportation, greatly increased the importance of comparatively small geographic shifts in urban housing and employment centers because relatively large numbers of people and volumes of travel are affected. (According to a news release by the Federal Highway Administration on December 19, 1972, urban streets and highways make up only 16 percent of the total mileage of roads in the United States but in 1971 accounted for 52 percent of total estimated motor vehicle-miles of travel.)

The relation between air pollution control, transportation, and land use will be different in different types of urban areas. The trend toward construction of increasing amounts of office space in the downtown areas of some cities, for example, when most workers live well outside the downtown area in "bedroom" suburbs, may lead to increased traffic congestion in the downtown area and to increased vehicle-miles of travel for commuters—both undesirable from the viewpoint of air pollution control. Some relief can be expected in the form of greater use of public bus transportation and in some cases in the development of fixed-rail transit facilities, although the latter may not have a very significant impact on total travel (12). Attention, however, must be directed to the nature and location of the land uses that generate the transportation needs in the first place. That is particularly true for those cities and suburban areas where low population densities will not support public transit.

Raising the issue of urban land use generates considerations that are broader than transportation planning and air pollution control. Some of the nation's most serious problems—hunger, poverty, crime, racism, drugs, pollution, physical decay, lack of public services, and inability of institutions to act effectively—are closely associated with urban areas. In the years ahead, the types of employment, housing, recreation, and general life-style available to a majority of American people will depend on the form and the functioning of cities. For that reason, transportation goals and air quality standards must be incorporated into an overall framework that accounts for all community plans, needs, and goals and all their social, economic, and environmental effects in urban areas.

To some extent, such a process already exists. Since 1965, it has been a requirement of the federal-aid highway program that federal-aid highway projects in urban areas having more than 50,000 population cannot be approved unless such projects are based upon a continuing, comprehensive transportation planning process carried on cooperatively by states and local communities (76 Stat. 1145, 23 U.S.C. 134). The requirement that the process be "continuing, comprehensive, and cooperative" has caused the program to become widely known as the "3C process."

Approximately 250 metropolitan areas across the United States now have 3C programs. Although the organizational arrangements for those programs vary widely, the transportation planning generally proceeds under the auspices of a top-level policy committee supported by various working committees such as a technical committee, a citizens advisory committee, and so on. Although the 3C process has had some success, transportation planners recognize that it must be strengthened if it is to provide an effective element in genuine comprehensive planning.

Present federal regulations include "environmental amenities" as one element to be evaluated in the 3C process. But more specific actions must be taken to effectively incorporate air pollution considerations in 3C programs. Technical advisory committees should be expanded to include representatives of the Environmental Protection Agency and the state and local agencies responsible for maintaining air quality. Citizen advisory committees should also be expanded to include organizations that reflect environmental concerns. Establishment in each state of statewide transportation planning processes to develop state transportation master plans would further the achievement of a number of transportation planning goals, including improved air quality.

Incorporation of air quality evaluation as part of the transportation planning process will require coordination with both state and local air pollution control agencies. To facilitate that coordination, transportation-related air quality impact should be evaluated on both a regional and a subarea basis for the short term (5 to 10 years) and the medium term (10 to 15 years). In addition, there should be a long-term (15 to 30 years) evaluation on a regional basis. The short- and medium-term evaluations should be the responsibility of the regional planning agency, although policies made at the state level may influence decisions. In the case of subareas, local-level evaluation will also be required when specific location and design alternatives are considered. For the long term, air quality planning may be affected by broad state and national policies dealing with land use and conservation of energy. The federal government and state governments, therefore, should be responsible for developing policy guidelines for use in formulating long-range transportation alternatives.

Cooperation under the 3C process among transportation, air pollution control, and planning agencies will be essential. A unified planning work program should be developed with allied planning organizations, including environmental planning agencies, to ensure that all federal, state, and local planning resources are effectively used. Transportation air pollution control studies should be integrated with the unified work program. Technical and training assistance from air quality agencies, particularly the Environmental Protection Agency, will be essential.

The 3C process is not the only planning process to be considered in a review of transportation planning for air pollution control. In addition to the 3C process, the environmental impact statements required under the National Environmental Policy Act of 1969 (83 Stat. 852, 42 U. S. C. 4321), the action plan program developed by the Federal Highway Administration under the authority of the Federal-Aid Highway Act of 1970 (21, 22), and the implementation plans required under the Clean Air Amendments of 1970 (84 Stat. 1680, 42 U. S. C. 1857c-5) provide additional planning mechanisms for incorporating air quality into urban transportation planning. The Federal-Aid Highway Act of 1970 also provides that the Department of Transportation, after consultation with the Environmental Protection Agency, shall promulgate guidelines to ensure that highways constructed under the federal-aid highway program are "consistent with" any approved plan for the implementation of any ambient air quality standard for any air quality control region designated pursuant to the Clean Air Act (84 Stat. 1735, 23 U. S. C. 109j). These guidelines are now being developed by the Federal Highway Administration.

The requirement for preparation and submittal of environmental impact statements derives from a provision of the National Environmental Policy Act of 1969, which states that all federal agencies shall include in every recommendation or report on proposals for legislation and other major federal actions significantly affecting the quality of the human environment a detailed statement by the responsible official on (a) the environmental impact of the proposed action; (b) any adverse environmental effects that cannot be avoided should the proposal be implemented; (c) alternatives to the proposed action; (d) the relation between local short-term uses of the human environment and the maintenance and enhancement of long-term productivity; and (e) any irreversible and irretrievable commitments of resources that would be involved in the proposed action should it be implemented.

Environmental impact statements must be filed for most major federal-aid transportation projects, and a number of impact statements filed for federal-aid highway projects involve a consideration of air pollution impact. Environmental impact statements are reviewed by various federal agencies including the Council on Environmental Quality and the Environmental Protection Agency. Failure to file an environmental impact statement for a project where one is required may result in a court injunction halting the project until the statement is filed.

A second planning mechanism for dealing with the air quality impact of highway transportation is the action plan program developed by the Federal Highway Administration. The program is designed to ensure that adequate consideration is given to possible social, economic, and environmental effects of proposed highway projects and that the decisions on such projects are made in the best overall public interest. Under the Federal Highway Administration program, each state transportation agency is required to develop an action plan for better identification of social, economic, and environmental effects; greater involvement of the public and other agencies in transportation planning and decision-making; greater use of the multidisciplinary process; and better consideration of alternatives in transportation planning. Action plans must be submitted to the Federal Highway Administration for approval not later than June 15, 1973.

Finally, a third planning mechanism for dealing with the effects of transportation on air quality is the implementation plan process of the Clean Air Amendments of 1970, discussed earlier in connection with short-term control strategies.

In general, the implementation plans submitted by each state set forth the procedures, standards, and timetables that will be followed by the state in controlling air pollution emissions from mobile and stationary sources to meet the national ambient air quality standards for particular air quality control regions within the deadlines specified by law. The implementation plans must contain such transportation and land use controls "as may be necessary" to achieve national ambient air quality standards. The implementation plans are also required by law to provide not only for the attainment of national ambient air quality standards but also for the maintenance of such standards. In the event of failure by a state to carry out its implementation plan, the Environmental Protection Agency must notify the state of its findings to that effect and may "enforce any requirement of such plan with respect to any person" through compliance orders and court actions (42 U.S.C. 1857c-8).

Under federal law, implementation plans must be revised from time to time to take account of revisions in national primary and secondary ambient air quality standards or the availability of improved or more expeditious methods of achieving such standards. Revisions are also required whenever the Environmental Protection Agency finds that an implementation plan is substantially inadequate to achieve national ambient air quality standards.

Air Quality Analysis and Evaluation

5. ANALYSIS METHODS FOR HIGHWAYS

The integration of air pollution control with transportation planning and operations requires methods both for monitoring and for predicting the effects of various transportation facilities on air quality. Measurement methods to fulfill the monitoring requirement now exist, although some questions have been raised concerning the manner in which they should be applied to highways. Prediction methods, or models, that anticipate the effect of highways on air quality exist for some but not all of the relevant air pollutants.

An essential part of the process of developing transportation control strategies and urban air pollution control plans will be the measurements of air quality. The Environmental Protection Agency has published a set of standard reference methods for measuring each of the air pollutants for which there is a national ambient air quality standard (2). Those methods, or any approved equivalent method, may be used for making air quality measurements.

Environmental Protection Agency regulations (40 CFR 51.17) governing the preparation of air quality implementation plans require that at least one air quality sampling site "be located in the area of estimated maximum pollutant concentration." EPA guidelines for locating air quality monitoring instruments in areas of estimated maximum pollutant concentration are given in a later section of this special report.

Notwithstanding those general guidelines, there are still a number of situations involving the air quality impact of highways for which the proper application of the national ambient air quality standards may not be entirely clear. Should the standards be applied, for example, on the highway? in the median? on a pedestrian overpass? in a tunnel? How should the standards be applied to a situation where the air pollution level is generally quite high but the exposure time of any given individual is quite low?

For highway air quality monitoring and modeling, it is useful to analyze air pollutants emanating from highways on a microscale and a mesoscale level. As air pollutants are emitted by motor vehicles in motion on a highway, the pollutants are caught up in the turbulent air flow generated by the vehicle and form a homogeneous cloud or "mixing cell" approximately twice the dimension of the vehicle. The air pollutants in that mixing cell are then acted on by local winds and by turbulence, causing the outward dispersion of the pollutants into the immediate vicinity of the highway. The local dispersion along the highway right-of-way constitutes the microscale level of analysis. At approximately 1 km downwind, the air quality effect of a single highway becomes indistinguishable from the emissions from other traffic arteries and other sources. That marks the beginning of the mesoscale.

For both the microscale and the mesoscale levels of analysis, monitoring equipment is available that can provide an assessment of the impact of highway-related air pollutants. Microscale air quality monitoring is usually required to provide background data for environmental impact statements, to develop an air quality data bank for the area, to define the worst case and the most probable case conditions, and to validate predictive air quality models. Mesoscale monitoring, on the other hand, is used primarily to provide a data base of air quality information that can be compared to air quality standards. Secondary purposes are to validate appropriate dispersion models and to define a background of existing air quality that is disturbed by microscale phenomena.

The Air Quality Workshop Group 1 reviewed the subject of highway air quality analysis and concluded that at the present time mesoscale highway air quality models provide a reasonably accurate method for predicting future mesoscale concentrations of inert air pollutants. The group also concluded that reliable mesoscale models for photochemical oxidants probably will not be available for several years because of the complexity of the atmospheric chemical reactions that are involved.

Because microscale highway air quality models are concerned with the diffusion in a narrow corridor surrounding the roadway, they are very sensitive to atmospheric conditions at the actual site. Rough ground surfaces, surface heating due to sunlight, and topographic features can significantly change the dispersal. Pronounced topographic features can cause the stagnation of air so that high concentrations of pollutants accumulate. The Air Quality Workshop Group 1 noted that a number of microscale highway air quality models have been developed and are being tested and concluded that the prospects are optimistic for the availability of validated microscale models in the near future.

It was also pointed out, however, that both microscale and mesoscale models when used to predict air quality 15 or 20 years into the future must rely on similar 15- to 20-year projections of land use and traffic. Experience suggests that, in some cases, those latter projections may be unreliable. Therefore, despite the validation of microscale and mesoscale models, air quality projections in some situations may prove to be inaccurate because of inaccuracies in traffic and land use projections used as input data. [Beaton, Skog, Shirley, and Ranzieri have developed a 6-volume set of manuals that provide a comprehensive interim approach for preparing air quality analyses for highway line sources (25, 26, 27, 28, 29, 30).]

Institutional Relations for Implementing Solutions

6. COORDINATION AMONG AGENCIES

If the relations between transportation and air pollution control are to be dealt with effectively, a substantial improvement in coordination and communication among state, local, and regional planning, transportation, and air pollution control agencies and the general public will be absolutely essential. Federal agencies should encourage and, wherever appropriate, require that such agencies and the public become involved, not in just after-the-fact reviews but from the early stages of program development.

In developing short-term transportation control strategies for air pollution control and long-term transportation plans that give appropriate recognition to air quality requirements and in designing and conducting the necessary technical and planning studies to support those efforts, transportation, air pollution control, and planning agencies will have to cooperate closely. Establishing an air quality transportation control program in a metropolitan area, for example, may in many cases be a herculean multijurisdictional task. The state will have overall responsibility, generally delegated to the state air quality agency, for preparing the air quality implementation plan, but various parts of the transportation system to be affected will be under the jurisdiction of the state transportation agency and various local transportation agencies. The input of the regional planning agency and numerous local planning agencies will be required to ensure that the transportation control program fits in as well as possible with other metropolitan plans and programs. Enforcement of the transportation control program will depend on supporting action by numerous local agencies including local air pollution control authorities, parking authorities, police departments, elected public officials, and so on.

In the case of long-term transportation planning for air pollution control, the situation may be even more complex, particularly from the regional viewpoint. From the long-term perspective, any major decision affecting the development of an urban area may be relevant to air pollution control. Numerous federal funding programs and virtually all state, regional, and local authorities may be involved at some point in the effort to maintain urban air quality.

Complex issues involving conflicting community goals will undoubtedly develop, and decisions will have to be made on the basis of 10- and 20-year projections of anticipated effects that may prove to be highly unreliable.

Mechanisms for creating the kind of cooperation, coordination, and communication that will be required to achieve and maintain national ambient air quality standards through transportation planning and control already exist but are not being effectively utilized. Those mechanisms include the air quality implementation plan process under the Clean Air Amendments of 1970 for achieving and maintaining national ambient air quality standards (84 Stat.

1680, 42 U.S.C. 1857c-5; 40 CFR 51 and 52; 29); the action plan program of the Federal Highway Administration for ensuring that state transportation agencies give adequate consideration to possible social, economic, and environmental effects of proposed highway projects and that decisions on such projects are made in the best overall public interest (21, 22); air quality guidelines currently being prepared by the Federal Highway Administration (84 Stat. 1735, 23 U.S.C. 109j); the 3C process under the federal-aid highway program for urban transportation planning (76 Stat. 1145, 23 U.S.C. 134; 30, 31, 32); the A-95 review process under a directive in Circular A-95 from the Office of Management and Budget, which requires that all local requests for federal-aid funds be processed through state and regional clearinghouses; the preparation and review of environmental impact statements under the National Environmental Policy Act of 1969 (83 Stat. 852, 42 U.S.C. 4321); and various review processes required under state law.

State transportation agencies and state air pollution control agencies must take the initiative to fully involve themselves in these existing planning and coordinating mechanisms. Appropriate federal agencies should encourage or require that state agencies take the initiative to become involved, not just in an after-the-fact review but from the early stages of program development.

Though important, better cooperation between state transportation and state air pollution control authorities, however, will by itself fall far short of providing a complete answer to the present lack of communication and coordination on matters relating to transportation and air quality. From the transportation viewpoint, much of the nation's urban road and street network is under the control of local, not state, transportation agencies. The role of the state agency in controlling air pollution through transportation planning and operations would in many cases be limited to, at most, technical assistance. In addition, incorporation of public transit programs would in many urban areas involve a regional agency that is not under the direct control of either state or local transportation authorities.

From the air quality viewpoint, air pollution control activities in many large urban areas have traditionally been the function of metropolitan rather than state officials. The Clean Air Amendments of 1970, however, have shifted the primary responsibility for air pollution control to the state agencies. Those state agencies must now find ways to effectively coordinate their activities with the local air pollution control officials who have more background and experience with local air quality problems. Local air pollution control officials will also be important in gaining local acceptance and implementation of air pollution control programs.

It is important to remember, therefore, that, although state transportation and state air pollution control agencies can provide valuable leadership and technical assistance, in many situations in urban areas the achievement of national ambient air quality standards through the planning and operation of transportation systems will depend on actions taken by local and regional agencies. The involvement of those agencies in any effort to improve coordination and communication is essential.

Probably the best mechanism for coordinating the efforts of all urban agencies at the local and regional level, at least in terms of long-range urban planning, is the 3C process discussed above. As indicated in that discussion, however, transportation planners recognize that the comprehensive plans developed under the

3C process have in some cases had little impact. To effectively coordinate transportation, air quality, and urban planning programs in metropolitan areas will require a greater commitment to use and strengthen the 3C process.

Finally, improved communication and cooperation are required not only among public agencies dealing with transportation, air pollution control, and urban planning but also between such agencies and the general public. If people are to support changes in transportation planning and operations to improve air quality, they must be fully informed of the air pollution control actions that are planned and why those actions are necessary. Moreover, the public must be involved at an early stage in air pollution control planning for both short-term and long-term transportation programs and continually involved throughout in an active capacity in the planning and decision-making process. All of the transportation, air pollution control, and planning agencies connected with developing changes in transportation planning and operations to improve air quality must share the responsibility for obtaining greater public involvement, and wherever possible such public involvement should be made an integral part of each agency's formal (and actual) operating program. Such requirements are particularly appropriate for the 3C process and the action plan program administered by the Federal Highway Administration and for the implementation plan program administered by the Environmental Protection Agency.

advisory committee

OBSERVATIONS AND COMMENTS

Much of the attention of those interested in transportation and land use controls to achieve and maintain national ambient air quality standards has focused on motor vehicle inspection and maintenance, vehicle emission control device retrofit, fuel conversion, increased use of public transportation, and various forms of motor vehicle restraint. All of these may prove to be important elements of particular air quality implementation plans. Several other major strategies, however, have been largely overlooked.

One of those is land use control. The commonly expressed view has been that, because major changes in land use cannot be decided on and implemented before 1977, land use control is strictly a long-range, post-1977 method for maintaining air quality. That view ignores the fact that major land use proposals already "in the pipeline"—e. g., for residential housing, office buildings, parking garages, transportation facilities, shopping centers—that could have a significant effect on ambient air quality because of the motor vehicle traffic that would be generated or attracted by the new development may be acted on and implemented before 1977. In those areas where major transportation control strategies are being considered, at least temporary restraints on major land use developments that would exacerbate the air pollution problem and frustrate the whole purpose of the transportation control strategies seem to be essential.

Such restraints on land use development may also make it possible to assume smaller annual increases in vehicle-miles of travel. In Los Angeles, for example, where particularly stringent transportation controls are being considered, motor vehicle-miles of travel are projected to increase by 20 percent during the next 5 years in the absence of restraints on growth, and similar increases can be expected for other U.S. urban areas where transportation control strategies are being considered. Reduction of that growth factor could reduce the amount of emission reduction required to achieve the national ambient air quality standards.

"Mini-episode control" is another possible control strategy that has received comparatively little emphasis, at least insofar as mobile sources of air pollution are concerned. Currently, emergency-episode controls are designed to deal with unusual and very severe air pollution emergencies by restricting travel, governmental activities, and operation of commercial, industrial, and institutional facilities during such emergencies to the extent necessary to prevent an excessive buildup of air pollutants to levels that would cause imminent and substantial danger to health.

Mini-episode strategies might be developed to deal specifically with the problem of pollutants among automobiles. Such strategies might be effective in those urban areas that can expect to exceed the national ambient air quality standards on only a limited number of days each year so long as motor vehicle emission controls perform as warranted and are properly maintained. Severe restriction of travel for a few days each year to avoid exceeding the national ambient air quality standards may be more desirable than to embark on multimillion dollar transportation control programs that have not been tested and may not work as anticipated. In succeeding years as the proportion of motor vehicles with 1975-76 emission controls increases, the number of days on which such emergency measures would need to be imposed should decline.

A third transportation control strategy that has not received general consideration is diversion of natural gas from interruptible commercial users for use in motor vehicles. A basic objection to the conversion of motor vehicles to dual-fuel systems that could use either gasoline or gaseous fuels has been that natural gas is already in short supply and that conversion to gaseous fuels could therefore have only very limited application. As a general proposition, that may be true; but in some cities it may be possible to increase the supply of available natural gas by diverting a portion of the natural gas now going to interruptible-commercial users, such as power plants, to use by motor vehicles. The gasoline that would otherwise have been used by motor vehicles would be used by the power plants. Another approach to replacing the natural gas would be to change the mix of products produced from liquid petroleum so that gasoline production is reduced and low sulfur fuel oil production for power plants is increased. Either way, the overall impact would be in improvement in air quality.

Aside from the fact that some potential control strategies have been largely overlooked, one of the great difficulties with transportation and land use controls for improving air quality is that the constraints imposed by legislative deadlines have severely limited the degree of analysis that could be applied to various alternative strategies. The concept of rollback, for instance, may lead to inaccurate evaluations of the air pollution reduction potential of particular control strategies because important spatial and temporal factors and basic meteorological and dispersal mechanisms are ignored.

As an example, the diversion of commuters from motor vehicles to public transportation has been widely discussed, but there has been insufficient analysis of possible displacement of air pollutants from the downtown area to the suburbs and possible dispersion of air pollutants from one part of the city to another. Public transportation improvements may be particularly undesirable where they would lead to more intensive development of the central business district coupled with increasingly far-flung suburbanization. All major transportation and land use control strategies will have to be carefully evaluated to ensure that unanticipated adverse air quality effects do not outweigh the potential air quality benefits.

Another potential problem is that some control strategies, while not producing any adverse effects on air quality, may not have much of a beneficial effect on air quality either. In the development of programs to meet air quality goals, therefore, continuing reference must be made to the costs and effects of each proposed program. Some programs may produce relatively few effects at a relatively large cost, and it may be possible to achieve the same air quality goals by less costly alternatives.

Many of the shortcomings resulting from the limited degree of analysis that has been applied to transportation and land use control strategies can be overcome by providing for a dynamic control strategy process that will make adjustments for factors such as new data, new control technologies, and changes in life-style. If the process is so structured, experience generated at each step may materially improve the effectiveness of succeeding steps. A series of short-term experiments might also be initiated on the application of particular control strategies. Such short-term experiments could provide a data base on the technical, social, and institutional effects of various alternatives; a means of disseminating information to air pollution control agencies, urban and transportation planners, elected officials, and the general public; and a means for introducing and implementing control strategies on the basis of least community disruption.

The subject of health effects of air pollutants is another area where careful evaluation will be important. Questions have been raised concerning the validity of the present national ambient air quality standards. There are uncertainties regarding the application of the primary standards to specific situations, for example, the case of high pollutant concentration coupled with low exposure time. It has also been suggested that the costs and benefits of achieving and maintaining the present national ambient air quality standards should be carfully examined and that the benefits received may not prove to justify the cost.

On the other hand, the national ambient air quality standards are supported by evidence that indicates that the standards are necessary to protect public health and welfare. It has also been suggested that present air quality implementation plans generally do not achieve such objectives because they represent only a mechanical application of the standards with little specific regard for sensitive receptors and that the application of the standards, therefore, needs to be strengthened. An it should be noted that little is known about possible long-term effects of air pollutants on the health of the general public.

Even if the technical questions concerning health effects and the feasibility of control strategies are resolved, some thorny institutional problems will remain. With the passage of the Clean Air Amendments of 1970, Congress created a national mandate for adopting air pollution controls, including transportation and land use controls where necessary, to meet national ambient air quality standards designed to protect the public health and welfare. Such transportation controls may involve restraints on motor vehicle travel. Yet the administrators of state highway and transportation departments are also faced with a mandate to use funds designated by Congress and by state legislatures for highway improvement programs that ostensibly are intended to accommodate increased travel demand generated by population growth, land development, and numbers of vehicles. Those mandates are conflicting and leave the highway administrator in an untenable position.

Some inconsistencies are also apparent in the air pollution control legislation itself. The timetables for new motor vehicle emission controls really bear no technical relation to the timetables for achieving the national primary ambient air quality standards, even though insofar as transportation is concerned the major share of emission reduction will come about through such emission controls and not through combinations of control strategies. It appears that some areas may be forced to adopt various types of control strategies only to have the need for them disappear several years later when a sufficient percentage of motor vehicles have 1975-76 emission controls. That will be true, of course, if the emission control devices actually work and new transportation and land use developments are planned and implemented with due regard for the national ambient air quality standards.

Other kinds of potential institutional problems involve the inadequacy or lack of particular institutions to implement plans and control strategies. Some state implementation plans call for various non-capital-intensive actions for which there is now no institutional structure (i. e., legal, funding, and administrative). Efforts to develop a prototype structure may be necessary.

Some implementation plans are aimed at altering both amounts of travel and modes of travel as a means of reducing motor vehicle emissions. Yet, travel volumes, locational concentration of trips, and modes of transportation used are only symptoms of the form and density of land development in urban areas. The key to integrating all of those factors is comprehensive planning of which transportation planning is but one of a number of planning elements. All too often, however, comprehensive urban planning exists only in form and not in substance. Unless more effective comprehensive planning is established that includes the interaction of land use and transportation decisions as well as greater public control of land development, maintaining air quality standards will be impossible.

Another important mechanism for focusing attention on the environmental effects of development, including impact on air quality, is the environmental impact statement process now performed on many federally funded projects. Most state, local, and private developments, however, do not require environmental impact statements. To provide total air quality impact evaluation, the procedure should be extended to include all major development regardless of source of funding.

One shortcoming of such project-level analysis, however, is that environmental factors and impacts outside the immediate project area are sometimes not effectively evaluated and integrated with broader systems planning where fundamental commitments and policy decisions are made. One approach to the problem might be to place greater emphasis on regional analyses that would provide information for both project planning and broader systems planning.

In the midst of emphasis on control strategies, new institutions, and environmental analyses, it would be all too easy to overlook the fact that the public will play an essential role in any program to improve air quality. Public participation in the planning processes that relate to air pollution control will be essential to develop and assess alternatives, provide perspective, and develop plans. Public acceptance will be the key to making such plans work. At a minimum, acceptance cannot be expected unless the nature of, and the need for, air pollution control plans and strategies is fully explained and every effort is made to assist the public in adjusting to new control programs where such programs are needed.

Finally, the whole implementation plan effort to improve air quality is going forward on an extremely sparse air quality data base. Control strategies in urban areas are being proposed that will have great social and economic impact on the public, and yet in many instances decisions regarding such control strategies are being made on the basis of measurements obtained at a single site location. Air quality data to comparatively assess various control strategies are also inadequate in many cases. The basic study, for example, on which current knowledge of the relation between vehicle emissions and average speed is founded was conducted in the early 1960's, and the data collected then may not reflect the behavior of modern emission-controlled cars. Clearly, there is a need for continuing air quality data acquisition and analysis.

William L. Garrison

OPENING REMARKS AT THE AIR QUALITY WORKSHOP

The issue of highways and air pollution yields a spectrum of problems depending on the abstractness of the view and the constraints that are accepted. Consequently, the first task is to clarify the level of generality at which the problem will be viewed and what will be taken as given. In short, existing legislation and its administrative interpretations are givens. Certain outcomes will be assumed, including, in particular, that the states will be able to produce workable clean-air plans and implementation processes and that emissions from the automobile engine will be controlled. The problem is, then, that of practicable short- and long-run adjustments of the transportation system in support of the objectives expressed in clean air and related transportation legislation. The problem also includes identification of alternatives, their practicability, and administrative arrangements to support alternative solutions.

But although interest in problem-solving requires pragmatic definition of the problem and its context, we must not be insensitive to the context within which the problem lies. For one thing, the immediate policy, administrative, and programmatic environment, which is taken as given, has some rather murky features. Also, adjustments of the interface between transportation and the environment set off many wide-ranging effects, and those must be in mind when adjustments even in a limited context are considered.

Immediate Problem Context

With respect to the immediate context for the analysis, the Environmental Protection Agency has recently reviewed implementation plans prepared by the states pursuant to the requirements of the Clean Air Act. The state plans have the objective of attainment and maintenance of national air quality standards, and the EPA Administrator has approved those plans with exceptions. Exceptions vary from state to state, but that is not unexpected given the diversity of the states. The unfinished business as far as transportation is concerned falls in the EPA requirement for transportation and land use controls, and those mainly, but not exclusively, present problems for the heavily urbanized states. Many of those states must select appropriate transportation control alternatives and demonstrate their efficacy. Questions yet to be settled are those of control strategies and their appropriateness, legislative authorization to support implementation of strategies, and appropriate regulations and administrative policies.

There is also a context on the highway side. Pursuant to the requirements of the Highway Act of 1970, consistency is being sought between highway planning and implementation and the requirements and spirit of the Clean Air Act. Clean air is one of numerous objectives and impact topics on the agenda of those who are concerned with highway investment and traffic control. Also, equipment suppliers are working to meet 1975 emission constraints.

What, in light of those developments, led me to characterize the immediate environment of the problem as somewhat murky? The answer to that question stems from 2 attributes of the context: (a) One is the skimpy knowledge base on which to generate and evaluate alternative control strategies, and (b) the other is lack of a process that will couple societal objectives and judgments to plans and to action. Lack of knowledge stems from ambiguous and conflicting data and limited understandings of mobility, environmental, and urbanization processes. The problem of estimating the vehicle mix in 1975 and after provides an example of lack of knowledge. Although it is known that there is a price elasticity of demand for automobiles and, thus, increased prices for automobiles may slow the entry of newer vehicles and the retirement of older vehicles, using that general understanding to estimate pollutants from 1975 and later mixes of vehicles is difficult. The situation becomes even more difficult, for those estimates must be made for a diverse set of urban places and use emission measurements based on data of limited scope and availability.

A set of unknowns arises because of the lack of knowledge of what government agencies might do in the future. Not only is knowledge lacking about the efficacy of alternatives such as retrofit, gaseous fuel conversion, and inspection and maintenance, but also future EPA policy and practice are not known.

Another level at which knowledge is lacking is that of the efficacy of the various control procedures that might be imagined. Almost any control or positive action in support of reducing highway-related emissions can be argued by using arguments based on fragmentary knowledge. Here are some examples.

1. Action: Decrease emissions by restricting vehicle travel in a portion of the city. Rebuttal: That will lead to congestion elsewhere and increase emissions.

2. Action: Provide freeways for free flow of traffic and reduced emissions. Rebuttal: Freeways just clog up and make for more congestion.

3. Action: Build rail rapid transit and get people out of cars. Rebuttal: Rail rapid transit is reasonable only when it is built as a long line-haul system. Such systems increase suburbanization and thus dependence on the automobile with its attendant emission problems.

Those simplistic actions and rebuttals reflect lack of knowledge of consumer choices and the settings within which actions might be taken. There is a lack of general principles and facts.

The claim that the coupling of planning with the processes of change is little practiced and little understood needs no particular elaboration for those in the planning fraternity. That has been a matter of great concern to those interested in urban development, urban transportation planning, and the enrichment of the planning process through the recognition of environmental impacts such as those represented in environmental impact statements. That was reflected in the 1971 report of the Council on Environmental Quality: "Yet much more remains to be done to assure that all agencies fully and objectively consider the environment in their actions, not just in conjunction with specific projects, but also in relation to the basic policies and program structures." That there is an unmet need for attention to implementation processes is reflected in the attention given to process in the Federal Highway Administration guidelines for environmental considerations.

Organization Into Subproblems

That much is needed to clarify the immediate context is reflected in the division of the problem into subparts and in the styles in which it is treated.

One subproblem is that of the state of the art in monitoring, modeling and predicting, and applying standards. Alternatives are limited by the data and methodologies available for evaluation.

Two subproblems focus on problem-solving elements arranged by time frames. One set of solutions can be implemented in the short term. Another set will require a longer term and planning program rearrangements.

Finally, there is the rather general subproblem of those institutional relations that are required in order to implement and operate control strategies.

The division into subproblems is in direct response to the need for better knowledge and better delimitation of uncertainties in the substantive, strategy, and implementation phases of the air quality problem. The style in which the subproblems are treated is one of synthesis. Individuals holding different knowledge resources meet and test and merge their understandings. The whole is greater than its parts, and what emerges is the set of best understandings of the problem and its solutions. To assist in that synthesis of knowledge, to focus what is already known, and to assist in creating a unified record, background papers have been prepared by experts in each of the subproblem areas.

General Considerations

In an early paragraph it was remarked that adjustments of the interface between transportation and the environment set off so many wide-ranging effects that those must be in mind when alternatives are selected. The organization of the work into subproblems biases against such considerations, for the subject is in bite-sized pieces and bounded statements are sought.

But when the solutions are used, the larger environmental mobility issues within which the problem of highways and air pollution is embedded must not be forgotten. Improvements in mobility for goods, for people, and for messages (through communications) have been achieved through statements and restatements of mobility goals and through national and local and private and public programs. Those improvements in mobility, in turn, have freed individuals and institutions from the tyrannies of their local environments, and they support the productivity that enables high levels of living. Too, they support a rich variety of choices for work and for socialization. Mobility improves the human environment. But mobility conflicts with environmental goals when the energy it uses contaminates the air and when the acquisition of the materials it uses scars the earth. Mobility facilties may or may not be compatible with their environment. At the same time that the mobility has enabled numerous choices of environmental resource-oriented pursuits, such as visiting recreational areas, it has so heavily used those resources that they are threatened. Great and dear goals are in conflict.

Two points will be made about the ways in which one should keep the overall environment of the problem in mind. One point has to do with the context of the present and the future, and the other has to do with the avoidance of the imposition of one's values on others.

There have been deep but as yet poorly recognized structural changes in society in the past decade or so. The number of jobs in primary and secondary industries has decreased, and ours has become a tertiary, service-oriented society in which the growth industries are those based on human resources as opposed to natural resources. Urbanization is essentially complete, although migration and population redistribution continue. As communications and activities based on tertiary skills grow, society is becoming what some critics have termed a post-urban society.

Those contextural shifts should be kept in mind—their implications for societal organizations, investment in human resources, broadened opportunities for self-actualization activities, and the like—when control strategies are described and tested and when alternatives are selected. The mistake of delimiting practicable and desirable control strategies for a society that no longer exists must be avoided. Attention must be to those action-oriented steps that conform with current and emerging societal aspirations and opportunities. We must improve the future and avoid polishing the past.

As administrators are well aware, styles of much public and private decision-making are changing rather radically. Previously, public and private managers made decisions about achieving institutional and private goals as they perceived them. Now, the process of goal statement and the identification of goal-achieving steps are becoming matters of much more general public debate and consensus.

In this problem arena, experts providing information to public and private decision processes are in uncomfortable positions. That situation is not of the expert's choosing and is not a part of his mandate, which is limited to the best scientific, knowledge-based presentation of alternative problem solutions. The expert does not set policy or implement programs. Yet, the knowledge base is so little distributed and so fragile that the expert holds a near monopoly on it, and his deliberations may have a powerful effect on subsequent actions. The danger is that of imposition of values in the process of identifying and wording alternatives and of, thus, imposing the values of the expert on those who hold different values. That danger should be remembered, and the results of the expert's problem-solving viewed as raw material from which those in different environments and those holding different values may choose.

working group 1

HIGHWAY AIR QUALITY ANALYSIS AND EVALUATION

charge

To deal with existing and future air pollution caused by transportation requires techniques to identify the nature, the causes, and the magnitude of the problem so that adequate solutions can be developed to protect the public health and welfare.

Examine and evaluate existing methods for monitoring highway air quality, for modeling or predicting the effects of future highway developments on air quality, and for applying ambient air quality standards to highway projects. Prepare a report expressing the group's conclusions and recommendations, and include any information that may be helpful to the responsible agencies and any explanatory material that is pertinent to support the conclusions and recommendations.

report

Group 1 focused its deliberations on (a) issues that confront highway and air pollution control officials as they assess the contribution of highways to ambient air pollution and plan for its reduction and (b) the adequacy of the current knowledge base with regard to modeling and monitoring.

The difficulty of the issues identified and discussed derives from the high degree of variability in both time and space of the physical and human behavioral factors that determine the relation between highways and air quality.

This report describes the processes that are relevant in relating highways to air quality. Succeeding sections discuss the most important processes and methods for understanding those processes. Included are vehicle emissions of air pollutants, transport of pollutants once they are in the atmosphere, air pollution monitoring, and air pollution modeling.

The report begins with a brief discussion of the ambient air quality standards and how those standards relate to highway air pollution.

No attempt has been made to achieve final resolution of the issues identified. In large measure, that is due to a consensus that the most appropriate final resolution is dependent on particular circumstances.

Air Quality Standards

In accordance with the provisions of the Clean Air Amendments of 1970, the Administrator of the Environmental Protection Agency has established ambient air quality standards for carbon monoxide, nonmethane hydrocarbons, nitrogen dioxide, particulate matter, sulfur dioxide, and photochemical oxidants. The attainment and maintenance of those standards, in the judgment of the Administrator, are necessary to protect the public health and welfare. The states are required by the Clean Air Amendments to adopt plans that provide for implementation, maintenance, and enforcement of those standards by specified dates. The ambient air quality standards are intented to protect people against exposures to high concentrations of pollutants for periods of time sufficiently long to injure health. Those periods range from 1 hour to 1 year depending on the pollutant.

The standards have been interpreted to apply to all points of public accessibility. On the other hand, mobility and short duration at any given highway location may make an individual's exposure to elevated pollutant levels a more meaningful criterion. That concept will be examined further in the sections on monitoring and modeling.

Phenomenology

Air pollution from highways and its levels can be qualitatively described in 3 phases:

1. Emissions into the atmosphere,
2. Transport and reactions during the first few minutes, and
3. Transport and reactions during the next few hours.

The first phase consists of pollutant generation in combustion and of evaporation leakage. When vehicles are idling, the vehicle-generated mixing is only minimal mainly because of spread of the exhaust and buoyancy of the warm gases. In a stream of moving traffic, the vehicles induce turbulent zones that dilute the exhaust and form homogeneous clouds termed "mixing cells." Those mixing cells are approximately twice the vehicle dimensions (height and width) and are used as the effective emissions source.

In the second phase, or microscale, local winds and turbulence (atmospheric and vehicle-induced) transport and disperse the pollutants. Generally, concentrations decrease with increasing distance from the source. In this phase, NO-NO_2-O_3 equilibrium is established, large particulates fall out, and interactions with the surrounding terrain are important.

At some distance downwind (approximately 1 km), the effect of a single highway is negligible; that defines phase 3, or the mesoscale. Concentrations are the sum of emissions from many highways and other sources. It is a background concentration that is superimposed (for inert pollutants) on the phase 2 sources. In phase 3, the mean winds and inversion height are important, and photochemical reactions occur.

Vehicle Emissions

Changes in the existing traffic network caused by transportation improvements affect air quality insofar as they affect vehicle operating modes, volumes, and miles traveled.

Emissions from vehicles, unlike those from most stationary sources, are not governed by a tightly controlled combustion process and are usually in a constant state of flux. Changes in the vehicle combustion process and the consequent pollutant emissions are caused by changes in the mode of vehicle operation. Other things being equal, it is obvious that emissions vary directly with traffic volume and miles traveled. Variations in vehicular pollutant emissions resulting from changes in those parameters affect, in a general sense, the overall air pollution burden and, in a specific sense, the receptors immediately downwind from the traffic facility.

Any study, therefore, that characterizes highway impact on air quality must be founded on traffic estimates that describe changes in the areal traffic network in terms of operating mode, traffic volume, and miles traveled. Additional factors necessary for such an analysis include a consideration of traffic growth and some time period over which the analysis should be made. Understanding the relation between the traffic parameters and the way in which air quality is affected is also necessary.

A highway can be considered as representing a continuous line source of pollutant emissions. The strength of that line source is dependent on 2 factors: the volume of pollutants coming from each individual vehicle and the number of vehicles on the highway at any given time.

The emission factors used in this approach to characterize pollutant volume from each vehicle vary with vehicle model year mix, percentage of heavy-duty vehicles in the traffic stream, speed of the traffic, vehicle operating mode (that is, whether the vehicle is on the freeway system or on the surface network), and deterioration of the vehicle pollution control system.

Emission factors have been developed based on those items. One approach is to estimate the model year mix of vehicles composing traffic for any particular future year. The relative emissions, for each model year vehicle in the mix, are based on the emission controls that were, or will be, in effect at the time of manufacture. Those emissions are weighted, based on the percentage of that model year in the mix, and then averaged to provide an emission factor that can be applied to a traffic estimate. Because the emission control devices can be expected to deteriorate as the vehicle accumulates mileage, a deterioration factor is applied to the emission factor. Separate tables are constructed for varying percentages of heavy-duty vehicles. Separate factors are also developed for those vehicles traveling on freeways as opposed to the mileage accumulated on surface streets.

The environmental effects of traffic emissions can be divided into 2 broad categories: mesoscale effects and microscale effects.

The mesoscale effects are felt in terms of overall air quality, or pollutant burden, throughout that portion of the air basin affected by the alterations in the traffic network. The volume of air affected depends on confining topography, inversion heights, and wind speed. Background levels of downwind air quality are a direct result of upwind emissions.

The traffic parameters used for mesocale air quality predictions are daily vehicle-miles and average trip speed. The average trip speed reflects the amount of acceleration, deceleration, and idle modes of engine operation and the cruise conditions. A knowledge of average trip speed coupled with the amount of miles traveled at that speed enables a quantitative determination of pollutant emissions from a particular stretch of road. It is also necessary to know the percentage of heavy-duty vehicle traffic.

Because a smaller percentage of average daily traffic occurs during periods of possible congestion (the rest of the time the traffic is free flowing), the use of steady-state speed-emission relations should be used to calculate the pollutant burden emitted by freeway mileage. Even greater detail could be obtained by using average trip speeds for peak-hour mileage and steady-state speeds for the remainder. At the present time, however, emission factors are insufficiently refined for this procedure, and the resultant calculations (25) are conservative.

Microscale effects are limited to the immediate highway corridor and are felt only by the adjacent downwind receptors. Pollutant concentrations in those areas are raised above background levels by the highway line source emissions. Because the highest concentrations must be pinpointed, it is necessary to obtain peak-hour traffic to calculate emissions at that time. Again, the percentage of heavy-duty vehicles and also the speed for various times of the day must be known.

In the microscale analysis, close examination of traffic volumes and speeds for various times of the day and seasons of the year may be important. Anomalous local traffic patterns and meteorological phenomena may combine to provide peak-hour pollutant concentrations at other than peak traffic hours. Occasionally, strange patterns may be found (33).

Traffic information provided for the microscale analysis must encompass time periods that will allow comparison with ambient air quality standards. Examination of carbon monoxide, for example, means that peak 1-hour traffic as well as maximum 12-hour traffic must be available for the analysis.

Transport and Dispersion: Mesoscale

Like pollution emission, the phenomena of transport and dispersion change when viewed on the mesoscale, which may be roughly defined by horizontal length scales of the order of 1 to 100 km. We are speaking here either of area sources of pollution or of a cloud of polluted air that has grown by turbulent mixing. On this scale, the fundamental forcing function continues to be the prevailing air motion, as determined by large-scale meteorological processes, but the forcing function is now modulated by wind variations associated with topographic variability. Contrasting topography such as land-sea or mountain-valley distribution typically generates diurnal wind regimes that have a profound influence on air pollution transport. The Los Angeles sea breeze system is a good example.

Diffusion processes continue in the horizontal but may become limited in the vertical by the presence of elevated stable or inversion layers. The depth over which mixing occurs, which may reach a constant value if established by an inversion layer, is a primary parameter for the mesoscale. The mixing depth is typically a quantity that undergoes substantial diurnal variation and may also vary widely in space.

The time scales associated with mesoscale phenomena are determined by wind speed and the space scales mentioned above and usually vary from 1 hour to 1 day. The time scale is long enough for photochemical reactions to become significant. Consequently, the products of the photochemical reactions between hydrocarbons and the oxides of nitrogen, such as oxidants, must be considered part of the phenomena of the mesoscale.

Vertical variation of the wind is important on the mesoscale. Diurnal wind regimes typically involve strong wind shear and even reversal of wind direction with height. In some cases, pollution concentration at a downwind location can be augmented by material that has been transported to the location by stronger winds aloft and then diffused downward.

Transport and Dispersion: Microscale

For convenience, microscale transport and diffusion phenomena can be restricted to a consideration of meteorological processes that occur within a horizontal length scale not exceeding 1 km and a vertical scale of a few tens of meters. The corresponding time scale is approximately 1 hour or less. Within those constraints, the nature of microscale transport and diffusion is usually controlled by the aerodynamic influence of local roughness elements (terrain and buildings), although in some cases the effect of localized surface thermal characteristics may also be important.

With regard to aerodynamic control of the microscale, a major consideration is the relation between the size and distribution of local roughness elements and the location of emission sources. Thus, roadway configuration can strongly influence concentrations. When the roughness elements have dimensions similar to the source or receptor height, the mean transport is usually not defined, and chaotic motion (locally induced turbulence) predominates. Additional generalizations cannot be made about the nature of those processes because each situation is unique and must be evaluated independently.

For the sake of illustration, consider 2 idealized yet not uncommon situations: (a) the ground-level, heavily traveled, and isolated freeway; and (b) the street canyon in the urban central business district. In the case of the freeway, the string of vehicles presents a nearly continuous obstruction to the mesoscale flow, while the heights of the emission source and obstruction are comparable. In the vicinity of the roadway, the flow is chaotic and the mean motion is poorly defined. Vehicular emissions are rapidly mixed in that zone before being transmitted downwind by the mean motion that is established again some distance downwind from the roadway. In addition to the roadway-mixed zone, which effectively increases the pollutant diffusion near the highway, the vehicle roughness may also modify the transport speed within the downwind segment of the freeway corridor. In the case of the transport and diffusion of pollutants emitted at the floor of the urban street canyon, the local roughness elements (buildings) are significantly larger than the source height. Experimental and theoretical observations have shown that, under those conditions and with a wind perpendicular to the buildings, the mean flow within the canyon is organized and different from the roof-level flow. The net impact is best described by the transport action of the wind, which piles up the pollutants at one side of the street before transporting and diffusing them upward.

Although those types of aerodynamic influences usually dominate on the local scale, thermally induced turbulence may sometimes be important as in the case of heat discharge by vehicles in a depressed roadway. Little is known of the significance of thermal influences on microscale dispersion nor, for that matter, of the magnitude of aerodynamic roadway effects. Considerable emphasis should be placed on the importance of microscale variations because they quite frequently control the magnitude of the local pollutant concentrations.

Mesoscale Monitoring

The primary purpose of mesoscale monitoring is to provide a data base of air quality information that can be compared to air quality standards. Secondary purposes are to validate appropriate dispersion models and to define a background of existing air quality that is disturbed by microscale phenomena. Mesoscale monitoring must also include meteorological elements that are necessary to stratify or to normalize (or to do both) the air quality data into meaningful categories.

The designer of a mesoscale monitoring unit must consider the specific parameters to be measured and the location of the unit. An important pollutant to consider is the level of oxidant (or ozone). Because photochemical reactions that produce ozone are generally considered to require an hour or more, the sources of pollutants forming ozone will normally be located at least several kilometers upwind and will be difficult to define. Other parameters that should be measured are nitric oxide and nitrogen dioxide, carbon monoxide, and nonmethane hydrocarbons. Also significant are concentrations of lead and nonspecific particulates. Although sulfur oxides are important on the mesoscale, less than 1 percent is emitted by vehicles.

One meteorological element that should be monitored is wind velocity (speed and direction). The limits to vertical mixing should also be defined. Radiosonde data may be used to determine both inversion height and mean transport wind speeds aloft.

A mesoscale monitor should be located so that it is responsive to variations in source configurations. It should be sufficiently distant from the source so that short temporal or spatial variations are not dominating influences. Recommendations for the number of stations based on population should be published by the Environmental Protection Agency.

A determination of sources must be made. Because of spatial smoothing, a detailed analysis of traffic characteristics is not required. The estimate of traffic volumes can be limited to areas approximately 1 km^2. Within that area, vehicle-miles, vehicle volumes, and average speeds should be determined (or estimated) on an hourly basis for local, arterial, and limited-access highways.

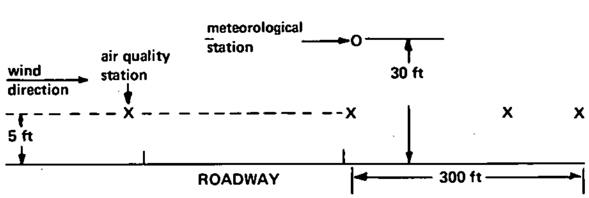
Microscale Monitoring

Monitoring close to roadways is used to determine traffic, emissions, local meteorology, and air quality. Traffic volume, speed, and other vehicle characteristics are measured and then combined with appropriate emission factors to determine the quantity of pollutants emitted. The dominant parameters in local meteorology are local winds, both speed and direction, and local turbulence, which depends on surrounding buildings and terrain.

The resulting emission estimates and meteorology measurements characterize the roadway impact on microscale air quality. In addition, air quality measurements are usually required to serve as background data for environmental impact statements, to develop an air quality data bank for the area, to define the worst case and most probable case conditions, and to validate predictive air quality models. The data can also be used to imply the probable impact of future roadways. Air pollutants that should be measured include carbon monoxide, nitric oxide, nitrogen dioxide, ozone, nonmethane hydrocarbons, total particulate matter, and lead. Pollutant concentration averaging times should be at least ½ to 1 hour; that should provide easier comparison with existing air quality standards and micrometeorological stability.

The proposed list of pollutants is extensive. Thus, the cost to purchase and operate a monitoring station may be prohibitive. A more modest air quality measurement program would focus on carbon monoxide and lead, and other gaseous pollutants could be approximated by emission ratios.

The siting for microscale roadway measurements should be standardized. Shown in the diagram below is one such example network for a minimum number of stations. This type of network is keyed to a point standard. In addition, locations where there are susceptible people should be monitored.



Mesoscale Modeling

The purpose of mesoscale modeling is to relate pollutant emissions over large areas to average air quality throughout similar large areas. A minimum area for resolution is 1 km^2, and the corresponding minimum averaging time for all variables considered is 1 hour. That time is consistent with the averaging times for ambient air quality standards.

If a total airshed, basin, or air quality control region is being modeled, a resolution of a few square kilometers is reasonable for processing by modern computers. Mesoscale air quality models are simply accounting systems to apportion the emissions to downwind concentrations. The total region may be divided into small cells (1 to 10 km^2) for air quality predictions. The same cells may be used for tabulating emissions into the atmosphere. The winds are used to determine how far (or to how many cells) the pollutants go in a given time. The pollutants are also transported from cell to cell by dispersion. Some models include vertical resolution and treat the vertical dispersion explicitly, while others determine ground level concentrations based on a well-mixed volume below an inversion. The type of model described above has been referred to as a multiple-box or grid model. That type of model has been applied to both carbon monoxide and photochemical pollutants throughout a basin.

Another type of model is based on the assumption of a normal (or Gaussian) distribution of pollutant concentration in the crosswind direction, downwind from a point source emission where the atmospheric concentrations look like a plume extending downwind. For that reason, the model is called a Gaussian plume. The point of emission can be integrated over the source-simulating line or as an area emission. This concept is being used for mesoscale modeling of carbon monoxide, but it is not applicable to reactive pollutants (photochemical smog).

At this moment, mesoscale modeling can be both a useful and a practical tool for inert pollutants. One can have reasonable confidence that the predictions (area- and time-averaged concentrations) are within a factor of 2 for similar accuracy in the model input data. The results of photochemical modeling are only just becoming available. Because of the inherent difficulties in describing the chemistry and the nonlinearities of the equations, a practical tool is probably a few years off.

Microscale Modeling

The purpose of a microscale highway model is to calculate the concentration of contaminants from motor vehicles in the vicinity of the highway (1 km or less). The actual technical approach used to generate microscale models is similar to that used for mesoscale models. Both Gaussian and diffusion models have been developed by various groups. The objective of this type of model is to properly characterize the diffusion of pollutants from a roadway so that the benefits of various roadway configurations can be realized.

In addition to modeling the effects of natural atmospheric dispersal on pollution concentrations, microscale roadway models must account for the heat and turbulence generated by the moving vehicles. A popular approximation is to assume that there is a mixing cell above the roadway in which the automotive pollutants are evenly dispersed. Often the automotive pollutants are assumed to be generated by a line, vertical strip, or horizontal strip parallel to the roadway. Because of the relatively short time scales involved, only the nitrogen oxide chemistry is addressed in roadway models.

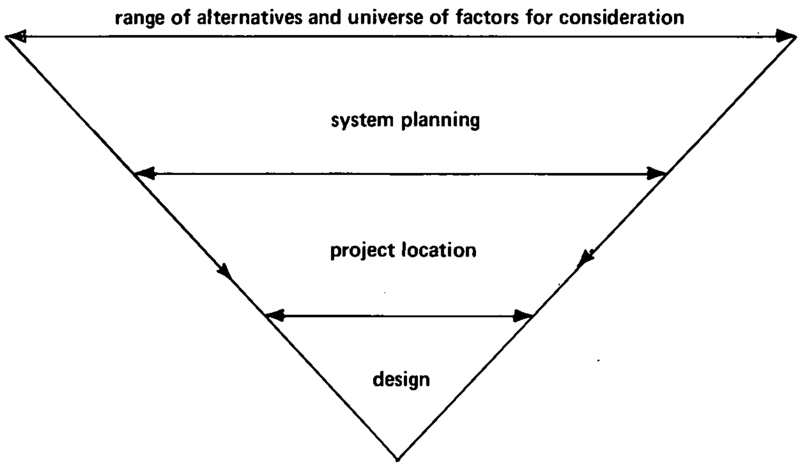
Because microscale models are concerned with the diffusion in a narrow corridor surrounding the roadway, they are very sensitive to atmospheric conditions at the actual site. Rough ground surfaces, surface heating due to sunlight, and topographic features can significantly change the dispersal. Pronounced topographic features can cause the stagnation of air and thus permit high concentrations of pollutants to accumulate.

The validation of existing models is being conducted.

Application of Monitoring and Modeling Methods to Transportation Planning Processes

Because the charge to Working Group 1 was to evaluate existing methods for monitoring and modeling air quality, it was deemed to be appropriate to indicate the scope of effort in those areas that should be undertaken at the various levels of transportation planning.

Transportation planning can be thought of in terms of an inverted pyramid where the width of the figure at various planning levels indicates both the range of alternatives and the universe of social, political, economic, and environmental factors that have to be considered.



It is generally recognized that air quality considerations should be present at each of the planning levels shown above. What is needed is a better definition of methods that are particularly suited to the different conceptual levels of transportation planning.

At the level of system planning, the rather generalized description of alternatives would warrant a regional evaluation of impact on air quality. Hence, mesoscale methods supported or validated by regional monitoring programs would be appropriate.

Mesoscale modeling at the system planning level would also provide the necessary prediction of "background" conditions to which concentrations predicted by microscale techniques must be added to show concentrations that will be experienced at critical observation points in the highway corridor (1 to 1,000 m). The mesoscale background value added should be that upwind of the proposed link to avoid double addition of pollutant predictions associated with that particular link.

State air pollution control boards should be primarily responsible for continued development of mesoscale monitoring and modeling programs. There must, however, be a close working relation between those agencies and other agencies that are responsible for the comprehensive urban transportation planning process. Updating of urban transportation plans should involve, as an integral function, the necessary updating of existing mesoscale air quality models. Microscale initiatives in monitoring and modeling must fall on those transportation agencies directly responsible for evaluating localized effects of location-design decisions.

Recommendations for Future Work and Research

The ultimate reason for monitoring and modeling all the various processes that lead to a specified concentration of air pollution is its impact on human health and welfare. Accordingly, research priorities should be established from a broad viewpoint that recognizes that human impact is the most important criterion. The time and resources available to Working Group 1 did not permit such an evaluation. Thus, no priority ranking is implied by the order in which the following research topics are presented.

1. The structure and dynamics of the mechanically mixed zone above highways and streets and the dependencies of those phenomena on meteorological and traffic parameters should be studied.
2. More realistic traffic and pollution emission models are needed. Emphasis should be placed on processes leading to spatial and temporal variability.
3. Realistic human mobility models should be developed so that human exposure can be related to air quality standards.
4. Studies should be conducted to determine what parameter is the best indicator of the influence of turbulence and stability on microscale transport and dispersion of pollution emitted by highways and streets.
5. Detailed studies of air pollution concentrations and diffusion processes in the vicinity of complicated highway configurations should be conducted. Such information is essential to the development of useful models of critical locations.
6. Systematic comparative studies of the properties and performance of the numerous models of air pollution phenomena should be made. It would be highly valuable if a national service were available to help local agencies to determine which modeling approach would be useful in particular applications.
7. Instrumentation systems and sampling networks should be studied to determine whether spatial and temporal variability is adequately measured in existing systems and how an optimum approach should be designed. Particular attention should be paid to which additional parameters, such as solar radiation, that are not now commonly measured should be included in the future. The repeatability and accuracy of the entire sampling and analysis system should be rigorously examined.
8. The foregoing recommendations imply costs and benefits that should be estimated as part of the priority-setting process. In addition, the overall incremental cost-effectiveness of achieving specified air quality standards is recognized as an important ultimate objective.

discussion

Question: Does the last recommendation that cost-benefit analysis be done relate to the question of whether or not to achieve standards?

Response: We deliberated quite long on that point and felt that the question was not whether the standards are to be achieved but rather what standards should be looked at.

Question: You mentioned that mesoscale models are getting to a point where they can be used but that microscale models are not validated yet and may not be for another year or two. Can anybody give us some quantitative or qualitative estimate of the confidence that we can have in the existing models?

Response: We believe that a model should be put through a series of tests in a region to show how well it does compared to historical data. In mesoscale modeling for inert pollutants, we are achieving a factor of 2 very easily, but it is hard to say that we will achieve a factor of 2 everywhere. We have also been achieving 20 percent, but I am a little cautious in saying that we will get that in the future.

Additional Response: I think that is true for validating present modeling systems with actual data. But predictions with models are based on traffic estimates and estimates of emission factors. We are compounding estimates, in other words. Therefore, for predictions, we have had far less reliability than when we used actual validated data.

Additional Response: Again there is a distinction between mesoscale and microscale. We may have more microscale models and more valid models, but we are not sure. Progress is going faster there. Years may be a gross overestimation; months may be possible. It depends on who comes to us and says we need them.

Question: Did Working Group 1 discuss the problem of how to disseminate this knowledge and these techniques to those in the field who will use them?

Response: We do need some dissemination because some of the results so far in various reports indicate that models have been applied very loosely and that too much confidence has been put in some predicted results.

Additional Response: In the summarization of our report, I did not read one comment in enough detail, and that was recommendation 6 regarding the systematic comparison of studies. I know of 2 current programs that are trying to do things along those lines, but a lot more work has to be done.

Question: You did not indicate where you would measure carbon monoxide as a means of tuning your model. I have always been puzzled as to whether the concentrations coming out of the model indicate carbon monoxide.

Response: For the microscale, we did suggest a modeling-monitoring setup that included a 5-ft elevation at particular locations extending 300 ft downwind. For the mesoscale, models predict concentrations that are averaged over spatial resolutions of a few square kilometers at times on the order of hours. Therefore, it is not clear how to compare that prediction to a point measurement that is made at some air pollution control district by a tube sticking out a window and that may be influenced by local effects.

Comment: My problem is that there is no place to put a setup where it is not influenced by local effects.

Response: That is a problem, but you have the one possibility of adding local effects to the mesoscale effects and then trying to validate it.

Additional Response: We did recognize that problem, and that is the reason why we recommended that the concept of a dosage be applied rather than the particular point measurement. If we are aware of the variability and if we can then relate the measurement at this point to the area average of that pollutant and its variability, we will have a more reliable, in our opinion, indicator of what air quality is.

Question: Did you give any thought to providing guidance to state transportation planners on the amount of modeling that should be undertaken to assess the extent of air pollution problems or the extent of measurements that should be undertaken?

Response: That brings us back to the cost-benefit analysis that should be done. Given an application, perhaps we could address that problem; but a general transportation or highway application is hard to quantify. We did suggest a minimal program on which to build, depending on budgets and the size of the project and its location.

Question: Did you consider modeling and measurements pertaining to corridor studies and to regional transportation system studies?

Response: I think it is the feeling of Working Group 1 that the systems approach is the desirable approach to take. I think we are limited by logistics in the amount of data and the nature of the data that we can use for this. In addition, and this was not within the realm of our deliberations, the systems approach must necessarily include a whole range of political subdivisions and planning across political boundaries. I think monitoring and modeling techniques are available. We can either use what we have or develop it further, but the technological problems will arise in connection with the data base for the inputs to the modeling program, for example, traffic and land use factors.

Question: Did you consider what might be coming in the way of instruments other than point source monitoring?

Response: We did not in the report, but we did in our discussions. We remarked about the future availability of things like correlation spectrometers with fixed path length or undefined path length so that we might look across a certain amount of area. We did that with the idea that remote sensing will eventually be the type of sensing applied, but our discussions were brief.

Question: Was there any feeling as to whether that might come about and how desirable it might be?

Response: It is under development right now. I think General Electric is doing some work on the problem. A tremendous amount of data reduction and, I think, computers along with the machine are required; but as to whether such an approach will become practically available, I do not have the faintest idea.

Comment: I want to emphasize the need for monitoring in urban areas. I hope the group will recommend that local agencies install monitoring equipment before the implementation of any control strategies. If we find that a strategy is not working, we can stop it and start something else. The second point I want to emphasize regards technology. In New York City, we found that we were measuring air pollution one way, and the federal agencies were asking us to measure it another way. They just recently found out that we were measuring it right and they were measuring it wrong. Before we can really define the air quality in urban areas, we have to come to grips with the technology of instrumentation. Finally, I want to emphasize that we should recognize that motor vehicle pollution is a localized urban problem. It is in high-density urban areas like New York or Boston or Philadelphia that we are having trouble complying with air quality standards. I do not think we should impose on the rest of the nation a program that perhaps will be costly from a social, economic, and environmental point of view.

working group 2

SHORT-TERM CONTROL STRATEGIES

charge

Air quality implementation plans required by the Clean Air Amendments of 1970 have been prepared for all major American cities. A number of those implementation plans contemplate air pollution control strategies such as the following: vehicle inspection and maintenance programs, retrofit of exhaust control devices, gaseous fuel conversions, increased transit usage, and traffic control strategies including capital improvements, traffic flow improvements, work schedule changes, disincentives to the use of individual vehicles, and increased car pooling. Many of those control strategies have some relation to the programs and activities administered by highway agencies. Such agencies, however, have had little, if any, involvement in the preparation of the air quality implementation plans, and it is not clear to many highway agencies what their proper role and responsibility should be.

Prepare a report expressing the group's conclusions and recommendations on the role that highway agencies can play in carrying out state air quality implementation plans and in properly relating their programs and activities to air pollution control strategies such as those listed above. Include any explanatory material that is pertinent to support conclusions and recommendations and any other information that may be helpful.

report

Assumptions and Objectives

Working Group 2 discussed and evaluated a number of transportation control strategies for achieving national primary standards of ambient air quality by 1975. The group's discussions and recommendations were based on the following assumptions:

1. Reducing air pollution is desirable;
2. Standards for compliance are realistic, reasonable, and supportable;
3. Techniques will be implemented to reduce air pollution to meet national primary standards of ambient air quality by 1975 as outlined in the Clean Air Amendments of 1970 as interpreted by the Environmental Protection Agency; and
4. Implementation plans and strategies will be enforced strictly.

The major objectives of transportation control strategies evaluated were to (a) reduce the amount of vehicle-miles traveled (VMT) and (b) improve vehicle performance. The group felt that strategies that will improve vehicle performance will have marginal effect and will require supplementary measures to control counterproductive effects but that strategies that will reduce VMT will be most effective.

There were diverse opinions as to the extent to which modal diversions could realize the required reduction in VMT. There was, however, a consensus that achieving VMT reductions will require substantial changes in travel habits. Those changes include increased vehicle occupancy for private passenger cars and greater use of public transportation. It was also agreed that improvements alone in public transportation will not be sufficient to induce the VMT reductions that are required. Part of the reason for this is that, because of its present direction, public transportation primarily serves downtown travel, which usually represents a small fraction of total urban travel.

Strategies

1. IMPROVE TRAFFIC FLOW

The achievement of improved traffic flows requires the application of traffic engineering measures designed to alleviate delays and to increase average vehicle speeds. The air quality benefits of such steps are dependent on current conditions—increasing average speeds in areas where they are very low is more beneficial than increasing speeds in areas where they are already relatively high. Improved traffic flow actions must be accompanied by other strategies that prohibit an increase in the volume of vehicles; otherwise, air quality benefits will be canceled by increased traffic volumes.

2. STAGGER WORK HOURS

The shifting of employee work hours might be applicable in smaller urban areas where traffic peaking is sharp and essentially unrestricted by capacity limitations and in larger urban areas where additional public transit capacity can be provided. In both cases, the initiation of more extensive work-hour staggering will spread the demand placed on the highway or transit facilities depending on the application. In both instances, air quality benefits would ensue.

3. IMPROVE PUBLIC TRANSIT

This strategy obviously requires an existing public transportation system but in addition requires parking controls and traffic restraints. Particular actions to improve transit include priority treatment of transit vehicles, i.e., preferential and exclusive bus lanes and unrestricted turning movements; sheltered bus stops; bus terminal parking; and exoneration of transit vehicles from traffic detours. The improvements will result in the increase of average transit speeds, a reduction or reversal in the disparity of travel times via automobile and transit, an increase in transit vehicle productivity, and increase in the comfort of passengers waiting at transit stops.

4. STAGGER DELIVERIES

Goods should be delivered in high traffic areas during periods of light traffic movement.

5. KEEP TRAVEL WAYS CLEAR

Incidences such as construction and maintenance operations, processions, and accident cleanup cause congestion and delays on highways and streets that otherwise have adequate capacity. Highway agencies should schedule roadway repair during periods of lightest traffic and give a higher priority to clearing disabled vehicles from roadways.

6. INFORM AND EDUCATE PUBLIC

Information should be provided to the public on the air pollution problem and the requirements to achieve air quality in any specific area. The information should detail the part to be played by the public in providing for the success of control strategies.

7. INSTITUTE PARKING CONTROLS

Long-term parking control is a component of the strategy to induce greater public transportation use and reduced automobile commuting and may be accomplished through either pricing or regulation. The concept involves rationing the supply of space for all-day parking, reallocating existing parking capacity for short-term parkers, and creating a greater transit demand by commuters.

8. RATION FUEL AND VEHICLES

Gasoline and vehicle rationing could be invoked either in combination or separately, assuming that there is appropriate enabling legislation. Fuel rationing will reduce mileage per vehicle, and vehicle rationing is a means to control total automobile population in an area.

9. RESTRAIN TRAFFIC

Traffic restraint strategies reduce traffic volumes in selected areas and may or may not reduce total automobile travel. The restraints can be economic or physical. Economic control is achieved through road pricing (toll collection), whereas physical controls include street closures, traffic-free zones, and bypass routing. This strategy must be coupled with public transporation services in automobile-restricted areas.

10. REQUIRE EMISSION INSPECTION

Identification of those vehicles requiring maintenance or retrofit devices or both to meet applicable emission standards presumes the existence of an emission measuring program. Inspections will identify high emitters and determine the degree to which controlled vehicles remain as warranted by manufacturers. Emission inspections can be conducted as part of normal safety inspection programs by government or private stations or as a separate operation where safety inspection does not exist. An inspection program is essential to a policy of selective replacement of vehicles and the preservation of "new" car emission standards.

Proper maintenance and engine adjustments can reduce emissions in pre-1972 cars by 15 to 30 percent. That percentage can be increased if vehicles that cannot be adjusted are not driven. Retrofit devices might reduce emissions another 30 percent. However, better retrofit methods will have to be developed, especially for larger vehicles such as delivery vans or trucks.

Even though post-1972 cars are equipped with pollution control devices, potentially they could pollute more than standards allow. The reason is that the control devices involve mechanisms that can break down in a number of ways or fail altogether without the knowledge of the operator or those responsible for the air quality program. An improperly functioning control device may permit as much as 5 times more pollution than one that functions properly.

Furthermore, post-1972 cars have drivability problems that will increase with age, and adjusting them for maximum performance will lead to vastly increased emissions. The exact magnitudes of those effects are unknown. Therefore, a vehicle inspection program for emissions as well as improved maintenance schemes is essential to ensure that the vehicle emission reductions predicted in most implementation plans will actually occur. Inspection should include diagnostic tests because garages will lack the necessary equipment to conduct their own tests. A vast educational program both for maintenance personnel and for the driver is also essential.

Inspection of vehicles will allow some control over vehicle replacement. Most air quality implementation strategies make assumptions as to the rates at which old high-polluting cars are replaced by new low-polluting models. Economic factors, both those that are external and those introduced by the pollution control program, might significantly alter those rates and thus outweigh any of the transportation control strategies mentioned.

11. USE CLEANER FUEL IN FLEETS

Fleet vehicles such as taxis and government passenger cars can be operated on cleaner burning fuels including liquid natural gas, compressed natural gas, and liquid propane gas. Use of these fuels is particularly applicable to pre-1975 model vehicles inasmuch as statutory emission standards of 1975 and later vehicles exceed the emission benefits of those fuels.

12. CONTROL IDLING ENGINES

Pollutants are produced at a high rate while vehicle engines are idling. One strategy is to require that engines stop during traffic delays and goods delivery.

13. IMPROVE ENFORCEMENT

Constant and regular enforcement of traffic regulations is required to keep all travel ways clear of illegally parked or standing vehicles and exclusive travel ways, such as bus lanes, clear of unauthorized vehicles.

14. ADOPT 4-DAY WORKWEEK

A 4-day workweek will reduce the total number of work trips per person by 20 percent, and making every day of the week a workday will reduce the concentration of work trips.

15. INCREASE AUTOMOBILE OCCUPANCY

Increasing the number of automobile passengers per trip will reduce traffic volumes and will require some form of car pooling, especially by commuters.

16. BYPASS THROUGH TRAFFIC

In large central cities, through traffic can account for about 5 to 20 percent of total traffic volumes, even during peak hours. From an air pollution control viewpoint, bypassing through traffic would (a) shift vehicle-miles of travel away from already congested central city streets and (b) smooth traffic flows by a separation of through and local traffic in the areas affected. Both results would reduce emissions in high pollution areas of the central city, the first by redistributing emissions elsewhere, and the second by bringing higher average vehicle speeds, fewer stops and starts, less idling, and reduced emissions associated with those improvements.

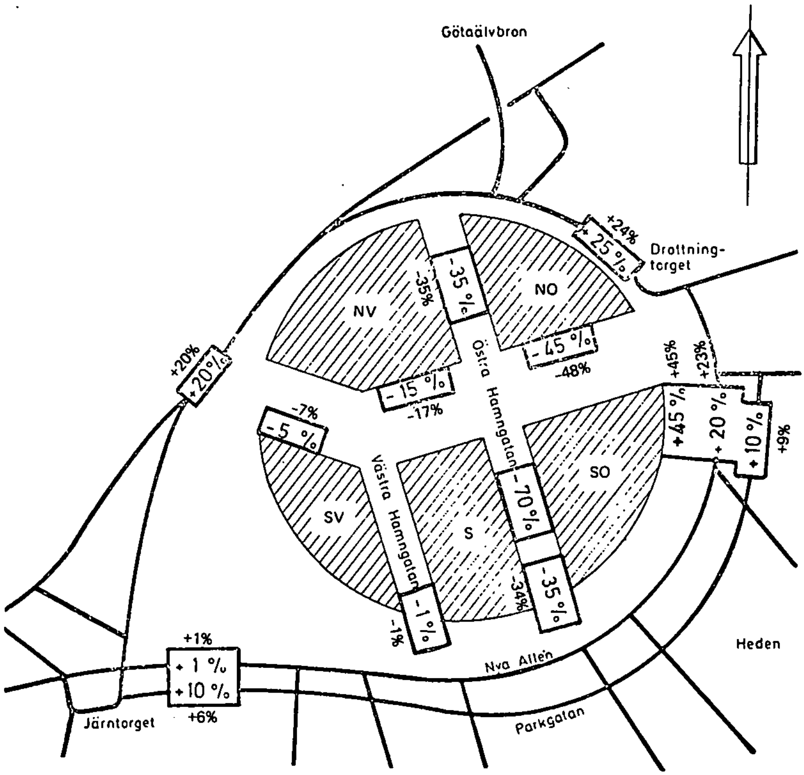
Several possibilities are available to bypass through traffic and include the use of circumferential routes, inner-city barriers, and directive signs or signals.

An important example of the bypassing technique, using inner-city barriers, was implemented in Gothenburg, Sweden, in 1970. Traffic restrictions were initially instigated in Gothenburg at the urging of various public officials concerned with the severe traffic congestion developing during pre-Christmas shopping hours. The chief of the fire brigade was concerned with difficulties in gaining access to CBD areas for fire equipment. Officials involved with traffic accidents, public transit, and air and noise pollution also supported traffic restrictions. The planning and implementation of Gothenburg's traffic restraint scheme are discussed in another report (34).

The Gothenburg CBD was divided into wedge-shaped quadrants. Physical barriers were constructed between those quadrants, thus making traffic through the CBD impossible (except emergency vehicles such as fire, ambulance, and public transit were permitted to pass). In effect, each quadrant became a self-contained precinct with only local circulation allowed. All other traffic was required to use a ring road, entering and leaving each quadrant at designated locations, as shown in Figure 2 (36), where the hatched areas are quadrants and the lines represent major arterials. Percentages given are changes in vehicle volumes 2 weeks and 8 weeks (box) after the scheme was introduced on August 18, 1970.

The success of the barriers in decreasing through traffic can be clearly seen. After 8 weeks of operation, traffic on one of the main arterials (Östra Hamngatan) decreased by 70 percent; traffic shifted to the peripheral streets. Barriers have not been used in large scale anywhere in the United States as yet, and the size of the experiment in Gothenburg (whose population numbered slightly

Figure 2. Traffic restraint system in Gothenburg, Sweden.



more than 444,000 in 1971) does not provide adequate evidence that a similar strategy can be easily and quickly transferred to any major U.S. city. In fact, given the size and extent of vehicle ownership in most major cities in the United States, it is doubtful that a similar experiment could be implemented until after at least 2 or 3 years of planning. To the extent that similar measures depend on new construction, they are not likely to be implemented in fewer than 5 years. Even the comparatively small Gothenburg experiment entailed a planning period of 7 years. Once the plans were final, preparatory work included reconstructing certain intersections on peripheral routes to accommodate increased traffic loads, relocating tram stops, route signing, street painting, placing physical barriers, and informational advertising.

Strategy Analysis

A summary analysis of the suggested control strategies is given in Table 5. Technical feasibility relates to the availability of proven technical solutions. Institutional feasibility relates to the difficulty in implementation, the need for legislation, public resistance or acceptance, time delays due to the political decision-making process, and so on. Because of the lack of data and time, Working Group 2 had no opportunity to make a thorough quantitative evaluation of the impact of the control strategies proposed. The estimates of possible impact reflect a majority consensus of the working group as to the relative importance of the strategy. The extent to which some of the proposed strategies are feasible was also taken into consideration. Any measure that would reduce

Table 5. Analysis of strategies.

Strategy	Feasibility: Technical	Feasibility: Institutional	Impact	Highway Agency Role	Time Required (year)	Funding Required
1	Good	Good	Low	Major	< 1	Low
2	Good[a]	Possible (study required)	High or low[b]	Cooperation and assistance	< 1	Low
3	Good	No consensus			1	High
4	Study required	Study required		Cooperation and assistance		
5	Good	Difficult[c]	Variable (study required)	Major	< 1	Low
6	Good	Good	Low	Cooperation and assistance	< 1	Low
7	Good	Difficult	High	Cooperation and assistance	> 1	Revenue producing
8	Difficult	Impossible	High	Limited or none	> 1	
9[d]	Difficult	Difficult	High (study required)	Cooperation and assistance	> 1	Revenue producing
9[e]	Difficult	Difficult	Variable[f]	Major responsibility or cooperation and assistance	> 1	Low
10	Difficult	Difficult	High[g]	Limited or none	> 1	High
11	Good	Difficult	Possibly high	Leadership	< 1	Moderate
12	Good	Good	Low	Limited or none	< 1	Low
13	Good	Difficult	High	Limited or none	< 1	High
14	Good	Difficult	Possibly high	Leadership	> 1	Moderate
15	Good	Difficult (study required)	High	Cooperation and assistance	< 1	Low
16	Good	Good	Low regionally	Major	< 1	Low

[a]If carefully done.
[b]Low in big cities and high in small cities, but more difficult in small cities.
[c]Because of the necessity for interjurisdictional coordination.
[d]Economic.
[e]Physical.
[f]Depends on the magnitude of the area.
[g]Most important variable for modal diversion.

pollution by more than 10 percent is considered high. The impact will also vary from place to place, and local judgment will be necessary.

The strategies are not limited to those under the jurisdiction of highway agencies. The highway agency may have major responsibility for carrying out the strategy, may cooperate in or coordinate the effort and provide technical assistance, or may play a limited role or no role at all.

Feedback Effects

Certain transportation control strategies may have feedback effects that tend to counteract and reduce or eliminate their effectiveness, and those strategies will have to be complemented by others before air quality benefits can occur. Improvements in traffic flow, for example, might induce heavier traffic volumes and thwart the basic objective of higher average speeds. Therefore, motor vehicle restraints may be necessary if traffic flow is improved. Improved traffic flow may also induce more riders to use their cars, and that would also be counterproductive in the long run.

There are other examples of this possible feedback effect. A program of rationed parking will not work without an accompanying program of increased public transportation capacity. A 4-day workweek will reduce rush-hour traffic but might increase VMT because people who normally ride in car pools or on public transportation will use their cars on their free days for either recreation or shopping. Three free days each week will also encourage long trips. The extent of such feedback processes and the elasticity of the systems involved are unknown. Frequent reevaluation on a local scale is, therefore, important.

Some of the major interdependencies among transportation control strategies are listed below.

Strategy	Complementary Strategies
1. Improve traffic flow	3, 7, 9, 13
2. Stagger work hours	1, 3, 6
3. Improve public transit	1, 6
4. Stagger deliveries	13
5. Keep travel ways clear	4, 13, 6
6. Inform and educate public	
7. Institute parking controls	3, 15, 6
8. Ration fuel and vehicles	3, 15
9. Restrain traffic	3, 4, 6, 13, 15, 16
10. Require emission inspection	
11. Use cleaner fuel in fleet vehicles	
12. Control idling engines	13, 6
13. Improve enforcement	7
14. Adopt 4-day workweek	1, 3
15. Increase automobile occupancy	9
16. Bypass through traffic	9

Strategy Implementation

To successfully implement transportation control strategies to reduce air pollution requires a broad-based political and, accordingly, public support. Without public support, there is little likelihood of initial implementation or successful continuation of programs. Public support can be obtained only if the public is adequately informed about the control measures and given valid, convincing evidence that the controls are needed.

Air quality standards must be realistic and supported with factual information showing the dangers to public health that would result from pollution levels in excess of the standards. Costs and benefits of the strategies should be identified, and the public should understand who pays what amount and who benefits to what degree—in both social and economic terms. All aspects of discrimination against particular socioeconomic groups must be identified and evaluated, and principles of equity and fairness must be followed in the application of control strategies. Where certain types of vehicle travel are restrained, alternative means of transportation must be provided to adequately meet the needs of the public.

Implementing control strategies will also require support agencies and mechanisms, including trained technicians, adequate and available equipment, and necessary enforcement personnel.

Transportation service and facilities should be developed with the same consideration given to air pollution control as to mobility improvement, socioeconomic impact, and other factors. The importance of each consideration will depend on each specific case or region. Each region should determine the extent of its problems in the light of national air quality standards and those implementation strategies that best meet its particular needs.

The need for satisfactory air quality is the concern of the entire society, and all segments of society must be involved in a cooperative effort to solve the air pollution problem. Because air pollution does not respect political boundaries, various jurisdictions must coordinate their activities. Regional air pollution control cannot be accomplished successfully by individual municipalities or counties. In any region or air basin, air pollution control may involve several independent government agencies at the federal, state, and local levels. A high degree of cooperation among agencies will ensure regional solutions and at the same time maintain a sensitivity to local interests and desires. The fact that air pollution control must transcend local jurisdictional boundaries does not mean it must necessarily override local authority. Nor does it mean that local officials working together cannot produce a satisfactory program.

Those agencies responsible for street and highway transportation systems should establish close relations with local air pollution control boards and with the state air resources agency. Designated personnel within such transportation agencies should be thoroughly familiar with all federal and state laws and local regulations relating in any way to air quality. Designated personnel should be familiar with the state air quality implementation plan and especially the sections relative to transportation requirements.

State air quality implementation plans may incorporate all or portions of the air pollution control strategies discussed earlier. The transportation agency may act by assuming direct responsibility for the initiation of activity or provide technical assistance and coordinated support. In other instances, the agency may have limited participation. In any case, all forms of participation should be made in active and close relation with air quality experts directly concerned with the responsibility for implementing the air quality program.

In the development of transportation control strategies, care should be taken that proposed measures do not cause irreparable damage because of severe traffic restrictions in downtown areas. Shifting commuters from private to public transportation is highly desirable and always beneficial. The same does not necessarily apply to shoppers or people coming to restaurants and theaters. Elimination of those vehicle trips might simply divert them to suburban alternatives and ruin those vital functions of a city. It is becoming more and more evident that the full implications of transportation control measures are often unknown, and extreme care is therefore essential. The possible benefits of technical measures such as inspection, retrofit, maintenance, and selective replacement of highly polluting cars are in the short run considerably larger than those obtained by other types of transportation control strategies. Also their social and economic side effects may be less than those of other remedial measures such as rationing gasoline or vehicles or severely restricting automobile travel. However, many aspects of the problem are not well known, and it is difficult to make quantitative estimates. Data collection could be an important function for highway departments.

Working Group 2 did not believe, however, that total reliance should be placed on technical solutions such as better cars. Many of the strategies proposed such as a shift to public transportation are necessary for other reasons aside from air pollution control and should therefore be vigorously pursued. It might, however, be sensible to limit nontechnical strategies to those that are desirable from the viewpoint of overall transportation policy or at least to avoid counteracting desirable long-range solutions to the problem of achieving urban air quality.

Summary

1. Traffic control strategies should be dealt with on a regional rather than a local basis.
2. Short-term strategies should be consistent with long-term strategies.
3. Transportation policies should contain a built-in discipline to minimize travel, minimize fuel consumption, and reduce trip length.
4. Control strategies should take social as well as economic costs into account.
5. Control strategies should provide alternatives to prohibited activities.
6. A strong public relations effort should be a major aspect of implementation of control strategies.
7. A public relations effort should emphasize auxiliary benefits of control strategies such as reduced accidents and improved travel times.
8. The major problems of implementation are institutional rather than technical.
9. Traffic enforcement, emission inspection, and motor vehihicle trip reductions are necessary but not sufficient conditions for achieving air quality standards.

Advisory Statement

The following statement is submitted by Working Group 2 for consideration by the Advisory Committee. The group did not take a position on the statement, and discussion indicated considerable pros and cons.

The preceding report assumes that automobile manufacturers will, in fact, meet required emission standards. If they do not, there is only one strategy that will reduce vehicle emissions to the mandatory levels. That strategy is motor vehicle restraint.

At the moment it is politically infeasible to implement a system of vehicle restraint that aims to reduce VMT substantially on a region-wide basis. Nevertheless, the possibility of doing so must be contemplated if "clean" cars turn out not to be clean enough. We, therefore, recommend that "defensive" research be undertaken to develop vehicle restraint systems that can be implemented and that might be used on a fail-safe basis.

discussion

Question: Did Working Group 2 give much attention to the question of the role of state highway agencies in connection with air quality implementation plans? Most of the strategies that you mentioned really fall outside the functional responsibility of state highway agencies. What do you think is the role of the state highway agency?

Response: We considered the highway agency role for each transportation control strategy, and we determined that in some cases highway agencies would have very little participation in effecting the strategy. But we observed that, because each control strategy influences transportation, highway agencies must be involved in the overall planning. Second, for most control strategies there is a very definite participatory role for the highway agency either directly or indirectly by providing technical information to others.

Question: Can you give an example of the role that a highway agency would play for 1 or 2 of the strategies?

Response: In our opinion, the highway agency would have virtually no responsibility for carrying out the inspection program strategy, yet members of this working group, some of whom were highway agency officials, felt that vehicle inspection is a very essential strategy. Public transportation improvements, except those systems that do not operate on highways, definitely fall within the responsibility of a highway agency. Buses travel on highways, and highway agencies have to set aside spaces for exclusive and preferential bus lanes. Highway agencies can put parking areas near bus terminals, certainly an allowable kind of expense through the federal-aid highway program. The District of Columbia highway department is involved right now in the installation of bus patron shelters. The vehicle restraint strategy involves traffic operations, and in most cases highway agencies are responsible for traffic operations. Incidentally, when the working group discussed the role of the "highway agency," it took that term to include state as well as local and county road departments and any other department that has any kind of responsibility at all for the operation of a highway system regardless of governmental level. We did not limit our discussions to state agencies.

Question: Did you consider the strategy of increased or decreased urban freeway construction?

Response: No.

Question: You do not consider that a short-term strategy?

Response: No.

Question: To succeed, any short-term transportation control strategy must be tied in with zero growth rate in the central business district. Was that discussed in your working group?

Response: One or two of us discussed that point. Any short-term transportation control strategies will have to be compatible with long-term prospects. In other words, you could not put forth a strategy that would contradict a long-term project such as the development of satellite cities.

Additional response: We realized that another working group was involved with long-term strategies. Those obviously have to begin on the short term, but we steered away from getting into that area just simply to narrow the scope of our deliberations.

Question: The results of the Six-City Study might be characterized as, if not negative, at least not overly positive insofar as the feasibility and effectiveness of short-term transportation control strategies are concerned. What was the general overall opinion of Working Group 2 on the effectiveness, desirability, and feasibility of short-term transportation control strategies? Do we need to devote a lot of attention to them, or are we talking about a lot of things that are not going to work very well anyhow?

Response: The working group agreed with the findings of the Six-City Study in most areas. It is important, however, to understand the context in which we looked at transportation control strategies. We assumed that there would be great strides made in vehicle emission control, and we realized that in some cases that in itself would not be sufficient to meet national ambient air quality standards and that more marginal actions would have to be taken. The strategies that we discussed are those kinds of marginal actions. We realized that in many cases there would be institutional barriers. We knew that another working group was concentrating on that problem, and so all that we did was to identify those areas where we thought institutional barriers would be encountered, hoping that some solutions would be developed by the other working group. We were optimistic, I think for the most part, that the strategies that we identified as being highly effective and ones that we thought were technically feasible could be carried out.

Additional response: The chance of reducing air pollution through transportation controls, even by using vehicle restraint, the most effective control, will be practically negligible because at most it will result in a 25 percent reduction in emissions and that can be achieved only by adopting extreme economic or political measures. It will be very hard to justify that on the basis of air pollution reduction because nobody will be aware of a 25 percent reduction in air pollution. California was supposed to have reduced carbon monoxide and hydrocarbon emissions by 30 percent in the past 3 years according to all estimates, and there is no proof of any decline whatsoever. If you are going to sell something that is politically unpopular to people and that will not make any difference that they can observe, you are going to have the whole program backfire. The only thing that will have an effect is improvement in the emission characteristics of cars.

Additional response: In brief, we realized that the whole question involves more than air quality. All of these strategies do. Yet, our task was to try to assess each strategy from an air quality context. We went a step further. We said that there are other benefits and there are costs. We were quite concerned with the possible inequities, for example, of a parking tax. People having high incomes can afford to pay a parking tax, but those having low incomes cannot. The poor person would, therefore, do more for making a parking control strategy successful than the wealthier person, and that concerned us. But again we just cited that; we could not go any farther than that.

Question: Is it your feeling that a definite improvement must be noticed? For example, when I go home I plan to try to take off some weight not because I feel very bad right now and will feel much better if I do, but because I do not want to have a heart attack in 20 years. So, it seems to me that a strategy could be evaluated in terms of how much better off you might be in the future than if you had gone on with unchanged ways.

Response: We were aware of that approach. On the other hand, strategies are going to be built into implementation plans, and our approach was not to make any decision for any metropolitan area but to say that, if this strategy is chosen, it will not be very effective, it will be very expensive, and it will cause a great political struggle. We tried to do that kind of analysis for every strategy, and each one was deliberated on at length.

Question: What did you take the meaning of short term to be?

Response: Between 1975 and 1977.

Question: Do you think all of these strategies are technically feasible within that time?

Response: We identified several that we felt would be quite difficult to implement technically.

Question: We have heard comments that we need to evaluate transportation control strategies so that we know how well they are doing. Does group 1, having heard these strategies, think the instrumentation is good enough now to monitor their effectiveness? Also, are there models that can evaluate the efficacy of alternative transportation control strategies before one is selected?

Response: I get the impression that people do not believe in the technology of monitoring. Although it has holes, it is reasonable. The problem is the expense involved and the number of monitoring stations required. A general monitoring network may cost as much as the strategy.

Comment: We are now talking about expense and are looking at numbers developed from monitoring. Most of the transportation control strategies, and this was not my view alone but the opinion of others in the working group, will reduce emissions 10 percent or so. There is no way to detect a 10 percent reduction by air pollution monitoring. Monitoring to evaluate how well the control strategies work will have to involve traffic studies or something other than simple measuring of air pollution.

Question: Will you please paraphrase—do not read—your nonrecommendation or your advisory statement.

Response: We made an assumption at the beginning of our deliberations that the major cutback of contaminants in the atmosphere in urban areas would be through vehicle emission control under the Clean Air Act. We also realized that there are doubts among many people as to whether such a reduction in vehicle emissions can, in fact, be achieved. It is forecast now, and it is a statutory requirement. Nevertheless, there are questions as to whether it will in fact be achieved. That being the case, the nonrecommendation is that the Advisory Committee consider immediately having a "defensive" research program. That defensive research program would be an investigation into how vehicular traffic can be restrained in a major urban area because we identified vehicular restraint as being the most effective of all the strategies we considered in reducing atmospheric pollutants. We said that, in case it becomes necessary to impose vehicular restraints to a higher degree than now being contemplated, research must begin now to allow 3 to 5 years to develop the plans, the methodologies, and the techniques for imposing more rigorous vehicular restraints.

Question: I listened with great interest to your recommendation for mandatory motor vehicle inspection programs. I am surprised you did so in light of the fact that almost all research, the Six-Cities Study and so on, has shown that this method is at most 10 percent effective and is probably not a short-term method at all. Five years is considered to be the time needed to get a full-blown program going, and by that time we are past 1977. An inspection and maintenance program will require a special training program and has other shortcomings. Why did you make this recommendation?

Response: We recognized that emission controls are quite effective in reducing emissions. Without an inspection program, how are we going to be sure that those emission controls remain effective as automobiles are driven and as they get older? We say that the only way to be sure is by having inspection programs. Data from inspection programs will allow governmental authorities to require mandatory motor vehicle maintenance or to ban vehicles. One of our group members spoke at length about the possibility of deliberate and selective replacement of vehicles. To summarize, we think emission controls are very important, but they must be regularly checked to ensure that control is occurring.

Question: Did you discuss the details of an inspection program?
Response: No. We recognized that there is not a consensus on what the program should be. We are only pointing out that in our judgment it is necessary to develop and to institute inspection programs.

Question: My understanding is that, at least from the viewpoint of the U.S. Environmental Protection Agency, there is no satisfactory vehicle inspection program. On the other hand, New Jersey is going ahead with such a program. What are the prospects for motor vehicle inspection?

Response: We checked out a number of test cycles, and I think the U.S. Environmental Protection Agency supports our view, or we support theirs, that the Clayton key mode is a satisfactory emission test cycle for a short test. It gives the consumer some feedback as to what is wrong with his automobile. We feel that program should be implemented. In New York City we plan to apply it to fleet vehicles. What we propose to do first is operate a taxi inspection system in which taxis are tested 3 times a year. That will be a good first demonstration. Some information that might be interesting is that in our own test work with city vehicles we found by using the federal test procedure that a basic, not major, tune-up reduced carbon monoxide more than 50 percent.

Question: In New York City and a number of other cities, such as Dallas, Houston, San Francisco, and Seattle, high-rise buildings are being constructed quickly and contain millions of additional square feet of space. Our analysis has shown that to be unsound, and we have proposed that New York City decentralize into urban subcenters. Although neither the state nor the city accepted the proposal, I think that they will within the next few years.

You mentioned that it was necessary to rely on new motor vehicles to comply with federal light-duty motor vehicle emission standards. What does a city do that has a major truck emissions problem for which there are very loose emission standards?

Response: We have suggested in our report that truck emissions have to be studied and regulated. Everybody has claimed, contrary to what I believe, that this is a widespread problem. Based on the statistics I have, I do not think any city besides New York has that problem. But the local people must decide.

Comment: In New York City, we have installed catalytic devices on heavy-duty gasoline-powered vehicles operated in fleet service. They are reducing emissions by 70 to 80 percent and are working very well.

Comment: The idea of an inspection program is that it makes a retrofit program more effective, whether for heavy-duty vehicles such as we are considering in New York or for light-duty vehicles.

For air pollution control to be effective, our opinion in New York City is that an inspection program is really needed.

Comment: In a real-world situation, I have heard not 10 percent reduction as a result of motor vehicle inspection but rather 5 percent. We have data from the California Air Resources Board that indicate that 35 percent of the new vehicles delivered have only the plain, simple things wrong: timing, engine spark, idle rpm. I can even adjust those myself, yet automobile agency mechanics cannot. I am not against vehicle inspection, but it is a big job. In Maryland, it would cost about $10 million a year. If there are a great many benefits obtained from it, I think we should do it. But I certainly would urge a real-world evaluation before it is undertaken. You can find out what is going on with new vehicles delivered by the major car companies without an inspection system. You can take them off the street and make measurements of their emissions as they do in California. My final point is that older model cars emit, say, 100 pounds of air pollution; a 5 percent reduction in that as a result of an inspection system would be 5 pounds a day. If the vehicles emit only 10 pounds of air pollution, then a 5 percent reduction is only $\frac{1}{2}$ pound a day. We should not, therefore, be misled by percentages when the base is changing.

Response: It depends on what you want to do. There are 2 totally separate problems. One is the pre-1972 car. There is no question that, if all those cars would perform well, a 5 percent reduction would be meaningless. But that the emissions from those cars have been reduced must be confirmed. When a car becomes 3 or 4 years old and does not drive so well, there is a strong incentive to adjust it to optimum performance. Properly adjusted, it emits 50 to 70 grams of carbon monoxide per mile.

Failure of the emission control devices on post-1975 cars may increase emissions from those vehicles by 20 or 30 times the controlled-emission rate. The emission control devices on those cars may also be intentionally maladjusted.

Question: Whether there is an inspection system by 1975 or not seems to depend largely on what we want to do with it. I think there is probably little doubt that some form of inspection system can be implemented now, but there is considerable doubt as to whether a short inspection system can be developed by 1975 that could be used to determine whether cars comply with the federal standards. Will you briefly describe the considerations that led your working group to the sort of ranking that you have of the relative effectiveness of some of these transportation control strategies?

Response: First, we had a very wide cross section of persons in the working group: traffic engineers, chemical engineers, and people from environmental agencies. We understood that each strategy had a handicap. A good example of that is improved traffic flow. Improved traffic flow on a facility, by itself, could not be effective because that would invite, especially during commuting hours in any major city, increased use of that facility. We, therefore, concluded that there would have to be some other measure to prevent increased use that would cancel the flow improvements. We also were aware that there is a direct correlation between vehicle-miles driven and total emissions produced and between air quality and emissions produced; if there are no vehicle-miles driven, there are no vehicular emissions and there is no air pollution from motor vehicles. For that reason, we ranked all actions that seemed to lead toward reducing vehicle-miles of travel as being the most effective in reducing air pollution. We realized, though, that in some cases a control strategy that appears to reduce vehicle-miles of travel may not and that was the reason we said that in almost every case there had to be correlation.

working group 3

IMPLICATIONS FOR TRANSPORTATION PLANNING

charge

Integrating air quality considerations in the long-range transportation planning process is an important need. Integration is not now being accomplished on a broad scale; whether it can be is not clear. Air pollution control, for example, is one of many factors that must be considered in transportation planning. Other factors include socioeconomic costs and benefits, other environmental effects, technical feasibility, interaction between transportation planning and land use planning, potential impact of energy policies on transportation planning, and effects of multiregional and multimodal investment in urban transportation.

Prepare a report expressing the group's conclusions and recommendations on how responsible agencies can address and solve this problem. Include any information that would be helpful to the agencies and any explanatory material that may be pertinent to support the conclusions and recommendations.

report

Adequate comprehensive planning is a prerequisite to all functional planning. The form of urban growth, the development of land use, and the formulation of policies related to the allocation of regional and national resources dictate alternatives in transportation planning.

In the opinion of Working Group 3, comprehensive planning has not been adequately developed at the federal, state, and local levels. At the federal level there is a need for policies on land use, energy, environmental criteria, and allocation of national resources. At the state and regional levels, the primary need is for a comprehensive planning process that is responsive to national policies and that provides credible policy guidelines for directing growth patterns. Only within such a framework can long-range transportation planning be successfully undertaken.

To define the organizational structure of the comprehensive planning process or to specify in detail the scope of its activities was beyond the charge to Working Group 3. Rather, the charge was to describe how to integrate air quality considerations into the transportation planning process. The group felt that this process can be structured to adequately incorporate air quality considerations by (a) changes in the organizational structure of the transportation planning process, (b) addition of items to the work program of that process, (c) revision of the process to ensure the environmental assessment of various system alternatives, and (d) development of greater citizen involvement in the process through public hearings.

Organizational Structure

Certain changes should be made in the structure of the present organizations that carry out the continuing, cooperative, comprehensive urban transportation planning process. Those changes should ensure adequate representation and expertise for environmental considerations. Recommended changes are shown in Figure 3.

The typical present organization of the 3C planning process provides for citizen advisory and technical committees that report to and advise the policy committee. Citizen advisory committees should be expanded to include organized agencies that reflect environmental concerns, specifically those that are directed toward the improvement of air quality.

The technical committees should be expanded to include (a) the U. S. Environmental Protection Agency as one of the participating federal agencies, (b) the state agency responsible for development or implementation of the air quality implementation plans required by the Clean Air Amendments of 1970, and (c) the local or metropolitan agency responsible for air quality control.

Working Group 3 also recommends that each state establish a statewide transportation planning process to develop a state transportation plan that includes an evaluation of the movement of commodities. The organization charged with the responsibility for administering the master state plan should include representation from the state environmental protection agency or the air pollution control agency.

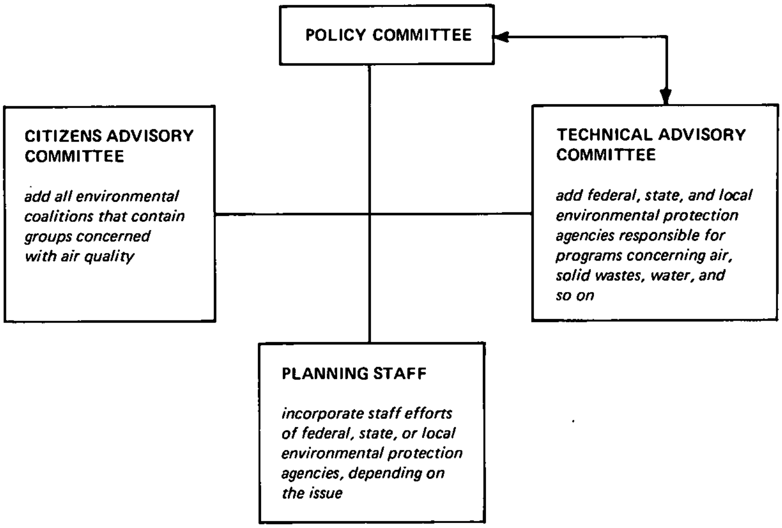
Planning Work Programs

Working Group 3 makes the following recommendations regarding activities that should be included in the planning work program of the transportation planning agencies at the state and metropolitan levels.

1. An evaluation of air quality should be incorporated as a part of the planning process. That will require coordination with both state and local environmental protection agencies or air pollution control agencies.

2. A unified work program should be developed with allied planning organizations including environmental planning agencies

Figure 3. Recommended additions to organization for urban transportation planning.



to ensure that all available planning resources at federal, state, and local levels are integrated and effectively used. It is essential that technical assistance from air quality agencies be available and used in the formulation and evaluation of long-range transportation systems.

3. The impact of air quality as it relates to transportation should be evaluated in the short term (5 to 10 years), medium term (10 to 15 years), and long term (15 to 30 years). The short-term impact can best be evaluated at the local level and should be the responsibility of the regional planning agency. The medium-term impact must be evaluated at the regional level, but the policies developed at the state level may influence local decisions. Long-term impacts of state and national policies for energy conservation, land preservation, and the like will affect air quality planning considerations at the regional and state level. State and federal governments should be responsible for the development of air quality guidelines for use in the formulation of long-range transportation alternatives.

4. Regional air quality considerations should include short-, medium-, and long-term periods; subarea evaluation within air quality regions should include short- and medium-term periods; and project evaluation should be limited to short- and medium-term periods. State and regional transportation planning agencies should be capable of responding to agency and citizen concern for air quality and the impact of transportation alternatives at the regional and corridor scale. Additional evaluation of the impacts on air quality should be required at the local level when specific location and design alternatives are considered.

5. Analytical tools for determination of air quality effects of long-range transportation systems will be required. The best available analytical tools commensurate with the area and degree of air pollution problem should be used. The air pollution analytical tools used for emissions and air quality prediction (diffusion) should be consistent with the time and geographic scales of analysis.

Because of the importance of land use models in predicting long-range transportation needs and air pollution effects, models should be carefully selected and developed to ensure an adequate air quality analysis. Special research should be undertaken to develop a variety of operational land use models at the federal and state levels to ensure that reasonable land use models are incorporated into the annual work program.

The U. S. Environmental Protection Agency, the U. S. Department of Housing and Urban Development, and the U. S. Department of Transportation should provide leadership and funding in the development of the air quality and land use models that are necessary for an adequate incorporation of air pollution considerations into the long-range transportation planning process.

The U. S. Environmental Protection Agency, working jointly with the U. S. Department of Transportation, should provide the technical assistance and manpower training necessary to apply air pollution analytical tools to long-range transportation planning.

The analytical models incorporated into the metropolitan work programs should be included in the 3C process during a major update of the plan. The analytical models incorporated in the statewide work programs should relate to analytical models developed by the metropolitan areas and should be accomplished during major master plan formulations and updates.

6. In the development, testing, and evaluation of alternative

long-range transportation systems that work toward achievement of air quality, consideration should be given to the type and location of air pollution emissions related to transportation sources, air quality resulting from transportation-related emissions, and the incidence of air quality on land use and sensitive receptors.

7. Long- and short-range transportation and air pollution control studies must be integrated to ensure compatibility.

8. The transportation-air pollution control study must also be integrated with the unified work program.

9. The contribution to urban air pollution of intracity freight movement by trucks must be recognized. Trucking activities should be analyzed for their impact on local air quality.

Environmental Impact Assessment

In the development of transportation systems, environmental impacts should be assessed on a system basis, and environmental protection agencies should assist in the development of those assessments and place particular emphasis on air quality considerations.

Citizen Participation

Adequate public hearings should be held prior to the adoption of a transportation plan. At that hearing, the alternate systems considered should be presented and the impacts of each discussed.

discussion

Question: If I interpret you correctly, you would like to see the transportation agency have the capability to evaluate both the corridor air quality effects and the area-wide air quality impacts of a transportation proposal, either a route improvement proposal or system proposal. That seems to me to be an enormous job, because you cannot evaluate the effects of a transportation proposal independently of the air quality situation that exists and is likely to exist in the future from all the composite effects. It seems to me, therefore, that if a transportation agency is to properly analyze the effects of a transportation proposal, it has to have the capability to handle the total environmental analysis for a metropolitan area because the two cannot be independent.

Response: I think cooperation is required from the agencies involved. The transportation agency must at least be able to respond to the transportation system impacts as a minimum effort. Whether they should respond to the total impacts is debatable. If all appropriate agencies cooperate in the studies, the total impact will be assessed.

Additional Response: We are only proposing that as an interim measure. We mentioned in the introduction to our report the need for comprehensive planning, and I think we agreed that the comprehensive planning process should be organized under one agency head that would be served by all other functional planning agencies, including transportation. In other words, there would be a national planning group responsible for ensuring the compatibility of all regions among themselves and within themselves. That planning group would, in effect, control the funding for more regional activities. I am giving my interpretation of this long-range proposal, and it may not be shared by the entire working group.

Question: You make it very plain that you are fully in favor of the idea that the impact of the total highway system on air quality must be considered through the planning process. But it is a matter of the chicken and the egg. Do you also recommend that those who undertake new land development, particularly large developments, be made to submit an environmental impact statement that they do not now have to submit?

Response: We did not go that far. We recognized that problem but dealt specifically with the transportation planning process.

Comment: But the transportation planning process is only a follow-on to serve the transportation needs generated by various land uses.

Response: Right, and as I see it, and as I am sure you do too, it is a constant feedback process in which transportation systems are developed based on a given or predicted land use, and then those transportation alternatives are tested against land use patterns. I see air quality working the same way. However imperfectly we do it, that is what we are trying to do.

Comment: Yes, we have the one end tied down, but we are letting the other end dangle free.

Response: I think it always will.

Question: Need it be? That is my point.

Response: I cannot speak for the working group. As an individual, I think there is always going to be a lot of latitude in land use development and there is going to be a constant testing. The best we should hope for is that given land use decisions will be tested against the transportation element of a comprehensive plan as well as in terms of its environmental impacts.

Comment: A new office building, for example, in Chicago has more impact on air pollution than any given highway system or route in the whole city.

Response: Travel is not for travel's sake. Travel is to serve the region.

Question: Did Working Group 3 consider the use of long-term transportation planning for the purpose of changing methods of transportation? In other words, for creating a balanced transportation system?

Response: We talked quite a bit about reduction of vehicle-miles of travel either through land use arrangements or through supplements to the existing highway system, i.e., increased public transportation. Again, we felt that should come out of the planning process in the individual cities. We did not want to make a blanket recommendation to cover New York City as well as Topeka.

Additional Response: I suppose I could present a minority report on that. We did discuss it at length. And there was no consensus within the committee. The issue of energy policy and balanced transportation, I think, is very serious. My own opinion is that air pollution with regard to transportation is just too narrow an area. There are too many interactions among many of the other environmental problems. I feel that we have to address the overall problems of transportation in terms of economic priorities, impact on the environment, and perhaps decreased movement of goods and people.

In discussions of how to develop a comprehensive planning process, the subject of the influence of transportation planning on land use planning in the United States was discussed at some length. We noted that because transportation is so heavily funded it tends to be a dominant factor in land use development. And we feel, at least I feel, that is wrong. Land use determines trip demand. It is servicing certain land uses and not necessarily the movement of motor vehicles that pollutes the air. I think that once that is recognized we can control land use and in turn control the use of vehicles.

Comment: Several others talked about vehicle-miles traveled and old vehicles versus new vehicles. According to the U. S. Department of Transportation, a new car or truck averages about 14,500 miles during its first year of operation. Prior to being scrapped, an old car or truck averages about 5,700 miles. There were 12 million new cars and trucks built and sold last year. There were 8 million that were scrapped. That is a 4 to 1 ratio. Four new cars travel about 4 times as many vehicle-miles as do the ones that are just going to be scrapped. At the same time, we have reduced vehicle emissions from old cars by 75 percent, roughly. So we are about even. That is a good argument for putting major emphasis on reducing vehicle-miles traveled through a variety of controls, particularly through economic strategies.

Response: Our concern as a working group was, Is this within the purview of the transportation planning process? Does the transportation planning process put dimensions on the transportation system rather than make decisions, if you would, on the life-style of the community or the individuals in the community or the form or shape of the community? I think the consensus of the group was that the transportation planning process should be designed to provide dimensions to problems, including air quality, and not make the decision.

Question: At the very beginning of your report you stated that air quality is only one of a number of issues that the planning process has to consider and that everything you said should be put in that context. I have seen some indications that after an initial decline air pollution levels may go up again in 1985 or 1990. In other words, the situation may once again become worse in some urban areas. Even if the air is cleaned up enough to meet the national ambient air standards, more things may need to be done in order to maintain that level. What will be the impact of air quality on the planning process? Will it become an overall determining factor under our present legislative setup, whether we like it or not, or is the picture reasonably optimistic?

Response: I am not sure I understand what you are asking specifically.

Question: Suppose that I am a transportation planner in 1985. I may recognize the need to consider many factors, but I face a given urban area with ambient air quality standards that are just about being exceeded. If I propose major changes in transportation facilities, I may find it very hard to justify those proposals because I may, in effect, be suggesting that we abandon the air quality standards in that particular area. Is that pessimistic? Are we going to be faced with that situation?

Response: Our group did not specifically address that. I think we felt that air quality was important, certainly, but we felt also that there were other issues such as energy that might very well be more important overall than our concern with air quality related to transportation systems. We certainly did not make a judgment as to which factors were the most important.

Additional Response: We began our sessions with the assumption that we were starting the process where emission standards were already met. Our job was then to structure a planning process to ensure maintenance of those standards, not to achieve them.

Additional Response: In my area, we do not expect to be able to meet the standards without some form of vehicle restraint. We have to reduce travel if we are to meet the standards. And this is in the short term. All we are saying here is that the planning process should be responsive to those concerns during the long range without dictating or making the judgment as to the value of that concern.

Question: If, in fact, most of us agree that in the long run the energy consumption rate is a far more severe problem than is air quality, and knowing consumption of energy is in fact a source of air pollutants, I wonder why you did not suddenly conclude that in the long range you have to structure a transportation planning process that will bring about a reduction in per capita consumption of energy? Let that be a transportation problem, and begin to seek those transportation solutions that would bring about that effect. I wonder why you did not conclude that that is the long-range problem rather than trying to solve air quality problems that we may not even have the fuel to produce in 1990 or 2000? Transportation facilities last for 20 or 30 years. That takes us right into the time when there will be a depletion of petroleum or close to it.

Response: I do not think we felt competent to put dimensions on the energy crisis. We were concerned that the ability of a transportation system to reduce travel was really not so important as the ability to reshape the city. This comes back to our long deliberations on the need for an adequate comprehensive planning process.

Additional Response: We did debate that at some length, but again we were limited by what we were charged to do: Integrate air pollution control into the transportation planning process. We assumed that in developing a comprehensive planning process we would take into account the 2 factors that I feel will influence future transportation: energy availability and economic priorities. But, again, the working group felt it just was not within our charge to develop those subjects in any detail. You are right; energy conservation will have a far more profound effect than air pollution control.

Additional Response: But not just on transportation.

Additional Response: It is going to require a restructuring of America in the next 50 years. We thought that this should be the subject, perhaps, of another National Academy of Sciences committee activity.

Question: With regard to long-range strategies and the need for even more energy, did you consider what would be needed to transfer a significant part of the transportation system to much smaller cars? If you could do that, the energy problem would practically disappear.

Response: We did not consider that.

Additional Response: That will have a big influence but will not reduce energy consumption that much. Transportation, according to the work done by the Oak Ridge National Laboratory, consumes 55 percent of the nation's energy. Of that, passenger cars account for about 25 percent.

Question: You mean petroleum?

Response: No, all energy. The calculations took into account all forms of transportation—the energy required to manufacture transportation equipment, to refine petroleum, and so on. Then I added to that the external costs that are not normally associated with transportation such as the loss of life from highway accidents and other societal costs that can be modified and translated into energy consumption. I think it is about 55 percent.

Question: Did you consider the long-run desirability, feasibility, or possibility of alternative forms of transportation technology?

Response: Not specifically. Again, we were concerned that the process should be established and should consider those things. The organizational structure was our primary concern so that those considerations would be included in the process. That is the reason for the environmental assessment of the system. What really is the impact of the proposed system?

working group 4

INSTITUTIONAL RELATIONS FOR IMPLEMENTING SOLUTIONS

charge

Solution of air pollution problems requires coordinated effort by a variety of agencies and groups, including those concerned with environmental matters, land use planning, and transportation. That coordination is currently limited. Methods are needed for analyzing the strengths and weaknesses of existing institutional relations and for improving coordination and communication at all levels.

Prepare a report expressing the group's conclusions and recommendations on how responsible agencies might address and solve this problem. Include any information that will be helpful to the agencies and any explanatory material that is pertinent to support the conclusions and recommendations.

report

Working Group 4 tried to identify relatively specific issues in regard to institutional relations in the development and implementation of land use and transportation strategies to reduce air pollution. We further tried to set forth some recommendations on how those issues could be dealt with. Our report is organized in the form of issues or problems and associated recommendations.

1. COMMUNICATION AMONG STATE AGENCIES

Issue

There is frequently poor communication, if any, between state highway agencies and state air quality control agencies in relation to the development of transportation control strategies in state air quality implementation plans.

Recommendations

1. Action Plans should emphasize coordination of the air quality, transportation, and land use planning processes among state and metropolitan governmental bodies. [The Action Plan is developed by state highway agencies to ensure adequate consideration of environmental, social, and economic effects of proposed highway projects as required by the Federal-Aid Highway Act of 1970 (23 U.S.C. 109h).]
2. The Action Plan should indicate that it has been reviewed by the state air quality control agency.
3. The U.S. Environmental Protection Agency should require that state implementation plans for achieving ambient air quality standards indicate that those portions dealing with transportation control strategies have been reviewed by appropriate state and regional transportation planning agencies.
4. The A-95 process should be monitored by a state official with multiagency authority to ensure continued effectiveness and should be expanded to include review of comprehensive plans.

5. The state air quality control agency should be represented on metropolitan transportation planning bodies.

2. COORDINATION BETWEEN STATE AND LOCAL AGENCIES

Issue

State air pollution control agencies are largely responsible for implementing nonfederal actions required by the Clean Air Act. The act allows states to carry out their responsibilities through actions by local governmental air pollution control agencies if the state so chooses. In many states, local agencies have done and are doing a large part of the total air pollution control job. In some cases, such local activities have had almost no state agency influence or control. The Clean Air Amendments of 1970 require states to become more involved in air pollution control activities in general, to secure certain information from local agencies (or develop it themselves), to submit regional air quality implementation plans, to submit plans for control of land use and transportation to achieve ambient air quality standards, and so on. Those activities, to be successful, require a degree of coordination and cooperation between state and local air pollution control agencies never before required and, in most cases, never before practiced. There are uncertainties, delays, confusion, and inefficiency in some states because it is not clear how transportation and land use control strategies will be developed and implemented within the air quality control agencies themselves and in relation to land use planning and transportation agencies.

Recommendations

1. Each state should establish the respective transportation and land use responsibilities of state and local air quality control agencies. The state must be able to assume the local responsibility in the event that the local agency fails to perform adequately. Objective criteria for determining when such state "take-over" should occur will be helpful.

2. State and local air pollution control agencies should work closely together in developing transportation and land use strategies for meeting air quality standards. (Because implementation of strategies will often involve substantial actions within the purview of local governments, local involvement is essential at all stages.)

3. As a condition for award of control program grants, the Environmental Protection Agency should require state and local air pollution control agencies to submit evidence that workable arrangements have been made in regard to division of responsibilities between the agencies. General EPA guidelines should be issued as to the kinds of relations that will be deemed acceptable, leaving it to the state and local agencies to develop arrangements that they find suitable to their needs.

4. State air quality control agencies should evaluate their air quality laws to determine whether amendments are needed to properly organize activities within the state and then seek to have such changes made as are deemed necessary.

3. COORDINATION OF LAND USE AND TRANSPORTATION STRATEGIES

Issue

Coordination of planning activities and responsibility for seeing that plans are carried out are widely dispersed among planning, transportation, air quality, zoning, and other agencies at state, metropolitan, and local levels of government. The problems are particularly acute in interstate regions. If cohesive plans are to be evolved and implemented, coordination must be improved. Those agencies now responsible for development and implementation of land use and transportation strategies to achieve ambient air quality goals will be operating within the existing structure. They may be able to contribute to improving existing unsatisfactory situations.

Recommendations

1. The membership of appropriate committees of various planning agencies having functions affecting air quality should include representatives of air quality control agencies.

2. If existing institutions do not have such representation, task forces or steering committees should be formed to provide general guidance to working staffs who are preparing land use or transportation plans or strategies for reducing motor vehicle travel.

3. The various agencies involved in planning, transportation, and air quality control should brief each other and other agencies on policies, philosophies, and the general trend of ongoing activities.

4. STRENGTHENING OF REGIONAL PLANNING

Issue

Comprehensive metropolitan plans are a key element in the determination of future air quality. Air quality control agencies and the public have not had much input to such plans through their various stages of evolution. Such plans provide the starting point for design and construction of specific land use and transportation facilities. At that point, the public and the air quality control agencies frequently become involved and may oppose the concepts of the overall plan and particular projects.

In most cases, plans developed for regional planning agencies have no strong influence on actual development and zoning actions. If those plans were given stronger legal standing, community development could be better directed and controversies about general concepts and frequent changes in generalized development patterns could be minimized.

Recommendations

1. Legislation should be passed that requires public hearings to be held on comprehensive metropolitan plans and categorical parts of such plans, i.e., the park plan, the road plan, and so on.

2. The legislation should designate an agency, e.g., a regional planning council, to promulgate a generalized comprehensive metropolitan plan and should require appropriate procedures for and reviews of plan development and a definition of the nature and characteristics of the plans contemplated.

3. Legislation should be passed that requires all development in a metropolitan area to be consistent with the generalized plan and the identification of a legal entity to ensure that development is consistent with the plan and to arbitrate disputes.

4. To ensure that metropolitan plans are consistent with efforts to achieve air quality and other environmental standards, the law should require that, before any plan is adopted by the promulgating agency, it must be reviewed by cognizant environmental control agencies. Federal agencies, such as the Department of Housing

and Urban Development and the Department of Transportation, may be able to require such a review as a condition of their acceptance of a metropolitan plan. (There are some well-founded opinions that the job of developing a regional plan for a major urban center cannot be done well enough to warrant its being followed.)

5. PREVIOUSLY PLANNED PROJECTS AND AIR QUALITY

Issue

Ongoing or previously planned transportation projects often have been conceived with little consideration being given to air quality. On the other hand, imposing air quality considerations after projects begin can result in delays in development and in serious problems relating to spent funds, acquired property, family relocation, and disintegration of system plans. The extent to which ongoing projects may be changed (including the no-build alternative) because of air quality considerations must be determined. Time investments, social and economic cost, and improvements in air quality must be carefully weighed.

Recommendations

1. The U. S. Department of Transportation and the U. S. Environmental Protection Agency should jointly establish general guidelines on how to balance environmental considerations and economic and technical considerations.
2. Efforts should be initiated on a high-priority basis to assess the air quality implications of metropolitan area transportation plans in those areas where major components of the plan are proposed for early construction.

6. PROJECTS NOT FEDERALLY FUNDED

Issue

Many highways are built without federal funds and thus are not subject to the requirements of the National Environmental Policy Act of 1969. Those roads, however, may create air quality problems.

Recommendation

States should be encouraged to implement procedures similar to those called for by the National Environmental Policy Act with regard to all state-supported transportation and land use projects.

7. AIR QUALITY ANALYSIS FOR ENVIRONMENTAL IMPACT STATEMENTS

Issue

There is a lack of understanding among environmental agencies and transportation agencies as to what constitutes an adequate air quality analysis for environmental impact statements. Resolution of that issue requires consensus on procedures and models for conducting air quality analyses and on policy and technical questions of land use as it relates to air quality. The Federal-Aid Highway Act of 1970 (23 U. S. C. 109j) requires the Secretary of Transportation to promulgate guidelines to ensure that highways constructed pursuant to the act are consistent with implementation plans for achieving ambient air quality standards. Those guidelines should alleviate some procedural problems. A further problem is that metropolitan highway plans must be and are system-wide in nature; however, environmental impact statements often are concerned with small segments of a highway rather than the total system.

Lack of agreement between environmental and transportation agencies on the air quality impact of a highway cannot be resolved, however, through simple concurrence in a set of guidelines and an appropriate model for air quality analysis. The difficult root issue of metropolitan regional land use planning arises when the environmental agency considers air quality and other environmental impacts that will occur during the life of the highway facility. How can either the transportation agency or the environmental agency ascertain the long-term environmental impact of highway-related residential and industrial development without a land use plan? The demands of environmental agencies for more information about the environmental impacts on an urban system of which the highway is to be an integral part is an attempt to obtain the kinds of information from transportation planners that should be obtained from metropolitan regional land use planners.

Recommendations

1. The U. S. Environmental Protection Agency and the U. S. Department of Transportation should develop specific technical guidelines, procedures, and models for preparation of air quality analyses of highways.

2. Those 2 federal agencies should also establish a team to investigate and establish guidelines for land use consideration in the evaluation of environmental impacts of transportation plans.

3. Every reasonable effort should be made to evaluate the environmental impact of transportation systems on a metropolitan basis at the earliest feasible stage of system development. Evaluation of the environmental impact of specific parts of a transportation system, as they reach stages of specific location and design, should be made within the context of the total metropolitan plan.

8. ARRANGEMENTS FOR IMPLEMENTING CONTROL STRATEGIES

Issue

Many strategies for reducing transportation-related air pollution can be implemented relatively promptly by local government actions. However, the responsibility for developing and evaluating strategies is metropolitan in nature and is generally done by state and federal agencies.

Recommendation

State, regional, and local agencies should develop specific, cooperative organizational and operational plans for implementing transportation control strategies for air pollution.

9. STATE AND LOCAL PARTICIPATION IN EPA RESEARCH ON CONTROL STRATEGIES

Issue

The Clean Air Act requires that implementation plans for achieving and maintaining ambient air quality standards include measures for transportation and land use control, if needed. The plans were to be submitted by the Environmental Protection Agency on or before February 1, 1972. A number of plans that needed strategies for transportation and land use control did not contain them. Recognizing the limited time that was available to develop plans, the Environmental Protection Agency extended the deadline to February 15, 1973, and, at the same time, initiated in August 1972 work through various research contracts and other means to assist states in preparing the necessary transportation control strategies. Funds are limited, and federal contracts for developing such strategies amount to only about $25,000 for each of the 14 major urban centers. It is clear that the strategies will be based on very limited data collection and evaluation. The risk of reaching erroneous or oversimplified conclusions and recommendations is substantial. If that should occur, credibility and the successful implementation of strategies developed in the future will be inhibited, and substantial funds and energies might be spent on ineffective projects.

Recommendations

1. The Environmental Protection Agency should ensure that all appropriate state and local agencies are involved in the development of land use and transportation strategies that EPA undertakes or funds. Maximum possible use should be made of state and local resources that may be applied to the work. State and local agencies should participate actively in such EPA projects on their own initiative.

2. The strategies that are developed should be described in suitable terms and with appropriate reservations to ensure that the agencies that will later be required to implement them will recognize their strengths, weaknesses, and reservations.

10. VEHICLE EMISSION DATA

Issue

Detailed vehicle emission data in a particular format are needed in community air quality modeling. Present sources of such data are the U. S. Environmental Protection Agency, automobile manufacturers, and the California Air Resources Board. Those doing community air quality modeling do not seem to receive the needed data on a timely basis.

Recommendations

1. The Environmental Protection Agency could develop and operate a vehicle emission information collection and dissemination system so that information is promptly available to all interested parties.

2. The California Air Resources Board should be encouraged to publish and distribute its vehicle emission data for which it would receive appropriate recognition and remuneration.

3. The Environmental Protection Agency could request or influence the automobile manufacturers to publish their vehicle emission data.

4. The Environmental Protection Agency, perhaps in cooperation with the National Science Foundation, should work toward balancing modeling needs with emission data capabilities.

11. PUBLIC INFORMATION ON AIR POLLUTION CONTROL ISSUES

Issue

Citizens and political leaders do not seem to be well informed about air pollution as it relates to transportation and land use control strategies. The responsibility for seeing that they obtain this information, on which their cooperation and support depend, has not been clearly assigned.

Recommendations

1. The state highway agencies should be encouraged by the Federal Highway Administration to develop and implement, in cooperation with their respective state air pollution control agencies, a system to inform the public of the issues involved, including benefits and costs of the various air pollution control, corrective, and preventive measures and the actions that citizens can take to help reduce air pollution from transportation sources.
2. State and local air pollution control agencies should conduct public informational meetings to inform the public about transportation and land use control strategies so that citizens can participate more effectively in public hearings on state implementation plans containing such strategies.

discussion

Question: You mentioned that public hearings should be held for metropolitan plans. Are you referring to transportation plans?

Response: No, we are referring to comprehensive metropolitan plans developed typically by some kind of regional group. In Baltimore that group is the Regional Planning Council. In Washington, it is the Metropolitan Washington Council of Governments. As far as we know, in most places public hearings are not required on those comprehensive long-range plans.

Question: Did you give any consideration to the need for changes in the legal structure, at either the federal or state levels, that might encourage cooperation?

Response: We did not discuss in detail the major revamping of existing institutions. In a few places in our report, we indicated that it was required by law or regulation that certain things be done. We did not do a bit-by-bit analysis of the section in the Clean Air Act dealing with transportation and land use control strategies as to whether Congress adopted a proper law.

Question: Is it evident in any way that there are areas of vagueness as to who has responsibility for certain actions?

Response: We did discuss a gubernatorial-level committee composed of decision-makers from state departments of transportation and state environmental agencies. I think that perhaps an entity established by legislation would be appropriate. In our state we do have a state planning agency, and we would use that organization.

Comment: I would like to make a self-initiated comment here. It seems to me that until we get to a point where we have at least statewide planning and plans that are carried out the cities are going to be in a mess. I was on a tour in Iran on behalf of the World Health Organization. In Iran, which has a semimonarchical government, there is the Plans Organization that has absolute control over where anything is put in the whole country; it also approves budgets. I do not advocate monarchy (and dictatorship is all right if I am the dictator), but we do have a problem with planning in a democratic society. How do you govern and plan in the metropolitan New York area and still maintain democracy? I do not know how to do it.

Comment: I think Working Group 3 mentioned the need for a national planning agency. I second that idea. The effect of that type of agency would then permeate to all the states, and they would presumably follow suit. The problems are probably prodigious in terms of the "big brother" type of agency that has to approve everything. But we are so deeply into air, noise, and water pollution control, public transportation, and land use concepts that an agency of this kind is really essential as an overviewer of all of the problems.

Comment: We may be able to do that if we can create a plans organization or land use control organization in such a way that the membership is elected by the public or somehow placed in absolute responsiveness to the public will. Then, it is all of us acting through the members who are making our cities better.

Comment: You are now recommending a change in the Constitution.

Question: I want to make sure that I get the thrust of your recommendations. An air quality agency determines that certain things should be done in order to carry out an air quality implementation plan or at least get the state where it should be in terms of air quality—some things by the mayor, some by the transportation agency at the state or metropolitan level, and so on. Is it your idea that you get those people involved in the planning process and that you obtain their cooperation that way, or do you keep going to them and saying, "We have done a lot of thinking about this, and we would sort of like you to get on the bandwagon. Here's what we want you to do." How do you see it actually working in practice?

Response: It is a matter of interpersonal relations and the way people work. I do not think anybody cares to do something when another person brings him a piece of paper and says, "I have determined that you have a problem and I have developed a solution to your problem. Will you please do this?" He would feel much better and be much more likely to respond favorably if you went to him and said, "I think maybe we have a problem. I think we should investigate the problem and find out about it and see whether we can develop some way to solve the problem and whether we can do whatever is necessary to get rid of the problem." Good management techniques must be used to incorporate those whom you expect to act at a later time in the early stages of program development. Intergovernmental relations work pretty much like interpersonal relations, I think.

Comment: I would like to make a few remarks about funding and the need for more funding for planning. I think that the potential economic impact of some of the transportation control strategies that will be needed to comply with the Clean Air Act can be quite high. In New York City, we think it will take about a $100 million in public funds a year to comply with the Clean Air Act. The U.S. Environmental Protection Agency appears to be operating on a very meager planning budget, and I think there should be a big increase. But, in addition, I think that, because we are a motor-vehicle-dependent society and because those vehicles are major contributors not only to the air pollution problem in urban areas but also to many other major urban problems, the U.S. Department of Transportation should increase its planning activity by a factor of five, or perhaps more. Instead of $1\frac{1}{2}$ percent funding or 2 percent, it should be 10 percent. The impact of a $1 billion highway on a community is quite profound. To spend a meager

$1\frac{1}{2}$ percent on planning when the architect for that thing rips off 10 percent is just a major inequity.

Response: I could not agree more. I have been in air pollution control for a long time and have never worried much about cost until relatively recently. We can do an awful lot of things to our stationary sources and not spend so much money. For $20 per capita per year we can do a tremendous amount of sanitizing of stationary sources. A clean car costs about $300; that is about $2.4 billion a year forever, essentially. I think it would be worth spending at least $2.4 million to find out whether we are doing the right thing. As far as I know (and I have not seen the publications), the systems analysts say that we are doing the right thing.

Comment: That is only one element of it, though. The transportation planning and implementation element consumes some $25 billion a year, 10 times the sum talked about for emission controls.

Question: It is fairly obvious from listening to most of the plans proposed for short- and long-range strategies that we will be faced with a change in life-style or, if not a change in life-style, at least a tremendous social cost. Did you consider whether the body politic when faced with a tremendous social cost or a sudden change in life-style might react negatively?

Response: That is certainly a valid question, but it was not within the purview of our working group.

Comment: One thing that is applicable all across the board here is costs versus benefits. What else can you spend money for to get greater benefits? You alluded to that when you mentioned the $20 per capita cost for stationary sources versus the $300 cost per car.

Comment: I think cost-benefit analysis is essential for all activities, including transportation planning. Every new car on the highway costs $500 in societal costs every year in terms of highway accidents. What about the cost-benefit of that?

Response: I would like that investigated along with everything else.

Response: I understand that the U.S. Environmental Protection Agency is doing research to determine the extent of the health effects of carbon monoxide, that is, the primary effect of carbon monoxide on human health rather than secondary or aesthetic effects. Most of us concerned with air pollution control realize that there has been a significant amount of "hand waving" in determining ambient air quality standards, and I would hope that the ongoing research at EPA would continue to temper those standards and bring them closer and closer to reality. My opinion is that the secondary effects, the effect on plants, animals, and aesthetics, will probably be more important than some of the health effects that reportedly have been caused by air pollution.

Comment: EPA estimates the societal cost of vehicular pollution at $1.5 billion annually. That is just 3 percent of the U.S. Department of Transportation's estimate of the societal cost of accidents. I want to put some relative perspective on what we are talking about here. Air pollution is only one aspect of the overall problem of transportation in America today, and I think it should be recognized as such. I think that we need perhaps another committee activity to deal with that complex of issues of the societal cost of transportation.

Response: I would concur, but I think the societal costs of air pollution are staggering. A problem with dealing with numbers is that it is very hard to assess the cost of a death that is caused by air pollution. And studies have definitely shown that air pollution does increase deaths, particularly of those who have respiratory problems to start with.

Question: How many deaths are there a year?

Response: There have been isolated studies. One was done in New York City that showed thousands of deaths attributed to increased air pollution.

Question: Per year in New York City?

Response: I do not know the exact number or whether they occurred during 1 year or 10 years.

Comment: That, I think, is the point. We are spending billions of dollars in public funds, but we do not know why we are spending it. That is, we do not know the cost-effectiveness of it.

Comment: I think it is essential that any planning agency be fully accountable to the public at all times. All of its plans, all of its data, every single stage of what it does should be open and available. If that is not done, the administrative agency will constantly be trying to refine those data. It is very important that there be some kind of constant public accountability.

Response: That is why I suggested that the board of directors of the planning agency be elected officials so that they would be responsive to the people. Provisions would be made for public review, public hearings, and as always court tests of any actions.

Comment: I think that some of us from California are surprised by the fact that in the various states there apparently is a lack of interaction between transportation agencies and the local air resources board authorities. Maybe it is because our problems are more acute, but what has been suggested here is actually occurring in California. The California Division of Highways and the Department of Public Works were intimately involved in this problem long before there was a federal implementation plan. In fact, while the federal implementation plan was being developed, we already had large-scale projects and committee activities involving both the transportation and air resources agencies, even at the local levels. The highway division districts are very intimately involved at this time with all of the local authorities and also local people themselves who are concerned with air pollution problems. That situation is working in one state, and I see no reason why it cannot work in all states.

Question: Is that why Los Angeles has more freeways than any other city?

Response: No, but that is why Los Angeles has more problems than any other city. There is a very close interaction among local agencies within Los Angeles through the federal implementation plan.

Comment: I have no reason to question what you say, but I am also fairly sure that in almost all states the air pollution official probably has not spoken to the highway official more recently than a year or 6 months ago. And they have not spoken to the official in the department of motor vehicles very much.

Comment: That is a clear indication, perhaps, that the problem has not been considered so extensively as it has in California. I do not consider it to be a difficult task to establish the relationship. It can be done.

Comment: I think the major problem with citizen participation is lack of funds to provide for citizen involvement. Citizen groups cannot pay for a professional staff to disseminate information, coordinate any effort to review public policy, or develop technical expertise. Programs have to be developed, at least funding must be available from the federal level, to accommodate those activities if there is to be meaningful citizen participation.

Response: I would agree if "federal" is removed from in front of the word "funding." I am not sure I want the federal government to fund all our public information activities.

Comment: There are 2 problems: Public apathy and virtually no funding available from foundations for environmental activities today. It has dried up.

Comment: Unlimited funding is not going to ensure public participation.

Response: But no funding guarantees no public participation.

U.S. Environmental Protection Agency

SAMPLING LOCATION GUIDELINES

This report has reference to an earlier report (35) and is concerned with guidelines for installation of air monitoring instruments at particular sampling sites, especially those located in the area of estimated maximum pollutant concentration and established for the purpose of determining compliance with national primary standards for ambient air quality.

Minimum number of air quality monitoring sites and frequency of sampling are specified in the earlier report (35, Sec. 420.17). General considerations governing distribution of air quality monitoring sites within an air quality control region are also described in an earlier publication (36).

Specific guidelines for locating air monitoring instruments in areas of estimated maximum pollutant concentration are given in Table 6. Sampling station guidelines are different for defining average CO concentration for 1 hour and 8 hours because people would not ordinarily be exposed to CO concentrations that occur in a downtown area having high traffic density for a period of 8 hours. When only a single sampling site is established to satisfy the minimum air quality surveillance requirement of the implementation plan, a site should be chosen that meets the guidelines for 8-hour averaging time. Distance from the street is specified in the sampling location guidelines for CO because of the strong dependence on nearness to the street and CO concentration. For the same reason, height from the ground of the air inlet is more restrictive than for the other pollutants. It is desirable, however, to sample as close as possible to the breathing zone within practical considerations; sampling height limitations are specified accordingly for those pollutants. There are no well-established meteorological dispersion models currently available for selecting areas of expected maximum concentration for the secondary pollutants. Selection of high concentration areas, described in Table 6, for those pollutants is based on available information on reaction kinetics of atmospheric photochemical reactions involving hydrocarbons, nitrogen oxides, and oxidants; atmospheric data on diurnal variation in pollutant concentration; distribution of primary mobile sources of pollution; and meteorological factors. A minimum distance away from major traffic arteries and parking areas is specified for the oxidant monitoring site because NO emissions from motor vehicles consume atmospheric ozone. NO_2 is considered to be both a primary stationary-source pollutant and a secondary pollutant, and air monitoring stations for this pollutant should be located consistent with the respective station location guidelines. Differences in horizontal and vertical clearance distances are based on increased probability of reaction between reactive gases and vertical surfaces.

Sampling locations selected in areas of estimated maximum pollutant concentration should be evaluated in light of actual aerometric and meteorological data, urban and industrial growth and development, and

Table 6. Sampling location guidelines for areas of estimated maximum pollutant concentration.

Pollutant Category	Pollutant	Station Location	Position of Air Inlet: Height[a] (ft)	Vertical[b] (ft)	Horizontal[c] (ft)
Primary stationary source	SO_2	Determined from atmospheric diffusion model, historical data, emission density, or other information and representative of population exposure	< 50	> 3	> 5
	NO_2		< 50	> 3	> 5
	Particulate matter		< 50	> 3	> 3
Primary mobile source	CO[d]	Representing area having high traffic density, slowly moving traffic, obstructions to air flow (tall buildings), and pedestrian population such as major downtown traffic intersections (<20 ft from street curb)	< 15	> 3	> 3
	CO[e]	Representing area having high traffic density in residential area such as major thoroughfare in center city or suburban area (< 50 ft from street curb)	< 15	> 3	> 3
Secondary	O_x	Representing residential area downwind of downtown area (5 to 15 miles from downtown and >300 ft from major traffic arteries or parking areas)[f]	< 50	> 3	> 5
	NO_2	Representing residential area downwind of downtown area (< 5 miles from downtown)[f]	< 50	> 3	> 5

[a]From ground.
[b]Clearance above supporting structure.
[c]Clearance beyond supporting structure; not applicable where air inlet is located above supporting structure.
[d]1-hour averaging time.
[e]8-hour averaging time.
[f]Downwind of prevailing daytime wind direction during oxidant season.

other pertinent information. Wherever feasible, it is desirable to conduct a preliminary aerometric survey as a means of selecting sampling locations for maximum pollutant concentration.

In addition to the specific guidelines given in Table 6, the following general guidelines are applicable to sampling station location.

1. Except for the sampling station for determining 1-hour carbon monoxide concentrations, avoid locations, such as those adjacent to buildings, parapets, or trees, where there are restrictions to air flow in the vicinity of the air inlet.

2. Avoid sampling locations that are unduly influenced by downwash from a minor local source or by reentrainment of ground dust. Examples include locations close to a stack on the roof of a building where the air inlet is located or close to the ground near an unpaved road. In the latter case, either elevate the sampler intake above the level of maximum ground turbulence effect or place the sampler intake away from the source of ground dust.

3. Avoid locations that may be inaccessible in adverse weather conditions, prone to vandalism, or otherwise insecure.

It is recognized that for practical considerations it may not be feasible to select sampling sites that meet all of the specific and general guidelines. In that event, it is especially important that the sampling stations selected be defined in such a manner that enables comparison of results obtained with those obtained at other sampling stations meeting these guidelines. That may be accomplished by delineating the critical parameters including elevation, vertical clearance, horizontal clearance, distance from curb, distance from downtown, distance from major traffic arteries or parking areas, restrictions to air flow in the vicinity of sampler, nearby local sources, and meteorological parameters.

REFERENCES

1. Federal Register. Vol. 38, No. 49, Wed., March 14, 1973.
2. Federal Register. Vol. 36, No. 84, Fri., April 30, 1971.
3. Environmental Quality. U. S. Council on Environmental Quality, 3rd Ann. Rept., Aug. 1972.
4. Cumulative Regulatory Effects on the Cost of Transportation. U. S. Office of Science and Technology (RECAT Rept.), Feb. 28, 1972.
5. Federal Register. Vol. 38, No. 6, Wed., Jan. 10, 1973.
6. Federal Register. Vol. 37, No. 221, Wed., Nov. 15, 1972.
7. Federal Register. Vol. 36, No. 228, Thu., Nov. 25, 1971.
8. Federal Register. Vol. 35, No. 219, Pt. 2, Tue., Nov. 10, 1970.
9. Kircher, D. S., and Armstrong, D. P. An Interim Report on Motor Vehicle Emission Estimation. Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, N. C., Oct. 1972, rev. Jan. 1973.
10. National Air Quality Standards Act of 1970. 91st Congress, 2nd Session, Senate Rept. 91-1196, Sept. 17, 1970.
11. Rose, A. H., Jr., Smith, R., McMichael, W. F., and Kruze, R. E. Comparison of Auto Exhaust Emissions From Two Major Cities. In Evaluating Transportation Controls to Reduce Motor Vehicle Emissions, Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, N. C., APTD-1364, Nov. 1972.
12. Evaluating Transportation Controls to Reduce Motor Vehicle Emissions. Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, N. C., APTD-1364, Nov. 1972.
13. A Guide for Reducing Automotive Air Pollution. Office of Air Programs, U. S. Environmental Protection Agency, Research Triangle Park, N. C., Nov. 1971; NTIS, PB 204 870.
14. Lee, L., et al. SMOG: A Report to the People. Environmental Quality Laboratory, California Institute of Technology, Pasadena, 1972.
15. Federal Register. Vol. 38, No. 8, Fri., Jan. 12, 1973.
16. Federal Register. Vol. 38, No. 45, Thu., March 8, 1973.
17. 1969-70 Nationwide Personal Transportation Survey. Office of Planning, Federal Highway Administration, preliminary results.
18. Shinnar, R. System Approach for Reducing Car Pollution. Science, Vol. 175, March 24, 1972, pp. 1357-1360.
19. Easterling, M. Periodic Motor Vehicle Inspection as a Smog Abatement Measure in the South Coast Air Basin. Environmental Quality Labo-

ratory, California Institute of Technology, EQL Memo. 2, Jan. 1973.
20. Control Strategies for In-Use Vehicles. Office of Air and Water Programs, U. S. Environmental Protection Agency, Nov. 1972.
21. Policy and Procedure Memorandum 90-4. Federal Highway Administration, Sept. 21, 1972.
22. Report to Congress on Section 109(h), Title 23, United States Code, Guidelines Relating to the Economic, Social and Environmental Effects of Highway Projects. 92nd Congress, 2nd Session, Aug. 1972.
23. Beaton, J. L., Skog, J. B., Shirley, E. C., and Ranzieri, A. J. Meteorology and Its Influence on the Dispersion of Pollutants From Highway Line Sources. Materials and Research Department, California Division of Highways, Sacramento, Air Quality Manual CA-HWY-MR657082S-(1)-72-11, April 1972.
24. Beaton, J. L., Skog, J. B., and Ranzieri, A. J. Motor Vehicle Emission Factors for Estimates of Highway Impact on Air Quality. Materials and Research Department, California Division of Highways, Sacramento, Air Quality Manual CA-HWY-MR657082S-(2)-72-10, April 1972.
25. Beaton, J. L., Skog, J. B., and Shirley, E. C. Traffic Information Requirements for Estimates of Highway Impact on Air Quality. Materials and Research Department, California Division of Highways, Sacramento, Air Quality Manual CA-HWY-MR657082S-(3)-72-09, April 1972.
26. Beaton, J. L., Skog, J. B., Shirley, E. C., and Ranzieri, A. J. Mathematical Approach to Estimating Highway Impact on Air Quality. Materials and Research Department, California Division of Highways, Sacramento, Air Quality Manual CA-HWY-MR657082S-(4)-72-12, May 1972.
27. Beaton, J. L., Skog, J. B., Shirley, E. C., and Ranzieri, A. J. Analysis of Ambient Air Quality for Highway Environmental Projects. Materials and Research Department, California Division of Highways, Sacramento, Air Quality Manual CA-HWY-MR657082S-(5)-72-13, July 1972.
28. Beaton, J. L., Skog, J. B., and Shirley, E. C. A Method for Analyzing and Reporting Highway Impact on Air Quality. Materials and Research Department, California Division of Highways, Sacramento, Air Quality Manual CA-HWY-MR657082S-(6)-72-14, July 1972.
29. Directory of Governmental Air Pollution Agencies. Air Pollution Control Association, Pittsburgh.
30. Organization for Continuing Urban Transportation Planning. HRB Spec. Rept. 139, 1973.
31. Report to the Congress: Progress and Problems of Urban and Transportation Planning. U. S. General Accounting Office, B-174182, Nov. 19, 1971.
32. Directory of Urbanized Area Transportation Planning Programs. Office of Highway Planning, Federal Highway Administration, Nov. 1972.
33. Johnson, W. F., Dabert, W. F., Ludwig, F. L., and Allen, R. J. Field Study for Initial Evaluation of an Urban Diffusion Model for Carbon Monoxide. Stanford Research Institute, Menlo Park, Calif., June 1961.
34. Elmberg, C. M. The Gothenburg Traffic Restraint Scheme. Organisation for Economic Co-operation and Development, May 1971.

35. U. S. Environmental Protection Agency. Requirements for Preparation, Adoption and Submittal of Implementation Plans. Federal Register, Aug. 14, 1971.
36. Guidelines: Air Quality Surveillance Networks. Office of Air Programs, U. S. Environmental Protection Agency, Research Triangle Park, N. C., Publ. AP-98, May 1971.

PARTICIPANTS IN THE AIR QUALITY WORKSHOP

Howard L. Anderson, Office of Development, Federal Highway Administration, U.S. Department of Transportation

Robert J. Anderson, Jr., Department of Economics, University of California, Riverside

Jack F. Andrews, New Jersey Department of Transportation, Trenton

John L. Beaton, California Division of Highways, Sacramento

Salvatore J. Bellomo, Research and Environmental Planning Department, Alan M. Voorhees and Associates, Inc., McLean, Virginia

George Bulineau, Georgia Department of Transportation, Atlanta

Ralph D. Brown, Jr., Illinois Department of Transportation, Springfield

A. G. R. Bullen, School of Engineering, University of Pittsburgh

Joseph Canny, Office of the Assistant Secretary for Environment and Urban Systems, U.S. Department of Transportation

James E. Clark, III, District of Columbia Department of Highways and Traffic, Washington, D. C.

Walter Dabberdt, Stanford Research Institute, Menlo Park, California

Susan Denham, School of Law, Columbia University, New York

Vince DeSimone, Automobile Club of Southern California, Los Angeles

Mahlon Easterling, Environmental Quality Laboratory, California Institute of Technology, Pasadena

William L. Garrison, School of Engineering, University of Pittsburgh

B. B. Gerhardt, Colorado Department of Highways, Denver

S. William Gouse, Jr., Carnegie Institute of Technology, Carnegie-Mellon University, Pittsburgh

Fred C. Hart, New York City Department of Air Resources

Alan Hoffman, Office of Air Programs, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina

Joel Horowitz, Office of Planning and Evaluation, U.S. Environmental Protection Agency

Harold H. Huber, Pennsylvania Department of Transportation, Harrisburg

Howard A. Jongedyk, Federal Highway Administration, U.S. Department of Transportation

Brian T. Ketcham, New York City Department of Air Resources
Jerry Kurtsweg, U.S. Environmental Protection Agency, Seattle,

Ray G. L'Amoureaux, Florida Department of Transportation, Tallahassee
Michael Lash, Office of Environmental Policy, Federal Highway Administration, U.S. Department of Transportation
Gary L. Latshaw, Environmental Systems Laboratory, Sunnyvale, California
Felipe Lebron, Bureau of Air Quality Control, Maryland Department of Health and Mental Hygiene, Baltimore
Eugene Lehr, Coordination and Research Division, Office of the Assistant Secretary for Environment and Urban Systems, U.S. Department of Transportation
Armand LePage, Office of Federal Activities, U.S. Environmental Protection Agency
Denis M. Lohman, Bureau of Air Quality and Noise Control, Pennsylvania Department of Environmental Resources, Harrisburg

Daniel R. Mandelker, School of Law, Washington University, St. Louis
Sumner Myers, Institute of Public Administration, Washington, D.C.
Leonard O. Myrup, Division of Environmental Studies, University of California, Davis

Kenneth E. Noll, University of Tennessee, Knoxville

John Olin, Air Quality Division, Minnesota Pollution Control Agency, Minneapolis
George Osborne, Federal Highway Administration, U.S. Department of Transportation, Atlanta

John Philbrook, U.S. Environmental Protection Agency, Denver
Robert Probst, Federal Highway Administration, U.S. Department of Transportation
Clyde E. Pyers, Maryland Department of Transportation, Baltimore

Joseph S. Revis, Institute of Public Administration, Washington, D.C.

William E. Schaefer, California Department of Public Works, Sacramento
Jean J. Schueneman, Bureau of Air Quality Control, Maryland Department of Health and Mental Hygiene, Baltimore
Gordon M. Sessions, Bethesda, Maryland
Reuel Shinnar, Department of Chemical Engineering, City College of New York

Earl C. Shirley, California Division of Highways, Sacramento
Ralph Sklarew, Division of Meteorology, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina
John B. Skog, California Division of Highways, Sacramento
Ben L. Smith, Tennessee Department of Transportation, Nashville
M. P. Strong, North Carolina Highway Commission, Raleigh

Ronald A. Venezia, Office of Air Programs, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina
Leonard Vik, Division of Air Pollution Control, Illinois Environmental Protection Agency, Springfield

Michael T. Walsh, New York City Department of Air Resources
Harry B. Weaver, Motor Vehicle Manufacturers Association, Detroit
George V. Wickstrom, Metropolitan Washington Council of Governments, Washington, D. C.
Byron H. Willis, Air Pollution Control Planning Services, Environmental Research and Technology, Inc., Lexington, Massachusetts
John S. Winder, Metropolitan Washington Coalition for Clean Air, Washington, D. C.
Frederick Winkler, Office of Air Programs, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina
Thomas D. Wolsko, Center for Environmental Studies, Argonne National Laboratory, Illinois
James R. Wright, Highway Research Board, Washington, D. C.

ADVISORY COMMITTEE ON HIGHWAYS AND AIR QUALITY

William L. Garrison, School of Engineering, University of Pittsburgh, chairman
Howard L. Anderson, Office of Development, Federal Highway Administration, U. S. Department of Transportation
Robert J. Anderson, Jr., Department of Economics, University of California, Riverside
John L. Beaton, California Division of Highways, Sacramento
Salvatore J. Bellomo, Research and Environmental Planning Department, Alan M. Voorhees and Associates, Inc., McLean, Virginia
Ralph D. Brown, Jr., Illinois Department of Transportation, Springfield
Mahlon Easterling, Environmental Quality Laboratory, California Institute of Technology, Pasadena
Michael Lash, Office of Environmental Policy, Federal Highway Administration, U. S. Department of Transportation
Eugene Lehr, Coordination and Research Division, Office of the Assistant Secretary for Environment and Urban Systems, U. S. Department of Transportation
Henrik E. Stafseth*, Michigan Department of Highways, Ann Arbor
Ronald A. Venezia, Office of Air Programs, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina
Byron H. Willis, Air Pollution Control Planning Services, Environmental Research and Technology, Inc., Lexington, Massachusetts
John S. Winder, Metropolitan Washington Coalition for Clean Air, Washington, D. C.
Frederick Winkler, Office of Air Programs, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina

James R. Wright, Highway Research Board staff representative

**During the course of this study, Mr. Stafseth, who was the Michigan State Highway Director, became Executive Director of the American Association of State Highway Officials and found it necessary to resign from the Advisory Committee because of the extra demands on his time in his new position. He did not participate in the preparation and review of this report.*

THE National Academy of Sciences is a private, honorary organization of more than 800 scientists and engineers elected on the basis of outstanding contributions to knowledge. Established by a congressional act of incorporation signed by Abraham Lincoln on March 3, 1863, and supported by private and public funds, the Academy works to further science and its use for the general welfare by bringing together the most qualified individuals to deal with scientific and technological problems of broad significance.

Under the terms of its congressional charter, the Academy is also called upon to act as an official—yet independent—adviser to the federal government in any matter of science and technology. This provision accounts for the close ties that have always existed between the Academy and the government, although the Academy is not a governmental agency and its activities are not limited to those on behalf of the government.

The **National Academy of Engineering** was established on December 5, 1964. On that date the Council of the National Academy of Sciences, under the authority of its act of incorporation, adopted articles of organization bringing the National Academy of Engineering into being, independent and autonomous in its organization and the election of its members, and closely coordinated with the National Academy of Sciences in its advisory activities. The two Academies join in the furtherance of science and engineering and share the responsibility of advising the federal government, upon request, on any subject of science or technology.

The **National Research Council** was organized as an agency of the National Academy of Sciences in 1916, at the request of President Wilson, to provide a broader participation by American scientists and engineers in the work of the Academy in service to science and the nation. Its members, who receive their appointments from the President of the National Academy of Sciences, are drawn from academic, industrial, and government organizations throughout the country. The National Research Council serves both Academies in the discharge of their responsibilities. Supported by private and public contributions, grants, and contracts and by voluntary contributions of time and effort by several thousand of the nation's leading scientists and engineers, the Academies and their Research Council thus work to serve the national interest, to foster the sound development of science and engineering, and to promote their effective application for the benefit of society.

The **Division of Engineering** is one of the eight major divisions into which the National Research Council is organized for the conduct of its work. Its membership includes representatives of the nation's leading technical societies as well as a number of members-at-large. Its Chairman is appointed by the Council of the Academy of Sciences upon nomination by the Council of the Academy of Engineering.

The **Highway Research Board** is an agency of the Division of Engineering. The Board was established November 11, 1920, under the auspices of the National Research Council as a cooperative organization of the highway technologists of America. The purpose of the Board is to advance knowledge of the nature and performance of transportation systems through the stimulation of research and dissemination of information derived therefrom. It is supported in this effort by the state highway departments, the U.S. Department of Transportation, and many other organizations interested in the development of transportation.

HIGHWAY RESEARCH BOARD
NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL
2101 Constitution Avenue Washington, D. C. 20418

ADDRESS CORRECTION REQUESTED

NON-PROFIT ORG.
U.S. POSTAGE
PAID
WASHINGTON, D.C.
PERMIT NO. 42970

000015
L F ERICKSON

IDAHO DEPT OF HIGHWAYS
P O BOX 7129
BOISE ID 83707