TRANSPORTATION SOURCE AIR POLLUTION IN VIRGINIA

REPORT OF THE SECRETARY OF TRANSPORTATION AND PUBLIC SAFETY TO THE GOVERNOR AND THE GENERAL ASSEMBLY

House Document No. 24

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COMMONWEALTH OF VIRGINIA
OFFICE OF THE GOVERNOR

Report of the Secretary of Transportation and Public Safety to The Governor and the General Assembly of Virginia

TO: THE HONORABLE MILLS E. GODWIN, JR., *Governor of Virginia*
and
THE GENERAL ASSEMBLY OF VIRGINIA

I. INTRODUCTION

The 1973 General Assembly enacted House Joint Resolution No. 254 which directed the Secretary of Transportation and Public Safety

> . . . to explore and encourage the development of all means of transportation which will reduce air pollution while efficiently and economically serving the citizens of Virginia. . . .

The Secretary of Transportation was also directed to report annually on the progress of the Commonwealth's efforts to carry out the purpose of the resolution.

Pursuant to the requirements of House Joint Resolution No. 254, I requested the assistance of the Division of State Planning and Community Affairs (DSPCA) in the preparation of a report which would examine the degree to which various transportation modes contribute to Virginia's air pollution problems and which would make recommendations regarding the most appropriate actions for the Commonwealth in reducing transportation source air pollution. For this initial effort, it was agreed that a thorough analysis was desirable and should include an examination of the following subject areas:

- definition of the air pollution problem
- identification of areas where pollution levels have reached or exceeded national air quality standards
- evaluation of the impact of the automobile as well as other transportation modes on pollution levels
- description of alternative transportation strategies that could impact the level of transportation source pollution
- recommendation of those strategies that would most effectively provide both air quality and mobility to all Virginia citizens

I also requested that the DSPCA work with appropriate state, local and federal agencies in gathering information for the report and in defining and evaluating the alternative transportation strategies.

I am pleased to submit the attached report on *Air Quality and Mobility in Virginia.* In this report, the DSPCA has developed a comprehensive analysis of Virginia's existing and potential transportation source air pollution problems. It provides an extensive discussion of many alternative transportation strategies and makes specific recommendations regarding those strategies that appear to be most appropriate and effective for State involvement at this time.

Although I agree generally with all the recommendations of the DSPCA, I believe that some of them are more amenable to the needs and desires of the citizens of the Commonwealth than are others. In the following two sections, I will briefly outline the primary findings of the report and present my recommendations for alleviating transportation source pollution in the State.

II. SYNOPSIS OF TRANSPORTATION SOURCE POLLUTION— PROBLEMS AND SOLUTIONS

Until recently, pollution of the atmosphere usually remained at such levels that natural phenomena could absorb or disperse the pollutants. Now, however, several factors are creating situations in which emissions into the atmosphere are so extensive that harmful changes to the equilibrium of the natural environment occur. These changes result from the unbalanced interaction between pollutant sources and meteorological conditions.

Pollution sources have increased in number, and the resulting emissions have created a saturation of the atmosphere around the sources. Population growth has contributed to this situation, but a more deterministic factor is the concentration of increasingly larger numbers of people on a relatively small portion of land area—the major metropolitan areas. In the Commonwealth, for example, approximately 70 percent of the population will be residing in metropolitan areas by 1990. At the same time, advances in industry and technology have caused an increasing dependence upon machines to perform certain tasks. This in turn has caused greater pollution levels, since the burning of fuel to run the machine creates pollution. Futhermore, modern society has grown to depend on the automobile and truck as its primary means of transportation of both people and goods. Because of the increased numbers of these vehicles and their basically inefficient propulsion systems, this trend has resulted in increased traffic congestion, inefficient use of fuel resources, and additional pollution.

Hence, the problem is more complex than simply increased amounts of atmospheric pollution. It is the result of a style of life that both concentrates pollution sources and increases their numbers. Therefore, the solutions require actions that encompass far more than simply reducing pollution levels—it requires a change in the kind of life-style to which most people have grown accustomed. With respect to transportation, a new view of mobility and movement between community activities will be necessary.

Nevertheless, the problem must be explored in order to define acceptable solutions. In the following paragraphs, a brief overview of the DSPCA's initial analysis is provided.

The most influential pollutants produced by transportation sources

are carbon monoxide, hydrocarbons, oxides of nitrogen, photochemical oxidants, and lead. Of these, carbon monoxide is perhaps the best known. There is a strong interrelationship among hydrocarbons, oxides of nitrogen, and photochemical oxidants since it is the reaction between the hydrocarbons and nitrogen oxides in the presence of sunlight that creates photochemical oxidants. Although lead has been a potential problem pollutant in the past, it will become increasingly less influential as non-lead fuels become available during 1974.

The dominant transportation source of pollution is the motor vehicle, whether it is an automobile, a truck, a bus, a train engine, an aircraft, or a ship. At the same time, it should be recognized that the vehicle is only one element of the total transportation system. The other components, which consist of (1) the transportation network over which the vehicle travels, (2) terminal or parking areas, and (3) control mechanisms, such as stop lights which guide the flow of vehicles, contribute indirectly to the concentration or accumulation of pollution. For example, an efficiently planned street network can help to reduce the amount of pollution by allowing the vehicles to travel under generally free-flow conditions. On the other hand, street networks that are poorly planned and are controlled ineffectively create congestion and increase the amount of pollution emitted from vehicles.

All transportation modes pollute. However, the DSPCA's report verifies the propensity of certain modes to pollute more than others. From the data gathered, the automobile is shown to be the major transportation source of pollution, both state- and nation-wide. The automobile is also a rather inefficient means of transportation when compared with other forms of public transportation except the jet airplane. It should be noted, however, that this comparison holds true only if these modes operate at load levels of 50 percent—a bus that carries loads of five or six passengers is operating at a very low level of efficiency. Consequently, these two facts point out the need to de-emphasize automobile travel while emphasizing the utilization of other more efficient and less polluting transportation systems.

Pollution measurements have reached critical levels in three regions of the State in the past two years. These regions are Northern Virginia, Richmond, and Tidewater. Both the carbon monoxide and oxidant air quality standards were exceeded on several occasions, thus indicating the potential need for developing some form of pollution control strategy. To date, however, only the Northern Virginia area has been required to do so. This does not preclude the desirability or necessity of transportation control strategies in the other two or any other areas of the State where air quality standards are exceeded.

Also discussed in the DSPCA report are several alternative transportation strategies which, if implemented, could reduce the effect of automotive air pollution in the State. Essentially, five separate categories of strategies are described. Summaries of these are provided below.

(1) *Vehicle-oriented Strategies.* In this category, the vehicle is the primary target of any pollution control measures. Included among the alternatives are the *Federal New Car Emission Program,* periodic inspection/maintenance of the vehicle, retrofitting of the vehicle with devices to clean up its emissions, use of alternative fuel systems for certain groups of vehicles (especially fleet vehicles), and control of evaporative losses incurred during the transfer and storage of fuel supplies.

(2) *Strategies to Reduce Vehicular Traffic.* The thrust of these strate-

gies is toward increasing the number of person-trips per vehicle, reducing the number of daily person-trips, restricting automobile usage, and minimizing the distances of typical trips. The key to the practicability of these strategies is the recognition that the individual strategies are highly interrelated and that their effectiveness depends on the provision of alternative modes of travel *and* sanctions against the inefficient use of the automobile. Increased usage of public transportation systems is the focal point of these strategies. However, improvements to existing systems are essential in order to encourage their use. Public transportation systems must increase their reliability and accessibility and provide a level of service that is comparable with that of the automobile before they will be acceptable alternatives. As public transportation becomes a viable alternative, then steps can be taken to encourage its use by discouraging the use of the private automobile, particularly for work-related commutation. Disincentives to automobile use may involve use regulations or pricing restraints, such as parking controls, restraints on vehicle use, carpools or bus-pooling, idling restrictions, or four day 40-hour work weeks.

(3) *Strategies to Improve Traffic Flow.* Traffic flow modifications potentially reduce the pollution created by automobile traffic because the improvements allow the vehicles to avoid congestion situations which tend to increase vehicle emissions. Caution should be taken when considering these strategies because of the tendency of roadway improvements to attract additional traffic and to incur subsequent congestion problems. Generally, these strategies deal with such improvements as reverse lane operations, ramp controls, lane alignment, reversible one-way streets, and signal light progression.

(4) *Strategies to Reduce Pollution Concentration.* With these strategies, the purpose is to spread pollution sources over a larger area and over a longer period of time. Such action potentially creates less pollution concentration because the pollutants can be dispersed more easily. For areas with photochemical oxidant problems, however, such strategies would have minimal, if any, effect due to the regional impact of this pollutant. Highway design considerations are one method for affecting pollution concentration, staggering of work hours is another.

(5) *Other Strategies.* Several additional strategies are discussed in the report. Among these strategies are: land use or activity planning; gasoline and/or other fuel rationing; alternatives to the internal combustion engine; alternatives to automotive intercity travel; and taxes on engine displacement, horsepower, or fuel consumption.

Presently, several state agencies have initiated programs or projects which have contributed or will contribute to a reduction in the amount of air pollution created by transportation sources. In some cases, these actions have been specifically designed to address the pollution problem. Among these are the program activities of the State Air Pollution Control Board and the Air Quality Planning Committee of the National Capital Interstate Air Quality Control Region. In other cases, the actions have been brought about by the need to reduce traffic congestion or to resolve specific transportation problems, with the latent result of overall reductions in the amounts of transportation source pollutants. The Shirley Highway Express Bus Project in Northern Virginia is an excellent example. This exclusive

busway was inaugurated by the Virginia Department of Highways and the Federal Department of Transportation in 1969 and presently carries approximately 30,000 transit riders each weekday. Furthermore, in 1973 the Department of Highways in cooperation with the Richmond Metropolitan Authority initiated the Parham Road Express Bus Project in Richmond, which has proven to be a very successful project. A similar project was recently initiated in the Norfolk-Virginia Beach Corridor, and the Department of Highways is currently evaluating the potential for additional projects in other parts of the Commonwealth. Implementation of high-speed passenger rail service in the Washington-Richmond Corridor, as suggested in a recent feasibility study report, would also affect pollution emissions in the Commonwealth, especially along the heavily traveled I-95 corridor.

III. RECOMMENDATIONS

The recommendations developed by the Division of State Planning and Community Affairs (DSPCA) represent two levels of implementation: (1) those actions which should occur over the short-term; and (2) those actions that, because of their complexity and immediate impracticability, are long-range in application.

Under the first category, the DSPCA suggests the following specific actions by the State: the institution of an inspection/maintenance program for emission control equipment as a part of the semi-annual safety inspection program; an extensive analysis of the practicability of parking controls and vehicle use restraints in the Richmond area where a large number of State employees work; the utilization of existing State computer facilities to implement a carpool locator service (such a service would also be available to private employers desiring to use it); the implementation of a tax surcharge that would discourage the use of automobiles possessing high emissions characteristics; and the encouragement and financial support of improved public transportation systems.

Under the second group of recommendations, several potential concepts are outlined, but only one specific recommendation is made—the creation of an interdisciplinary committee whose primary function would be to define State policy regarding the relationships between land use, transportation, and environmental considerations. Through such a committee, the State would have the flexibility to analyze, from a more comprehensive vantage point, the inherent, interrelated problems associated with each of these three disciplines.

I agree, in substance, with the DSPCA's suggested strategies; but, I feel that the current situation with regard to energy resources has a more critical influence over the choice of strategies than is reflected in the DSPCA's report. It should be noted, however, that the report was prepared before the actual severity of the "energy crisis" was realized and before the situation was aggravated by the Middle East conflict. Even though energy conservation was a consideration in evaluating alternative strategies, it was simply one among several criteria used. Therefore, in light of this critical development, I think that modifications to certain recommendations presented in the report are necessary.

I believe that the recommendation of an inspection/maintenance program for antipollution controls would be both difficult and excessively expensive to implement at this time. This is especially true considering the current possibility of extensions to the required deadlines for the *Federal New Car Emissions Program.* At the same time, I do feel that an inspec-

tion/maintenance program is essential to the effectiveness of the emissions control program, and, therefore, must be considered as a long-range alternative contingent upon federal legislation in this area.

Parking controls and vehicle use restraints are important considerations in encouraging the use of public transportation systems. However, existing public mass transportation systems in the Commonwealth's metropolitan areas do not provide levels of service which can be substituted for that generally provided by the private automobile. Until these mass transportation systems can be considered as acceptable alternatives (i.e., providing service that is basically comparable to that of the automobile), parking controls and vehicle use restraints should be fully evaluated prior to implementation. I do, however, think that the recommendation under this group of alternatives (i.e., generally, to examine existing State parking policies to determine whether certain changes directed toward discouraging the unnecessary and inefficient use of automobiles by State employees) is practical and can potentially result in improved air quality and, therefore, deserves your consideration.

I feel that the State must make a positive commitment to the development and/or improvement of public mass transportation systems in our metropolitan areas. *As we are beginning to realize, the private automobile can no longer be allowed to function as our only major transportation mode.* It has been shown to be the dominant transportation source of air pollution, and it is a relatively inefficient means of transportation. What is needed is a better balance between the automobile and public mass transportation systems. While I am confident that the automobile will not be totally replaced by the bus or train, I feel strongly that we should strive toward replacing it for certain types of trips. It is to this end—a better balanced transportation system—that I feel the Commonwealth must be committed, even though the costs may be high.

Such a commitment necessitates the establishment of a General Transportation Fund, which could be used not only in capital acquisitions for public transportation systems, but also to support ancillary services or other transportation programs that could be shown to contribute to improved air quality and transportation service.

To support such a fund, there are several alternatives. The DSPCA's report suggests a graduated surcharge on vehicle registration. An additional gasoline tax is another possibility. An additional one cent per gallon tax would supply this fund with an estimated $22,000,000 annually. Another alternative is to earmark a certain amount of money from the General Fund. I feel that some combination of these would best support the State's needed commitment to the development of effective public transportation systems.

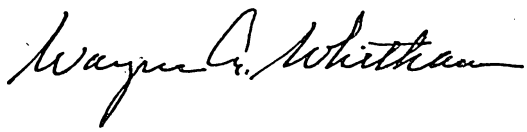
Carpooling is also an effective means of reducing the impact of automotive pollution, and it complements public transportation systems, particularly in low density suburban areas where transit service is difficult to provide. As the DSPCA's report points out, increasing the occupancy rates of automobiles by at least one person per car would have profound effects on pollution concentrations, congestion, and fuel consumption. Consequently, I think that it behooves the State to implement a carpool locator service that would be available to anyone desiring to use it. The Virginia Department of Highways has access to carpool locator programs and could implement such a service at a minimal expense to the Commonwealth. I support the DSPCA's recommendation concerning carpooling; I feel that it deserves your immediate consideration.

The relationship among land use, transportation systems, and pollution potential is increasingly a critical developmental consideration. I feel that the recommendation to create an interdisciplinary committee with the responsibility of defining State policy in these three functional areas is one of sound foresight. Unless we are able to deal with problems at their foundations, then we are merely coping with them. We are not actually analyzing or resolving the problems. This interdisciplinary committee, however, will have the capability to encompass the separate functional areas in a way that does not exist today. Consequently, their analyses will be able to specify policy alternatives which will provide the State with more clearly defined directions for future development—growth that is environmentally sound, organized, and accessible.

IV. CONCLUSION

The recommendations, as outlined above, provide the Commonwealth with an overall strategy for alleviating the impact of transportation source pollution on the quality of our environment. I trust that it will be the pleasure of the General Assembly to act favorably upon my recommendations.

Respectfully submitted,



AIR QUALITY AND MOBILITY

IN

VIRGINIA

PREPARED FOR
SECRETARY OF TRANSPORTATION
AND
PUBLIC SAFETY

BY
DIVISION OF STATE PLANNING AND COMMUNITY AFFAIRS
DECEMBER 1973

ABSTRACT

TITLE:	*Air Quality and Mobility in Virginia*
AUTHOR:	Larry E. Harrison Transportation Planner Transportation & Public Safety Section Division of State Planning & Community Affairs
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ABSTRACT:	This report contains an evaluation of the degree to which various transportation modes contribute to Virginia's air pollution problems, as well as a discussion of alternative transportation strategies which could reduce the levels of transportation source pollution. Recommended State actions are also contained in the report.

COMMONWEALTH OF VIRGINIA
OFFICE OF THE GOVERNOR

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December 10, 1973

The Honorable Wayne A. Whitham
Secretary of Transportation and
Public Safety
Office of the Governor
910 Capitol Street
Richmond, Virginia 23219

Dear Secretary Whitham:

I am pleased to submit to you our report, Air Quality and Mobility in Virginia. The report was prepared in accordance with your request for this agency's assistance in: (1) evaluating the degree to which various transportation modes contribute to Virginia's air pollution problems, and (2) recommending alternative strategies for reducing transportation source air pollution.

We are indebted to many federal, State and regional agencies for their cooperation and assistance in the conduct of our study work. These agencies, and other sources of information, have been identified in the report text, notes and bibliography.

It has been a pleasure assisting you in this matter and I hope that the report information and recommendations will be of value to you in preparing your initial report to the Governor and the General Assembly as required by House Joint Resolution No. 254.

With kindest regards, I am

Yours truly,

Charles A. Christophersen

CAC:pd

Enclosure

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I. INTRODUCTION

In recent years the problems of a polluted atmosphere have become increasingly prominent. Most Virginians, especially those residing in the Commonwealth's major metropolitan regions, are quite familiar with air pollution, having experienced much pollution-originated haze and pollution episodes of various degrees of severity. Pollution readings have become a fixed element of the daily weather reports. But this familiarity does not convey the complexity of the problem of air pollution, nor does it reflect the synergistic context of the problem. This report will attempt to describe the air quality problem in the Commonwealth of Virginia and will recommend an initial program for the improvement of air quality as well as mobility.

What is air pollution?

Generally, pollution of the environment occurs when a product is used, made, or discarded. Pollutants are the unwanted by-products of these actions. When a fuel is consumed, unless the process for converting the fuel into energy is highly efficient, pollutants are emitted into the air. The resulting pollution becomes a problem because it introduces a *harmful* alteration of the equilibrium of the natural environment. The degree to which the alteration is harmful depends on the interaction between two principal factors: the pollutant sources and the meteorological conditions of the area.

Pollutant sources are numerous. The State Air Pollution Control Board's publication, *Regulations for the Control and Abatement of Air Pollution,* provides a comprehensive listing of known stationary sources. Transportation, or mobile, sources are defined in that publication as, "Any vehicle, including, but not limited to, any motor vehicle, truck, or other land craft, air craft, locomotive, bus, or ship, rail vehicle, or water craft, which emits or may emit any air contaminant." [1] Since the focus of this report is upon transportation sources of pollution, the stationary sources will be omitted from further discussion except where applicable discussion is required.

The definition of transportation sources provided in the State Air Pollution Control Board's publication is comprehensive and directs attention to the vehicular component of the transportation system as the actual source of pollution. It should be understood, however, that any transportation system includes, in addition to the vehicle, a network or guideway over which the vehicle must move, a terminal or parking area at which the vehicle stays when not moving, and a control system which directs or controls the movement of the vehicles. Furthermore, these other transportation system components concomitantly contribute to the pollution of the air. For example, a network of streets with redlights at each intersection produces high levels of air pollution due to the resultant stop-and-go movement patterns. Thus, an evaluation of an area's pollution levels must consider all elements of the transportation system.

Meteorological conditions prevailing in the region may also contribute to excessive levels of pollutants. The atmosphere surrounding the earth is in a natural state of motion. In regions where the movement is strong both horizontally and vertically, air pollution is least likely to occur. In these regions, the strong movement has the effect of increasing the amount of air into which the pollutants are emitted, causing greater dilution. The pollutants will also be dispersed more effectively. On the other hand, the potential for air pollution is greatest in areas dominated by stagnant air masses and light winds. Under such atmospheric conditions, the upper air layer temperatures are higher than those in the lower air layers, thus creating an inversion which acts as a lid preventing the polluted air from rising and dispersing.

Furthermore, a daily cycle is created by the natural movement, heating, and cooling of air masses. During the day, the wind and sun combine to create unstable atmospheric conditions which tend to disperse pollutants, i.e., strong horizontal and vertical air motion is created due to the air near the earth's surface being warmer than the air in the upper atmospheric layers. At night, the opposite is generally true: the air cools less than the earth's surface, thus generating a stable condition which tends to accumulate pollutants. When this daily cycle is broken by a prolonged period of stability, air pollution becomes a severe problem.

It would seem, therefore, that the atmosphere has within it a natural process for dispersing pollutants. Why, then, do critical air pollution problems exist in major metropolitan areas?

Air Pollution as a Critical Problem

Environmental pollution of one kind or another has run concurrent with human existence on this earth. In the past, however, the range of pollutants as well as the quantities of pollutants were not as extensive as they are today. Several factors have been identified as contributors to the critical nature of today's air pollution problem. The following factors stand out as the three major ones.

Population Growth. A large population would normally create more pollutants than would a small one. Thus, our population growth has generated increased pollution levels. However, a more important consideration under this category is the increasing proportion of people living on a relatively small portion of the total available land area. In the Commonwealth, 64.8 percent of the people live in seven metropolitan areas; by 1990, this percentage will increase to 70.1. The result of this urbanization is an increasing burden on the air capacity surrounding these metropolitan areas. Unless this characteristic of growth is stablized to some degree, the quality of air could approach critical levels.

Expansion of Industry and Technology. As the Commonwealth's population increases, consumer demands also increase. And as industrial and technological capacities are expanded to meet these demands, a dependence upon the machine to perform tasks is created. To continue this process one step further, as the need for machines increases, the demand for fuels to operate the machine will also increase. The result is an increase in by-products from the use of the machine, i.e., pollutant emissions into the atmosphere. An example of this type of problem is the demand for a supersonic transport. Because of its characteristic high altitude flying, pollution emissions occur in a very thin and ecologically sensitive layer of the earth's atmosphere. The pollutants' effects could possibly decrease the ability of the outer layer of the atmosphere to reduce the impact of the sun's ultraviolet rays.

Dependence on the Automobile as the Primary Source of Transportation. The mobility provided by the automobile is probably the dominant factor contributing to a person's dependence on it for transportation. Mass production techniques have allowed automobiles to be built at a cost almost everyone can afford. The automobile is also a convenient mode of transportation, allowing a level of flexibility unequaled by any other existing transportation mode.

Road transportation has also been subsidized more than other modes of transportation. The emphasis placed on road construction has given the American people an extensive highway network and a degree of freedom to travel wherever and whenever they choose. Certainly, this emphasis on highway travel has not been totally bad for the country. However, other modes of transportation have suffered from this. For example, the eco-

nomic advantages of goods shipment by rail have been sacrificed to increased truck shipping. Effective forms of public mass transportation have been sacrificed to the use of the personal car, with its resultant congestion, pollution, and fuel and land consumption. Thus, although our mobility has increased as a result of our emphasis on highway transportation, as former Secretary of Transportation John Volpe has stated, ". . . a road can create more problems than it solves. . . ."

The above three factors have materialized somewhat simultaneously to create a situation in which the air that we breathe for our survival is being contaminated to the degree that this vital resource might be used up. That is, in certain areas the atmosphere could become so polluted that it would no longer be fit to breathe.

In the Commonwealth, it is difficult to believe that air pollution is a problem, especially on crisp fall days when the sky is crystal clear. Nonetheless, in at least three areas of the state ambient air quality has reached levels which are harmful to the health of certain people. The problem does affect us, as citizens of the Commonwealth, and positive action must be taken to alleviate pollution problems where they exist and to maintain air quality where the problem has yet to occur.

The development of a program to maintain a quality environment must be approached from an overall systems viewpoint because ambient air quality is a function of the interaction of many sources of pollution and meteorological conditions. Such a program must be able to answer several basic questions: how clean should the air be? at what cost, for what purpose, and at what future time? With a better understanding of the problems involved, sensible alternatives can be proposed.

II. NATIONAL AMBIENT AIR QUALITY STANDARDS

The Federal government has assumed the initiative in combating degradations of the environment. Primarily, federal regulations are aimed at halting unrestrained development until an analysis can be made of the impact of such development on the surrounding environment.

In 1969, Congress passed the National Environmental Policy Act. The primary purpose of this legislation was to insure that the environmental effects of all major proposed federal legislation, plans, and programs be considered prior to implementation. The Council on Environmental Quality was created to insure that the purpose of the Act was carried out.

With this growing concern for the environment, Congress also began a re-evaluation of air pollution legislation. The outcome was the Clean Air Act of 1970. This act required the Administrator of the Environmental Protection Agency to establish national ambient air quality standards. The Administrator was also required to set standards of performance for new stationary sources and for motor vehicles.

Accordingly, National Ambient Air Quality Standards were promulgated for six atmospheric pollutants: carbon monoxide, hydrocarbons, nitrogen dioxide, photochemical oxidants, particulate matter, and sulfur dioxide (see Table I). The primary standards are based on public health considerations and must be met by mid-1975. Secondary standards are aimed at protecting the public welfare and should be achieved by the earliest date commensurate with technological and economic feasibility.

Performance standards for 1975 model motor vehicles require a 90 percent reduction from the 1970 level of emissions of carbon monoxide and hydrocarbons.

TABLE I

NATIONAL AMBIENT AIR QUALITY STANDARDS
(CONCENTRATION NOT TO BE EXCEEDED MORE THAN ONCE PER YEAR)

Pollutant	Averaging Time	Primary Standard*	
Photochemical Oxidants	1 hour	160 ug/m^3 (0.08 ppm)	Same as primary standard
Hydrocarbons (methane-free)	3 hours (6-9 a.m.)	160 ug/m^3 (0.24 ppm methane equivalents)	Same as primary standard
Nitrogen dioxide	Annual (arithmetic average)	100 ug/m^3 (0.05 ppm)	Same as primary standard
Carbon monoxide	8 hours	10 mg/m^3 (9 ppm)	Same as primary standard
	1 hour	40 mg/m^3 (35 ppm)	
Sulfur dioxide	Annual (arithmetic average)	80 ug/m^3 (0.03 ppm)	60 ug/m^3 (0.02 ppm)
	24 hours	365 ug/m^3	260 ug/m^3 (0.10 ppm)
	3 hours		1300 ug/m^3 (0.05 ppm)
Particulate Matter	Annual (geometric-mean)	75 ug/m^3	60 ug/m^3
	24 hours	260 ug/m^3	150 ug/m^3

*Equivalent "ppm" concentrations are based upon a reference temperature of 25°C and a reference pressure of 760 mm of mercury.

For nitrogen dioxide, a 90 percent reduction is required from the 1971 level of emissions. However, a one year extension has been granted by the Environmental Protection Agency, and the above reductions will apply to the 1976 model motor vehicles.

These federal actions have, therefore, inaugurated a legal involvement of the people with their environment. Certain levels of air quality must be maintained, or actions must be initiated to reduce excessive pollutant levels to within the limits established by law. The burden of establishing and implementing control strategies for meeting the ambient air quality standards rests with the states. The Commonwealth's pollution problems must, therefore, be analyzed, and the most appropriate means for resolving these problems must be found. Consequently, programs must be developed to improve air quality and, where necessary, legislation enacted to enforce these programs.

III. TRANSPORTATION SOURCE POLLUTANTS AND THEIR CHARACTERISTICS

Pollutants have been described as the unwanted by-products of certain actions. Particularly in the machines that move us from place to place, efficiency is not maximum and the result is incomplete combustion which produces undesirable emissions (when they are cumulatively produced in quantities not capable of being naturally dissipated without harmful effects). Table II shows the primary pollutants produced by transportation sources: carbon monoxide, hydrocarbons, and oxides of nitrogen. Particulates and oxides of sulfur are also emitted, but in negligible quantities compared with the emissions from stationary sources. The secondary pollutants, photochemical oxidants, are produced from the chemical reactions between oxides of nitrogen and hydrocarbons in the presence of ultraviolet sunrays.

Pollution from automobiles is the dominant contributor of transportation pollution. As Table II points out, they account for 65 percent of the carbon monoxide, 46 percent of the hydrocarbons, and 37 percent of the nitrogen oxides produced. This means that the major cause of transportation pollution is the automobile or, more appropriately, the increasing use of the automobile as the primary source of transportation.

For the Commonwealth, this same trend of transportation-originated pollution prevails. In fact, the State percentages show that the Commonwealth has a greater portion of carbon monoxide, hydrocarbons, and oxides of nitrogen pollutants than does the national average (see Table III). Furthermore, automobile emissions far surpass emissions attributed to all other transportation sources.

ESTIMATED PERCENTAGES OF NATIONWIDE
ATMOSPHERIC EMISSIONS
1969

Sources	Emission Components (percent)				
	SO_x	Part	CO	HC	NO_x
Transportation	3.3	2.3	73.7	52.9	47.1
o Automobile	0.9)	1.1)	(64.7)	(45.7)	(36.6)
Fuel Combustion in stationary sources	73.0	20.5	1.2	2.4	42.0
Industrial processes	22.5	40.8	7.9	14.7	0.8
Solid waste disposal	0.6	4.0	5.2	5.3	1.7
Miscellaneous	0.6	32.4	12.0	24.7	8.4
Totals	100.0	100.0	100.0	100.0	100.0

Note: SO_x expressed as SO_2 and NO_x expressed as NO_2

Source: Environmental Quality: The Second Annual Report of the Council on Environmental Quality, August 1971.

TABLE III

ESTIMATED PERCENTAGES OF VIRGINIA
ATMOSPHERIC EMISSIONS
1970

Sources	Emission Components (percent)				
	SO_x	Part	CO	HC	NO_x
Transportation	3.7	2.0	92.5	80.9	50.2
o Automobile	(1.0)	(0.7)	(84.8)	(45.9)	(29.7)
Fuel Combustion	85.6	66.0	5.7	8.8	47.5
Industrial Processes	10.5	31.0	0.3	1.0	1.8
Solid Waste Disposal	0.2	1.0	1.5	2.8	0.5
Evaporative Losses				6.5	
Totals	100.0	100.0	100.0	100.0	100.0

Source: Air Quality Implementation Plan, State Air Pollution Control Board, 1970.

Carbon Monoxide (CO)

Carbon monoxide is perhaps the best known pollutant. It is a colorless, odorless, tasteless gas produced by the incomplete combustion of carbonaceous materials. Its primary characteristic as a pollutant is its poisonous effect at high concentrations. Carbon monoxide is absorbed through the lungs and reacts primarily with the hemoglobin of red blood cells. This results in the replacement of oxygen by CO in the blood to form carboxyhemoglobin. This reduces the oxygen carrying capacity of the blood and, at high blood content levels, kills by asphyxiation.

The effect of carbon monoxide poisoning depends upon the percentage of carboxyhemoglobin in the blood, which is related to the concentration of carbon monoxide in the air, the length of exposure, and the degree of activity of the individual.

Hydrocarbons (HC)

Hydrocarbons represent the major class of reactive organic matter in the atmosphere which is responsible for photochemical smog. Some hydrocarbons undergo chemical reactions with highly reactive matter generated by the action of sunlight on other components in the atmosphere (particularly NO_2) and produce photochemical smog. Other hydrocarbons contribute to atmospheric aerosols which reduce visibility.

The actual health effects of hydrocarbons occur only at concentrations so high that oxygen intake is impeded. The principal concern with hydrocarbons is the cause-effect relationship between their concentration and oxidant concentrations. Although the resultant oxidant concentrations occur two to four hours after the hydrocarbons are emitted into the atmosphere (i.e., after the photochemical reactions among hydrocarbons, sunlight and nitrous oxides have had a chance to occur), a scientific relationship has been established between hydrocarbon emissions and oxidants produced in the air. This relationship forms the basis of the photochemical oxidant standard presented in Table I. The primary components of photochemical smog (ozone, aldehydes and peroxyacyl nitrates) cause most of the harmful effects of hydrocarbon air pollution.

Nitrogen Oxides (NO_x)

As discussed above, the presence of nitrogen oxides in the ambient air is essential to photo-oxidation of hydrocarbons and to the development of photochemical smog. Of the various oxides of nitrogen, the most significant as air pollutants are nitric oxide (NO) and nitrogen dioxide (NO_2). In the internal combustion engine, nitrogen and oxygen in the combustion air are subjected to temperatures in excess of 2,000°F, resulting in the formation of nitric oxide. A small fraction of the nitric oxide is subsequently converted to nitrogen dioxide.

NO produces no harmful consequences at ambient concentrations measured thus far. Its toxic potential lies in its tendency to oxidize into nitrogen dioxide. NO_2 has been shown to produce increased incidence of respiratory diseases at high ambient air concentrations. It also causes damage to certain fabrics and accelerates the corrosion of certain metals.

The effects of the resultant photochemical smog have already been described in the section on hydrocarbons.

Photochemical Oxidants

In the preceding discussions, photochemical oxidants have essentially been explained. These pollutants are secondary pollutants since they are

created by the action of sunlight in a series of complex reactions between hydrocarbons and oxides of nitrogen. Because the formation of these pollutants depends on specific atmospheric conditions, peak oxidant concentrations tend to occur during late morning and early afternoon hours. Unlike the intensity of carbon monoxide effects near the source, the impact of photochemical oxidants is potentially regional. Also, depending on the air movement patterns and the effects of added emissions, concentrations of oxidants can be high in areas removed from the actual source of the primary pollutants which cause oxidants.

Photochemical oxidants irritate the mucous membranes, especially the nose and throat. They can also reduce resistance to respiratory infection and aggravate respiratory diseases. Ozone, which is the main constituent of photochemical oxidants, has its main effect on the respiratory system. Vegetation and certain materials are also damaged by the reactions of these pollutants.

Lead

Lead is used as an additive to certain fuels in order to provide the antiknock characteristics needed for high compression engines. It can accumulate in persons and is toxic under conditions of prolonged and excessive exposure. High concentrations of lead in the bloodstream can interfere with the formation of hemoglobin in the red blood cells; it also affects certain liver and kidney functions.

The use of leaded fuels also produces harmful engine deposits that not only increase engine maintenance costs but may also reduce the life of the engine. Additionally, lead in the automobile's exhaust can affect the utility of some of the antipollution devices which are being proposed to meet pollution emission standards.

Other Pollutants

There are a number of other pollutants, especially particulates and sulfur oxides, emitted from transportation sources. The relative impact of these pollutants, as indicated by both the national and state data in Tables II and III, is quite small compared with nontransportation sources. Therefore, this report will only consider the five pollutants described in the preceding section.

IV. BASIC RELATIONSHIPS BETWEEN AIR POLLUTION AND TRANSPORTATION

The growth rate of transportation sources of pollution is consistent with the increased use of the automobile as the dominant mode of transportation. There is also a similar association with increases in affluence, which affords to a major portion of our population the opportunity to own and use the automobile as a personal means of transportation. In Table IV, the growth in emissions from transportation sources for the period 1940-1970 is shown. For particular modes of transportation, the trends of growth have shown similar increases, but the automobile dominates in quantities of growth and in overall growth rates (see Table V, Carbon Monoxide Emissions).

One favorable observation noted in this historical overview is the leveling off or even slight reduction in vehicle emissions in recent years. This can be attributed to the imposition of federal regulations on vehicle emissions, beginning in 1968. Nevertheless, the dominance of the automobile in creating pollution prevails, and its impact must be alleviated in

order to clean up the polluted air in and around the metropolitan areas of the State and nation.

Likewise, other modes of transportation possess characteristics which contribute to air pollution problems and which might be altered somewhat to reduce the impact of emissions on air quality. A brief comparison of these modal characteristics follows.

TABLE IV

EMISSIONS FROM TRANSPORTATION SOURCES
1940-1970
(10^6 Tons/Year)

Source Category	1940	1950	1960	1968	1969	
CO	34.9	55.4	83.5	113.0	112.0	
HC	7.5	11.8	18.0	20.2	19.8	
NO_x	3.2	5.2	8.0	10.6	11.2	11.7

TABLE V

CARBON MONOXIDE EMISSIONS FROM TRANSPORTATION SOURCES, 1940-1970
(10^6 Tons/Year)

Source Category	1940	1950	1960	1968	1969	1970
Gasoline vehicles	32.1	48.1	73.9	98.4	96.8	95.8
Diesel vehicles	Neg[a]	0.1	0.4	1.0	1.0	0.8
Railroads	Neg	0.1	0.1	0.1	0.1	0.1
Vessels	Neg	Neg	Neg	1.7	1.7	1.7
Aircraft	Neg	1.7	2.1	2.9	2.9	3.0
Other nonhighway use	2.7	5.5	7.0	8.6	9.0	9.5
Total	34.8	55.5	83.5	113.0	112.0	111.0

[a]Negligible (less than 0.05×10^6 tons/year).
Source: Nationwide Emission Trends, 1940-1970

Emissions from aircraft occur as long as the engines are running, but most affect the ambient air quality during their landing-take off (LTO) cycle. This LTO cycle includes taxi, take-off, climb-out, approach, and landing. The impact of this cycle is dependent upon the amount of time spent in each portion of the cycle, although heaviest emissions occur during taxiing and idling when the aircraft engine(s) is operated at greatly reduced power. Thus, at congested metropolitan airports the potential for high levels of pollution concentration is great because of the delays encountered in landing and taking-off operations. The EPA has suggested that the Federal Aviation Administration modify ground operating procedures to reduce the number of engines used and the time in taxi and idle modes of operation. Such a policy is presently under examination.

Emissions from railroad locomotives are relatively less than those from most other transportation sources of pollution. This is due basically to the efficiency and simplicity of the diesel internal combustion engine used to power most locomotives in this country. The physical location of railroad tracks also influences the impact of this mode on the air quality of an area—railroads are usually separated from highway networks, thus allowing the emissions from locomotives to be more readily dispersed than does the additive effect of motor vehicle usage over roadways of various types (comparisons of actual emission rates will be made in a subsequent section).

Steamships and motor ships also produce pollutants, but the impact is dependent upon the propulsion system used. Motor ships have internal combustion engines operated on the diesel cycle; thus, their emissions are similar to locomotive emissions. Steamships are any waterborne vessels powered by steam turbines driven by an external combustion engine. With either propulsion system, the problem associated with emissions arises when movement occurs near ports or when ships are in port but still need to operate engines (at a reduced, and less efficient rate) to provide power for the ship's lighting, heating, refrigeration, etc. In the Commonwealth, this kind of pollution exists only in the Tidewater area.

As stated before, the automobile is the most dominant polluter of air quality. For the year 1970, the State Air Pollution Control Board estimated that the gasoline-powered vehicle contributed at least 85 percent of all carbon monoxide emissions, 46 percent of all hydrocarbon emissions, and 30 percent of all oxides of nitrogen emissions. This is compared to 7.7 percent of CO emissions, 35 percent of HC emissions, and 20.5 percent of NO_x emissions from all other transportation sources, combined. Of the foregoing 35 percent HC emissions, a large portion (approximately 26 percent) has been attributed to evaporative emissions which originate mainly in the transfer and storage of gasoline products. Thus, the overall contribution of the automobile to hydrocarbon pollution increases from 46 to 72 percent.

Table VI shows the estimated breakdown of tons of pollutants per year contributed by various transportation sources in Virginia. The data in this table verifies the dominance of the automobile (or gasoline-powered vehicle) as a polluter of the air. However, diesel powered vehicles and aircraft also contribute significant amounts of the three main pollutants. This suggests the need for at least a three-fold program for pollution reduction in the State.

In the following sections, discussions will focus on several factors which cause the automobile to be the major source of transportation pollution.

Control Technology. By law, the Administrator of the Environmental

Protection Agency (EPA) was required to set standards for reducing the total emission levels on new motor vehicles. These emission standards apply to carbon monoxide, hydrocarbons, and oxides of nitrogen pollutants. Table VII indicates the effect of these standards on reducing the overall rate of pollutant emissions from highway-use vehicles. As the table shows, the impact of these standards will greatly reduce the total amount of pollutants being emitted from automobiles, allowing ambient air quality levels to be either achieved or maintained (in most areas where pollution is not now a serious problem).

TABLE VI

ESTIMATED TRANSPORTATION EMISSIONS
IN VIRGINIA
1970

	Emission Components (tons/year)				
Sources	SO_x	Part	CO	HC	NO_x
Road Vehicles					
o Gasoline	5,022	90,089	2,322,937	287,919.5	201,142.4
o Diesel	11,322.6	6,119	91,224.5	16,767.1	130,825.5
o Evaporative				84,497	
Railroads	606	233	653	466	699
Vessels		2,647	1,583	1,237	1,781
Airplanes	2,399	7,616	117,872	37,637	5,060
Gas Storage and Handling				76,624	
Totals	19,349.6	25,623.9	2,534,269.5	507,147.6	339,507.9

Source: Air Quality Implementation Plan, State Air Pollution Control Board, 1970.

TABLE VII

EMISSION FACTORS FOR GASOLINE POWERED MOTOR VEHICLES
(Average speed: 19.6 mph; 45 mph)

Emissions	1965 g/mi	1970 g/mi	1971 g/mi	1972 g/mi	1973 g/mi	1974 g/mi	1975 g/mi
Carbon Monoxide							
19.6 mph	87	36	34	19	19	19	1.8
45.0 mph	44	18	17	10	10	10	0.9
Hydrocarbons							
Evaporation							
Crancase	3.8	3.0	0.5	0.2	0.2	0.2	0.2
Exhausts							
19.6 mph	8.8	3.6	2.9	2.7	2.7	2.7	0.23
45.0 mph	5.1	2.1	1.7	1.6	1.6	1.6	0.13
Nitrogen oxides (NO_x as NO_2)							
19.6 mph	3.6	5.1	4.8	4.8	2.3	2.3	2.3
45.0 mph	4.7	6.6	6.2	6.2	3.0	3.0	3.0

Source: U.S. Environmental Protection Agency, Compilation of Air Pollution Emission Factors, 2nd Edition, April, 1973.

There are, however, several problems involved in the application of these standards. First, in large metropolitan areas, the effects of the standards will not be truly felt until controlled vehicles comprise a vast majority of the vehicle population. It has been suggested that this will not occur until the mid-1980's. In the meantime, relatively high-polluting vehicles will make up the majority of the vehicle population, requiring additional control strategies to be implemented. Also, in April of 1973, the Administrator of EPA decided that problems associated with implementing the emission standards were of sufficient complexity to warrant a one year extension to the mid-1975 deadline. This action obviously further complicates the previous problem.

However, the interim period standards do have some effect on vehicle emissions, and, with the one year extension, additional studies can be made to determine alternative emission control devices and/or to reevaluate the basis for existing emission standards (there has been much scientific disagreement over the required stringency of emissions standards).

Influence of Mode of Travel. The mode of travel also affects the level of emissions in an area. In Table VIII, based on 1972 data, several modal emission factors are compared. The *actual* emissions of these other modes of transport are much less than the emissions of the automobile. In the same manner, the *potential* of the other modes to pollute the air is even less because of the large number of passengers which may use a mass transportation vehicle. A simple example will serve to explain this potential: the average occupancy of a commuting vehicle (automobile) is 1.4 persons, while a bus can transport 45-50 people at once (assuming full capacity during peak hours); thus the bus can potentially reduce the number of commuting vehicles by 34. The impact of this potential may be quantified by comparing the emission factors of the diesel bus with those of the automobile multiplied by 34. The result is staggering!

TABLE VIII

EXHAUST EMISSION FACTORS FOR VARIOUS TRAVEL MODES
GRAM PER VEHICLE MILE
1972

Pollutant	Auto[a]	Diesel Bus[b]	Diesel Locomotive[b]	Electric Rail[c] Power Source Coal	Gas	Oil
CO	85.00	20.41	6.35	.19	negl.	.01
HC	9.50	3.36	4.54	.37	negl.	1.09
NO_x	6.17	33.57	6.80	37.19	.05	35.38
SO_x	.18	2.45	5.90	13.97	.02	27.21
Particulates	.30	1.18	2.27	29.30	.73	3.44

[a]1972 emission factors, based on 25 mph and cold start operation.

[b]Based on fuel consumption estimate of 5 mi/gallon.

[c]Expressed as grams per train mile where one train is comprised of four cars, in married pairs, i.e., two power units per train.

Source: Salvatore J. Bellomo, Providing for Air Quality and Urban Mobility, a report prepared for presentation at Fifth Annual Summer Meeting, Highway Research Board, July - August 1972.

As older vehicles are replaced by newer, controlled vehicles, the variation between the emissions of the automobile and the mass transportation modes will decrease. This should improve the overall air quality, unless the number of automobiles on the road continues to grow in unprecedented fashion. Thus, assuming that automobile usage does continue to grow and that mass transit usage declines or remains relatively stable, automobile pollution *potential* will continue to increase.

Propulsion efficiency is also a consideration in comparing modes of travel. In a study conducted to determine energy research needs, the efficiency of several modes of transportation were compared. Table IX, which assumes an occupancy rate of 50 percent, details the results of this analysis. The automobile again is shown to be an inefficient mode of transportation. Assuming that the occupancy rate of the automobile is increased to 4, the efficiency would increase to 64 passenger-miles per gallon. Likewise, decreasing the occupancy rates of the public transportation modes reduces the efficiency levels of these modes (this would represent existing situations in which buses travel city streets with only four or five passengers). Therefore, the propulsion efficiency of the automobile, even with four passengers, is low compared to other modes of public transportation. However, unless the mass transit systems operate with at least 50 percent occupancy, their efficiencies are also minimal. Consequently, strategies that increase the occupancy rates of all modes of transportation would greatly increase their efficiencies.

TABLE IX

PROPULSION EFFICIENCY

	Passenger miles/gallon
Automobile (sedan, two people)	32
Conventional trains	80-130
Electric Metroliner	50
Two-deck suburban train	200
Ten-car subway train	75
Buses	100-125
Jet planes	22

Source: Energy Research Needs. Resources of the Future, October, 1971.

Influence of Vehicular Speed. Data on the influence of speed is available only for the automobile. Table VII shows the amount of pollutants emitted at two levels of speed, 19.6 miles per hour and 45 miles per hour. The former represents typical urban, congested speeds, while the latter represents free-flow vehicular movement. For both carbon monoxide and hydrocarbons, emission levels decrease as the *average* vehicular speed increases. For oxides of nitrogen, however, a different relationship exists—as the average speed increases so does the NO_x emissions. These divergent results are due to the influence of the fuel/air ratio supplied for combustion in the engine, as well as the combustion temperature of the engine. When the engine operation is at a low level, the fuel/air ratio is richer. This leads to incomplete combustion of the fuel and large amounts of CO and HC emissions. As the engine warms up and average speeds increase, the engine's operation reaches its most efficient levels with leaner fuel/air ratios resulting in greater amounts of oxygen available for interaction with nitrogen.

Similar to this phenomenon is the concept of hot and cold starts. It has been suggested that most pollutants are emitted (approximately 90 percent of CO and 80 percent of HC for post-1975 automobiles [2]) during the first few minutes of vehicle operation. The foregoing should be considered in the selection of appropriate strategies for reducing air pollution, since some of the alternative concepts being mentioned today (e.g., fringe parking lots and other types of connections with a mass transportation system) may produce basically the same amounts of pollution as would inbound commutation.

Influence of Operational Characteristics. The operating cycle of the automobile is fundamental to the amount of pollution produced and the concentration of the pollutants. Of the four basic operation cycles, idling produces the greatest amounts of carbon monoxide and hydrocarbons. In situations where automobiles go through this cycle every block with much time spent in idling, concentrations of pollutants develop at or near the areas where idling and acceleration occur. The significance of this characteristic relates to the dominance of congested travel, especially during peak hours, in most metropolitan areas. Efforts to improve the flow of vehicles should result in a reduction of the impact of the operating cycle, but only if the number of vehicle operations does not increase significantly. If an increased number of vehicle operations occurs, the resultant increase in emissions from these vehicles may cancel out any reductions due to the increased free-flow. The ultimate result could be even more pollution than would have existed without any traffic flow improvements.

Associated Factors Contributing to Air Pollution. The degree of air pollution concentration depends upon several other conditions which are related to transportation sources only in a secondary way, if at all. Some of these factors, such as the meteorology and the topography of the subject area, have been discussed previously. This section will describe certain conditions which contribute to the accumulation of pollution concentrations.

Land use patterns are undoubtedly influential in creating situations which encourage the use of the private automobile as the primary source of travel (for all trip purposes). Yet the automobile, with an average occupancy rate of 1.4 persons, is a very inefficient mode of transportation, consuming much fuel and polluting the air to unhealthy levels in some cases. Suburban sprawl, with its separation of land-use activities and lower development densities, creates a situation that does not support the economic operation of mass transportation systems. As a result, the auto-

mobile has become the principal means of transportation between the various activity centers. The organization of land uses has been disjointed and dependent upon economic considerations instead of being planned and structured for the convenient and effective movement of people.

The result of this adopted pattern has been an increasing amount of vehicle miles traveled. More important, however, is the corresponding increase in the number of trips made by automobile. Both of these situations have been influential in the creation of harmful levels of air pollution.

Somewhat closely associated with the above considerations is a lack of concern for an integrated, multi-modal transportation system. Only recently has the federal government recognized the need to consider transportation as a system, composed of varying modes whose characteristics suggest an ability to perform certain transport functions efficiently. Obviously, in most cases railroads move freight and people much more efficiently over long distances than do any other modes of ground transportation. However, other factors must also be considered before modal choices are made. Only recently have we begun to place emphasis upon the various modal characteristics in an attempt to establish a balanced transportation system and to recognize people's need for accessibility to many different kinds of activities.

V. TRANSPORTATION-ORIENTED AIR POLLUTION PROBLEMS IN VIRGINIA

By and large, the critical air pollution problems in the Commonwealth are in the major metropolitan areas. These areas contain large population concentrations, and, therefore, the pollution levels are more likely to reach or exceed national standards. Nevertheless, air quality must be maintained throughout the State. Thus, efforts to explore and encourage alternative transportation systems to reduce air pollution should be oriented toward an overall improvement in air quality. At the same time, it is in the metropolitan areas that stricter strategies will have to be developed and implemented. Presently, however, only the Northern Virginia area is required by EPA to implement transportation control strategies.

The severity of the pollution problem is a function of (1) the size of area experiencing the problem, (2) the number of days per year that the various established standards are exceeded, (3) the number of pollutants contributing to the problem, and (4) the number of sources. The following discussion will focus on the seven Air Quality Control Regions (AQCR) of the Commonwealth and the three main transportation-originated pollutants: carbon monoxide, hydrocarbons, and oxides of nitrogen. The *State Air Quality Implementation Plan* and the quarterly publication, *Virginia Air,* are the primary sources of information for the following analysis.

In Table X, each area's contribution to total state transportation pollution is depicted. AQCR's I, III, and IV appear to contribute relatively little to overall statewide pollution. AQCR's II and V contribute a somewhat larger proportion while AQCR's VI and VII appear to contribute substantial amounts of pollutants per year. Together, it is estimated that AQCR's II, V, VI, and VII contribute 71.9 percent of all the State's CO pollution, 70.3 percent of all HC pollution, and 62.2 percent of all NO_x pollution. These four regions include most of the metropolitan areas of the State, and it may be assumed that the metropolitan areas account for a significant proportion of the respective regional totals (however, no data is available to substantiate this assumption).

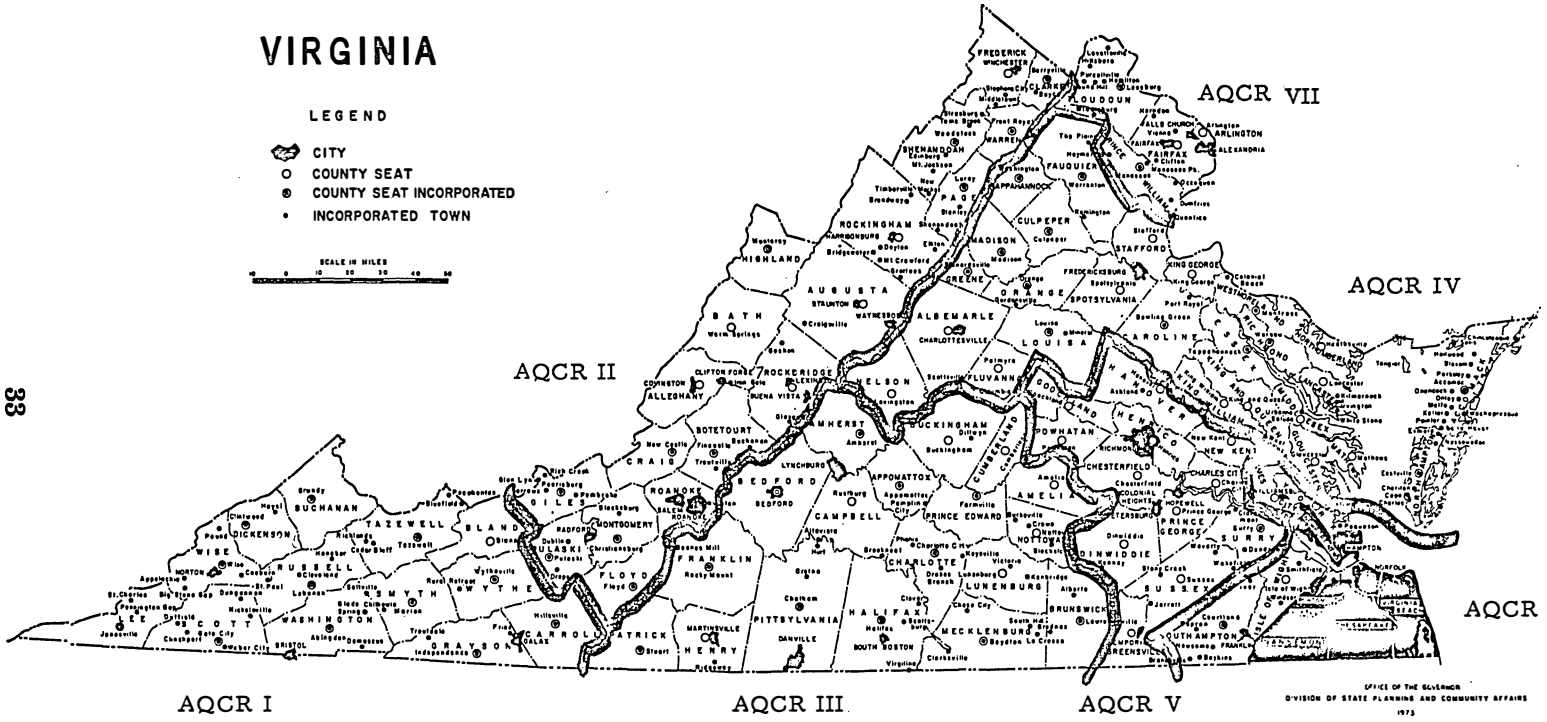


Figure 1. Air Quality Control Regions

TABLE X

AREA CONTRIBUTION TO TOTAL STATE TRANSPORTATION POLLUTION

Air Quality Regions	Pollutants (Percentages) CO	HC	NO_x
I	5.9	7.2	5.5
II	13.7	13.4	21.6
III	11.1	11.1	15.4
IV	11.4	11.3	17.0
V	14.6	14.2	11.5
VI	23.5	20.3	17.5
VII	20.1	22.4	11.6
Totals*	100.3	99.9	100.1

* Do not total 100.0 due to the rounding procedure used.

Source: Air Quality Implementation Plan, State Air Pollution Control Board, 1970.

The percentages of transportation pollutants compared with the overall pollutant estimates for each AQCR are shown in Table XI. The dominance of transportation source pollutants is quite evident, except in AQCR I where nontransportation sources are mainly responsible for the air pollution. The estimates of gasoline engine pollution substantiate prior assumptions and statements about the dominance of the automobile in the emission of air pollutants.

In Virginia, travel by automobile is the primary means of transportation. Consequently, the high percentages of pollutants originating from the automobile is expected. However, in specific regions, other modal emissions could contribute potentially high levels of pollutants. For example, emissions from steamships or motor ships are factors in the Tidewater region where Virginia Port Authority facilities and military bases attract a large number of shipping operations. At the present, however, these activities only account for approximately one percent of the total CO, HC, and NO_x emissions for the area.

Aircraft emissions are significant in the Northern Virginia, Richmond, and Tidewater regions. Dulles International and Washington National Airports are very active facilities in the Northern Virginia area. Together they handled approximately 504,000 aircraft operations in 1970, contributing 10.7 percent of the CO emissions and 18.1 percent of the HC emissions in AQCR VII. In the Tidewater region, aircraft emissions were also significant—10.3 percent of the CO emissions and 12.3 percent of the HC emissions. These latter percentages are high because of the existence of two commercial airports in the region plus extensive aviation activity at several military airfields. In the Richmond region, aircraft emissions accounted for 1.1 percent of HC emissions and 0.3 percent of CO emissions.

TABLE XI

TRANSPORTATION POLLUTION AS A PROPORTION
OF TOTAL REGION POLLUTION
(STATE AVERAGE ALSO GIVEN)

Air Quality Regions	Pollutants (Percentages) CO	HC	NO_x
State Totals	92.5 (84.8)	80.9 (45.9)	50.2 (29.7)
I	56.7 (55.5)	50.4 (22.3)	18.8 (13.8)
II	91.4 (84.1)	70.1 (39.5)	65.3 (29.5)
III	93.9 (88.1)	81.5 (45.0)	84.2 (44.2)
IV	96.9 (90.0)	89.4 (50.2)	85.6 (41.3)
V	96.7 (93.8)	86.0 (56.9)	51.5 (37.4)
VI	97.9 (85.9)	89.6 (54.9)	31.1 (21.4)
VII	99.1 (87.6)	90.7 (44.4)	56.7 (43.0)

( ) indicates percentage attributed to gasoline engine.

Source: Air Quality Implementation Plan, State Air Pollution Control Board, 1970.

The measurement of the air quality in the seven AQCR's represents a recent State effort. The State Air Pollution Control Board is responsible for monitoring air quality, and this agency has a full-time staff involved in this activity. Measurements of air quality must be evaluated with respect to the National Ambient Air Quality Standards. Monitoring sights have been located throughout the State, and the most recent data collected are being used in this report.

During 1972, AQCR's V, VI, and VII had one-hour readings exceeding the photochemical oxidant standard. In Richmond, this occurred during 80 hourly readings. In Northern Virginia, the one-hour standard was exceeded 61 times. In the Tidewater region, the standard was exceeded three times. For Richmond, Northern Virginia, and the Tidewater regions, the maximum oxidant readings during 1972 were 0.145 ppm, 0.180 ppm, and 0.170 ppm, respectively. The standard for photochemical oxidants is 0.08 ppm.

For carbon monoxide, none of the AQCR's recorded one-hour readings in excess of the standard; however, the eight-hour standard (9 ppm) was exceeded in all three areas: in Richmond twice (maximum reading 9.6 ppm), in the Tidewater region 15 times (15.1 ppm), and in Northern Virginia 50 times (11.6 ppm).

Data for 1973 were available for only the first two quarters of the year. Nevertheless, during that six month period, the oxidant standard was exceeded 48 times in Richmond (maximum reading 0.125 ppm), eight times in the Tidewater region (0.150 ppm), and 232 times in Northern Virginia (0.175 ppm). In Richmond and Northern Virginia, the one-hour standard for carbon monoxide was exceeded once (44 ppm) and twice (41.2 ppm), respectively. The eight-hour standard was exceeded 47 times in the Tidewater area (14.2 ppm) and 53 times in Northern Virginia (16.7 ppm).

The data presented above indicate that Richmond, Northern Virginia and the Tidewater regions are the critical air pollution problem areas in the State. In Northern Virginia, plans and programs have already been developed as a part of the National Capital Interstate Air Quality Region's transportation control strategy. These programs are aimed at reducing emissions to levels at which national air quality standards can be met by 1977. In both the Richmond and Tidewater regions, no transportation control strategies are required yet; however, from the data presented, these areas will almost certainly have to initiate some form of transportation controls unless it can otherwise be shown through the emissions control program and stationary source controls that the air quality standards will be met by 1975.

No other areas of the State have exceeded air quality standards. Consequently, air pollution control strategies should be considered for the above three areas of the State. However, other less restrictive programs should also be considered for implementation throughout the State in order to maintain or improve existing air quality.

VI. ALTERNATIVE STRATEGIES FOR ACHIEVING AIR QUALITY

Next to be discussed is the analysis and evaluation of alternative strategies which would impact the air quality of the Commonwealth, and the selection of the most applicable alternative(s) for reducing the amount of pollution emitted into the ambient air from transportation sources.

Vehicle-oriented Strategies. The primary focus of the federal govern-

ment has been toward cleaning up the motor vehicle's propensity to pollute the air. Under the *Federal New Car Emissions Program,* all cars produced and marketed since 1968 have had certain emission controls, which have become increasingly stringent and will culminate in the 1976 model year. The impact of these controls on emission levels will be significant, reducing the pollution of the automobile by 90 percent for hydrocarbons, carbon monoxide, and oxides of nitrogen. A problem exists, however, in the attrition rate of pre-1976 vehicles in use. These automobiles are not controlled to the 1976 emission levels, and it will be approximately 10 years, or into the 1980's, before the full effect of this program is realized.

Consequently, in the metropolitan regions where there are large population and automobile concentrations, the emissions program may not provide sufficient emission reductions to meet 1975 pollution requirements. Other alternatives, which could supplement the federal program, insuring its effectiveness in operation and extending its concept to other classes of vehicles, include periodic vehicle inspection/maintenance, retrofitting of vehicles, use of alternative fuel systems for certain groups of vehicles, and control of vehicle-oriented evaporative losses.

Pollutant emissions from operating vehicles can be reduced by insuring that engines and emission control devices are maintained in good operating condition. These reductions can be assured through periodic inspections of operating vehicles and the repair of vehicles that fail to meet inspection standards. The degree of emission reduction obtained will depend on the frequency of inspection and the particular inspection standards used, but it has been estimated that emissions from pre-1972 automobiles can be reduced by 15 to 30 percent through proper maintenance and adjustment. Post-1972 vehicles would also benefit from an inspection/maintenance program since their antipollution control equipment may break down and, thus, increase their pollution emissions.

The following test procedures are available: the idle emissions test, the loaded emissions test, and adjustment and maintenance. The idle emissions test is performed by operating the vehicle at idle engine speed and analyzing a sample of the exhaust. If the vehicle fails to meet established emission limits, it is then required to receive corrective maintenance. Expected reductions from this type of inspection procedure range from 7-11 percent for hydrocarbon emissions and 3-10 percent for carbon monoxide emissions. The loaded emissions test requires that the vehicle be operated on a dynamometer which is programmed to simulate actual driving conditions. During each of the operating conditions, the emissions are evaluated. Failure to comply with established standards requires the vehicle to be repaired. Expected reductions from the loaded emissions test range from 8-15 percent for hydrocarbon emissions and 4-12 percent for carbon monoxide emissions. The adjustment and maintenance program provides for periodic repair and adjustment of vehicles to prescribed specifications without a prior emissions test. This method thus requires periodic maintenance regardless of need, and is generally effective in reducing emissions, although inequitable in its application.

Retrofit measures are defined as the application of a device or system of any modification or adjustment beyond regular maintenance to a motor vehicle for the purpose of reducing emission levels. These measures accelerate the reduction of pollution emissions already begun by federal emissions programs, where such a need exists. Three general types of retrofit devices are vacuum spark advance disconnect (VSAD), air bleed, and catalysts. Because of inherent difficulties associated with the development of all but VSAD, this is the only retrofit device being seriously con-

sidered for implementation by 1975. Moreover, the oxidizing catalytic converter devices currently being examined may produce other more harmful emissions than the ones the catalytic converters were developed to reduce, hence, substituting one problem for another. Equally important is the fact that, within the time frame of implementation for retrofit programs, a proposal for retrofitting pre-1968 vehicles is unnecessary since most of the vehicles of this age group would have been replaced. Thus the retrofit programs should concentrate on emission control in post-1967 vehicles, if there is a demonstrated need for some form of retrofitting of vehicles.

Fleet vehicles, including taxis and government owned vehicles, account for a large number of vehicle-miles traveled. Consequently, conversion of these vehicles to cleaner burning fuels, such as liquid natural gas, compressed natural gas, or liquid propane gas, represents a potential reduction in pollution emissions. This alternative is particularly applicable in large metropolitan regions where the fleet vehicles' miles traveled account for a significant portion of the total vehicle-miles traveled. Use of these cleaner fuels is particularly applicable to pre-1975 model vehicles since emission standards for post-1975 vehicles are comparable to those of gaseous fuel engines. However, the advantages of a strategy such as this must be weighed against the availability of these cleaner fuels and the demands by other users of these fuels. Studies of the potential for this strategy in Southern California have substantiated its cost-effectiveness.

The handling and transfer operations associated with the storage of gasoline (i.e., the filling of underground storage tanks at service stations and the filling of automobile gasoline tanks) contribute a substantial portion of hydrocarbon emissions through evaporative losses. In the Commonwealth, this type of emission contributed an estimated 26 percent of the total hydrocarbon pollution in 1970. In the Northern Virginia, Richmond, and Tidewater regions, this pollution source contributed an estimated 13 percent of the statewide hydrocarbon emissions. From the foregoing example, it can be seen that a strategy to control evaporative losses in the handling of transportation fuels is important to an overall transportation control strategy.

Strategies to Reduce Vehicular Traffic. Under these alternative strategies, the emphasis is on reductions in the vehicle-miles of travel. Basically, these strategies are aimed at increasing the number of person-trips per vehicle (i.e., increasing the number of persons riding in automobiles and public transit systems), restricting automobile usage, reducing the number of daily person-trips, and minimizing the distances of typical trips. The interrelationships among these should be stressed since their effectiveness depends upon the provision of alternative modes of travel *and* sanctions against the inefficient use of the motor vehicle.

The diversion of trips made by automobile to modes of mass transportation offers probably the most effective, long-range method for alleviating both air pollution problems and traffic congestion.

Mass transportation systems require several years for total development, and, therefore, any short-term strategies must focus on existing systems (primarily bus transit) and on immediate improvements to these existing systems. The important considerations with regard to the development or improvement of mass transportation systems, as attractive alternatives to automobile travel, are relative travel times, travel costs, and quality of service. Consequently, the success of this alternative depends on how competitive the mass transportation service is when compared to the service provided by the private automobile. It must be frequent, reli-

able, and accessible to most of the metropolitan region. While cost reduction schemes affect the use of mass transit systems, it has been found that the most important factor is travel time—the public will ride a transit system if it provides a service that is basically comparable to that of the automobile.

Some improvements being considered as means to achieve the necessary comparability are preferential and exclusive bus lanes on major highways and city streets, one-way streets with two-way buses, sheltered bus stops, bus terminal parking (this would include fringe park-and-ride and kiss-and-ride terminals), and expansion of existing service areas.

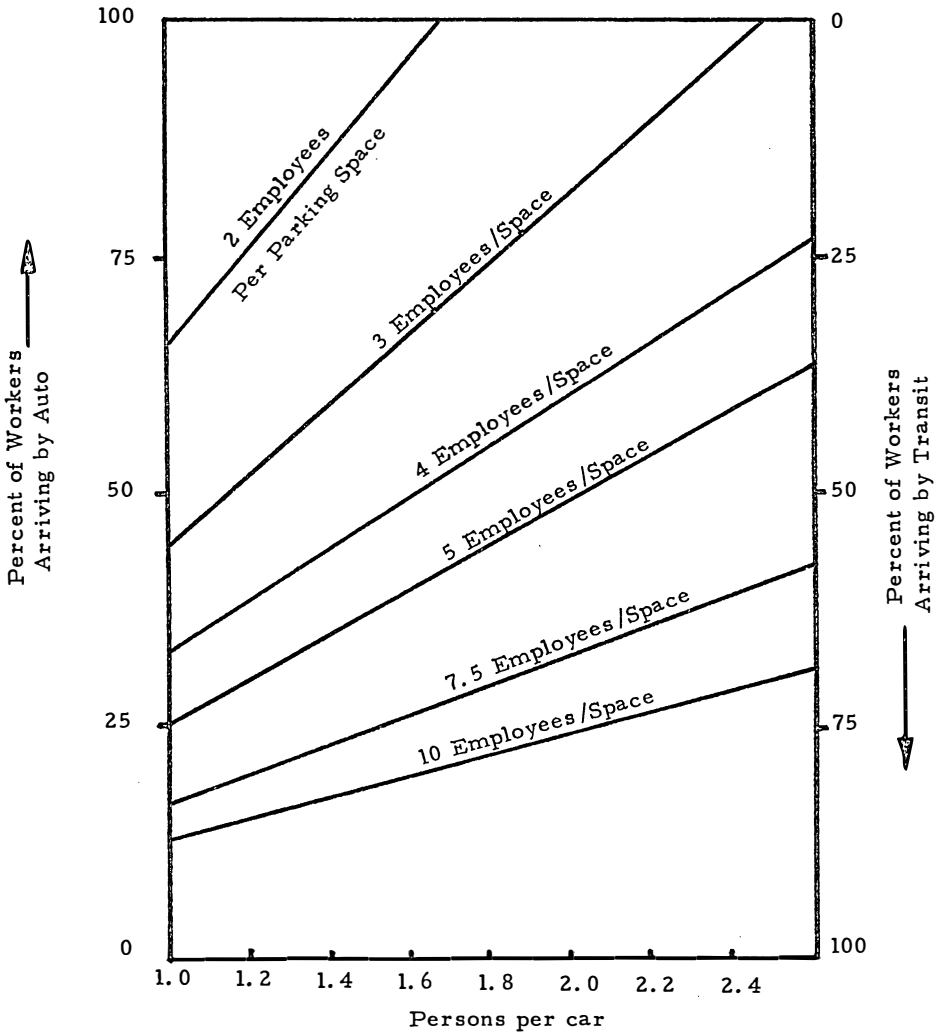
In conjunction with service improvements to mass transit systems, there should be forms of regulation and pricing restraints on the use of the vehicle. Such controls act as incentives to the use of the improved transit service.

It is evident from several studies (including transportation control strategy development plans in the Washington, D.C. and Los Angeles areas) that these disincentives to vehicle use must be incorporated as part of a transit improvement program before any significant impact will be achieved in reducing vehicle-miles traveled. The basic controls being discussed are parking controls, restraints on vehicle use, carpools or buspooling, idling restrictions, and four day 40-hour work weeks.

Parking controls are aimed at increasing the use of mass transportation facilities by reducing the incentive to drive the personal automobile for commutation purposes. Parking controls can be achieved by either regulation or pricing policies. Pricing policies include the elimination of free or nominal parking rates especially in areas of high density employment. This places the burden of payment for the space directly on the driver who decides to use it. Likewise, generally higher parking rates could be charged for all-day parking in order to discourage commutation by automobile. Beyond this, the total number of parking spaces available could be reduced by eliminating on-street parking, and by modifying zoning and/or building permit regulations which specify required parking for certain types of land use. Figure 2 shows the impact that such a policy could have on increased mass transit usage. It must be emphasized, however, that although these strategies can effectively decrease the number of employees who drive to work, mass transit must be a viable alternative capable of accommodating new riders before such strategies can be implemented.

Restraints on vehicle use can potentially reduce the volume of vehicular travel in selected areas, but whether this strategy will reduce total vehicle travel is questionable. The restraints can be either economic (e.g., road pricing techniques such as tolls) or physical (which includes auto-free zones, bypass routing, and street closures). Whatever the case, public transportation services must be coupled with such a strategy.

Figure 2. Basic Relationship Between Auto Use, Car Occupancy and Parking Requirements for Work Travel



Source: National Capital Region Transportation Planning Board, Parking in Downtown Washington, 1960-1968, Informal Report No. 18 (Washington, D. C., 1969)

Notes: Work travel only. Assumes 8 of 10 employees arrive by auto or transit. Assumes all spaces utilized.

Increasing car occupancy will reduce the number of vehicle-miles traveled. This can be accomplished by some form of carpooling or buspooling program, especially for work trips. Carpooling can be encouraged through the following incentives: (a) where parking is limited, parking permits could be issued to carpools, (b) where parking is unlimited, preferential carpool parking areas could be provided, and (c) priority freeway and tollway lanes could be provided for buspools and carpools. Pricing policies also could encourage the use of buspools and carpools. Buspools or carpooling can have a significant impact on areas outside the central city, where little if any transit service is provided due to the low density development patterns of suburban areas.

Any regulatory measures aimed at restricting vehicle idling times would likewise be a positive step toward cleaner air since the concentration of carbon monoxide in exhaust gases of an idling vehicle is nearly twice that of a cruising vehicle. While it would be difficult to construct and enforce a useful regulation to limit idling, it is conceivable that a public information program could achieve driver cooperation in shutting off auto engines wherever long delays are anticipated or encountered.

The four day 40-hour work week has also been discussed as potentially reducing vehicle-miles of travel. In theory, such a program reduces the number of worktrips per person by 20 percent, and by making every day of the week a workday, this strategy could potentially reduce the concentration of worktrips. On the other hand, this alternative might in fact increase the overall VMT as well as increase the average trip length due to the additional leisure time created by three day weekends.

Two additional considerations beginning to influence urban transportation strategies are the use of bicycles and pedestrian movements. Bicycles have grown in popularity in the last ten years to the extent that they now have surpassed automobiles in annual sales. It has been estimated that 50 percent of these were bought to be used by adults. The ability of the bicycle to impact upon automobile commutation depends on several factors.[3] The safety of this mode of transport must be increased, particularly with respect to the bicycle/automobile roadway conflict. Similarly, the utility of the bicycle as an effective alternative to automobile use is dependent upon weather conditions, distance to be traveled, and storage of the vehicle upon reaching a destination. Consequently, the obvious air quality advantage of this mode of travel can be realized only after the factors discussed above are resolved.

In like manner, the pedestrian (as an individual mode of movement) creates no real pollution problems. However, the overall metropolitan development process has negated this healthful and efficient means of travel. Cities have expanded to the level at which it is difficult, at best, to walk to work or any other activity. Whenever it is possible to walk, all pathways are at some point in conflict with vehicular movement. This conflict thus increases pollutant emissions.

Strategies to Improve Traffic Flow. The primary function of this group of strategies is to apply traffic engineering techniques to the design of automobile roadways in order to alleviate delays and increase average vehicle speeds. The influence of vehicular speed and operation cycle has been noted previously; the benefits of such programs would depend upon the current traffic condition since increased average speeds are more effective in areas where current speeds are relatively low. These kinds of improvements must also be accompanied by strategies that restrict increases in volumes of automobiles because street improvements tend to induce ad-

ditional traffic, which causes total emissions to increase. Consequently, after a period of time, the emission levels may in fact be higher than if the traffic flow improvements had not been implemented.

In general, these strategies deal with such roadway improvements as reverse lane operations, ramp controls, interchange design, lane alignment, reversible one-way streets, signal light progression, widening of intersections, helicopter reports on traffic conditions, and loading regulations which would limit loading and unloading of deliveries during certain periods of the day. These are strategies with which highway departments already deal through the federal TOPICS program (Traffic Operations Program to Increase Capacity and Safety) and their urban planning programs.

Strategies to Reduce Pollution Concentration. Strategies that spread the pollution sources over a larger area and over a longer period of time potentially create less pollution concentration by allowing pollutants to be dispersed more easily. In some situations, however, the photochemical oxidant problem is compounded due to this type of action because of the reactive nature of this pollutant and its dependence upon meteorological phenomena for its creation. The application of this strategy thus depends on the individual situation.

Highway design considerations are one method for affecting pollution concentration. Studies of pollution accumulation along roadways due to the location, design, and type of facility, have been analyzed and show that roadway design does influence the concentration of certain pollutants.

Another technique that potentially affects pollution concentrations is the staggering of work hours. It has been suggested that such a program would be most applicable in both smaller urban areas where traffic peaks are sharp and essentially unrestricted by capacity limitations and in larger urban areas where additional public transit capacity can be provided. The impact of such a strategy would also depend on the number of employers participating in the program. If only a small percentage were involved, the impact would be minimal. This has been the result in a pilot project in New York City.

Other Strategies. Several additional strategies should be discussed because of the ultimate influence that they may have on the air pollution problem. These strategies include: land use or activity planning; gasoline and/or other fuel rationing; alternatives to the internal combustion engine; alternatives to automotive intercity travel; and taxes on engine displacement, horsepower, or miles-per-gallon.

Ultimately, the long range solution to the air pollution problem will come from improved land use planning and a complementary transportation system that will be able to satisfy the divergent travel demands of the community. If transportation planning can respond to improved land use planning and, thereby, reduce the necessity to travel to the extent that exists today, a significant step will have been taken toward reducing air pollution. Historically, however, this complementary land use/transportation relationship has not always existed. In many cases, transportation systems have served to stimulate land development activities. Then, because of the land economics involved, subsequent transportation improvements have been reactions to the resultant development. Consequently, the utilization of land use and transportation planning as essential, interdependent considerations in an overall community design has been recognized only minimally.

These planning deficiencies are now being recognized and plans to

rectify them are beginning to take shape. The emergence during the past several years of state planning and transportation agencies is intended to provide for and control overall state development, with environmental quality clearly in mind.

The emergence of "complex sources" of pollution requires state involvement in land use planning. Under federal (EPA) regulations regarding state plans for evaluating complex sources, states must identify areas within their boundaries in which there is potential for exceeding any national air quality standard within the next ten years. Additionally, the states are required to analyze the impact of growth and development in the identified areas. For new sources (viz., major highways and airports, large regional shopping centers, major municipal sports complexes and stadiums, large parking facilities, and large amusement and recreational facilities), a complete analysis must be made of the nature, design and size of the facilities, times of operation and demands made on transportation facilities, and its impact on air quality, topography and meteorology of the area.

As a result of these new environmental considerations, land use planning must play a more effective role in community structure development in the future. The ultimate result will be a more systematized growth of cities. However, more explicit definitions of methodologies in this area of planning must be the result of careful and comprehensive involvement of localities, the states, and the federal government. The implications of this strategy must be recognized as long range in nature although certain actions may be immediate due to federal environmental regulations.

The impact of the "energy crisis" is now being felt by all segments of the population. Conservation measures currently being proposed, many of which will be implemented, recognize the finiteness of energy resources and reflect actions that are necessary to the conservation of these available fuel supplies. But, the population of the earth is energy dependent. The standard of living achieved by most developed countries would not exist without sophisticated resource-consuming machines to do the work. Nevertheless, certain policies have already been adopted which will limit the amount of fuel available for certain purposes, and in the future, it may be necessary to accept a life-style that is less resource consuming.

The impact of such a situation must be recognized as beneficial to the air pollution problem, due to the origination of air pollutants. As discussed previously, pollutants are the undesirable byproducts of fuel consumption. Since less fuel of all kinds will be available for use, then probably less pollution will be created. This is not meant to be facetious; it does, however, point out a situation in which we will have to look for alternatives to excessive and unnecessary fuel consumption. Transportation is one area in which alternatives for conservation exist. In the previous sections of this report, many transportation alternatives have been discussed. Particularly in the major metropolitan areas, unnecessary and inefficient use of transportation is the use of the automobile. In the future, such freedom may not exist for certain kinds of trips or during certain time periods. Fuel rationing, which has been initiated only as a wartime strategy to conserve fuel, may be a reality in the near future. Such actions ought not to be interpreted as infringements upon personal liberties; instead, alternative strategies should be developed now to accommodate the finiteness of natural resources and to avoid inefficient uses of these resources.

There are several additional alternatives which, if implemented, could lead to the development of more efficient means of transportation. Some of

these are: taxes on engine displacement, horsepower, miles per gallon, etc., (thus encouraging the use of more efficient vehicles); the development of alternatives to the internal combustion engine; and the development of alternatives to the motor vehicle in intercity transportation.

At the present time, automobile manufacturers are centering their efforts toward meeting the 1976 emission standards on modifications of the internal combustion engine. The techniques have complied with federal standards each year, but, increasingly, the modified engines have performed less efficiently and less economically. This is due in part to the antipollution control devices placed on engines. Through the use of tax incentives on engine displacement, horsepower, or miles per gallon, the automobile manufacturers could be encouraged to develop effective vehicular propulsion systems. Likewise, these same tax incentives could be aimed at the consumer through graduated registration fees, thereby encouraging the consumer to demand smaller, more efficient vehicles.

Alternative propulsion systems do exist and are propelling mass produced vehicles. Certainly, presently unknown or unevaluated systems could be developed, given the necessary research and development capacity.

Three current alternative propulsion systems which do or will meet the 1976 emission standards and also operate efficiently are the stratified-charge engine (Honda Civic), the rotary engine (Mazda), and the diesel engine (Mercedes-Benz).

The stratified-charge engine is an adaptation of the conventional piston engine. It achieves low emissions from very lean fuel/air ratios, without the performance drawbacks of poor ignition and combustion, by using basically two combustion chambers—a lean mixture in the main combustion chamber is ignited by a rich charge burning in a small adjoining chamber. Because of its similarity to the conventional internal combustion engine, it would be adaptable to existing mass production techniques. One serious drawback is that it makes the conventional engine even more complex than it now is.

In contrast to this, the rotary engine (Wankel) simplifies the design of the internal combustion engine. Its greatest advantage is its capacity to accommodate conventional emission control equipment. Several problems hinder its widespread use: (1) uncontrolled Wankels produce more hydrocarbon emissions than does the conventional engine, although the Wankel produces less oxides of nitrogens; and (2) the Wankel, in its present stage of development, gets poor fuel economy.

The advantages of the diesel engine over the conventional engine have been discussed previously. The diesel, when properly tuned, meets 1976 standards without the use of emission controls; and it has the additional advantages of good fuel economy and generally lower maintenance costs. There are, nevertheless, some problems with the diesel engine: it is heavier, noisier, and more expensive than conventional engines.

Several additional propulsion systems are being analyzed, although no mass production models exist. These are gas turbines, Rankine-cycle (steam) engines, and electric engines. However, no adequate evaluations are available at this time.

Intercity travel likewise contributes to the overall tonnage of pollutants emitted each year although, because of the nature of intercity travel, the impact is not as intense as that created by intracity travel. In the United States, intercity travel by automobile increased 32.6 percent (from 706.1 billion to 936.4 billion passenger-miles) during the 1960-68 period.

At the same time railroad revenue passengers decreased 38.4 percent (from 21.6 billion to 13.3 billion passenger-miles). Domestic air travel increased a whopping 197.6 percent (from 34.0 billion to 101.2 billion passenger-miles). Goods movements by motor trucks and rail transportation steadily increased during this period, with motor truck movement accounting for 396.0 billion ton-miles and rail service accounting for 757.0 billion ton-miles in 1968. Domestic goods movement by air increased by approximately 273 percent—from 0.778 billion ton-miles in 1960 to 2.900 billion in 1968.[4] In the Commonwealth, similar statistics were available only for automobile and truck travel on Virginia's Interstate and Rural Primary System, but passenger car travel increased by approximately 64.0 percent and intercity truck movement by approximately 55.0 percent. The implications of these growth rates suggest a potential degradation of the Commonwealth's overall air quality.

Consequently, alternatives for more efficiently and effectively moving people and goods between cities ought to be included in strategies for improved mobility and air quality. Again, as was true with urban public transportation systems, intercity mass transportation systems move goods and people more efficiently and with less polluting effects than do individual motor vehicles. As illustrated in Table VIII, buses and trains operate at much lower polluting levels than do individual automobiles. At the same time, buses and trains travel much more efficiently than motor vehicles (see Table IX). Air transportation, which is predominantly a jet engine-propelled system, can create severe air quality problems if that mode of travel continues to grow at its present rate. Since aircraft do not create pollution problems until approaching, landing, and taking off from airports, air transportation will reinforce the already existing air quality problems in major metropolitan areas.

Accordingly, a strategy which effectively encourages expansion of intercity transport by rail or by bus would support efforts to reduce air pollutants; perhaps more important at this particular time, it would encourage the use of more efficient modes of transportation. Such action would complement metropolitan area air quality improvements because of the overall reduction in automobile use.

Strategy Evaluation

Generally, an evaluation of the potential of each strategy was provided in the individual discussions. These strategies will be summarized in Table XII, showing their basic feasibility and impact. Also shown are the interrelationships among the strategies. This facet of the evaluation indicates where the effect of a strategy on air quality could be enhanced by the simultaneous implementation of other supportive strategies.

TABLE XII

EVALUATION OF STRATEGIES

	STRATEGY	FEASIBILITY			IMPACT	SUPPORTIVE STRATEGIES
		TECHNICAL	INSTITUTIONAL	COSTS		
1.	PERIODIC INSPECTION/ MAINTENANCE PROGRAM	MODERATE TO GOOD - Depends on the type of program instituted (either loaded emissions or idle emissions tests).	DIFFICULT TO MODERATE - Depends on the organizational structure necessary to establish standards and initiate the program. Legislation is required to implement such a program.	HIGH - Costs involved include capital costs for equipment, training costs for educating mechanics to perform tests and administrative costs. To implement such a strategy would cost approximately $2.00 per vehicle.[a] This would increase the cost to car owners by that amount for each inspection.	HIGH - There would be no impact on modal mixes, trip generation or origin - destination patterns. However, such a program would assure the impact of the emission standards program (overall 5 to 12 percent reduction in emissions is possible[a]).	
2.	RETROFIT EMISSION CONTROL DEVICES	DIFFICULT TO MODERATE - Depends on the type control device used and the vehicles to which retrofits are attached.	DIFFICULT - Same as above.	MODERATE TO HIGH - Costs involved would be assumed by individual car owners. Cost estimates for installation of retrofits range from $25.00 to $300.00.[a] Maintenance cost must also be considered.	HIGH - Same as above. Overall impact varies according to type of device used and pollutant being controlled, but a 25-50 percent reduction in emissions has been estimated.[a]	
3.	USE OF ALTERNATIVE FUEL SYSTEMS	GOOD	DIFFICULT	MODERATE - Initial investment is high, but the increased fuel economy obtained would likely justify the investment.	POTENTIALLY HIGH - Depends on total number of vehicles involved and the percentage of vehicle-miles of travel attributed to them. Most effective on pre-1975 vehicles due to the emissions advantage of alternative fuel systems during that period.	
4.	CONTROL OF EVAPORATIVE LOSSES	MODERATE - Storage controls already exist. Transfer of fuel remains a problem.	GOOD - Standards would have to be established in the State air pollution control laws.	HIGH - Costs involved would be assumed by individual fuel distributors and service station operators. Maintenance costs must also be considered.	MODERATE - Storage and transfer of existing fuels account for a relatively large proportion of HC emissions. Control of this source would reduce oxidant potential.	
5.	IMPROVEMENTS TO PUBLIC MASS TRANSPORTATION	GOOD	MODERATE - Depends on public acceptance of mass transportation systems.	HIGH	POTENTIALLY HIGH - Level of success depends on the implementation of several other strategies. Alone, its impact on air quality would be low. An overall 5 to 25 percent reduction in emissions is possible.[b]	6, 7

	PARKING CONTROLS	GOOD	MODERATE - Cities and towns and the Highway Commission presently have the authority to control parking on public streets and roads. However, the authority to establish zoning restrictions and surcharges would require modifications to existing statutes.	LOW OR REVENUE PRODUCING - Elimination of all free parking and initiation of a parking surcharge would increase revenues coming to localities. When combined with increased patronage of public transportation, this strategy would be revenue producing.	HIGH - This strategy could change the modal mix of vehicles and, when combined with public transportation improvements and carpooling, would not impact trip origins and destinations. The result, however, would be a reduction in the overall level of pollution in the affected area.	5, 8
7.	VEHICLE USE CONSTRAINTS	DIFFICULT TO MODERATE	DIFFICULT - There is much public opposition to this set of alternatives.	LOW OR REVENUE PRODUCING - If the strategy takes the form of a toll system, then it is a source of revenue. If the strategy utilizes a physical restraint, relatively little investment would be required. Costs or revenues would be assumed by the jurisdiction applying the strategy.	VARIABLE - The impact of this strategy would depend on the area of application, i.e., small urban areas would benefit little from restraints on vehicle use. Where applied, changes in modal mix would result. Care must be taken that such a strategy does not just move the pollution problem to another area.	5, 6, 8
8.	INCREASE VEHICLE OCCUPANCY (CARPOOLING AND BUSPOOLING)	GOOD	DIFFICULT TO MODERATE - Only at private parking facilities would the use of incentives to carpooling be difficult to implement.	LOW - Costs for instituting manual or computer systems to locate potential carpool users are low and can produce significant results. This service could be implemented at virtually any level, but the costs would have to be assumed by the sponsor of the service.	HIGH - This strategy could theoretically produce 50 percent less vehicle usage for commuter trips. The impact is therefore significant in reducing pollutant emissions.	6, 7
9.	IDLING CONTROLS	GOOD	MODERATE - Enforcement of this strategy would be difficult. As a result, the primary responsibility for adhering to the controls would lie with the individual.	LOW	LOW	
10.	FOUR-DAY WORKWEEK	GOOD	DIFFICULT	LOW	MODERATE TO HIGH - The potential impact of this strategy lies in its capacity to distribute pollution concentrations. Such a strategy could also result in increased vehicle-miles of travel and longer trip lengths during three free days, thereby reducing the effect of this strategy.	
11.	BIKEWAYS	GOOD	GOOD	LOW TO MODERATE - The design of bikeways determines the cost of this strategy.	HIGH - Bicycles emit none of the pollutants emitted from motor vehicles. Depending on the safety and acceptance of this alternative mode, the impact on air quality is significant.	6, 7, 13, 15

12.	PEDESTRIAN MOVEMENT	GOOD	GOOD	LOW TO HIGH - The design of pedestrian movement systems determines the cost of this strategy.	POTENTIALLY HIGH - However, because of the nature of most community development, extensive pedestrain movement is infeasible. High potential exists through reducing vehicle/ pedestrian conflicts.	7, 13, 15
13.	TRAFFIC FLOW IMPROVEMENTS	GOOD	GOOD	LOW TO HIGH	LOW - The primary purpose of these strategies is to increase the average vehicle speed, thus decreasing the congestion and high emission levels associated with low average speeds. There would be no change in modal mix but potentially an increase in trip generation. The result of this could be subsequent increases in congestion and pollutant emissions.	5, 6, 7, 11, 12, 14
14.	STAGGERED WORKHOURS	GOOD	MODERATE - Public acceptance is questionable.	LOW	LOW - Unless a large proportion of employers participate, this strategy would result in minimal impact on levels of emissions.	
15.	LAND USE PLANNING	GOOD	DIFFICULT - Public's acceptance of controls on land uses is questionable, and this strategy will be opposed by many vested interest groups. Recent environmental laws, however, provide sanctions for increased control over land use activities.		HIGH - Orderly, controlled development of cities and towns and even states result in the location of land uses based on the necessary interrelationships among them. The results of this are reductions in unnecessary trips and organization of transportation systems which can adequately accommodate travel needs. At the same time, significant reductions in pollutant emissions would also occur.	
16.	TAX INCENTIVES FOR USE OF MORE EFFICIENT VEHICLES	GOOD	DIFFICULT - Public acceptance is questionable and legislation is required to enact taxes.	REVENUE PRODUCING	HIGH - Increased use of existing or future low emission vehicles would have a great impact on air quality.	
17.	ALTERNATIVES TO THE INTERNAL COMBUSTION ENGINE	DIFFICULT TO MODERATE	DIFFICULT - Pollution control has heretofore centered on the internal combustion engine. Alternatives exist but acceptance by automotive manufacturers is questionable.	HIGH - Initially, costs to develop suitable alternatives to the internal combustion engine would be borne by private businesses. Ultimately, however, the consumer would pay for the implementation of this strategy.	HIGH	

18.	ALTERNATIVES TO AUTOMOBILE INTER-CITY TRAVEL	GOOD	DIFFICULT - States lack control over the type of service provided by inter-city mass transportation modes.	HIGH - Same as above.	MODERATE TO HIGH - As with urban public transportation, the use of the strategy will depend upon public acceptance and the degree of restrictions placed on vehicular use.

[a]U. S. Environmental Protection Agency Estimates
[b]Assumes Implementation of Supportive Strategies

VII. PRESENT AIR QUALITY ACTIVITIES OF THE STATE.

The nature of problems associated with transportation-originated pollution suggests a multiagency approach in defining control strategies. Although no such approach has been formally initiated in the Commonwealth, separate actions by various agencies have contributed to some reduction of air pollution or will do so once implemented. A discussion of these activities can suggest what additional actions are required to improve Virginia's air quality.

State Air Pollution Control Board (SAPCB)

The original responsibilities of the SAPCB were oriented toward stationary sources of pollution. The SAPCB was required to evaluate air quality and to establish regulations regarding the emissions from stationary sources. With the growing concern for the environment and the recognition that the automobile is a major contributor of potentially harmful carbon monoxides, hydrocarbons, and oxides of nitrogen pollutants, the emphasis of SAPCB programs was expanded to include mobile sources. Furthermore, with the enactment of the Clean Air Act of 1970, the multifaceted structure of the air pollution problem really came into focus. Not only were pollutant standards and emissions standards established, but this act called for the implementation, where necessary, of transportation and land use control strategies in order to meet the standards by 1975.

As mentioned before, Northern Virginia is the only region in the State requiring the implementation of transportation control strategies. In this region, the SAPCB is working with the Washington Council of Governments and the state of Maryland to establish coordinated and effective control strategies.

The SAPCB is also trying to develop a monitoring network which will effectively measure the air quality of the various regions of the State. Such a monitoring system is essential to the identification of critical pollution problem areas in the State.

Additionally, the SAPCB is presently developing regulations regarding complex sources of pollution. These regulations, as presently proposed, will place the SAPCB in the position of a land use review agency, in addition to its other functions.

Air Quality Planning Committee (AQPC)

This committee was created to coordinate interstate air quality planning in National Capital Interstate Air Quality Control Region. The committee is composed of members from Washington, D.C., and the states of Virginia and Maryland. It is empowered to recommend air quality policies for the region, to recommend revisions to air quality standards, to make emergency episode plans, and to develop air quality plans. The committee's recommendations form the basis of Northern Virginia's transportation control strategy, which includes expanded mass transit, bus priority lanes, carpool services, increased parking costs, and vehicle maintenance and inspection. It should be noted, however, that the responsibility for adopting, implementing, and enforcing the strategies rests with the State and its local governments.

Virginia Department of Highways (VDH)

The primary function of the VDH is to plan, develop and maintain the State's highway system. Historically, the VDH has approached this responsibility from an engineering orientation. In recent years, however, the growing complexity of highway construction, due to environmental con-

siderations and the need for more effective forms of mass transportation, has necessitated the organization of a multidisciplined team by the VDH for the purpose of evaluating the need for a highway facility versus its potential detrimental social, economic, and environmental effects. The VDH has established an Environmental Quality Section which is responsible for assuring full consideration of the environmental impact of highway projects. Federal legislation has had much to do with this change of attitude—the National Environmental Policy Act requires impact studies of certain projects; the Federal-Aid Highway Act requires that all federally funded highway projects be consistent with the State's Air Quality Implementation Plan and not impede an area's attainment of air quality standards; and the Federal Highway Administration has required the State to develop a Highway Action Plan defining the State's procedures for meeting the requirements of the Federal-Aid Highway Act of 1970.

Several additional activities of VDH, which affect or potentially affect air pollution levels, are projects aimed at alleviating congestion. In the Northern Virginia area, the VDH and the Federal DOT have sponsored an exclusive express bus roadway along the Shirley Highway. This busway is currently carrying approximately 30,000 transit riders each weekday. Existing legislation also allows the designation of certain lanes for exclusive bus or carpool use; this action is currently in effect for the Northern Virginia area. In the Richmond area, the VDH sponsored the construction of a fringe parking facility which is served by express bus service via I-64 and I-95 to downtown Richmond. The success of this project is illustrated by the need to expand the parking facility in order to accommodate demand. The VDH is also involved in evaluating and assisting in the planning for mass transit systems (bus transit) in other metropolitan areas of the State.

Other projects sponsored by the VDH include (1) a project to develop a computerized carpool locator service for a selected group of state employees in the Richmond Central Business District (the results of the project were impressive, indicating a real potential for the implementation of a carpool service among the selected State employees) and, (2) a study of the feasibility of a Statewide network of bikeways.

Transportation Districts

To date, regional transportation districts have been formed in two of the Commonwealth's seven urbanized areas. These two districts, the Northern Virginia Transportation District and the Tidewater Transportation District, were organized in accordance with the Transportation District Act of 1964 (as amended). The respective transportation district commissions are currently implementing or planning to implement transportation improvement programs which should have a significant impact upon reducing air pollution levels in these two urbanized areas. These programs are principally directed toward planning for and providing improved regional public mass transit systems and services. Additionally, however, the Northern Virginia Transportation Commission will likely become actively involved in assisting the Virginia Air Pullution Control Board in the implementation of the transportation strategies required to meet the air quality standards as promulgated by the Environmental Protection Agency for the Northern Virginia portion of the Washington Metropolitan area.

Washington-Richmond Corridor Study (WRCS)

In October of 1973, Governor Holton released the results of a study of the feasibility of high-speed rail passenger service between Richmond and Washington. One of the purposes of this study was to determine the

impact of improved rail service on the use of I-95. Study estimates indicate a relatively significant impact on VMT, with the rail service potentially capturing between 9 and 17 percent of the Washington-Richmond travel market.

VIII. RECOMMENDATIONS

The growth in automobile travel has had divergent results. The convenience and flexibility provided by the automobile allows a freedom in mobility heretofore unknown. On the other hand, personal transportation has grown exceedingly expensive in terms of energy consumption, time spent in commutation, and deterioration of the natural environment. As a result of this inconsistency, the advantages of automobile use for certain kinds of trips are now being questioned, particularly with respect to the total cost associated with that use. In this reevaluation, alternative modes of travel and transportation strategies are being considered, recognizing nevertheless that neither personal accessibility nor environmental quality should be sacrificed in the process.

Many of these alternatives have been discussed in this report. With each of the strategies, a firm commitment of the people is required in order to insure successful implementation. It is important that the public be fully informed of the long range consequences of any actions involving accessibility and environmental quality. At the same time, practicable alternatives must reflect the changes which have occurred in our society, such as the growing service orientation of the economy.

The resulting requirement to recommend both environmentally sound transportation strategies and ones which are practicable is a difficult task. To emphasize one over the other negates the equally important considerations of both, and requires changes that may not be entirely necessary.

The Commonwealth has three areas where pollution emissions are at levels which are considered in excess of the health standards established by the Environmental Protection Agency. In the Northern Virginia area, a transportation control strategy has already been devised and will be implemented by 1977. In the Richmond and Tidewater areas, no strategies have been proposed but such strategies may be required given the air quality data presented in this report. Yet, it is also entirely possible that these two areas will meet national standards by 1975, through the new car emissions program and through controls on evaporative losses in the transfer and storage of gasoline. Reliance on these two strategies, however, would only perpetuate increasing dependence on the automobile as the primary means of transportation; and with increased VMT, it is likely the standards would soon be exceeded. A more positive strategy seems to be required.

In the remainder of the State, the proportions of CO, HC, and NO_x pollutants originating with transportation sources are basically the same as in the three metropolitan areas discussed above. However, the concentrations have not yet reached levels in excess of national standards. The quality of the air is nonetheless deteriorating, and will continue to do so unless certain actions are taken.

The following sections describe what actions should be taken by the State to reverse the tendency toward environmental degradation as a result of automobile use. The proposals are both immediate and long range in application and will be discussed as such. The immediate proposals refer to actions which could be implemented within the time frame of two to five years, resulting in a more immediate impact on the quality of Vir-

ginia's air. Long range proposals refer to specific actions or concepts whose overall impact should be evaluated more thoroughly in order to specify particular actions.

Because the Northern Virginia region (AQCR VII) is already under legal requirements to implement transportation control strategies in order to improve its air quality, the recommendations of this report should be considered as strategies in addition to AQCR VII's plan, unless specifically stated otherwise. This report's recommendations are general and do not apply to a specific level of pollution reduction as in AQCR VII's plan.

Immediate Actions

Specific actions recommended include inspection/maintenance of emission control equipment, improved mass transportation service, parking controls and vehicle use constraints, tax incentives, and carpooling and/or buspooling programs. Statewide application of these programs, except for the inspection/maintenance and tax incentive proposals, is unnecessary and therefore not recommended. The State should, however, encourage local governments and appropriate regional planning bodies to consider the other strategies.

Inspection/Maintenance Program. So that the advantages of the Federal New Car Emissions Program can have a lasting effect, a statewide inspection/maintenance program should be implemented. This program would insure the proper functioning of the emission control equipment and could be implemented by modifying the existing semiannual vehicle safety inspection program to include an analysis of the emissions from controlled vehicles (i.e., vehicles with the antipollution control devices). Under such a program, failure to achieve specified emission levels based on vehicular model year and control devices installed would require the owner to perform, or have performed, mandatory maintenance procedures to bring his vehicle into compliance with the established emissions standards.

The AQCR VII plan will utilize the idle emissions test which minimizes the costs associated with establishing such a testing procedure. A statewide system similar to this one would be suitable for implementation, but the AQCR VII's suggested approach should not preclude the selection of another test procedure by the State. It should also be noted that Federal funding (up to two-thirds of the total costs) may be obtained to assist in constructing and operating the program.

Implementation of this strategy is possible by 1976-1977, given the approval and funding by the General Assembly during its next session. The SAPCB plans to present its AQCR VII proposal to the 1974 General Assembly. Instead, it is recommended that a statewide program be proposed, yielding statewide benefits.

The following strategies should be considered for specific locations unless otherwise noted.

Improved Mass Transportation Service. Historically, public mass transportation service has been provided by private companies which depend on the fare box for their economic viability. Recently, due to the failure of the service generated to support the costs of operation, there has been a tendency for privately owned transit companies to become publicly owned. As a result, public agencies and municipalities must assume the responsibility for providing mass transportation service and must also assume financial support of the service. This trend, which is not only statewide but also nationwide, reflects the almost total reliance of the American

people on the automobile. Transit systems, which depend on high density development along radial routes, have been unable to compete with the level of service provided by the automobile. Suggestions for reversing this trend are numerous, but generally they can be summarized as follows: (1) improve the level of service provided by mass transportation systems, (2) provide some form of subsidy for the system, and (3) institute sanctions against automobile use. It is generally agreed that (1) and (2) are not enough incentives to effectively increase transit patronage. At the same time, disincentives to automobile use *must* be accompanied by effective alternative modes. Thus, in order to at least initiate transit improvements, some form of subsidization must be provided.

In the three regions of the State where air pollution levels are critical, mass transit improvements could reduce emission levels by 5 to 25 percent. The improvements should include purchase of buses or other transit vehicles, development of connector transit service through use of fringe parking lots, expansion of service areas, use of exclusive rights-of-way (either separate lanes of separate roadways) by transit facilities, improved public information about transit service, and use of paratransit systems (such as taxis, jitneys, small demand responsive systems) in connection with regular/express transit service.

Federal programs are available to assist in the development or expansion of public transportation service. Development of fringe parking lots and designation of exclusive transit-use lanes can be accomplished through the assistance of the State Department of Highways. The State Department of Highways also, under certain conditions, provides limited financial assistance to local governments in the purchase of buses.

It is recommended that the State agencies work with appropriate localities to identify specific public transportation improvements needed to reduce the level of vehicular emissions in their areas. The State should also provide additional financial assistance as an incentive to the development of improved public transportation service.

Parking Controls and Vehicle Use Restraints. This group of strategies represents the types of sanctions necessary to encourage the use of mass transportation. Recommendations regarding the implementation of these strategies depends on an analysis of air quality requirements and transportation potential in a specific area. Two considerations to keep in mind, however, are, first, to aim the strategies toward all-day commuter (work-related) parking, and, also, to reduce or eliminate free or nominal-cost parking spaces in high density employment areas.

It is recommended that, in the Richmond area where there is a large number of State employees, an analysis of State parking policies be made with the specific purpose of:

(1) evaluating the potential of alternative transportation mode use;

(2) exploring the possibility of increasing parking fees to the predominate commercial rate;

(3) exploring the potential of parking space assignments based on vehicle occupancy (carpools), use of automobile during work hours, and special cases;

(4) examining the potential for eliminating certain parking spaces.

Alterations to the parking requirements of existing zoning and building code regulations may also influence the use of the automobile. The

potential of such action as a possible incentive to the use of mass transportation programs should be explored.

Carpooling. Carpooling is a useful strategy for both improving air quality and reducing traffic congestion. It is a practical alternative to single-occupancy vehicle use in areas where population density levels are too low to support mass transit service.

At the present time, the Virginia Department of Highways has the necessary computer systems to implement a carpool locator service. The estimated costs for operating this service are relatively low, and the benefits are high considering potential reductions in pollution levels resulting from the effective implementation of this service.

In conjunction with the recommendations of the previous section, the State should:

(1) implement a computer-assisted carpool locator service utilizing the facilities available at the VDH,

(2) implement regulations which would encourage the use of carpools by State employees (this should be done in conjunction with the results of the State parking policy study recommended above),

(3) provide preferential treatment to carpools and transit facilities at toll booths and along major highways, and

(4) provide technical assistance to large employers who desire to participate in the carpool locator service.

Tax Incentives. The use of tax incentives would benefit many of the strategies discussed in the previous sections. The primary purpose for the strategy, however, is to promote the development and/or utilization of more economical and more environmentally acceptable means of transportation. It is recommended that consideration be given to attaching surcharges to automobile registration fees. These surcharges should be graduated according to engine displacement, vehicle weight, estimates of vehicle efficiency, vehicle emissions, or any other method designed to discourage the use of automobiles possessing high emissions characteristics. The money derived from this strategy should be placed in a General Transportation Fund and used to help support mass transportation systems, including the operation of the carpool locator service.

Long Range Actions

The following strategies must be analyzed and evaluated more thoroughly before any specific recommendations can be developed. These strategies are nevertheless considered essential to the implementation of long range transportation programs that are both effective and environmentally acceptable.

Land Use Planning. Unstructured arrangements of activities create community patterns of land use which have longer distances between activities and require many single purpose trips. If activities were located according to the functional relationships between them, the resulting structure of activities could shorten trip distances and facilitate combined trip purposes. The ultimate outcome of this action would be an overall reduction in the need for vehicular travel and a concomitant reduction in transportation related pollution. Steps are now being taken at the Federal level to incorporate these kinds of land use considerations into environmental programs. The Commonwealth should begin active participation in this complex facet of planning.

It is recommended that an interdisciplinary committee be formed as

soon as possible for the purpose of defining State policy regarding the relationships between land use, transportation, and environmental considerations. Membership on this Committee should include the Secretary of Transportation and Public Safety, Secretary of Commerce and Resources, Executive Director of the Governor's Council on the Environment, and appropriate agency heads in State Government. All State agencies would be available to assist the Committee in the performance of its function.

Intercity Transportation of People and Goods. The encouragement of the most efficient and least polluting modes of intercity transportation should be a priority concern of the Commonwealth. An example of State initiative in this area is the Washington-Richmond Corridor Study, mentioned earlier in this report. Additional possibilities, such as alternatives to freight shipment by truck, should be explored, emphasizing efficiency and environmental compatibility.

Other. Bikeways, pedestrian movement, and traffic flow improvements should also be considered in more detail with respect to their effectiveness in reducing air pollution.

The VDH is currently conducting a study of the feasibility of a Statewide system of bike trails. The results of this study should establish the feasibility of bicycling as an alternative urban transportation mode and recommend specific State strategies toward bicycling.

Techniques for minimizing the conflict between pedestrian and vehicular movement should be evaluated. Such studies could be conducted as part of the Highway Department's metropolitan transportation planning programs.

Traffic flow improvements reduce the capacity of an automobile to pollute by allowing efficient, minimally-controlled movement. The Virginia Department of Highways should be encouraged to continue and to expand its work with localities in developing effective traffic flow patterns.

Conclusion

These recommendations have been evaluated in the context of several possible strategies and appear to represent the most appropriate direction for Statewide involvement in the reduction of transportation-originated air pollution at this time. The immediate actions proposed would reduce the impact of air pollution primarily by emphasizing the use of various forms of mass transportation and by instituting a law requiring the proper functioning of antipollution control devices. The long-range actions have been proposed in order to more thoroughly identify the relationship among land use, pollution potential and transportation systems and to create a policy-making body that could focus State-level actions on the overall problem.

The Commonwealth can alleviate, if not eliminate, the problem of air pollution generated by transportation sources. However, a concerted effort is required. It is hoped that this report will serve as a stepping stone toward the attainment of both air quality *and* mobility in Virginia.

Notes

[1] Virginia State Air Pollution Control Board, *Regulations for the Control and Abatement of Air Pollution* (March 1973), p. 16.

[2] R. E. Wendell, J. E. Norco, and K. G. Croke, "Emission Prediction and Control Strategy: Evaluation of Pollution from Transportation Systems," in *Journal of Air Pollution Control Association,* Volume 23, Number 2 (February 1973), p. 93.

[3] Jason C. Yu, "The Bicycle as a Mode of Urban Transportation," in *Traffic Engineering* (September 1973), pp. 36-38.

[4] Automobile Manufacturers Association, Inc., *1970 Automobile Facts and Figures,* p. 54.

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