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THE CLEAN AIR ACT AND TRANSPORTATION CONTROLS

AN EPA WHITE PAPER

OFFICE OF AIR
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THE CLEAN AIR ACT AND TRANSPORTATION CONTROLS: AN EPA WHITE PAPER

INTRODUCTION

The proposal of transportation control plans formulated to bring the air quality of our major urban areas into compliance with the mandates of the Clean Air Act has created considerable public concern about the social and economic implications of these controls. The purpose of this paper is to analyze the impact and feasibility of key components of the plans being proposed and to examine the relationship between the implementation of a set of feasible transportation controls and the attainment of the air quality standards. The important inspection/maintenance and hardware retrofit approaches to motor vehicle emissions control are described in Sections A and B of this paper, and estimates of their effectiveness and costs are presented. Measures designed to control emissions through reducing auto use, such as improved mass transit, are discussed in Section C. In Section D the various individual control measures are related to actual transportation control plans. The effects on air quality of the combinations of control measures are assessed, and several significant sources of uncertainty in our forecasts of the air quality impact of transportation controls are identified.

BACKGROUND

The Clean Air Act Amendments of 1970 directed EPA to set national air quality standards which would protect the public health and welfare from the known effects of the major air pollutants. In 1971, such air quality standards were established for six pollutants, including the four primarily associated with motor vehicles, i.e., carbon monoxide (CO), nitrogen dioxide (NO_2), photochemical oxidant (OX), and hydrocarbons (HC). Hydrocarbons are reactants in the formation of oxidants and at ambient concentrations have no known health effects.

The standards for the motor vehicle related pollutants have been exceeded in a number of our major urban areas. Out of the 247 Air Quality Control Regions (AQCR's) in the United States, in the period 1970-1971 54 regions exceeded the air quality standard for oxidant, 29 exceeded the carbon monoxide standard and 2 exceeded the nitrogen dioxide standard (under the old monitoring technique it was believed that 47 AQCR's exceeded the NO_2 standard). In all, 58 AQCR's representing nearly 55 percent of the nation's population exceeded the ambient air quality standards for one or more of these pollutants (see Appendix A).

The Environmental Protection Agency's plan to achieve the air quality standards on a national basis includes the implementation of controls on stationary sources (power plants, industrial facilities and general area sources), the Federal new car emissions standards and in-use vehicle emissions controls. The anticipated reductions in pollutant concentrations resulting from the implementation of stationary source controls and new vehicle emissions standards are projected to reduce the number of AQCR's exceeding the air quality standards to 29 by 1975 (see Table 7). These include approximately 40 percent of the nation's population.

Having controlled the emissions from stationary sources and new vehicles to the extent possible, those States containing the AQCR's still projected to exceed the air quality standards will be required to implement appropriate transportation controls (i.e., controls of in-use vehicles) to meet the requirements of the Clean Air Act. The control of emissions from these vehicles is essential because although motor vehicles are not the only source of HC, CO and NO_x emissions, they are the primary source of these pollutants in our urban areas. Table 1 shows the general range of relative contributions of emission sources in our urban areas.

TABLE 1

MIX OF EMISSION SOURCES IN URBAN AREAS - 1971

Pollutant	Percent of Total Emissions		
	Automobiles	Trucks, Buses & Motorcycles	Stationary Sources
CO	77-87	8-10	3-15
HC	50-65	5-10	25-45
NO_x	40-50	8-13	37-52

The data clearly indicate the importance of automotive emission controls. The Federal new car emissions standards, particularly for cars produced in 1975 and beyond, will go a long way towards reducing the role of the automobile in the pollution of our cities. In many urban areas presently exceeding the air quality standards, the reduction in new car emissions alone will eventually bring regional air quality within the standards. However, there are other regions which must look to transportation controls as a long run complement to the Federal new car emissions standards, because reductions in new car emissions alone will never bring the achievement of the air quality standards. In either case, the full impact of the new car standards will not be realized for some time. Vehicle population growth, in-use vehicle deterioration and the slowness of vehicle turnover greatly reduce the impact of these standards in the time period of the mandated attainment of the air quality standards. For example, relative to 1972, automotive CO and HC emissions will be reduced by only about 35% by 1975 and 50% by 1977. Therefore a reduction in the emissions of vehicles presently on the road are key to the efforts to meet the requirements of the Clean Air Act.

EMISSIONS CONTROL TECHNIQUES

The control of in-use vehicle emissions generally takes three forms:

A. The retrofitting of vehicles with systems or devices which directly reduce exhaust emissions.

B. The inspection and maintenance of vehicles to ascertain and maintain adequate emissions performance.

C. The reduction of vehicle miles travelled through the use of traffic controls, mass transit, parking taxes, etc.

A. Retrofit Devices

A retrofit approach can be defined as the addition of any device or system and/or any modification or adjustment made on a motor vehicle after its initial manufacture to achieve a reduction in emissions. The retrofit packages most commonly discussed for use in light duty vehicles include:

1. <u>Vacuum Spark Advance Disconnect (VSAD) with Lean Idle</u>

Two basic engine modifications employed by the motor vehicle manufacturers in meeting Federal exhaust emissions standards have been the leaning of air/fuel ratios and the modification of ignition (spark) timing. Therefore, the modification of these parameters in pre-controlled (pre-1968) vehicles should reduce exhaust emissions. Because 1968 and newer vehicles have utilized these modifications to some extent to meet Federal emissions standards, this retrofit technique is considered to be applicable primarily to pre-controlled vehicles, but not to approximately 10% of those pre-controlled vehicles which do not employ vacuum spark advance.

Low mileage EPA tests of this system indicate average emissions reductions of 25% for HC, 9% for CO and 23% for NO_x from a tuned baseline. Durability data developed by General Motors over 25,000 miles without maintenance show no deterioration in the reduction of HC and NO_x over time, but do show approximately a 20% deterioration for CO.

The initial cost of purchase and installation of this system, which is commercially available, is estimated to be $20. Device maintenance can probably be limited to an annual readjustment of the idle air/fuel ratio and would cost about $5.00. A minor fuel economy reduction of approximately 2% is associated with the ignition timing adjustment achieved by this retrofit technique. This would increase vehicle operating costs about $.60 per 1,000 miles of operation.

2. Air Bleed to the Intake System

Many devices have been designed to introduce, by one means or another, excess air into the intake system of a vehicle. The effect is one of reducing HC and CO levels, possibly with some small increase in NO_x levels. The reductions achieved vary directly with the amount of air allowed into the intake system. This technique is applicable to some extent to all light duty vehicles, but because of the relatively lean air/fuel ratios on controlled vehicles the technique is primarily applicable to pre-controlled vehicles.

Tests conducted on this system for EPA indicate an expected reduction of 21% for HC, 58% for CO and 5% for NO_x. Durability data on the system are not adequate for judging the performance of this control technique over time.

The installed cost of the air bleed system tested for EPA is estimated to lie in the range $56 to $64. A fuel economy improvement of 4% is associated with the use of this device which would reduce operating costs by $1.20 per 1,000 miles of operation.

3. Oxidation Catalyst

Because of the automotive industry commitment to the use of catalysts in meeting future federal emission standards, it follows that catalyst systems are being identified as retrofit candidates as well. Catalyst retrofits are applicable to cars capable of running adequately and without excessive engine wear on a commercially available lead free gasoline. Our best estimate of the proportion of cars to which catalytic systems are applicable is 20% of pre-1971 and 75% of 1971-1974 model year vehicles.

Low mileage emissions tests conducted for EPA showed mean emissions reductions of 68% for HC, 63% for CO and 48% for NO_x for catalyst systems (plus VSAD) installed on 11 pre-controlled vehicles. Emissions tests on a fleet of cars being run by the State of California show low mileage reductions of 70% for HC, 70% for CO and 14% for NO_x for controlled cars equipped with air pumps. Tests on cars without air pumps showed very unsatisfactory results.

The durability data generated for catalyst retrofit systems are limited and the results are mixed. No firm conclusions on retrofit catalyst durability can be drawn at this time. The fleet test in California should provide a great deal of useful data on catalyst durability as the test progresses.

Estimates of the cost to be borne by the consumer for a catalyst retrofit package will vary according to the type and age of the consumer's vehicle, and the organizational structure selected for retrofit installation. With an installation program run in State-owned (or franchised) inspection and installation centers, the average initial cost would be approximately $125. However, with an installation program designed to make use of traditional distribution channels and local service establishments, the initial price could rise to well over $300. The fuel penalty of catalyst systems is negligible (perhaps 1%).

Retrofit packages similar to those discussed above for light duty vehicles are also potentially applicable for heavy duty vehicles and motorcycles. However, a great deal more research will need to be carried out on the cost, effectiveness and applicability of these techniques before their use can be considered for these motor vehicles.

4. Service Station Vapor Controls

Although the hydrocarbon vapors emitted to the air from service stations cannot be considered in-use vehicle exhaust emissions, the relationship between these vapor losses and vehicle use is so direct that their control can legitimately be thought of as a transportation control.

The average service station sells approximately 25,000 gallons of gasoline per month and in the process is estimated to emit nearly 400 pounds of hydrocarbon vapor. By 1975 uncontrolled vapor losses of this magnitude will make the service station as important a source of HC emissions as some of the vehicles it serves. Translated into grams/mile the HC emissions from the service station exceed the 1976 new car HC standards.

Service station vapor losses result primarily from vehicle fueling and tank truck unloading. Vapors emitted in these processes account for over 90% of the total vapor loss. Vapor displacement control techniques are presently being developed which show the potential for reducing these emissions by over 80% by 1977 (a reduction of over 75% in total service station vapor losses). The annualized cost of service station vapor controls is estimated to be approximately $3.20 per car serviced by the controlled service station.

B. Inspection/Maintenance (I/M)

All inspection/maintenance approaches include two phases: an inspection phase used to screen the vehicle population to determine which vehicles should be required to receive maintenance; and a maintenance phase, in which appropriate corrective maintenance is performed on the selected vehicles.

1. Light Duty Vehicle I/M

Recent studies have demonstrated that significant reductions in light duty vehicle emissions can be achieved through enforced I/M programs. The effectiveness of a program depends primarily upon the fraction of the vehicle population forced to receive corrective maintenance. A program of inspecting idle mode emissions is estimated to result in reductions of 11% for HC and 10% for CO if 50% of the vehicle population fails the initial inspection and receives corrective maintenance. An initial failure rate of only 10% provides reductions of 6% for HC and 3% for CO. A loaded mode inspection should provide a 15% HC and 12% CO reduction at a 50% initial failure rate and an 8% HC and 4% CO reduction at a 10% initial failure rate. These reductions are representative of an annual inspection program. More frequent inspection and maintenance would be expected to lead to larger average emissions reductions.

Annual emissions inspection in State operated lanes is estimated to cost less than $2 per vehicle. Maintenance costs observed in fleet studies of various I/M approaches have been found to lie in the range of \$20 to \$30 for those vehicles failing the inspection test. However, the annual average maintenance cost to all vehicles subject to inspection is estimated to be about \$3 per vehicle when the cost of maintenance which would normally have been performed voluntarily is netted out of the estimated maintenance cost.

The impact of I/M programs on fuel economy has not been adequately determined.

2. <u>Heavy Duty Vehicle and Motorcycle I/M</u>

I/M programs for HDV's and motorcycles are potentially applicable, but programs have not yet been carried out to accurately assess the degree of control achievable for these vehicles.

- <u>Implementation Time Frame</u>

The dates at which the control techniques discussed above can be implemented vary according to the time needed to develop and evaluate each control measure, to manufacture control devices and build or modify automobile service facilities, to conduct pilot studies and to phase in or install the control system. Table 2 summarizes the best estimate of the time requirements for each of these technical implementation constraints. It should be noted that these estimates do not reflect those aspects (primarily institutional) of the implementation programs of particular air quality regions which would facilitate or delay the use of these control techniques.

TABLE 2

IMPLEMENTATION TIME PHASING

Technique	Development & Evaluation	Facilities Prep or Manufacturing	Pilot Study	Phase-in	Date
LDV Retrofit					
VSAD	1	6		12	1/75
Air Bleed	18	6		12	6/76
Catalyst	18	6		18	1/77
LDV I/M					
Idle*		12	3	12	9/75
Loaded*		12	6	12	12/75
HDV Strategies					
Retrofit	29	6		12	6/77
I/M	21	6	6	12	5/77
Gas Station Control					
Stage I**		12		12	6/75
Stage II***		18		18	6/76

*Subtract 6 months if facilities already exist.
**Stage I is control of tank trunk to storage tank losses.
***Stage II is control of automobile fueling vapor losses.

- Consumer Costs

The cost of the emissions control measures discussed above can be viewed in terms of the incremental out-of-pocket costs likely to be incurred by various automobile owners in the initial year of the control program's implementation or in terms of the average annual cost likely to be incurred by all vehicle owners if the cost of the control program can be spread to all vehicle owners.

Table 3 sets forth the range of out-of-pocket costs likely to be incurred by the average vehicle owner in the year of program implementation. The cost data reflect an assumption that the owners of vehicles of various ages will be required to pay cash for the installation of pollution control devices, the inspection and maintenance of the vehicles and the modification of the service stations servicing all vehicles.

TABLE 3

POSSIBLE CONSUMER COSTS IN YEAR OF IMPLEMENTATION

New Cars		
Control Devices		$160.00 - $200.00*
I/M		1.20 - 31.20**
Gas Station Control		3.20 - 3.20***
	TOTAL	$164.40 - $234.40
1968 - 1974 Cars		
Control Device (Catalyst)		$90.00 - $140.00
I/M		1.20 - 31.20
Gas Station Control		3.20 - 3.20
	TOTAL	$94.40 - $174.40
Pre-1968 Cars		
Control Device (VSAD or Air Bleed)		$30.00 - $59.00
I/M		1.20 - 31.20
Gas Station Control		3.20 - 3.20
	TOTAL	$34.40 - $93.40

*Incremental cost of control devices over what is presently found on new cars.

**Range of costs reflects the fact that some cars will require maintenance, others will not.

***The average cost per car of controlling gasoline station vapors if the cost is passed on to the consumer over a 5-year period.

The data in Table 3 show that the initial cost of the hardware oriented emissions controls can be substantial if the vehicle owner is forced to finance the cost entirely in the first year. However, financing techniques available to both the individual vehicle owner and the impacted AQCR can be used to spread these costs (over time and to other individuals) and lower their impact.

Table 4 details the impact of various financing schemes on individual income groups. The dollar costs represent those that would be incurred in a city which employs a full complement of the control techniques discussed above (Appendix B sets forth these costs for each device). Therefore these costs can be viewed as the upper bound of annual costs to be incurred in any AQCR employing hardware oriented transportation controls.

TABLE 4

ANNUAL EXPENDITURES FROM VARIOUS FINANCING TECHNIQUES

	Household Income Groups ($Thous)					
	0-3	3-5	5-7.5	7.5-10	10-15	15+
Average # of Cars/household	.48	.81	1.18	1.29	1.48	1.75
Average Age of Car	7.0	6.1	5.7	4.8	4.6	4.0
State Financing*						
1. Fee per Car	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00
% of Income	1.5	.6	.4	.3	.2	.1
2. Avg fee/household	$10.87	$18.35	$26.73	$29.22	$33.52	$39.64
% of Income	.7	.5	.4	.3	.3	.2
Consumer Financing**						
1. Cost per Car	$48.18	$48.34	$50.02	$50.94	$51.58	$53.42
% of Income	3.2	1.2	.8	.6	.4	.3
2. Avg Cost/household	$14.98	$26.29	$37.88	$42.46	$49.49	$61.33
% of Income	.9	.7	.6	.5	.4	.3

*Assumes that the AQCR using transportation controls will finance hardware controls with a 5-year 8% loan, the cost of which is passed on to all vehicle owners over 5 years as an increased registration tax.

**Assumes the owner of the vehicle being modified will finance the capital of the control hardware with a 3-year loan at 18%, the loan is paid off in 3 equal annual payments.

The date in Table 3 clearly indicate that the poor generally own fewer and older cars and therefore in absolute dollar terms, in-use vehicle controls will cost the average poor family less than the average rich family, no matter what the financing technique. However, the relative impact of the costs incurred is always regressive. Whether the control plan is financed through an increased vehicle registration tax[1/] or consumer loan, the poor household will always pay relatively more of its income. It should be noted however that using our financing assumptions the data indicate that a uniform registration tax is no less regressive than consumer financing (assuming the rich and poor can get similar financing terms) and that in absolute terms the poor family would actually pay less if it could finance the installation of emissions control systems itself ($14.98 for 3 years compared to $10.87 for 5 years).[2/]

- Cost-Effectiveness

The cost-effectiveness of the control techniques shown in Table 2 can best be described in terms of the pounds of pollutants controlled per dollar expended on the control device. Tables 5 and 6 describe the cost-effectiveness of HC and CO control devices respectively.

1/ The regressiveness of a registration tax can be reduced by reducing the tax with the age of the vehicle.

2/ With a registration tax the poor are forced to share in the control costs of the multi-car rich.

a. HC Controls

The data in Table 5 show that control techniques designed to reduce HC emissions from pre-controlled vehicles and service stations are clearly the most cost-effective. However, one must not confuse cost-effectiveness with the relative importance of a control technique in eliminating a regional air pollution problem. The figures in parentheses in Table 5 show the reductions in total HC emissions from the implementation of each control technique.[1/] These data show that the use of pre-controlled vehicle retrofits in 1977 (Air Bleed or VSAD) will reduce total HC emissions in the air quality region by only approximately 1%. Therefore, the cost-effectiveness of pre-controlled vehicle retrofits are very high, but they achieve relatively little in the way of improvements in air quality. Conversely, measures such as I/M and catalytic retrofits, which are applicable to controlled vehicles, have relatively low cost-effectiveness but higher air quality impact. Gasoline marketing controls prove to be both important and cost-effective in eliminating regional HC emissions. Finally, it should be noted that I/M is a pre-requisite for all retrofit measures owing to the need to keep the retrofit devices in

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[1/] Calculations based on a region with 30% stationary source HC contribution such as Philadelphia, Baltimore and Indianapolis.

good operating condition. Hence, it is not possible in practice to select an approach such as VSAD, for example, based on its high cost-effectiveness and implement it without inspection/maintenance.

TABLE 5

COST-EFFECTIVENESS OF HC CONTROL TECHNIQUES*

	Date of Program Implementation**	
	1977	1980
I/M (all cars)	1.64 (3.6%)	.54 (1.5%)
Catalyst ('72-'74)	1.79 (3.77%)	1.31 (3.0%)
Catalyst ('68-'74)	1.90 (5.5%)	1.23 (3.6%)
Air Bleed (pre-1968)	5.48 (1.0%)	5.20 (.5%)
VSAD (pre-1968)	6.91 (1.2%)	8.36 (.6%)
Gasoline Station Controls	10.67 (7.1%)	11.56 (9.6%)

*Cost-effectiveness increases with the size of the figure.
**The cost-effectiveness of the 1976 HC standard is 3.7.

b. CO Controls

The cost-effectiveness calculations for CO controls follow a progression similar to that seen for HC controls. Retrofit devices for pre-controlled vehicles again prove to be the most cost-effective but measures for controlled vehicles have the greatest impact on air quality. However, the CO emissions reductions (shown in parentheses) achieved by these control techniques are considerably higher than those achieved for HC. Air bleed retrofits, for example, yield a 7.1% reduction in total CO emissions in 1977, while air bleed only yielded a 1% reduction for HC. The relative importance of CO control techniques is generally higher because regional CO problems are caused primarily by motor vehicles. Again, inspection/maintenance is a pre-requisite for retrofit.

TABLE 6

COST-EFFECTIVENESS OF CO CONTROL TECHNIQUES*

	Date of Program Implementation**	
	1977	1980
I/M	17.5 (7.7%)	8.8 (6.3%)
Catalyst ('72-'74)	20.0 (8.4%)	15.2 (9.2%)
Catalyst ('68-'74)	24.7 (14.5%)	15.5 (11.8%)
VSAD (pre-1968)	31.8 (1.1%)	40.9 (.7%)
Air Bleed (pre-1968)	194.0 (7.1%)	192.7 (4.9%)

*Based on an AQCR with 5% stationary source contribution such as Seattle, Phoenix and Minneapolis.

**The cost-effectiveness of the 1976 new car CO standard is 32.9.

- Summary

The data cited above on the cost-effectiveness and importance of various emissions controls lead to a number of conclusions about these control techniques:

a. Service station vapor controls - the control of service station vapor losses is both highly cost-effective and important in controlling regional HC emissions (these factors also grow with time). Therefore, these control systems should be developed and implemented as early as is technologically feasible.

b. Inspection/maintenance - although relatively cost ineffective, I/M is an essential component of nearly all transportation control plans, because it is needed to assure the proper installation and performance of vehicle retrofits as well as new car emissions control devices. In addition, its effectiveness in improving air quality is relatively high as it is applicable to both pre-controlled and controlled vehicles.

c. VSAD and Air Bleed - retrofit devices designed to control the emissions of pre-controlled cars are relatively more cost-effective than other retrofit devices. However, having said this, it must also be pointed out that the use of these devices (particularly in control of HC) will not substantially reduce total regional emissions because they can be installed on only a relatively small group of vehicles (pre-1968).

d. Catalyst - the control of 1968-1974 automotive emissions with catalyst retrofits will generally provide a substantial reduction in total regional emissions. However, the high initial cost of catalytic systems makes this control technique somewhat less cost-effective than those designed for pre-controlled cars.

C. Reductions of Auto Use

Increasing public awareness of the adverse effects of the automobile on the urban environment, and legislation such as the Clean Air Act that has resulted from this awareness, make it clear that urban development policies that have encouraged and relied upon unrestricted use of the automobile must be changed. Controls must be placed on automobile use; transit must be subsidized to at least the same extent as the automobile, and means must be found to prevent future urban growth from generating large volumes of traffic. The need to reduce urban area auto use is no longer at issue. The problem is how to do it without excessively restricting the mobility of urban area residents.

Among the possible approaches to the solution of this problem, increased transit usage and quality seem to offer the greatest potential for success over the long run. Other possible approaches include increased carpooling, reducing trip frequencies or trip lengths, and direct vehicular restraints (e.g., vehicle free zones). The potential merits and limitations of transit improvements, increased use of carpools, and direct vehicular restraints are discussed in the following sections. Present knowledge does not permit meaningful discussion of the problem of reducing trip frequencies or lengths without excessively impairing mobility.

1. Improved Transit

It is well known that transit usage in the United States is extremely low. Only about four percent of person trips in urban areas take place by transit, and transit carries only about 14 percent of work trips. However, transit vehicles emit less carbon monoxide and hydrocarbons per passenger mile than cars do. Thus, total vehicle emissions could be considerably reduced if more people would travel by transit instead of by car. For example, if the percentage of work trips using transit could be increased to 50 percent, urban area vehicle emissions of HC and CO might be reduced by 15 percent. If 90 percent of workers used transit, vehicle emissions could decrease by one third.

The low level of transit ridership in the United States is frequently attributed to America's "love affair" with the automobile, but there are more tangible reasons as well. For example, nearly 50 percent of urban area residences are located three or more blocks from the nearest transit stop, and 30 percent are six or more blocks from the nearest stop. Transit routes are strongly downtown oriented, but only about 10 percent of trips go downtown. Transit trips take nearly twice as long as auto trips. And, auto parking costs tend to be heavily subsidized, averaging only $0.75 per day in downtown areas although commercial rates can exceed $3.00 per day. Clearly, present transit service in the United States does not offer a very attractive alternative to the automobile.

There are many ways of increasing the attractiveness of transit relative to the automobile. Bus travel times can be reduced by giving buses priority treatment on streets and freeways. The distances between residences and bus stops can be reduced. Schedule frequencies can be increased. Suburban and crosstown service can be expanded. Fares can be reduced, and auto parking or road use charges increased.

There is a growing body of evidence indicating that high quality transit can attract high levels of ridership, particularly when auto use is expensive or difficult. For example, the Shirley Highway Express in the Washington area, whose buses operate in lanes that are separated from automobile traffic, has achieved a peak period ridership of nearly 40 percent. Before the service started, ridership was 27 percent. Average ridership in the Washington area is only 19 percent. In Los Angeles charter buses are being used to carry workers from outlying residential locations to industrial employment centers. Service is provided on a subscription basis at a cost less than that of the automobile. The bus operator estimates that the bus service carries over 90 percent of potential users and is now constrained from expanding the service by lack of vehicles. In Chicago, and New York City, where downtown auto use is difficult and expensive, 70 to 90 percent of downtown trips take place by transit. In addition, EPA studies suggest that if transit travel times can be made comparable with auto travel times, as many as 50 percent of work trips would take place by transit. If auto drivers had to pay $2.00 to $5.00 per day to park, work trip transit ridership could exceed 90 percent if the transit were available. These considerations indicate that high quality transit can achieve high levels of ridership without the imposition of such extreme measures as gasoline rationing. In other words, the most important transit problem is not one of finding ways to generate demand but one of creating high quality transit systems to serve the potential demand.

Planning and implementing substantial transit improvements are likely to present severe problems in the period 1973-77 owing to the difficulties of designing suitable transit systems and acquiring the necessary vehicles. Existing transit does not have the capacity to achieve large reductions in auto use. Most urban transit systems operate at more than 75 percent of capacity during periods of peak work travel. EPA calculations indicate that with this level of capacity usage, the maximum reduction in auto use that can be achieved by existing transit fleets is about five percent. Achieving a 10 to 20 percent reduction in auto use could require expansions of current transit fleets of at least 50 percent and possibly over 300 percent. Threefold fleet expansions in many urban areas could exceed the short-run production capacity of the bus manufacturing industry. In addition to bus production problems, there appear to be significant short-run planning problems. Most existing urban area transit plans are projected to achieve decreases in auto use of less than 10 percent. The most ambitious transit plan that has come to EPA's attention, that for the Washington Metro System, is projected to be capable of achieving a 20 percent reduction in auto use if it were fully implemented in 1976. In fact, the system will not be completed until 1983. These production and planning problems suggest that although the potential for reducing auto use through improved transit is large, it may be unrealistic to expect reductions greater than 10 to 20 percent by 1977.

The cost of bus transit depends on the detailed characteristics of the bus system, notably on vehicle occupancies. Transit buses cost roughly $1.00 per mile to operate compared with $0.07 per mile for cars. Hence, a transit system that carries roughly 40 riders per vehicle round trip will cost about the same as the auto. Higher occupancy systems might achieve net savings of $100 per rider per year. However, with low occupancies costs could reach $900 per commuter per year. There is clearly a potential for achieving substantial emission reductions at a net cost savings through increased use of bus transit. However, precise cost estimates will not be possible until detailed plans for emissions-control oriented transit systems have been developed.

2. Carpooling

Average automobile occupancy in the United States is about two persons per car. For work trips auto occupancy is about 1.4 persons per car. Since the average automobile is capable of carrying at least four persons, these statistics suggest that substantial reductions in automobile use may be achievable through increased use of carpools. The use of carpools as an emissions control approach has the additional attraction of having a low, possibly negative, cost.

The principal problem with increased carpooling is that carpools are highly restrictive in terms of the service offered. Car-poolers must have trip origins and destinations that are close to each other, must desire to travel at the same times of day, and, to minimize the problems of locating carpool partners, must make trips that are repetitive from day to day. These considerations suggest that the greatest potential for increased carpool usage is in connection with peak period work trips, particularly those to areas of high employment density.

Experience to date with carpool programs suggests that policies to encourage carpooling might double auto occupancies for down-town peak period work trips. These trips are responsible for about seven percent of urban area auto travel. Non-downtown peak period work trips account for roughly 20 percent of urban area auto travel. There has been very little experience with carpooling programs in connection with these trips. However, if a 10 percent to 50 percent increase in auto occupancy is adopted as a realistic range of possible effects, the net effect of carpool policies on total urban area auto use might be a five to ten percent reduction.

Carpooling and transit appear to be competitive, not complementary, approaches to reducing auto use. Both approaches operate most easily in connection with peak period work trips to high density areas, and transit improvements tend to attract carpoolers from their pools. It is therefore unlikely that the effects of transit and carpooling on auto use will be additive. For example, if transit improvements alone can achieve a 15 percent reduction in auto use and carpooling alone can achieve a 10 percent reduction, the auto use reduction obtained from implementing both approaches together is likely to be less than 25 percent. Since, in addition, transit appears to have a greater long-term potential for reducing auto use than does carpooling, carpooling may be most suitable as an interim approach to auto use reduction that can be replaced by improved transit as it becomes available.

Carpooling programs appear capable of achieving net cost savings. A carpool program for the Washington, D. C. area based on a locator system and increased parking fees has been estimated to require an initial investment of $1.3 million and to have operating costs of

$0.6 million per year. If this system achieves a three percent increase in auto occupancies for peak period downtown work trips, the savings it achieves in auto operating costs will equal the annualized costs of the system.

3. Vehicular Restraints

Traffic and emissions in urban areas can be reduced through the use of vehicular restraints such as traffic free zones, partial traffic bans, parking restrictions, and vehicle use charges. With the exception of traffic free zones, all of these approaches to traffic restriction are applicable, in principle, over entire urban areas. However, to minimize community disruption, their widespread use can be effected only if suitable transit facilities are available. The possible effects of restraint measures are discussed here with the assumption that either the necessary transit is available or the restricted zones are small enough to be accessible on foot.[1/]

[1/] The complementarity between transit and vehicular restraints serves to facilitate transit as well as the restraints. By relieving congestion in high density areas, vehicular restraints can significantly contribute to fast, reliable transit service. Indeed, the effect of vehicular restraints combined with transit improvements could be to make transit travel faster and more reliable than cars were under congested, pre-restraint conditions. The quality of the transportation system would, thus, be improved for all travellers including former auto users who switched to transit.

Total traffic bans are the only forms of vehicular restraints with which there has been extensive experience. Traffic is banned from portions of the central districts of over 100 cities in Europe and Japan. The affected areas are typically small (less than 1 km maximum dimension) owing to the need to provide foot access to the zones. Reductions in 5 to 10 hour CO concentrations of 50 percent to 80 percent have been reported. No effects on oxidant have been reported, but they are undoubtedly small.

Available evidence from Europe and Japan indicates that traffic bans have a beneficial effect on retail business in the ban areas. Indeed, some merchants in Rome are reported to have gone on strike to protest their street's exclusion from a traffic free zone. Long-term traffic bans have tended to be linked with measures to increase parking and transit availability on the periphery of the ban areas. There is no evidence of increased pollution or congestion in peripheral areas.

Traffic free zones are necessarily restricted in size owing to the need to provide foot access. Restricted areas might be expanded considerably (perhaps to one square mile) through the use of partial traffic bans. These could consist of applying restrictions only to private autos; enforcing restrictions only during selected portions of the day; enforcing restrictions only on selected roadways; linking several small traffic free zones by corridors to which access is not restricted, or licensing vehicular access to selected areas. The potential benefits and problems of the various approaches appear to be similar; increasing the size of the restricted areas and the stringency of estrictions tends to increase the potential air quality improvements but also tends to increase problems of access, circulation, and peripheral congestion and pollution. There has been no experience with partial traffic bans in relatively large areas. Many of their potential problems may be solvable. Thus, programs of experimentatinn with the various types of restrictions could be of considerable value.

The use of parking restrictions to reduce auto use and emissions has attracted much recent interest. The only known data on the effect of parking restrictions on air pollution are from an experiment in Marseilles, France, where a comprehensive parking ban in the central city was found to reduce local CO concentrations by 40 percent.

In downtown areas, the total supply of parking spaces tends to exceed parking demand by about 30 percent. On-street parking accounts for only about 13 percent of the downtown parking space.

About 45 percent of downtown parkers are commuters. It thus appears that downtown parking restrictions will be most effective if they are directed at both off- and on-street parking, are structured to take account of varying degrees of excess capacity among parking facilities, and are designed to encourage commuters to use transit or carpools.

Increasing the cost of auto travel relative to other modes is another frequently suggested approach to reducing auto use. Measures to raise auto costs include increased registration fees, increased fuel costs, road use charges, parking taxes, and the sale of daily licenses for access to selected areas within a city. There has been little experience with any of these measures. Indeed present public policy tends to work in the opposite direction from the one desired: registration fees are often lower for old, heavily polluting cars than for newer and cleaner ones; tolls are imposed to pay for facilities when they are new and uncrowded but are removed when the facilities are paid for, which is when they are most needed; monthly auto commuter tickets are available at a discount under daily tickets; and all-day parking is frequently cheaper per hour than short-term parking.

When auto charges are keyed to daily auto use, the net cost per trip is presumably what influences people's decisions as to mode and frequency of travel. In the discussion of transit it was suggested that a \$2.00 to \$5.00 per day charge for auto work trips could cause substantial shifts of commuters to transit if adequate transit were available. Daily costs in this range could be imposed directly through parking or access license fees. An equivalent mileage charge would be \$0.10 to \$0.25 per mile for a 10 mile commute. A fuel tax of \$1.40 to \$3.50 per gallon might be roughly equivalent, although the effect of the fuel tax on a given commuter would depend on the fuel consumption of his car.

There is evidence that non-work trips, particularly shopping trips, are at least as sensitive to fees as work trips. However, it is not known to what extent this sensitivity reflects changes of mode, destination, or trip frequency in response to costs. Thus, while it is likely that auto use fees will be effective in discouraging non-work auto travel, the effects of such fees on discouraged travellers and on economic activity cannot be assessed at present.

AIR QUALITY CONSIDERATIONS

The foregoing sections have considered the effects on auto emissions of various emissions control approaches when each is implemented independently of the others. However, transportation controls in most regions needing them will involve combinations of two or more individual control measures. In this section the combinations of measures included in regional transportation control plans are discussed; the effects on air quality of these groups of measures are assessed, and some important uncertainties in forecasts of the air quality effects of transportation controls are identified.

It was noted earlier that the application of stringent stationary source controls and the Federal new car emissions standards should of themselves reduce the number of AQCRs projected to exceed the ambient air quality standards in 1975 to about 29. EPA is in the process of finalizing and approving in-use vehicle control plans for these 29 air quality control regions. These plans, depending upon the magnitude of the problem in the individual regions, include some combination of the measures discussed previously, along with specific measures tailored to the needs or circumstances of the individual region.

Of these 29 regions, it is expected that El Paso, Rochester and Cincinnati can achieve the standards by 1975 through the implementation of an inspection/maintenance program and improvements in existing transit systems. However, these three regions are projected to achieve the air quality standards by 1977 through the influx of new vehicles alone.

An additional 7 regions, including Springfield, Seattle, Spokane, Dallas, Mpls-St. Paul, Chicago and Portland, are projected to meet the air quality standards by 1975 through the use of an inspection/ maintenance system and substantial improvements in transit. The remaining 19 regions all require hardware retrofits, an inspection/ maintenance program, and/or significant reductions in vehicle usage to achieve the standards by 1975. However, lead time constraints on the implementation of major traffic controls and transit improvements, and on the installation of various emissions hardware controls have pushed the date of air quality standard attainment beyond 1975 for these regions.

Of the 19 regions sighted above, only six regions, including Philadelphia, Pittsburgh, National Capital, Salt Lake City, San Antonio and New York City (CO only)[1/], can achieve the air quality standards by 1977, but only with the use of emissions control retrofits as well as major transit improvements and/or other measures that substantially reduce vehicle use by up to 20 percent.

[1/] The downtown New York City CO problem should be cleaned up in 1977; but the areawide oxidant problem, involving portions of New York, New Jersey and Connecticut, will require reductions in emissions areawide which are beyond present expectations for 1977.

Based on EPA's present analysis, the remaining 14 regions of Phoenix, Baltimore, Boston, Denver, New York City (OX only), San Joaquin, San Diego, Southeast Desert, Sacramento, Los Angeles, San Francisco, Houston, Beaumont, and Fairbanks probably cannot be reasonably expected to meet the air quality standards even by 1977. Compliance with the air quality standards in these regions appears to require not only inspection/maintenance and the fullest possible vehicle retrofit, but also reductions in vehicle use of substantially more than 20 percent. In light of the limitations on the short-run potential for reducing auto use, achieving the air quality standards by 1977 is likely to require unreasonable changes in the present life styles of those regions and could result in the paralysis of entire urban areas. Final determination however, of both the exact reductions in traffic required and the feasibility of achieving those reductions cannot be made until information presented during the public hearings on the plans can be analyzed to determine exactly what each of the regions can do in terms of transit improvement and traffic reduction by 1977.

Additional reductions due to the influx of new, cleaner vehicles will make compliance in nearly half of these remaining 14 regions a reasonable post-1977 goal. However, those regions with the most severe oxidant problems are not expected to achieve the standard without improvements in transit systems, land use, and stationary source control technology which are not presently available.

Table 7 summarizes EPA's present assessment of a feasible compliance schedule.

TABLE 7

STATUS OF REGIONS REQUIRING IN-USE VEHICLE EMISSIONS CONTROLS TO MEET THE OXIDANT AND CARBON MONOXIDE STANDARDS 1/

Group	Regions	Planned Strategy	Projected Year of Compliance
I	El Paso Rochester Cincinnati	Stringent stationary sources control; automotive inspection and maintenance	1975
II	Springfield Seattle Spokane Dallas Minneapolis-St. Paul Chicago Portland	Same as Group I + major transit improvements	1975
III	Philadelphia Pittsburgh National Capital Salt Lake City San Antonio Downtown NYC (CO)	Same as Group II + hardware retrofit + reductions in vehicle miles travelled (VMT) of up to 20%	1977
IV	Los Angeles 2/ San Francisco Denver Boston Phoenix-Tucson Beaumont 3/ Fairbanks Sacramento San Diego San Joaquin S. E. Desert 4/ Interstate NYC Region (OX) Baltimore Houston	Same as Group III but with VMT reductions over 20%	Post-1977

1/ This allocation of regions represents the findings of our analysis at this time. Public hearings being held in these regions could lead to some shifts in this categorization.

2/ Group IV regions include some which may require only marginally more than 20% reduction in vehicle miles travelled (Boston, San Joaquin) and some which have serious stationary source problems (Houston, Beaumont).

3/ Measures still being considered.

4/ Standards to be achieved through Los Angeles plan.

- Air Quality Projection Sensitivity

Projections of emissions and air quality, and the resultant determination of which regions will or will not meet the standards are critically dependent upon numerous assumptions. Emissions projections in each region are characterized by a given baseline pollutant level (observed peak CO and oxidant levels in a given year), the relative degree of emissions contribution from various sources, the projected trends in emissions sources' growth, the types of controls to be initiated and continued, and the emissions reduction effectiveness of control measures. The air quality projections are very sensitive to minor variations in the assumptions cited above.

The analysis of the oxidant and carbon monoxide compliance schedule presented above is based on our best present knowledge of the factors contributing to the achievement or non-achievement of the standards. However, because of the sensitivity of any air quality projection to relatively small uncertainties in input data, this analysis is fraught with uncertainties. The air quality impact of shifts in some of the key inputs is discussed below.

1. Emissions Inventory

The emissions inventory is an attempt to identify and quantify the sources of emissions in our urban areas. Both the magnitude of the emissions and the role they play in the development of the observed high pollutant concentration are difficult to define. Particularly in the case of hydrocarbon control, errors in the inventory can significantly alter the outcome of an emissions projection. The contribution of stationary sources (gasoline marketing, petroleum industry, paint and organic solvent use) is about 20 to 40 percent in most metropolitan areas. However, our knowledge concerning these types of emissions sources and the exact quantities and types of hydrocarbons they emit, is limited. Furthermore, an error in assessing the importance (reactivity) of these emissions in the formation of oxidant will also have a marked impact on the air quality predicted.

2. Growth Rates

The growth rates of emission sources are another possible source of error in these projections. If the number of sources or size of the sources grow faster than we have predicted, the percentage reduction in emissions needed for achieving and maintaining the air standards will be greater.

3. Control Strategy Effectiveness

The projections of emissions reflect reductions in emissions due to in-use vehicle controls; Federal new vehicle emission standards for automobiles, trucks, and buses; and Federal new source performance standards for certain categories of stationary sources. They also reflect substantial reductions in emissions from new and existing stationary sources due to present and planned State and local regulations.

State and local control of stationary source hydrocarbon emissions can be extremely important. For example, if an air quality region has a 30 percent stationary source hydrocarbon contribution in 1970, by 1977 a 20 percent reduction in the emissions of these stationary sources can be as important as a 24 percent reduction in traffic. If the stationary sources continue to be uncontrolled through 1985, a 20 percent reduction in their emissions at that time could be equivalent to 100 percent elimination of the automobile.

One can see from this comparison that stationary source control is going to be another critical facet of the overall implementation strategy. The projections of emissions used in the plans assume very effective stationary source control programs for most of the regions. The effectiveness of these programs will depend upon the formulation, promulgation and active enforcement of strong regulations and the ability of the industry to apply the needed control techniques. Failure in any of these areas will greatly jeopardize the achievement and maintenance of the standards. One area of particular concern and uncertainty is the precise manner in which many of the regulations for solvent users are written. That is, many regulations now on the books restrict emissions of only the more reactive classes of hydrocarbons. The true effectiveness of such regulations and the possible impact on air quality of not controlling the less reactive (but not inert) hydrocarbons is not known at this time.

4. Baseline Air Quality

High concentration of air pollution are the result of adverse (stagnant) meteorological conditions and the accumulation of emissions in the air under these conditions. In determining the allowable amount of emissions for a given region, one must know the maximum observed pollutant levels (the second highest level is used in some air quality projections)[1/] and the rate of emissions during that year.

Unfortunately, meteorological conditions are not consistent from year to year. Because of this, the meteorological conditions causing the observed high levels of pollutants used in our projections may not be representative of a region's real potential for achieving the air quality standard in a given time period. In addition, one must keep in mind that even if the baseline air quality levels assumed in our

[1/] The air quality regulations allow the standard to be exceeded once a year.

analysis are statistically representative of a once-a-year occurrence, that is no assurance that meteorological conditions in some AQCR's won't lead to violations of the ambient air quality standards at some point in the future.

- <u>Sensitivity of Compliance Schedule for 1977</u>

Many of the AQCR's have projected air quality levels very near the standards in 1977. For this reason, slight errors in the assumptions used to predict the air quality can greatly affect our count of those regions which will or will not comply with the standards. Table 8 shows the impact of overestimating or underestimating two of the most critical variables: baseline air quality and base-year contribution of stationary sources. The data show that if errors were consistently made in one direction or the other a difference of 15 regions in or out of compliance could result. It also indicates that our estimate of only 14 regions not being in compliance by 1977 is probably optimistic.

This high degree of sensitivity and uncertainty would further suggest that our ability, or anyone else's ability, to make a firm commitment on exactly which regions will or will not comply by a given date is somewhat limited unless, of course, one applies a very large margin of safety to the allowable emissions ceiling.

TABLE 8

IMPACT OF ANALYTICAL UNCERTAINTIES
ON REGIONS REQUIRING IN-USE VEHICLE CONTROLS
IN ORDER TO COMPLY WITH OXIDANT AND CO STANDARDS

Impact of Uncertainties	Do not Comply in 1977*	Comply in 1977
Base Case	14	15
Favorable**	10	19
Unfavorable***	25	4

*Assuming VMT reduction over 20 percent is not feasible.
**Baseline air quality and stationary source contribution over-estimated; growth rate and control effectiveness assumed correct.
***Baseline air quality and stationary source contribution under-estimated; growth rate and control effectiveness assumed correct.

- Improvements in Air Quality

In spite of the analytical uncertainties in this compliance analysis and our serious doubts that several large cities will be able to comply with the 1977 deadline, there is no doubt that the air in the United States will be cleaner in the next decade than it has been in the last two decades. Figures 1 and 2 give a comparison of air quality now and that expected in 1977. The plots show cumulative population of the regions vs. the maximum level of pollution observed in that region; for all regions exceeding the standard. Obviously, not every person in a region will be exposed to the maximum level for that region and these plots must not be construed as representative of actual individual exposures. These plots do, however, give a relative indication of the magnitude of the air pollution problem today and the amount of improvement we can expect by 1977. One can see that even in those areas still in excess of the standards in 1977, great reductions in the air pollution levels will have been accomplished. In addition, most of these regions will be very near to the standard.

FIGURE 1
OXIDANTS

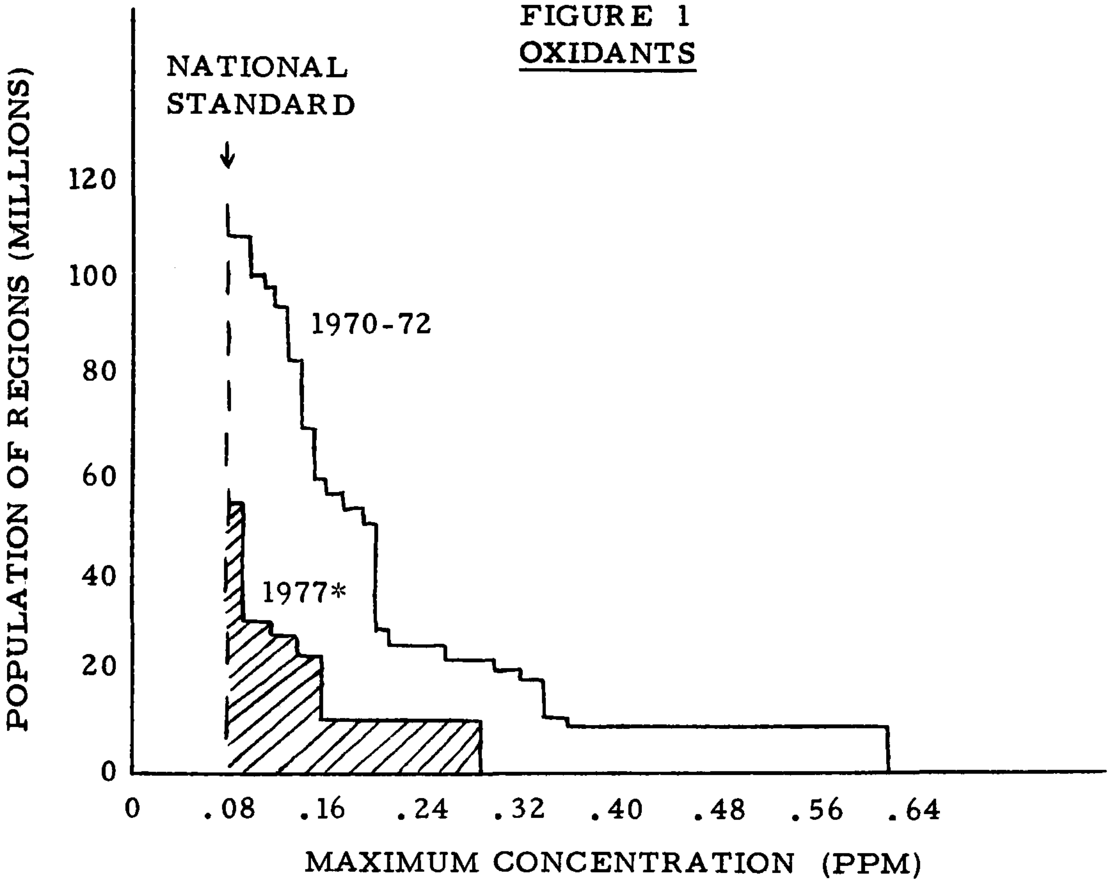
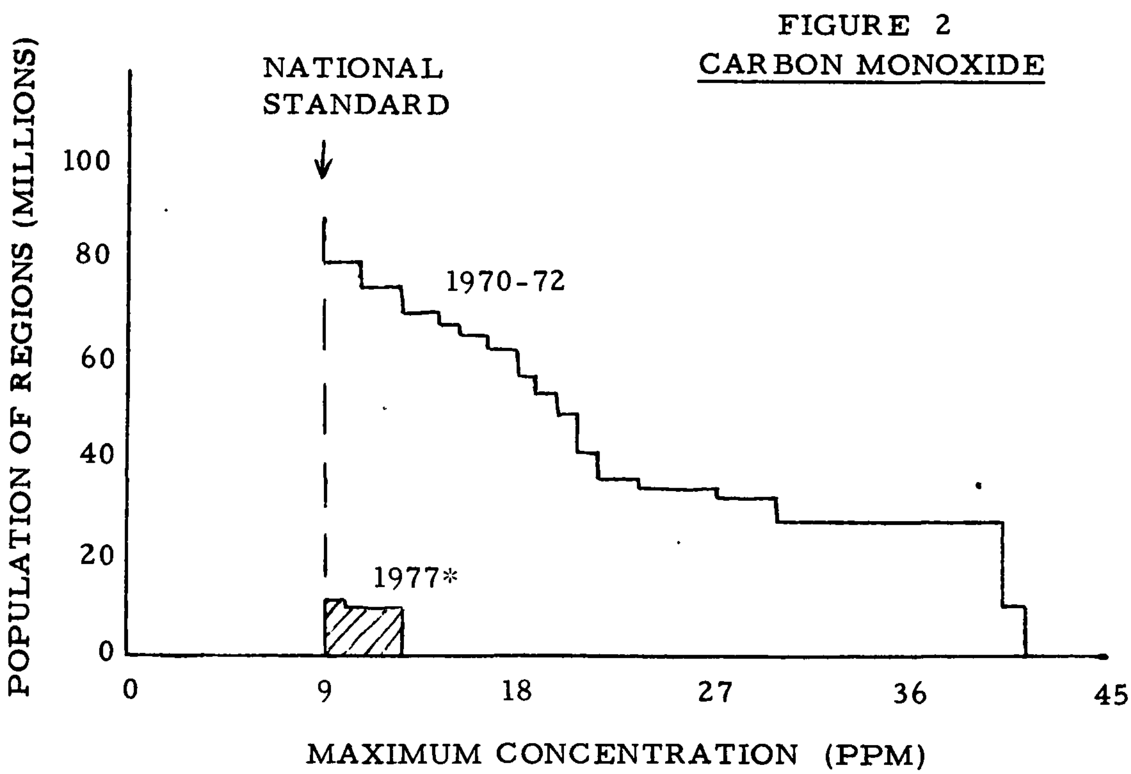


FIGURE 2
CARBON MONOXIDE



*Assuming I/M, retrofits, stationary source controls and 20 percent reduction in auto use.

APPENDIX A - Regions exceeding the Air Quality Standards for CO, NO_2 and Oxidants (1969 to 1971 monitoring data)

AQCR	Pollutant OX	CO	NO_2	AQCR	Pollutant OX	CO	NO_2
Birmingham	X	X		Boston	X	X	
Mobile - Pensacola	X			Toledo	X		
N. Alaska		X		Minn.-St. Paul		X	
Clark - Mohave	X	X		New Jersey		X	
Phoenix - Tucson	X	X		Alb.-Mid Rio Grande	X		
Memphis	X			El Paso-Las Cruces	X	X	
Los Angeles	X	X	X	Genesse-Finger Lakes	X		
N. Central Coast	X			Niagara Frontier	X	X	
Sacramento Valley	X	X		Charlotte	X		
San Diego	X	X		Cleveland	X		
San Francisco	X	X		Columbus	X		
San Joaquin	X	X		Central Oklahoma	X		
S. E. Desert	X			N. E. Oklahoma	X		
Denver	X	X		Portland	X	X	
Hartford - New Haven	X	X		S. W. Pennsylvania	X	X	
NY-NJ-Conn	X	X		Middle Tenn.	X		
Philadelphia	X	X		Austin-Waco	X		
National Capital	X	X		Corpus-Christi	X		
Jacksonville-Brunswick	X			Dallas-Ft. Worth	X		
E. Wash.-N. Idaho		X		Houston-Galveston	X		
Chicago	X	X	X	San Antonio	X		
St. Louis	X	X		Wasatch Front	X	X	
Louisville	X			Hampton Roads	X		
Cincinnati	X			State Capital	X		
Indianapolis	X	X		Puget Sound	X	X	
S. Central Iowa	X			S. E. Wisconsin	X		
Kansas City	X	X		Central N. Y.	X		
S. Central Kansas	X			Dayton	X		
S. Louisiana-S. E. Texas	X						
Baltimore	X	X					

APPENDIX B

ANNUALIZED INVESTMENT COST OF CONTROL TECHNIQUES PER CAR PER YEAR

	DATE OF PROGRAM IMPLEMENTATION		
	1975	1977	1980
VSAD + Lean Idle			
-State financed*	$ .85	$ .35	$ .09
-Owner financed**	9.20	9.20	9.20
Air Bleed			
-State financed	2.25	1.06	.28
-Owner financed	27.57	27.57	27.57
Catalyst (1968-1971)			
-State financed	4.27	3.18	1.33
-Owner financed	60.49	60.49	60.49
Catalyst (1972-1974)			
-State financed	7.29	6.61	4.65
-Owner financed	52.52	52.52	52.52
I/M Loaded Mode			
-State financed	4.50	4.50	4.50
Gasoline Marketing			
-Industry financed	3.19	3.19	3.19
State's annual fee to all cars*	$21.80-$22.65	$18.54-$18.89	$13.95-$14.04

*Assumes investments are financed by the State at 8% and paid off in 5 equal annual payments.

**Assumes consumer financing at 18% paid off in 3 equal annual payments.

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16. ABSTRACT

Implementing the Federal air quality standards in certain cities will require reductions in automobile emissions greater than those anticipated from new car emissions standards. Methods of achieving the needed additional emissions reductions include mechanical measures, such as retrofit, and measures to reduce auto use, such as transit improvements. By 1977 these measures, taken collectively, appear capable of reducing auto emissions by as much as fifty percent. However, the ability of such automobile controls to achieve satisfactory air quality in a city is highly dependent on the extent of non-automotive emissions sources in the city and on initial pollutant concentrations.

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MONITORING AND AIR QUALITY TRENDS REPORT, 1973

ADDENDUM AND ERRATA

DECEMBER 1974

ADDENDUM

This report is intended to portray recent nationwide air quality trends and air quality status for the year 1973 for air pollutants for which National Ambient Air Quality Standards (NAAQS) have been established. The data used in preparation of this report are the latest available monitoring information reported by the states or collected by EPA and summarized in the National Air Data Bank (NADB). It must be pointed out that the majority of these data were collected in heavily industrialized or populated portions of the country and as such do not reflect the full impact of major point sources such as coal-fired utility plants that are located in nonurban areas. It is estimated that over 97 percent of the monitoring sites were established to monitor urban pollution levels and only very recently have the states' monitoring resources and monitoring priorities been directed to monitoring the effects of large, more isolated pollutant sources.

There are several additional factors that must be considered when using this report to interpret the air quality status of any particular geographical area. First, as explained in the report, the states' monitoring networks are not yet fully established and, thus, do not always represent the full geographical coverage required in assessing air quality. As a consequence, violations of the air quality standards may be presently undetected in some regions. For example, on a nationwide basis, the states' implementation plans propose a total of 698 continuous sulfur dioxide monitors and 1434 bubblers.* As of June 1974, (the cutoff date to prepare summaries for publication), 350 of the proposed continuous instruments (50 percent) and 1104 of the proposed bubblers (77 percent) were reporting at least fragmentary data to the NADB.† There were 59 AQCR's reporting either no data or insufficient data (less than a valid quarter for any station) to support even the most tentative appraisal of the 24-hour standard.

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*Monitoring and Air Quality Trends Report, 1973, Table 3-6, p. 65.

†More stations have been reported to the NADB (422 continuous, 1506 bubblers) but these represent extended networks in certain AQCR's.