WAYS TO REDUCE AIR POLLUTION THROUGH PLANNING DESIGN AND OPERATIONS

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This paper presents a compendium of case examples that illustrate how air pollution emissions and concentrations can be reduced through proper planning, design, and operation of transportation systems and urban development. These reductions are in addition to those obtained by legislative air pollution controls on vehicles and stationary source emissions. Air pollution components discussed consist of carbon monoxide, sulfur oxides, particulates, hydrocarbons and nitrogen oxides. The case studies examined vary from the simulation of work travel and air pollution for a hypothetical city of 2½ million people to individual analyses of air pollution reductions in Twin Cities, Seattle, Montgomery and Prince George's Counties (Maryland), Great Britain, and other areas. With respect to planning, it was found that the spatial arrangement of economic activities, the development of dense corridors to increase transit usage, the diversion of more travel to freely operating freeways, and the reduction of trip length have positive effects on reducing air pollution levels. For design, it was found that concentrations resulting from vehicular pollution can be minimized if the highway is segregated from adjoining structures either by distance or by other open space barriers. When these separations are not possible, ventilation will be required in cases to meet acceptable air quality standards. With respect to operations, the improvement of traffic flow, the use of transport pricing policies, and the use of smaller cars with smaller engines can reduce the pollution levels for carbon monoxide and hydrocarbons significantly.

•A MAJOR concern for society is the quality of life both now and in the future. An important part of that concern is the quality of the air that we breathe. The purpose of this paper is to present a compendium of case examples that illustrate how air pollution emissions and concentrations can be reduced through planning, design, and operation of transportation and urban development. These case studies have been developed as a starting point for a continuing research program to be undertaken by the Air Pollution Control Office of the Environmental Protection Agency, in cooperation with the U. S. Department of Transportaion and the U. S. Department of Housing and Urban Development. This program is directed toward the reduction of air pollution through transportation and urban planning actions in addition to reduction through emission controls.

AIR POLLUTION

Air pollution is usually measured in terms of the concentration over time (dosage) of 5 major types of pollution: carbon monoxide, sulfur oxides, particulates, hydrocarbons, and nitrogen oxides. These pollutants are associated with certain primary emitters and have certain effects in the laboratory and in present regional concentrations. Table 1

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TABLE 1

MAJOR COMPONENTS OF AIR POLLUTION AND ASSOCIATED EFFECTS IN THE TRI-STATE REGION

Pollutant	Primary Emitters	Effects	
		In Laboratory	In Present Regional Concentrations
Carbon monoxide	Motor vehicles	Kills animals	None verified
Sulfur oxides	Power plants, space heaters, industrial sources	Produces respiratory disease	Can shorten life of aged, chronically ill, and very young
Particulates	Power plants and incinerators	Produces infection	Irritating to membranes, increases cleaning cost
Sulfur oxides and particulates combined	Power plants and incinerators	Produces respiratory disease and infection	Can increase death rate of very old, very young, and chronically ill
Nitrogen oxides and hydrocarbons	Motor vehicles and power plants	Produces cancer	Minor eye smarting, due to good air drainage

gives these effects for the Tri-State Region (16). These effects are the major concern and can vary from irritation to eyes to serious health effects such as cancer or even death. These pollutants, on a nationwide basis, have emissions that vary from 100.1 million tons for carbon monoxide to 20.6 million tons for nitrogen oxides as given in Table 2 (17). One of the chief contributors of total nationwide emissions is the motor vehicle, which accounts for as much as 63 percent of carbon monoxide emissions.

To attack these pollution levels, federal, state, and regional goals and objectives have been established. An example of this is the air quality objectives developed by the Air Resources Management Program for Metropolitan St. Louis given in Table 3. They are based on years of research and observation of the effects of air pollution and are designed to protect the health, welfare, and comfort of the public and to minimize economic losses. Because some pollutants combine chemically to form more harmful materials than the original emissions, ascribing a single effect to a single pollutant would be an erroneous oversimplication. The goals, therefore, apply to city air containing a variety of pollutants. Although reaching the goals noted for St. Louis will result in the benefits listed, no allowance for the time needed to achieve them was considered in their selection. These goals are intended to apply to areas where urban activities are concentrated.

To tackle the problem on the vehicle power source and other nonstationary sources, certain legislative standards are being established and provide an effective means for coming to grips with the problem. Figure 1 shows natural emissions of carbon monoxide, hydrocarbons, and oxides of nitrogen for vehicles today and under various legislative standards. These standards will, if adopted and enforced, have a tremendous effect

TABLE 2

ESTIMATED NATIONWIDE EMISSIONS OF 5 MAJOR POLLUTANTS IN 1968

Pollutant	Transportation	Fuel Combustions in Stationary Sources	Industrial Processes	Solid Waste Disposal	Other	Total	Percent of Total by Motor Vehicle
Carbon monoxide	63.8	1.9	9.7	7.8	16.9	100.1	63
Hydrocarbons	16.6	0.7	4.6	1.6	8.5	32.0	52
Nitrogen oxides	8.1	10.0	0.2	0.6	1.7	20.6	39
Particulates	1.2	8.9	7.5	1.1	9.6	28.3	4
Sulfur oxides	0.8	24.4	7.3	0.1	0.6	33.2	2

Note: Amounts are in millions of tons.

TABLE 3

PARTIAL LIST OF AIR QUALITY GOALS FOR ST. LOUIS INTERSTATE AIR POLLUTION STUDY AREA

Pollutant	Goals (maximum permissible concentrations)	Benefits From Achieving Goals
Sulfur dioxide[a]	0.02 ppm, annual average 0.10 ppm, 24-hour average, not to be exceeded for more than 1 percent of the days in any 3-month period 0.20 ppm, not to be exceeded for more than 1 hour in any 4 consecutive days 0.50 ppm, not to be exceeded for more than 5 min in any 8-hour period	Elimination of sulfur dioxide taste and odor from air
Reactive sulfur (sulfation[b])	0.25 mg sulfur trioxide per 100 cm^2 per day, annual average 0.50 mg sulfur trioxide per 100 cm^2 per day, for any 1-month period	Reduced incidence of colds, coughing, throat irritation, broncho-constriction, and other respiratory diseases and symptoms Decreased physical stress on healthy persons Reduced deaths from cardiovascular and pulmonary causes
Hydrogen sulfide[c]	0.03 ppm, ½-hour average, not to be exceeded more than twice in any 6 consecutive days 0.05 ppm, ½-hour average, not to be exceeded more than twice a year	Elimination of odor except to most sensitive persons Elimination of blackening of lead-based and mercury-additive paints Elimination of vegetation damage Elimination of respiratory and eye irritations
Oxidants[d]	0.15 ppm, 1-hour average	Reduced vegetation damage Improved visual acuity Reduced eye, nose, and throat irritation Improved visibility
Carbon monoxide[e]	30 ppm, 8-hour average 120 ppm, 1-hour average	Improved body oxygen supply function Improved reflex time and clarity of thought and sight Decreased incidence of headaches associated with inhalation of carbon monoxide
Total suspended particulates[f]	75 mg/m^3 of air, annual geometric mean 200 mg/m^3 of air, not to be exceeded for more than 1 percent of the days in a year	Reduced vegetation damage Improved visibility

[a]Measured by West-Gaeke or conductometric method.
[b]Measured by lead-peroxide candle.
[c]Measured by lead-acetate-impregnated filer-paper procedure.
[d]Measured by potassium iodide-colorimetric method.
[e]Measured by nondispersive infrared method.
[f]Measured by high-volume sampler.

on reducing total nationwide emissions. The 4 cases for which calculations on these various legislative standards were performed are as follows:

1. No emission controls. All vehicles were assumed to emit hydrocarbons and carbon monoxide at a rate corresponding to that of pre-1968 vehicles.
2. Existing emission standards. All 1968 and later model vehicles were assumed to meet established federal emission standards when new. Exhaust control systems were assumed to deteriorate in effectiveness with age.
3. Proposed 1972 and 1975 standards. In addition to the existing standards included in case 2, proposed 1972 and 1975 standards were included in the calculations. It was assumed that when new all 1972 and 1975 vehicles would meet the standards. Exhaust control systems were assumed to deteriorate in effectiveness at the same rate as for case 2.
4. 1975 application of 1980 emission goals. Exhaust emission goals proposed for 1980 were applied to 1975 model and later vehicles. No 1972 standards were included. Exhaust control systems were assumed to deteriorate in effectiveness at the same rates as for case 2.

With these emission controls, what can the transportation and city planner and engineer do to reduce further not only emissions but also measurable concentrations through planning, design, and operation of transportation systems and urban development? The planner and engineer must have guidelines that indicate the air pollution reductions possible for given actions.

PLANNING

Several studies were developed to illustrate how carbon monoxide, hydrocarbons, and oxides of nitrogen can be reduced through better arrangements of land use and economic activities, the amount and spacing of highways, and higher transit usage. These studies were based on (a) an analysis of simulated travel patterns resulting from alternative urban forms and highway and transit systems in a hypothetical city and (b) an analysis of alternative metropolitan plans in Chicago, Seattle, and the Twin Cities. In addition to the analysis of alternative metropolitan plans, an investigation was also undertaken at a submetropolitan scale to determine the impact of alternative land use and transport arrangements for Montgomery and Prince George's Counties in Maryland.

Hypothetical City Analysis

Travel patterns were simulated (3) for a hypothetical metropolitan area of 625 sq mi and 2½ million people under varying assumptions regarding urban patterns, highway networks, and transit networks. Figure 2 shows these varying assumptions. Eight different urban patterns were investigated. The spatial allocations of population and employment investigated included sprawl, moderate corridors, heavy corridors, corridors rotated, extreme corridors rotated, satellite cities, centralized employment and sprawl population, and centralized employment and radial population.

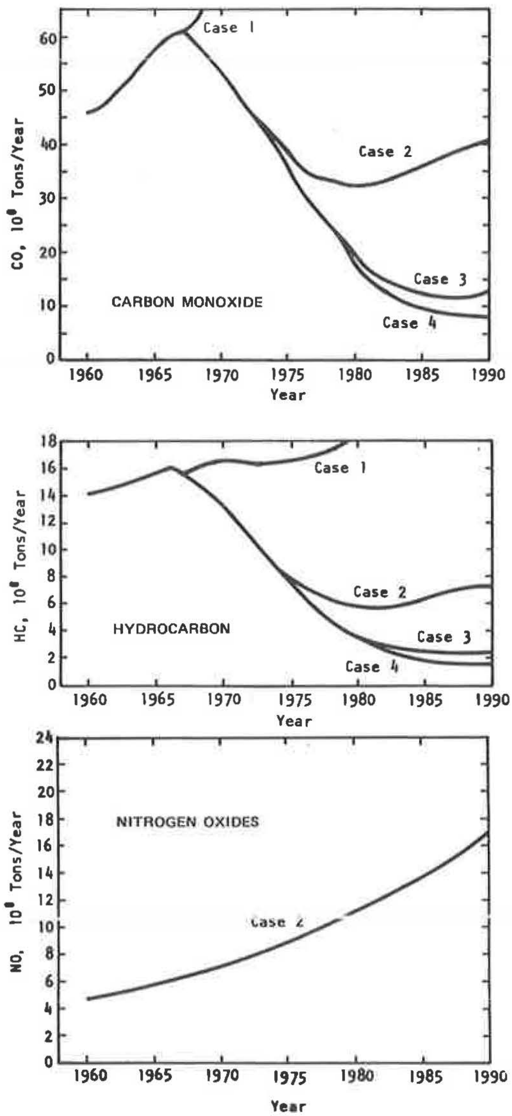


Figure 1. Reduction in carbon monoxide, hydrocarbon, and nitrogen oxide emissions based on various legislative standards.

The following 4 highway networks were examined: basic arterial grid; freeways along major arterials; major radial freeways with an outer beltway and inner loop added; and additional radial freeways and an inner beltway added for maximum coverage. The 3 basic transit networks examined consisted of a basic bus network with express bus service; rapid rail along major radials with bus service; and relocated rapid rail service and an outer rapid rail loop. A series of alternatives were then constructed, and work travel patterns were simulated resulting in estimates of trip length (a surrogate for vehicle-miles of travel), average network speed, and transit usage.

What do the travel patterns for these alternatives indicate with respect to air pollution reductions? Figures 3, 4, and 5 show emissions per vehicle-mile versus average network speed in miles per hour for 3 major air pollutants: carbon monoxide, hydrocarbons, and oxides of nitrogen for post-1975 and pre-1968 emission regulations. For carbon monoxide and hydrocarbons, an increase in average network speed decreases emission rates per vehicle-mile. Increases in average speed, however, cause increases in emissions of oxides of nitrogen.

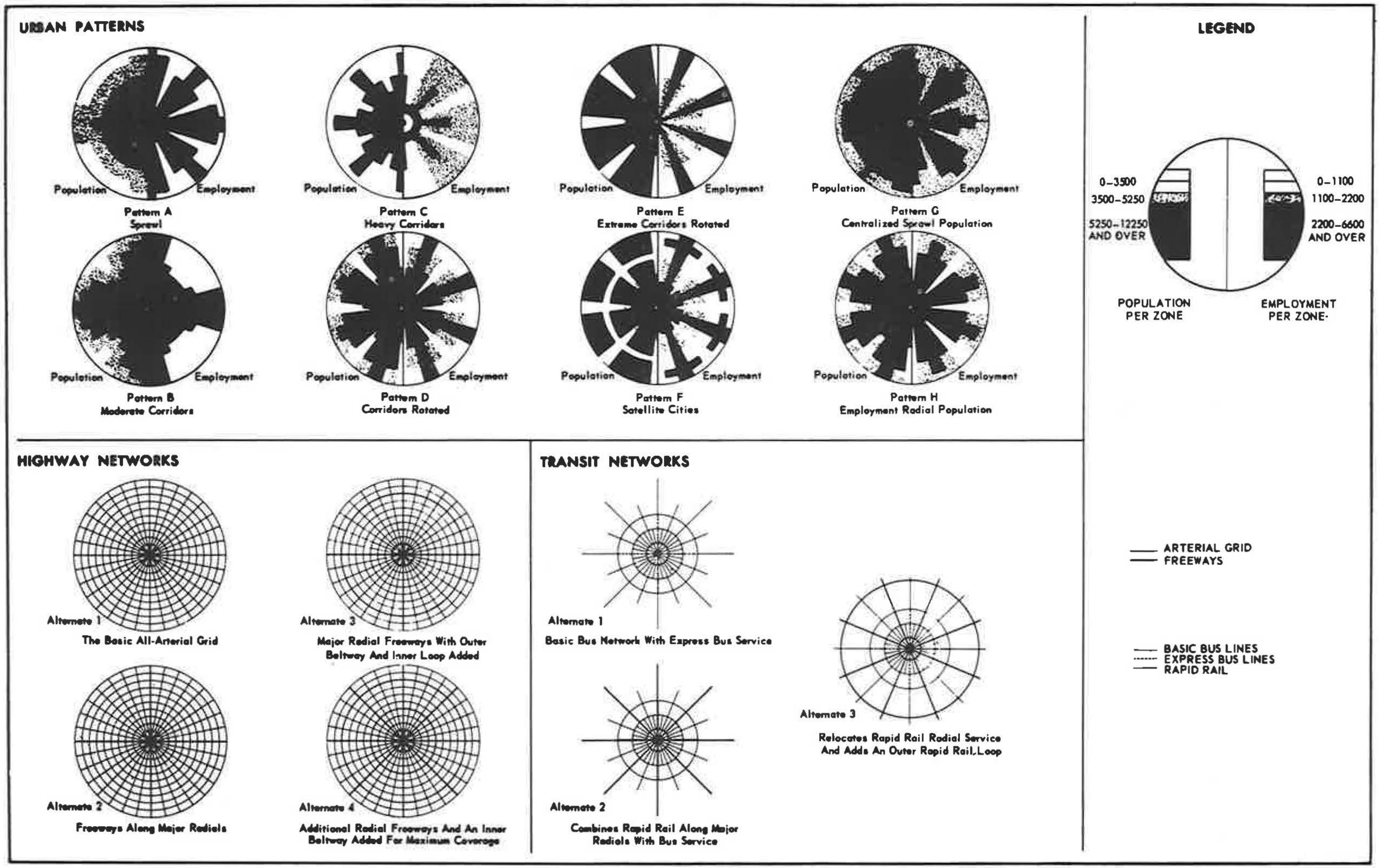
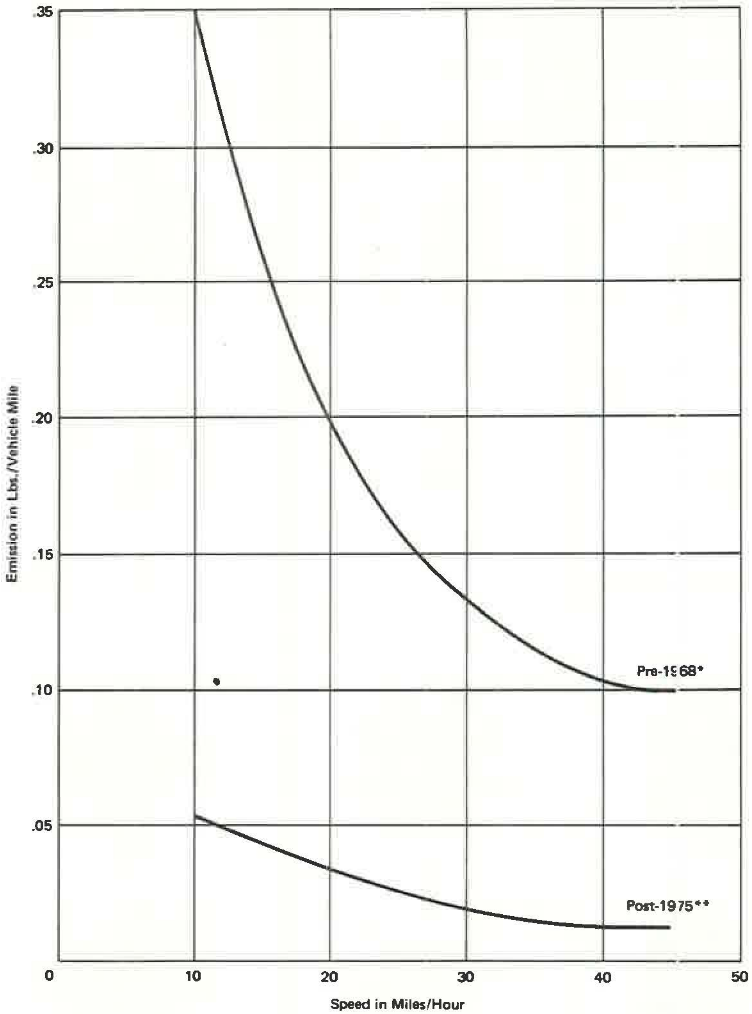


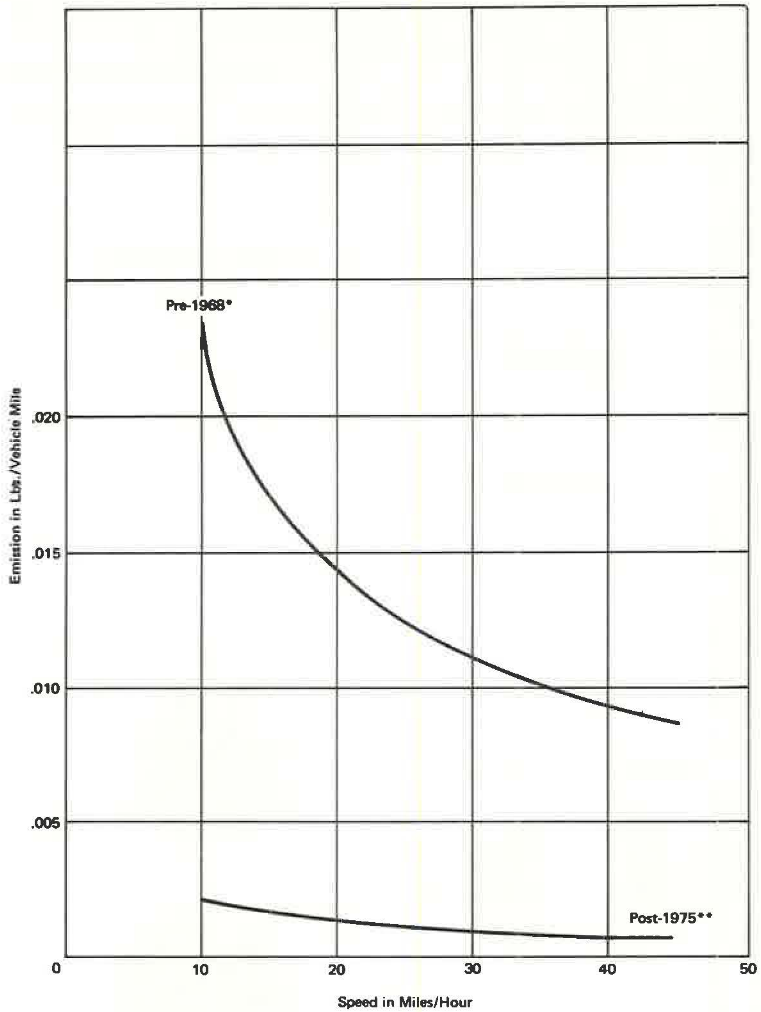
Figure 2. Urban forms and transportation systems in hypothetical city.



* Source: 2nd Report Secretary of H.E.W. to U.S. Congress pursuant to P.L. 88-206 Clean Air Act, 2/19/65, Table 1.

** Based on 1975 Emission Standards Set by U.S. Congress

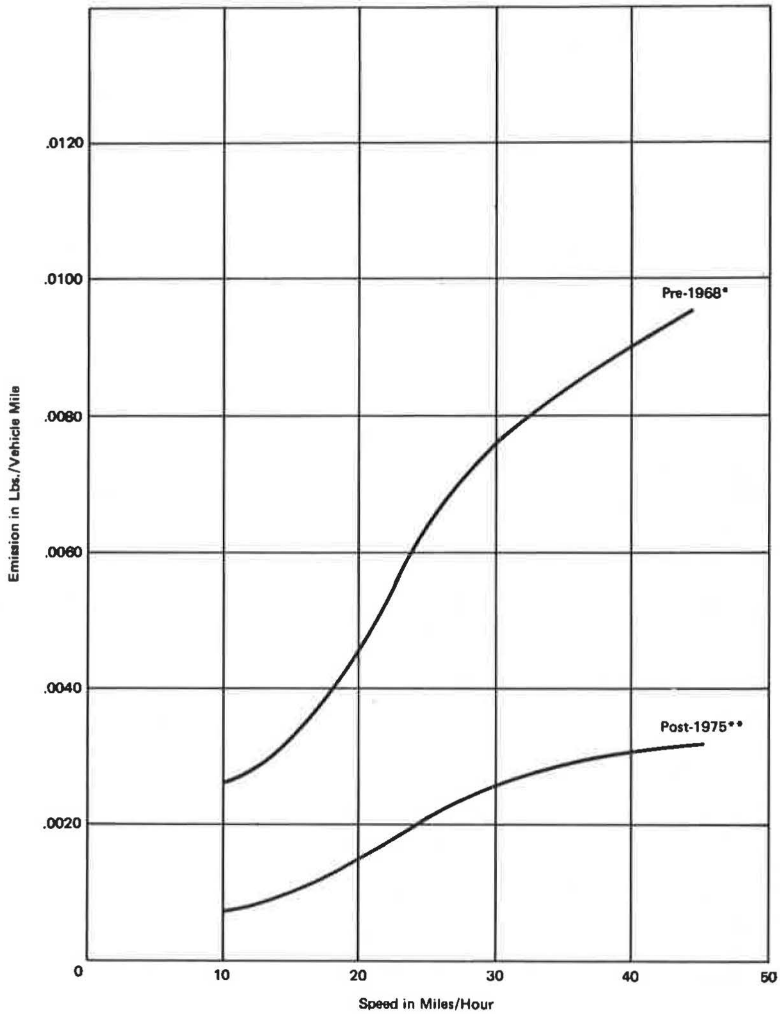
Figure 3. Carbon monoxide vehicular emission versus speed.



* Source: 2nd Report Secretary of H.E.W. to U.S. Congress pursuant to P.L. 88-206 Clean Air Act, 2/19/65, Table 1.

** Based on 1975 Emission Standards Set by U.S. Congress.

Figure 4. Hydrocarbon vehicular emission versus speed.



* Source: 2nd Report Secretary of H.E.W. to U.S. Congress Pursuant to P.L. 88-206 Clean Air Act, 2/19/65, Table 1.

** Based on 1975 Emission Standards Set by U.S. Congress.

Figure 5. Nitrogen oxide vehicular emission versus speed.

An application of the relationships shown in Figures 3, 4, and 5 to the travel simulation information made it possible to identify the effect of different urban patterns on trip length for similar transport systems. Changes in pollution from motor vehicles due to proportional changes in trip length for different urban patterns having similar highway networks and average speeds are given in Table 4. Corridors and satellite development had the greatest impact on reducing vehicle-miles of travel and, hence, air pollution.

Changes in air pollution for motor vehicle work travel due to changes in average speed for different highway networks and the same urban pattern are given in Table 5 for 2 urban patterns. A more extensive freeway network for a constant urbanization pattern does result in reductions in carbon monoxide and hydrocarbons. However, oxides of nitrogen were found to increase with the more extensive freeway network on a total emissions basis. This indicates the need for basic research in control technologies for oxides of nitrogen.

TABLE 4

AIR POLLUTION REDUCTIONS FOR CHANGES IN URBAN PATTERNS

Urban Pattern	Highway Network	Change in Air Pollution for Work Travel[a] (percent)
Moderate corridors	Freeways along major radials	-2.8
Heavy corridors	Additional radial freeways and an inner beltway added for maximum coverage	-20.4
Rotated corridors	Basic arterial grid	-3.6
Satellite cities	Basic arterial grid	-7.5
Centralized sprawl population	Basic arterial grid	+1.7

[a]Compared to the sprawl population pattern.

In addition, the simulation study showed that improved transit service and corridors work toward increasing transit usage for work trips and reducing air pollution during the peak period because of the reduction in automobile travel. Figure 6 shows the effect of improved transit service on modal split and air pollution reductions versus distance from the central business district. Air pollution reductions varied from 18 percent in the CBD to 1 percent in the periphery of the hypothetical city. The curves indicate that increases in transit service at a distance of 4 to 5 miles from the CBD can have a pronounced effect on increasing transit usage and reducing air pollution. Figure 7 shows the effect that increasing urban densities in corridors has on air pollution reductions. It should be noted, however, that these examples are for emissions and do not indicate the effect of increased urbanization on ambient air concentrations.

Metropolitan and Submetropolitan Analyses

An analysis conducted in a variety of metropolitan areas verified the directions with respect to air pollution reductions indicated by the hypothetical city analysis.

In Chicago (5), the air pollution implications of 3 alternative metropolitan plans were analyzed on the basis of emission estimates for 2 pollutants: oxides of nitrogen emissions and suspended particulate emissions from certain industry groups. The alternative plans investigated included a finger plan (high-density corridors), a multitown plan, and a satellite cities plan. For these 2 pollutants, it was found that the finger plan and satellite cities plan were equivalent with respect to particulates. However, with respect to oxides of nitrogen, the finger plan was superior. On the basis of these tests, it was concluded that the finger plan was best from an air quality standpoint. In this plan, although there were fairly high residential and industrial concentrations, there was also a dilution potential

TABLE 5

AIR POLLUTION REDUCTIONS FOR CHANGES IN HIGHWAY NETWORK

Urban Pattern	Highway Network	Base Network	Changes With Different Highway Networks Compared With Base Highway Network (percent)					
			Pre-1968 Emission Rates			Post-1975 Emission Rates		
			CO	HC	NOx	CO	HC	NOx
Sprawl	Freeways along major radials	Basic arterial grid	-13	-4	+82	-9	-29	+52
Sprawl	Additional radial freeways and an inner beltway added for maximum coverage	Basic arterial grid	-35	-14	+154	-31	-19	+160
Moderate corridors	Major radial freeways with an outer beltway and inner loop added	Freeways along major radials	-11	+5	+30	+5	+5	+26

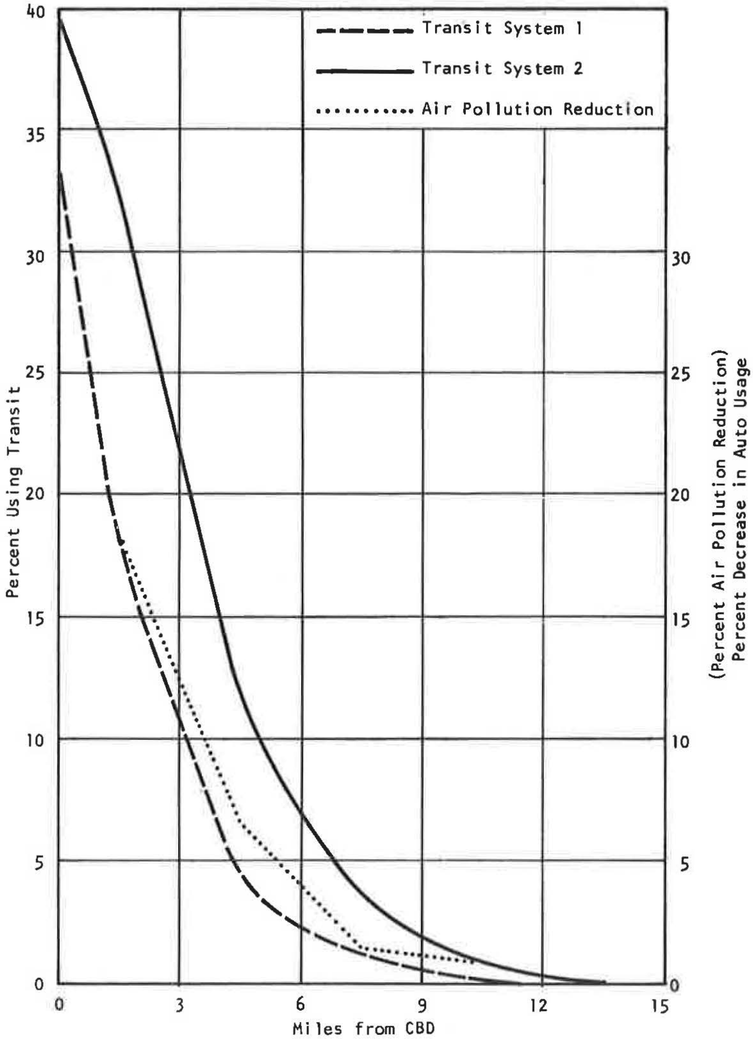


Figure 6. Effect of improved transit service on modal split and air pollution in high-density corridor.

for pollutants. This was because the development corridors were elongated and bordered on either side by large green areas. The plan also had an advantage in terms of reducing motor vehicle pollution because of the greater potential for rail and bus travel.

In Seattle, Washington, 2 alternative transportation networks based on two different land use systems were evaluated from the standpoint of their impact on air pollution. Plan A continued the existing trends in land development and plan B patterned development into a "cities and corridors" concept. Comparison of the daily emissions calculated for the 2 projected Seattle networks indicated that the pattern of activities in an urban area, which influences transportation demands, can reduce the amount of motor vehicle pollution. Total emissions from the network designed for the land use configuration if current development trends continue were predicted to be approximately 12 percent higher than those from the network designed for the cities and corridors concept as given in Table 6 (6). The analysis concluded, however, that the land use configuration

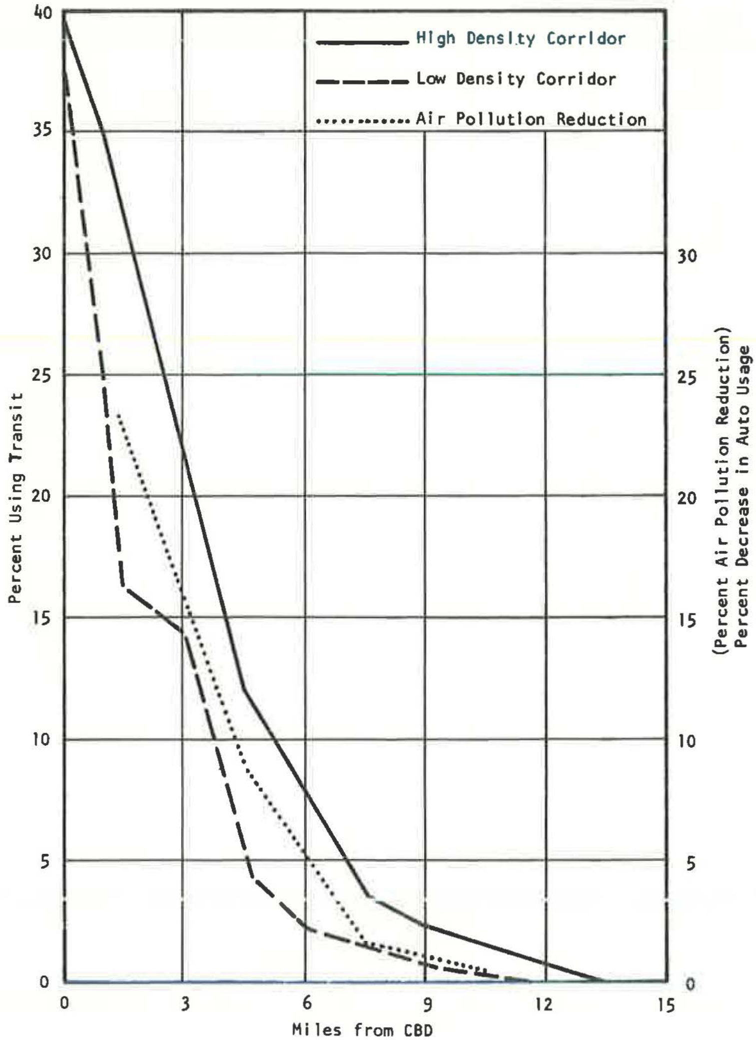


Figure 7. Effect of corridors on air pollution and modal split.

preferable from an air pollution standpoint cannot be determined until total area emissions and, more important, total ambient pollutant concentrations are estimated and compared.

In the Twin Cities area, it was found that the regional air pollution impact of transit was negligible. However, the positive impacts (air pollution reductions) in the downtown

TABLE 6

MOTOR VEHICLE EMISSIONS FROM 1985 STUDY SYSTEMS FOR SEATTLE-TACOMA, WASHINGTON

Plan	Daily Vehicle-Miles of Travel	Carbon Monoxide[a] (lb/day)	Hydrocarbons[a] (lb/day)
Existing development trends	28,787,000	3,252,000	273,000
Cities and corridors concepts	25,038,000	2,884,000	241,000

[a]Assumes no controls on vehicles.

area were considerable. It was found that automobile use during peak hours could be reduced by about 13 percent by 1985 in and within about 2 miles of the downtown area as a result of substantially improved express transit. Air pollution in these critical areas could be expected to be reduced by a similar amount. In a regional context, even those test systems that cause the largest diversion from automobiles would only reduce regional 1985 automobile use by about 3 percent as compared with a system in which transit is not improved. These findings for Twin Cities were based on a given land use for 1985 and a constant highway network.

Montgomery and Prince George's Counties in Maryland (Washington, D. C., suburban area) were also examined for air pollution impacts of alternative plans. Five alternative land use plans for 1990 and several highway patterns were examined. A fixed rapid rail system was assumed for each alternative. For each of these tests, the amount of hydrocarbons and carbon monoxide generated by the vehicle-miles of travel for the alternative plans tested was calculated based on congested and average operating speeds. Table 7 gives a comparison of the pollutant production related to the alternative plans. An index of the weighted average of pollutants produced per vehicle-mile was calculated and showed that concept plan C (addition of new towns and corridors of development) contributed the least amount of air pollution as a result of less overall congestion in the network.

DESIGN

The design of transportation systems, especially of highways, can be an effective tool in reducing the air pollution concentrations in the ambient air. Good design improves the operational characteristics of a transportation system (a fact that will be discussed in the next section) and, thus, reduces the emissions from motor vehicles; it can also be used to minimize the concentrations of air pollution to which people, vegetation, and structures are exposed.

Proper design of highways from an air pollution standpoint involves an understanding of the spatial interrelationships between highways and the surrounding structures. What is needed is information on how the pollution generated on the highway affects the surrounding areas. This involves calculations of the air pollution concentrations away from and above roadways for different types of highways. Figures 8 and 9 show the decline of carbon monoxide concentrations with increasing distance above and beside the roadway in relation to the pollution level at the roadway. Thus, if the pollution concentration at the roadway can be determined from traffic volume and travel speed, the absolute values of carbon monoxide concentrations at different distances from the roadway can be computed. Such information is useful in deciding where a structure can be built in relation to a highway so that the pollution levels it will be exposed to will not exceed some accepted safe level. Similarly, the curve showing the decline of pollution with height above the roadway can be useful in determining air-right constructions.

TABLE 7

POLLUTANT LEVELS FOR ALTERNATIVE TRANSPORTATION AND LAND USE PLANS FOR MONTGOMERY AND PRINCE GEORGE'S COUNTIES, MARYLAND

Alternative	Year	Montgomery County			Prince George's County		
		Hydrocarbons (lb/day)	Carbon Monoxide (lb/day)	Index[a]	Hydrocarbons (lb/day)	Carbon Monoxide (lb/day)	Index[a]
Existing system	Pre-1968	56,300	663,260	0.145	70,650	856,440	0.154
	Post-1975	4,570	95,460	0.0218	5,820	127,150	0.0235
General plan	Pre-1968	149,500	1,874,290	0.158	198,600	2,491,880	0.157
	Post-1975	12,870	275,100	0.0242	16,500	365,100	0.0238
Concept plan C	Pre-1968	147,700	1,794,390	0.145	200,200	2,435,540	0.146
	Post-1975	12,180	262,600	0.022	16,440	354,820	0.0220
General plan C	Pre-1968	232,950	3,048,110	0.188	238,320	2,994,720	0.160
	Post-1975	19,520	454,700	0.0286	19,700	439,060	0.0242

[a]Total production/vehicle-miles.

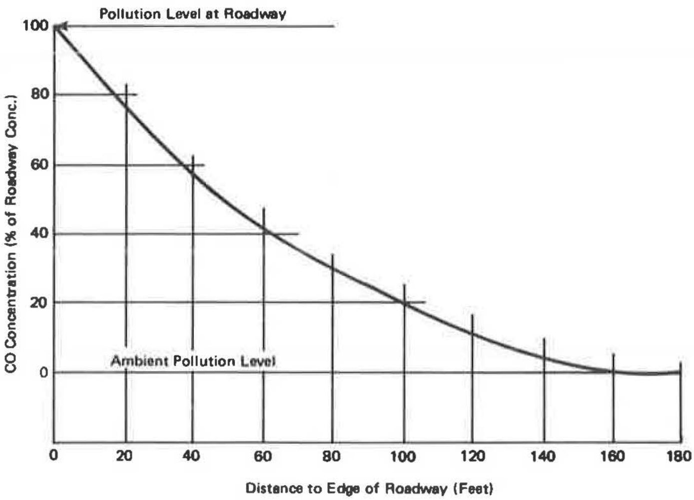


Figure 8. Pollution level versus distance to edge of roadway.

Another important design aspect that affects air pollution is the type of the highway to be built. Different types of highways that carry similar loads at similar operating conditions will produce an equal amount of pollutant emissions, but the concentrations of these pollutants will be different. A study (9) has been done that measured concentrations at and above 5 types of highways: a centered expressway with joint development structures, a centered expressway without joint development structures, an off-center expressway with joint development structures, an off-center expressway without joint development structures, and a centered expressway-boulevard. Three of these 5 cases are shown in Figures 10, 11, and 12. The effects of these highway types on pollution concentrations for the climatic and metereological conditions of the case study can be approximated by calculating the average concentrations at the roadway level for each highway type. The average of concentrations on the 4 lanes for the centered expressway without joint development structures is 39 ppm, whereas a similar calculation for

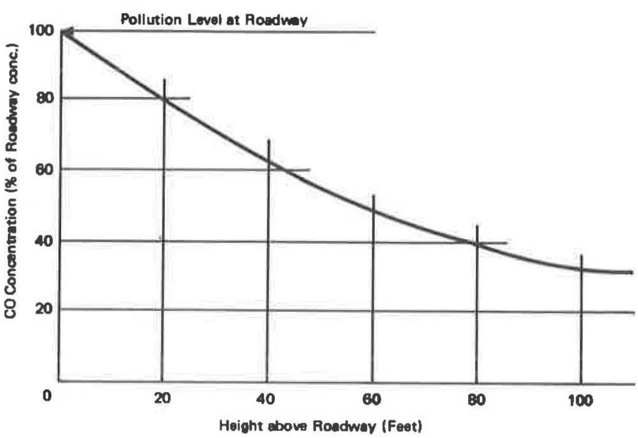


Figure 9. Pollution level versus height above roadway.

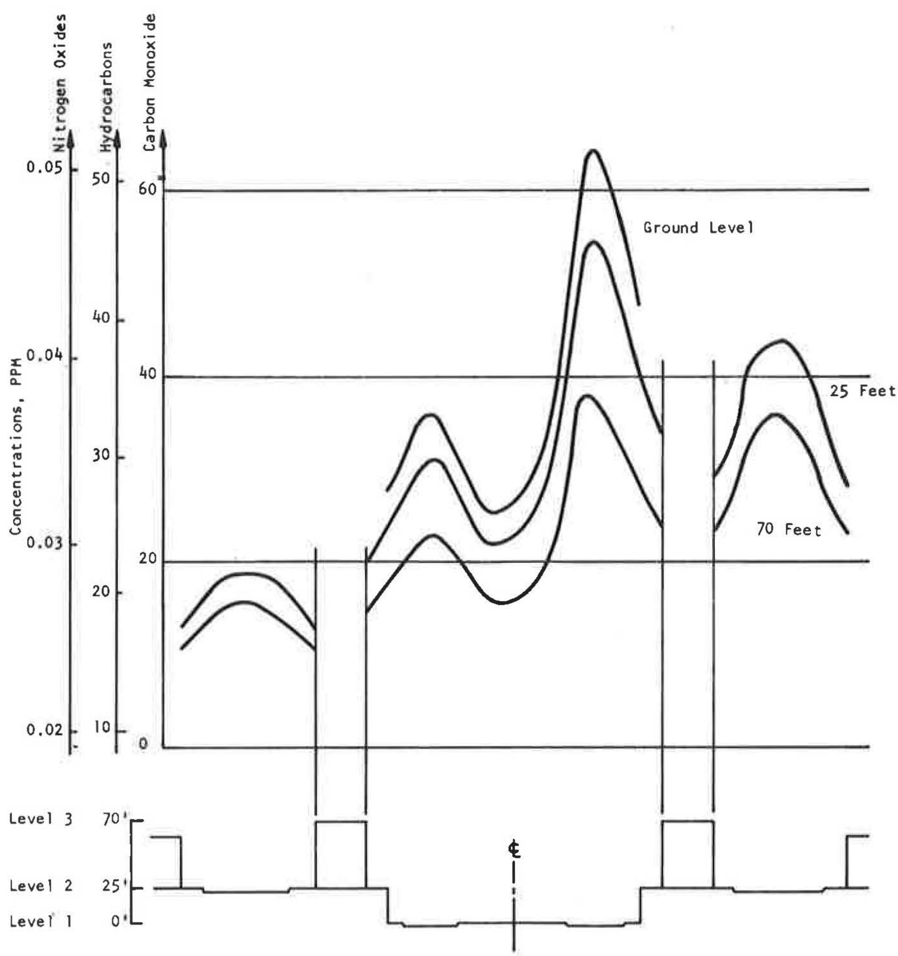


Figure 10. Pollution levels along transverse street cross section of centered expressway with joint development structures.

the boulevard-expressway is 49 ppm, an increase of 26 percent. The effect of adjoining structures can be seen by comparing pollution levels shown in Figure 10 with those shown in Figure 11.

To summarize, the design efforts in air pollution reduction are not aimed so much at reducing total emissions as at reducing concentrations of points where human beings or sensitive objects are located. This can be accomplished by the design of the highway itself and by regulating the relationship between the highway and the adjoining land use.

The smooth operation of transportation systems is one of the most important means of reducing air pollution. Vehicles cruising at a constant speed on an uncongested highway emit relatively fewer pollutants than does traffic operating under congested conditions. Emissions during idling, acceleration, and deceleration are many times higher than those during constant speed conditions. Measurements show that the emission rate is 1.5 times the crusing rate when vehicles are idling and 9 times the cruising rate when vehicles are decelerating (11). As a result, traffic in the central business district, which is usually the most congested area, produces about 4 times more carbon monoxide than does expressway traffic, while arterial and local street traffic produces about twice as much.

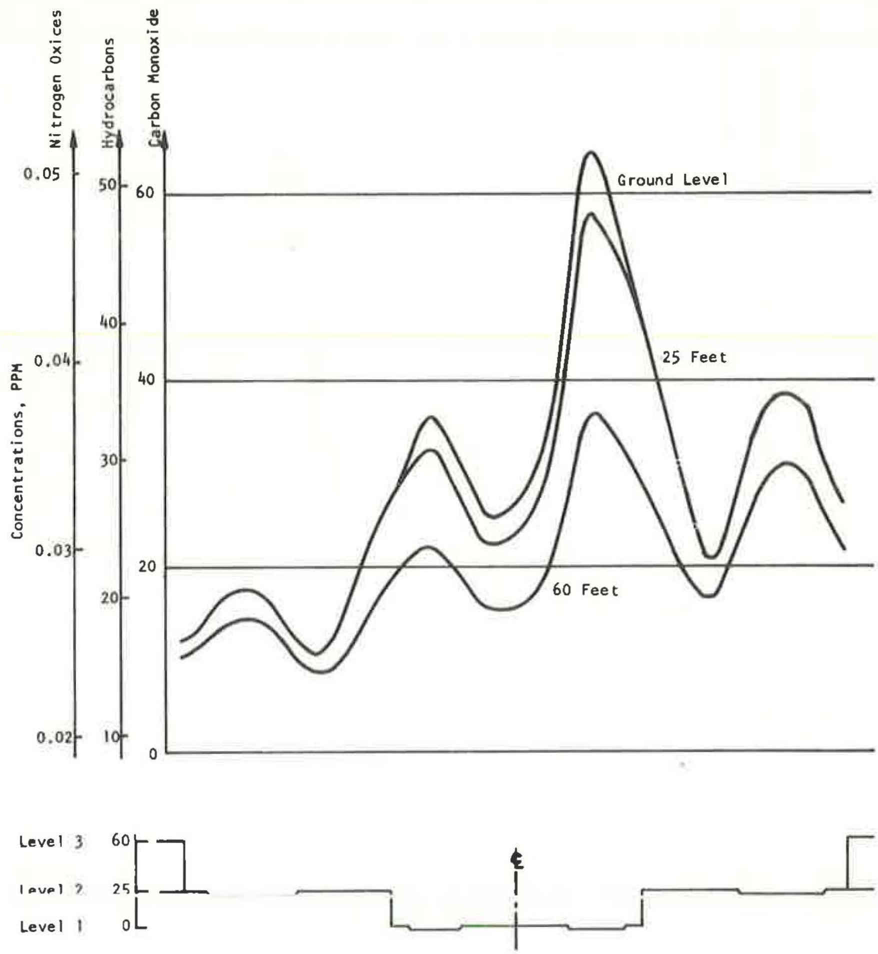


Figure 11. Pollution levels along transverse street cross section of centered expressway without joint development structures.

Speed is also an important determinant of the amount of air pollution that is generated. This subject was touched on previously, and Figures 3, 4, and 5 show the relationships between pollutant emissions and vehicular speeds.

Figure 13 shows a comparison of a typical city street and freeway operations (11). Improvements in the operation characteristics of transportation systems thus offer a very important tool in the fight against pollution, perhaps the most important next to emission control devices. Figure 14 shows the effect of wind direction, traffic volumes, and height above the roadway on carbon monoxide concentrations for an urban arterial street in Frankfurt, Germany (15). This figure and Figure 13 show the effect that higher traffic volumes have on carbon monoxide concentration. The traffic engineer should be cognizant of these impacts in the evaluation of traffic operational schemes.

One of the most significant programs that can be useful in reducing air pollution levels by improving operational characteristics is the Federal Highway Administration's traffic operations program called TOPICS. Even though air pollution reduction is not one of the objectives of the program, it is an important by-product of improved traffic flow. Actions such as synchronizing traffic signals and using computerized signal systems improve traffic flow up to 30 percent and more, and a comparable decline in air

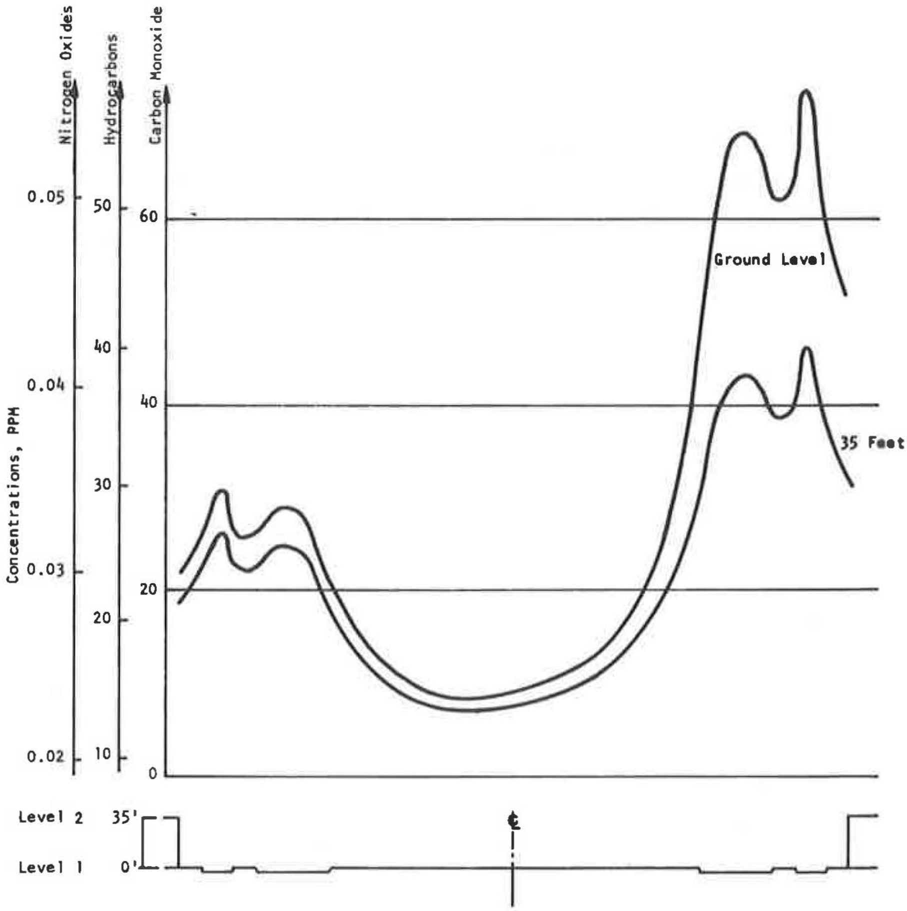


Figure 12. Pollution levels along transverse street cross section of centered expressway-boulevard.

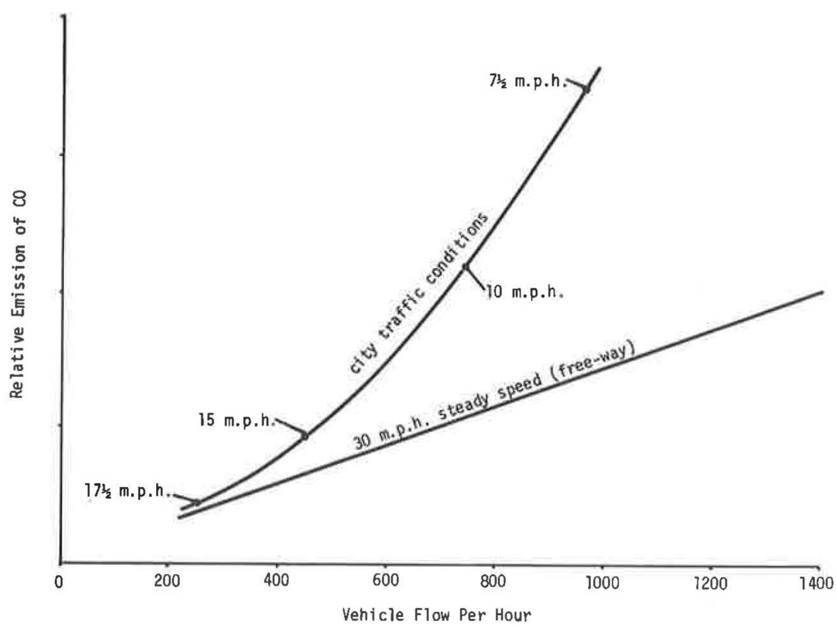
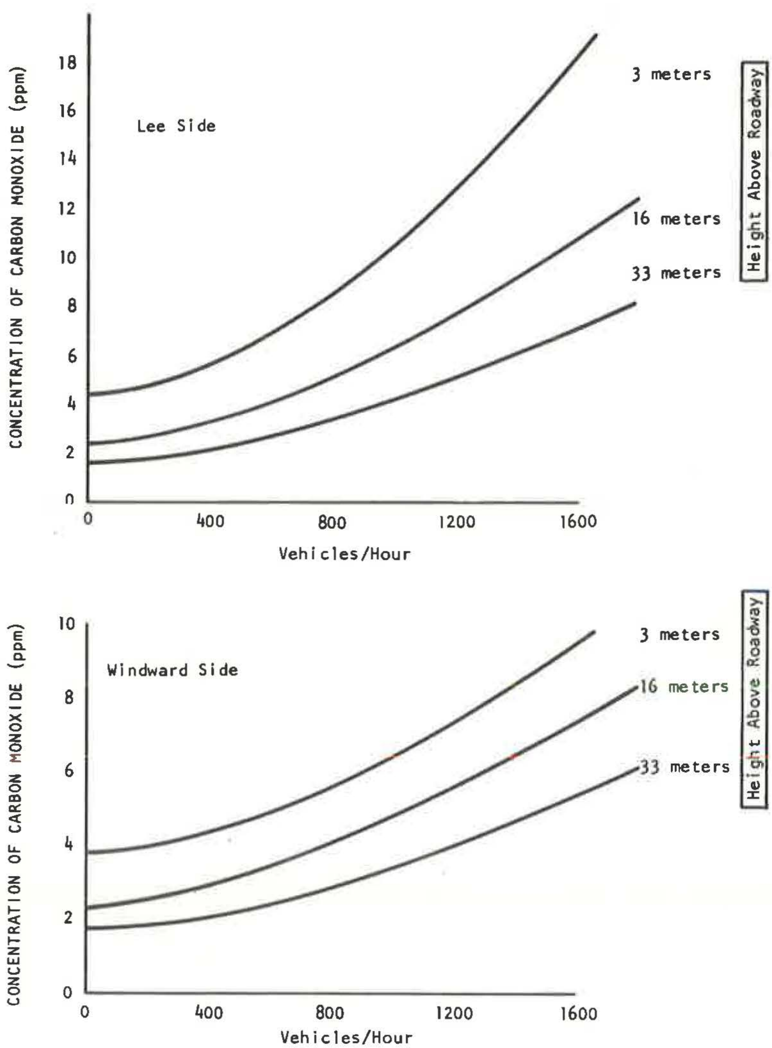


Figure 13. Comparison of city street and freeway conditions.

pollution can be expected for the operating systems. Unlike the effects of pollution reduction through planning and design of new development and facilities, pollution reductions through operation can affect the whole area.

Pricing can also be used as an operational tool to ameliorate air pollution through the reduction of vehicular travel. In Canberra, Australia, it was found that parking costs can reduce vehicular travel by increasing car occupancy and transit usage (18). This reduction in travel thereby reduces the air pollution generated by vehicles. As indicated, a $1.00 parking cost reduced air pollution in Canberra by 30 percent in the town centers and 40 percent in the central area (Fig. 15).

Another method of reducing pollutant emissions from motor vehicles is the use of smaller vehicles with smaller engines. A study carried out in Great Britain (11)



Source: Georgii, H.W.; Busch, E.; Weber, E.; "Investigation of the Time and Space Distribution of Carbon Monoxide in Frankfurt AM Main"

Figure 14. Carbon monoxide concentrations depending on traffic volumes.

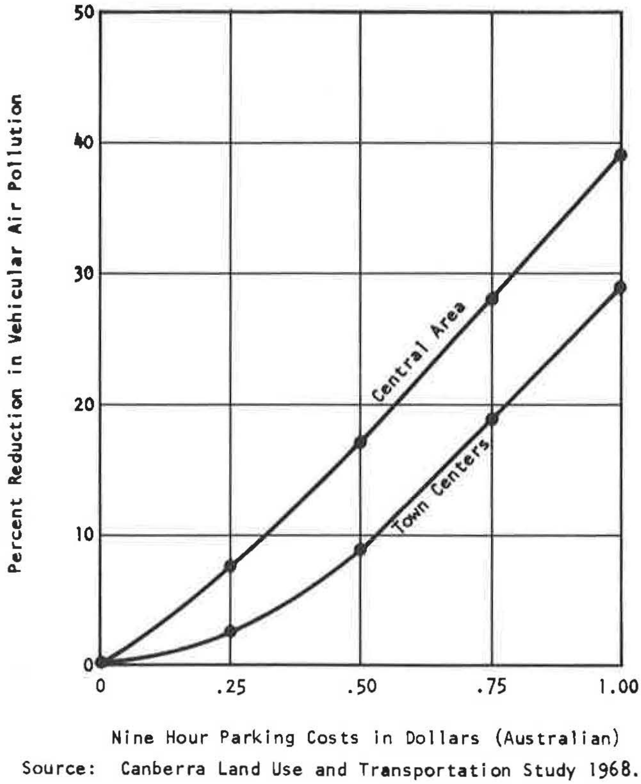


Figure 15. Effects of parking costs on vehicular air pollution emissions.

concluded that smaller cars would emit about one-third the volume of exhaust gas of the present medium-sized cars and, assuming that they emit no higher concentration of carbon monoxide, the benefit would clearly be proportional to the number of such cars in use. Therefore, the encouragement of such vehicles can be a policy used to reduce air pollution levels.

CONCLUSIONS

The case examples described in this paper have shown the relative reductions in air pollution emissions and concentrations that can be realized through the proper planning, design, and operation of transportation and land use systems. These actions, which require a process similar to that shown in Figure 16, can be used to supplement present legislative emission controls.

With respect to planning, the creation of dense corridors and of new satellite cities reduces vehicular travel and, hence, reduces air pollution. The dense corridor concept encourages transit usage that in turn results in a decline of air pollution emissions because of lower use of automobiles. The air pollution impact of this change, however, is not of such magnitude as to have a regional importance but is significant in heavy activity centers such as downtown areas or major development corridors. Similarly, the creation of new cities as an alternative to suburban sprawl reduces automobile travel and, consequently, air pollution. The pollution resulting from that portion of travel still done by automobiles can be reduced by channeling automobile traffic into freeways rather than arterials because freeways have improved speed conditions. However, such an action requires controls on development around freeways.

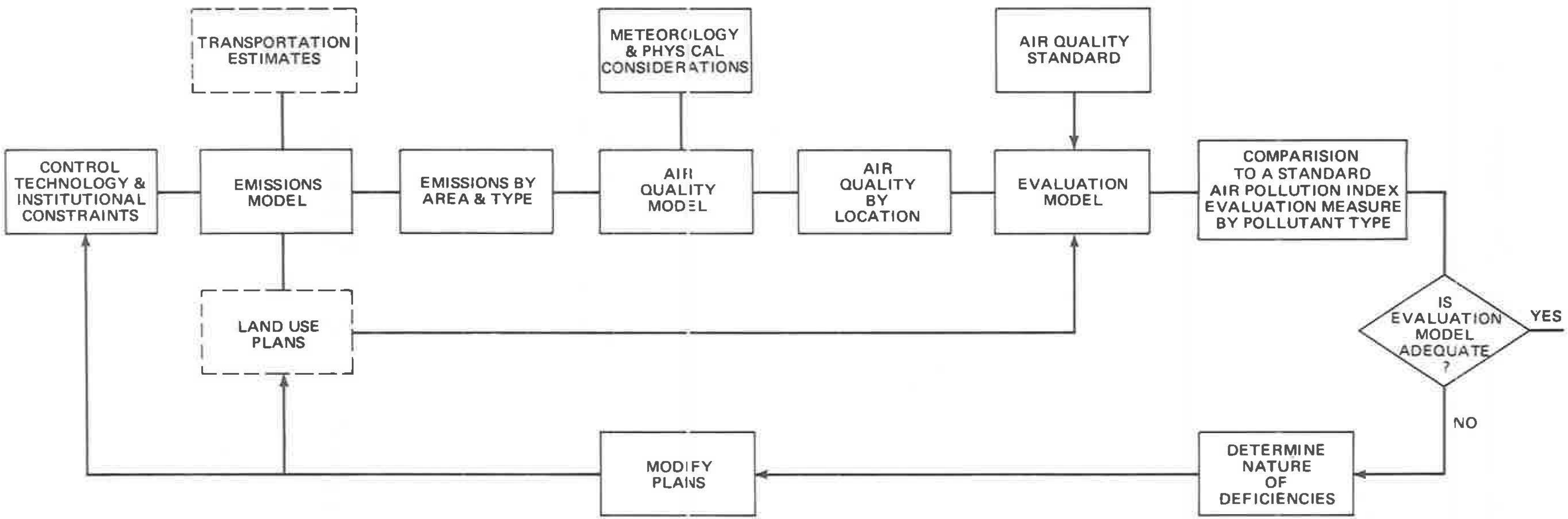


Figure 16. Process for incorporating air pollution considerations in planning process.

With respect to design, concentrations resulting from vehicular pollution can be minimized if the highway is segregated from adjoining structures either by distance or by other barriers such as green spaces. When neither of these is possible, such as when air-right structures are built, ventilation will be required in cases to meet acceptable air quality standards.

In the case of vehicular operations, the improvement of traffic flow by means such as synchronized traffic signal channelization and pricing policies (parking and tolls) for transport facilities can be of considerable impact in reducing air pollution. In addition, an increase in the use of smaller cars with smaller engines can reduce air pollution levels significantly.

This summary of possible means of attacking air pollution through urban and transportation planning, design, and operations as demonstrated by case studies indicates the different areas where further information, if applied, can be an aid in reducing air pollution.

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