Air Quality Considerations in
Transportation and Urban Planning
A Five-Year Program Guide

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AIR QUALITY CONSIDERATIONS IN TRANSPORTATION AND URBAN PLANNING

A FIVE-YEAR PROGRAM GUIDE

Prepared for

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CHAPTER 1
INTRODUCTION

OBJECTIVES AND STUDY PURPOSE

The quality of air in urban areas is a matter of growing concern. A generation ago, reference to Los Angeles' smog by prominent comedians invariably drew laughter. Today, public opinion polls show air pollution near the top of the list of problems identified by Americans. Political leaders find a need to be as conversant about the threat to the environment as they are about foreign affairs and local taxes.

The increasing awareness of the seriousness of air pollution has been reflected in a series of legislative and administrative actions designed for public agencies to forge the tools for achieving satisfactory standards of air quality. This study was prepared to assist the public agencies in their task. Specifically, the purpose of the study was to develop a five-year program of research and support activities to be undertaken by the Office of Air Programs of the Environmental Protection Agency, in coordination with other Federal bodies such as the Department of Transportation and the Department of Housing and Urban Development. The scope of the research program is to determine and demonstrate the air pollution aspects of urban and transportation planning and to encourage the inclusion of air quality control considerations in the planning process.

Since air quality is related to other environmental matters, this study fits into a broader framework. Urban planning decisions related to the optimization of environmental welfare should encompass all environmental problems together - air, water, solid waste, wastewater, etc. This kind of comprehensive thinking is illustrated in the creation of the new Environmental Protection Agency (EPA), which combines most Federal organizations dealing with the environment into one organizational structure.

The treatment of environmental problems through urban and transportation planning is a complex process, as illustrated in Figure 1.1. The five-year program addresses the air quality problem within this environmental planning framework. It is hoped that the resulting program will serve as a model for work in other areas of planning for environmental protection so that similar tools for considering the aspects of such problems as water pollution and solid waste disposal, for example, will be developed and used in the environmental planning process.

The need for the study is based on the fact that urban planning decisions, which have profound effects on ambient air quality, are often made without proper consideration of their air pollution consequences. For example, the choice of an all highway system instead of a transportation system including rapid transit will affect an urban area's air quality. Similarly, land use arrangements such as the location of industry or houses and metropolitan growth patterns such as sprawl (development in many directions), corridors, satellite cities and new towns, all influence the levels of ambient air pollution. Most urban land use and transportation planning activities of the past have considered environmental effects only indirectly, if at all, and then only in a non-quantitative manner.

The failure of planners and decision-makers to consider air quality effects, despite the growing recognition of the undesirable consequences of environmental pollution may be explained by two basic factors: the lack of precise information on urban planning and air pollution relationships and the absence of a methodology to incorporate air pollution considerations in the urban and transportation planning processes. Therefore, research is needed to link planning actions quantitatively to their environmental consequences. The results of this research will inform planners and decision-makers about the air quality consequences of their actions and will point to the land use and transportation alternatives that can best be used to control air pollution.

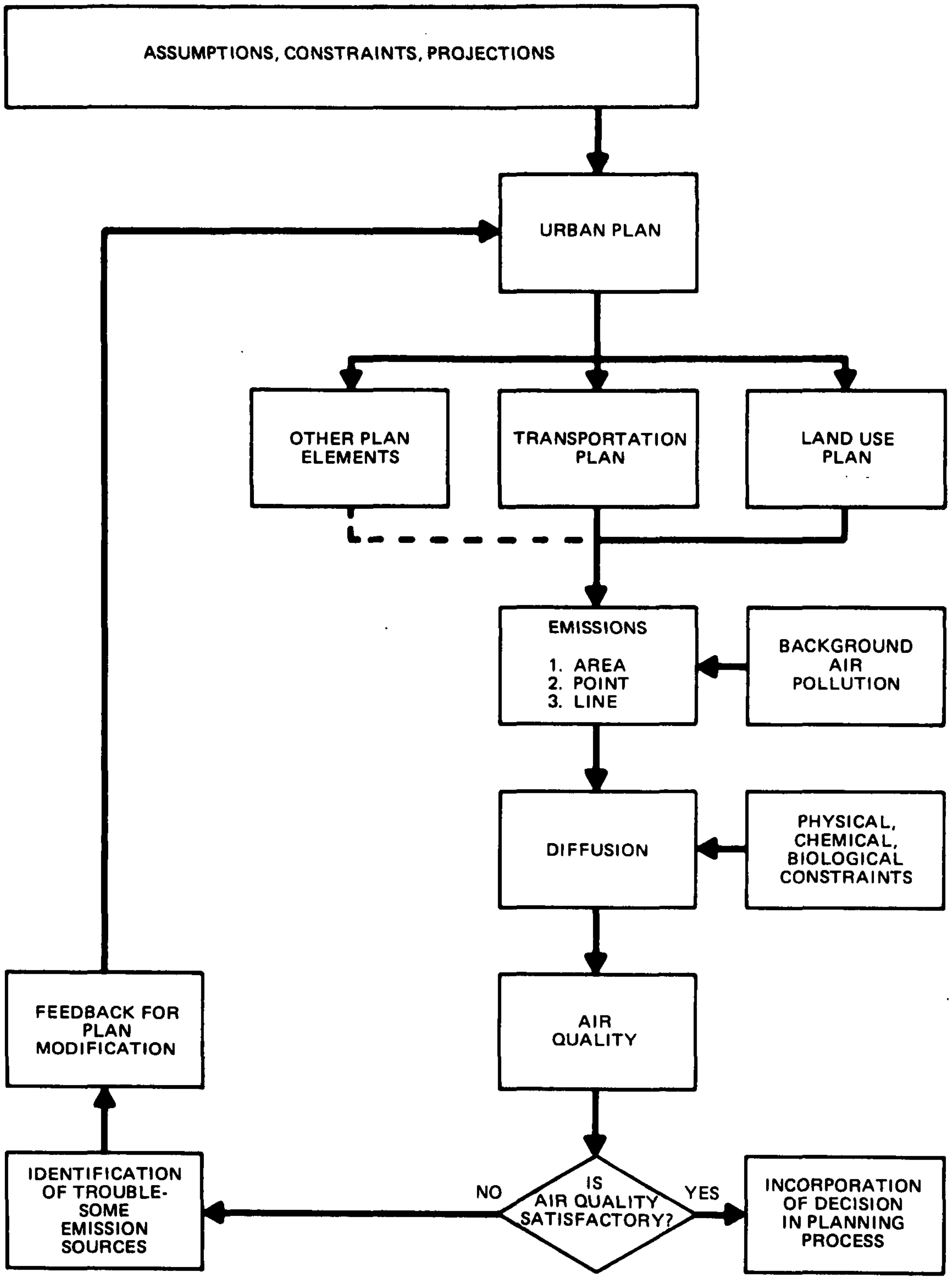


Figure 1.1 Air Quality Considerations in the Planning Process

REPORT ORGANIZATION

This introductory chapter is followed by a summary of findings and recommendations (Chapter 2). The findings are page-referenced to aid the reader in locating detailed text. The recommendations include a summary of the basic work items for the five-year program of research and support activities.

The contribution that urban and transportation planning can make to the improvement of air quality is developed in Chapter 3. The interrelationships between air pollution, land use, and transportation systems are described, based on an intensive state-of-the-art review. The role of urban and transportation planning in air quality control is discussed in the following contexts: land development and density patterns; spatial arrangement of buildings and site activities; planning of transportation systems; design and construction practices; and operation of buildings and transportation facilities.

Information about the impact of planning actions on air quality was derived from a computer simulation study of work travel for a city of two and one-half million people, library research of more than 200 references listed in Appendix A, and analysis of data from various professional papers published here and abroad, including Japan, Sweden, Germany, and Great Britain. The chapter concludes with a strategy for encouraging the incorporation of air quality considerations into the urban and transportation planning process.

The proposed five-year program to incorporate air quality considerations into transportation and planning functions is presented in Chapter 4. The program objectives are supported by various legislative goals and, in particular, the Clean Air Amendments of 1970. Needs of the transportation and urban planner based on review of Federal, state, and local practices are outlined. The types of needs are categorized into basic information, techniques, guidelines, governmental inducements, and support activities. Basic work items are developed to fulfill the needs of the planner: adapting the basic research of OAP and other Federal agencies to the planning process; performing case studies, simulation studies, demonstration studies, and administrative and legal studies; and providing information dissemination, training, and support activities.

Chapter 5 describes the projects to be undertaken during the five-year program period. A preliminary project schedule is presented together with cost budgets for the program.

The report includes four appendices. The literature that has been surveyed is presented in Appendix A. Appendix B describes the study organization which led to the preparation of this report and the supplementary guides - "A Guide for Reducing Automotive Air Pollution" and "A Guide for Reducing Air Pollution Through Urban Planning." Appendix C is an introduction to air pollution written for the urban and transportation planner who may not be familiar with the multifaceted aspects of air pollution. Appendix D reviews existing governmental practices at the Federal, state and local levels.

CHAPTER 2

SUMMARY OF FINDINGS AND RECOMMENDATIONS

The causes of air pollution are complex. The elimination or substantial reduction of air pollution is equally as complex. The pollution sources with which this report is concerned relate to the use of energy, a use which is closely correlated with the productivity of our society. The most desirable control measures by which air quality could be improved would be those that do not hinder useful productivity but avoid waste of energy. The principle of conservation is therefore a real factor in air quality control.

Measures which help to disperse pollutant concentrations or which reduce exposure of human beings, animal and plant life to pollutants are an essential part of an effective control program. Measures which filter out or reduce the amount of harmful emissions from a source also are a major part of a control program. In a world of rapidly growing population and productivity, however, the avoidance of unnecessary or uneconomic travel, unnecessary use of heat or light, or other forms of energy waste will become increasingly important.

There are no easy answers. Indeed, many actions that will be beneficial will have concomitant harmful effects. This situation is not unique to the field of air pollution. Every day, individuals make decisions which involve trade-offs, selecting those actions which produce benefits that outweigh the costs. So it must be with improving the quality of air in urban America. It is important to recognize what some of these trade-offs involve. For example, increasing the average travel speed of a group of vehicles traversing a section of roadway will reduce the ambient concentration of hydrocarbons and carbon monoxide, but probably increase the concentration of oxides of nitrogen. Increased travel speed also tends to lengthen trips, thus resulting in increased use of automobiles.

Decreasing the density of land development reduces concentrations of air pollution, but increases dependence on the automobile as a transportation mode. Such circumstances underline the importance of stringent control of the sources of pollutants. But much can be done through better planning, design and operation of pollutant sources in urban areas. The following measures can result in improvements in air quality:

- Average trip lengths can be significantly reduced by the controlled development of land (page 3-3).
- Planned relationships among industrial, commercial and residential land use can reduce pollution levels (page 3-11).
- More effective use of open space and green belts can reduce pollutant concentrations and the number of people exposed to unacceptable air pollution levels (page 3-11).
- A major portion of the impact of sulfur dioxide pollution can be eliminated by proper location of heating and power plants (page 3-13).
- Response to geographical location, topography, and meteorological-climatological factors can be effective in avoiding exposure to pollutant concentrations or the development of such concentrations (page 3-19).
- Buildings and site activities can be arranged to take advantage of topographical, climatological and meteorological factors to reduce exposures (page 3-23).
- Centralized heating plants can be effective over the long term in reducing emissions from large-scale developments (page 3-34).
- Improved public transportation can reduce vehicular travel in varying amounts, depending upon the areas involved (page 3-36).
- Significant reduction in certain air pollutants can be gained through effective highway planning (page 3-45).
- Designing transportation facilities to be compatible with adjoining land uses can have a significant impact on the number of people exposed to undesirable levels of air pollution (page 3-48).
- Highway design with respect to gradients, curves, and points of conflict can have modest effects on the reduction of air pollution (page 3-56).

- Incorporation of air quality considerations in the design of stationary sources of pollutants can have a major effect on long-term reductions (page 3-58).
- Control of freeway operations to ensure smoother traffic flow can be significant both for short-range and long-range reduction of certain pollutants (page 3-62).
- Significant reductions in the emission of some pollutants can be achieved through the use and arrangement of various traffic control devices (page 3-65).
- Changes in raw materials and fuels, changes in processes and equipment, and changes in maintenance practices can substantially reduce pollution derived from stationary sources (page 3-68).

A five-year work program has been designed to help achieve higher air quality. The basic work items in this program are:

- Adaptation of basic air pollution research to the planning process (page 4-16).
- Case studies on the impacts of transportation and land use on air quality (page 4-18).
- Simulation studies on the impact of transportation and land use on air quality (page 4-21).
- Demonstration projects aimed at showing air quality changes through transportation and land use planning (page 4-23).
- Legislative and administrative studies to implement urban and transportation plans and programs critical to reducing air pollution (page 4-25).
- Dissemination of information and development of training programs (page 4-27).

CHAPTER 3

IMPROVING AIR QUALITY THROUGH TRANSPORTATION AND URBAN PLANNING

INTRODUCTION

Increasingly stringent air pollution emission controls are a logical first step in reducing air pollution in an urban area. But what other courses of action can the urban and transportation planner and engineer take to reduce not only total emissions but also their impact on the community? Better planning, design, and operating policies are not only possible, but also necessary to achieve effective air quality control.

A comprehensive approach to all aspects of air pollution reduction has not generally been included in urban and transportation plans and programs. Such an approach ranges from broad-scale or regional land use planning through zoning and neighborhood or other small area planning. It involves architecture and landscaping, public works planning and engineering, and traffic engineering, including transportation engineering and planning. The fields of public administration, legislation, and enforcement are also involved.

This chapter examines the opportunities for air quality improvement within this broad framework of urban expertise. A compendium of case examples is presented to illustrate how air pollution emissions, concentrations and exposure levels can be reduced through better planning, design, and operation of transportation systems and other aspects of urban development. These case studies are presented as a basis for estimating some of the benefits attainable through the proposed five-year program to be undertaken by the Environmental Protection Agency, Office of Air Programs (OAP) in coordination with the Department of Transportation Department of Housing and Urban Development, and other Federal agencies. With this program as a base, better direction can be given to indicate methods for reducing air pollution and its effects through means other than emission control devices on stationary and mobile sources.

In this chapter, air pollution in urban areas and the role of transportation and urban planning in mitigating air pollution are considered in the following five categories:

- Land development patterns and density
- Spatial arrangement of buildings and site activities
- Planning of transportation systems
- Design of facilities
- Operation of facilities

The present status of knowledge in each area is reviewed, reports and case histories cited, and information given to indicate the present state of technology. There is discussion of the increasing role of planning that will be necessary in the future if air pollution is to be controlled. Conclusions are drawn as to the needs for research, demonstration, and other projects and actions over the next five years to improve the capability for incorporating air quality considerations into transportation and urban planning.

Each of the five sections concludes with a summary, presented in tabular form, of the payoffs or an index of benefits, that can be expected from the types of actions discussed in that section. These payoffs are presented separately for short-term and long-term planning purposes. Payoffs were derived by first estimating the proportion of the population that could be affected by the changes in question. This is purely a judgmental estimate by the consultant, based on experience and research. Second, the approximate percentage reduction in ambient air pollution levels that might be expected to affect this population was estimated based on case studies and consultant review with the Office of Air Programs. The product of these two percentages provides an index to indicate the payoff that might be achieved from the improvement. This index is an approximate guide to the relative merits of the different improvement measures possible. It should be emphasized, however, that the figures are judgmental rather than empirical and that they are highly approximate. As research progresses, more precise information will be obtained.

"Short-term" refers to the kinds of changes that can be expected within the next five years. These are obviously limited because changes in the infrastructure (the base transportation and utility networks and industrial plants) and in the patterns of population and employment distribution cannot generally be expected to reach significant magnitude within that time.

"Long-term" payoffs are those that can be expected over a period of 20 years or more. In that period it is expected that the urban population in the United States will increase by 75-80 million. Provision for this enormous increase, together with replacement of obsolete development, will provide a substantial opportunity to plan and build in a rational manner to minimize air pollution and other negative social, environmental, and economic impacts. Thus, long-term payoffs can be much greater than short-term.

LAND DEVELOPMENT PATTERNS AND DENSITY

Land Development Concepts

The arrangement of land development patterns can be instrumental in improving air quality. The following results for Hartford, Connecticut, and Chicago, Illinois, illustrate the effect land development patterns can have on air pollution.

A comprehensive analysis of the relationships between air pollution and land use was undertaken for Hartford, Connecticut, by Yocom, et. al. [235]. This study showed clearly, as one would expect, that the distribution of air pollution sources was related to the arrangement of land development. Forecasts were made to develop emission inventory maps based on the predicted geographical distribution of land development and population, as well as on assumptions about control technology.

The land use development pattern for the year 2000, approved by the (Connecticut) Capitol Region Planning Agency, was used as a basis for estimating future air quality. Figure 3.1 is a map of the Capitol Region showing the proposed general land use in the year 2000, and the anticipated air quality without air pollution controls.

An alternative plan for the Capitol Region would terminate all further development in the Connecticut Valley, and instead concentrate future development along Route 44 to the northwest and Route 2 to the southeast. This arrangement would produce a developed area elongated in a direction perpendicular to the prevailing winds. Both plans would contain the same total population, at similar densities. By the year 2000 air quality would be as shown in Figure 3.2 if there were no air pollution controls in the region. It may be seen, comparing this with Figure 3.1 that while the area of questionable air quality might be somewhat larger, the overall area of less than "acceptable" quality would be much the same and the area of unacceptable air quality would probably be reduced.

Another study for the Hartford region [215] looked into the interrelationship between land use and trip length. The study considered five alternative land use plans, illustrated in Figure 3.3 for the year 2000. These land use plans represent the development pattern required by present zoning regulations and four other arrangements of land use that might be selected as desirable goals for the region's growth. In each case, the population and number of jobs are the same but their distribution and density vary. The black dots in the figure represent regional or subregional centers and the gray areas stand for intense urban development, primarily industry or high density residence. The remaining white areas can be considered low-density development and open space.

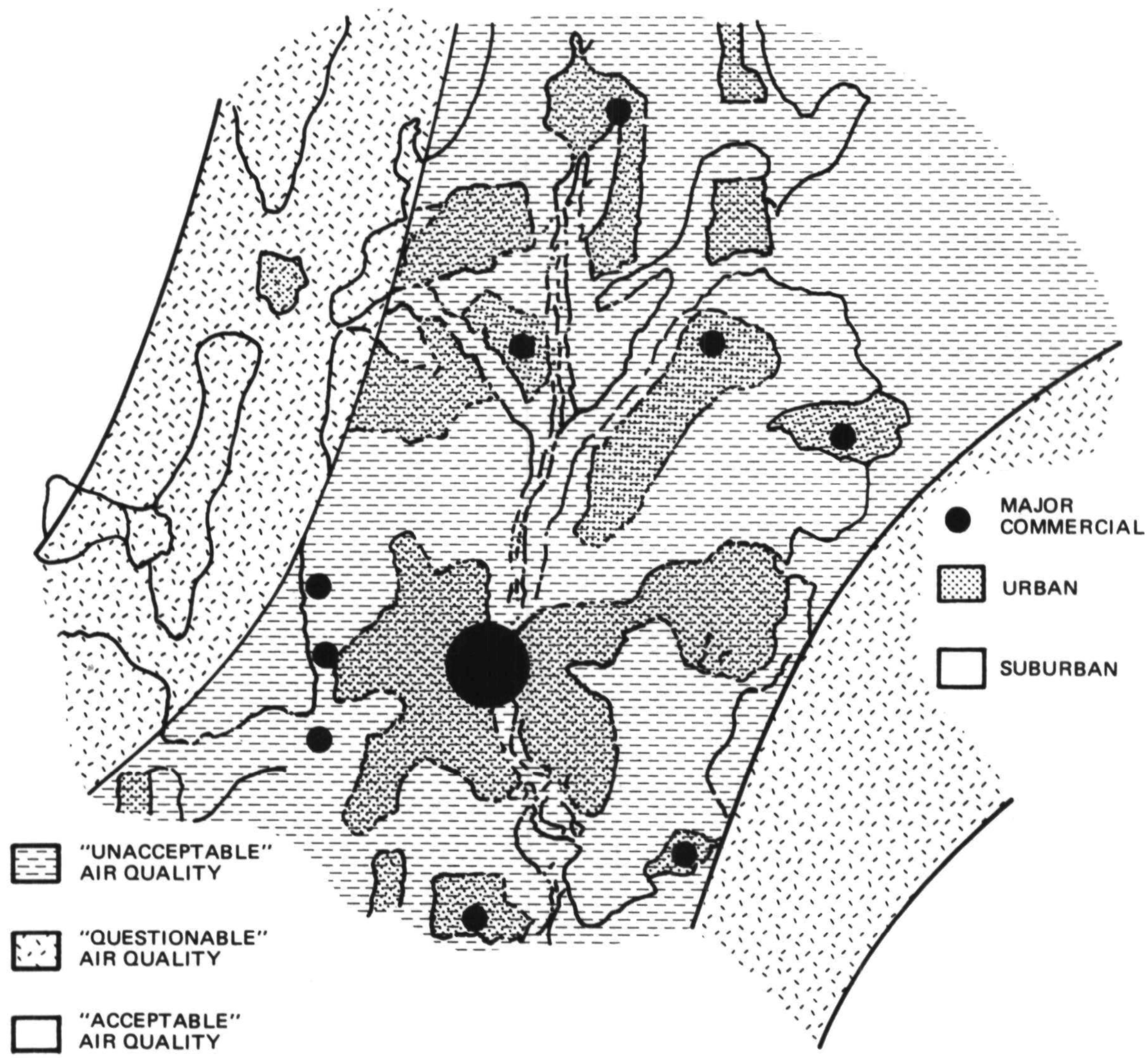


Figure 3.1 Potential Air Quality and Regional Development Plan for Hartford for the Year 2000 [234]

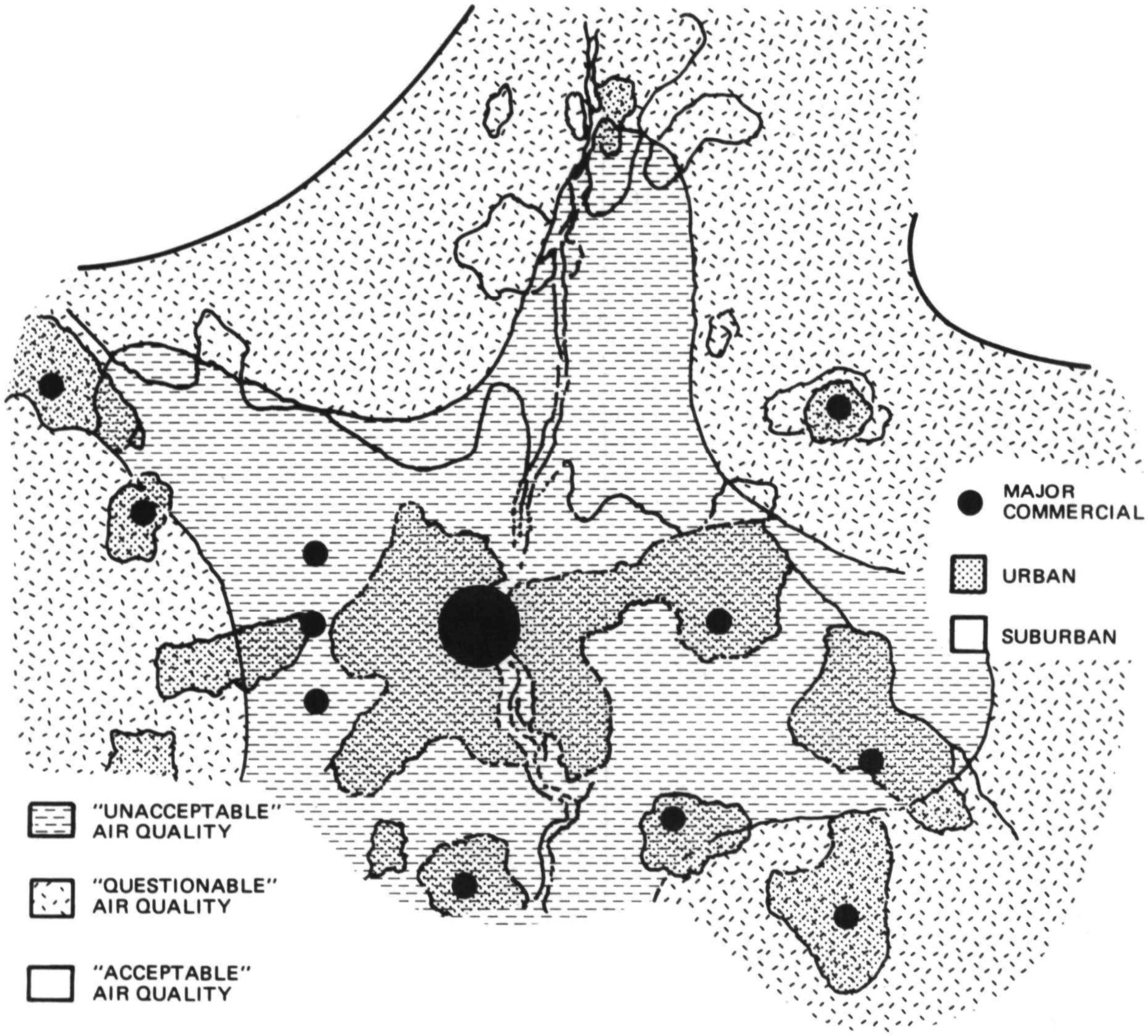


Figure 3.2 Potential Air Quality and Alternative Regional Development Plan for Hartford for the Year 2000 [234]

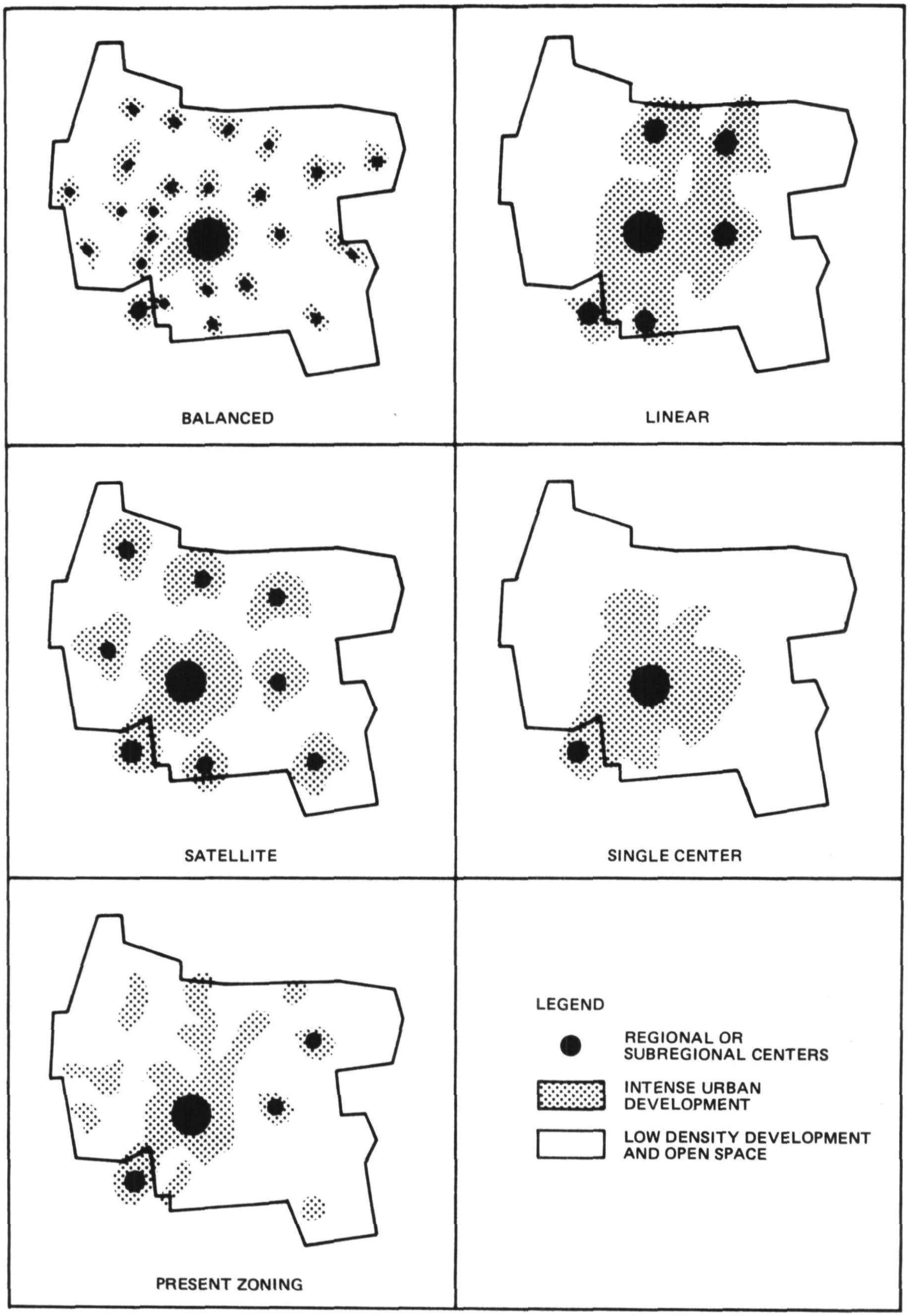


Figure 3.3 Alternative Land Use Plans for Hartford [215]

The air quality significance of Figure 3.3 can be seen from Table 3.1, which gives the average trip length for each of the different land use plans. This table indicates that trip lengths in the Single Center concept would average 24 percent longer than in the Balanced concept, with the other alternatives lying between. If all other factors (e.g., average speed, amount of transit use) remain constant, a change in trip length would result in an equivalent change in all automotive emissions.

Table 3.1. AVERAGE TRIP LENGTH BY LAND USE FOR HARTFORD [215]

Land Use Plan	Trips Length Relative to Existing Zoning
Balanced	0.92
Existing Zoning	1.00
Satellite	1.01
Linear	1.11
Single Center	1.14

In Chicago [137], the air pollution implications of three alternative metropolitan plans were analyzed on the basis of emission estimates for two pollutants: oxides of nitrogen and suspended particulate matter from certain industry groups. The alternative plans investigated consisted of a Finger Plan (high density corridors), a Multi-Towns Plan, and a Satellite Cities Plan. It was found that the Finger Plan and Satellite Cities Plan were equivalent with respect to particulates, and both were superior to the Multi-Towns Plan. The Finger Plan produced fewer oxides of nitrogen than the other two alternatives. The study concluded:

> "On the basis of these limited tests, the Finger Plan appears to have an advantage from an air quality standpoint. In this plan, although there are fairly high residential and industrial concentrations, there is also dilution potential for pollutants. This is because the development corridors are elongated and bordered on either side by large green areas. The plan also has an advantage in terms of motor vehicle pollution because of the greater potential for rail and bus travel."

Because changes in metropolitan land development concepts are largely related to new development, the short-term benefits will be small. Concepts related to development in built-up areas will have a minor impact. However, the long-term benefits of new land development patterns could affect about 25 percent of the future population. Air pollution reduction achieved in this way may be as high as 20 percent. This would mean that significant long-term reductions in air pollution problems could be expected in urbanized areas because of changes in development patterns.

Density Patterns

Population density affects automotive air pollution because it influences the amount of travel in a given area. Rydell and Collins [158] carried out a simulation study in which a formula was developed to indicate the relationship between average ground-level automobile pollution and population density under normal conditions.

When applied to the simulated city, the formula indicated that a decrease in population density would reduce the average level of air pollution, in spite of the fact that the decrease in density would cause automobile travel to increase.

This can be illustrated as follows. If an area were to experience a decrease in population density by an amount sufficient to increase average trip length by 10 to 20 percent, overall travel would increase by the same 10 to 20 percent. Assuming that no shifts of mode took place and that the average speed of automobile travel remained constant, automotive emissions would increase by the same amount. The spreading of the population at lower densities, under a larger air shed, however, would result in reduced emissions per square mile.

This is significant in light of existing fiscal pressures to build higher densities of development. It indicates that more attention should be given to control technology and microscale (small area) planning in order to keep air pollution at safe levels for the urban activities that will occur in these areas. It should be emphasized that these findings do not consider the fact that higher densities encourage transit usage and can, therefore, result in lower emissions.

The selection of density patterns will largely be restricted to new development. There will be more limited opportunities to change density in built-up areas. It would seem that changes in density patterns to reduce air pollution might affect the equivalent of one-half of new development, recognizing that other constraints will be operative. Therefore, density changes probably would affect only about 25 percent of the forecast population in urbanized areas. A reduction of only 5 percent in ambient air pollution levels related to such density changes could be expected. This would mean only a slight long-term reduction in air pollution problems in our urbanized areas. Little or no short-term benefits related to density patterns can be foreseen.

In addition to the small payoff factor, two disadvantages of lower density should be noted. One is that mass transit is less attractive and more costly to provide under conditions of low development density. Under certain conditions it is conceivable that lowered use of transit due to low density would add sufficient automobile travel to offset the theoretical gain in air quality. A second disadvantage of lower density is that the overall amount of automotive emission is increased. Policies which result in an increase of automotive emissions, even though pollutant concentrations may be reduced, must be questioned.

Industrial, Commercial, and Residential Land Use Relationships

It has long been a common practice to take into account the prevailing winds in an area when locating industries, but errors have been made in giving inadequate attention to conditions that may arise during periods of different wind direction. Because it is always desirable to ensure that air-borne emissions are blown away from residential areas, the planner must make increasingly comprehensive studies of local meteorology, climatology, and topography in order to improve spatial arrangements of industrial, commercial, and residential areas.

In an article [159] reviewing literature in the field, Rydell and Schwarz gave examples of efforts to relate land use and wind direction:

> "Stalingrad offers the most clear-cut example of designing the macro form of an urban area to minimize air pollution costs. Taking advantage of a wind that almost always blows from the same direction, the planners of this new city organized the major land uses in strips perpendicular to the wind direction. The prevailing wind passes over the residential, recreational, and park areas and only when it is beyond these zones does it accumulate major pollutants by reaching the highway, railroad, and industrial land uses [98]."

They cite Linz, Austria as a planning error in this regard:

> "Because the prevailing wind comes from the west, Linz was planned with residential areas to the west and industrial sites to the east. The attempt to have the wind blow pollution away as in Stalingrad largely failed, however. The mild east wind banks the pollution against the western mountains around this valley city. As a result the residential

area is often blanketed by smoke [99]. The failure of the Linz plan was due to an incorrect understanding of the relationship between wind and air pollution concentrations. High velocity winds cause rapid vertical and horizontal dispersion of pollution, while low velocity winds slowly carry pollution through nearby areas causing high pollutant concentrations. Wind frequencies must be weighted by the inverse of wind speed before they can be used to locate residential areas out of the path of industrial air pollution."

Open Space and Green Belts

The use of open space or of green belts may be a way of achieving the theoretical advantage of lower density without some of the disadvantages. There are other advantages as well.

For example, the Rydell and Schwarz article [159] states:

> "Traditionally, planners have used open space as a major tool to improve the quality of life in the city. Today we have even more reason to use this technique because open space, especially planted open space is not only aesthetically desirable, but acts to diminish the impact of air pollution in several ways.
>
> "Greenery absorbs moisture and cools by evaporation, creating a cooler, more humid climate than stone and exposed soil. Temperatures over grassy surfaces on sunny summer days are 10 to 14 degrees cooler than over exposed soil, and there can be as much as 1,500 BTU per square foot less heat per season over grassy surfaces [139]. This cooler moister air prevents dust formation."

The same source also describes the use of green or open spaces as buffers to protect pollution sources such as industrial areas. The buffer areas, which can be related to prevailing winds, provide an opportunity for pollutants to be diluted or dispersed. Hilberseimer [77] is referred to in this context. Others have studied wind and temperature changes over green areas compared to urban development, the implication being that such areas may aid in generating air currents that will carry away pollutants.

Cross [41] identifies approaches for the establishment of green belts as a control mechanism against air pollution. These are (1) control of plantings to reduce particulates or gases, (2) regional planning schemes that indirectly reflect air pollution considerations, such as satellite communities and corridor towns, and (3) planning schemes that directly reflect air pollution considerations, such as green belt neighborhoods, cluster subdivisions, and green belt towns.

Most effective use of open space and green belts in urban areas cannot be expected to reduce emissions but it can reduce concentrations and the number of people exposed to unacceptable air pollution levels. It is difficult, however, to predict what proportion of the population might be affected, based on information available at this time.

Heating and Power Plant Locations

In Stockholm [182] it was found that one of the principal sources of air pollution in the urban area was the heating of buildings, with sulfur dioxide the main polluting agent. In the winter of 1964 air pollution in Central Stockholm on several occasions exceeded the medical limit recommended by the National Board of Air Pollution Control (see Figures 3.4 and 3.5).

This led planners to conclude that:

> "...the power sources for the urban area must be concentrated and the power plants located outside the built-up area. The high energy consumption per person will probably make it economically possible to rely on extremely large units with a high combustion level, which could be located so far outside the urban area that the amount of flue gases in the atmosphere in the center of the region and in other inhabited areas would not exceed the medically accepted limit."

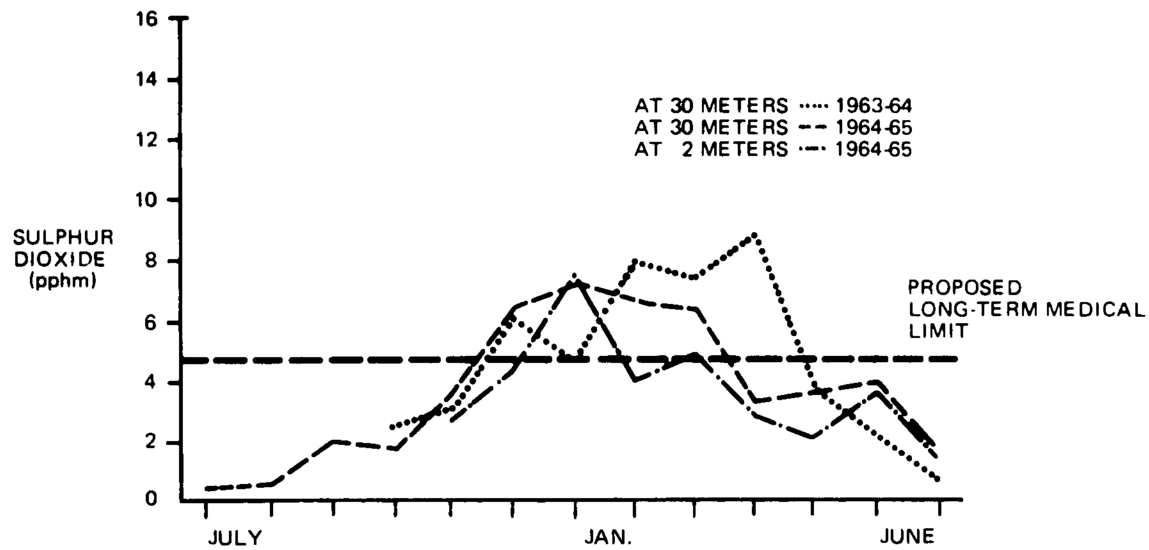


Figure 3.4 Air Pollution in Central Stockholm from 1963 to 1965 [182]

The location of heating and power plants offers planners potential for reducing air pollution exposures. For example, if plants now being planned to replace existing ones are properly located an almost immediate improvement can result. Although the number of such plants probably is small, the impact of relocation could be substantial for those living nearby.

There would thus be a small short-term impact. The long-range impact would be substantial if all new plants were located so that new development had direct exposure to such plants. Based on forecast urban population growth, the outcome may be that 50 percent of the population in 20 years could benefit from such a reduction. Proper location of these plants could reduce air pollution exposure problems as much as 20 percent.

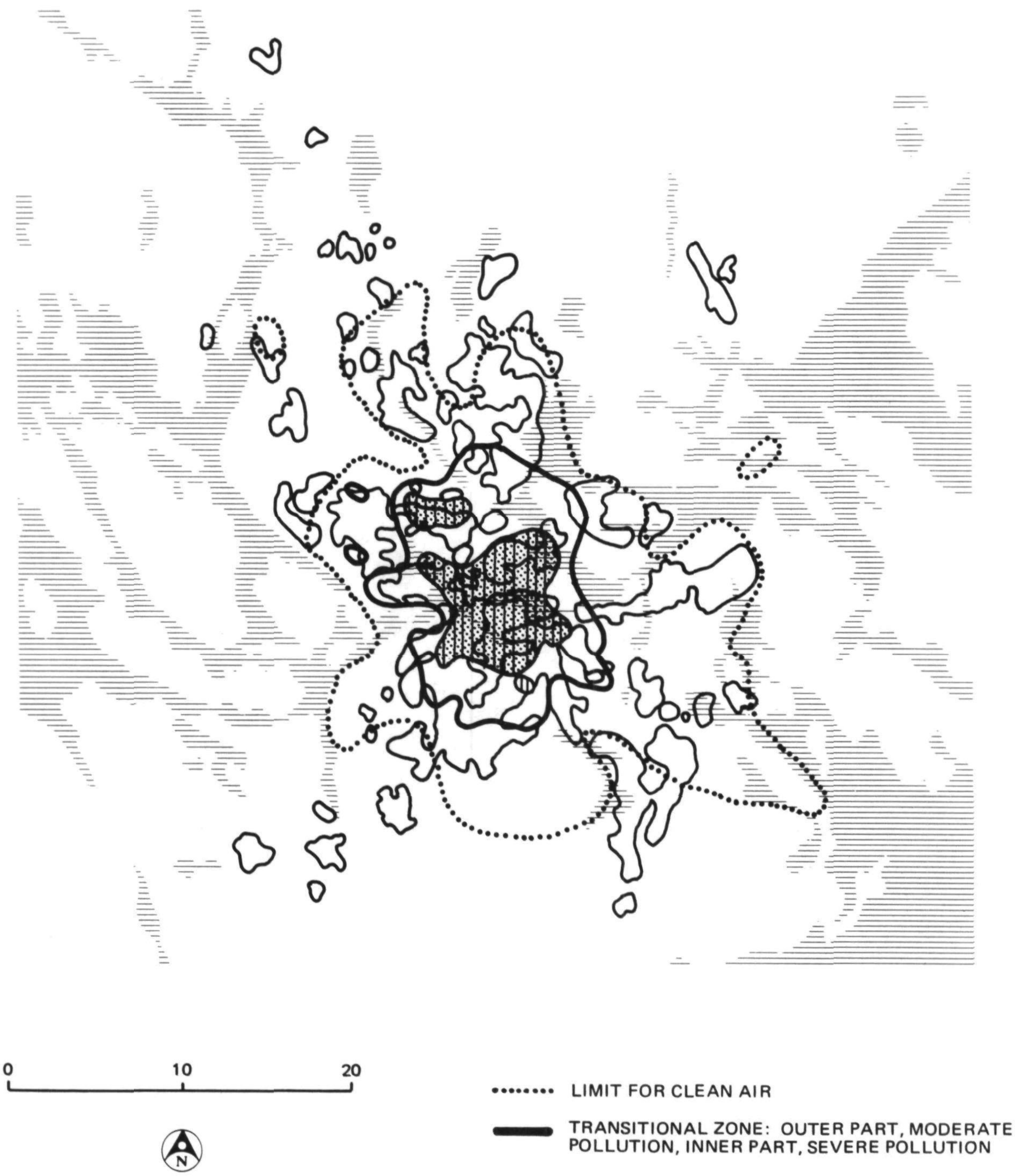


Figure 3.5 Air Pollution in Central Stockholm Exceeding Acceptable Medical Limits [182]

The problem of introducing pollutant sources into previously clean areas tends to act as an offsetting factor and redirect attention toward emission control. It will be increasingly difficult to find acceptable locations for major pollutant sources such as power plants, but this will not negate the importance of placing them where large populations will not be exposed to pollutant concentrations.

Summary

Land development patterns have pronounced effects on the formation and dispersal of pollutant concentrations, the extent of harmful exposures and even the quantity of pollutant emissions. In terms of overall land development patterns, planning efforts can improve air quality in a number of ways. These include positioning development so that prevailing winds carry pollutants away from developed areas, choosing patterns that tend to shorten average automobile trip lengths, avoiding large continuous expanses of development, using configurations that facilitate use of transit, and planning relationships among various land uses with a view toward pollutant dispersal patterns.

The density of development affects pollutant concentrations; lower density generally will result in better air quality although total pollutant emissions will be greater due to increased trip lengths, and a larger land area will be affected. Open space or green belts may be used to good effect, promoting air movement, serving as a moisture source, and providing a buffer between pollutant sources and land uses requiring protection. They may be a means, used properly, of lowering overall density with minimal tendency toward increased trip length or loss of mass transit potential.

The location of major pollutant sources such as power plants offers planners an opportunity to prevent exposure of developed areas although it will be increasingly difficult to find acceptable undeveloped locations.

Because of the long term injurious effects of deteriorating air quality on a global scale, emission control remains a primary requirement.

For this reason, the land development opportunities that help to limit emissions, such as those that shorten automobile trip lengths or encourage transit use, must receive particular attention. No matter how effective these steps may be, however, it will be worthwhile to choose development patterns that help to direct pollution flows away from developed areas and otherwise maximize their dilution and dispersion.

An encouraging feature is that models to predict conditions and strategies for the future are being developed. Although they are inadequate at the present time, they can be perfected and will become useful tools for urban and transportation planners in incorporating into future decisions all the complex aspects of minimizing air pollution.

Based on review and analysis of available material, it may be expected that a program dealing with the control of land development patterns and density in new areas could reduce air pollution problems significantly in the long range, assuming anticipated growth in urban areas. Short-term benefits would be minimal.

From the point of view of direct urban air quality improvement, the greatest impact would be brought about by proper control of power plant locations and, second, by new land development concepts. These techniques could affect at least one-half the increase in population that will occur in urban areas. Issues related to density, to industrial, commercial and residential land use relationships, and to open space can also contribute in the long run to air pollution reduction, but only slightly. None of these latter approaches appears to have significant short-term benefits.

The table below summarizes order of magnitude judgments of the possible impact within each subject area. These values are, of course, only general indications, not precise values, and the actual benefits attainable in a particular urban setting will depend upon the variables of existing and committed development patterns, physical constraints, growth rates, and the like. Nevertheless the figures are a starting point that will aid in selecting priorities, both for planning decisions and the new research and experimentation that are needed. The first column indicates the estimated percent of U.S. urban area population that might be affected by planning decisions in each subject area, while the second column is an estimate of the air quality improvement that might be experienced by the affected population. Thus, the third column, which contains the product of the first two, provides an estimate of the net areawide impact attainable. The indexes are additive only insofar as the concepts, i.e., land development, density, etc., are mutually exclusive. Each of the three columns is subdivided into short-term (5-year) and long-term (20-year) categories.

Table 3.2. LAND DEVELOPMENT PATTERNS AND DENSITY

Land Development Patterns and Density	Percent of Population Affected[a]		Percent Reductions in Air Pollution Concentrations[b]		Net Impact	
	Short-Term (1)	Long-Term (2)	Short-Term (3)	Long-Term (4)	Short-Term (1) x (3)	Long-Term (2) x (4)
Land Development Concepts		25		20		5
Density Patterns		25		5		1
Industrial, Commercial, and Residential Land Use Relationships		20		10		2
Open Space and Green Belts		10		10		1
Heating and Power Plant Locations	10	50	--	20	--	10
Total					--	19

[a]Based on judgment on the part of the consultant.

[b]Based on estimates by consultant in conjunction with discussions with Office of Air Programs personnel.

SPATIAL ARRANGEMENT OF BUILDINGS AND SITE ACTIVITIES

Locational Considerations

The atmosphere's capacity to disperse noxious emissions differs from one area to another, although most, if not all, large metropolitan areas are subject at times to conditions that produce high exposure levels. Nevertheless, the geographic location of an urban area helps to determine the total amount of air pollutant emissions that can be accommodated.

Some cities are located alongside oceans or in other areas where wind currents predominate in directions that consistently carry air pollutants away from the cities and over uninhabited regions. Some cities are located nearer the path of major global air streams and have stronger or more consistent winds than others. Other cities are handicapped by the presence of major generators of air pollution and already use much of their air resource capacity. It may be necessary to limit the development of some urban areas or modify urban and transportation plans in accordance with the air quality aspects of geographical location. Quantifying the air resource aspects of an area for urban and transportation planning requires the development of new tools and new conceptual approaches.

In Toronto [123], the role of Lake Ontario as both a source of water and a receptor of sewage effluent, the importance of the major east-west transportation facilities, and the difficulties of servicing the northern portion of the planning area have tended to create a broad urban ribbon along the shore of Lake Ontario. Gradually, as industrial and commercial establishments have become less dependent on central-city facilities, and as they have sought larger tracts of land, employment concentrations within the Toronto area have become more dispersed.

Where cities exist or are planned, topographic features, such as mountains, valleys, and river basins have a substantial impact on the dispersion of materials discharged into the atmosphere by man's activities. A city in a valley surrounded by mountains may experience such confinement of local air currents that air pollution becomes a major consideration in the planning process. Historical records are replete with incidents of air quality degradation caused by topographic factors that limit the size of the natural airshed over an urban area. When the airshed is small and air currents are confined, relatively small amounts of human activity may result in a substantial concentration of noxious air pollutants.

Planners must develop guidelines to evaluate topography and its effects on air quality in preparing land use and transportation plans and locating industries and transportation systems. Knowledge of the subject is far from complete, and additional studies are needed to permit the incorporation of air quality aspects of topography in urban and transportation planning.

Both the general meteorology and micro-meteorology of each urban area has a great impact on the dispersion of air pollutants, and must be considered. The height location of buildings channel and change air currents.

A great deal of thermal energy is released from any developed area. Under normal conditions warm air from this source will rise and disperse into the atmosphere. In this way, heat produced by man's activities causes a slight amount of turbulence in the atmosphere above most cities. Under normal atmospheric conditions the rising heat and gases are dispersed into huge circulating masses of air above the city, and many of the pollutants are carried away.

If temperature inversions occur (the temperature of the atmosphere remains approximately constant or even increases slightly with elevation) warm air is trapped and will not rise; there tends to be little vertical mixing or atmospheric dispersion. Gases and particulates released into the atmosphere under these conditions remain in a confined space and concentrations build up because the effective airshed is reduced. Temperature inversions are usually of short duration, but they can cause serious atmospheric pollution problems, such as those occurring from time to time in Los Angeles, New York City, Chicago, and other major cities.

Many aspects of an area's climate, such as temperature, diurnal variation in temperature, seasonal variations in climate, humidity, precipitation, whether as rain or snow, should all be considered by the planner as he includes air quality among his concerns.

Planners have noted that transportation and urban planning activities should include air quality implications of geographical location, topographic considerations, and meteorological-climatological factors. For example, Shields, [171]identifies the following factors as worth considering in urban planning activities:

- The avoidance of air pollution source locations inside an area where temperature inversions are frequent
- The avoidance of coastal sections of sharp river valleys as the location of heavy industry
- The proximity of adjacent city pollutant source areas to new developments
- The preservation of green belts between residential and industrial areas
- The location of principal traffic arteries as far as practicable from residential areas
- The proper arrangement of structures to promote maximum vertical movement of air
- The effect of new pollution sources on farming activities adjacent to the city area

Rydell and Schwarz [159] point out the following:

> "Buildings in different topographical locations are subject to different microclimates, which in turn are associated with different concentrations of pollution. A building on the crest of a hill is subject to a more moderate climate than a structure 25 feet lower in an adjacent valley.

Cooler air sinks into the "fog hole" and pollution will collect there, while the crest is exposed to high velocity which will blow the pollution by, minimizing its impact. The slopes not only experience warmer temperatures than either the crest or the valley, they receive the least impact from pollution. The windward slopes, which are struck by the brunt of the winds, are subject to less pollution than the leeward slopes, which have the more moderate climate [58, 95, 147]. Although the leeward slopes provide the best climate, the windward slopes are freest from air pollution.

"The way a building is located with respect to a lake also partly determines the impact of air pollution on the building's inhabitants. Locations on any shore of the lake are subject to clearer air than inland sites. This is due to the different heating and cooling rates of land and water. Water holds heat longer than land. In the daytime the lake will heat up more slowly than the surrounding shore. Because warm air is lighter than cool air, the warmer air over the surrounding land rises out over the lake, as the cooler lake air moves inland, bringing cooling breezes along the ground. In the evening the cycle reverses. Cool air from the shore moves out over the water and warm lake breezes rise over the land. The circulation thus produced sweeps pollution emitted along the shore away and up over the lake. Buildings sited on the lake leeward of the prevailing winds experience even greater temperature moderation from the lake breezes and even more effective dispersal of air pollution [90]."

The factors of geographical location, topography, meteorology and climate have a combined effect which is extremely important in determining the size of airsheds over urban areas and the degree of dispersion of gaseous and particulate emissions into the atmosphere. In the past most information has been obtained as the result of experience with existing situations. It is essential that a more sophisticated approach be developed, giving maximum priority to air quality potential, in order for planning to be carried out in a way that will avoid air pollution problems in major urban areas in the future.

We continue to build in areas with topographic and meteorological conditions that cause air pollution problems, creating bowls and pockets of air pollution. To prohibit development in such areas would not only reduce air pollution concentration but would also reduce the population exposed to such conditions. It is difficult to determine the land area subject to adverse meteorological effects, but it is conceivable that 10 to 20 percent of the forecast population could avoid such conditions in the long term if the policy were vigorously enforced. The improvement in air quality that this population would be exposed to could be on the order of 20 percent. The short-term impact would be much less, although some reduction in the number of people exposed to undesirable conditions might be achieved.

Building and Site Activity Arrangements

Air pollution concentrations in an urban atmosphere may vary over several orders of magnitude within short distances and are influenced to a large degree by the geometric configuration of buildings. The concentration of sulfur dioxide (SO_2) within the chimney of a coal-fired heating plant may be in the range of 1000 ppm, while day-to-day samples taken at street level may be 0.1 ppm or less. Within this range of concentrations SO_2 levels of 10 ppm are found quite frequently on roof tops, and 1 ppm may be found in upper-story apartments under certain conditions of local wind currents.

James Halitsky has published a number of papers dealing with various aspects of atmospheric diffusion of air pollutants in urban areas. In establishing typical pollution patterns [70], he lists the three major source groupings as follows:

- Tall chimneys at power plants, refineries, and municipal incinerators
- Numerous heating plant and incinerator exhausts at the roof-level of older five- and six-story buildings
- Automotive exhaust at street level

None of these source groupings is amenable to strict analytical treatment. The tall stacks may be considered as elevated continuous point sources, but there is a dearth of information regarding diffusion coefficients over urban areas. The roof-top emissions may be treated as rectangular area sources separated by clear bands formed by streets and avenues, but it is difficult to predict how rapidly the gases penetrate downward between buildings. Diffusion from ground-level sources (automobiles) is greatly affected by the channeling of air currents between buildings and the back flow in eddies created by building corners. Analytical methods for modeling such sources are inadequate.

The effect of buildings on air pollution was studied in a detailed urban design project for Skopje, Yugoslavia, [185]. The effect of rows of tall buildings in the exterior urban zone on the nature of air flow in the interior of the city was investigated by model experiments. Figure 3.6 illustrates the alternative arrangments of buildings examined for the tall buildings in the exterior zone. These tall buildings constituted what was labeled the "city wall." The relationships between the velocity distribution of local air currents and the height of buildings, distances between buildings or blocks, open spaces within buildings, and the relative location of buildings to adjacent streets were examined.

Figure 3.7 illustrates the findings of one test that was performed. Here, the impact on wind flow of the relative arrangment of the city wall structures and interior buildings is investigated. The same type of city wall (Type 1) is used throughout the experiment shown in this figure. In Alternative A, only the city wall is present; in Alternative B only the interior buildings are present; in Alternative C both types of structures are present and are offset with respect to each other. The figure shows the wind profile under each one of the alternatives.

Figure 3.8 is concerned with the impact of the relative width of streets on wind flow. Here again, only one kind of city wall (Type 1) is used and the arrangement of the two kinds of buildings is kept constant. In Alternative A the city wall structures are more widely separated from each other than are the interior walls; in Alternative B the separation is the same for both types of buildings; in Alternative C the interior structures are set

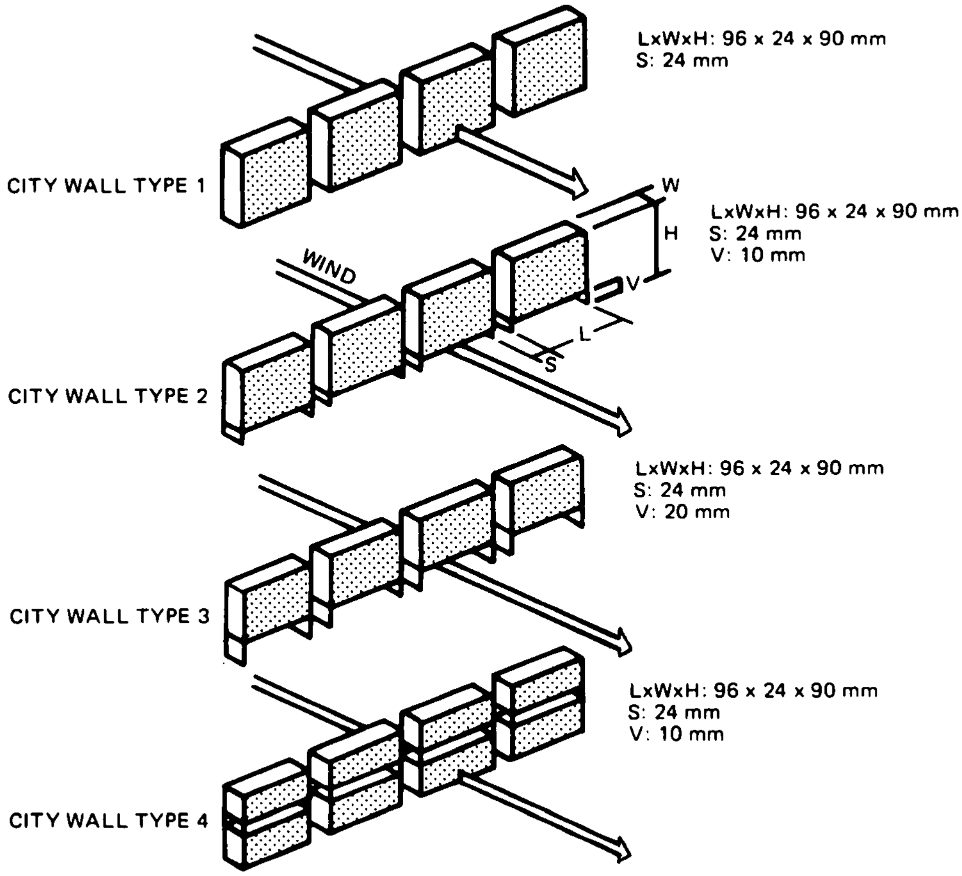


Figure 3.6 Building Arrangements Examined for Exterior Zone in Skopje [185]

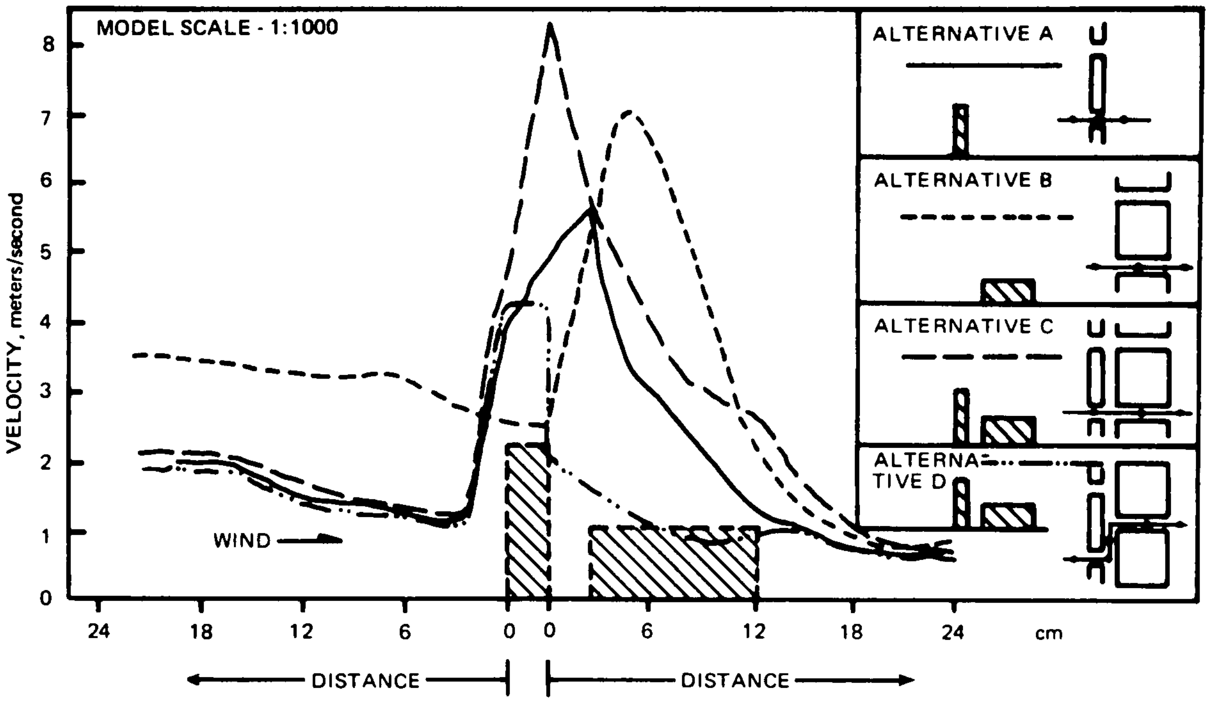


Figure 3.7 Wind Velocity Distribution for Various Building Arrangements in Skopje [185]

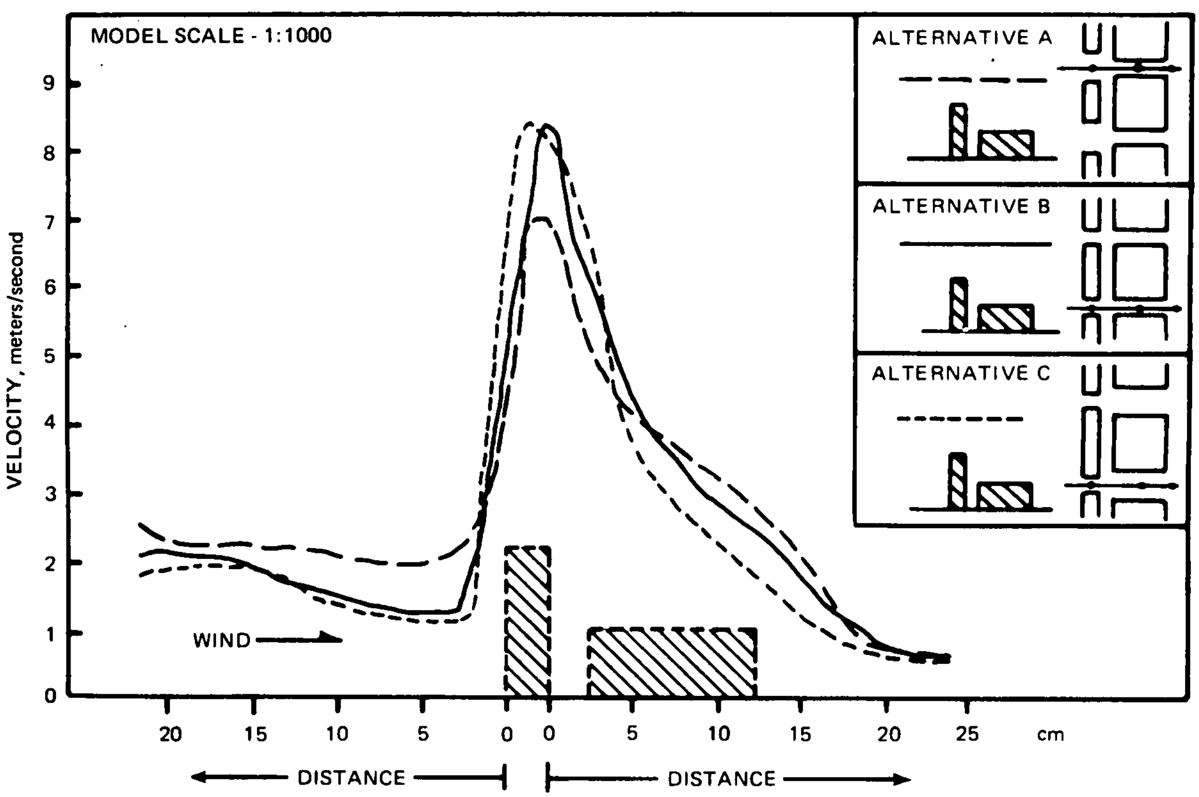


Figure 3.8 Wind Velocity Distribution for Various Street Widths in Skopje [185]

farther apart from each other than are the city wall structures. Again, the impact of the alternative arrangements on wind flow is shown in the figure.

Figure 3.9 uses the same relative arrangement of buildings, but varies the design of city wall structures. In all cases the outer and inner buildings are aligned with each other. Alternative A utilizes city wall Type 1; Alternative B consists of city wall Type 2; Alternative C consists of city wall Type 4. The wind profiles are again shown.

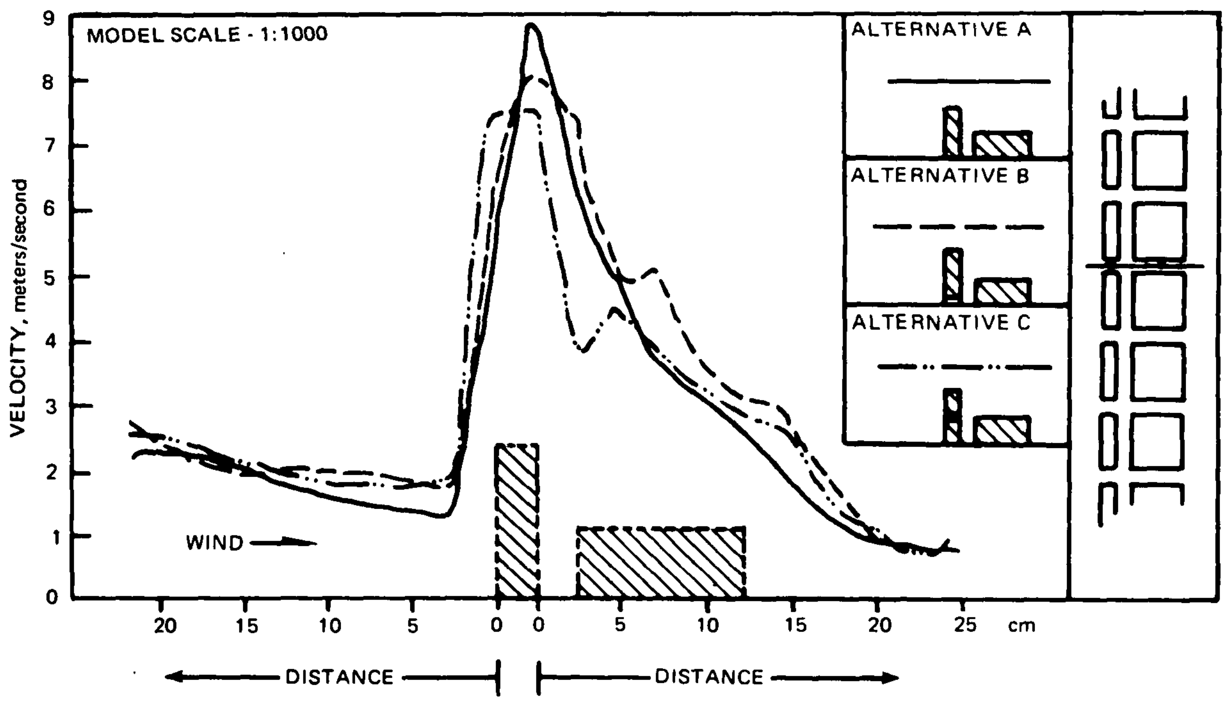


Figure 3.9 Wind Velocity Distribution Due to Types of City Wall in Aligned Arrangement [185]

Figure 3.10 shows a situation very similar to that of Figure 3.9. The only difference between the two cases is that in the test described in Figure 3.10 the outer wall structures and the interior structures were offset with respect to each other. The marked reduction in wind velocity that this change causes can be seen by comparing the wind profiles in the two figures.

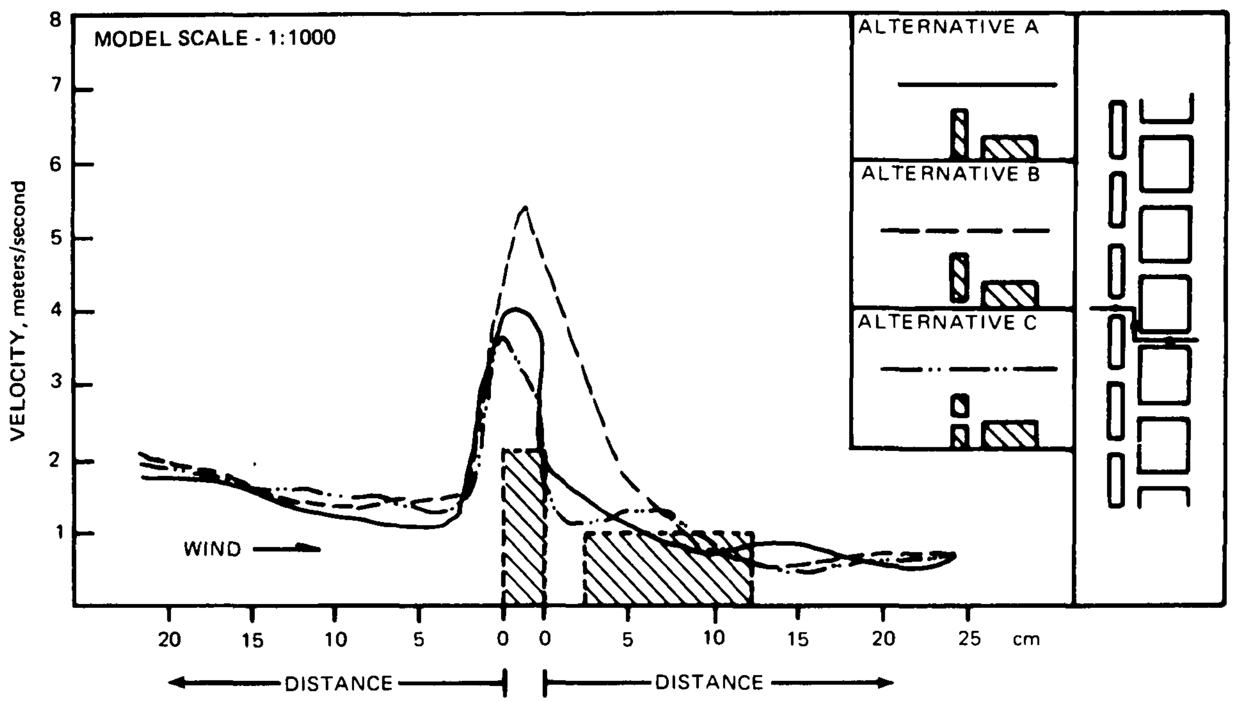


Figure 3.10 Wind Velocity Distribution Due to Types of City Wall in Offset Arrangement in Skopje [185]

These experiments on wind flow have important implications for air quality because they show that the arrangement of structures can be used to alter wind velocities. The desirable wind velocities for various circumstances should be identified by further research and the design alternatives to achieve desirable wind velocities should be clearly pointed out.

The Rydell and Schwarz review [159] also discusses air quality implications of building and site arrangements:

"The orientation of a building with respect to winds also has an important influence on the impact of air pollution. Various building configurations with respect to winds create different sized eddies around the structure. An eddy, which is a slowly revolving stationary mass of air, can trap pollution, increasing its concentration many times. The larger the eddies around a building, the smaller the volume of the wind that passes by the building to sweep the pollutants away [90]. As the pitch of the roof, the thinness, and the height and width of a building or a building block increases, the size of the eddies around the building increases. A row of uneven roofs creating rough surfaces can slow the wind, holding pollution in the area longer [90, 91, 95]. Yet, if controlled, these factors can be used to minimize the effect of pollution on the buildings. Building shapes can redirect or even reverse the direction of the wind [113]. Buildings can be constructed to maintain beneficial topographical effects. In some southern climates houses on stilts allow hot ground air to "roll" under rather than through the buildings, avoiding the heat and any pollution carried in the wind.

"Not only is the impact of air pollution on a building affected by how the building changes winds and eddies, but by the kind of climate the edifice itself creates. Placed on a slope, a building or mining debris can act like an artificial hill, creating a new slope climate [97]. The building can block cold air from spreading downhill, holding the air stagnant to gather increasing concentrations of pollution.

"Building materials and soil content also influence microclimate and the effects of air pollution. Masonry heats and cools slowly, moderating temperatures much as a body of water does, remaining warmer in the early evening and warming up later in the morning. Sand and gravel around the structure create a local desert-like climate - hot and dry - which encourages air to cool and rise, creating circulation. Loam and clay soils are cool and moist, conducive to stationary air and pollution [64].

"Streets, like buildings, alter microclimate by changing topography and creating new land shapes. Canyon like rows of tall buildings along narrow streets create a funnel effect, frequently doubling the wind speed, or, if the wind enters at a 45-degree angle, accelerating the velocity on the windward side and creating slower currents on the leeward [64. 95]. At night heat losses are larger at higher floors of tall buildings than at lower ones. These temperature variations over the height of tall buildings create upward currents in the city streets which can act with the high velocity winds to sweep pollution away. However, if much of the rooftop area of the city is about the same height, the rooftops and streets will radiate their warmth upward so rapidly as to create a cool layer of air at that rooftop level. Warm air above the cool layer forms a stable stratification, trapping the warmer polluted air below in the streets and between the buildings.

"In the natural environment hills or uneven slopes can block up pools of cool air. When streets or railroad beds are constructed that cut through these cold air dams, they may create cold air floods. If pollution is involved, air drainage may have serious consequences for the health of people in the valley. A new highway can also create a new alley for cold air and pollution to settle in. Anyone who drives knows of the efficiency of open-cut highways for trapping automobile exhausts. This principle also works in reverse: where there was once free drainage a railroad embankment or an artificially level highway can dam up pools of cold air and highly concentrated pollution.

"Streets, like stone masonry and different kinds of soil, affect the climate of the urban area. Concrete streets absorb heat during the day, then radiate it slowly into the early evening [95]. They provide no cooling evaporation, as does the foliage in the countryside. When streets make up 20 to 50 percent of the surface of the city, these factors are influential in causing the city to have a significantly more moderate, dryer climate, conducive to the formation of the "dust dome."

Yocom, Clink and Cote [263] describe a study in which air quality data was gathered for four pollutants inside and outside three pairs of structures during different seasons of the year. Suspended particulates, soiling particulates, carbon monoxide, and sulfur dioxide were measured at pairs of public buildings, office buildings, and private homes in the Hartford, Connecticut area. It is interesting to note that in a gas-heated home, the data indicated (Figure 3.11) that the carbon monoxide concentration inside the home was substantially higher than that outdoors and that in a home heated by coal (Figure 3.12) the sulfur dioxide concentration inside the house was at times much higher than that outdoors.

The data gathered from the preliminary program of summer season measurements in 1969 led to a number of interesting conclusions, some of which are listed below:

- In homes with gas heating and cooking, the heating system had no effect upon carbon monoxide levels; however, the gas stoves had a significant effect on indoor CO levels.
- Attached garages having a door opening from the garage directly to the house proper are a significant source of carbon monoxide inside such homes.
- Suspended particulate matter readily penetrated private homes in this study. Public buildings and air-conditioned office buildings were penetrated to a lesser extent.
- Carbon monoxide readily penetrated all the structures and existed in higher or lower concentrations only where proximity to sources or other obvious reasons existed.
- From carbon monoxide measurements in the summer season, there appeared to be little detectable influence from a submerged roadway on structures over the roadway other than the contribution to general pollution concentration outdoors; nor was there much detectable influence from an underlying parking garage on an air-conditioned building above.

With parking garages becoming an integral part and occupying the lower floors of many buildings in urban areas, and with increasing trends toward enclosing larger complexes to provide controlled or artificial air environments, it is clear that additional information is necessary to evaluate the impact of ambient air pollution on the indoor environment.

While it is apparent that the environment can be improved by better siting of buildings and by more effectively arranging the activities related to them, these techniques will not reduce overall air pollution emissions in such areas, but will reduce the number of people exposed to undesirable

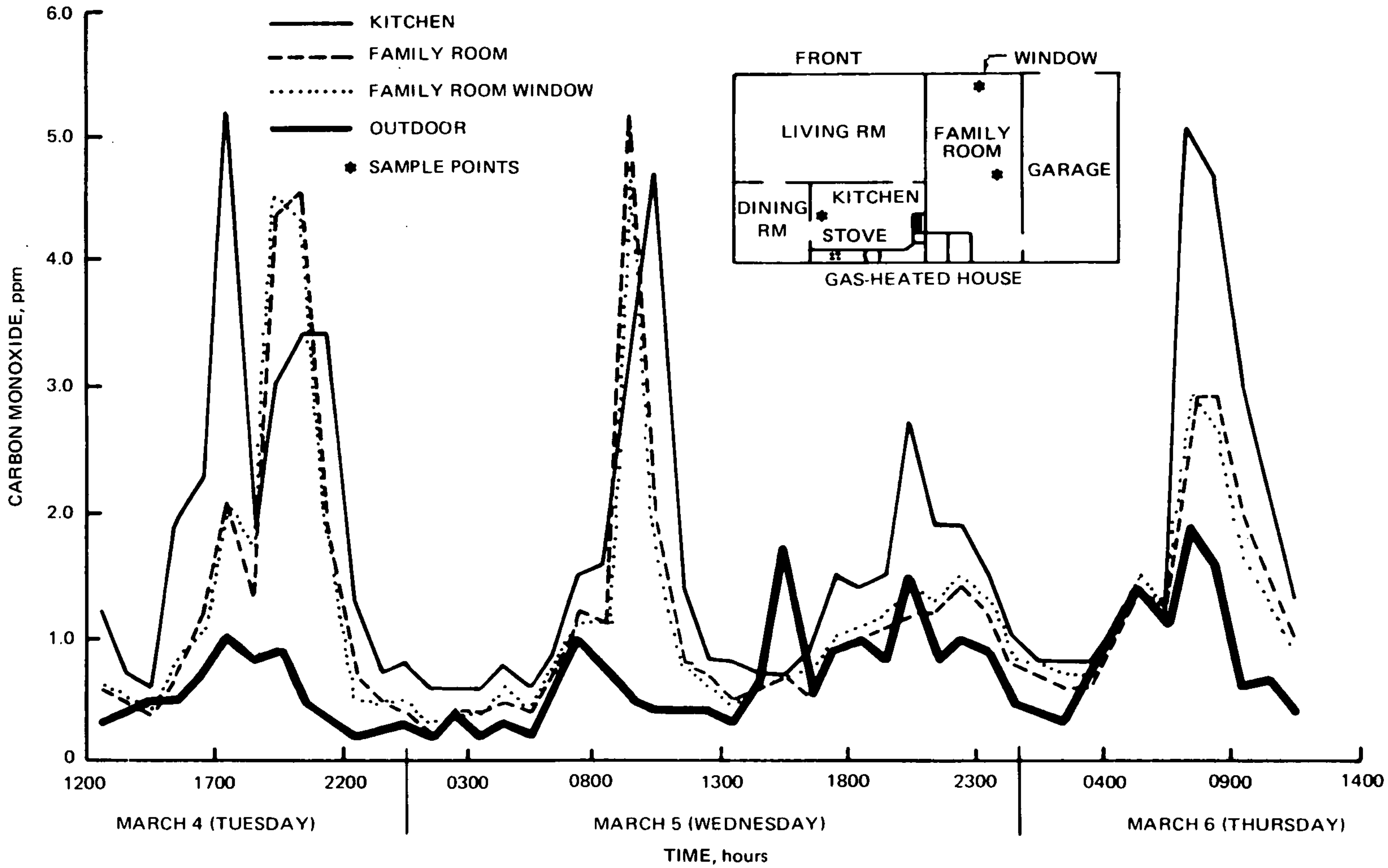


Figure 3.11 Time Variation of Carbon Monoxide for a Gas-Heated House [236]

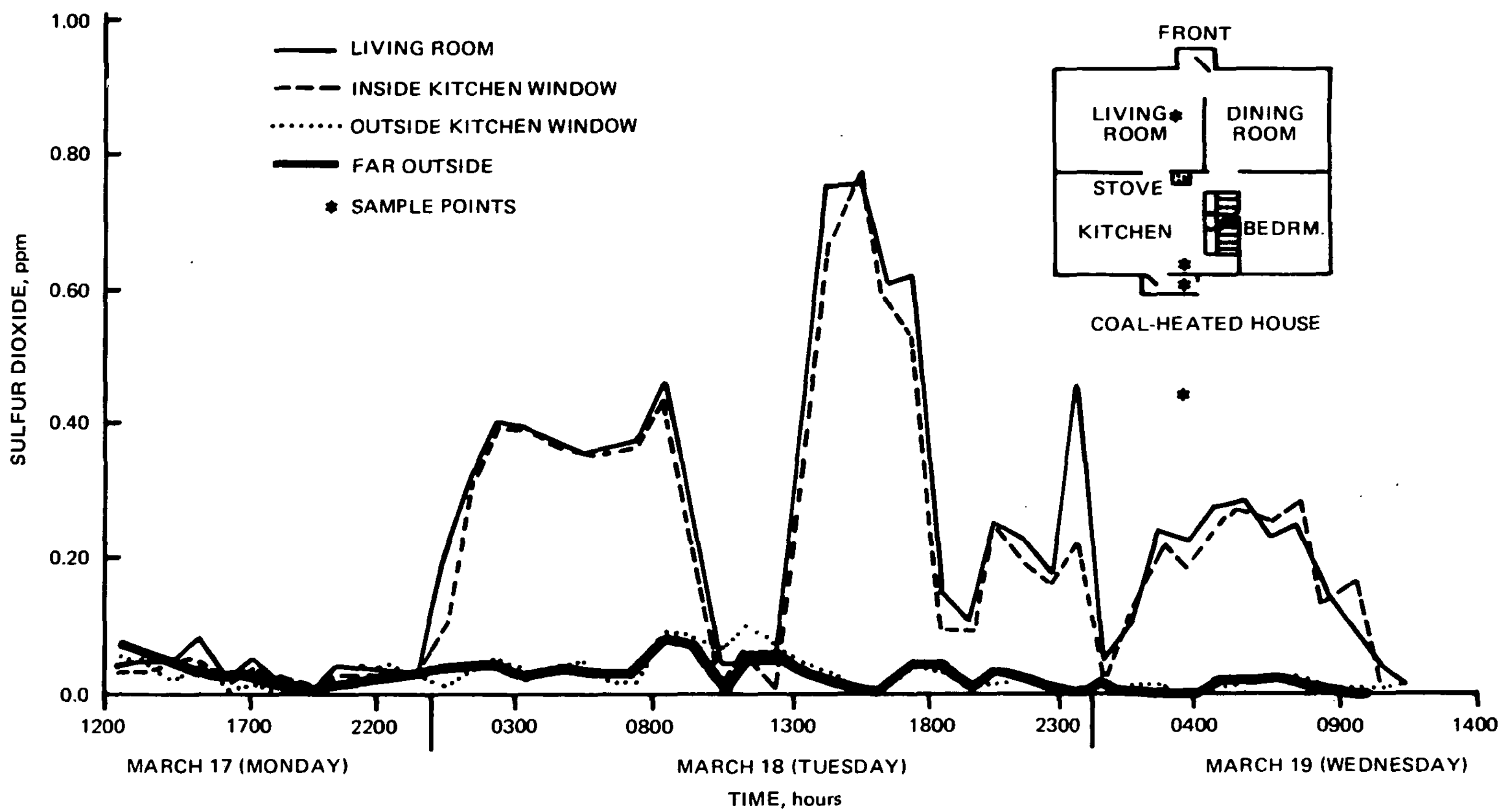


Figure 3.12 Time Variation of Sulfur Dioxide for a Coal-Heated House [236]

levels of air pollution. Bearing in mind that other techniques may alleviate the problem of pollutant sources such as tall stacks or rooftop emissions, motor vehicle pollutants may be the main source subject to avoidance through building and site arrangement. Effective response to available opportunities might affect 20 percent of the long-term population and produce a 10 percent improvement in air quality for those affected. There would not likely be more than a slight short-term impact.

Centralization of Heating Plants

The concept of economy of scale applies to heating and power plants and their fuel consumption when air pollution reduction is considered. A planning function that should not be overlooked, therefore, is the substitution of large plants for small ones. The latter tend to be relatively inefficient and generate a comparatively large amount of air pollution per unit of heat and power produced. Large plants may serve an entire area and produce relatively little air pollution per unit of energy converted. Buildings within a single complex, such as an industrial operation or an apartment park, often contain a single power plant from which power or heat is conveyed to each separate building through underground conduits. It would seem appropriate for this concept to be more widely utilized to provide heat for large blocks of residential and commercial buildings, thereby significantly decreasing the air pollution compared with use of numerous small and inefficient power plants.

Unfortunately there has not been enough research on the impact of centralized heating plants on air pollution, but a number of European countries, particularly Sweden, have moved toward central heating primarily to reduce air pollution. It does appear that managing central heating plants properly can have a very significant impact on reducing emissions and that these reductions can affect the bulk of the new population, particularly in view of the extent to which the urban population is being housed in multi-family units. The short-term impact, of course, would be slight in terms of air pollution reduction and the people that would be affected.

Summary

Consideration of local variations in climate, topography and meteorologic conditions in locating urban development is a valid means of avoiding pollutant exposures. Microscale variations in temperature, humidity and wind direction and strength can be used to advantage by locating pollutant sources where dispersal is advantageous and avoiding the placement of sensitive development where concentrations may tend to occur. The height, shape, orientation and grouping of buildings and other structures demonstrably influence air movement and quality. It will be possible to achieve better air quality through manipulation of these variables, as a better understanding of these phenomena is developed. Heating plants are a significant source of urban air pollution; small plants generally are less efficient than large ones and produce larger amounts of pollutant per unit of heat produced. Consequently the centralization of heating plants is an effective means of reducing emissions from this source.

Table 3.3. SPATIAL ARRANGEMENT OF BUILDINGS AND SITE ACTIVITIES

	Percent of Population Affected[a]		Percent Reductions in Air Pollution Concentrations[b]		Net Impact	
Spatial Arrangement of Buildings and Site Activities	Short-Term (1)	Long-Term (2)	Short-Term (3)	Long-Term (4)	Short-Term (1) x (3)	Long-Term (2) x (4)
Locational Considerations		15		20		3
Building Arrangements		20		10		2
Centralization of Heating Plants		20		20		4
Total					---	9

[a] Based on judgment on the part of the consultant.

[b] Based on estimates by consultant in conjunction with discussions with Office of Air Programs personnel.

PLANNING OF TRANSPORTATION SYSTEMS

In the preceding sections of this chapter the air quality significance of land use variables was discussed. The following section examines aspects of transportation systems alternatives on air quality. It should be noted that a distinction is made in this report between planning, which can be likened to strategic decisions of location, size, and general standards, and design, which may be termed the tatical aspect -- decisions involved in the particular location and specific detailing of a facility.

Transit-Highway Combinations

The effect of transit, highways, and urban development on a number of variables, including air pollution, has been simulated by computer for a hypothetical 625 square-mile metropolitan area of two and one-half million people. Varying assumptions about urban patterns, highway networks, and transit networks were used in the analysis as illustrated in Figure 3.13 [217]. Eight different urban patterns of spatial allocations of population and employment were investigated:

- Sprawl
- Moderate corridors
- Heavy corridors
- Corridors rotated
- Extreme corridors rotated

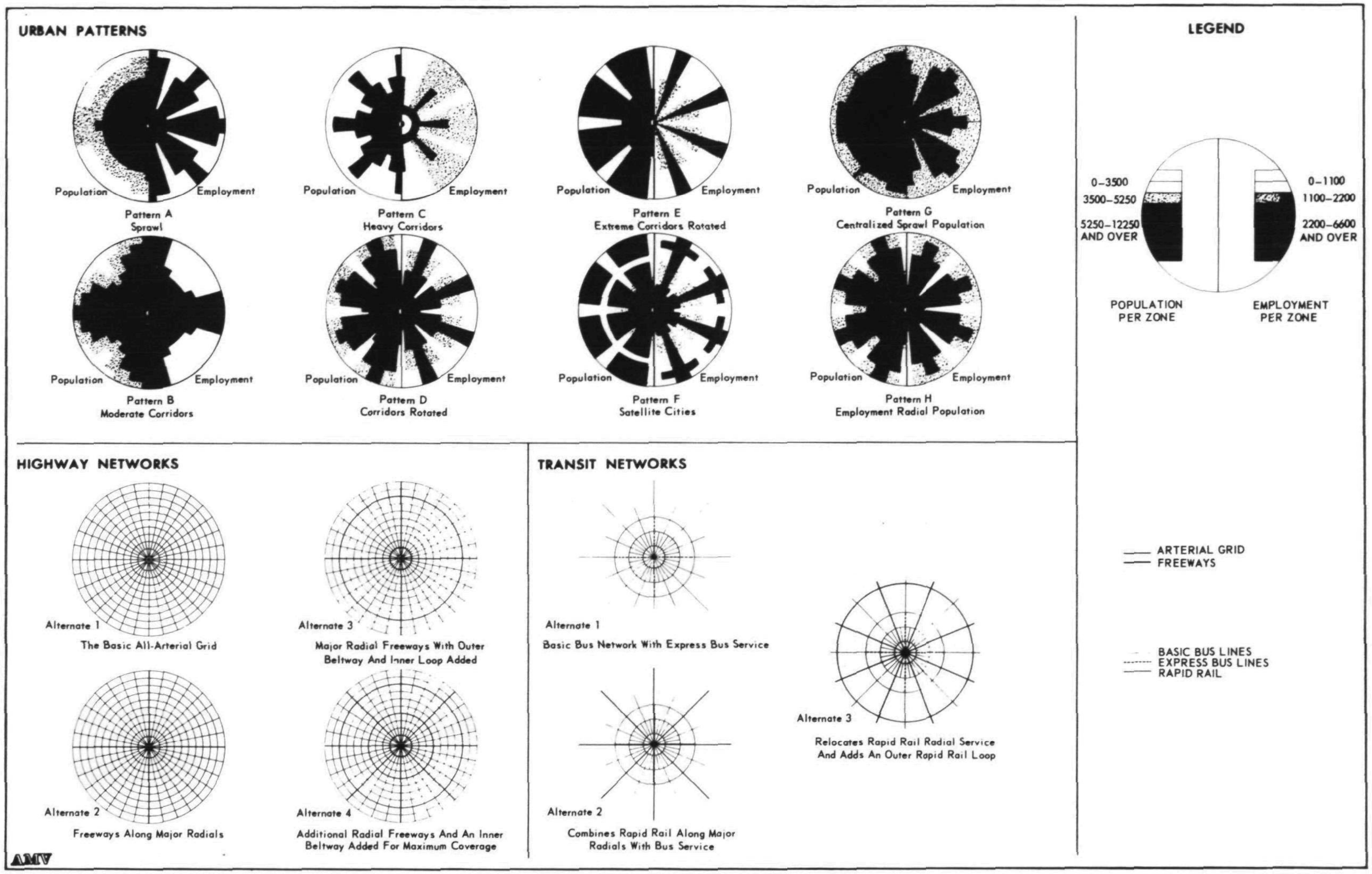


Figure 3.13 Description of Urban Forms and Transportation Systems Simulation Study [217]

- Satellite cities
- Centralized employment, sprawl population
- Centralized employment, radial population

Four highway networks were examined:

- A basic arterial grid
- Freeways along major arterials
- Major radial freeways with an outer beltway and inner loop added
- Additional radial freeways and an inner beltway added for maximum coverage

Three basic transit networks were reviewed:

- A basic bus network with express bus service
- Rapid rail along major radials with bus service
- Relocated rapid rail service and an outer rapid rail loop

A series of alternatives were constructed which defined various land use, highway, and transit configurations and work travel patterns were simulated to arrive at estimates of work trip length, average network speed, and transit usage for each alternative.

Table 3.4 shows the vehicular work trip length and average speed noted from the simulation of various combinations of urban patterns, highway, and transit systems. For each urban pattern considered it is possible to examine the effect of the transportation alternatives.

What do the changes in trip length, speed, and transit use mean with respect to air pollution reduction?

An increase in average network speed decreases carbon monoxide and hydrocarbon emission rates per vehicle mile. Figure 3.14 shows emissions per vehicle mile versus average network speed in miles per hour for two major air pollutants, carbon monoxide and hydrocarbons.

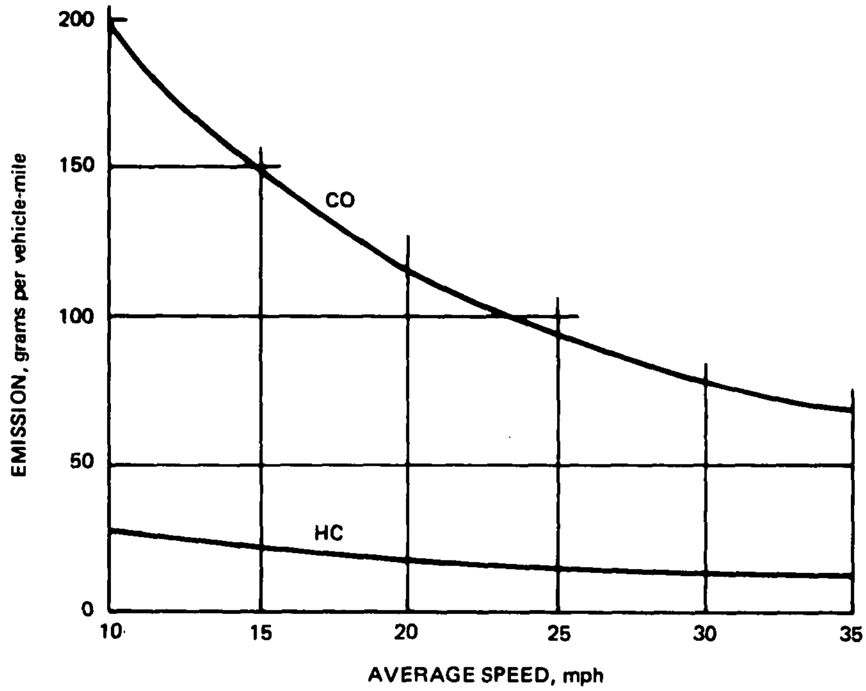


Figure 3.14 Relationship of Carbon Monoxide and Hydrocarbon Emissions to Speed [204]

Table 3.4. SUMMARY OF AUTO AND TRANSIT WORK TRIP LENGTHS FOR VARIOUS URBAN PATTERNS AND TRANSPORTATION SYSTEMS - SIMULATION STUDY [221]

Urban Pattern	Highway System	Transit System	Mean Trip Length: Auto Minutes	Auto Miles	Auto Speed (MPH)	Transit Minutes
A Sprawl	1	1	14.84	4.77	19.3	26.28
	2	1	12.83	5.08	23.8	26.06
	4	1	9.47	5.78	36.6	25.85
B Moderate Corridors	2	1	12.15	4.94	24.2	25.79
	2	2	12.31	5.02	24.4	20.75
	3	2	10.97	5.27	28.8	20.69
C Heavy Corridors	4	2	9.07	5.58	36.9	20.19
D Corridors Rotated	1	3	14.25	4.60	19.4	20.27
F Satellite Cities	1	3	13.98	4.41	18.9	19.68
G Centralized Sprawl Population	1	3	15.79	4.85	18.4	27.93
H Employment Radial Population	1	3	10.12	4.71	27.9	21.09

Table 3.5. AIR POLLUTION REDUCTIONS FOR CHANGES IN THE HIGHWAY SYSTEM

Urban Pattern	Highway System	Base Network	Percent Reductions[a] in Emission Rates	
			CO	HC
Pre-1968				
A Sprawl	2 Freeways along major radials	1 Basic arterial grid	-13	- 4
A Sprawl	4 Additional radial freeways and an inner beltway for maximum coverage	1 Basic arterial grid	-35	-14
B Moderate Corridors	3 Major radial freeways with outer beltway and inner loop added	2 Freeways along major radials	-11	+ 5
Post-1975				
A Sprawl	2 Freeways along major radials	1 Basic arterial grid	- 9	-29
A Sprawl	4 Additional radial freeways and an inner beltway for maximum coverage	1 Basic arterial grid	-31	-19
B Moderate Corridors	3 Major radial freeways with outer beltway and inner loop added	2 Freeways along major radials	+ 5	+ 5

[a]Percent reductions are calculated on the difference between an alternative highway system and the base network.

These emission rates may be applied to the travel simulation information in Table 3.4 to determine the effect of alternative land use patterns on emissions per vehicle mile. Changes in total emissions of these pollutants from motor vehicles used in work travel are shown in Table 3.5 for urban patterns A and B. The figures account for total vehicle miles and average speed in each alternative. From these data it may be observed that a more extensive freeway type system does result in reduced carbon monoxide and hydrocarbon emissions.

The relationship between nitrogen oxide emissions and vehicular speed is less well known. It is known that nitrogen oxide emissions increase with higher air-fuel ratios, but the relationship between nitrogen oxide emissions and speed is not direct. Although it can be assumed that nitrogen oxide emissions increase as vehicular speed increases, the increase in emissions may not be so large as to produce higher concentrations along a given length of road.

Improved transit service helps to increase transit usage for work trips and reduce air pollution during the peak period. Figure 3.15 illustrates for the same study the effect of improved transit service on

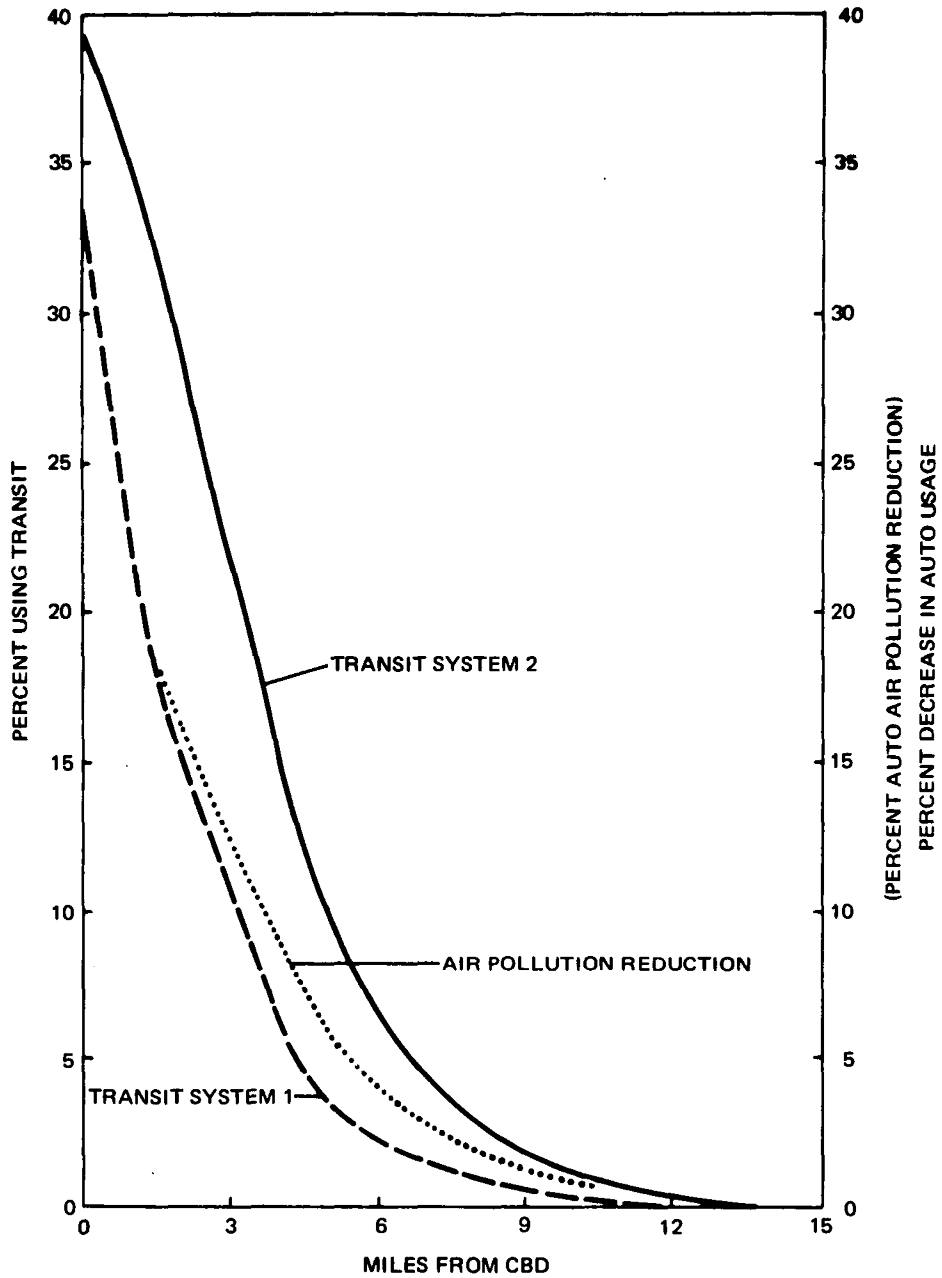


Figure 3.15 Effect of Improved Transit Service on Modal Split and Air Pollution in a High Density Corridor [217]

modal split and motor vehicle air pollution reductions taking into account distance from the central business district. Transit System 2 represents an improved level of transit service over Transit System 1, thereby diverting riders from automobiles and causing a reduction in automobile emissions.

The effect is to reduce air pollution from 18 percent in the CBD to one percent in the periphery of the hypothetical city. At a distance of four to five miles from the CBD there is a significant reduction in automobile air pollution as a result of the improved transit service. Note that all motor vehicle emissions including oxides of nitrogen would be affected.

In a study of transit improvement in the Twin Cities area [216] the overall regional air pollution impact of transit was found to be negligible. However, the positive impact (air pollution reduction) in the downtown area would be considerable. Auto 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. Automobile induced air pollution in these critical areas could be expected to be reduced by a similar amount. On the regional scale, the test systems that could produce the largest diversion from automobiles would reduce regional 1985 auto use by about 3 percent compared to current auto use. These findings for Twin Cities are based on a given land use plan for 1985 and a constant highway network.

Greater emphasis on transit improvements thus will favorably affect air quality. Various tests indicate that reasonable expenditures on transit encouraged by present Federal programs might reduce highway usage between 10 and 20 percent depending upon the areas involved. This effort, of course, would be on a long-term basis. It would probably affect a large portion of the urban population that now uses the automobile, presently about 80 percent. But the short-range impact is generally much smaller.

The most significant impact of transit on air quality relates to the transfer of travel between one mode and the other -- between auto and transit. Transit systems also differ in the amount of pollution they create directly. The Twin Cities study [216] investigated the direct air pollution created by alternative transit systems. The findings of the study are illustrated in Table 3.6. Air pollution levels related to transit are generally low, and there is not much that can be done to reduce them further. Therefore, actions in this direction can only have a minor effect.

Table 3.6. AIR POLLUTION IMPACTS FOR ALTERNATIVE TRANSIT SYSTEMS IN TWIN CITIES [216]

System	Direct Air Pollution Impact	
	Downtown	Regional
Rapid rail transit	Excellent	Negligible
Rapid rail transit with extended station spacing	Excellent	Negligible
Buses in freeways and streets	Fair	Negligible
Commuter railroad	Good	Negligible
Busways without CBD subways	Fair	Negligible
Busways with CBD subways	Fair	Negligible
Metered freeway buses	Fair	Negligible

Air travel currently constitutes only about 10 percent of passenger transportation expenditures in the United States [23]. Although most air trips are relatively long (in excess of 300 miles), aircraft in flight generate a negligible proportion of pollutants. Airport operations do not constitute a major air quality problem compared with other urban sources. There is, however, a potential problem of pollutant exposures at air terminal sites, although weather protection and noise control measures tend to protect air quality as well. As major airport activity increases there is also potential for air pollution efforts downwind from the facility [53]. Although no direct data are available, it appears that motor vehicle emissions at airports may generate as much pollutant concentration as do aircraft operations. Increased transit use for airport access could help to reduce the motor vehicle emission problem. No measurable regional-scale improvement in air quality can be expected from airport planning efforts, however.

The number of vehicle-miles traveled in parking structures and other terminals is low; the impact of improvements would not be very significant, except to reduce undesirable air pollution levels at the terminals caused primarily by exhaust from idling buses and/or automobiles waiting in queues.

Planning of Highway Systems

The analysis of an abstract city, described at the beginning of this section on transportation systems planning, dealt with variations in land use, the relative attractiveness of highways and transit, and alternative plans within each mode. While the previous discussion was concerned primarily with choice of mode, the data also illustrate the impact of highway system variations. Highway planning can provide for (a) capacity sufficient to reduce congestion, (b) higher speed linkages, and (c) in some cases, shorter, more direct paths between points. The first two types of highway improvement tend to reduce vehicular emissions of carbon monoxide and hydrocarbons due to smoother traffic flow and higher average speeds, but tend to induce longer trips for the same reasons. The third type of improvement will generally reduce all emissions. All three tend to generate more highway travel, including those trips which are attracted away from transit. Consequently, it is important to consider other transportation policy and/or land use changes along with plans for highway improvements.

Since so much of the travel in future years is going to take place in urban areas, the long-term impact of improved planning of urban highway systems is significant. If the long-term effects are applied to projected urban populations it may be assumed that 40 percent or more of the population could be affected by new highways and ancillary improvements. As indicated by the research that has been done to date, a 10 to 15 percent reduction in carbon monoxide and hydrocarbon emissions can be achieved by planning highways more effectively.

Summary

The studies described in this section have considered the relative reductions in air pollution emissions and concentrations that may be realized through the planning of transportation systems. It can be seen from the abstract city analysis that transportation plan features can significantly influence the choice of travel mode. Because transit produces relatively small pollutant emissions per passenger mile accommodated, increasing the use of transit reduces motor vehicle emissions. Although this air pollutant reduction is not great enough to have much regional importance, it is highly significant in such heavy activity centers as downtown areas or major development corridors.

Because of the low scale of transit-caused pollution, changes in the transit vehicle or other changes in the way a transit system is planned will not generally have a useful air quality impact, except for the effect on choice of mode and hence the amount of auto travel. Airports and other transport terminals including parking facilities are seen as having air quality significance within the immediate site area only.

Air pollution can be ameliorated through highway planning actions. Such actions include increasing capacity and speed, or shortening linkages. Transit improvements and appropriate controls on land development and transportation pricing may help to overcome the tendency of highway improvements to induce more and longer trips.

As shown in Table 3.7, greater emphasis on planning of transit and highway improvements could have a significant impact on air pollution problems in the long range, but would have little impact in the short-term. The impact of improvements to airports and other transportation terminals is rather slight, although they can affect the air quality related to users of the terminals to some extent. The estimates in the table are highly judgmental and attempt to assess the significance of the areas that would be affected as well as the amount of improvement attainable.

Table 3.7. PLANNING OF TRANSPORTATION SYSTEMS

	Percent of Population Affected[a]		Percent Reductions in Air Pollution Concentrations[b]		Net Impact	
Planning of Transportation Systems	Short-Term (1)	Long-Term (2)	Short-Term (3)	Long-Term (4)	Short-Term (1) x (3)	Long-Term (2) x (4)
Transit-Highway Combinations		60		10		6
Transit Systems, Airports, and Terminals		5		5		---
Highway Systems		40		10		4
Total						10

[a]Based on judgment on the part of the consultant.

[b]Based on estimates by consultant in conjunction with discussions with Office of Air Programs personnel.

DESIGN OF FACILITIES

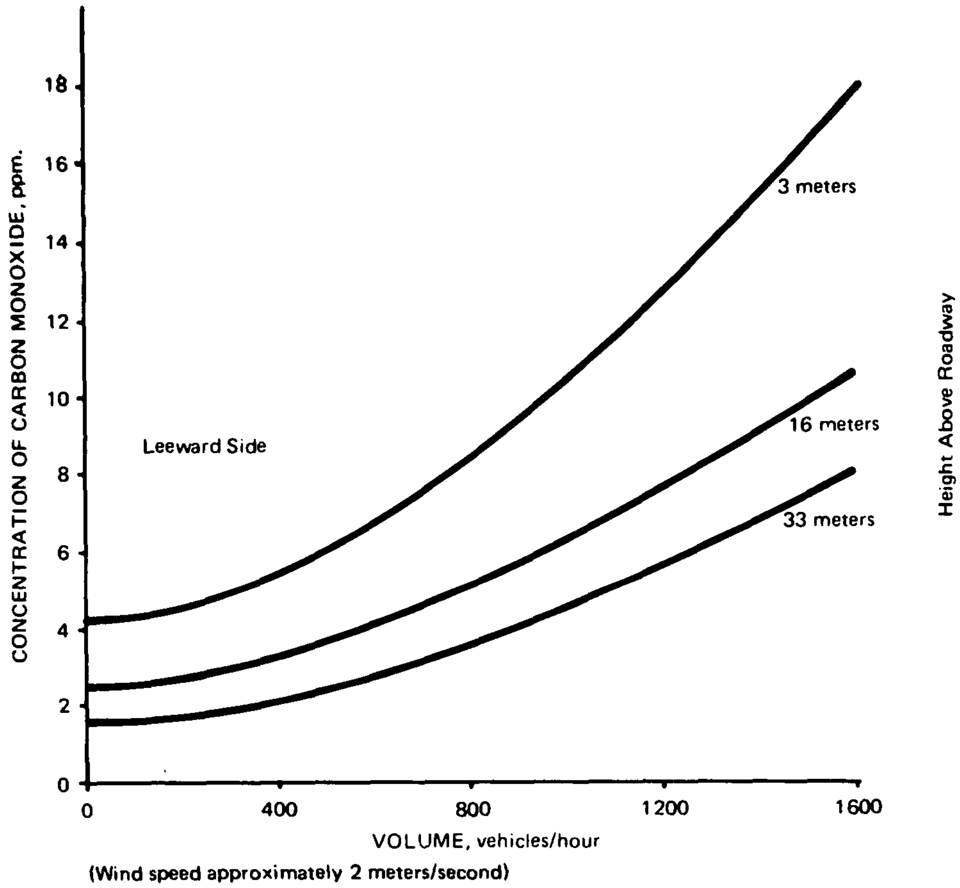
Transportation Facilities and Adjoining Activities

Statistics demonstrate dramatically the enormous increase in the use of automobiles in urban areas over the past quarter century. In 1945, 19 million passengers used mass transit systems annually in the nation; today, in spite of population increases and urbanization, the number is under 7 million. In 1945 there were 25 million privately owned automobiles and under 2 million miles of highways in the United States, while today there are about 90 million automobiles and nearly 4 million miles of highways. During this 25-year period, well over 100 transit systems have ceased operation in urban areas.

Considerable information has been accumulated on the relationship between the design of transportation systems and the amount of air pollution generated. It has been found that the design of transportation systems, especially of highways, can be an effective tool in reducing air pollution concentrations. Design that benefits air quality requires an understanding of the interrelationships between highways and air pollution in the vicinity of the roadway.

A number of studies have been made of air pollution distribution patterns vertically and horizontally from roadways to understand the effects of highways on pollution in adjacent buildings. Georgii, Busch and Weber [60] reported an investigation of the time and space distribution of carbon monoxide emission concentrations in Frankfurt-am-Main.

Figure 3.16 shows the carbon monoxide concentrations on both the leeward and windward sides of a roadway at heights of 3, 16, and 33 meters above the roadway. The carbon monoxide concentration study in Frankfurt-am-Main produced a basic, typical daily street air concentration pattern with one consistent morning and one consistent afternoon



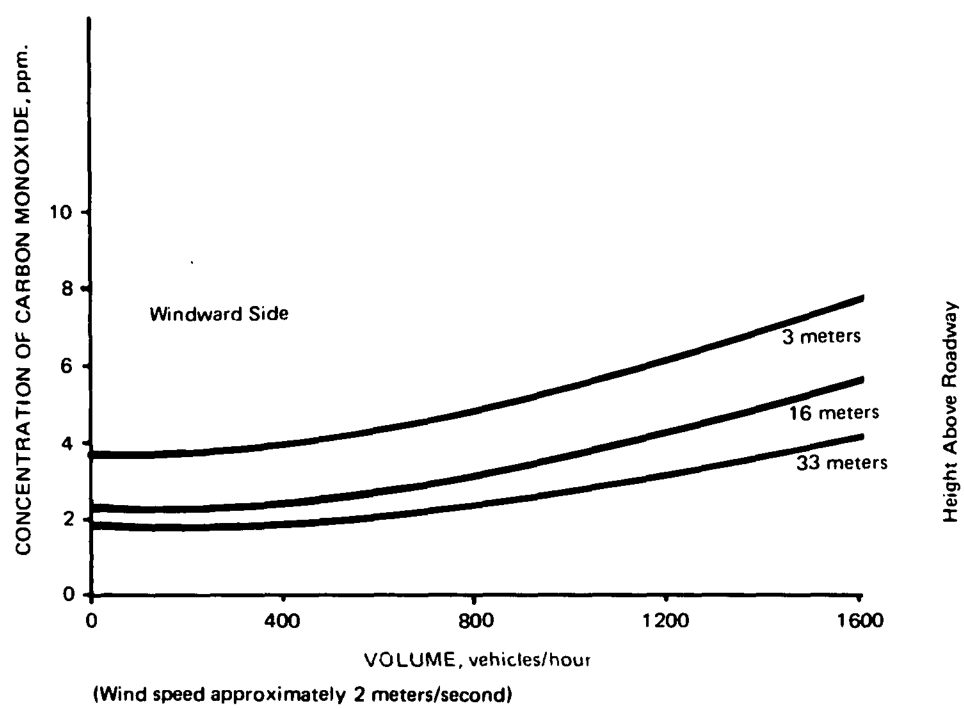


Figure 3.16 Carbon Monoxide Concentrations Depending upon Traffic Volumes [60]

maximum. A good correlation was found between the carbon monoxide concentration and the pattern of traffic density. It was found that the inverse of wind strength was second only to traffic density as a factor in determining carbon monoxide levels.

Table 3.8 compares the Frankfurt-am-Main carbon monoxide concentrations with those reported by the U.S. Continuous Air Monitoring Program (CAMP) conducted in 1964 in seven large American cities.

Table 3.8. MAXIMUM CARBON MONOXIDE CONCENTRATIONS IN FRANKFURT AND SEVEN AMERICAN CITIES [60]

Sample Site	Sample Days	Annual Average ppm	Monthly Average ppm	Daily Average ppm	Hourly Average ppm	5-Minute Value ppm
Frankfurt	228	10	12	22	49	--
Chicago	297	12	17	27	46	60
Los Angeles	353	11	14	22	47	50
Philadelphia	311	7	13	21	37	46
Cincinnati	218	6	11	17	22	49
St. Louis	295	6	9	17	25	45
Washington	253	6	6	13	28	37
San Francisco	326	5	6	10	22	40

In Frankfurt-am-Main, carbon monoxide concentration exceeded 30 ppm for short periods of time, with unfavorable diffusion characteristics prevailing on the lee side of buildings and for low wind speeds. The highest concentrations were measured during peak traffic times, at the beginning and at the end of the working day. The timing of traffic peaks in Frankfurt was far from optimum in use of the natural dilution characteristics of the atmosphere. Maximum atmospheric transport conditions occurred around noon, while in the early morning and evening peak hours air pollution situations were prevalent.

Figures 3.17 and 3.18 provide additional information on the decrease of carbon monoxide concentrations with distance vertically and horizontally from the roadway in relation to pollution level at the roadway. Such information is useful in deciding where to build a structure in relation to the highway so that pollution will not be likely to exceed a safe acceptable level. Similarly, the curve showing the decline of pollution with height above the roadway can be useful in determining air-rights construction.

Criteria for joint development of air-rights structures and major highways were published by Tippetts et al. [186]. A direct relationship was found between traffic density and carbon monoxide concentration at the roadway level. Emission studies showed an average of 0.3 to 1.5 ppm carbon monoxide concentration level for every 100 vehicles per hour.

As reported by Sturman [184], concentrations of nitrogen oxides, hydrocarbons, and carbon monoxide were measured at various levels above five different types of highways, including a centered expressway with adjacent structures nearby, a centered expressway without these joint development structures, and a centered expressway boulevard. The data in these three cases are shown in Figures 3.19, 3.20 and 3.21. The effects of the different configurations on pollution concentration can be seen by calculating the average concentrations at the roadway level for each highway type. For example, the average concentration on the four lanes for the centered expressway without joint development structures was 39 ppm, whereas a similar concentration for a boulevard expressway was 49 ppm, a difference of 26 percent.

T.R. McCurdy [105] identifies the following traffic corridor design considerations as possible steps toward minimizing the effects of vehicular air pollution:

- Absorption of pollutants at the roadway through the use of absorbent guard rails or other devices.

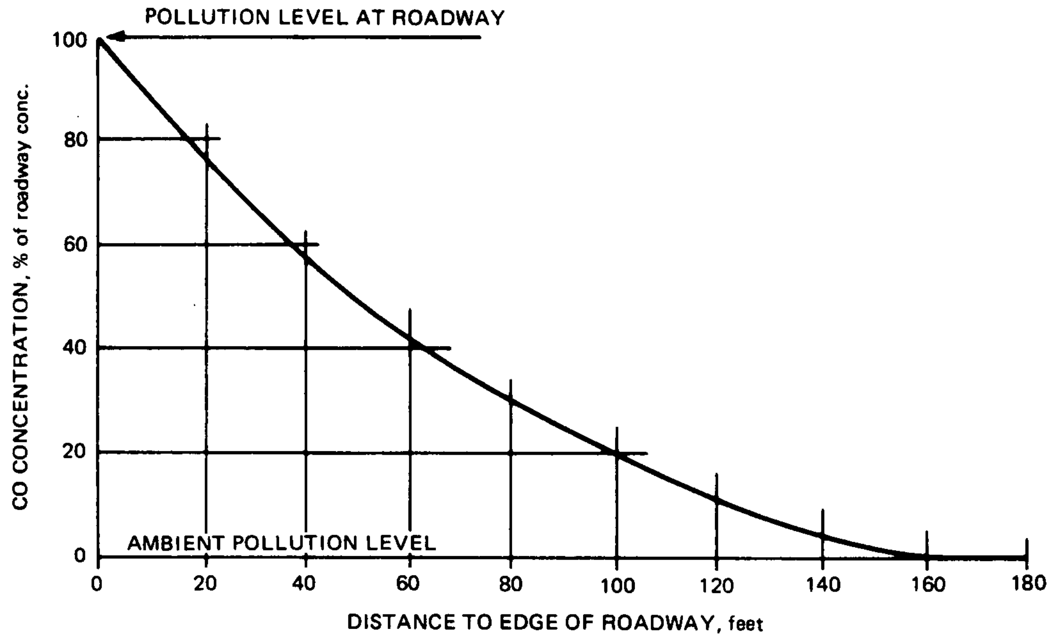


Figure 3.17 Pollution Level versus Distance to Edge of Roadway [186]

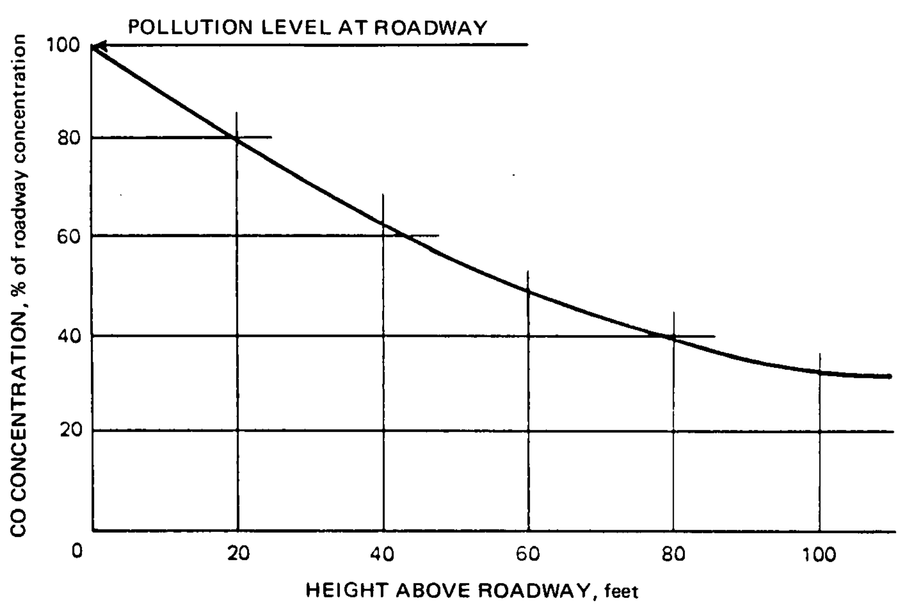


Figure 3.18 Pollution Level versus Height Above Roadway [186]

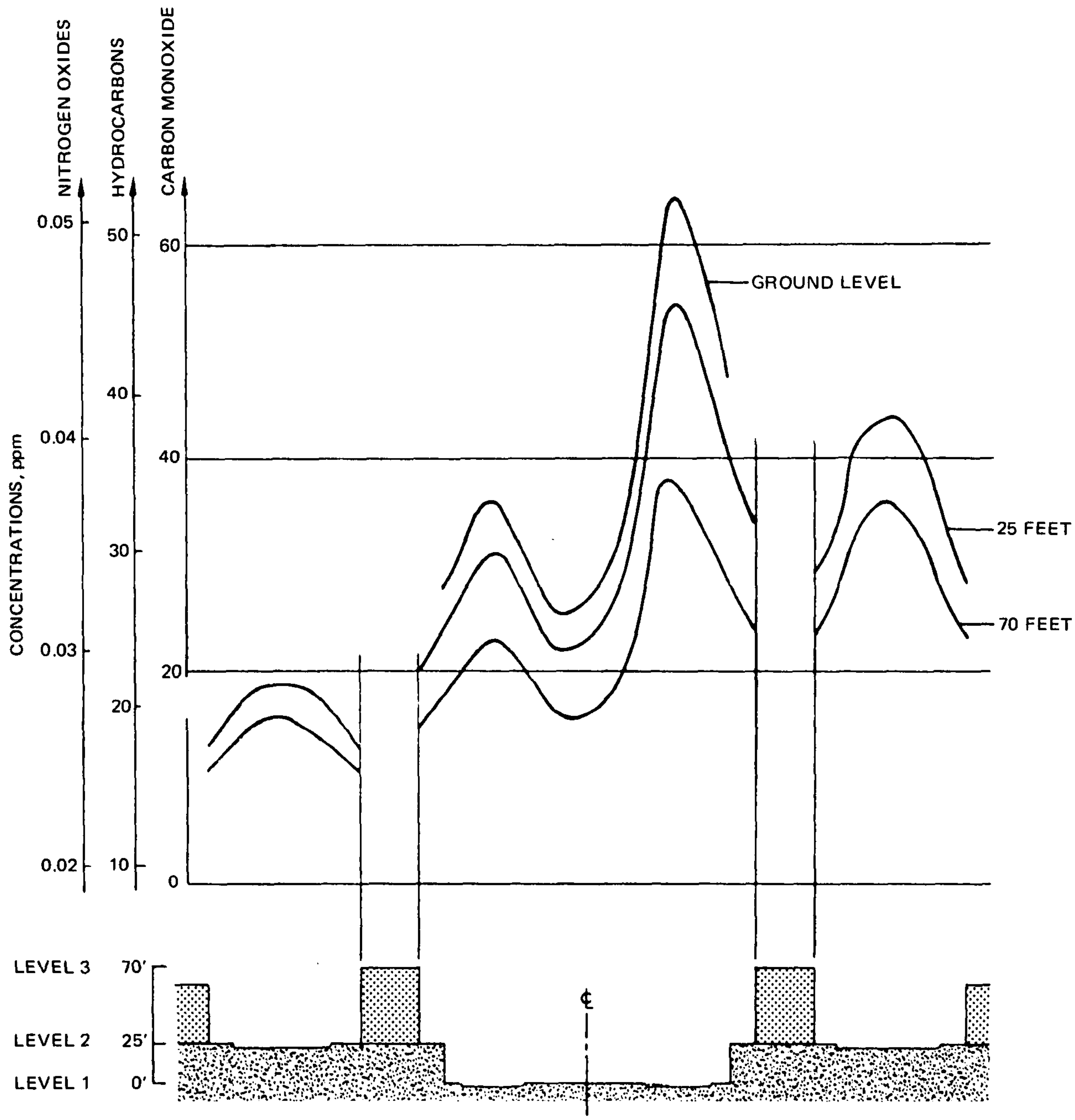


Figure 3.19 Pollutant Levels Along Transverse Street Cross-Section, Centered Expressway With Joint Development Structures [184]

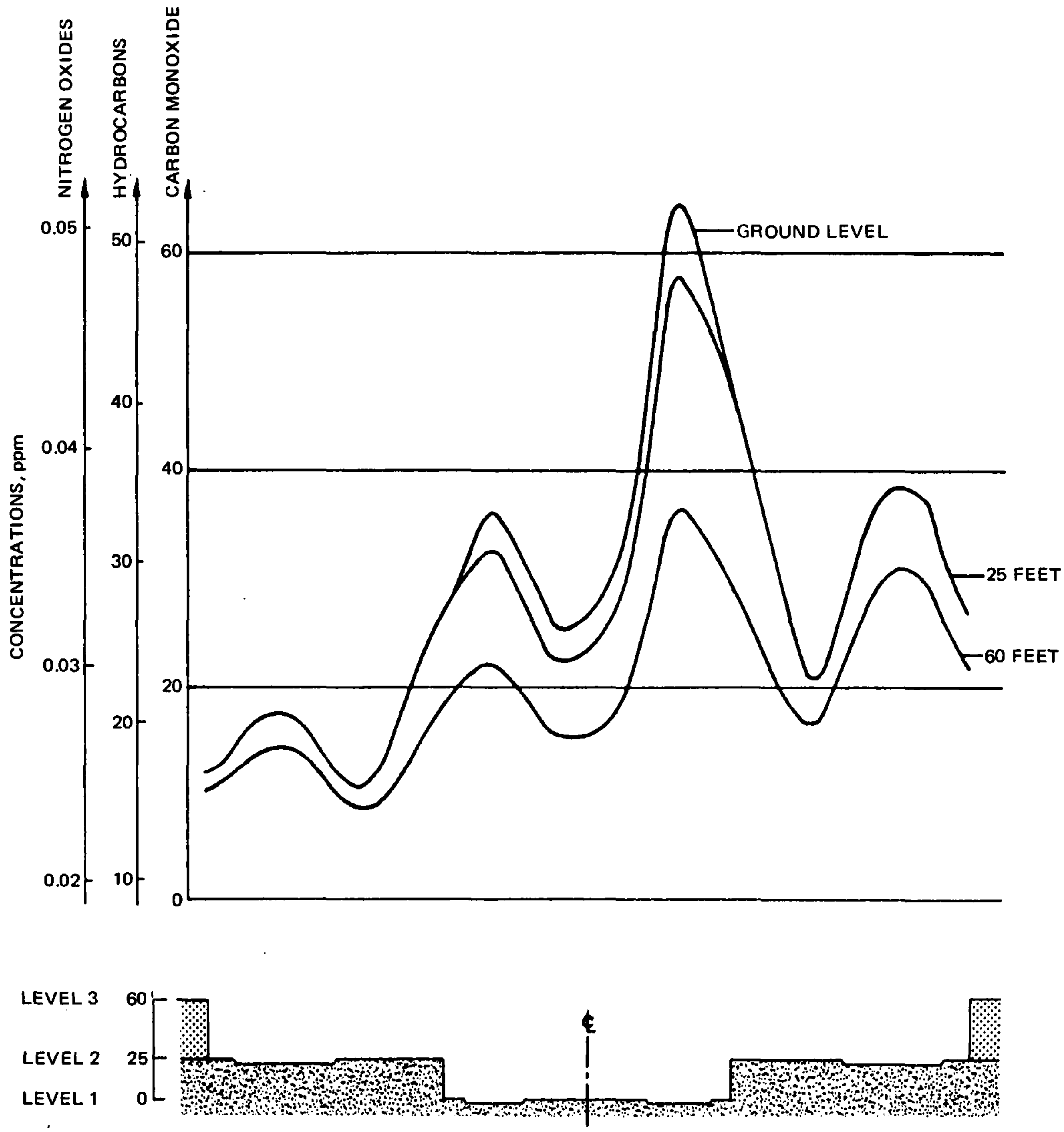


Figure 3.20 Pollutant Levels along Transverse Street Cross-Section, Centered Expressway without Joint Development Structures [184]

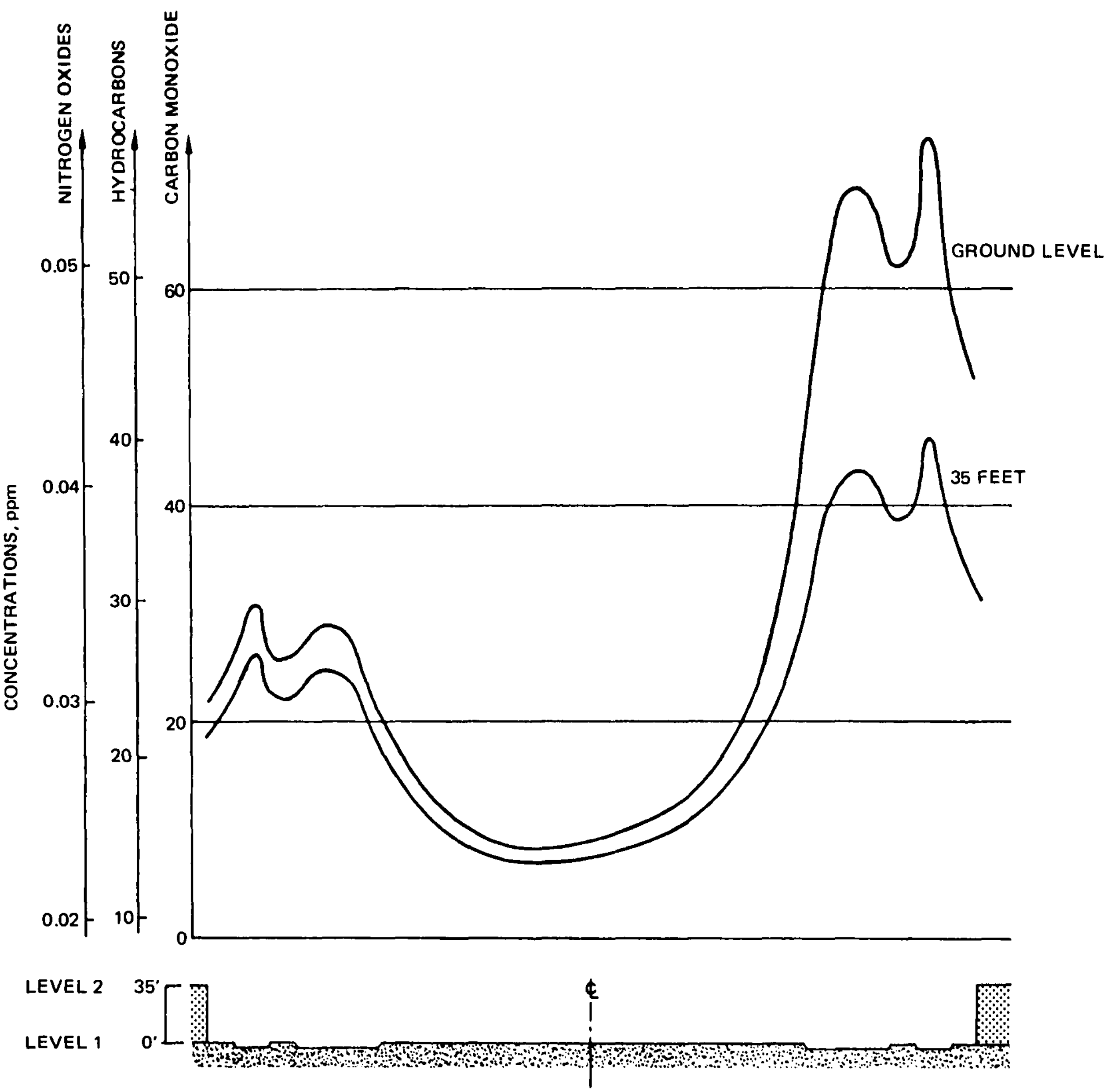


Figure 3.21 Pollutant Levels along Transverse Street Cross-Section, Centered Expressway Boulevard [184]

- Micro-meteorological factor controls to increase atmospheric dispersion of vehicular air pollution by increasing the wind turbulence in a particular locale. This can be accomplished through the design and location of structures.
- Open space planting considerations choosing plants that are resistant to air pollution damage.

The aspects of transportation facility design discussed here obviously cannot reduce emissions in the short or long range. They can, however, have a significant impact on the number of people exposed to undesirable levels of air pollution originating from transportation facilities. Many arterial streets generate high levels of air pollution. Between 10 and 20 percent of the population live along these streets, and 20 to 40 percent of the employment is along such streets. Thus, a significant number of people could be affected by improving the design of transportation facilities in relation to adjoining activities through use of greater setbacks or proper elevation relationships.

Highway Design

A recent study conducted in Chicago [186] showed that pollutants resulting from unburned fuel emitted from auto tailpipes are at a minimum when the vehicles are cruising at a constant speed. When vehicles are idling, the rate is 1.5 times the cruising rate and during deceleration, the rate is 9 times the cruising rate.

The study also showed that traffic in the central business district produced four times more carbon monoxide per vehicle mile than expressway traffic, while arterial and local street traffic produced about twice as much. Therefore, freeways designed to reduce stop-and-go traffic can contribute substantially to lessening the amount of carbon monoxide discharged into the atmosphere.

Highway design can affect the amount of air pollution emissions through, for example, alternative alignments and proper location of ramps. Although research on these aspects is limited, it appears that a small amount of air pollution reduction can be achieved by giving these factors the proper consideration in highway design. Based on anticipated population growth and concomitant needs for improved transport systems, nearly one-half of the travel in the future could be affected by such improvements.

Transit, Airports, and Transportation Terminal Design

Since transit systems and terminal facilities serve only a relatively small portion of the population and the possibilities for improvement are limited, the impact of design improvements would be very small. At the present time, there are few significant changes that can be made in the design of these facilities to reduce air pollution. However, there are situations that should be avoided in designing new facilities, in order not to expose people to undesirable levels of air pollution. A design practice to be avoided, for example, is the location of waiting rooms close to and inadequately protected from areas where many vehicles idle or warm up.

Construction Practices

Although research in this area is limited, it is evident that small reductions in air pollution can be achieved through improved construction practices and that these can have both short-and long-range impacts. Although the number of people affected will be fairly small, such improvements are justified on the basis of their immediate effect. Impacts to be avoided include on-site dust and fumes as well as certain manufacturing or processing operations associated with construction materials.

Design of Stationary Facilities

The design and construction of industrial plants can provide opportunities to reduce air pollution in urban areas. For example, the design of tall stacks for emission of air pollutants is generally an effective and economical method for reducing ground-level air pollution. There must, however, be a practical upper limit to the maximum stack height and size because of the diminishing returns and questions of cost, construction difficulty, and aircraft hazards. Other limiting factors include the frequency of unfavorable meteorological conditions, and the amount and type of emissions to be controlled.

One critical problem in air quality control today is to determine the limiting size of a single fossil fuel plant. This depends upon, among other factors, an accurate assessment of the ability to disperse pollutants. Differences in dispersion calculations alone cause estimates to vary by almost an order of magnitude. Resolution of these differences depends on improving the understanding of relationships between stack heights and dispersion of air pollutants. These relationships will, in turn, influence the design and location of stationary power units in the urban planning process.

In France, a new city, Vaudreuil, is being planned for the lower Seine region outside Paris. The city will provide housing and employment for up to 150,000 residents. The design will utilize new technology to eliminate as much noise and air pollution as possible. Among the concepts under consideration are routing of traffic through underground passages and tunnels, carrying smoke from factories in underground conduits, burning gases off at the source, and processing refuse to supply part of the city's central heating. The U. S. Department of Housing and Urban Development, together with other U. S. agencies, will make technical contributions to the French effort. The results of such innovative demonstrations will have great significance for our existing cities.

Although it is difficult to anticipate improvements to be brought about by the design of stationary sources, it seems from recent experience that emissions could be halved with such improvements in the short term and reduced by 75 percent in the long term. This, of course, would affect some of the population in the short range but the greatest impact would be in the long range.

Summary

As shown in Table 3.9, there are two areas that could have a significant impact on air quality -- highway design and the design of stationary facilities. Highway design probably has the greater potential because design improvements can actually reduce air pollution emissions, provided that the tendency for improvements to generate more travel is controlled. Improvements in construction practices could have short- and long-range benefits, although they would be relatively small in comparison with some of the other programs that have been described.

Table 3.9. DESIGN OF FACILITIES

	Percent of Population Affected[a]		Percent Reductions in Air Pollution Concentrations[b]		Net Impact	
Design of Facilities	Short-Term (1)	Long-Term (2)	Short-Term (3)	Long-Term (4)	Short-Term (1) x (3)	Long-Term (2) x (4)
Transportation Facilities and Adjoining Activities		10		10		1
Highway Design		40		10		4
Transit, Airports, and Terminal Design		5		5		
Construction Practices	10	10	10	10	1	1
Design of Stationary Facilities	10	70	10	10	1	7
Total					2	13

[a] Based on judgement on the part of the consultant.

[b] Based on estimates by consultant in conjunction with discussions with Office of Air Programs personnel.

OPERATION OF FACILITIES

The automobile is a major source of air pollution. Up to 85 percent of the pollution in some sprawling urban areas has been attributed to the automobile. Nationwide, it produces 90 percent of all carbon monoxide pollution. If air pollution is to be curtailed, dangerous emissions from automobiles must be substantially reduced.

One long-range hope for solving the vehicular air pollution problem is to substitute new propulsion systems which produce few pollutants and perform as well as or better than the present ones. Such systems should have good emission qualities, be reliable, and when mass produced be no more costly than present propulsion systems.

Considerable attention has been devoted to electric vehicles, however, the battery powered vehicle cannot yet be considered a feasible alternative to the present internal combustion engine passenger car. Batteries are bulky, expensive, and permit only limited range and speed. Refinements of electric vehicle propulsion systems are being made, but much more progress is necessary before the electric car can offer performance similar to the internal combustion automobile.

The Rankine engine and other engines utilizing steam are also under development. In the Rankine, or vapor cycle propulsion system, fuel is burned to heat up a working fluid consisting of water or some other neutral liquid. When the fluid is heated, it converts to vapor. This conversion takes place in a steam generator, and the vaporized fluid becomes the power source for the engine.

Since fuels used in automobiles and other modes of transportation contribute so significantly to air pollution, new energy conversion units will continue to be sought, while fuel for the present internal combustion engines will be modified to reduce air pollution. For example, non-leaded gasolines are being produced and utilized in greatly increasing quantities. Possibly,the conversion to use of the cleaner-burning natural or liquified petroleum gases will be increased. It will be necessary for urban and transportation planners to encourage changes in fuel utilization and to promote those changes that will lead to a lessened amount of air pollution within the urban area.

A 1967 British report, Cars for Cities [66] showed that the level of atmospheric pollution from motor vehicles could be reduced by acting on factors other than the amount of pollution from individual engines. Atmospheric levels are affected by engine size (which is roughly proportional to the quantity of exhaust gas emitted), the number of vehicles in operation, the density of traffic (which affects the proportion of time the engine is idling, accelerating, decelerating, or cruising), and the rate at which pollutants are dispersed by air movement.

According to the study, it is reasonable to set a short-term air quality objective of lowering the average concentration of carbon monoxide in the exhaust of new cars to half its present level. To do this, particular attention would have to be given to reducing the idling emission level. The report concludes that in the long-term the average concentration of carbon monoxide in engine exhausts could be reduced to about one-third the present level.

The study considers the use of smaller automobiles having engines that would emit about one-third the volume of exhaust gas of present medium-size cars. Assuming they would emit no higher concentration of carbon monoxide, the benefit could be substantial, depending on the number of such cars in use. If the automobile population twenty years hence consisted entirely of such vehicles, the amount of carbon monoxide per vehicle would be reduced to a third through this "size" factor alone. These emission effects can also be mitigated by operating techniques on highways and streets.

Freeway Operations

Figure 3. 22 shows the relative carbon monoxide emissions corresponding to five different modes of operation. If, instead of the stop-start traffic conditions of the typical city, a network allowed unobstructed movement at a uniform controlled speed of, say 30 mph, the reduction in the level of overall pollution would be as shown in Figure 3. 23.

Today, 20 to 30 percent of travel in urban areas is on freeways, and it is expected that in the long-term this proportion will be doubled. This means that anything that can be done to reduce emissions related to freeway use can have a significant impact, both in the short- and long-range. Operating practices that will ensure smoother flow on freeways during the peak-hour might reduce carbon monoxide and hydrocarbon emissions by one-third during that period. This could mean a reduction over 24-hours of 5 to 10 percent in the short-term, and 10 to 20 percent in the long-term. People affected by such an improvement would largely be those using the facility during peak periods, perhaps 10 percent of the total population in the short-term and probably twice that, due to the spreading of congested periods, in the long-term. Therefore, operational improvements on freeways could have a significant impact in the short- and long-range toward improving urban air quality.

PERCENT OF OPERATING TIME			
	Idling	Acceleration/ Deceleration	30 MPH
1	60	40	
2	44	56	
3	33	43	24
4	26	34	40
5			100

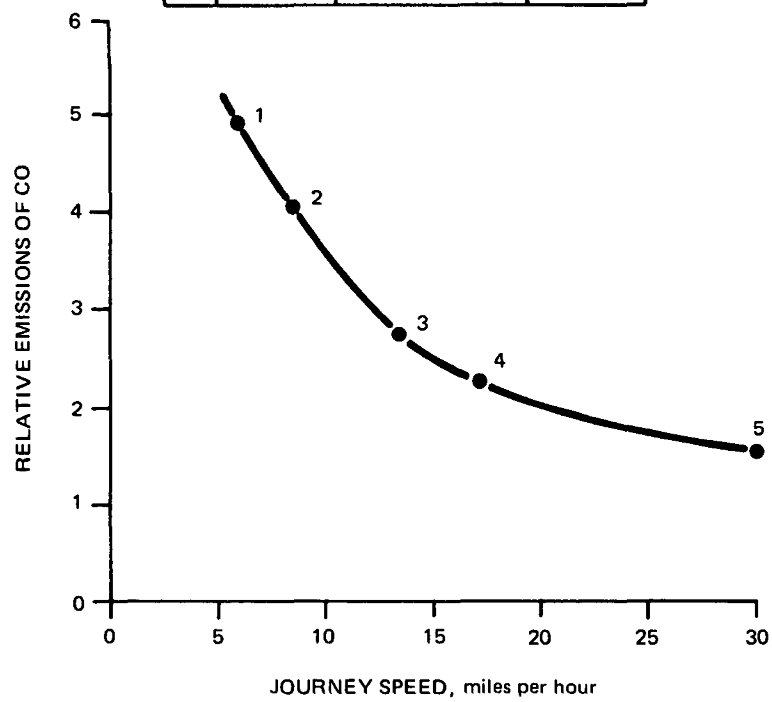


Figure 3.22 Effect of Speed on Relative Emissions of Carbon Monoxide per Unit Time, per Length of Roadway [66]

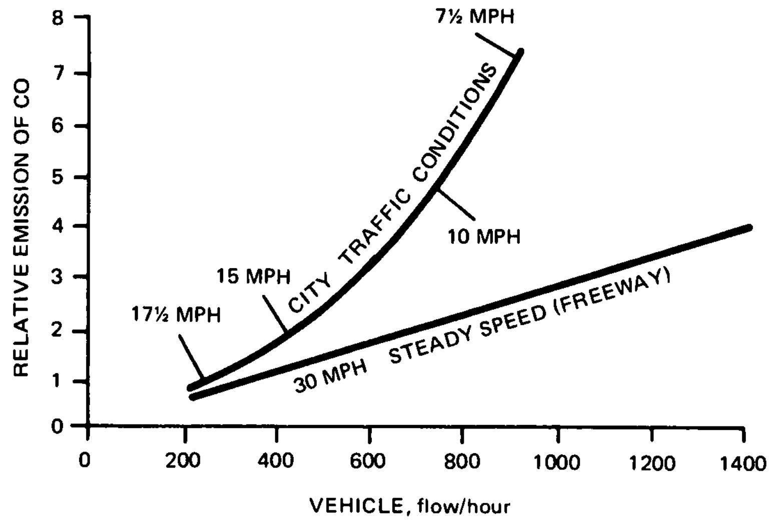


Figure 3.23 Comparison of City and Freeway Conditions [66]

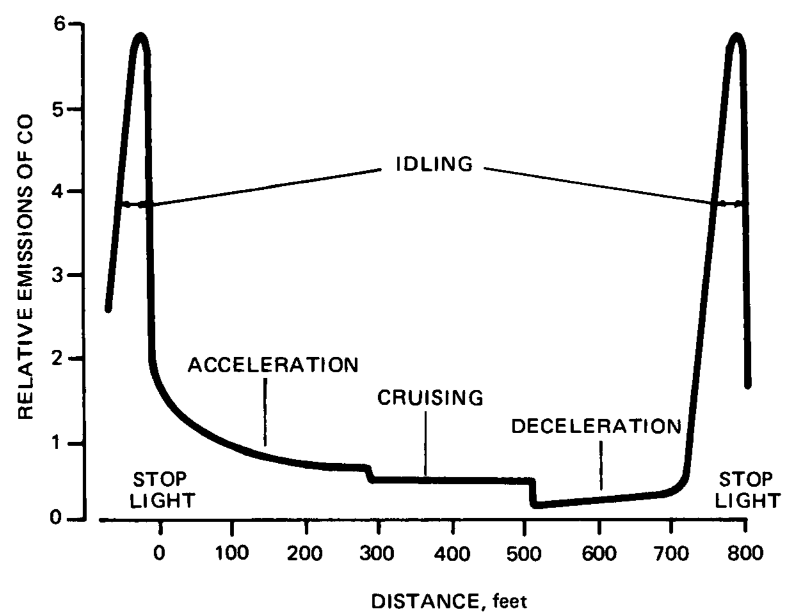


Figure 3.24 Relative Emission of Carbon Monoxide During Operating Cycle between Stops [66]

Arterial Street Operation

The smoothness of traffic flows on arterial streets is an important determinant of the amount of pollution emitted. The regulation of traffic flow, therefore, offers an opportunity to reduce emissions if the patterns of emission during different stages of the operation of a vehicle are understood.

The British study [66], considered the relative rates at which successive sections of a length of roadway are polluted by carbon monoxide. The case chosen for study was that of three cars stopped at traffic signals, idling, accelerating to 30 mph, running at that speed, decelerating for a stop at the next traffic light 800 feet away, and repeating the cycle. The result is illustrated in Figure 3.24, which shows the highly localized peak just before the traffic lights due to idling levels of carbon monoxide from stationary vehicles. The subsequent acceleration of the vehicles results in an immediate reduction in local pollution because, although the rate at which exhaust gas and carbon monoxide are emitted is higher, the time the vehicle spends in each successive unit of roadway diminishes as the vehicle gathers speed. When the car attains a uniform speed of 30 mph, there is a reduction in power requirement and pollution; a further reduction in carbon monoxide emission occurs when the vehicle decelerates because the throttle is still further closed.

But Figure 3.24 gives an indication of the relative importance, for local levels of pollution, of the levels emitted when idling, accelerating, cruising and decelerating. The general, rather than local, level of pollution in a length of roadway depends on the cycle of idling, acceleration, steady speed, and deceleration to which the traffic is subject.

The information on the relative emissions during the different cycles of operation, together with known relationships between the loading of the roadway and the operational characteristics of the vehicles, have been used to derive Figure 3.25. This figure suggests a rapid rise in carbon

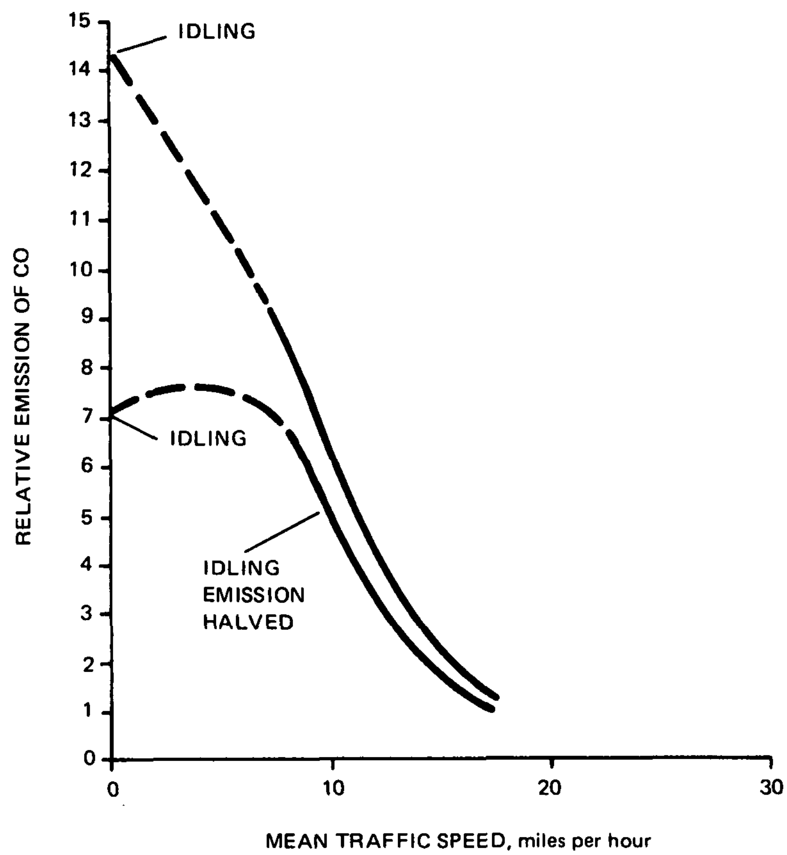


Figure 3.25 Effect of Traffic Flow on Emission of Carbon Monoxide per Unit Time, per Unit Length of Roadway [66]

monoxide emissions as average traffic speed falls, particularly in the range from 0 to 15 mph. Thus, there is a fourfold increase in pollution when traffic speed is reduced 50 percent from 15 to 7-1/2 mph, and a ninefold increase when traffic is slowed to a standstill, as in a traffic jam.

The preceding discussion points out the need for regulating traffic flow on arterial streets. Significant reductions can be achieved by careful arrangement of traffic signaling systems, and other operational procedures to ensure the smooth flow of vehicles on arterial streets.

One of the more significant methods which can be used to reduce air pollution levels is the recent TOPICS (Traffic Operations Program to Increase Capacity and Safety) program. Federal funds from the Department of Transportation have been available since January 1969 to assist cities in developing programs to obtain maximum efficiency and safety from existing major street networks through a systematic application of engineering techniques. Although air pollution reduction is not an objective of the program, it is an important by-product of improved traffic flow. Such actions as synchronization and computerization of traffic signal systems can improve traffic flow up to 30 percent and more; a comparable decline in air pollution can be expected.

Since the bulk of travel in urban areas, both now and in the future, will be on arterial streets, better operation of these facilities can have a material effect on urban air pollution levels. At the present time, about 70 percent of daily travel is on arterial streets. With further freeway improvements in urban areas this proportion may be reduced to 50 percent. It is anticipated, however, that congestion will continue to build up on arterial streets. Since about 40 percent of the travel on these facilities will be during congested periods, a reduction of air pollution emissions by one-half during these assumption periods could probably result in a 20 percent reduction in emissions throughout the day in the short-range and possibly twice that in the long-range. Thus, potential reductions, both in the short- and the long-range, are probably greater through improvements in the operation of city streets than through any other means considered in this study.

Transit, Airports, and Transportation Terminals

Although transit systems, airports, and terminal buildings provide service to a relatively small number of people each day, the operation of these systems can be improved substantially. Improved maintenance and operation of buses can reduce their emissions; new propulsion systems could also be effective. The decrease of aircraft taxiing, smoother ground access operations at airports, and the reduction of vehicle idling in parking garages and terminals can have an impact on the air quality in the neighborhood of these facilities. The number of people affected by these changes, however, would not be as large as those affected by improvements in arterial streets and freeways.

Operation of Stationary Facilities

One prime area of consideration in the operation of stationary facilities is that of fuel alternatives for the overall reduction of air pollution. Demands for energy in the United States are increasing daily and some experts predict that by the year 2000 demand for electric power will have increased tenfold from the present production. To fulfill the need for energy, fossil fuels are being converted to heat and light, generating air pollutants in the process. The smoke from such combustion contains concentrations of sulphur dioxide, sulphur trioxide, oxides of nitrogen, particulates, and numerous other compounds.

Three courses of action are available to solve the air pollution problem caused by the national appetite for energy, aside from regulating the individual components of the region, such as manufacturing, residential, utility, and commercial areas. Table 3.10 presents data and projections for total yearly SO_x emissions for 1970, 1975, and 1980, based upon anticipated control of the sulfur content of fuels and on changing patterns in the urban area. Note that coal emissions are expected to drop markedly by 1975 and remain relatively level to 1980.

The authors also discuss the types of air pollution - urban systems models that are being developed or should be developed in order to allow controlled urban evolution while minimizing air pollution. These models would eliminate some of the shortcomings of existing models and would

Table 3.10. ESTIMATED YEARLY SULFUR OXIDE EMISSIONS IN TONS FOR CHICAGO

	Heavy Manufacturing	Residential	Utility	Industry	Commercial	Total
1970	56,300	69,400	169,800	30,900	11,300	337,700
	17%	21%	50%	9%	3%	100%
1975	32,700	32,900	200	17,000	6,800	89,600
	36%	37%	0%	19%	8%	100%
1980	35,900	27,300	0	19,800	6,800	89,800
	40%	30%	0%	22%	8%	100%

lead to more effective long-range air pollution strategies; they should become tools for urban and transportation planners to assist in incorporating air pollution control into the normal planning function.

As an example of the impact of fuel changes, Figure 3.26 shows the reduction in pollution achieved through switching from high-sulfur fuel to low-sulfur fuel in residential heating units. The changes from coal to fuel oil and natural gas have substantial impact on emission quantities.

The use of oil as a fuel began more recently and has greatly diminished particulate air pollution compared to coal because of its more complete combustion. The third fossil fuel, natural gas, has now become a major source of energy for power production and is attractive because of its extremely low air pollution characteristics.

Cohen and Hurter [34] developed models of air pollution in Chicago, from which forecasts of sulfur oxide (SO_x) emissions for the years 1970, 1975, and 1980 were obtained. The four basic factors that influence the change in the SO_x levels in Chicago discussed by Cohen and Hurter were the control ordinance limiting the sulfur content of fuel, the natural evolution of the city, changes in fuel use patterns, and industrial migration. They discussed the degree to which each of these factors affects the demand itself: (1) substituting non-combustive methods of energy

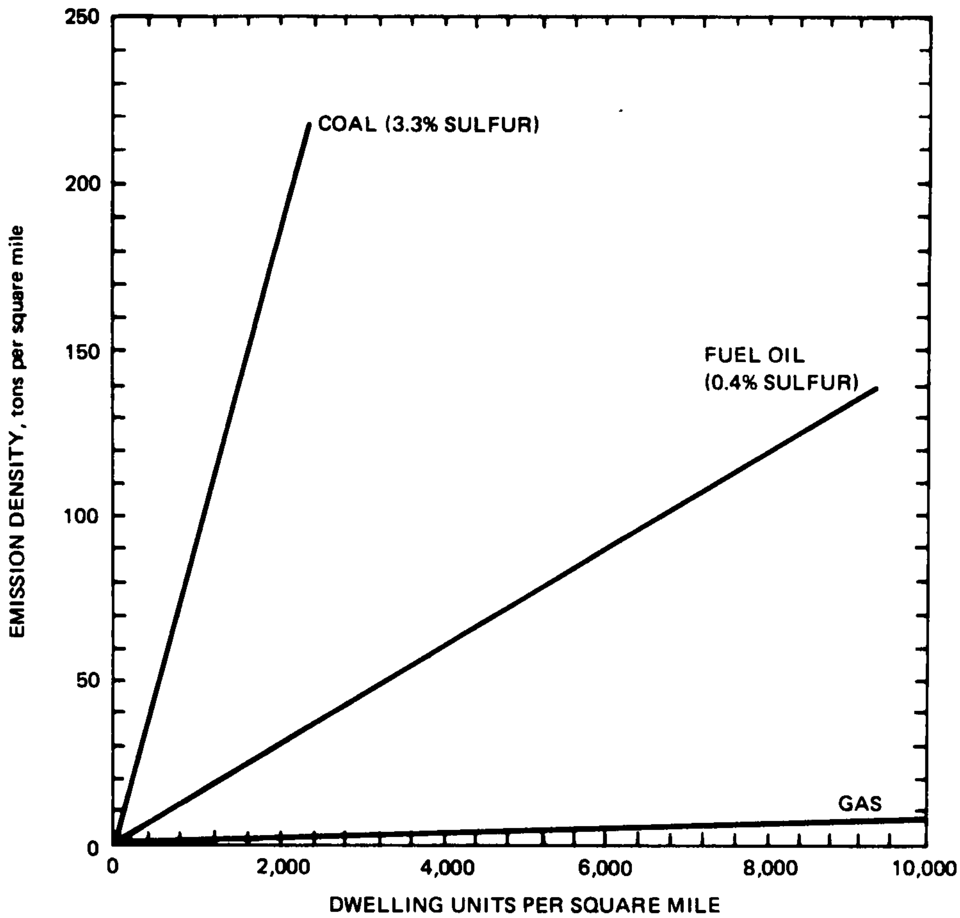


Figure 3.26 Sulfur Oxide Emissions from Burning Different Fuels in Residential Heating, St. Louis

production; (2) cleaning-up combustion by-products, using currently available control equipment; and (3) varying the fuels used in accordance with local air pollution conditions. Major changes in energy sources, however, such as from fossil fuel to nuclear fission are considered designor planning decisions rather than operating techniques. As a matter of convenience, however, all these alternatives are discussed in this section.

Forecasts considering use trends and known reserves indicate that combustion of fossil fuels (coal, oil, and natural gas) will continue to increase for a number of years. Of the three, coal combustion creates the worst air pollution. Stationary energy conversion plants were initially designed to use coal, since that was the only fossil fuel known to exist. The types of coal used in early times, and even until recent years, were selected on the basis of cost and BTU production rather than on their air pollution potential. Often characterized by high sulfur content and low combustion temperature, they result in the emission of vast amounts of sulfur compounds and soot into the air environment.

Since air pollution is successively reduced when substituting oil and natural gas, respectively, for coal, it is possible and it may be increasingly necessary in the future to plan for fuel switching throughout the year depending on the demand for energy and potential for air pollution crisis. K.G. Croke and E.J. Croke [40] investigated the Chicago urban area's capability to make significant changes in its emission pattern by emergency switching from high sulfur or oil to natural gas. During times of air pollution emergency, proper planning can reduce emissions either by fuel switching techniques or by production curtailment.

It is significant to note that increasing attention is given to the use of natural gas in stationary conversion units because of its lower pollution potential. Croke and Croke described the planning process for selecting different fuels for different seasons of the year and different air quality situations. They concluded that more attention should be given to developing criteria for selecting alternative fuels from the standpoint of air pollution control. With proper guidelines and criteria, it may be possible to allow coal and oil to be used in some plants, while natural gas may be prescribed for other plants within the same urban area. The total planning procedure would have as its final result, therefore, an overall reduction in amount, concentration, and location of air pollution through proper selection of the several energy sources.

Two non-combustive sources of energy are of particular interest. These are nuclear and hydroelectric power plants. It is conceivable that solar energy will eventually be a major "clean" source but major technological development will be required.

Hydroelectric power is a limited source because of the practical restriction in available sites for power generating plants. Hydroelectric plants account for less than 5 percent of the energy produced in the United States, considering both stationary and non-stationary sources. Although the amount of energy from this source will increase substantially, it is forecast to decline as a percentage of total national energy consumption.

The use of increasing amounts of nuclear energy is imminent. One forecast indicates it will equal coal as a source of energy by the end of the century. A vital planning function in the coming decade, therefore, will be the location of nuclear power plants on a regional basis. To meet future energy requirements, urban planners will be called upon to locate nuclear energy plants in the vicinity of major urban areas.

Nuclear power plants require approximately 50 percent more cooling capacity than do fossil fuel plants of equivalent size. If cooling towers are installed, as proposed for some nuclear power plants, air quality effects such as fog and humidity should be considered. If cooling is accomplished by cold water from rivers, lakes, or oceans, the quantities of water required will affect site selection.

Nuclear energy has important potential for air quality improvement, although its pollution hazards remain a subject of concern. Criteria for the selection of the particular energy system from the standpoint of air pollution control have not been well defined, and must be developed. In a nuclear reactor the split atoms, or "fission products," remain essentially within the fuel cladding until the reactor is refueled. Then the used fuel elements are removed, stored under water for a cooling-off period, and shipped to a reprocessing plant where unused fuel and valuable radioisotopes are extracted for future use. The remaining waste products are then discarded in storage tanks at underground burial sites, or can be packaged for disposal in other ways. The small amount of radio-activity produced by these operations can be controlled so that ordinarily it poses no health hazard.

About one-third of the air pollution in urban areas is related to stationary sources. Improvement from these sources is therefore essential and will have both short- and long-term effects. If stationary source pollution can be reduced by one-quarter in the short-range and one-half in the long-range, ambient air pollution would be reduced by about 10 percent in the short-range and 20 percent in the long-range. This reduction is judged to have an effect on over one-half of the population in both the short- and long-range period.

Summary

The use in urban areas of smaller cars requiring less energy for propulsion could aid in reducing all types of automotive emissions. Increasing the smoothness and average speed of traffic flow on freeways and particularly arterial streets can substantially reduce emissions of carbon monoxide and hydrocarbons. Advances in technology may allow use of alternative energy sources to a significant degree for automobiles.

Transit, airports and transportation terminals are subject to operational improvements that would improve air quality, especially for those persons actually using terminals.

Selection of cleaner fuels is a valuable means of reducing pollution caused by stationary energy sources. Response to regulatory measures including use of emission control devices also will be important. Increased use of non-combustive energy sources will have a long-term payoff.

Table 3.11. OPERATION OF FACILITIES

Operation of Facilities	Percent of Population Affected[a]		Percent Reductions in Air Pollution Concentrations[b]		Net Impact	
	Short-Term (1)	Long-Term (2)	Short-Term (3)	Long-Term (4)	Short-Term (1) x (3)	Long-Term (2) x (4)
Freeway Operation	10	20	10	20	1	4
Arterial Street Operation	20	50	20	40	4	20
Transit, Airports, and Terminal Operation	5	5	5	5		
Operation of Stationary Facilities	50	50	10	20	5	10
Total					10	34

[a]Based on judgment on the part of the consultant.

[b]Based on estimates by consultant in conjunction with discussions with Office of Air Programs personnel.

GENERAL SUMMARY OF POTENTIAL POLLUTION REDUCTIONS

This chapter has described the kinds of urban and transportation planning, design and operational measures that would have useful air quality implications. Many of these measures are substantiated by research or case studies, while others are more speculative at this stage of air quality control. Some of the needs for further research have been identified.

Based on present knowledge, tentative values have been placed on the potential impact of each measure identified. These can be used as preliminary indicators for decision making. They also suggest, together with the assessment of the present gaps in knowledge, where efforts to gain better quantitative information might best be directed.

Table 3.12 indicates these preliminary estimates of what could be accomplished in both the short- and long-range through the different programs considered. Improved operation of facilities appears to have the greatest payoff within both time scales. In addition, significant reductions in air pollution could be achieved by better planning for urban development and transportation systems, although the benefits would be limited mainly to the long-term.

The next greatest payoffs could be derived from the design of facilities and construction of facilities, which could also have some short-term payoffs, particularly in construction practices. The spatial arrangement of buildings and site activities appears to have the least payoff, but could have a psychological effect due to the potential direct impact on the visible physical environment in which people find themselves.

Table 3.12. WHAT CAN BE ACCOMPLISHED[a]

	Payoff Index	
	Short-Term	Long-Term
Land Development and Density Patterns	--	19
Spatial Arrangement of Buildings and Site Activities	--	9
Planning of Transportation Systems	--	10
Design of Facilities	2	13
Operation of Facilities	10	34

[a] The assumptions on which the payoff indexes are based are explained on pages 3-2 and 3-3 and in Tables 3.2, 3.3, 3.7, 3.9 and 3.11.

CHAPTER 4

PROGRAM

NEEDS AND OBJECTIVES

The primary purpose of this study was to develop a short-range program of research and support activities in transportation and urban planning to be undertaken by the Office of Air Programs and other Federal agencies. With this objective in view, the existing state-of-the-art was reviewed and the potential payoffs for reducing air pollution through planning actions were estimated.

This chapter describes the proposed program which is derived from several sources including existing legislation and policy at the Federal, State, and local levels; an intensive library research effort; a survey of professionals in the urban and transportation fields, and a dialogue with Federal and state agencies that were formulating projects related to their area of concern.

The program, as discussed in this chapter, is expected to yield a set of products to aid the planner:

- Techniques
- Guidelines
- Inducements
- Basic information and training

The program is structured around six work items:

- Adaptation of basic air pollution research to the planning process
- Case studies on the impacts of transportation and land use on air pollution
- Simulation studies on the impact of transportation and land use on air pollution
- Demonstration projects aimed at showing air pollution changes through transportation and land use planning

- Legislative and administrative studies to implement urban and transportation plans and programs critical to reducing air pollution
- Dissemination of information and support activities

Environmental Policy and Legislation

The need for the program can be derived from public policy statements and Federal legislation.

The President in his message to Congress in 1970 identified the following goals:

- For motor vehicles: the establishment of strict motor vehicle standards, testing representative samples of actual production, regulation of fuel composition and additives, and a research and development program in unconventional vehicles that would be virtually pollution free.
- For stationary sources: the establishment of nationwide air quality standards, designation of interstate air quality control regions, the establishment of emission standards, increase in court action, and higher fines against polluters.

Russell E. Train, Chairman of the Council on Environmental Quality has stated,

> "... environmental factors are now being given serious attention in our decision-making process -- a development that has been long overdue.
>
> "... delays related to environmental concerns may well increase in the future unless advance planning of the kind envisioned in the administration's power plant siting bill is initiated.
>
> "It is time that we stopped looking at environmental programs simply as a problem and start seeing them as an opportunity."

(The Washington Star, November 28, 1971.)

Pertinent sections of several air pollution acts are summarized below. The planner is most affected by the National Environmental Policy Act of 1969 and the Clean Air Act Amendments of 1970. Of note in the latter Federal act is the mention of land use and transportation controls.

Legislation Related to Air Pollution

- Clean Air Act (1963/1965)
  - Grants to aid air pollution agencies
  - Federal enforcement authority to attack interstate air pollution
  - National regulation of air pollution from new motor vehicles
- Air Quality Act (1967)
  - Air quality control regions
  - Air quality criteria
  - Air quality standards to be set by states
  - Comprehensive plans by states to implement air quality standards
- National Environmental Policy Act (1969)
  - Systematic interdisciplinary approach for planning evaluation and design
  - Methods to consider unquantified environmental amenities
- 1970 Clean Air Act Amendments
  - National air quality standards supersede state standards
  - Option for states to adopt more stringent standards
  - Achievement of air quality standards within 3 years of publication of plans
  - Land use controls in urban areas
  - Transportation controls to reduce impact of pollution from moving sources
  - Fuel policies in urban areas
  - Standards for existing and new stationary sources

- Public participation through public hearings, citizen action to seek enforcement

- Federal-Aid Highway Act (1970)
  - Guidelines consistent with air quality implementation plans
- Urban Mass Transportation Assistance Act (1970)
  - Impact of urban mass transit plans

The more recent Federal laws and regulations which relate to urban and transportation planning are:

National Environmental Policy Act of 1969 -- This act establishes a broad national policy directed toward improving the relationship between man and his environment, and creates the Council on Environmental Quality (CEQ). Section 102 (2)(C) of the act is designed to ensure that the environmental effects of all major proposed Federal legislation, plans, and programs are properly considered and a detailed statement be submitted which analyzes the environmental impact.

The Office of Management and Budget has revised the clearinghouse procedure for communicating environmental information among Federal, state, and local agencies by amendment February 9, 1971 to include the coordination of environmental impact analyses. If, after reviewing the comments, the Federal agency determines there will be a significant impact on the environment, it must submit an impact statement to the CEQ. The impact statement, reflecting all the comments received through the clearinghouse process, becomes part of the public record.

1970 Clean Air Act -- This act calls for the establishment of primary (relating to health) and secondary (relating to welfare) ambient air quality standards by the Administrator of the Environmental Protection Agency (EPA). The Administrator is also required to set standards of performance for new stationary sources of pollution and for motor vehicles. The act requires states to prepare plans by January 30, 1972 for achieving and maintaining the air quality standards within 3 years. The act states that the EPA Administrator shall approve air quality implementation plans prepared by states if such plans include:

> "... emission limitations, schedules, and timetables for compliance with such limitations, and such other measures as may be necessary to insure attainment and maintenance of such primary or secondary standard, including, but not limited to, land use and transportation controls." Section 110 (a) (2) (B).

In addition, the act provides for an accelerated research program to improve knowledge of the short- and long-term effects of air pollutants on health and welfare. (Section 103(8)).

Regulations Promulgated Pursuant to Clean Air Act (Federal Register, August 14, 1971) -- The EPA set out requirements by which the states should prepare, adopt, and submit implementation plans for air quality standards achievement, describing a "control strategy" by which a combination of measures are designated to achieve the aggregate reduction of emissions necessary to achieve and maintain a national standard. The measures might include:

- Emission limitations .
- Federal or state emission charges or taxes, or other economic incentives or disincentives.
- Closing or relocation of residential, commercial, or industrial facilities.
- Changes in schedules or methods of operating commercial or industrial facilities or transportation systems. These would include any short-term changes made in accordance with standby plans.
- Periodic inspection and testing of motor vehicle emission control systems.

- Emission control measures applicable to in-use motor vehicles, including mandatory maintenance, installation of control devices, and conversion to gaseous fuels.
- Measures to reduce motor vehicle traffic, such as commuter taxes, fuel rationing, parking restrictions and staggered working hours.
- Expanded use of mass transportation through measures such as increased frequency, convenience, or capacity, or by providing special bus lanes on streets and highways.
- Any other land use or transportation control measures.
- Any other variation of, or alternative to, the above measures.

1970 Federal-Aid Highway Act -- This act requires the Secretary of the Department of Transportation (DOT) to promulgate guidelines by October 1972 designed to ensure that new highways will be consistent with a state's air quality implementation plan. These guidelines will enable planners to predict and to minimize the effects of a proposed roadway on air quality.

Urban Mass Transportation Assistance Act of 1970 -- This act amends the Urban Mass Transportation Act of 1964, placing grant and loan applications under the "A-95" review process. In addition, it requires that the applicant afford adequate opportunity for public hearings for all parties interested in the economic, social, and environmental impact.

Literature Review

To identify the current state of knowledge with respect to air pollution related to urban planning and transportation an intensive library research was undertaken. More than 200 articles were examined; these did not include the set of Air Pollution Technical Information Center

(APTIC) abstracts already on record. The articles have been abstracted and are a separate by-product of this study.

Although useful information was found that quantified or qualified interrelationships between air quality and transportation-urban planning policies, the state-of-the-art review pointed to the fact that there is much work needed to develop the tools necessary to assess the consequences of public work actions (be they project or system related) on air quality or the effect of poor air quality on the uses and activities occupying the land.

Planners' Needs

This void in information was further substantiated through a survey of and discussion with professionals and agencies at various levels of government, as well as with citizens' committees. Federal, state and local practices were reviewed and the findings are documented in Appendix D.

Listed below are the agencies that were found to be concerned with air pollution:

- Environmental Protection Agency
- Executive Office of the President
- Department of Agriculture
- Department of Commerce
- Department of Health, Education and Welfare
- Department of Housing and Urban Development
- Department of Justice
- Department of State
- Department of Transportation
- Independent Agencies, such as AEC and FPC
- Selected Boards such as the Federal Radiation Council

States are actively involved in the formulation of implementation plans; the practices of several states were examined as described in Appendix D. State agencies examined consisted of environmental protection agencies, departments of transportation, air resource boards, and planning agencies.

Local institutions were also consulted, as described in Appendix D. These consisted of planning, transportation, and regulatory agencies as well as utility companies and public relations firms.

Professional groups contacted included the American Institute of Planners, American Public Works Association, Institute of Traffic Engineers, American Institute of Architects, and others with planning and design interests.

The review and discussions pointed out a basic need on the part of the planner for a set of tools that would assist in the assessment of relationships between air pollution and its causal factors. These needs generally fell into these categories:

- Techniques
- Guidelines
- Inducements
- Information and Training

Many groups complained also that they were being pressured to prepare air pollution impact statements and lacked the fundamental relationships needed to assess the consequences of key policy actions that were before the decision-makers. These needs of the professional emerged in spite of the fact that there were numerous Federal agencies involved with air pollution to some degree.

With involvement by so many agencies why do gaps in fundamental understanding and knowledge exist? Several reasons might explain this:

1. The funding levels for air pollution research were in many cases limited.

2. The research performed usually conformed to the immediate concern of the respective functional agency.

3. Until the recent establishment of EPA no single comprehensive forum existed to correlate and identify the interrelationships between air quality and transportation-urban planning policies.

Program Objectives

Based on these above findings, a five-year program to include air quality considerations in urban and transportation planning was formulated with the following objectives:

- Reduce air pollution through urban and transportation planning activities
- Assist in the implementation of the Environmental Policy Act of 1969 and the 1970 Clean Air Act amendments
- Carry out the above objectives through existing agencies and programs at all levels of government.
- Select individual projects of the program in the most cost-effective manner.

This five-year program has been prepared in order to describe the activities which the Office of Air Programs (OAP) and other Federal agencies should undertake to determine and demonstrate the air pollution impacts of different urban and transportation planning actions and to encourage the inclusion of these considerations in the planning process.

The identified needs can be met with a set of program products which will become the planners 'tools':

- Techniques
- Guidelines
- Inducements
- Information and Training

Techniques -- One of the aims of the program is to apply techniques that will enable the planner to measure the air pollution impacts of the various planning actions. These techniques will be based on research that will be carried on outside the scope of this program. The Office of Air Programs is conducting a number of research programs that will be designed to develop air pollution simulation models. These models will simulate the atmospheric phenomena that result in the dispersion of pollutants from their source points.

Techniques would be used to estimate air pollution emissions and concentrations for different:

- Arrangements of land uses
- Population and employment distributions
- Spatial arrangements of buildings and streets
- Design and construction methods of stationary and transportation facilities
- Stationary and traffic operational improvements.

One of the inputs to the model will be the pollutant emissions for line, area, and point sources for stationary and mobile polluters. Another input into the models will consist of meteorological and physical information which affects the dispersion of the pollutants. In addition, conditions which create secondary pollutants through atmospheric chemical reactions will be programmed into the models. Given this information, the models can be used to predict air pollution concentrations in different parts of the metropolitan area. These models will be required at the metropolitan and submetropolitan scale for evaluating short-term and long-term concentrations of different air pollutants.

The urban and transportation planner should be able to utilize these techniques in his attempts to influence ambient air pollution levels through urban and transportation planning actions. Some of these actions will result in the reduction of emissions; some will result in the reduction of the exposure of populated areas to air pollution; and some will result in changes in the dispersion characteristics of an urban area.

An example of a change in emissions is the reduction of motor vehicle pollution through increased transit usage. Change in exposure could involve the relocation of industrial plants away from population centers to areas where meteorological conditions would not cause the contamination of populated areas. Changes in dispersion characteristics could result from planning streets and buildings in a way that will facilitate beneficial wind movements.

The effects of such changes can be measured by inputting these changes or new developments into the air pollution models. Therefore, the planner should be familiar with the utilization of such models and techniques. The adaptation of basic air pollution research to urban planning and transportation will thus be one of the aims of the program.

Guidelines -- The program will result in numerous guidelines, on how planning policies can affect ambient air pollution levels. These guidelines will be developed after the air pollution impact of various planning actions have been measured through the use of the techniques described above. These principles will assist the planner in analyzing the relationships, quantitative and qualitative, that exist between planning and air pollution. They will also provide him with planning options for solving particular air quality problems. Information from the results of case studies, simulation studies, and demonstration projects will help in creating guidelines for future action by the planner. As contrasted with techniques, they will deal with substantive information, not methodology. Guidelines will be prepared for professionals who are at different stages of decision-making and who work in urban areas of differing size and character.

Guidelines would consist of principles related to:

- Arrangement of land development patterns - residential, industrial, commercial, and open space
- Limits on population and employment density
- Spatial relationship of site activities and buildings
- Planning transportation systems and land development
- Design and construction of stationary sources and transportation facilities
- Operation of stationary sources and transportation facilities

Inducements -- One of the major products of the program will be a set of procedures designed to induce governmental organizations at different levels to adopt air pollution considerations as part of their on-going programs. These inducements will consist of legislative, administrative, and funding tools that could be used to enforce plans that include air pollution control measures. The purpose of these inducements would be to encourage decision-makers at different levels of government to attack air pollution more strongly in terms of urban planning and transportation.

Inducements would consist of:

- Legislative
  - Requirements for environmental planning and programming at the state and local level
  - Model codes
- Administrative
  - Federal planning requirements for states
  - State planning requirements for local agencies
  - Mechanisms for fostering coordination among Federal and state agencies
- Funding
  - Study grants for planning
  - Demonstration grants

Basic Information and Training -- Other products of the program will be a comprehensive system of information dissemination and the training of personnel. Information access and dissemination are important aspects of this program because of the perceived lack of knowledge and information that confronts professionals at every level of the planning process. Since these professionals require different kinds of information, the necessity for a well-organized information system that would transmit the available knowledge and data wherever it is needed, is self-evident.

Typical information services might consist of:

- Library search routines
- Federal, state, local distribution lists
- Periodic literature surveys and reviews
- Computer search and record keeping
- Up-to-date mailing lists

The same is true of a comprehensive training system. The field of air pollution control is a new one which will generate a host of new methods and will require as many new skills. Furthermore, the skills that will have to be developed should be available at the right place in the decision-making structure. This will require a flexible framework for meeting personnel needs.

WORK ITEMS

From an understanding of the program needs and the desired products, six basic work items were formulated:

I. Adaptation of basic air pollution research to the planning process

II. Case studies on the impacts of transportation and land use on air pollution

III. Simulation studies on the impact of transportation and land use on air pollution

IV. Demonstration projects aimed at showing air pollution changes through transportation and land use planning

V. Legislative and administrative studies to implement urban and transportation plans and programs critical to reducing air pollution

VI. Dissemination of information and support activities

The basic flow diagram describing the linkages between the different work items and their relationships to the expected products is shown in Figure 4. 1.

Work Item I is geared to adapting basic research needed to undertake the case studies, simulation studies, and demonstration projects. It will consist of adapting the models and other techniques developed for general air pollution control purposes to the transportation and urban planning field. These techniques will deal with such items as collecting emissions data, collecting meteorological and topographical information, using air quality models, and evaluating air pollution impacts of alternative planning actions. In addition basic research needed specifically for the work program will also be developed.

Work Items II, III, and IV will assist in the development of guidelines for planners and engineers. These items are designed to clarify the relationships between air quality and the different planning actions and to recommend ways to tackle specific air pollution problems through urban and transportation planning. Each of these three phases will use a different approach to the development of guidelines.

Work Item V will deal with legislative and administrative studies needed to determine the legal, administrative and funding procedures necessary for enforcing air pollution control through urban and transportation planning. These procedures and support activities will be aimed at facilitating the implementation of planning actions that will reduce air pollution. The product of this work item will be a series of governmental inducements that will encourage planning agencies and local governmental units to take a more active part in the fight against air pollution through urban planning and transportation.

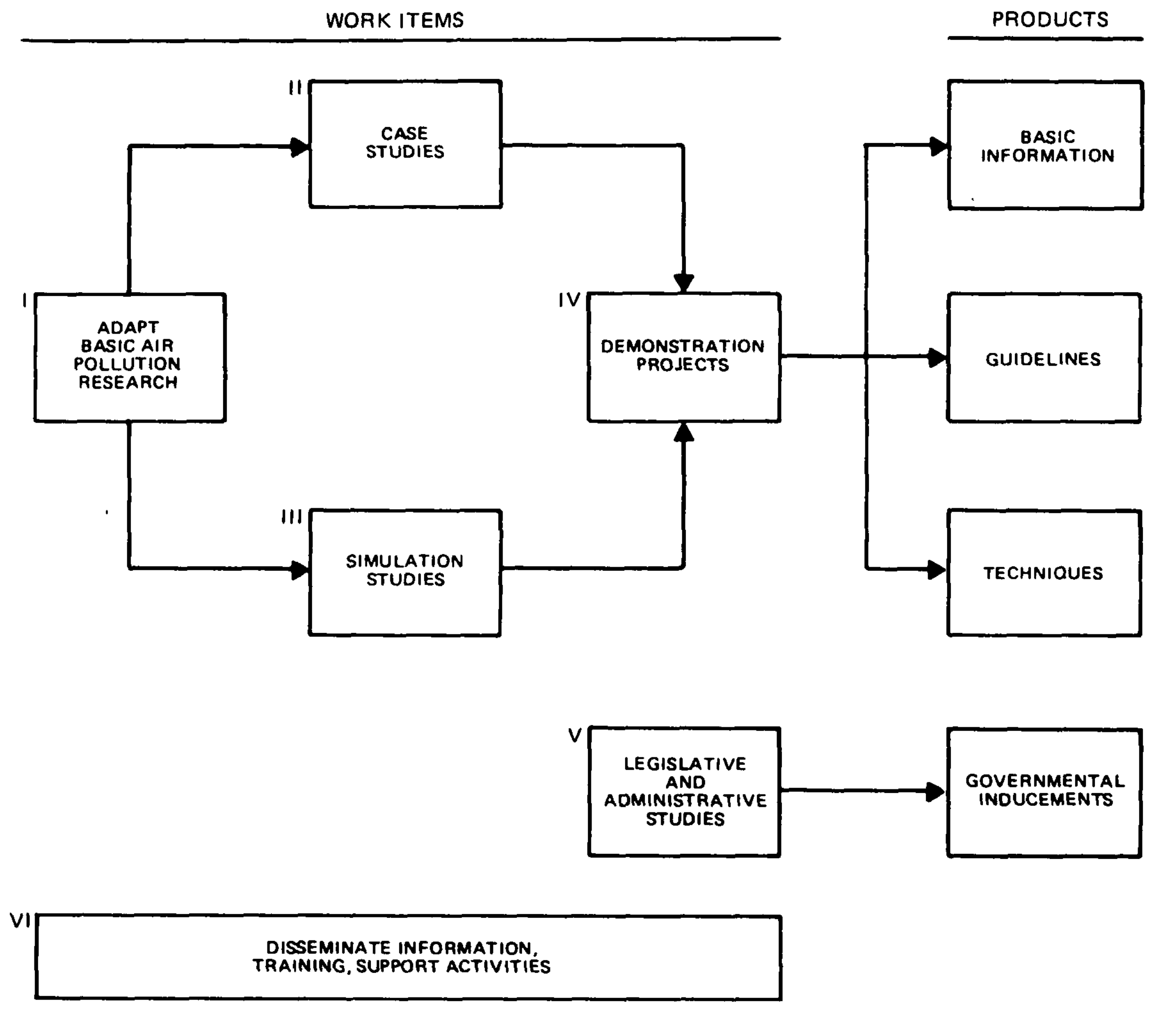


Figure 4.1 Interrelationship of Work Items

Work Item VI will serve two purposes. It will set up a clearinghouse for the gathering and dissemination of the information obtained in the different air pollution control programs throughout the country, and it will organize and manage the training of professionals to work at different levels of decision-making and implementation.

The work items are now described in more detail. It should be noted that, because of the comprehensive nature of urban and transportation planning and the totality of planning decisions on the urban environment, the air pollution aspect cannot be considered in isolation. However, since this program is designed to incorporate air quality considerations into ongoing comprehensive planning activities it is necessary to focus on this aspect. The program development will require that the work items be incorporated into other phases of the urban and transportation planning process.

Adaptation of Basic Research

The program will depend on research and information from other Federal and state sponsored programs. Although the scope of the program is limited strictly to urban planning and transportation, it is obvious that the basic research carried out in the air pollution field will be of interest to the urban and transportation planner by providing him with tools for his own work. This phase will collect such information and adapt it for the planner's use.

One of the inputs to this program is the setting of air quality standards; thus, the research activity that leads to the establishment of these standards should be understood by planners. They should also be aware of the reasoning behind the standards in order to compare the total costs of the planning actions necessary to reduce air pollution to specified levels with the total costs of high levels of pollution. Such comparisons are essential to decision-making at the local level. Therefore, one function of Work Item 1 will be to identify the standards of use to planners and engineers.

A second type of information that will be needed and that will be developed outside this program is information related to the emission characteristics of pollutant sources. The urban planner will need information on emissions by mobile and stationary sources in his area of concern. For stationary sources this includes the nature and amount of pollutants emitted by various industrial and civic activities. For mobile sources, it will mean the emissions from the different types of vehicles under various speed and operating characteristics. Relationships such as that between automotive emissions for carbon monoxide versus mode of operation and average network speed need to be qualified. In addition, automotive pollutants such as oxides of nitrogen and lead salts need to be further investigated.

Research external to this program should provide information on future developments that could change the emission characteristics of polluting activities. Research of this nature will center around technological innovations, standard-setting procedures, and enforcement policies. The results of emissions research as they affect this program will be gathered and the techniques of applying this information to urban and transportation planning will be developed.

A third kind of information that would be useful to planners and engineers relates to the meteorological and topographical variables that affect air pollution levels. The planner and the decision-maker are generally more interested in the concentrations of pollutants in different parts of the city than in the emission rates at the sources. Therefore, the emission data need to be converted into concentration information. This conversion requires an awareness of the variables that act on the pollutants and disperse them throughout the urban area.

The last type of information and technique that would be useful to urban and transportation planners and would be developed is the construction of metropolitan and submetropolitan air quality models. The development of these different air quality simulation models will be of invaluable help in measuring the air pollution impact of his alternative actions. Therefore, one of the most critical functions of Work Item 1 will be the development of techniques and procedures. In summary, Work Item 1 will introduce the results of basic air pollution research to the urban and transportation planner and make them aware of the techniques available for treating air pollution as an integral part of urban planning.

Case Studies

Case studies, together with simulation models and demonstration projects, have as their objective the determination of the interfaces between land use and transportation systems and air pollution.

The impact of these systems on air pollution can be used in conjunction with the models to be developed outside this program. For example, planning actions can generally alter the air quality characteristics of a metropolitan area, creating new inputs to the models in order to predict new concentrations. Also, planning actions can alter the dispersion characteristics which can then be incorporated, together with the meteorological and topographical variables used in the models, to convert emission data into information on concentrations. In addition to its more or less quantitative use in conjunction with air quality models, work to be performed in these three work items will provide insight about the directions to be taken in urban and transportation planning to improve the quality of the environment.

Case studies are useful in obtaining the greatest amount of information from existing situations and, therefore, involve relatively low risks. A case study usually consists of measuring significant variables related to certain properties of the transportation and land use systems in a particular area, and comparing and correlating these measurements under different conditions. For example, measurements of air pollution levels can be taken around highways of different cross-sections and compared, or measurements around the same facility can be compared under different weather conditions or at different times of the day or year. These provide valuable information with relatively low investment since they do not involve any construction or any significant structural changes.

"A Guide for Reducing Automotive Air Pollution" has been prepared for the Environmental Protection Agency (EPA) as part of this study. Based on a review of case studies the "probable effectiveness" of various transportation techniques and policies for improving traffic flow and the air pollution effects of these transportation policies was formulated, as shown in Table 4. 1.

While it is impossible to place a precise measure of effectiveness on each of the techniques or policies, there is sufficient knowledge to assign an approximate value. The table ranks the "probable effectiveness," using a scale of 1 (least effective) through 5 (most effective). The effectiveness of most techniques in reducing air pollution will vary from city-to-city due to variations in the extent to which the technique is already in use, the adequacy of the area's transportation system, or the micro-climate of the area. The difficulty of implementing specific techniques will depend on such factors as: the existence of necessary legislation, the willingness of state legislatures to pass new legislation, the ability of the appropriate government agencies to administer transportation controls within the existing institutional framework, the existence of alternative transportation

TABLE 4.1

TECHNIQUES FOR IMPROVING TRAFFIC FLOW, FOR REDUCING POLLUTION CONCENTRATION, AND FOR REDUCING AUTO TRAFFIC

Techniques for Improving Traffic Flow	Probable Effectiveness[a]
A. Freeways	
1. Reverse-lane operations	3
2. Driver advisory displays	1
3. Ramp control	2
4. Interchange design	2
B. Arterials	
1. Alinement	1
2. Widening intersections	3
3. Parking restrictions	2
4. Signal progression	2
5. Reversible lanes	3
6. Reversible one-way streets	3
7. Helicopter reports	2
C. Downtown Distribution	
1. Traffic responsive control	5
2. One-way street operations	3
3. Loading regulations	3
4. Pedestrian control	1
5. Traffic Operations Program to Increase Capacity and Safety (TOPICS)	5
Techniques for Reducing Pollution Concentration	
A. Staggered Work Hours	3
B. Roadway Concentrations	2
C. Cross-sections	2
D. Elevated, At-grade, Depressed Roadways	2
Techniques for Reducing Auto Traffic	
A. Transit Operations	
1. Bus lanes on city streets	1
2. Bus lanes on freeways	1
3. One-way streets with two-way buses	1
4. Park-ride, kiss-ride	3
5. Service improvements and cost reductions	2
B. Regulation	
1. Parking bans	4
2. Auto-free zones	4
3. Gasoline rationing	5
4. Idling restrictions	2
5. Four-day, forty-hour week	2
C. Pricing Policy	
1. Parking policy	2
2. Road-user tax	5
3. Gasoline tax	5
4. Car pool incentives	2
D. Planned Unit Development	2

[a] Based on traffic volume affected, pollution reduction, population exposure, and any adverse pollution impact (e.g., more or longer trips likely to be induced, or likely to cause traffic congestion). Higher numbers indicate greater levels of effectiveness.

modes, the costs of implementation, and the strong support of the public. Some measures such as engine-size taxes or fuel taxes must be applied on a statewide or even national scale, while other techniques may be most appropriately applied during severe pollution episodes.

In addition to the Automotive Guide the "Guide for Reducing Air Pollution through Urban Planning" is another product of this study. Table 4.2 illustrates a matrix of strategies and techniques in urban planning that could be pursued in the amelioration of the air pollution problem. These possible actions must be explored in further depth as part of the program to be of use in the creation of guidelines.

Thus, the final task is the preparation of comprehensive guidelines based on the experiences gained in all the case studies. These will provide planners, engineers, and other decision-makers with the knowledge derived from situations that have actually been experienced and that, therefore, have a relatively high degree of reliability.

Simulation Studies

Simulation studies provide the decision-maker and the planner with the opportunity of experimenting with alternatives that have not been tried before and that would be very costly or impossible to construct. In addition, they provide the planner with the opportunity of looking at a whole region simultaneously and evaluating the total impact of policy decisions.

On the other hand, simulation studies necessarily involve a high degree of simplification of actual conditions. Most aspects of a metropolitan area are reduced to a few simple patterns and several combinations of these patterns are tested. Thus, the results of simulation studies are by nature fairly theoretical and provide the professional with knowledge of the general impact of courses of action of broad magnitude, rather than supplying him with quantitative information on specific changes.

Table 4.2 Urban Planning Strategies and Techniques for Reducing Air Pollution

LEGEND

■ PRIMARY TECHNIQUES

● SECONDARY TECHNIQUES

STRATEGIES	A. REGIONAL DEVELOPMENT				B. LOCATION & DESIGN						
TECHNIQUES	1. Alternative Regional Forms	2. Balanced Communities and Subregions	3. Low Density Development	4. Regional Open Space Patterns	1. Location of Stationary Sources	2. Relocation of Stationary Sources	3. Control of Land Use Around Sources	4. Location of Sensitive Receptors	5. Location & Design Control of New Towns	6. Planned Unit Developments	7. Small Open Spaces
Comprehensive & Project Planning	●	●	●	●	■	●	●	■	●	●	●
Localized Zoning (Location & Density)	●	●	■	●	●	●	■	■	●	■	●
Regional Zoning (Location & Density)	■	■	■	■	■	●	■	■	■		
Performance Zoning					●						
Non-Conforming Use Laws						●	●	●			
Zoning Regulations for Site Use										●	■
Air Zoning & Smokeless Zones			●		●						
Subdivision Regulations								●	■	■	
Land Dedication Regulations										■	
Planned Unit Development Regulations								●	■	■	
Building & Housing Codes			●							●	
Urban Renewal		●				●	●	●	●	●	●
Land Acquisition Programs	■		●	■				●		■	
Open Space Tax Incentives	■		●	●							
Location & Re-location Incentives	●	■	●		●				●		
Speculative Public Investment	●	■			●	■			●		
Tax Equalization or Gov't Consolidation	●				■	■			●		
A-95 Review	●	●		●	●				■		●
Direct Urban Design		●								●	●

The simulation studies in this program will consist of constructing a number of abstract urban patterns, combining these abstract patterns with alternative land use configurations and transportation networks through the use of existing models and programs, and determine the air pollution impact of each alternative. The urban patterns should simulate metropolitan and submetropolitan areas of differing sizes. They should also illustrate the different kinds of possible urban development such as sprawl, corridorization, and satellite cities and should benefit from the state-of-the-art described in Chapter 3. Land use arrangements should exhibit the different mixes that are currently used or that can develop in the future, while transportation systems should consist of different networks, different modes, and combinations of modes.

The stationary source air pollution characteristics of the different land use arrangements and transportation systems should also be fed into the simulation models. These will be used by the models to aggregate the total air pollution effects due to a specific arrangement of land use patterns and transportation networks.

In the course of the simulation study, the different combinations of compatible urban patterns, land use arrangements, and transportation systems will be tried and evaluated from the standpoint of their air pollution consequences. After the different combinations have been tested, the specific arrangements that are most conducive to meeting air pollution goals will be analyzed in more detail, and recommendations will be made about which kinds of planning policies have potential application.

Demonstration Projects

Demonstration projects represent the most involved and committed level of research and development activity. They usually involve a sizable investment and a significant commitment on the part of the public. Therefore, they can only be undertaken when a fairly reasonable chance of success or positive result can be expected, and when all previous stages of research such as case studies and simulation studies have produced convincing evidence that the planning action is a correct one. Demonstration projects are used to convince the public, by a full-scale experiment, of the usefulness of a certain type of action as a last testing ground before applying the concept in an overall manner.

Demonstration projects should be used to show the air pollution impacts of some of the major directions in which public decision-making can proceed. Occasionally, some of these actions have mutually reinforcing effects and should be used in conjunction with each other. For example, a demonstration project can be used to show the impact of urban renewal both on air pollution and housing conditions. The evaluation of demonstration project results becomes more difficult as the scale of the project gets larger, and consequently, evaluation guidelines should be carefully established at the beginning of a project.

Some of the demonstration projects will show air pollution reductions by substituting mass transportation facilities for individual transportation wherever possible. There are two scales of operation in this respect: one consists of encouraging mass transit on a metropolitan scale, and the other of establishing small distribution systems in high activity areas.

Design and operational aspects of transportation systems should receive careful study in this work item. Such approaches as reversible lane operations, synchronization of traffic signals, and control of street intersections seem to be promising in reducing ambient air pollution levels.

In relation to the operational aspects of highway systems, studies will investigate the air pollution consequences of monitoring expressways and synchronizing traffic signals in arterials and other streets. The purpose of these actions is to maintain a steady flow of traffic and avoid congestion. A steady flow is known to reduce air pollution because emissions from motor vehicles increase during acceleration, deceleration, and idling. More quantitative data is needed in this respect, however, and these studies will attempt to provide it.

Some demonstration projects will concentrate on changes in the behavioral patterns of the residential population. One example of this is staggering work hours to reduce peak loads on transportation facilities currently being tested in New York City. As demonstration projects are completed in the course of the program, their impact should be fully analyzed, and any modifications that might be necessary should be carried out before the full-scale application of the concept.

Succeeding work items in the program will be concerned with support activities such as implementation of the air pollution control measures, information dissemination, and training program.

Legal and Administrative Studies

In order to fight air pollution through a comprehensive approach of source control and planning, plans and programs geared to ameliorate air pollution must be implemented. In many cases, the technical methods necessary for reductions might be available, but the institutional means of effectuating the plans might not be clearly known. It seems essential, therefore, to define adequately the responsibilities of governmental agencies operating at different levels and to provide them with the necessary inducements to carry out their responsibilities.

The first stage will be identification and listing of present and potential means by which air pollution can better be incorporated into urban and transportation planning. An important input to this will be a review of implementation tools presently used or proposed for other aspects of urban planning, such as zoning, code enforcement, and subdivision regulations. These will be examined to determine their usefulness in solving air pollution problems, and new methods that have specifically been proposed for air quality control will be investigated. Approaches such as establishing allowable emission densities according to land use will be studied. This comprehensive study should result in an awareness of the merit of each approach in combating air pollution.

Once these mechanisms are identified, the legal, institutional, cultural, and organizational problems that might prevent them from being properly and fully employed will be analyzed. A study of this nature is currently being undertaken by the Institute of Public Administration for the six metropolitan areas considered to be most critical from the standpoint of air pollution. In some instances, it will probably be found that plans to implement air quality goals are in conflict with other important matters of public concern. For example, the curtailment of some types of industrial activities might create regional employment problems, or certain means of overcoming air pollution might result in water pollution. These will be noted, and included in the list of problems.

The next task in this phase will be an effort to overcome these problems. Guidelines will be prepared to resolve conflicts and iron out existing differences. Where problems are created by a lack of public acceptance, ways of publicizing the consequences of air pollution will be determined. Where they are created by specific interest groups, means of promoting the public interest will be investigated.

The next step in this work item will consist of assignment of responsibilities to the different levels of government and to specific agencies or types of agencies at each level. This will require an analysis of the capabilities of such agencies and their goals. Where these capabilities are insufficient, ways of strengthening them will be investigated. The outcome of this plan will be a series of guidelines and inducements geared toward encouraging governmental agencies to tackle air pollution problems and explaining to them how to approach their responsibilities.

Information Dissemination and Training

The program will generate large amounts of information both during the program period and after its completion. The only way in which program findings can be applied effectively is through their dissemination to professionals during the planning and decision-making stages.

Very often, large sums are invested in research and development efforts, which turn out to be fruitless, because the people who are in a position to act and those who are conducting the research have no clear channels of communication. The purpose of this phase is to create a scheme for achieving communication and incorporating the findings of the research efforts into the application of plans without unnecessary delay.

Together with the need for an information dissemination system goes the need for a rigorous training program to supply the necessary skills at all levels of decision-making. This will ensure the proper understanding of the air pollution problem and of the means of overcoming it. Part of this work item's effort will go into designing a suitable training system.

The design of both the information and the training systems will be accomplished by reviewing the responsibilities of each level of decision-making as developed in the preceding work item, and identifying their information and skill needs. The systematic evaluation of these needs will result in an organized structure of information delivery and training.

Another purpose of this work item is the dissemination to the public of the information that leads to the setting of standards. This activity has a twofold purpose. First, by publicizing the costs associated with air pollution and the levels at which it must be held to achieve a safe and pleasant environment, and by emphasizing the consequences of the problems, it is hoped that a higher level of public awareness and commitment will be created than now exists, and therefore, a step toward the achievement of a cleaner atmosphere will have been taken. Second, by making the facts about air pollution easily available to everyone, and by emphasizing the fact that this is a social problem and not an individual one, it is hoped that the disparity between actual costs and perceived costs will be reduced and that a common understanding of the problem will be created.

The first requirements for the training program will be to conduct a skills inventory of current staff, to determine the most effective utilization of this staff for initiating a training and/or retraining program, and to identify the need for additional employment. The need for utilization, training and retraining, and employment can be visualized on several skill and knowledge levels:

- Research findings
- Instruction
- Practice
- Guidelines
- Administration and management

These would be required at each level of government - Federal, state, regional, local.

General training and retraining goals should be narrowed to meet identified overall needs as well as the specific needs of each agency. These training needs may be distilled from analyses of projected job requirements compared with existing skills derived from the inventory. To benefit from all elements of the program, the training should be conducted in the actual job environment as much as possible. A written training program should be developed to assist other agencies in similar programs.

PROGRAM ADMINISTRATION

A suitable method for administering the program will be necessary as an adjunct to the program implementation. Because of the diversity of participants - EPA, HUD, DOT, HEW, and other agencies at Federal, state and local levels - administration can best be accomplished by establishment of a Policy Board composed of individual and high level representatives from each agency involved in the program. In order to be effective, the board members should have equal authority and responsibility for the program and should function jointly as a team.

Other characteristics required for the board include:

- All members should have equal information about the program
- The leader should be chosen by the board members and should be highly skilled in his role
- The board should meet frequently enough to become well-established and develop related working relationships.
- The interaction, problem-solving, and decision-making activities of the group should occur in a supportive atmosphere

It will be necessary to implement the program with a strong sense of participation among the board members which will increase agency and staff motivation and productivity. The feedback from staff and field agencies should be sought and utilized to review and evaluate the program in process. One of the goals of this procedure should be to reduce and eliminate interagency conflicts and competition and assign individual responsibility. The program will require close coordination at the national level. Similar administrative and review boards may be established at state and local levels.

The general manpower and administrative principles outlined above are not new to Federal practice; they are suggested here as a guide to program implementation.

CHAPTER 5

PROJECTS

OVERVIEW

This chapter develops the funding levels for each of the work items described in Chapter 4 and a program structure for implementation during the five-year period. Based on the potential of the possible approaches to reduce air pollution and the necessary support required to achieve these reductions, the following percentages of the total program budget are allocated to the six work items:

• Adaptation of research	10%
• Case studies	20%
• Simulation studies	20%
• Demonstration projects	20%
• Legal and administrative studies	10%
• Information dissemination and training	20%
Total	100%

The proportion allocated to the first four work items is further subdivided according to the following five action areas, identified in Chapter 3.

- Land development patterns and density.
- Spatial arrangement of buildings and site activities.
- Planning of transportation systems.
- Design of facilities
- Operation of facilities.

The final cost percentage breakdown is shown in Table 5. 1.

The total amount to be expended in this five-year program is based on consultant judgment and evaluation of investments in similar programs and their payoffs. The base parameters for the five-year program are derived from expenditures in the research program related to the internal combustion engine presently being conducted by the OAP and the anticipated payoffs from that program. From these evaluations it is estimated that the total sum to be expended in the five-year research program for air quality considerations in urban and transportation planning will range from $35 million to $45 million. For estimating purposes, a total of $37.5 million is used; the allocation of these funds would mean the following expenditures on each of the work items:

• Adaptation of research	$ 3,750,000
• Case studies	7,500,000
• Simulation studies	7,500,000
• Demonstration projects	7,500,000
• Legal and administrative studies	3,750,000
• Information dissemination and training	7,500,000
	$37,500,000

Table 5.2 shows how this amount is distributed based on the proportions shown in Table 5.1.

The distribution of the work items over the five-year period was derived from priorities established by their sequence in the overall program structure described in Chapter 4. The program spans five fiscal years. Table 5.3 shows the percentage of the funds allocated to each work item to be spent in each one of the five years. Table 5.4 shows the actual dollar amounts that correspond to these percentages.

Tables 5.5 through 5.10 indicate how the money allocated to each of the work items is divided among the different action areas. The allocation formula for the five-year program is based on the following assumptions:

- Annual allocation of the total funds to be spread evenly over the five years to provide adequate funding and manpower.
- A sequencing of projects so that a sufficient data base can be developed during the early years to be input to the simulation studies.

TABLE 5.1

COST PERCENTAGE BREAKDOWN FOR FIVE-YEAR PROGRAM

Action Area	Work Items: Adaptation of Research (%)	Case Studies (%)	Simulation Studies (%)	Demonstration Projects (%)	Subtotal (%)	Legal and Administrative Studies (%)	Information and Training (%)
Land development patterns and density	2	4	4	--	10.0		
Spatial arrangement of buildings and site activities	1	2	2	6	11.0		
Planning of transportation systems	1.5	3	3	--	7.5	10	20
Design of facilities	2	4	4	7	17.0		
Operation of facilities	3.5	7	7	7	24.5		
Total	10	20	20	20	70.0	10	20

TABLE 5.2

COST BREAKDOWN FOR FIVE-YEAR PROGRAM
(in thousands of dollars)

Action Area	Work Items: Adaptation of Research ($)	Case Studies ($)	Simulation Studies ($)	Demonstration Projects ($)	Subtotal ($)	Legal and Administrative Studies ($)	Information and Training ($)
Land development patterns and density	750	1,500	1,500	--	3,750		
Spatial arrangement of buildings and site activities	375	750	750	2,250	4,125		
Planning of transportation systems	560	1,125	1,125	--	2,810	3,750	7,500
Design of facilities	750	1,500	1,500	2,625	6,375		
Operation of facilities	1,315	2,625	2,625	2,625	9,190		
Total	3,750	7,500	7,500	7,500	26,250	3,750	7,500

TABLE 5.3

PERCENTAGE OF FUNDS TO BE SPENT EACH YEAR, BY WORK ITEM

Work Item	Fiscal Year					Total (%)
	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Adaptation of Research	60	40	--	--	--	100
Case Studies	40	30	30	--	--	100
Simulation Studies	10	20	30	40	--	100
Demonstration Projects	10	15	20	30	25	100
Legal and Administrative Studies	10	10	10	20	50	100
Information and Training	5	10	15	20	50	100
Weighted Average	20	20	20	20	20	100

TABLE 5.4

DISTRIBUTION OF FUNDS BY FISCAL YEAR AND WORK ITEM (thousands of dollars)

Work Item	Fiscal Year					Total ($)
	1 ($)	2 ($)	3 ($)	4 ($)	5 ($)	
Adaptation of Research	2,250	1,500	--	--	--	3,750
Case Studies	3,000	2,250	2,250	--	--	7,500
Simulation Studies	750	1,500	2,250	3,000	--	7,500
Demonstration Projects	750	1,125	1,500	2,250	1,875	7,500
Legal and Administrative Studies	375	375	375	750	1,875	3,750
Information and Training	375	750	1,125	1,500	3,750	7,500
Total	7,500	7,500	7,500	7,500	7,500	37,500

- A combination of similar types of projects, such as highways, transit, etc., to provide a cost-effective exchange of information for case studies, simulation studies, and demonstration projects.
- The need for implementation and inducement procedures to be concentrated in the latter years of the program so that the findings may be effectively utilized as follow-up to the research program.

This is one set of several possible alternatives and may be considered a base from which to make modifications. Table 5.11 is a summary of work item allocations by action area over the five-year period.

The remainder of this chapter is concerned with the individual projects that constitute the five-year program. The projects pertaining to each action area are listed separately, their costs are estimated, and these costs are distributed over the duration of the projects. This gives a total picture of each action area in terms of its constituent projects.

TABLE 5.5

ALLOCATION OF FUNDS TO ACTION AREAS
IN WORK ITEM I: ADAPTATION OF RESEARCH
(thousands of dollars)

Action Area	Fiscal Year 1 ($)	2 ($)	3 ($)	4 ($)	5 ($)	Total ($)
Land Development Patterns and Density	360	390	--	--	--	750
Spatial Arrangement of Buildings and Site Activities	200	175	--	--	--	375
Planning of Transportation Systems	450	110	--	--	--	560
Design of Facilities	400	350	--	--	--	750
Operation of Facilities	840	475	--	--	--	1,315
Total	2,250	1,500	--	--	--	3,750

TABLE 5.6

ALLOCATION OF FUNDS TO ACTION AREAS
IN WORK ITEM II: CASE STUDIES
(thousands of dollars)

Action Area	Fiscal Year 1 ($)	2 ($)	3 ($)	4 ($)	5 ($)	Total ($)
Land Development Patterns and Density	175	400	925	--	--	1,500
Spatial Arrangement of Buildings and Site Activities	450	300	--	--	--	750
Planning of Transportation Systems	775	250	100	--	--	1,125
Design of Facilities	500	700	300	--	--	1,500
Operation of Facilities	1,100	600	925	--	--	2,625
Total	3,000	2,250	2,250	--	--	7,500

TABLE 5.7

ALLOCATION OF FUNDS TO ACTION AREAS
IN WORK ITEM III: SIMULATION STUDIES
(thousands of dollars)

Action Area	Fiscal Year 1 ($)	2 ($)	3 ($)	4 ($)	5 ($)	Total ($)
Land Development Patterns and Density	--	200	400	900	--	1,500
Spatial Arrangement of Buildings and Site Activities	--	150	375	225	--	750
Planning of Transportation Systems	200	300	500	125	--	1,125
Design of Facilities	250	375	475	450	--	1,500
Operation of Facilities	350	475	500	1,300	--	2,625
Total	750	1,500	2,250	3,000	--	7,500

TABLE 5.8

ALLOCATION OF FUNDS TO ACTION AREAS
IN WORK ITEM IV: DEMONSTRATION PROJECTS
(thousands of dollars)

Action Area	Fiscal Year 1 ($)	2 ($)	3 ($)	4 ($)	5 ($)	Total ($)
Land Development Patterns and Density	--	--	--	--	--	--
Spatial Arrangement of Buildings and Site Activities	--	---	500	1,000	750	2,250
Planning of Transportation Systems	--	--	--	--	--	--
Design of Facilities	--	250	500	750	1,125	2,625
Operation of Facilities	750	875	500	500	--	2,625
Total	750	1,125	1,500	2,250	1,875	7,500

TABLE 5.9

ALLOCATION OF FUNDS TO ACTION AREAS
IN WORK ITEM V: LEGAL AND ADMINISTRATIVE STUDIES
(thousands of dollars)

	Fiscal Year					
	1 ($)	2 ($)	3 ($)	4 ($)	5 ($)	Total ($)
Total -- All Areas	375	375	375	750	1,825	3,750

TABLE 5.10

ALLOCATION OF FUNDS TO ACTION AREAS
IN WORK ITEM VI: INFORMATION AND TRAINING
(thousands of dollars)

	Fiscal Year					
	1 ($)	2 ($)	3 ($)	4 ($)	5 ($)	Total ($)
Total -- All Areas	375	750	1,125	1,500	3,750	7,500

TABLE 5.11

FIVE-YEAR PROGRAM SUMMARY
FUND ALLOCATION BY ACTION AREA
(thousands of dollars)

Work Item		Action Area[a]	Fiscal Year 1 ($)	2 ($)	3 ($)	4 ($)	5 ($)	Total ($)
I.	Adaptation of Research	A	360	390				750
		B	200	175				375
		C	450	110				560
		D	400	350				750
		E	840	475				1,315
	Total		2,250	1,500				3,750
II.	Case Studies	A	175	400	925			1,500
		B	450	300				750
		C	775	250	100			1,125
		D	500	700	300			1,500
		E	1,100	600	925			2,625
	Total		3,000	2,250	2,250			7,500
III.	Simulation Studies	A		200	400	900		1,500
		B		150	375	225		750
		C	200	300	500	125		1,125
		D	200	375	475	450		1,500
		E	350	475	500	1,300		2,625
	Total		750	1,500	2,250	3,000		7,500
IV.	Demonstration Projects	B			500	1,000	750	2,250
		D		250	500	750	1,125	2,625
		E	750	875	500	500		2,625
	Total		750	1,125	1,500	2,250	1,875	7,500
V.	Legal and Administrative		375	375	375	750	1,875	3,750
VI.	Information and Training		375	750	1,125	1,500	3,750	7,500
	TOTAL		7,500	7,500	7,500	7,500	7,500	37,500

[a] A - Land Development Patterns and Density
B - Spatial Arrangement of Buildings and Site Activities
C - Planning of Transportation Systems
D - Design of Facilities
E - Operation of Facilities

I ADAPTATION OF RESEARCH

A Land Development Patterns and Density

1. Modify methods for estimating emissions from stationary sources for application to regional analysis (30%).
2. Modify diffusion models related to stationary sources for regional analysis (30%).
3. Modify meteorological inputs for stationary sources for application to regional analysis (30%).
4. Identify criteria related to air quality that should be met in planning for land development and density patterns (10%).

Project I-A	EXPENDITURES					
	Fiscal Year					
	1	2	3	4	5	Total
1	$150,000	$ 75,000	--	--	--	$225,000
2	75,000	150,000	--	--	--	225,000
3	100,000	125,000	--	--	--	225,000
4	35,000	40,000	--	--	--	75,000
TOTAL	$360,000	$390,000	--	--	--	$750,000

I ADAPTATION OF RESEARCH

B Spatial Arrangement of Buildings and Site Activities

1. Modify methods for estimating emissions from stationary sources for application to micro analysis (25%).
2. Modify diffusion models related to stationary sources for micro analysis (25%).
3. Modify meteorological inputs for stationary sources for application to micro analysis (30%).
4. Identify criteria related to air quality that should be met in planning spatial arrangement of buildings and site activities (20%).

Project I-B	EXPENDITURES					
	Fiscal Year					
	1	2	3	4	5	Total
1	$ 78,750	$ 15,000	--	--	--	$ 93, 750
2	53,750	40,000	--	--	--	93, 750
3	47,500	65,000	--	--	--	112, 500
4	20,000	55,000	--	--	--	75, 000
TOTAL	$200, 000	$175, 000	--	--	--	$375, 000

I ADAPTATION OF RESEARCH

C Planning Transportation Systems

1. Modify methods for estimating emissions from moving sources for application to regional analysis (25%).

2. Modify diffusion models related to moving sources for regional analysis, to complement I-A-2 (30%).

3. Modify meteorological inputs for moving sources for application to regional analysis, to complement I-A-3 (30%).

4. Identify criteria related to air quality that should be met in planning transportation systems (15%).

Project I-C	EXPENDITURES					
	Fiscal Year					
	1	2	3	4	5	Total
1	$140,000	--	--	--	--	$140,000
2	140,000	$ 28,000	--	--	--	168,000
3	140,000	28,000	--	--	--	168,000
4	30,000	54,000	--	--	--	84,000
TOTAL	$450,000	$110,000	--	--	--	$560,000

I ADAPTATION OF RESEARCH

D Design of Facilities

1. Modify methods for estimating emissions from stationary sources for application to corridor analysis (30%).
2. Modify diffusion models related to stationary sources for corridor analysis (30%).
3. Modify meteorological inputs for stationary sources for application to corridor analysis (30%).
4. Identify criteria related to air quality that should be met in design of facilities (10%).

Project I-D	EXPENDITURES					
	Fiscal Year					
	1	2	3	4	5	Total
1	$150,000	$ 75,000	--	--	--	$225,000
2	125,000	100,000	--	--	--	225,000
3	100,000	125,000	--	--	--	225,000
4	25,000	50,000	--	--	--	75,000
TOTAL	$400,000	$350,000	--	--	--	$750,000

I ADAPTATION OF RESEARCH

E Operation of Facilities

1. Modify methods for estimating emissions from moving and stationary sources for micro and corridor analysis (30%).
2. Modify diffusion models related to moving and stationary sources for micro and corridor analysis, to complement I-B-2 and I-D-2 (30%).
3. Modify meteorological inputs for moving and stationary sources for micro and corridor analysis, to complement I-B-3 and I-D-3 (30%).
4. Identify criteria related to air quality that should be met in operation of facilities (10%).

Project I-E	EXPENDITURES					
	Fiscal Year					
	1	2	3	4	5	Total
1	$394,500	--	--	--	--	$ 394,500
2	200,000	$194,500	--	--	--	394,500
3	194,500	200,000	--	--	--	394,500
4	51,500	80,000	--	--	--	131,500
TOTAL	$840,000	$474,500	--	--	--	$1,315,000

II CASE STUDIES

A Land Development Patterns and Density

1. Determine the impact that different development densities have on air quality (20%).
2. Determine the impact that the location of various critical industries, inside and outside the central city, has on air quality (25%).
3. Determine the impact that the arrangement of open space in a community has on air quality (20%).
4. Determine the impact that different land development patterns have on air quality (25%).
5. Determine the extent to which total air resources (air shed) of representative metropolitan areas are lost to pollution (10%).

Project II-A	EXPENDITURES					
	Fiscal Year					
	1	2	3	4	5	Total
1	$175,000	$125,000	--	--	--	$ 300,000
2	--	100,000	$275,000	--	--	375,000
3	--	100,000	200,000	--	--	300,000
4	--	75,000	300,000	--	--	375,000
5	--	--	150,000	--	--	150,000
TOTAL	$175,000	$400,000	$925,000	--	--	$1,500,000

B Spatial Arrangement of Buildings and Site Activities

1. Determine the impact that the size, shape, and spatial arrangement of buildings and structures have on air pollution levels in subarea development (20%).
2. Determine the impact that topographical factors have on air pollution levels in subarea development (20%).
3. Determine the impact that meteorological factors have on air pollution levels in subarea development (20%).
4. Determine the impact that surrounding transportation facilities have on air pollution levels in subarea development (20%).
5. Determine the impact that stationary sources have on air pollution levels in subarea development (20%).

Project II-B	EXPENDITURES					
	Fiscal Year					
	1	2	3	4	5	Total
1	--	$150,000	--	--	--	$150,000
2	$150,000	--	--	--	--	150,000
3	150,000	--	--	--	--	150,000
4	150,000	--	--	--	--	150,000
5	--	150,000	--	--	--	150,000
TOTAL	$450,000	$300,000	--	--	--	$750,000

C Planning Transportation Systems

1. Determine the relationship of air pollution to various freeway systems (30%).
2. Determine levels of emission associated with various street systems (20%).
3. Determine the air pollution impact of various transit systems (20%).
4. Determine the air pollution factors that should be considered in the site selection and planning of new airports, and the expansion of existing ones (20%).
5. Develop criteria related to air quality that should be met in planning transportation systems (10%).

Project II-C	EXPENDITURES					
	Fiscal Year					
	1	2	3	4	5	Total
1	$337, 500	--	--	--	--	$ 337,500
2	225,000	--	--	--	--	225,000
3	--	$125,000	$100,000	--	--	225,000
4	100,000	125,000	--	--	--	225,000
5	112,500	--	--	--	--	112,500
TOTAL	$775,000	$250, 000	$100,000	--	--	$1,125,000

II CASE STUDIES

D Design of Facilities

1. Determine the impact that highway alternatives and roadway alinement have on air quality (28%).
2. Determine the air pollution factors that should be considered in the design of airports (20%).
3. Determine the impact that alternative designs of rapid transit lines have on air quality (20%).
4. Determine the impact that design alternatives of industrial plants have on air quality (16%).
5. Determine the impact that design alternatives of heating and power plants have on air quality (16%).

Project II-D	EXPENDITURES					
	Fiscal Year					
	1	2	3	4	5	Total
1	$200,000	$220,000	--	--	--	$ 420,000
2	200,000	100,000	--	--	--	300,000
3	100,000	200,000	--	--	--	300,000
4	--	90,000	$150,000	--	--	240,000
5	--	90,000	150,000	--	--	240,000
TOTAL	$500,000	$700,000	$300,000	--	--	$1,500,000

II CASE STUDIES

E Operation of Facilities

1. Determine the relationships between air pollution and emissions and traffic flow characteristics (such as speed, amount of congestion, etc.) of freeways, arterial streets, and local streets (25%).

2. Determine the impact that various bus and rapid rail transit operational conditions have on air quality (15%).

3. Determine the impact that operation of an airport has on air pollution levels (10%).

4. Determine the impact that operational practices and types of fuels used by stationary sources (power plants, municipal incinerators, industrial plants) have on air quality (25%).

5. Determine the impact that operational characteristics of fuels and manufacturing processes used by industrial plants have on air quality (25%).

Project II-E	EXPENDITURES					
	Fiscal Year					
	1	2	3	4	5	Total
1	$ 450,000	$200,000	--	--	--	$ 650,000
2	390,000	--	--	--	--	390,000
3	260,000	--	--	--	--	260,000
4	--	200,000	$462,500	--	--	662,500
5	--	200,000	462,500	--	--	662,500
TOTAL	$1,100,000	$600,000	$925,000	--	--	$2,625,000

III SIMULATION STUDIES

A Land Development Patterns and Density

1. Simulate various density patterns to determine their impact on air quality (10%).
2. Simulate various land use development patterns to evaluate their impact on air quality (30%).
3. Simulate various metropolitan land use patterns with different meteorological conditions to evaluate their impact on air quality (25%).
4. Simulate various metropolitan land use patterns with different topographical conditions to evaluate their impact on air quality (25%).
5. Identify criteria that would guide the development of appropriate density and development patterns from an air quality point of view (10%).

Project III-A	EXPENDITURES					
	Fiscal Year					
	1	2	3	4	5	Total
1	--	$ 75,000	$ 75,000	--	--	$ 150,000
2	--	125,000	125,000	$200,000	--	450,000
3	--	--	100,000	275,000	--	375,000
4	--	--	100,000	275,000	--	375,000
5	--	--	--	150,000	--	150,000
TOTAL	--	$200,000	$400,000	$900,000	--	$1,500,000

III SIMULATION STUDIES

B Spatial Arrangement of Buildings and Site Activities

1. Simulate various topographical conditions to determine their impact on air pollution levels in subarea development (20%).
2. Simulate various meteorological conditions to determine their impact on air pollution levels in subarea development (20%).
3. Simulate surrounding transportation facilities to determine their impact on air pollution levels in subarea development (20%).
4. Simulate various stationary sources to determine their impact on air pollution levels in subarea development (20%).
5. Simulate various sizes, shapes, and spatial arrangement of buildings and structures to determine their impact on air pollution levels in subarea development (20%).

Project III-B	EXPENDITURES					
	Fiscal Year					
	1	2	3	4	5	Total
1	--	$ 75,000	$ 75,000	--	--	$150,000
2	--	75,000	75,000	--	--	150,000
3	--	--	75,000	$ 75,000	--	150,000
4	--	--	75,000	75,000	--	150,000
5	--	--	75,000	75,000	---	150,000
TOTAL	--	$150,000	$375,000	$225,000	--	$750,000
	--	$150,000	$375,000	$225,000	--	$750,000

III SIMULATION STUDIES

C Planning Transportation Systems

1. Simulate alternative freeway configurations to determine their impact on air quality (10%).

2. Simulate various alternative street patterns to determine their impact on air quality (20%).

3. Simulate various alternative transit systems to determine their impact on air quality (25%).

4. Simulate various concepts of airports to determine their impact on air quality (20%).

5. Simulate transportation systems of metropolitan areas of varying size, meteorological and topographical conditions to determine the impact that size and meteorology and topography have on air quality (25%).

Project III-C	EXPENDITURES					
	Fiscal Year					
	1	2	3	4	5	Total
1	$112,500	--	--	--	--	$ 112,500
2	87,500	$137,500	--	--	--	225,000
3	--	163,000	$119,000	--	--	282,000
4	--	--	100,000	$125,000	--	225,000
5	--	--	281,000	--	--	281,000
TOTAL	$200,000	$300,000	$500,000	$125,000	--	$1,125,000

III SIMULATION STUDIES

D Design of Facilities

1. Simulate air pollution levels related to different highway cross sections under various wind and climatic conditions, traffic volumes, and speed conditions (40%).

2. Simulate air pollution levels related to different arrangements of structures around typical highway designs under various wind and climatic conditions, traffic volumes, and speed conditions (20%).

3. Simulate air pollution levels related to a typical airport under various air traffic, ground operations, and wind and climatic conditions (10%).

4. Simulate air pollution levels related to residential areas with typical floor plans under various weather and control technological conditions (10%).

5. Simulate air pollution levels related to power plant facilities and solid waste incinerators under various meteorological, fuel technological, and surrounding land use conditions (20%).

Project III-D	EXPENDITURES					
	Fiscal Year					
	1	2	3	4	5	Total
1	$200,000	$200,000	$200,000	--	--	$ 600,000
2	--	100,000	100,000	$100,000	--	300,000
3	--	75,000	75,000	--	--	150,000
4	--	--	--	150,000	--	150,000
5	--	--	100,000	200,000	--	300,000
TOTAL	$200,000	$375,000	$475,000	$450,000	--	$1,500,000

III SIMULATION STUDIES

E Operation of Facilities

1. Simulate air pollution levels related to different types of arterial traffic operations (25%).
2. Simulate air pollution levels related to different types of freeway operations (including freeway metering) in urban areas (20%).
3. Simulate the impact that staggering work hours has on peak hour traffic and air quality (10%).
4. Simulate air pollution levels related to various enforcement procedures for stationary and moving sources (10%).
5. Simulate the impact that various pricing policies for transportation systems have on air quality (20%).
6. Simulate the impact that changes and improvements in transit operation procedures have on ridership and air quality (15%).

Project III-E	EXPENDITURES					
	Fiscal Year					
	1	2	3	4	5	Total
1	$350,000	$306,200	--	--	--	$ 656,200
2	--	168,800	$200,000	$ 156,200	--	525,000
3	--	--	--	262,500	--	262,000
4	--	--	100,000	162,500	--	262,500
5	--	--	100,000	425,000	--	525,000
6	--	--	100,000	293,800	--	393,800
TOTAL	$350,000	$475,000	$500,000	$1,300,000	--	$2,625,000

IV DEMONSTRATION PROJECTS

B Spatial Arrangement of Buildings and Site Activities

1. Demonstrate the impact that air pollution related to new towns and satellite cities has on stationary and non-stationary sources (20%).

2. Demonstrate the impact that the separation of residential communities from through-traffic arterials has on air quality (15%).

3. Demonstrate the impact that total energy systems in a neighborhood or subdivision have on air quality (15%).

4. Demonstrate the impact that centralized heating, incinerating, and other utilities within building groups have on air quality (15%).

5. Demonstrate the impact that high activity centers have on air quality (20%).

6. Demonstrate the feasibility of reducing air pollution through urban renewal projects (15%).

Project IV-B	EXPENDITURES					
	Fiscal Year					
	1	2	3	4	5	Total
1	--	--	$150,000	$150,000	$150,000	$450,000
2	--	--	--	337,500	--	337,500
3	--	--	200,000	137,500	--	337,500
4	--	--	150,000	187,500	--	337,500
5	--	--	--	--	450,000	450,000
6	--	--	--	187,500	150,000	337,500
TOTAL	--	--	$500,000	$1,000,000	$750,000	$2,250,000

IV DEMONSTRATION PROJECTS

D Demonstration and Design of Facilities

1. Demonstrate the impact that different types of public transit vehicles have on air quality (20%).

2. Demonstrate the impact that a people-mover system in a high activity center has on air quality (20%)

3. Demonstrate the impact that the separation of vehicular traffic from pedestrian movement has on air quality (20%).

4. Demonstrate the impact that the use of green space has on air quality (20%).

5. Demonstrate the feasibility of underground conduits to carry industrial gaseous wastes and their impact on air quality (20%).

Project IV-D	EXPENDITURES					
	Fiscal Year					
	1	2	3	4	5	Total
1	--	$250,000	$275,000	$ --	$ --	$525,000
2	--	--	225,000	300,000	--	525,000
3	--	--	--	250,000	275,000	525,000
4	--	--	--	200,000	325,000	525,000
5	--	--	--	--	525,000	525,000
TOTAL	--	$250,000	$500,000	$750,000	$1,125,000	$2,625,000

IV DEMONSTRATION PROJECTS

E Demonstration and Operation of Facilities

1. Demonstrate the impact that freeway operations (including freeway metering) have on air quality (25%).

2. Demonstrate the impact that improved traffic operation measures have on air quality (25%).

3. Demonstrate the impact that different parking regulations within and without central cities have on air quality (15%).

4. Demonstrate the impact that fuel switching in industrial and power plants according to atmospheric conditions has on air quality (15%).

5. Demonstrate the impact that various operational practices related to municipal incinerators has on air quality (20%).

Project IV-E	EXPENDITURES					
	Fiscal Year					
	1	2	3	4	5	Total
1	$375,000	$281,200	--	--	--	$656,200
2	375,000	281,200	--	--	--	656,200
3	--	312,600	81,200	--	--	393,800
4	--	--	218,800	175,000	--	393,800
5	--	--	200,000	325,000	--	525,000
TOTAL	$750,000	$875,000	$500,000	$500,000	--	$2,625,000

V LEGISLATIVE AND ADMINISTRATIVE STUDIES

1. Determine institutional mechanisms by which air quality can better be incorporated into urban and transportation planning (10%).
2. Identify and study ways to overcome institutional and legal problems of implementing land use controls and traffic regulations aimed at improving air quality (10%).
3. Set up guidelines and inducements for the national government to implement air pollution plans related to urban and transportation planning by working with appropriate Federal agencies (10%).
4. Set up guidelines and inducements for state governments to implement air pollution plans related to urban and transportation planning (10%).
5. Set up guidelines and inducements for individual communities and planning agencies to implement air pollution plans related to urban and transportation planning (10%).
6. Set up and administer the dissemination and monitoring of grants aimed at improving air quality related to city and transportation planning (50%).

Project V	EXPENDITURES					
	Fiscal Year					
	1	2	3	4	5	Total
1	$375,000	$ --	$ --	$ --	$ --	$375,000
2	--	$375,000	--	--	--	375,000
3	--	--	$375,000	--	--	375,000
4	--	--	--	$375,000	--	375,000
5	--	--	--	--	375,000	375,000
6	--	--	--	375,000	1,500,000	1,875,000
TOTAL	$375,000	$375,000	$375,000	$750,000	$1,875,000	$3,750,000

VI INFORMATION DELIVERY AND TRAINING PROGRAM

1. Identify the air pollution information needed for proper action at the Federal, state and local levels (3%).
2. Identify the air pollution training needs for carrying out the programs at the Federal, state, and local levels (3%).
3. Set up and carry out a clearinghouse to gather all air pollution related information and to relay it for research (20%).
4. Set up and carry out an information dissemination system to provide the needed air pollution information at the Federal, state, and local levels (20%).
5. Set up and carry out a training program to meet the air pollution skill needs at the Federal, state, and local levels (34%).
6. Set up and carry out information and education programs for citizen groups (20.00%).

Project VI	EXPENDITURES					
	Fiscal Year					
	1	2	3	4	5	Total
1	$225,000	$ --	$ --	$ --	$ --	$225,000
2	--	225,000	--	--	--	225,000
3	150,000	225,000	250,000	250,000	625,000	1,500,000
4	--	--	500,000	500,000	500,000	1,500,000
5	--	300,000	250,000	500,000	1,500,000	2,550,000
6	--	--	125,000	250,000	1,125,000	1,500,000
TOTAL	$375,000	$750,000	$1,125,000	$1,500,000	$3,750,000	$7,500,000

APPENDIX A

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APPENDIX B
STUDY ORGANIZATION

The study was organized in a series of phases shown in Figure B.1. Each phase was designed to achieve specific objectives.

Phase I involved a series of meetings with officials of the Office of Air Programs (OAP) of the Environmental Protection Agency and other Federal Agencies concerned with air quality control. Following these meetings the study design was prepared. (*Note)

In Phase II areas of concern were identified through the assembly of information on state and local practices related to air pollution planning. Federal air pollution planning practices were reviewed in order to establish the needs for carrying out research and development projects, demonstration projects, and for producing guidelines and criteria, education information, and support activities. Potential air pollution reductions that would be achieved by different planning programs were also examined in Phase II. These were grouped into a number of categories according to their scope.

Objectives of the various Federal agencies concerned with interrelationships between urban and transportation planning and air pollution were gathered from public documents such as laws, messages to Congress,

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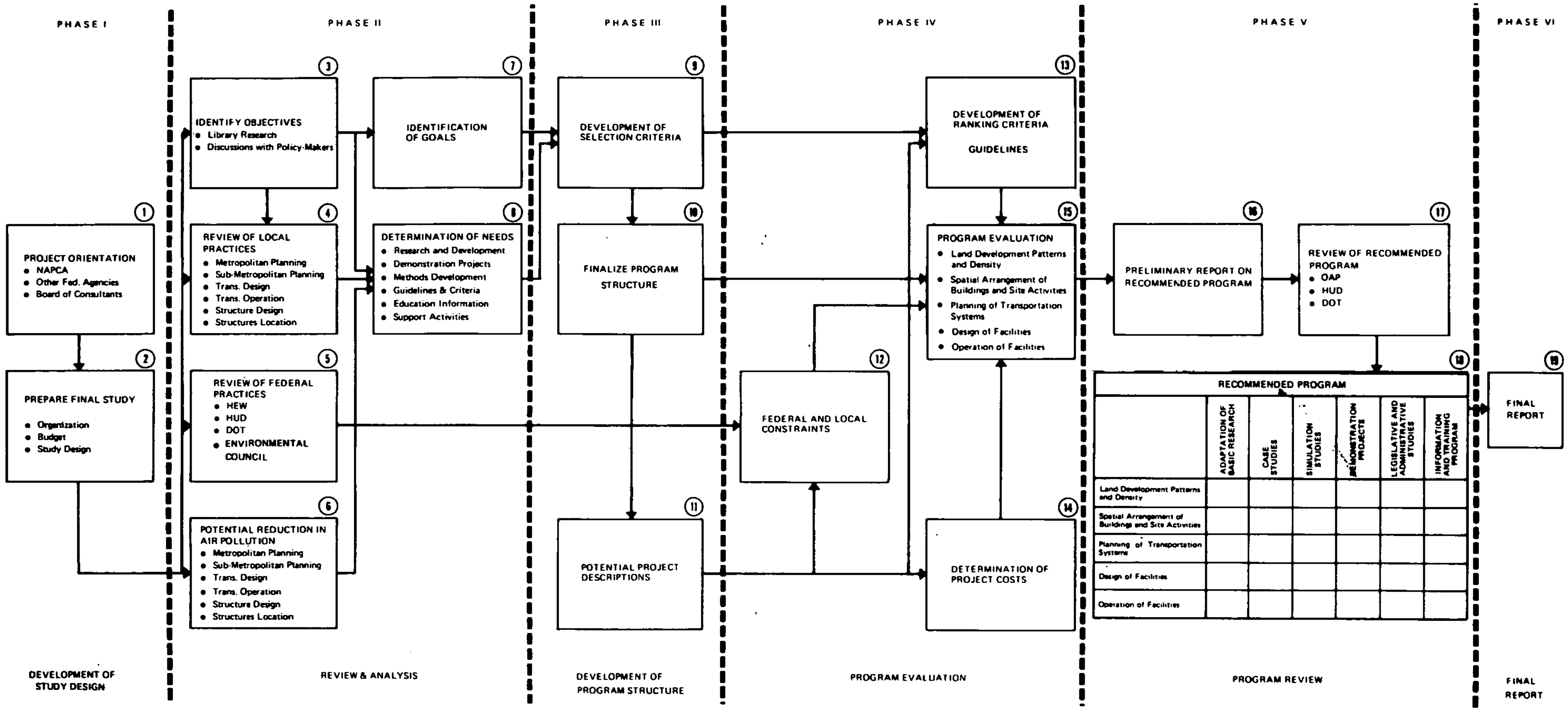
*Note: During the course of the study the designation and organizational structure of the contracting agency was changed several times:

National Air Pollution Control Administration, (NAPCA), Environmental Health Service, Public Health Service, Department of Health, Education and Welfare
Air Pollution Control Office (APCO), Environmental Protection Agency
Office of Air Program (OAP), Environmental Protection Agency

The relationship to the study was essentially unaffected, however.

FIGURE 2

WORK FLOW DIAGRAM



agency policies, administrative directives, and through discussions with policymakers. The review of state and local air pollution planning practices included city, county, and metropolitan agencies, and appropriate private organizations and individuals. The review of Federal practices concentrated on identifying the activities of each agency and where opportunities exist for cooperation among agencies.

In Phase III the program needed to reduce air pollution through urban and transportation planning processes was,formulated. A list of the projects that would be useful in achieving air pollution reductions was prepared and descriptions for each project were detailed.

Phase IV evaluated the program structure developed in Phase III. The Federal and local constraints that would affect program implementation were established. The rigidity of these constraints were identified and their effects on the program determined. Cost estimates were prepared for the various projects.

In Phase V review and final adoption of the program were accomplished. A preliminary report was developed and reviewed to obtain feedback on the recommended program, together with costs and responsibilities for carrying out the programs.

Phase VI consisted of preparing the final report--this document. In addition to this report two planning guides specifically oriented toward professionals such as planners and traffic and transportation engineers were prepared. These are:

1. A Guide for Reducing Air Pollution Impacts through Urban Planning.
2. A Guide for Reducing Automotive Air Pollution.

APPENDIX C
INTRODUCTION TO AIR POLLUTION

To effectively incorporate air pollution considerations into urban and transportation planning, the planner must become familiar with air pollution terminology and characteristics. The purpose of this appendix is to provide this information.

TYPES OF POLLUTANTS AND THEIR SOURCES

Classification of Pollutants

Air pollutants are commonly classified as either gaseous or particulate. Gaseous pollutants behave much like the air itself; they do not settle out. Particulate pollutants may be either solid or liquid, and their performance in the atmosphere varies according to chemical composition and size: heavier particles settle close to the point of emission; and smaller, less-dense particles travel great distances. Urban aerosols, formed by the grinding or atomization of solids and liquids, are particulate matter ranging in size from approximately 6×10^{-7} to 1 micron; they include mist, smoke, dust, fumes, and spray.

Air pollutants also can be categorized as either primary or secondary. A primary pollutant is emitted directly into the atmosphere and initially retains its form as emitted. A secondary pollutant is formed in the atmosphere from reactions that may be chemical, photochemical, or biological.

A third way of classifying pollutants is by chemical composition -- either organic or inorganic. Many of the most common pollutants -- the oxides of carbon, nitrogen, and sulfur -- are inorganic; organic pollutants include hydrocarbons, aldehydes, and ketones.

To classify an air pollutant properly, all three classifications should be used; for example, carbon monoxide is a primary, inorganic, gaseous pollutant.

Units of Air Pollution Measurement

Air pollutants can be quantified in several ways: on the basis of emissions from sources, according to concentrations in the ambient air, or according to rates of exposure.

The source strength of air pollutants can be quantified in units of mass or weight per unit volume; for example, grams per cubic meter of air or pounds per cubic foot. Emissions may also be stated in terms of weight per unit time, weight per unit weight of product, weight per BTU, weight per unit area for area sources, or mass per unit distance for vehicles.

Concentrations of pollutants in the ambient air are normally reported as mass or weight per unit volume of air, such as micrograms per cubic meter. The unit parts per million (ppm), although used, is being discontinued. Settleable particulate matter sometimes is expressed in terms of tons per square mile per month or the currently recommended grams per square meter per month; and suspended particulate is measured in micrograms per cubic meter or Coh's (Coefficient of Haze), a unit of measurement of visibility interference.

Also of concern in the expression of concentrations of air pollutants is the quantity and duration of exposure experienced by plants, animals, or humans. Called the dosage or rate of exposure, units indicate both concentration and time involvement, with levels stated in terms of micrograms per cubic meter either per hour, 8-hour period, day, or year. In many cases, the average concentration over a given period of time is of concern; in other cases, the maximum concentration is more important.

When reviewing regulations or statements concerning concentrations of air pollutants, it is important to understand the units used; that is, whether they relate to the ambient air concentrations, to emissions, or to exposure dosages.

Air Pollutants and Their Sources

Pollutants emitted to the air in greatest abundance are carbon monoxide (CO), particulate matter, oxides of sulfur (SO_x), oxides of nitrogen (NO_x), and hydrocarbons (HC). Emission inventories of these five pollutants are commonly divided into five source categories: transportation, fuel combustion in stationary sources, industrial processes, solid waste disposal, and miscellaneous. Nationwide emissions by category for 1969, presented in Table C. 1, indicate that carbon monoxide is the major pollutant by weight, and that transportation activities are the major carbon monoxide contributor. [120] A different study [199] indicates that emissions of urban origin from stationary combustion and transportation activities account for greater than 75 percent of the total emissions in these five pollutant categories. The motor vehicle (gasoline and diesel) is a major contributor to air pollution. It contributes approximately 60 percent of the total carbon monoxide from all sources, about 50 percent of the hydrocarbons, and 35 percent of the nitrogen oxides.

Oxides of sulfur are chiefly products of fossil fuel combustion. About 80 percent of the sulfur in coal and nearly all that in liquid and gas fuels appears in flue gases as sulfur dioxide (SO_2). Almost all fuels, except wood, contain sulfur; however, they differ widely in their sulfur content. Bituminous coal has a high sulfur content; in some locales as high as 6 percent. Most crude oil contains less than 1 percent. Gasoline seldom contains more than 0. 25 percent. For the relative sulfur content of various fuels, see Table C. 2. Natural gas is virtually free of sulfur.

TABLE C. 1. ESTIMATED EMISSIONS OF AIR POLLUTANTS BY WEIGHT,[a] NATIONWIDE, 1969[120]

Source	CO	Particulates	SO_x	HC	NO_x
Transportation	111.5	0.8	1.1	19.8	11.2
Fuel combustion in stationary sources	1.8	7.2	24.4	0.9	10.0
Industrial processes	12.0	14.4	7.5	5.5	0.2
Solid waste disposal	7.9	1.4	0.2	2.0	0.4
Miscellaneous	18.2	11.4	0.2	9.2	2.0
Total	151.4	35.2	33.4	37.4	23.8

[a]In millions of tons per year.

TABLE C. 2. SULFUR CONTENT OF FUELS[199]

Type of Fuel	Percent by Weight
Bituminous	0.3 - 6.0
Anthracite	0.6 - 1.0
Coke	1.0 maximum
Wood	Negligible
Crude Oil	0.2 - 1.7
Fuel Oil	1.0 maximum
Diesel Oil	0.5 maximum
Gasoline	0.1 - 1.0

Another common source of SO_2 in the atmosphere is metallurgical operations. Many ores, such as copper, lead, and zinc are primarily sulfides. During the smelting of these ores, sulfur is oxidized and is evolved as sulfur dioxide.

The more important sources of particulate matter are industrial process operations, domestic heating plants, industrial power plants, refuse incinerators, open fires, construction activities, diesel engines, and automobiles (see Table C.3). The amount of particulate matter released from each of these sources varies considerably. The most common emissions are carbon or soot particles, metallic oxides and salts, oily and tarry droplets, acid droplets, silicates and other inorganic dusts, and metallic fumes.

Ozone is the principal constituent of the atmospheric substances called photochemical oxidants. They are secondary pollutants, formed by the action of sunlight in a series of complex reactions between hydrocarbons and oxides of nitrogen, which are both emitted primarily from transportation sources.

VARIATIONS IN AIR POLLUTION CONCENTRATIONS

Variations in air pollutant concentration at or near ground level are a function of both meteorological parameters and emissions, both of which vary in time and space. Both fluctuate from place to place according to daily and annual patterns; the latter also exhibit weekly variations. Thus, pollutant concentrations are a function of location, time of day, day of the week, and season of the year.

Variations According to Location

Variations according to location are the natural produce of non-uniform distribution of pollution sources (freeway versus center city

TABLE C.3. SOURCES OF ATMOSPHERIC PARTICULATE MATTER

Combustion	Materials Handling and Processing	Earth Moving	Miscellaneous
Fuel burning	Loading and unloading (sand, gravel, ores, coal, lime, bulk chemicals)	Construction (roads, dams, buildings, site clearance)	House cleaning
Incineration	Mixing and packaging (fertilizers, chemicals, feed)	Mining (blasting, sorting, refuse disposal)	Sand blasting
Open fires	Crushing and grinding (ores, gravel, chemicals, cement)	Agriculture (land preparation, soil tilling)	Crop spraying
Burning dumps	Food processing (milling, e.g., flour, cornstarch; drying; handling grain)		Poultry feeding
Forest fires			Rubber-tire abrasion
			Engine exhaust

traffic) and the random movements of air and weather patterns (rain and fog). Figure C.1 illustrates significant variations in pollutant concentration (in this case, carbon monoxide) as recorded at three different sites in the Detroit area.

The many meteorological observations accumulated over decades permit a fairly reliable estimate of the air pollution potential in various sections of the United States. Regions with a clean sweep of winds within the major storm tracks are least likely to develop high pollution conditions; regions dominated by stagnant air masses and light winds are most likely to experience high pollution conditions.

Variations by Time Periods

Space heating and solar radiation are the two major factors influencing seasonal variations in air pollution levels. Secondary pollutants, such as photochemical oxidants, generally are worst in the late summer or autumn when optimal combinations of solar radiation, temperature, and atmospheric stagnations coincide.

Weekly variations in carbon monoxide are a function of the different transportation and activity patterns associated with weekdays, weekends, and holidays. A study [35] revealed a distinct 20 percent decrease in the average carbon monoxide concentrations during the weekend compared to the higher weekday levels. In urban communities where there are many weekend travelers, the reduction is considerably less.

In general, meteorological conditions at night encourage the accumulation of pollutants; those in the day encourage their rapid dispersion Diurnal variations in carbon monoxide concentrations are illustrated in Figure C.1. Figure C.2 shows diurnal variation in concentrations of hydrocarbons, nitrogen oxides, and oxidants. In these examples, carbon monoxide, hydrocarbons, and nitrogen oxides exhibit two daily peaks. Considerable work[21] has been directed toward correlating these peaks

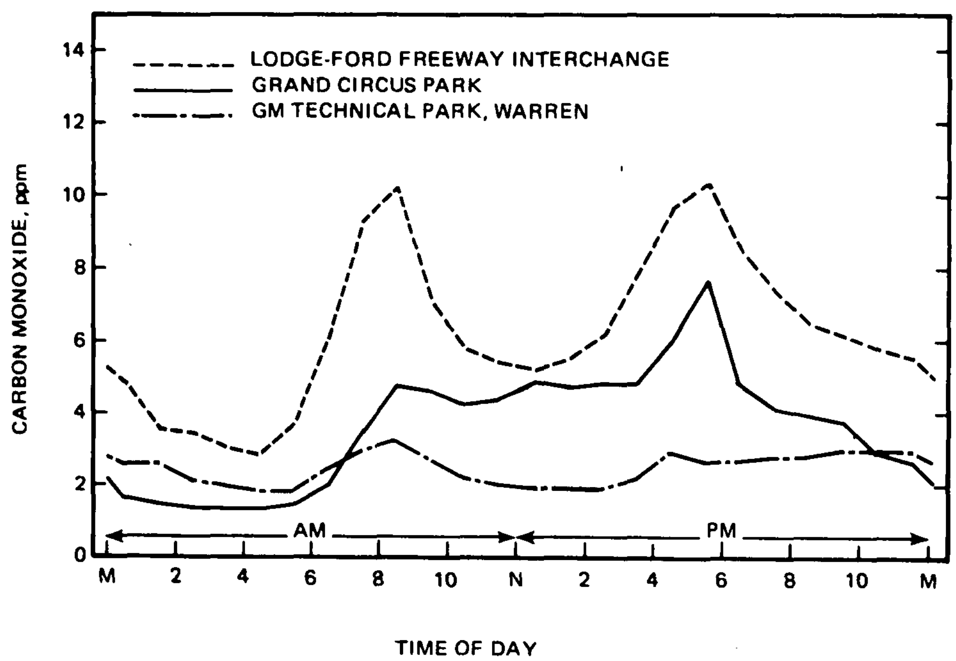


Figure C.1 Hourly Carbon Monoxide Concentrations on Weekdays in Detroit Area [35] with traffic flow and meteorological factors. The studies have indicated that concentrations of these three pollutants generally exhibit a higher correlation with traffic volume than with meteorological conditions. Only one peak has been observed for photochemical oxidants. It generally occurs near midday, in spite of more atmospheric mixing at that time, due to favorable reaction conditions of solar radiation and temperature. A delay between the hydrocarbon and nitrogen oxide peaks and the oxidant peak is normal because the oxidants are produced by chemical reactions involving hydrocarbons and nitrogen oxides.

Figure C.3 illustrates the daily variation in ground-level pollutant concentrations that can be expected some distance downwind from a tall stack on a clear day with light winds. In this example, the pollutant is emitted from the stack at a constant rate; therefore, the changes shown in ground-level concentration result entirely from meteorological influences. The morning maximum is due to a stable atmosphere and prevention of upward dispersion of the pollutant by an inversion layer, a meteorological condition described in the following section. The rapid decrease in concentration is due to the heating of a progressively deeper layer of air above the ground and mixing of the pollutant throughout this layer. After the period of maximum heating, increased stability near the surface causes concentrations to increase in the late afternoon.

METEOROLOGY

Meteorological and topographical conditions in some areas favor the accumulation of pollutants. Lighter particles and gases diffuse only as rapidly as meteorological conditions permit. During this diffusion, the nature of the pollutants may be changed by natural, physical, or chemical processes, such as solar radiation, rain, fog, and interaction with the normal constituents of the atmosphere. Typical examples are the oxidation of nitric oxide to nitrogen dioxide and the photochemical action that forms oxidants.

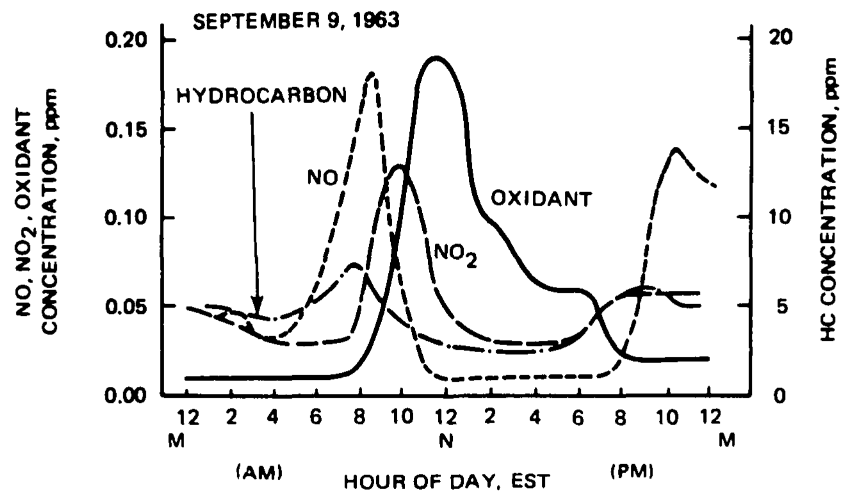


Figure C.2 Concentrations of Nitric Oxide, Nitrogen Dioxide, Hydrocarbon, and Oxidant During a Smoggy Day in Cincinnati, Ohio [181]

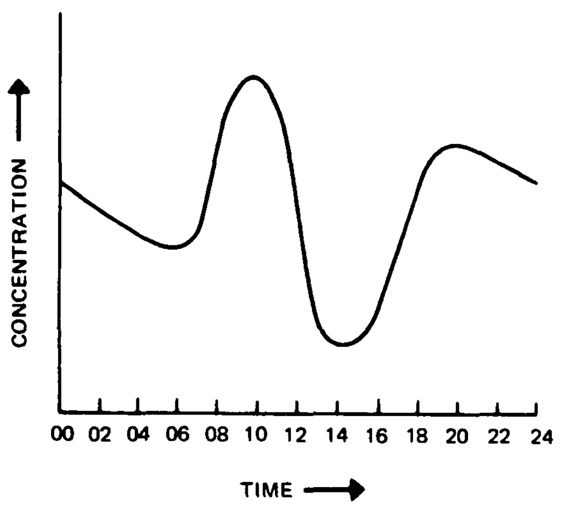


Figure C.3 Diurnal Variation of Ground Level Concentrations From Elevated Urban Sources [39]

In a dry atmosphere, the adiabatic lapse rate (rate of temperature decrease with increase in elevation) is $1^{\circ}C$ per 1000 meters ($5.4^{\circ}F$ per 1,000 feet). When the actual lapse rate is greater than this theoretical rate, a parcel of air that begins to rise continues to do so, and the atmospheric condition is called "unstable." If, however, the actual lapse rate is less than the adiabatic rate, the surface air remains near the surface and the atmospheric condition is called "stable."

An increase of temperature with altitude (an inversion) can occur at any time, but is most common during the night and early morning. An inversion acts as a lid; it separates layers of air and prevents polluted air from rising. If an inversion is accompanied by low winds, a layer of highly polluted air may build up over a broad area.

Three major forces -- wind, heating, and cooling -- cause shifts from stable to unstable conditions and back again. Wind, in addition to horizonatal motion, usually has vertical eddies and, since rapid vertical air motions tend to be adiabatic, helps to establish an adiabatic lapse rate. The sun, which heats the surface more than the air, increases the lapse rate, and, thus, contributes to instability. Conversely, at night the ground loses more heat by radiation than the air does, tending to make the surface cooler than the air layers above; this cooling contributes to stability. Usually there is a daily cycle from stability to instability and back again. When the cycle is broken and the atmosphere remains stable for a prolonged period, a serious accumulation of pollutants is possible.

High pollution potentials are generally favored by light winds and clear skies which promote the formation of temperature inversions. A buildup of high pollution concentrations in the central core of the cities then occurs as the result of this inversion "lid" coupled with a near-surface air movement toward the center city. This air flow is the result of the heat island effect in which the asphalt and concrete city heats up and acts like a chimney, drawing in cooler air from the surrounding areas.

High pollution potential is defined as a stagnating anticyclonic condition which, coupled with the continued operation of several sources, is conducive to the occurrence of high concentrations of pollution. As defined, the high pollution potential refers to developing meteorological conditions only. The National Meteorological Center in Suitland, Maryland, prepares daily 36-hour alerts. This information, called Air Stagnation Advisories (ASA), is available through U. S. Weather Bureau Stations. Being an objective system, the method has its shortcomings, the greatest of which is the lack of individual appraisal and forecasting for each city, based on its local meteorology and areal distribution of pollution sources. The local air pollution control office can provide the necessary in-depth knowledge of a specific urban community.

Within the space of a few miles, microclimatic conditions may considerably influence the effects of pollution. A detailed survey of the meteorological terrain is needed to assess variations in local conditions; this is particularly advisable when planning future communities and industrial areas. For example, it used to be a rule of thumb to locate industrial areas downwind of a settlement with respect to the prevailing wind direction. Unfortunately, in many instances the wind at times of stagnation or near-stagnation conditions may be quite different from the most frequent wind. In some cases, the slight draft under those conditions may be entirely opposite to the prevailing wind, thereby causing a more severe pollution condition than would have been anticipated.

SITE CONDITIONS AFFECTING DISPERSION

The city in a general sense may be considered a collection of microclimates. The pattern and profile of the air motion in the total atmosphere over an urban area are modified, sometimes considerably, in each of these microclimates by the spatial arrangement and character of buildings and other structures, by surrounding vegetation, and by roadway configurations.

Superimposed on this is the air movement resulting from traffic flow. In addition, the relative influence of each of these factors depends on the magnitude of the background air movement and solar heating conditions. Factors found to be dominant at higher wind speeds may decline in significance at the lower wind speeds which present the greater potential for severe pollution episodes.

Urban Heat Island Effect

The combined effects of topography and urbanization decidedly influence the radiation, moisture, and temperature conditions of a city. These, in turn, modify the wind flow patterns. In an urbanized region, vegetation is replaced by a vast man-made environment, resulting in changes in moisture conditions which, in turn, alter the heat distribution. The air is heated by multiple sources including industries, automobiles, space heating, and solar radiation.

It has been estimated that the automobile is an important artifical heat source in the street canyons of a city. Very heavy traffic in parts of London, for example, add an estimated $8^{o}F$ to the air temperature. Bach[12] calculated that for the built-up area of Sheffield, England, the annual artificial heat generation is about one-fifth of the direct solar radiation received. The ratio is one-third for Berlin. Particulate matter, a by-product of most artificial heat generation, may be 5 to 25 times greater in the urban area than in the rural area.

Temperatures in the urban heat island have been found to be on the order of $5\text{-}8^{o}C$ greater at night than in the surrounding rural areas. Sidewalks, roads, and concrete buildings have relatively high heat capacities and conductivities. The daytime heat storage is greater than for grass-covered fields or forests. The lack of evaporational cooling from the dry building surfaces increases the stored solar energy. After sunset, the stored daytime heat is released from buildings and pavements resulting in air temperatures and winds in the city higher than those occurring in the surrounding country. Munn [124] notes that the heat storage ability of a city is believed to be the major factor of the heat island formation. He adds that the city is a collection of microclimates, each dependent upon the character of a built-up area within the entire city.

The heat island effect is found to be maximum in late summer and early autumn when the skies are clear and winds are light. Figures C.4 and C.5 illustrate the morning and evening air culation and dispersion models in a city and in the surrounding country under anticyclonic conditions.

Building Configuration Effects

The orientation of a building with respect to the winds produces significant distortions in the local wind pattern. The significance of the flow distortions becomes clear when vehicular emissions exist within an area surrounded by buildings. Air currents can trap pollution, confining it close to the buildings. Pollutants emitted from building roof vents may also become trapped. Hence, roadway vehicular emissions and emissions from rooftops can be conveyed into windows, doorways, and air intake systems.

As background wind speeds decrease, the effect of the vertical temperature profile (lapse rate) increases and becomes a major controlling factor in the atmospheric dispersion of vehicular emissions in the urban street canyon.

During periods of light winds and clear skies, air flow around buildings is, to a great degree, the result of convective updrafts coupled with winds flowing into the center of the urban heat island. The updrafts remove pollutants from the area of the building more effectively than strong horizontal winds if no inversion exists.

The upward dispersion of vehicular emissions is often restricted in the early morning hours by the presence of a stable layer existing from the

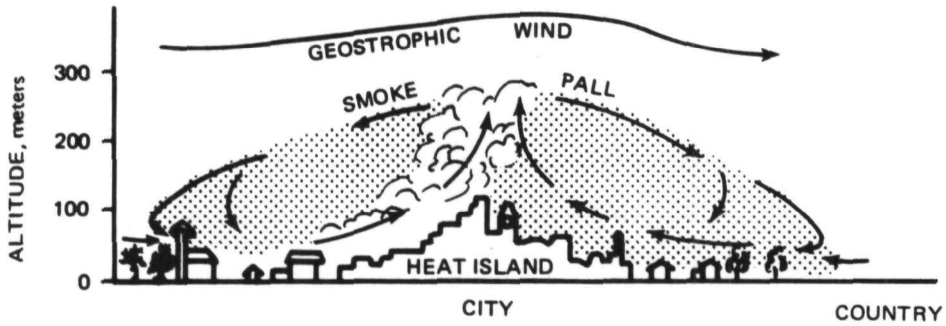


Figure C.4 Urban Circulation and Dispersion After Sunrise [12]

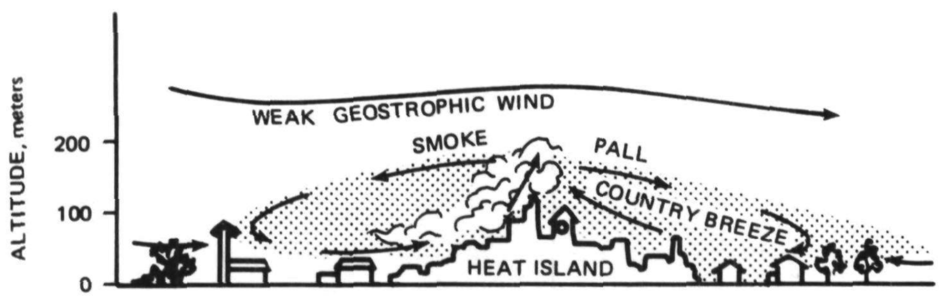


Figure C.5 Urban Circulation and Dispersion After Sunset [12] ground to roof level. The pollutants are trapped in or below this layer. This phenomenon is most pronounced in the walled street canyons of urban centers.

Various building configurations and orientations alter the air flow pattern considerably. Rows of tall buildings lining urban streets modify the microclimate by changing the topography and general aerodynamic boundaries. In these street canyons the dispersion of the pollutants is determined by the turbulent wake of the traffic, by the differential heating of building tops and streets, and by the general background air movement. Wind speeds at street level may be only 40 percent of the wind speed above the roofs of the buildings.

More open roadway planning with the buildings set back will alleviate this canyon effect. While traffic volume along a roadway section has the most direct relationship to emissions, the higher midafternoon wind speeds are the most effective factor in reducing the urban street canyon air pollution concentrations. This effect is gradually lost later in the afternoon as the overall wind speeds start to decrease and traffic volume once again peaks.

<u>Roughness Effects</u>

The background wind is also modified by the texture and height of surrounding features: buildings, trees, grass, brush, and streets. For example, as wind passes from an orchard to an open field, the wake effect is similar in many ways to that behind a building. Within approximately one-quarter mile, the original near-surface wind speed is re-established. There is an updraft in the air movement as it encounters a rougher surface, such as a row of trees.

Thus, a wide tree-covered green belt along both sides of a major traffic artery provides more rapid dispersion of vehicular emissions. In an urban area, similar transitions can be arranged -- between roadway and green belt, park and buildings, parking lots and streets, and low- and high-rise buildings. The resulting turbulence can lead to more dispersion and dilution.

URBAN AIR POLLUTION MODELS

Many mathematical models describing the diffusion process have been developed to relate pollutant emissions to ambient pollutant levels. These models vary from one equation of plume dispersion from a single source to complex programs capable of considering all sources in a major metropolitan area and providing the resulting ground-level concentrations at all locations in the area. The great number of calculations in all but the most simple models requires the use of a computer.

A mathematical model, with appropriate input data and the proper interpretation of results, can be a valuable tool for the planner. It can be used to determine: (a) consequences of a new pollution source on pollutant levels and patterns; (b) effects of alternative solutions in urban planning on pollution levels; (c) evolving pollution patterns in an expanding city; (d) effectiveness of various control strategies to reduce pollution levels in an area; and (e) emergency curtailment measures to be taken during episodes of high pollution levels.

A model should be selected to match the amount of data available, types of sources being considered, and time span of importance (e.g., long-term pollutant average for planning purposes and one-hour maximum for emergency episode prevention). The data required fall into three categories: (1) source information, including location, emission rates, and stack exit parameters; (2) meteorology, particularly wind speed, wind direction, and mixing depth; and (3) measured pollutant levels to verify or calibrate the model output.

Some caution should be exercised in using modeling results. The accuracy of output values is limited by the accuracy and adequacy of the input data. Also, the models are derived by assuming normal dispersion patterns and, therefore, are generally not capable of predicting pollutant levels near localized obstructions or in the vicinity of highly irregular topography.

APPENDIX D

FEDERAL, STATE AND LOCAL PRACTICES

FEDERAL PRACTICES

The review of government practices in the field of air pollution programs was completed during the summer and fall of 1970. This period preceded significant legislative and administrative changes. Most importantly, the Environmental Protection Agency (EPA) was established as an independent agency in December, 1970 and the Clean Air Act Amendments were passed by Congress also in December, 1970. Therefore, many of the Federal agencies whose functions were reviewed prior to December, 1970 either no longer exist or are not directly concerned with air quality programs; in other instances new agencies have been formed and others have been restructured.

The functions of the following agencies were reviewed for this study:

- Executive Office of the President
  - Council on Environmental Quality
  - Environmental Quality Council
  - Citizens Advisory Committee on Environmental Quality
  - Council of Economic Advisors
- Department of Agriculture
  - Agricultural Research Service
- Department of Commerce
  - Business and Defense Services Administration
  - Environmental Science Services Administration
- Department of Health, Education and Welfare
  - Public Health Service
    - National Air Pollution Control Administration
    - Bureau of Criteria and Standards
    - Bureau of Engineering and Physical Sciences
    - Bureau of Abatement and Control
- Department of Housing and Urban Development
  - Renewal Assistance Administration

Department of Justice
  Land and Natural Resources Division

Department of State
  International Scientific and Technological
    Affairs Bureau

Department of Transportation
  Assistant Secretary for Research and Development
  Assistant Secretary for Environment and Urban Systems
  Federal Aviation Administration
  Federal Highway Administration
  Urban Mass Transportation Administration

Independent Agencies
  Atomic Energy Commission
  Federal Power Commission

Legislative Branch
  Library of Congress
    Environmental Policy Division, Legislative Reference
      Service.

Selected Boards
  Federal Radiation Council

The 1970 Clean Air Act Amendments require the Administrator of the Environmental Protection Agency to establish primary (relating to health) and secondary (relating to welfare) ambient air quality standards as well as performance standards for new stationary sources of pollution and emission standards for new motor vehicles. The act requires states to prepare implementation plans for achieving and maintaining primary air quality standards by 1975. If states do not prepare such plans the act authorizes the Administrator to do so and gives him powers of enforcement.

The EPA is responsible for research, monitoring, standard-setting and enforcement activities related to air pollution abatement and control. EPA also coordinates and supports research and antipollution activities carried out by state and local governments and other groups. EPA is also active in reinforcing interagency actions among Federal agencies.

Within EPA the Office of Air Programs is responsible for conduct of air pollution prevention and control programs. The Office of Research and Monitoring in OAP provides basic research services as well as evaluation of existing and proposed control technology. Enforcement measures are handled by the Office of Enforcement of EPA.

Although EPA received the bulk of the ongoing air programs, some remain within the jurisdiction of other Federal departments of independent agencies. Functions of these agencies may be advisory, such as the National Industrial Pollution Control Council; research, such as the quasi-federal National Academy of Science; or enforcement, such as the Federal Aviation Administration in the Department of Transportation.

The Department of Health, Education and Welfare and the Department of Housing and Urban Development still maintain an active interest in programs to reduce environmental impacts on the urban population.

In effect, all governmental agencies are required to consider the impact of their actions on environmental quality. The National Environmental Policy Act of 1969 provides that for any proposed action significantly affecting the environment, a detailed statement must be submitted analyzing the following points:

"(i) the environmental impact of the proposed action,

(ii) any adverse environmental effects which cannot be avoided should the proposal be implemented,

(iii) alternatives to the proposed action,

(iv) the relationship between local short-term uses of man's environment and the maintenance of long-term productivity, and

(v) any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented."

The Office of Management and Budget in the Executive Office of the President has established a framework for communicating environmental information among Federal, state, and local agencies. In this framework, selected state, regional, and local planning agencies are designated as "clearinghouses" to be notified by any state or local agency intending to submit an application for Federal financial assistance. The agency requesting Federal aid then obtains comments from interested persons and groups on the environmental impact of the project, and these comments are included in the request to the Federal agency. If, after reviewing the comments, the Federal agency determines there will be a significant impact on the environment, it must submit an impact statement to the CEQ.

STATE AND LOCAL PRACTICES

The review of state and local practices was conducted prior to enactment of the 1970 Clean Air Act Amendments and is therefore obsolete in the current context. (The original review information may be found in the draft report dated May 1971, "A Five-Year Program to Incorporate Air Pollution Considerations in Urban and Transportation Planning.") The following are some general comments:

State Programs

Air pollution control has traditionally been under state jurisdiction. The role of the Federal government in this area has emerged fairly recently, and even though this role has gradually been increasing, the power of the state governments remains the most important tool in reducing air pollution. The 1970 Clean Air Act Amendments require states to establish air quality standards based on the criteria published by the Environmental Protection Agency. In addition, states are required to develop comprehensive plans for carrying out the necessary work to achieve these standards.

The attitude of the states toward air pollution control has been significantly varied. Where some states, notably California, have made impressive efforts in curbing air pollution, certain others have kept their efforts to a minimum. This variation in the attitude of the states is one of the reasons for the increased involvement of the Federal government in this area.

National efforts have first been oriented toward solving interstate pollution problems, and setting uniform standards for motor vehicle emissions. But these measures were found to be inadequate, and the 1970 Clean Air Act Amendments allow the Federal government to set certain national standards for emissions from stationary sources as well, while allowing the states to adopt more stringent standards if they find it necessary. The act also requires that the comprehensive plans to be prepared by the states achieve the air quality levels established in the standards in a period of three years.

Local Programs

Regional, county and municipal programs vary considerably depending both on the amount of local jurisdiction granted to the local agency and on the degree to which local agencies have taken the initiative in setting goals and formulating air quality programs. Notable achievements have been made, for example, by Cook County, Illinois in developing zoning ordinances which set performance standards for stationary sources.

Personal Interviews

During the course of this study interviews were carried out with representatives of local agencies that would presumably be involved with air pollution problems, with the purpose of identifying their needs in dealing with air pollution through urban and transportation planning. The agencies that were interviewed can conveniently be classified in five groups:

1. Planning Agencies:

   Pasadena Planning Department
   St. Louis City Planning Commission
   St. Louis County Planning Department
   Southwestern Illinois Metropolitan Area Planning Commission
   East-West Gateway Coordinating Council
   Alliance for Regional and Community Health, Inc.

Middlesex County Planning Board

Washington Council of Governments

Denver Regional Council of Governments

2. Transportation Agencies:

Los Angeles Department of Traffic

City of Los Angeles, Bureau of Engineering

Missouri State Highway Department

St. Louis County Department of Highways and Traffic

Illinois Division of Highways, East St. Louis District

Bi-State Transit (St. Louis)

City of St. Louis, Board of Public Service

Tri-State Transportation Commission

3. Regulatory Agencies:

Pasadena Public Works Department

Pasadena Building Department

Pasadena Fire Department

St. Louis County Department of Public Works

4. Utilities:

Pasadena Water and Power Department

Southern California Gas Company

5. Public Relations Firms:

Begley and Cunningham (Clayton, Missouri)

Fleishman, Hillard, Wilson, and Ferguson, Inc.
(St. Louis, Missouri)

The result of these interviews indicated that these agencies did not directly and systematically consider air pollution in their day-to-day operation. Very often these agencies expressed a desire to incorporate air pollution in their operations but found it difficult for a number of reasons:

- Lack of standards to determine what levels of pollution should be considered hazardous to health or objectionable for other reasons.
- Lack of information on the possible courses of action that would be instrumental in reducing ambient levels of air pollution.
- Budgetary restrictions and lack of funding to carry out the necessary actions.
- Lack of trained personnel to undertake the job of dealing with air pollution on a day-to-day basis.

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