THE UTILIZATION OF LAND USE AND TRANSPORTATION PLANS IN AIR QUALITY MAINTENANCE PLANNING

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alan m. voorhees & associates, inc. ■ TRANSPORTATION & URBAN PLANNING

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CHAPTER I

INTRODUCTION

A. REQUIREMENT FOR AIR QUALITY MAINTENANCE PLAN PREPARATION AND ANALYSIS

The 1970 Clean Air Act (as amended) has mandated all states to identify areas which exceed the National Ambient Air Quality Standards. These standards, as set forth by EPA, prescribe the control of sulfur oxides (SO_x), particulate matter (TSP), carbon monoxide (CO), hydro carbons (HC), nitrogen oxides (NO_x), and photochemical oxidants. This is to be accomplished by the State Implementation Plan (SIP). In addition, all states, pursuant to 40CFR51.12(c), are required to identify areas that have the potential to exceed any NAAQS over the 10-year period 1975-1985. These areas will be called Air Quality Maintenance Areas (AQMAs), identified by the states, and reviewed by the Administrator, who will issue an official list of designated AQMAs.

For these areas, the states will submit plans to prevent any national standards from being exceeded over the following 10-year period. For each pollutant in each of the AQMAs for which analysis indicates a potential problem, tailored maintenance strategies must be submitted. These plans, Air Quality Maintenance Plans (AQMPs), will be prepared, adopted, and submitted in compliance with guidelines which will be issued in August 1974 by EPA. Considerations such as terrain, meteorological conditions, transportation and land use planning, and economic considerations will be incorporated into the AQMP.

<u>The Guidelines for 10-Year Air Quality Maintenance Plans</u> are to be prepared in four volumes as follows:

Volume 1: Plan Preparation

Volume 2: Control Strategies

Volume 3: Land Use and Transportation Considerations

Volume 4: Case Studies

In addition, EPA will prepare a <u>Guidelines for Analysis of Air Quality Maintenance Areas</u> to be released in several volumes in August 1974.

This report is a preliminary document which will provide information to be incorporated into Volume 3 of the Guidelines for 10-Year

Maintenance Plans and the Guidelines for Analysis. It is being released to the states at this time to provide some insight into the possible utilization of land use and transportation plans in the preparation and analysis of air quality maintenance plans.

B. REPORT ORGANIZATION

The report is organized as follows: Chapter II describes a procedure for analysis of an air quality maintenance area. This procedure utilized land use and transportation planning data to disaggregate projected emissions to a subcounty base suitable for dispersion modeling.

Chapter III presents a general approach for considering air quality maintenance in the comprehensive planning process. A procedure for analyzing the impact of land use and transportation plans or policies is described. This analytical procedure would provide review and evaluation of both air quality maintenance plans and comprehensive community plans. The analytical procedure may require the development of techniques to relate land use to air quality. These analytical requirements are discussed.

Chapter IV presents an Air Quality Control Officer's Guide to Planning. The comprehensive plan and the 3-C Process are described. This discussion is intended to provide air quality planners with a brief review of comprehensive planning and its implications for air quality maintenance planning.

Appendix A illustrates a detailed methodology for projecting and allocating emissions and/or air quality in Air Quality Maintenance Areas. This methodology will be superseded by the EPA guidelines for analysis.

Appendix B is a review of the state-of-the-art in Quantifying the Relationship Between Land Use and Air Quality. Appendix C summarizes selected studies which were reviewed in the preparation of the state-of-the art summary.

Appendix D is a brief description of Air Quality Models which may be useful in preparing an analysis of air quality maintenance requirements. The EPA guidelines for analysis will describe such models in detail.

Appendix E is an annotated bibliography of activity allocation procedures which may be useful in the development of analysis procedures for incorporating air quality maintenance into comprehensive planning.

CHAPTER II

PROCEDURES FOR ANALYSIS OF AN AIR QUALITY MAINTENANCE AREA (AQMA)

This chapter describes a minimum procedure for the detailed analysis of an AQMA to determine whether a maintenance plan is necessary for any area within an AQMA. The analysis is also intended to provide the basis for maintenance strategy analysis and plan development.

This document is not EPA policy at this time, as EPA is currently preparing guidelines for analysis of air quality maintenance areas. EPA guidelines will incorporate portions of several studies currently under contract.

This report is being released to the states at this time to provide initial guidance to those air pollution agencies that may be required to participate in the preparation of an Air Quality Maintenance Plan. Some air quality planning agencies may already have a more sophisticated analysis procedure or technique and data base. Such agencies should coordinate their analysis efforts with the regional EPA office to ensure that the procedures and data base are sufficiently documented to allow EPA to review the analysis for adequacy and accuracy.

The analysis procedure described in this document will usually not be applicable to "natural resource" AQMA designations. Such areas must be evaluated on an individual basis according to the available air quality and planning information. These AQMAs should seek guidance from their EPA regional office to coordinate analysis requirements.

Reviewers of this document are requested to submit comments directly to EPA to facilitate the preparation of the most useful Guidelines for Analysis document.

A review of the state-of-the-art in relating land use or activity to air quality concluded that no model or technique is currently available that can be applied to general land use plans to determine their air quality impact (see Appendix B).

Ideally, air quality impact analysis could be incorporated into the comprehensive planning process (see discussion in Chapter III), to resolve these deficiencies. However, the scope of such effort is probably beyond the time and manpower available to complete the Air Quality Maintenance Plans. Therefore, the back-up methodology at this time is one that is immediately applicable. This implies that no research effort or model development is required, and emissions projection and air quality analysis techniques can be performed with little additional expenditure of funds or manpower. These restrictions limit the accuracy of the emissions and air quality techniques and projections described in the following sections. The immediate results should be used as an indication of the magnitude of the problem and a description of the most probable spatial distribution of the problem.

A. CRITERIA AND ASSUMPTIONS

1. Criteria

In developing the methodologies for projecting and allocating emissions and/or air quality within AQMAs, the following criteria are established:

- The techniques should be immediately available and generally applicable in all AQMAs.
- The methods should allow for pollutant-specific evaluation.
- The analysis results should be useful in determining:
  - Areas within the AQMA that could exceed the air quality standards for any given pollutant by 1985.
  - Maximum pollutant concentration in those areas that would occur without a maintenance plan.
  - Significance of the major source types to the air quality problem, i.e., manufacturing sources, power plants, mobile sources, or area sources.

2. Assumptions

Regional air pollution source growth is a by-product of the socio-economic and transportation development. This development process is not static, and the planning process this is intended to monitor and rearrange this development is a continuing process. Guidelines for AQMA Plan Development state that the plan and assumptions should be reviewed after five years and at five year intervals thereafter. In the interim, monitoring and surveillance will report the progress and effectiveness of the maintenance measures. However, if any of the planning data upon which the maintenance plan are based change significantly between reviews, the impact of such change on the maintenance effort should be investigated immediately.

The assumptions inherent in the application of the methodologies to analysis of an AQMA are as follows:

- Air quality maintenance planning assumes that the air quality standards will be achieved by existing implementation control measures. State Implementation Plans (SIP) adequately account for growth between the time of plan implementation and the date for achieving the primary standards (1975,1977).

- Some form of land use plan or demographic data are available for each county in the AQMA.

- If the AQMA is designated for Carbon Monoxide, some form of detailed traffic network data are available and the impact of the Transportation Control Plan on the traffic network and associated 3-C Transportation Plan has been accounted for.

- Before applying the projection or disaggregation techniques specified in this document, the state has upgraded the county emissions inventory using the techniques specified in the Manual of Instructions for Projecting County Emissions (prepared by Booz-Allen under contract to EPA).

B. GENERAL APPROACH

The purpose of the detailed analysis of projected air quality in the AQMA is to support air quality maintenance plan (AQMP) development by providing:

- A description of where and when a subarea within the AQMA may be expected to exceed the air quality standards without an AQMP, and

- An estimate of the effectiveness of proposed AQMP control measures in reducing existing emissions or guiding the location of significant new sources of emissions.

To serve this purpose a detailed analysis of the AQMA should provide the following two products:

- An air quality analysis of the AQMA indicating the spatial and temporal distribution of the pollutant emissions or concentrations in sufficient detail to relate to proposed strategies.

- A complete definition of the pollutant and related source problem that will serve as an aid to strategy development and analysis. The preparation of these two products is described in the following sections.

1. Preparation of the Air Quality Analysis of the AQMA

The purpose of the detailed air quality analysis is to determine where within the AQMA air quality standards are expected to be exceeded within the 10-year plan period, and the extent of the problem in each area where an air quality standard is expected to be exceeded. Figure II-1 illustrates the general steps required to prepare the air quality analysis of an AQMA.

Step I--Prepare a Controlled Emissions Inventory

For each pollutant of concern, a projected inventory of emissions should be prepared for the expected year of attainment of air quality standards for that pollutant (1975 or 1977). This inventory should reflect the impact of all existing SIP controls so that any further control requirements can be analyzed.

Step II--Project 1980, and 1985 Emissions and Air Quality for the AQMA

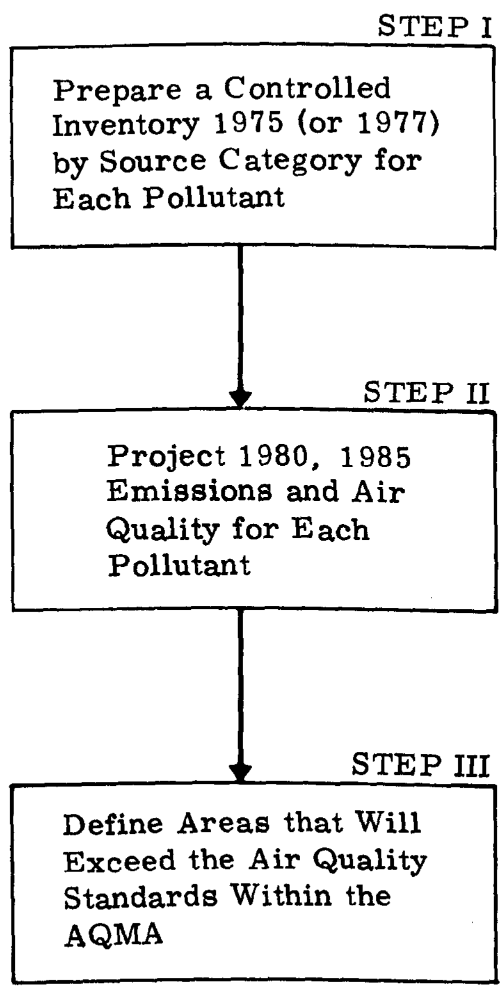
For each pollutant of concern, prepare a projection of the 1980 and 1985 emissions and resultant air quality distribution. Details of a methodology for projecting and allocating emissions and air quality for each pollutant are described in Appendix A.

Step III--Define Areas that will Exceed the Ambient Air Quality Standards Within the AQMA for 1980 or 1985

Compare the emissions or air quality projection obtained from Step II with the primary and secondary air quality standards. Where short term averages are specified in the NAAQS, techniques should be used to relate the annual projections to short term conditions. These techniques will be described by EPA in the Guidelines for analysis of AQMAs.

Ideally, a calibrated diffusion model would be applied to a detailed projected emissions inventory to obtain the desired spatial and temporal definition of the pollutant problem. If such a model has been calibrated for the AQMA, it should be applied to a data base that is sufficiently detailed and accurate to support the model. If 1980 or 1985 air quality is to be modeled, the projected emissions data must also be of sufficient

FIGURE II-1
PREPARATION OF THE AQMA AIR QUALITY ANALYSIS



detail and accuracy to justify application of a calibrated diffusion model. Where either the calibrated diffusion model is not available, or the data base required by the model can not be prepared within the time frame for AQMA analysis and AQMP development, the following procedure is recommended:

- Prepare a study plan to develop the required data base.
- Obtain guidance from the EPA regional office on the applicability of various diffusion models to the AQMA.

2. Pollutant Source and Control Definition

Figure II-2 illustrates the methodology for preparing a definition of the pollutant and source problem. This problem definition is to be performed for each area within the AQMA that the analysis indicates a maintenance plan will be required. Such an area may range from an entire county to just a few square kilometers. Following is a discussion of the steps presented in Figure II-2.

Step I--Organize the Emissions Inventory

Prepare a table of emissions by source group for each pollutant of concern, ranking the sources by order of contribution to total AQMA emissions. The analysis of air quality should supply this information. The sources should be grouped by the following source types:

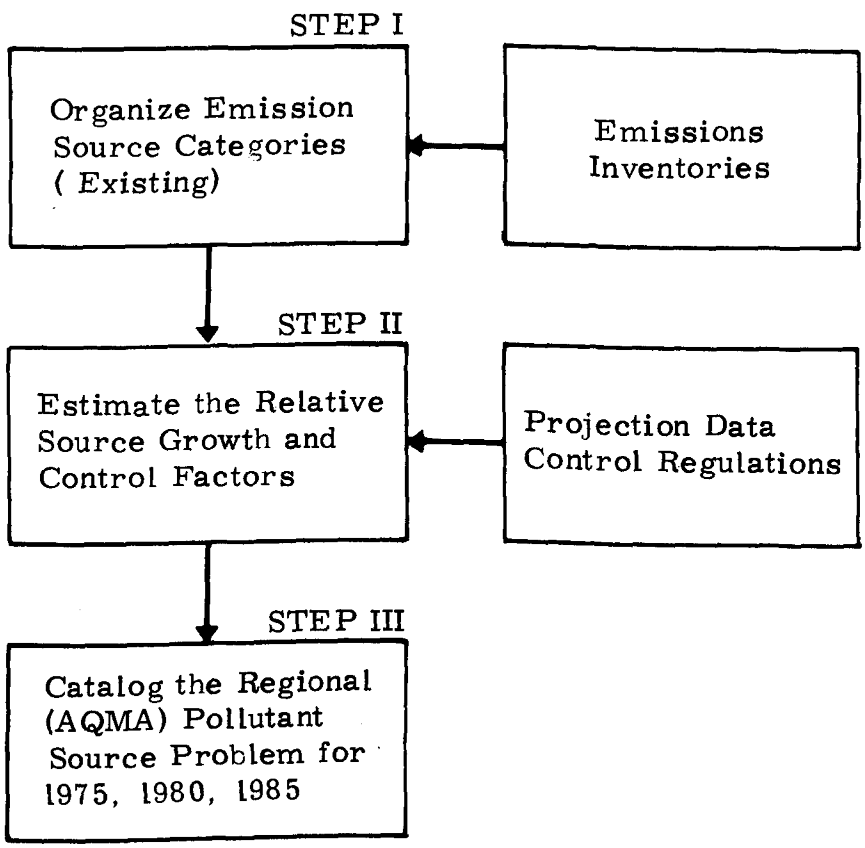
- Area Sources
- Power Plants
- Point Sources
- Mobile Sources

This inventory can be further refined by ranking within source categories if data are available.

Step II--Estimate the Relative Source Growth and Control Factors

Prepare a table, by source type, of projection factors, growth estimates, and control factors using best available projection data, economic factors, and area control regulations.

FIGURE II-2
POLLUTANT SOURCE DEFINITION



Step III--Catalog the Regional (AQMA) Pollutant Source Problem for 1975, 1980, 1985

The data developed in Steps I and II can be catalogued to provide a description of the relative source and pollutant problem in the AQMA. This table will provide an indication of the following:

- The significance of each source type to the pollutant problem as it exists (1975), in the near future (1980) and long-term (1985)

- The existing level of source control

- The possible control of a source type by either direct source control measures or source location guidance

C. SUMMARY

The methodologies described above represent an approach considered to be applicable in most urban areas within the period for plan analysis and development. It may be expected that each area will make modifications to the methods described, based on local conditions and resources.

There are several areas of deficiency in this approach that may require considerable effort to resolve. The most significant deficiencies are:

- The accuracy, completeness, and level of detail of the existing emissions inventory is inadequate to support the level of analysis required to define the air quality problem and the source contribution to that problem. Time and effort must first be devoted to upgrading the existing inventories.

- The analysis approach is a one time, sequential approach resulting in a description of projected air quality. Emissions control plans, energy reduction plans, and transportation plans are currently being developed or revised that will have a significant impact on the basic assumptions of the growth and distribution of all pollution sources. Therefore, the growth rates and distribution factors used in the emissions projection techniques may be in considerable error. To be effective, the analysis approach must be responsive to these plans and other community policy decisions that may impact the growth rate or distribution of sources. The preferred analysis approach would be an iterative, continuing process, capable of simulating response to policy changes by changing the projection assumptions.

- The basic emissions inventory, projection data, and disaggregation or distribution data are not in comparable formats. In addition, where sets of each of these data types are obtained from more than one jurisdiction or agency responsible for collecting such data, the format may vary. A detailed, standardized, regional data base and data handling system are needed.

- The techniques for relating emissions to air quality vary considerably in the level of detail and format of input data required. If air quality is the intended end product of the analysis process, the development of the emissions data base and projection data must be coordinated with the requirements of the diffusion model(s) to be used. This coordination does not currently exist.

The following chapter describes an analytical process for relating land use and transportation to air quality that could be incorporated into the comprehensive planning process. This would provide a continuous mechanism for resolving the deficiencies in the available analysis approach. The discussion is conceptual in nature and is not intended to be definitive. A definitive process for a community should include an evaluation of available institutional resources and a formulation of the procedure for incorporating air quality maintenance considerations into comprehensive community planning. Air Quality Impact Analysis would be only one tool in the formulation of a Community Planning Policy.

CHAPTER III

AIR QUALITY MAINTENANCE AND COMPREHENSIVE PLANNING

A. GENERAL APPROACH FOR CONSIDERING AIR QUALITY MAINTENANCE IN THE COMPREHENSIVE PLANNING PROCESS

Ambient air quality is a function of the distribution of pollutant sources as well as the physical, meteorological, and climatological characteristics that determine how pollutants will concentrate within a given area. The distribution of the sources of emissions is determined by land use and its attendant activities. The maintenance of air quality depends upon the long-term changes in these land use activities. Air quality considerations must therefore be made a part of the comprehensive planning process.

A regional comprehensive plan is a necessity if long-range land use and environmental objectives are to be attained. While air quality considerations may be incorporated into local planning efforts, it is obvious that the overall guidance must be provided from a regional perspective. The technical and administrative problems of local planning to achieve air quality, support the need for a regional approach to develop policies related to air resource management. For example:

- Local efforts to improve air quality cannot be accomplished without comparable efforts at the regional level.
- Local land use plan impacts cannot be quantified without a regional approach.
- Local land use plan impacts on traffic volumes cannot be evaluated except within the context of regional multimodal traffic models.
- Oxidant is an areawide pollution problem which cannot be solved on a local basis.

Therefore, in future regional comprehensive plans, air quality maintenance considerations will constitute a critical segment of the policies relating to urban form, open space planning, stationary source location, and transportation planning. Implicit in this is the notion that the regional plan can be an effective instrument for attaining long-range air quality and other environmental objectives only if it goes beyond simply compiling local land use plans into a regional format.

Goals and policies as they relate to air quality must be clearly articulated in order to provide local planning agencies with the constraints that should be placed upon land use decisionmaking.

In order to accomplish the institutionalization of the air quality maintenance segment into the comprehensive plan, three areas must be explored:

- Planning
- Implementation
- Enforcement

Planning incorporates air quality considerations into the comprehensive plan and develops a maintenance strategy for each type of pollutant. Implementation and enforcement deals with achieving compliance with air quality standards upon which the maintenance plan and strategies are based.

These aspects of the institutionalization of air quality maintenance planning are discussed as two elements--(1) mobile source planning and implementation, and (2) planning and implementation for control of particulates and SO_2. This distinction is made as these elements parallel transporatation planning and land use planning respectively.

1. Mobile Sorce Pollutants Control

- Planning - The 3-C agency should incorporate air quality maintenance constraints into the evaluation of alternative transportation plans for the five-year updating. This could be accomplished by an annual review of the impact of the 3-C plan on air quality. Analytical techniques, such as the SAPOLLUT* model are currently available for such use.

- Implementation and Enforcement - The A-95 review process is the one mechanism for implementation of the mobile source planning policies. The process would be reinforced by the "consistency" review and determination, indirect source review, and the Transportation Control Plan. Enforcement responsibility should remain with the state air pollution control agency, and where appropriate, with the regional EPA. Many legal, technical, and administrative issues must be resolved to implement such a program. The preparation of the AQMP should address these issues and propose a timetable for implementing.

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*Final Manual: Special Area Analysis, U.S. Department of Transportation, August 1973.

2. Particulate and Sulfur Oxides Control

- Planning - As the region develops alternative land use plans, the constraints of air quality standards must be an element of environmental impact. The impact of proposed public and private development upon the land use plan must be determined. Proposed projects that involve Federal funds are required to submit Environmental Impact Statements. The planning agency role is to review projects for land use compatibility as well as air quality and other environmental impacts.

- Implementation and Enforcement - While the control of projects that have Federal funding is adequately covered by the requirements for an Environmental Impact Statement, the long-term regional impact of all projects must be considered. As comprehensive plans are developed with air quality constraints, the environmental impact review process should include compatibility with the plan as a criterion for evaluation.

  Enforcement of air quality control for proposed sources which do not have Federal funding should be the concern of a permit system for State air pollution control agencies. In order to incorporate considerations of the effects of such sources on regional growth and the resultant air quality, the comprehensive planning agency should be notified of each request for a permit to construct. The results of the planning agency review should become a criterion for permit approval.

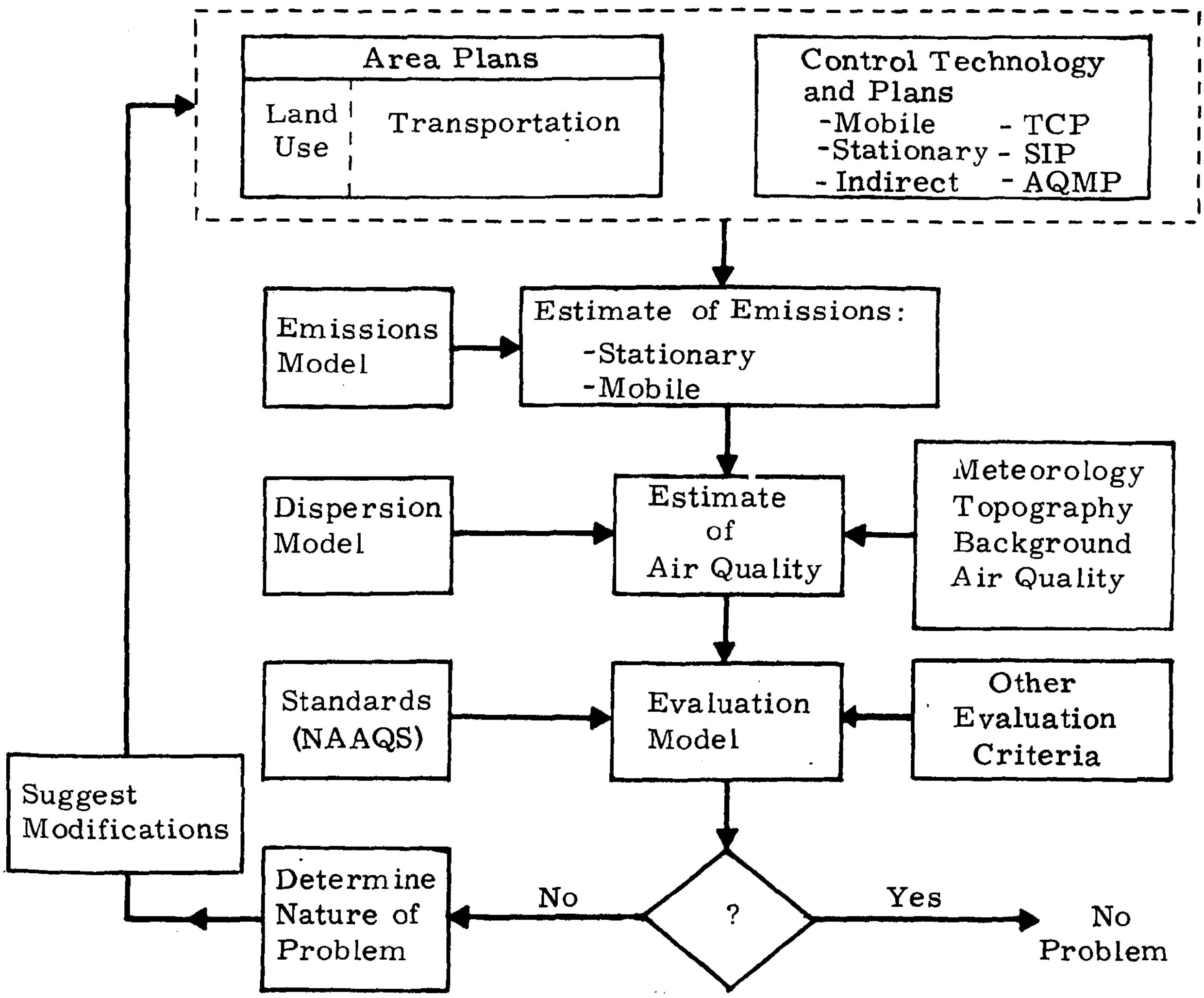
B. A PROCESS FOR ANALYZING THE IMPACTS OF LAND USE AND AIR QUALITY PLANS OR POLICIES

In order to consider air quality in the plan development process, some analytical process must be available to define the impact of alternative land use and transportation plans or policy changes on air quality. In addition, the preparation of air quality maintenance plans requires the analysis of the impact of air quality control strategies on land use and transportation and the resultant impact on air quality.

A conceptual analysis process for relating land use and/or transportation plans to air quality is shown in Figure III-1. Since the process is iterative, it can also be used to evaluate the impact of area land use and transportation plans. This process could be applied at several points in the development, evaluation, and implementation of air quality maintenance plans as follows:

FIGURE III-1

A PROCESS FOR RELATING LAND USE AND TRANSPORTATION PLANS TO AIR QUALITY



ILLUSTRATIVE PROBLEMS:

- Source Control
- Intensity and Type of Land Use
- Location
- Transportation
  - Parking
  - Pricing
- Timing of Development

ILLUSTRATIVE EVALUATION CRITERIA:

- Energy Needs
- Environmental Impact
- Physical Constraints
- Socioeconomic Impact
- Air Quality Maintenance

1. Plan Development and Evaluation

- Evaluation of the air quality or emissions impact of existing land use and transportation plans.

- Evaluation of the air quality or emissions impact of alternative future land use and transportation plans under different assumptions of control technology or energy needs.

- Evaluation of the impact of AQMP strategies, Transportation Control Plan Strategies (TCP), and other SIP strategies on land use and transportation requirements and the resultant air quality impact.

2. Plan Implementation

- Suggest modifications to transportation plans, land use plans, or SIP's at plan update or critical review.

- Suggest an emissions allocation procedure based upon the estimate of emissions.

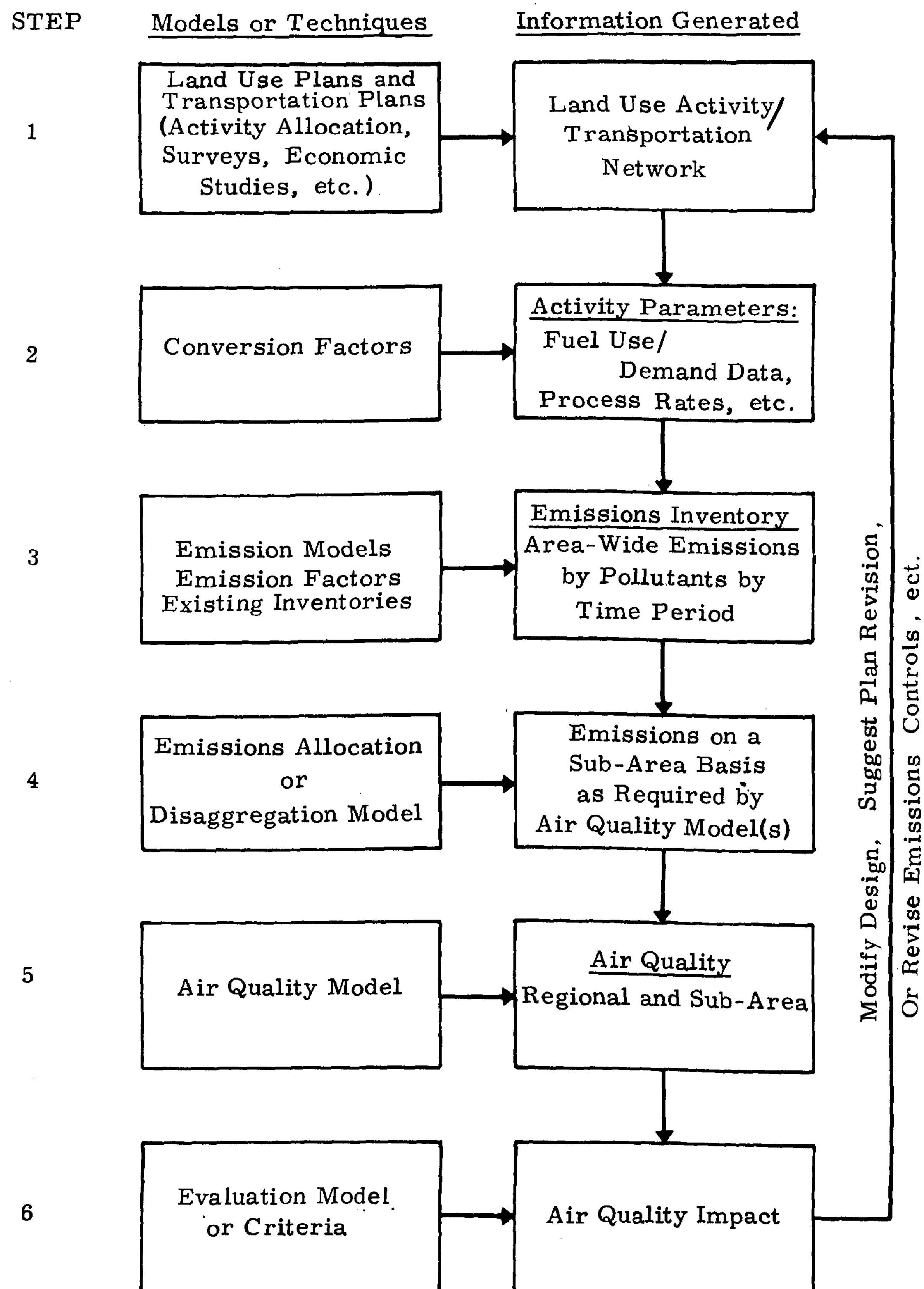
The process flow diagram (Figure III-1) implies that land use and transportation plans or policies must provide information relevant to emissions that would result from the plan or policy before it can be translated into the impact in air quality. The following section briefly describes the information required to relate land use to air quality and discusses the availability of techniques to provide this information.

C. INFORMATION ACCESS AND ORGANIZATION TO RELATE LAND USE TO EMISSIONS AND AIR QUALITY

A generalized flow of information required to relate land use to air quality is given in Figure III-2. As can be seen, the land use or transportation plans do not currently provide the emissions data needed to estimate air quality impact as required by the process shown in Figure III-1. If air quality considerations were a determining factor in the land use planning process, basic emissions data would be collected in conjunction with the basic inventory requirements of a land use or transportation plan.

The content and form of current emissions inventories is mainly a function of modeling requirements. Therefore, one or more intermediate

FIGURE III-2
INFORMATION ACCESS REQUIREMENTS OF A PROCESS TO RELATE LAND USE AND TRANSPORTATION PLANS TO AIR QUALITY



modeling or conversion techniques is needed to translate the land use activity data into the required emissions inventories.

Steps 1 and 2 of the flow diagram indicate that the land use and transportation plan must first be quantified to provide data relevant to the "intensity" of use in the specified land use category. This has been done historically by a combination of economic analyses, surveys (origin-destination studies), and application of activity allocation models. Land use activity allocation models have been developed within a wide range of complexity and data base requirements. A brief annotated bibliography of activity allocation models is given in Appendix E to this report. Where such models have been executed, the results would be useful in providing the input necessary for the development of the emissions inventory activity parameters (Step 3). However, their results are specific to the communtiy evaluated and the basis for conclusions should be carefully considered before attempting to relate them to other areas.

In the Hackensack Meadowlands Air Pollution Study (see Appendix C), estimated emission rates for various land use categories in the areas were developed (see Table III-1). These emission rates are very limited in accuracy because of the limited and generalized land use and activity data upon which they are based. However, they may be useful to planners as a rapid evaluation technique for gross planning estimates at the early stages of plan design. It is recognized that the emission rates in this table are highly specific to the Hackensack planning district, and it would be necessary to create such a table specific to each area of concern. An attempt was made in the "Air Pollution/Land Use Planning Project" (see Appendix C) to prepare such a table which would be generally applicable; however, the results indicate that these factors cannot be generalized. By generation of Table III-1, or by similar techniques, the emissions inventory for the plan area can be developed for each specific pollutant.

At this point, a rough estimation of the total regional (plan area) air quality impact of the given plan could be made by using a simple proportional model such as "roll-back" to relate emissions to air quality. However, this procedure gives no indication of the resultant spatial distribution of the pollutants within the region (plan area). An air quality planner using a regionwide roll-back technique to evaluate air quality impact of a proposed land use plan could conceivably allocate the pollutant sources in such a manner as to violate the air quality standards within a subarea, although the regional air quality level would still appear to be within the air quality standards. In order to locate and avoid such "hot-spot" problems in the plan, the emissions

TABLE III-1

SUMMARY OF ESTIMATED 1990 ANNUAL EMISSION RATES
FOR HACKENSACK MEADOWLANDS LAND USE CATEGORIES

Land Use Category	Pollutant Emissions (lb/year/acre)				
	TSP	SO_2	CO	HC	NO_x
Residential					
10 Dwelling units/acre	25	1	35	12	7
20 " " "	180	120	4	54	85
30 " " "	180	120	4	54	85
50 " " "	250	160	5	75	120
80 " " "	200	140	4	63	100
Commercial & Industrial					
Commercial	60	45	1	12	95
Manufacturing					
Light	1100	1100	10	140	850
Heavy	5400	5400	60	900	5400
Research	2	15	1	5	35
Distribution	60	45	1	12	95
Special Use	60	45	1	12	95
Airport (1)	100	1000	3000	350	100
Transport Center	180	130	2	36	300
Cultural Center	45	35	1	9	70
Open Space	0	0	0	0	0
Other (2)	Emission Factors				
Highway (lb/10^6 VMT)	700	400	11000	1000	1500
Parking Lots (lb/10^3 hrs idling)	4	4	12	3	1

(1) Assumes 400,000 flights/year from Teterboro Airport, and 700 acre area.

(2) Activities are not specified on basis of emissions/unit area.

Source: The Hackensack Meadowlands Air Pollution Study, Summary Report, Environmental Research and Technology, October 1973.

data must be disaggregated to the level of detail required to visualize such problem areas.

If an air quality model (Step 5) is being used to evaluate the effectiveness of a land use control strategy, the data allocation procedure and air quality model used must also be representative of the level of detail required by the strategy definition. For example, a land use strategy that requires control of the location of specific sources would require a site-specific emissions data allocation system.

Many air quality models are currently in use in specific areas or studies. These models range from the proportional models such as "rollback" to highly complex models that are related to fundamental theory. The utility of these air quality models is dependent on the specific application. A limited review of some types of air quality models and their applicability is given in Appendix D to this report. An additional guideline document is being prepared by EPA to discuss air quality models for air quality maintenance plans. As the model complexity or level of analysis requirements increase, the concurrent emissions inventory requirements (Step 3) increase. Ideally, quantified land use should provide the emission inventory to meet the scale requirements of the air quality model. If such detailed quantified land use and activity data are prepared, Step 4 would become unnecessary.

D. ANALYTICAL TECHNIQUES REQUIRED TO RELATE LAND USE AND TRANSPORTATION PLANS TO AIR QUALITY

It is apparent from the previous discussion that a community-specific analytical process must be developed to relate land use or transportation plans to air quality. The process would consist of all the analytical techniques or models required to provide the information needed to relate comprehensive planning decisions to their impact on air quality, and air quality planning decisions to their impact on land use and activity. The process should also provide information and guidance for the planner, local legislative bodies, and the public so that they might clearly perceive the air quality impact of their planning decisions.

The process developed to relate land use to air quality must operate at two levels:

- First, it must be able to relate the impact of the local planning decision on the subarea land use activity, and resultant air quality.

- Second, it must be able to relate this subarea or project level decision to its impact on the total regionwide (AQMA) air quality.

In addition, the process developed should have the following characteristics:

- It must be specific to the AQMA or planning area in order to fully utilize the information resulting from the 3-C or land use plan.
- It must relate to other planning efforts--environmental, socioeconomic, etc.
- It should provide useful and reliable information to assist the formulation of policy and administrative guidelines.
- It should provide relevant information on subarea (i.e., county or planning district) issues that can be communicated simply to planning officials and the community.
- It should address pollutants of concern.
- It should incorporate unique terrain, and meteorological features, that may affect ambient air quality.
- It should be flexible and be able to incorporate the state-of-the-art in economic projections, land use models, emissions models, air quality models, techniques for quantifying impact, new source control technology, etc.
- It should provide information in a form that can be simply communicated to officials, citizen groups, and other units.

Development of techniques or models that require basic research, extensive data base development, or are costly should be deferred beyond the one-year time period given for AQMA plan development. Development of a sound data base and detailed quantification of regional land use and transportation plans should be considered as an integral part of this process development.

CHAPTER IV

AN AIR QUALITY CONTROL OFFICER'S GUIDE TO URBAN PLANNING

Serious efforts to include air pollution considerations in planning activities as well as to include land use policies or controls in programs for achieving air quality standards is a recent phenomenon. Impetus has been given to the introduction of land use and transportation consideration into air resource management by Federal legislation* requiring states to identify areas which, due to existing air pollution levels and/or projected growth rates, may have the potential for exceeding federally established air quality standards.

These areas are designated as Air Quality Maintenance Areas (AQMA). The states must then perform a thorough air quality analysis of each of these AQMAs and develop a plan demonstrating how National Air Quality Standards will be maintained if such analysis indicates that the standards would otherwise be exceeded.

Because it is anticipated that the agency preparing the air quality maintenance plan in many areas will be the air pollution control agency this chapter is directed toward personnel in such agencies. Therefore, it contains a generalized description of land use and transportation planning including the types of information in the plans, the legal aspects of the plans, and a discussion of the responsible agencies.

A. THE COMPREHENSIVE PLAN

The land use plan, as a document, exists within the broader framework of the comprehensive plan (sometimes called the master plan). "It (the comprehensive plan) indicates in a general way how the citizenry of a jurisdiction, represented by its leaders, wants its community to develop physically over the next 20 to 30 years."** In this context, the word "comprehensive" generally means that the developed plan encompasses all geographic parts of the community and all functional elements that bear on physical development. In the past, the emphasis on physical development has often excluded considerations of the environment, resulting in the generation of negative impacts. A redefinition of the comprehensive planning process that seeks a more balanced approach to the consideration of economic, social, and environmental variables is a recent factor in the planning process. At the present time, several agencies, including EPA and the Department of Housing and Urban Development (HUD), are

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* Clean Air Act (as Amended in 1970)

**Alan Black, "The Comprehensive Plan," Principles and Practice of Urban Planning, edited by William I. Goodman and Eric C. Freund (Washington, D.C.: ICMA, 1968).

developing a procedure to reflect this expanded concept. This new approach, however, is presently found in very few plans, since most have predated it.

The comprehensive plan as a policy statement presents a picture of proposed development of both public and private land within the planning area. The comprehensive plan as a schematic map presents the spatial allocations and location of various land use categories plus transportation and community facilities. Although there is no rigid format for the plan, the elements included have tended to become standardized. The following is a generalized sequence of the information included:

- Background Information - This includes a statement of the community goals reflected in the plan, basic assumptions, and descriptions of the population, economy, and existing land use. Many plans also include such geographic considerations as soils, geologic factors, flood plains, and topographic conditions. In order to provide the reader with the proper perspective, the area's history and regional setting are also included.

- Functional Plans - This series of specific land use and facilities plans form the body of the document. The plans generally include transportation, residential areas, and recreation and community facilities. Depending on the area, the plans may also include proposals for public utilities, commerce, and industry.

- The Comprehensive Plan - The final product is generally a map of the planning area on which the major functional plans are brought together to show their interrelationships. The map may be supplemented with an implementation strategy.

In spite of the fact that the elements included in a plan are fairly standard, there is a wide variation in the level of detail. This variation is in large part due to the strong motivation by the Federal government for the development of comprehensive plans at various jurisdictional levels, from local to regional and state.

Although comprehensive planning has existed as a concept for over 50 years, it only began to move to the forefront of local planning agency concerns after World War II. The impetus was caused by the Federal government's increasing tendency to make financial assistance conditional upon conformance to a local comprehensive plan. This requirement has been supplemented by Federal funds to be used for the purpose of preparing these plans. Two of the chief sources of this type of Federal planning grant have been Section 701 of the Housing Act of

1954, as amended, (the "701 Program") and the transportation planning grants under the Federal-Aid Highway Act of 1962 (the 3-C Process). The 701 planning grants were made under these programs to established state or local planning units which apply for them. Under these grants, the primary concern was with housing, transportation, or general land use. However, whatever the primary focus, planning was generally integrated to some extent into the total urban scene. In spite of these programs, not every area has a comprehensive plan, or the more basic land use plan.

A basic component of the Comprehensive Plan is a document, or series of documents, known collectively as the land use plan. This plan is primarily concerned with the geographic allocation and amount of land development required for the various space-using functions of urban and suburban life--industry, wholesale business, housing, recreation, education, and the religious and cultural activities of the people. Therefore, the land use plan has a great influence on the other functional areas included in the comprehensive plan such as transportation, public facilities, and public utilities. For this reason, this part of the comprehensive plan provides a direct link between planning and environmental quality.

The land use plan differs from the comprehensive plan in that it generally deals only with the uses of private land, although there are planning agencies that do not make this distinction. The land use plan should not be confused with the zoning map or the zoning ordinance. The land use plan is not legally binding; hence, it is essential that the necessary legislation be prepared, adopted, and enforced to transform the general concepts into patterns which have legal substance.

Zoning is one of several legal devices for implementing the proposals for land development set forth in the plan. The zoning map is a part of the zoning ordinance and is generally conceived as a scheme of districting an area for purposes such as regulating land use, population density, lot coverage, bulk of structures, and parking requirements. Both the zoning ordinance and the zoning map may be more detailed than the land use plan.

The process for developing a land use plan is not fixed; therefore, the procedure described in this section is generalized. The format and procedures presented here have been adapted from the work of F.Stuart Chapin. For a more detailed discussion of these topics, the reader is referred to his book, <u>Urban Land Use Planning</u>.* It should be stressed that the analytical procedures presented in this section do not represent a definitive listing; rather, they represent the approaches most commonly used by planning agencies at different levels.

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*F. Stuart Chapin, <u>Urban Land Use Planning</u> (Urbana, Illinois: University of Illinois Press, 1965).

The traditional approach to land use planning begins with a projection of future economic growth in the area. This projection is based on trends in both the national and the regional economy. Given the projection, in terms of the amount and type of economic activity translated into employment levels, future population is estimated. Projections of economic activity and population are then translated in turn into estimates for future land demand for industrial, commerical, residential, and public activities. This represents the demand side of the process, which must be matched against the supply of land. Land supply is evaluated according to availability (vacant or unused land) as well as to the available land's suitability and capacity for the various proposed activities. Availability is determined through an inventory of existing land use. The suitability and capacity of a parcel is defined in terms of accessibility, size, and general physical quality. Quality denotes environmental characteristics to a varying degree. "Generally, consideration is given to a parcel's buildability considering soil and slope conditions. The basic assumption of this approach is that economic growth will bring positive benefits to the community and that such growth can best be fostered by designing the land use pattern to maximize accessibility within the system of economic activity."* This approach to land use from a purely economic point of view has been coming under increasing scrutiny because of increasing sensitivity to environmental effects. Future land use planning procedures will evaluate the suitability of land for certain uses from the point of view of cost to the developer, from the perspective of land as a resource to be protected from misuse, and from potential environmental impacts of its development.

This process results in a document that is the basic element of the comprehensive plan. It is generally presented toward the end of the report as a composite of those functional plans for specialized types of land use. The generalized land use plan for the area usually does not show individual detailed parcel uses. The land use areas are broad, and the boundaries are sometimes imprecise. For the exact location of facilities or parcel uses proposed, sector or neighborhood development plans should be reviewed.

In a very few large urban areas, e.g. Baltimore, Dallas-Ft. Worth, and San Diego the land use and land activity patterns have been quantified for a computerized land use/land activity model. This procedure permits evaluation and projection of land activity over time; however, it is not readily available at present in most urban areas, and thus are not discussed in this chapter. Detailed discussion of the land use models may be found in Appendix E and the application to such models may be found in Appendixes B and C.

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*Edward J. Kaiser, et al., "Land Use Planning: The Cornerstone of Local Environmental Planning and Control," Land Use and the Environment, edited by Virginia Curtis (Washington, D.C.: EPA, 1972).

The following sections will discuss the land use plan in greater detail to provide the evaluator with the necessary information to use the plan in the determination of the air quality for an area. Particular attention will be given to the preliminary studies that form the basis for the plan as well as the data that they provide, which may have applicability for air quality analysis.

1. The Land Use Plan

The land use plan, as a pattern for existing and proposed activities, provides a map of potential patterns of air pollution. For the purposes of air quality modeling, one way of looking at sources of pollution is to place them in one of the following categories:

- Point Source - a single major emitter located at a point. A similar type of source is that designated as "stationary."
- Line Source - a major highway link or other transportation link denoted by its end points. This source is also occasionally referred to as a "mobile" source to differentiate it from "stationary" above.
- Area Source - An aggregation of smaller, less specific sources that exist over the space of an area. This includes residential emitters and single emitters and highway links deemed too small to be considered as individual point or line sources by the model. The boundaries of the area are not fixed. They may or may not coincide with those of political jurisdictions. The total area may be divided up into squares and referenced to some type of grid coordinate system if this is the form the model requires.

As the land use plans (as differentiated from comprehensive plans) generally deal with the allocation of private land, public facilities and major transportation facilities may not be detailed. This, of course, means that major line sources or point sources that are sited on public land may not be shown on the map. In order to consider major transportation sources of pollution, the transportation element of the comprehensive plan or the 3-C transportation process will have to be used as a base. Public land uses (point and area sources) will usually be shown on the comprehensive or public facilities plan and hence those will provide a basis for part of the air quality analysis.

Given the categories that are included in the plan, this section will discuss how the information used in the calculated demand for a particular use can be used in the projection of air pollution emissions. In addition, the supplementary information presented in each functional plan will be evaluated for its utility in air quality projections.

a. Preliminary Information and Studies - In general, the minimum information produced through the studies done prior to the development of the land use plan usually include:

- Current and forcasted urban population--the total and by sex and age groups
- Current and forecasted urban area employment by major SIC (Standard Industrial Classification) category
- Map and tabular summary of existing land use area by planning district (if that is the system used) and category
- Map and tabular summary of vacant and renewal land characteristics and area
- Summary of the current stock of dwelling units by structure type and planning district*

The specific types of studies that are often done to determine the allocation of land include economic, employment, population, activity, and urban land. These studies will be examined briefly, with each discussion describing the types of methodologies that can be used to obtain the relevant statistic. This will then be evaluated for its utility in projecting air quality.

Urban Economy - "The destiny of an urban center is controlled by the extent and character of its productive or income-producing activities and their general vitality. Studies of the economic basis of these activities hold the key to how the city has developed, where it is today, and what its future prospects are."** Viewed in this way, the economy conditions the amount of development that occurs, and, hence, influences land use projections. With a knowledge of the trends in the economy, the planner is better able to develop yardsticks which can be used in estimating land requirements. "As an example, studies of employment are a key element in population forecasts, and population estimates are, in turn, used for scaling land development needs. Estimates of future land requirements for industrial uses are based on manufacturing employment trends, and future space needs for commercial uses draw upon employment trends in wholesale trade, etc. Finally, plans for various sizes of shopping centers draw upon studies of population and purchasing power in and around the urban center."***

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* Chapin, Op. Cit.
** Ibid.
***Ibid.

Two standard approaches to economic projections are the (1) regionally oriented and (2) the urban centered. Whichever approach is taken, the results are a set of statistics showing the projected growth for various types of industry in the area. These are then used as a base for other types of projections.

- Regional Orientation - The underlying assumption of this approach is that economic activity in the urban center is affected by other centers of economic activity in its immediate region and is ultimately linked to the national economy as a whole. Hence a city's future economic position is dependent on its capacity to develop new productive resources and to expand existing ones in relation to other cities in the region engaging in the same activities.

- Urban Centered - The assumption here is that the analysis begins in the urban area but at the same time is extremely focused in that it seeks to explain the city's economic structure in terms of the goods and services that it produces that are consumed outside of the localized area of study. It identifies it as the "base of the urban economy the goods and services that are consumed externally."

Presented below are three approaches to the study of regional spheres of influence:

- Input-Output Analysis - An approach concerned with the dynamics or commodity flows between aggregates of industry. These aggregates (focal points) can be single urban centers or a whole metropolitan complex of centers.

- Regional Accounts System - This is designed to analyze all forms of income-producing activity.

- Approximation Analysis - Uses conventional divisions of the nation into regions, subregions, etc., and by crude step-down procedures from the larger parent area, develops gross measures of how the parts of the whole are estimated to share in total national productive activity.

The primary urban-centered approach to the calculation of economic growth is the economic base, which has received rather extensive applications in city planning analyses. Base theory considers the structure of the urban economy as made up of two broad classes of economic efforts--

(1) the basic activities which produce and distribute goods and services for export to firms and individuals outside a defined localized economic area, and (2) the service or nonbasic activities whose goods and services are consumed at home. The concept holds that basic lines usually means growth in service activities and thus growth in the total economy.

The preferred method of determining what proportion of current employment is engaged in activities which produce for export and what proportion is engaged in activities producing for local consumption is through a local economic base survey.

Employment Studies - Employment forecasts serve two functions in the land use planning process: (1) they provide information of concern to population studies which, in turn, are used in estimating space needs for residential areas, shopping centers, and community facilities; and (2) they supply a direct yardstick for use in determining the land requirements for industrial and non-retail commercial areas.

In industrial areas, space requirements are estimated on the basis of adopted industrial density standards, i.e., manufacturing workers per acre of industrially used land or standards of a more detailed nature based on floor area, shift size and structural density. In wholesale areas, space requirements are derived from various floor area standards of employees per square foot of building space. Office space requirements are developed on the basis of floor area standards relating employment to space taken up by the category of use.

Various sources of employment statistics are available for use in estimating future employment:

- The U.S. Bureau of the Census - From the decennial reports are statistics such as total labor force, the civilian labor force, total employment, manufacturing employment.

- Census of Manufacturers

- Census of Business

There are various methods of forecasting employment; several commonly used methodologies are:

- Input-Output Analysis - Using the estimates of the effective demand for all the various economic lines in the area of concern for a particular year and estimates of labor productivity for all industries and for the subcategories of manufacturing, finance, insurance, and real estate as givens, the actual employment estimates are obtained by dividing values of estimated future output by the appropriate values for output per worker. The method, however, presents a great many problems, particularly with regard to the existence of data in the correct form.

- Income Statistics - The alternative to the use of dollar measures of transactions between industries and worker productivity in these transactions as the components of the ratio for deriving employment is to go to a broader more inclusive accounting system involved in income and product statistics. In this instance, concern is with all forms of income-producing activity, investment, and trade as well ad industrial production.

- Apportionment of National Employment Estimates - Apportionment procedure implies a system of analysis which determines how smaller geographical areas share in estimates previously prepared for a parent area. Following this general procedure, two series of employment data may be used in this method: Bureau of Census employment series or the Bureau of Labor Statistics employment series.

- Estimation by Direct and Indirect Ratio Procedures - The most commonly used approaches to estimating future employment in a locale of interest are to use simple ratio procedures. These estimate how a particular study area will share in the projected employment of some larger geographic area. In the direct local-national ratio approach, percentages of local to national employment are computed for past decades from census reports and ordered in a time series. A curve is fitted to the data and projected to the desired forecast date. The value of the projected ratio is then applied to the given estimate of future national employment in order to get future employment in the study area. The indirect ratio approach involves a step-down procedure.

The result of any of the analyses is a breakdown of employment by type, which will be used to calculate the amount of acreage required for each type of commercial or industrial use.

Population Studies - To be useful, growth potential must be expressed in terms of the population it can be expected to sustain in terms of the size of the population, its composition and characteristics, and its spatial distribution. Population size provides an estimate of space requirements for various land use categories. Investigations into population composition assist in estimating residential space requirements for various types of dwelling units consistent with family size, income level, etc. They also assist in determining the amount of space needed for recreation areas, schools, and other community facilities. The examination of residential population distribution spatially provides a basis for the location of the various facilities.

Sound demographic analysis is predicated on accurate population data. Some basic sources are:

- Complete periodic census enumeration
- System of continuous population registration
- Estimation of population
- Unpublished census data

To be useful in planning studies, this data has to be used in (1) estimating current population between census enumerations; (2) projecting future population in the study area.

b. <u>Population Forecasts</u> - Perhaps the single most important population study for planning purposes is population forecasting. The following lists some of the most common forecast methods used in small area studies:

- <u>Migration and Natural Increase</u> - This procedure, used extensively by state agencies, is one of adjusting the last census figures of the locale of interest to reflect changes that have occurred to date, considering the effects of migration and natural increase separately.

- <u>Censal Ratio Methods</u> - These are used by both state and city agencies and include any method utilizing ratio procedures. The simplest form of the ratio procedure makes a direct stepdown from Bureau of the Census state population estimates to one particular county or SMSA without examining trends in other counties. This should be used, however, with caution.

- <u>Methods Based on Symptomatic Data</u> - These methods, widely used by city planning agencies, derive estimates of the current population by reference to observed trends in data series which are found to have a close relationship to population change and for which current data are available. The vital statistics used include school enrollments, electric meter, water meter, or telephone installations; registered voters, etc.

- The Cohort Survival Method - This rather complex method requires an experienced population analyst to execute the forecast. The method adjusts figures from the last census forward by age group and sex group year by year to the date of the forecast, with separate adjustments made for each of the three major components of population change: death, birth, and net migration.

- Migration and Natural Increase Method - This method starts with a current estimate of the population, and by introducing adjustments first for migration and then for natural increase on a year-by-year basis it develops annual estimates into the future until the forecast date is reached.

- Estimates Based on Forecasts for Larger Areas - This method employs a previously prepared forecast for some larger geographical area and by ratio procedures establishes how the local area may be expected to share in the forecast population of the larger area.

- Estimates Based on Employment Forecasts - Where employment forecasts have previously been prepared for the study area, this method is often used as a basis for making population projections. Using ratios, the method expands future employment figures to labor force estimates, which are then expanded to population equivalents.

- Mathematical and Graphical Extrapolation Methods - This includes arithmetic and geometric projections, trend extrapolation by the method of least squares and estimates based on the logistic curve.

c. Population Distribution - Estimates of the distribution of future total population among the various neighborhoods have obvious implications for the study of residential areas and their community facilities. Two approaches are commonly used to study the distribution of population:

- Analysis of daytime population distribution
- Residential distribution

Urban Activity Systems - This type of analysis is not yet a standard part of the land use planning process. Traditionally, planning agencies have gone into land use studies looking at the effects of activity systems rather than seeking to define and understand activities themselves as producers of land use patterns. It should be recognized that there are no fully tested techniques of analysis for this component.

One method in existence is the origin and destination study done in transportation planning. In the survey, the respondent is asked to identify major activities of various members of the household during the preceding 24-hour period, or he may keep a diary over a longer time frame. The object of the survey is to be able to identify specific recurrent behavior patterns which will then enable the planner to make analyses of space use and travel in order to develop an integrated set of proposals for land use and transportation to be set forth in the comprehensive plan.

Urban Land Studies - These studies focus on an investigation of the features of the land itself. The information obtained describes the uses for which a particular parcel of land is most suited from a physical perspective. Specific types of studies that would provide this type of information include:

- Compilation of data on physiographic features
- Existing land use surveys
- Vacant land survey
- Hydrological and flood potential study
- Studies of aesthetic features

For reference, the following types of maps may be used:

- Engineering maps
- Topographic maps
- Property or tax maps

This information often indicates constraints on a particular type of use that could potentially be located on the parcel. It is at this point in the pre-plan analysis that traditional environmental concerns can and should be included in the process.

2. The Utility of the Land Use Plan

The information that goes into the development of a land use plan is of a wide variety. The question then is one of whether these preliminary sources are useful in projecting air quality for the area covered by the plan.

The basic method for the prediction of future air pollution concentration levels expected from the implementation of a land use plan is through the use of an atmospheric dispersion model. Models of this type translate data on emission patterns into patterns of expected concentrations for given timeframes. In addition to emissions data, dispersion models require meteorological and topographic data in order to make estimates of concentration patterns. Also, local air quality measurements are needed to evaluate and refine model performance and to specify confidence limits for the model results.

As mentioned in the introductory portion of the land use discussion, one way of approaching the calculation and projection of emissions is by dividing sources into three generalized categories--area, line, and point sources. This is not the only way to classify sources of pollution, but it does relate well to land use concepts; hence, the utility of land use data will be evaluated within this framework.

a. Area Sources - In order to calculate this category of emissions, it is necessary to know:

- The location of residential areas
- The types and densities of the housing
- General population

This information, traditionally supplied in a general land use plan and accompanying text, should be adequate to provide a basis for the calculation of area sources. Population figures will provide a rough estimate of the number of cars that will be on the local area streets, which in turn can be used in the calculation of emissions. The housing densities and types generally indicated on the map will give an indication of the number of heating units that can be expected. In areas indicated for potential high density development, emissions from incinerators, if permitted by law, will also have to be taken into consideration. An additional piece of information needed in order to calculate emissions from heating units is the source of energy. This can be obtained from the utility companies in an area, if the local planning agency has not already obtained it.

Once the sources of emissions have been determined and the potential levels have been established, the evaluator must know the physical characteristics of the area--particularly variations in topography and wind patterns--in order to estimate actual pollution levels. These two things, of course, will have an effect on whether the pollutants are dispersed or whether they accumulate over an area. In conjunction with this, the proximity of significant amounts of open space should be taken into account, as it has an effect on ameliorating pollution concentrations. Information on open space is also presented on the land use map.

Other components of area source pollution are local commercial and office facilities (with the exception of regional shopping centers). These are indicated on the land use map. Greater detail as to the type of facility can often be gained through an examination of the zoning map and ordinance which often indicates whether the area is the downtown, or a community or neighborhood shopping center.

Zoning ordinances frequently differentiate among types of commercial uses and often require different amounts of parking space be provided. As previously discussed, the amount of space allocated for commercial use is based on economic forecasts for the area plus consideration of population and disposable income. This type of information gives an indication of the number of cars that will be attracted to an area which can be related to automotive emissions. Some of these zoning requirements may be shifting as a result of the parking plans being developed as part of the Transportation Control Strategies in many urban areas. Commercial areas also produce emissions from heating and, possibly, incineration facilities which should be included in the calculations. These totals from small scale commercial facilities are then included in the area totals.

b. Point Sources - The land use plan, through its studies of industrial demand and the capacity of particular sites for specific industrial uses, provides an indication of potential locations for industrial point sources. Depending upon the level of detail included in the plan, the land use map, particularly the specific map known as the industrial plan, may reflect the broad industrial categories of light, medium, or heavy industry. If the map is for a less developed area, it may only show one general purpose industrial category. In the latter case, it will be more difficult to determine which areas will, in fact, represent point sources. It should also be noted that the differentiation into several industrial land use types does not indicate the process used or the pollutants emitted.

The distinction made in most zoning ordinances is between light and heavy manufacturing. The difference between the two is based on the degree of noxious effect--noise, odor, dust, etc. The regulations themselves merely list permitted or prohibited industries by industry type. Many of the newer zoning ordinances, however, are prescribing performance standards for industry. These define the maximum amount of noise, smoke, dust, and other external effects that an industry in a given district may produce. If this type of ordinance exists, the maximum levels of emissions by zone may already be known.

Performance standards for industrial districts should be viewed with caution, however, as some jurisdictions to not have the technical capabilities within the planning or zoning department to enforce the standards. In addition, the performance standards for air quality should be reviewed to determine if they do in fact provide for the control that was intended.

Many areas also do a special industrial survey that locates specific types of industry in areas with which they are most compatible. In the comprehensive plan for the City of Philadelphia, the city was divided into five zones, each with characteristics of particular interest to industry. These zones were then matched with the most suitable industrial type, designated by a three-digit SIC code. This level of specificity, while not locating the exact parcel on which a particular industry is sited, does provide approximate areas where pollution concentrations of a certain type may be expected. If this type of information is available, it would be as an adjunct to the land use plan and it should be consulted for use in air quality projections. In any case, industries in the area should be consulted on any plans that they might have for the expansion of facilities. Business or real estate pages of local newspapers often tell of plans for new facilities of industries moving into the area. Chambers of Commerce or any local or state industrial development commissions are added sources of information.

The location of public utilities is usually determined by the utility companies. The local planning agency obtains the information from them and reproduces it on a land use map. As utility companies often buy up land in anticipation of need, the projections could reflect this additional knowledge. Depending on the regulations of the state and whether they are publicly or privately owned, they may not be subject to local zoning. In the case where they are not, pollution from other sources may have to be reduced in order to meet the standards where a power plant is to be located in an area.

<u>c. Line Sources</u> - The information gained from the land use plan does not really contribute to the calculation of line sources of pollution, which represent emissions from motor vehicles along principal highways and emissions from aircraft. The studies previously discussed, particularly the urban activity systems, can contribute information to line source calculations. The basic data sources are the origin and destination (O-D) studies which locate where people are going so that volumes of specific roads can be calculated. This, along with data on speeds, provide a basis for the calculation of emissions. If O-D studies are not available, then data on the capacity of the major roads, plus highway speeds, can be used to calculate a more generalized picture of line sources of pollution in an area. Again, it should be mentioned that the comprehensive plan map should be used rather than the land use plan alone. In the comprehensive plan, the land use and transportation plans are combined, allowing the evaluator to relate land use and transportation

more precisely. However, the 3-C plan for an area would probably be the best source of transportation planning information.

3. The Influence of Land Use Planning on Development

In order for a land use plan (or a comprehensive plan) to be useful as a tool in achieving the objective of air quality maintenance, it must be supported by an enforcement mechanism. If the planning agency or local government does not have the legal power to enforce its plan, then there is no assurance that the plan as developed will ever be implemented. The knowledge that the plan forming the basis of the projections will be implemented also increases the validity of any projections that are made. The power of a plan as part of an overall strategy depends not only on the ability to enforce it but also on the role of a particular plan in the total planning picture. If the plan is part of a total planning process, ranging from the micro, or local, to the macro, or regional, level, then the information it provides has greater applicability and is more useful.

The following sections discuss both of these elements--the mechanisms for enforcement and the integrative aspect of the plan.

a. The Mechanisms for Enforcement - Various types of controls can contribute to the enforcement of the plan. The first level of control lies with those responsible for the development of the plan and its subsequent implementation. Generally, the comprehensive plan and the component land use plan are developed by the planning agency. The land use plan is a guide, and as such it is not legally binding. The comprehensive plan, while not passed as an ordinance, is generally adopted by the legislative body as a policy guide by resolution. The land use plan, however, does form the basis for the zoning ordinance, which is one of the legal mechanisms for ensuring that the plan is implemented. One problem is that in many places the zoning ordinance preceded the plan, which makes rational development more difficult. In other cases, the zoning ordinance may exist without the plan, which means that development can be haphazard.

As land use planning has traditionally been a local concern, the greatest powers for enforcement (particularly in the form of zoning) exist at the local level. As part of the Hackensack study, it was found that the agencies with jurisdiction over large areas--state, regional, or county--typically have an extremely limited power base as they are made up of components which have their own authority in the area of land use, as defined by state-enabling legislation.

In a study of the Baltimore-Washington area, it was found that the strengths of land use controls declined as one moved from the central zones outward. Hence, areas experiencing the most rapid change in land use are least equipped to control development, as they often have no zoning. In addition, the planning authority in the region is fragmented; hence, the patterns of land development have largely been shaped by the uncoordinated actions of thousands of private developers and multiple jurisdictions. This means, of course, that the larger the geographic area covered by the plan and the larger the number of component jurisdictions, the less likely that the areawide planning agency will have the tools necessary to enforce it.

Dissatisfaction with the results of local land use controls has caused many states to adopt statewide or regional approaches to land use planning. In Alaska, Colorado, Connecticut, Delaware, Georgia, Hawaii, Maine, Maryland, Massachusetts, North Carolina, Rhode Island, Vermont, and Wisconsin, either a new state organization or an existing agency is required to implement some degree of statewide land use planning or zoning or both, or to carry out some sort of planning and land use regulation aimed at particular classes of land such as wetlands or tidal areas. In addition, in some states--such as California with the San Francisco Bay Community Development Commission or the Tahoe Regional Planning Agency, New Jersey with the Hackensack Meadowlands Development Commission, or New York with the Adirondack Park Agency--a regional agency has been created to deal with some special problems of land use planning and control. "These various measures are primarily directed at resource use problems. However, they are significant in the fact that they do represent a break with past sole reliance on local land use planning. Some establish state controls that replace local controls; others provide a combination of state and local controls with the statewide concerns clearly dominant. Regional zoning, as differentiated from state level controls, is much more rare, existing only in Jacksonville, Florida; Indianapolis, Indiana; and Nashville, Tennessee. This is due to the consolidation of governments. The statewide and regional approaches to land use planning and control are, however, too recent to have been fully tested for either their competence, efficacy, or legal powers."*

It should be noted that although an area may have a plan and a zoning ordinance to enforce it, there are ways to change zoning and, in that way, to compromise the land use plan. At the local level, a legislative body or planning commission may grant a rezoning, or a zoning board of appeals may grant a zoning exception or variance. This type of flexibility in the zoning pattern is not necessarily bad, as it may allow for the introduction of innovation, amelioration of a hardship or grievance, correction of a mistake in the original zoning, or accom-

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*Richard Babcock and David Callies, "Ecology and Housing: Virtues in Conflict," Modernizing Urban Land Policy, edited by Marion Clawson (Baltimore: Johns Hopkins University Press, 1973).

modation to changed conditions. However, it does decrease the reliability of projections based on the plan.

The existence of effective land use controls is critical to the use of land use planning for maintaining air quality. There are presently several techniques for controlling urban and suburban growth and development, including:

- Location and timing of public improvements such as roads, sewers, sewer treatment plants, and water lines.

- Lending policies and the restrictions which may be imposed by private lending agencies and the government agencies that supervise them or insure their loans

- Government subsidies, loans, and other programs for renewal, development, and redevelopment

- Public land use controls--zoning, subdivision regulations, building codes, health regulations

- Tax policies that would encourage the inclusion of environmental objectives into the private decision-making process

Many of these elements are generally delineated in the Capital Improvements Plan which is the planned budget for 2 to 5 years for the local jurisdiction.

The following section will discuss zoning in greater detail as it is the predominant mechanism for land use control. In general, the power may be transferred by the state, through enabling acts to the governments at either the local, county, or regional level. Some states authorize all three types of zoning while others restrict power to the local level. This decision is generally based on the nature of development within the state and the system of land use control that would appear to be appropriate.

As the concerns of a municipality, county, and regional agency usually vary considerably, the zoning ordinance, in terms of the provisions and the districts or zones defined, will also vary. Zoning at the regional level, where it exists, will differ from that of the municipality or the county in that it represents a coordinating function and usually will be carried out by a body with representation from the constitutent counties. A regional planning commission constituted in this fashion may have the authority to prepare various zoning codes and ordinances for its area, but these must be approved and adopted by the constituent counties before they have the force of law.

At the local level, where zoning has been the traditional regulating mechanism, it has been shown that "zoning controls have been of limited value in guiding new suburban land development. The typical suburb is either unable or unwilling to enact zoning and other controls that are strong enough to effectuate a general plan for the area. The difficulty, however, has been political, not legal."*

Because of the local basis for zoning, the regulations have often proved obstructive to the development of land use plans at a broader scale. In the past, land use zoning was used by units of local government for local ends; hence, when it came to the issue of overall economic and social development, and the implementation of a metropolitan strategy, local land use zoning and controls have been notably deficient. The result has been that development has generally assumed the form of uncontrolled sprawl.

Gradually, however, there has been a change in the thinking about land use regulation away from the belief that the purpose of the regulation was for the protection of the commodity value of land. There was a realization that important social and environmental goals require more specific controls on the use that may be made of scarce land resources. This change in attitude is seen not only in the new state role in land use regulation but also in the actions of many local governments. Modern zoning ordinances typically rely less on pre-stated regulations, and require the developers to work with local administrative officials in designing a type of development that fits more closely into the surrounding area. Typical of this new direction are planned unit development (PUD) zones which encourage larger scale development in which the various land uses are arranged and designed according to the comprehensive plan for the specific site as opposed to the traditional lot-by-lot development. There is also a greater tendency on the part of local governments to develop more specialized use districts which permit only those uses appropriate to the geographic area rather than to some abstract category of uses. This is evidence of the growing attempt to tailor land use regulations to local needs. Finally, and probably most significantly, for the purposes of planning, there has been a rapid increase in recent years in local zoning and subdivision regulations in relatively undeveloped areas. Here the concern is with the development of optimal long-range land use patterns.** This new, more comprehensive

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* Modernizing Urban Land Policy, ed. Marion Clawson (Baltimore: Johns Hopkins University Press, 1973).

**Fred Bosselman and David Callies, The Quiet Revolution in Land Use Control (Washington, D.C.: Government Printing Office, 1971).

approach to zoning may eventually eliminate the over-use of re-zones, exceptions and variances that tend to distort the patterns.

b. The Integrative Aspect - If the land use and comprehensive plans are to be useful tools, they should be part of a comprehensive integrative effort to achieve this objective; the broader the base of the plan, the more likely that it will have some effect. This section will discuss how the planning agency interfaces with other agencies that might provide specialized information, as well as the relationship of the plan to other land planning efforts.

As the concern for the environment is only just beginning to be incorporated into the comprehensive land use planning process, there has traditionally been very little need for coordination between the local planning agency and any existing environmental agencies in the area. The present concern with expanding the definition of the comprehensive plan to include environmental considerations, and the requirements of NEPA and the A-95 Review have probably resulted in an increased level of interaction between these two groups. In the area of air pollution, the Hackensack Meadowlands Air Pollution Study has indicated that there is a lack of a clear distinction between the responsibility of the planner for the abatement of air pollution problems in the long term and that of air pollution control officials. It was found that many planners felt that it is not within their jurisdiction to incorporate air pollution into the planning process, but rather felt that more effective solutions could and should be achieved by direct control of emission sources through the air pollution control agencies and their powers of regulation and enforcement. It would appear that a greater coordinative effort is necessary so that both strategies are implemented as well as being mutually supportive. This type of coordination is particularly important for the control agency so that control strategies can be closely related to the land use patterns that are developed.

The relationship of a plan to plans of a larger and/or smaller scale depends to a large extent on the existence of a standard system of land use categories throughout the area under consideration. There has been a great problem of comparability of plans as many areas use their own definitions and collect differents types of data at different levels of detail. This means that local land use plans cannot always be summed to produce a regional plan. There are examples where the land use plan for a region does represent a compilation of the land use plans of the component jurisdictions. In this case, greater specificity in regional projections can be gained from looking more closely at the studies that went into the land use patterns for each of the component jurisdictions. Because of the variability of the plans, it is difficult to say where regional and local plans are compatible and where they are not. A significant source of conflict may occur in the case where local plans may reflect community goals over which they have very little control. For example, a no-growth policy in some local jurisdictions, may be an appropriate response to the community's ability to provide adequate facilities and services. However, the local government may possess neither the regulations nor the will to withstand private development. On the other hand, especially in less developed areas, local "boosterims" and wishful thinking may result in vast areas being planned and zoned for commerce and industry with little support by economic realities. The evaluator will have to make a decision on a case by case basis.

c. The Planning Document as a Reliable Source of Information - The degree to which land use plans and zoning maps will be useful to the air pollution control officers will vary widely from agency to agency because of the uncertainty that is inherent in the findings and recommendations contained in planning documents. Some of the factors that must be taken into consideration are:

- A characteristic of almost all plans is that they are not current. The base year for much of the socioeconomic projections is information from the census. Techniques for updating such information vary considerably. Land use inventories are continuously updated in some agencies, while others may be several years old. In addition, local actions affecting the plan may not be reflected on the plan.

- Many plans may be so general as to be of little use as a guide for quantifying and locating future problems in air resource management. In such cases, the text to the plan may be more important than the map, as specific development policies or guidelines may be well articulated. For example, the planning map may not indicate the location of commercial facilities while the text may describe locational criteria, service areas, range of facilities according to function, size, etc. In the decision-making process, then, the planners would not be committed to a specific location in advance but would measure private development proposals against these criteria set out in the plan.

- Planning maps may indicate significant areas for urban development which would not necessarily be reflected on the zoning map. In such cases, the local strategy is to "under zone," thereby requiring all potential developers to appear before local planning and zoning boards and legislative bodies to gain plan approval. Under such circumstances, the local government is likely to have more influence on the type of development that occurs than if the developer already has the appropriate zoning. The plan indicates the proposed land use and provides a guide for zoning action.

4. The Potential for Change

An effective comprehensive plan is not a static document but rather represents a dynamic process that is regularly updated to reflect new conditions and objectives. The incorporation of new information with regard to the relationship between land use and air quality should be part of the updating procedure. The review process is particularly important for plans in areas that still developing but are already experiencing air pollution problems.

The basic guidelines for the development of a comprehensive plan suggest that the plan should be reviewed annually. "Once a year the legislators should re-examine the plan and consider possible amendments."* These amendments would normally be initiated by the planning staff. They would then be screened by the planning commission and forwarded to the legislators." The importance of the annual review cannot be overemphasized. This is the main process which is intended to assure that the plan will be kept up to date. If it is neglected it is possible that the plan will "ossify" and be ignored. Annual review, however, is a fairly recent innovation."**

There should be a major reconsideration of the entire plan after five or ten years. This should provide for an overhaul of the entire plan, including new surveys, updated forecasts, and the restudy of major alternatives. The effort expended on this should be similar to that put into the original plan, and the same general procedures should be followed. The rationale behind this step is that amendements made at annual review time will not suffice to keep the plan current after an extended span of years. Gradual changes (particularly those caused by re-zonings, variances, and exceptions) may be imperceptible.

The ability to change the plan may not always serve the best interests of those interested in air quality. That is why it is incumbent upon those who have responsibility in this area to review plans at the operative level and to provide inputs that will provide a basis for developing plans that contribute more to the achievement of air quality goals.

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* Alan Black, "The Comprehensive Plan," Principles and Practice of Urban Planning, edited by Goodman and Freund (Washington, D.C.: ICMA, 1963).

**Ibid.

B. THE 3-C PROCESS

The term "3-C process" comes from the Federal-Aid Highway Act of 1962 which requires that all programs for Federal Aid Highway Projects approved after July 1, 1965, in urban areas of more than 50,000 population must be based on a Continuing, Comprehensive transportation planning process carried on Cooperatively in the state and local communities.

1. Current Practice

Generalizations about the process and procedures followed in the planning studies are very difficult because no two studies follow identical methods or procedures. All studies vary widely in terms of the level of detail for specific portions of the study and the analytical processes used to analyze and evaluate data in the planning process.

While there is considerable variation in the detailed procedures used in each study, the comprehensive planning process requires that certain concepts are common to all 3-C planning efforts. These include evaluations of existing and future economic, population, and land use data; estimates of future demands for all modes of public and private transportation; inventories and analyses of all existing transportation facilities; the development of a comprehensive transportation plan; and the implementation of a continuing program to monitor and, as necessary, revise the original transportation plan. The guidelines for implementing the 3-C process are documented in a series of Policy and Procedure Memoranda (PPM) prepared by the Federal Highway Administration (FHWA). Copies may be obtained from the regional FHWA office or the local 3-C transportation planning agency. (The relevant document in PPM 50-9.)

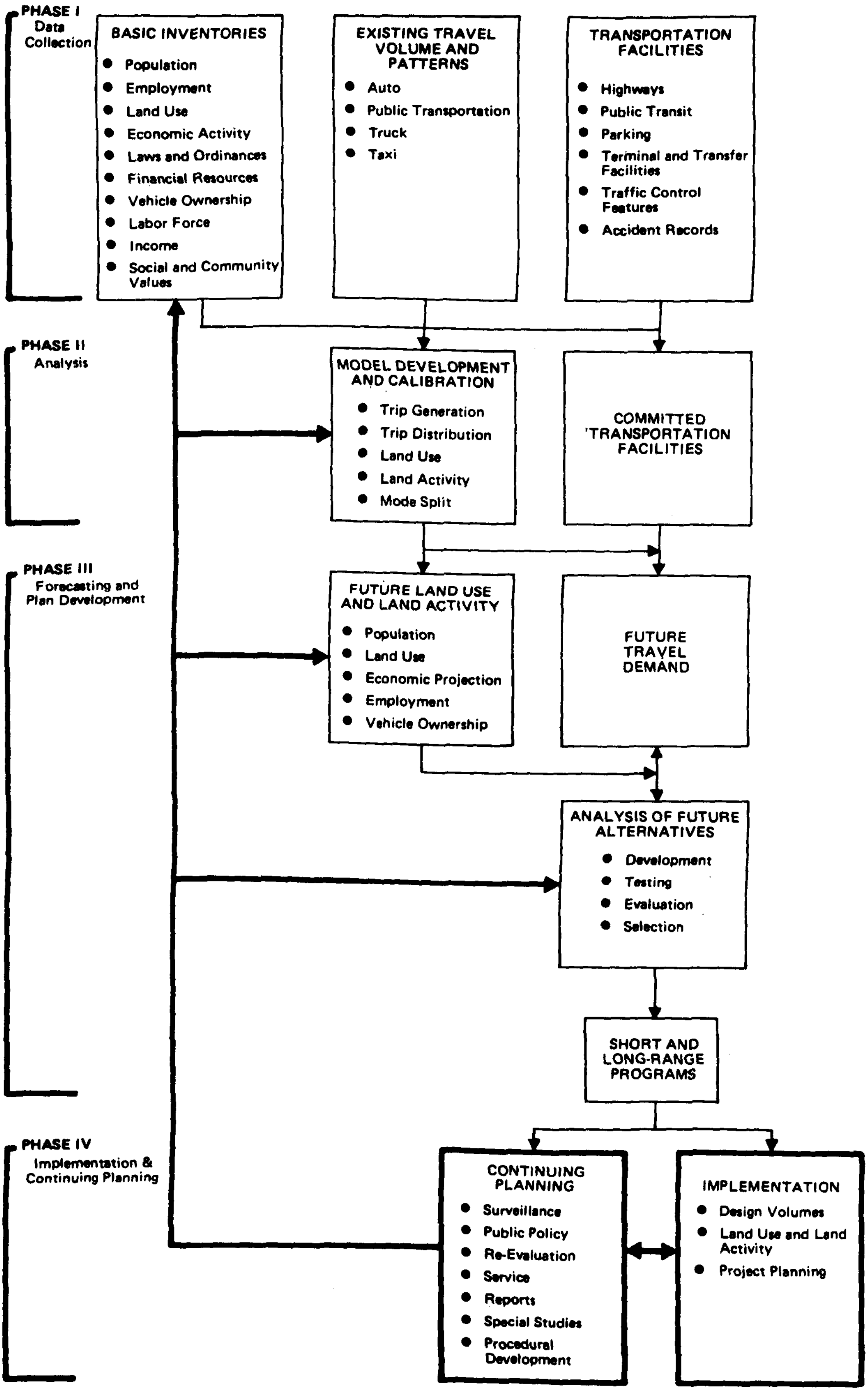
Figure IV-1 shows the generalized activities of almost all 3-C planning processes grouped into the following four phases:

- Phase I: Data Collection - Various surveys are conducted to provide a detailed and complete picture of existing travel and socioeconomic conditions in the study area.

- Phase II: Analysis - Analytical methods are used to develop an understanding of the factors influencing travel demands and develop procedures for estimating future travel demands and transportation requirements.

- Phase III: Forecasting and Plan Development - In light of the anticipated land use and land activity, transportation demands in the study area are forecasted, alternative transportation strategies are developed and tested, and a final transportation plan is developed.

Figure IV-1


PHASE I
Data Collection
BASIC INVENTORIES
Population
Employment
Land Use
Economic Activity
Laws and Ordinances
Financial Resources
Vehicle Ownership
Labor Force
Income
Social and Community Values
EXISTING TRAVEL VOLUME AND PATTERNS
Auto
Public Transportation
Truck
Taxi
TRANSPORTATION FACILITIES
Highways
Public Transit
Parking
Terminal and Transfer Facilities
Traffic Control Features
Accident Records
PHASE II
Analysis
MODEL DEVELOPMENT AND CALIBRATION
Trip Generation
Trip Distribution
Land Use
Land Activity
Mode Split
COMMITTED TRANSPORTATION FACILITIES
PHASE III
Forecasting and Plan Development
FUTURE LAND USE AND LAND ACTIVITY
Population
Land Use
Economic Projection
Employment
Vehicle Ownership
FUTURE TRAVEL DEMAND
ANALYSIS OF FUTURE ALTERNATIVES
Development
Testing
Evaluation
Selection
SHORT AND LONG-RANGE PROGRAMS
PHASE IV
Implementation & Continuing Planning
CONTINUING PLANNING
Surveillance
Public Policy
Re-Evaluation
Service
Reports
Special Studies
Procedural Development
IMPLEMENTATION
Design Volumes
Land Use and Land Activity
Project Planning

- Phase IV: Implementation and Continuing Planning - Under a continuing program to monitor the planning concepts used in the development of the original transportation plan, the transportation strategy developed in Phase III is implemented and its effectiveness monitored.

The end results of this process are twofold. First, based on a detailed investigation and analysis of the existing situation, a transportation plan and program can be developed that serves as a common framework for all agencies charged with transportation systems improvement and operation in the study area. Second, it provides the basic information and procedures for continually reviewing the appropriateness of transportation strategy as required by changing events and changing community goals and objectives. In almost all major urban areas, the transportation planning process is in Phase IV, Implementation and Continuing Planning.

2. Legislative Requirements

The Federal-Aid Highway Act of 1944 was the first Federal program to provide regular Federal-aid highway funds for use in urban areas. The 3-C planning process in all urban areas with population over 50,000 were established in response to Section 9 of the Federal-Aid Highway Act of 1962, which amended Chapter I of Title 23, United States Code, by the addition of a new section, 13A, which states:

> It is declared to be in the national interest to encourage and promote the development of transportation systems embracing various modes of transport in a manner that will serve the states and local communities efficiently and effectively. To accomplish this objective the Secretary shall cooperate with the states, as authorized in this title, in the development of long-range highway plans and programs which are properly coordinated with plans for improvements in other affected forms of transportation and which are formulated with due consideration to their probable effect on the future development of urban areas of more than fifty thousand population. After July 1, 1965, the Secretary shall not approve under Section 105 of this title any program for projects in any urban area of more than fifty thousand population unless he finds that such projects are based on a continuing comprehensive transportation planning process carried on cooperatively by states and local communities in conformance with the objectives stated in this section.

A description of all Federal, state and local legislation as it applies to the current 3-C planning process in all urban areas is beyond the scope of this document. The following is a listing of some of the major Federal legislation relating the 3-C planning process and air quality control.

Clean Air Act of 1970 (42 USC 1857(h-7). Purpose: To require the Environmental Protection Agency to review and comment in writing on the environmental impacts of any matter relating to duties and responsibilities granted pursuant to this Act or other provisions of the authority of the Administration when such impacts result from a project to which section 102(2)(C) of the National Environmental Policy Act of 1969 applies.

Federal-aid Highway Act of 1970 (23 USC 109). Purpose: To require the Secretary of the Department of Transportation to issue planning and design guidelines to be applied to all highway projects which are approved after the issuance of such guidelines. Under the FHWA guidelines for Section 109(h) (PPM 90-4), each highway agency shall develop an Action Plan which describes the organization to be utilized and the process to be followed in the development of Federal-aid highway projects from initial system planning through design.

Section 23 USC 109(h) directs the following:

> Not later than July 1, 1972, the Secretary, after consultation with appropriate Federal and state officials, shall submit to Congress, and not later than 90 days after such submission, promulgate guidelines designed to assure that possible adverse economic, social, and environmental effects relating to any proposed project on any Federal-aid system have been fully considered in developing such project, and that the final decisions on the project are made in the best overall public interest, taking into consideration the need for fast, safe, and efficient transportation, public services, and the costs of eliminating or minimizing such adverse effects and the following:
>
> (1) air, noise, and water pollution
> (2) destruction or disruption of man-made and natural resources, esthetic values, community cohesion and the availability of public facilities and services
> (3) adverse employment effects, and tax and property value losses
> (4) injurious displacement of people, businesses and farms
> (5) disruption of desirable community and regional growth

Such guidelines shall apply to all proposed projects with respect to which plans and specifications and estimates are approved by the Secretary after the issuance of such guidelines.

The Urban Mass Transportation Assistance Act of 1970 and Section 204 of the Demonstration Cities Act of 1966, further clarified by Bureau of the Budget Circular A-95. Purpose: To require submission of all applications for the planning or construction of facilities using Federal loans and grants to the designated areawide agency responsible for metropolitan and regional planning prior to Federal approval of the application.

These agencies (A-95 Clearinghouse) have the responsibility for reviewing and commenting upon all applications for Federal assistance for public projects to assure that "to the maximum extent possible, consistent with national objectives, all Federal aid for development purposes shall be consistent with and further the objectives of the state, regional, and local planning."

Air Quality Guidelines for Use in Federal-aid Highway Programs (23 CFR 770) Purpose: To promulgate air quality guidelines for use in planning and construction of proposed highway improvements constructed pursuant to United States Code Title 23. Under these guidelines, highway agencies planning, constructing, and maintaining highways pursuant to 23 U.S.C. shall consult with appropriate local, state, and Federal air pollution control agencies and assure that decisions on highways are consistent with approved State Implementation Plans and that adequate consideration is given to preservation and enhancement of air quality.

Each 3-C transportation plan must be reviewed annually by FHWA in order to obtain certification for funding of Federal-aid projects. Under another FHWA directive (PPM 50-11), an Intermodal Planning Group must also be established so that planning for all modes of transportation can be integrated.

All state highway agencies that propose projects for which plans, specifications, and estimates are approved by FHWA must develop an "Action Plan" as required under Section 109, Title 23, United States Code. The "Action Plan" for each state highway agency specifies for that agency the specific organizational structure and processes to be followed in the development of Federal-aid highway projects from initial planning through design. Therefore, the organizational structure and proceedings for each agency could vary to reflect the unique situation of each state.

Most of the 3-C planning studies are currently in the continuing planning phase of the study and therefore an "Operations Plan for Continuing Urban Transportation Planning" has been prepared. Each of these plans includes:

- An outline of the organizational structure for performing continuing planning, including related committees

- An outline of the scope of the continuing planning, with a breakdown of the functional and financial responsibilities of all participating agencies

- A description of the surveillance methodology to be employed in identifying changes in land development and travel demand, including assignment of responsibility for providing inputs to the various models

- A description of the land use and travel forecasting procedures to be utilized, including specific information required for the various analyses.

- A description of any work remaining to be completed on the ten basic elements (PPM 50-9 paragraph 5) including a schedule for completion of work.

3. Responsible Agencies

The specific organizational structures for each of the existing 3-C planning programs vary to some degree. In general, the following types of committees are formed:

- Policy Committee (sometimes called a Policy Board, Coordinating Committee, Steering Committee, etc.). - This committee is composed of local elected officials and representatives of agencies or organizations which have been designated by the state to provide policy guidance and direction for the study. In most cases, this committee also includes representatives of the state and FHWA.

- Technical Advisory Committee - This committee generally consists of staff appointed from the various state, regional, and local governmental agencies participating in the study, plus representatives of other agencies or organizations who have special skills in various study items or a special interest in the transportation planning process. In general, it is the responsibility of the Technical Advisory Committee to direct the study and review all procedures for technical adequacy and to make recommendations to the Policy Committee.

In some areas, citizens' committees have formed to aid in the establishment of communications between the technical staff and the public. These committees also help provide lines of communication between the public and the governmental units represented on the Policy Committee.

Generalization about the agencies with statutory authority to conduct planning studies and adopt plans for their respective areas is very difficult because of the many variations that exist throughout the country. In some areas, city planning commissions and/or metropolitan planning commissions are the only local agencies with this authority.

4. General Description of the 3-C Process

Generalizations about the 3-C planning process are diffcult because no two studies follow identical working methods and procedures. The specific type of data collected, the level of detail, and the level of analysis performed in each study vary to a considerable extent. The following is a generalized description of the type of data collected and the types of information developed in each of the four phases of the 3-C process.

a. Phase I: Data Collection - The major inventories conducted in the initial phase of the 3-C planning process can be combined into three general classes:

- Basic Inventories of Existing Land Use and Land Activity, Economic Data and Social and Community Values.

  The land use and land activity data in general is collected at the traffic zone level. The number of traffic zones within a study area vary in total number from several hundred to more than 4,000 and from a single block to many square miles in area. Traffic zones are generally small geographic areas in the more populated areas and large geographic areas in the outlying, less populated areas.

  The land use data is generally measured in acres per zone and would include the following classifications:

  - Low density residential
  - High density residential
  - Industrial

- Commercial
- Agriculture
- Public and quasi-public
- Vacant
- Roads and streets

In some cases the land use codes contained in "The Standard Land Use Coding Manual," Urban Renewal Administration and U.S. Bureau of Public Roads, dated January 1965, are used.

Land activity data by traffic zone would include:

- Population
- Dwelling units
- Median and/or mean family income
- Auto registration
- Employment (by standard industrial classification code)
- Labor force
- School enrollment

• <u>Existing Traffic Volumes and Patterns</u>

Three basic types of surveys are made to determine the number, purpose, mode, and time of day trips are made by all persons and vehicles within, into, out of, and through the transportation study area. These three surveys are the home interview, external, and truck and taxi surveys.

In the home interview survey, a sample of all dwelling units within the study area is selected, and all trips made by the residents of these dwelling units are recorded. The sample size varies from 12 percent for small urban areas to 4 percent or less for very large urban areas. The characteristics of the dwelling unit are also recorded in this survey. These characteristics would include number of persons in the household, number of cars owned, total household income, number of persons employed, type of employment, age of residents, etc. The data for each trip made on a given day by each member of the household would include the purpose of the trip, the origin and destination of the trip, the mode of travel (auto driver, auto passenger, transit passenger, walk to work, etc.). the time the trip began and ended, the number of passengers in each vehicle, etc.

In the external survey, 25 to 50 percent of all vehicles crossing the external cordon line of the study area on major routes on a given day are interviewed. The origin and destination of the trips, trip purpose, number of persons per vehicle, type of vehicle, time of interview, etc., are recorded for each vehicle trip interview collected at the external cordon.

In the truck and taxi survey, a 10 to 20 percent sample of all trucks and taxis garaged within the study area is selected. All trips made by these vehicles on a given day are recorded. The same type of information collected at the external cordon line is recorded for each trip.

All of the trip interview data is expanded to reflect the sample rates, checked and verified so that travel information reflecting all trips made on a typical day of the survey period is produced.

In some studies, an on-board transit survey is also conducted. In this type of survey, a large sample of the transit riders is interviewed to provide in-depth transit travel pattern data. Two common types of transit surveys are direct interviews conducted on the vehicle by trained personnel and the postcard survey in which questionnaires are distributed to passengers on the transit vehicle.

From the expanded travel pattern survey data, a detailed tabulation of the number of trips made between any zones within the study area by time of day, trip purpose, and mode of travel is developed.

- Transportation Facilities Survey

The third general class of inventories conducted in the first phase of the 3-C planning process, is a detailed inventory of all transportation facilities within the area to determine the quantity and quality of the existing transportation system. Included in the facilities survey are:

  - Detailed inventory of all highway facilities which include detailed tabulation of pavement width and intersection approach width, all traffic control and traffic engineering features, as well as extensive traffic volume data. From this data, existing levels of service and the capacities of the facilities are determined.

- Detailed inventories of the existing transit system and its usage. This information would include location of routes by type of service, transfer points, frequency of service, and operating characteristics and statistics.

- Travel time studies to determine the peak and off-peak hour speeds on the various segments of the transportation facilities.

- Parking inventories to identify the quantity and usage of existing parking in the major urban areas.

- Location and inventory of major goods terminal and transfer facilities.

- Location and analysis of major traffic generators.

- Tabulation and analysis of accident data.

From the facilities survey data, highway and transit "networks" are developed. These networks are computer-processable representations of the existing highway and transit system operating in the area.

The trip data from the travel pattern survey can be used in connection with these networks and a system of electronic computer programs to produce "network assignments." These assignment procedures and techniques allow zonal trip interchange data to be allocated to specific elements of the transportation system--transit trips to various combinations of transit routes, auto trips to various highway facilities, etc. Through these procedures and techniques, it is possible to approximate the movement of people and vehicles between various land activities on the existing transportation facilities.

The information available from the assignment techniques would include vehicle miles of travel, average speeds on various components of the network, types of trips on various segments of the transportation facilities, vehicle and person trip ends by traffic zone, trip length in miles and time for various types of trips and modes of travel, and the various area to area movements that result in specific volumes on individual transportation facilities or combination of facilities, etc.

b. Phase II: Analysis - The fundamental purpose of the second phase of the transportation study is to develop procedures to estimate future travel demands. The analysis is aimed at obtaining an understanding of the fundamental characteristics of travel, its repetitiveness, stability, and regularity. These findings are quantified in a series of mathematical formulas that relate travel demand to the land use/land activity and transportation system characteristics within the study area. The analysis is focused on quantifying the answers to specific questions, such as: What are the relationships that exist within the transportation study area between the magnitude of trips generated by or attracted to various land activity and the intensity of activity of each location? What effect does spatial separation of varying land activities have on the number of trips made between one portion of the study area and another? What unique patterns exist in the present distribution of travel demands? How are these patterns explained, and how will they relate to the transportation demands of the future? How reliable and how stable are the various methematical formulations used to develop travel demand estimations? What factors influence the number of trips made within the area?

These and similar questions must be asked, analyzed, and carefully answered so that subsequent forecasts will rest on a firm foundation. The results of this analysis of the base year survey data provide the basic input for the forecasting phase of the study.

In general, the following type of mathematical models are developed, calibrated and validated in the larger transportation studies.

- Land Activity Models

  These models provide a technique for distributing regional activity levels to small areas and subsequently to drive other land activity and socioeconomic data related to the activity distribution. Three general types of activity allocation models are in current use. They are trend analyses, econometric models and probability-based models. (See Appendix E for detailed discussion of these models.) It should be noted that this level of quantified land activity modeling has been applied in only a few urban areas. Other areas apply the technique described below.

- Trip Generation Models

  These models provide a technique for formulating the relationships between the trip made in an area and the characteristics of the area such as land use, land activity measures, or other economic activity measures. Many alternative techniques are used for trip generation. The two most common techniques are multiple-regression analysis and cross-classification analysis. The multiple-regression analysis is a statistical technique in which multivariable equations are developed to relate land activity measures within an area to the number of trips by trip purpose generated by the area. Cross-classification is a technique in which the tripmaking attributes of persons or households by trip purpose can be measured when the changes in two or more other attributes of the person or household are accounted for.

- <u>Trip Distribution Models</u>

Once the zonal trip generation is developed, the trip distribution models are applied to predict the distribution of these trips between the zones within the study area. The three most common trip distribution models are the growth factor technique, the gravity model techniques, and the intervening opportunities model. In the growth factor technique such as the Fratar method, an existing trip distribution is modified by applying origin and destination factors for each zone in an iterative process until the desired trip growth at each zone is reached. This technique is generally used only in smaller and slowly growing areas.

The intervening opportunity model is a probability function based on the premise that total travel time from a point is maximized, subject to the condition that every destination point considered has a stated probability of being acceptable. More precisely, the opportunity model states that the probability that a trip will terminate within some volume of destination points is equal to the probability that this volume contains an acceptable destination, times the probability that this volume contains an acceptable destination, times the probability that an acceptable destination closer to the origin of the trip has not been found.

The model operates on inputs concerning the total trips originating in a zone, the total destinations in a zone, and an empirically derived probability constant which requires the average density of trip ends and the trip length.

The gravity model is the most widely used of the three trip distribution techniques. It is based on the assumption that trips produced at an origin and attracted to a destination are directly proportional to the total trips produced at the origin, the total trip attraction at the destination, an empirically derived measure for interchange travel between zones with a given impedance separation, and in some incidences a socioeconomic adjustment factor.

- Mode Split Models

  These models are generally applied to a disaggregate of total person trips into auto-driver trips, auto-passenger trips, and transit-passenger trips. Three types of mode split procedures are the most commonly used: direct transit and auto trip generation, trip-end modal split models, and trip-interchange modal split models. In the direct trip generation, transit and auto trips are developed directly from trip generation equations. The trip-end modal split model uses the total person trips produced by the trip generation equations and produces an estimate of the auto and transit trips prior to trip distribution. The trip-interchange modal split models use the person-trip distribution from the trip distribution models.

c. Phase III: Forecasting and Plan Development - The development of a transportation plan for the area calls for the preparation and testing of alternatives and evaluating results in light of the overall goals and objectives of the communities in the study area. This procedure results in the recommendation of the regional transportation program based on the established objectives and standards of all of the communities contained within the study area. Preparing alternative transportation plans calls for imagination and judgment as well as a deliberate attempt to arrange the transportation facilities so that future transportation strategies can be developed within the limitations of the financial constraints and community values.

Each of the alternatives tested must be evaluated in light of the total developments of the area as well as the specific facilities and their effect on their immediate environment. Existing and planned renewal and redevelopment areas, housing projects, new subdivisions, industrial districts, regional parks, open space, etc., must be taken into account. The selected plan must be as compatible as possible, and must, to the extent possible, promote other community goals and objectives, including air quality, energy conservation, and mobility.

The final result of this phase of the planning study is a coordinated and acceptable plan of action to meet the needs generated by the forecasted land activity, land use, and traffic demand and to provide the study area with the best solution to the transportation needs that will exist in the future.

- Forecasting

  In the plan development and analysis process carried out in many metropolitan areas, multiple land use and transportation plans were considered. In some areas, transportation alternatives were developed in relation to a single land use plan or forecast.

In those studies in which only a single land use plan was used, the first step in the forecasting procedure was to estimate the future land use and land activity for the entire study area. These forecasts were then disaggregated so that the employment, population, and other land activity measures are distributed into the subareas of the region.

The next step in the forecasting procedure is to convert the estimates of future land use and land activity into estimates of future travel demand. This is done by applying the mathematical procedures developed in the analysis phase to the forecast land use and land activity information. The result of this procedure is a systematic and detailed estimate of the location and magnitude of future travel demands throughout the area. Once the future travel demand is established, it is studied in relationship to the available transportation system in the area. In this way, the location of future facilities and services was developed and evaluated. In the metropolitan areas where alternative comprehensive land use and transportation plans are tested, the procedures for developing alternative land use and land activity forecast varied greatly.

In some studies various land use and land activity concepts such as radial corridor development, multitown (satellite towns) development, compact city, spread city, linear city, etc., are selected as general land use and land activity forms. Forecasts of future land use and land activity were developed based on these concepts and various alternative transportation plans. In some studies, the type and density of activity forecasted for a given area was strongly influenced by the relative level of proposed transportation facilities and service available to the area. In other studies, various combinations of these approaches for developing alternative land use and transportation plans were used.

- <u>Plan Development and Testing</u>

  In addition to the variations in developing various land use and land activity forecasts, several transportation alternative concepts were used in most studies to develop and test alternative plans. These included transportation variations such as highway-intensive plans, freeway-intensive, radial systems, grid systems, minimum improvement, maximum improvement, etc., as well as various combinations of these network concepts.

  In testing and evaluation of each of the land use plans and transportation alternatives, many types of procedures and techniques were emphasized. One generalized procedure, common to almost all studies, involves the development of future travel demands, the assignment of these travel demands to the transportation network, and the evaluation of the assigned volumes relative to some performance measures.

In addition to the evaluation of the performance of a single land use and/or transportation plan, comparison of the alternatives was also made in most areas. In many studies, comparisons and evaluations to a no-improvement alternative, in which only the existing transportation facilities and service were included in the network, were also made.

Performance measures used in these evaluations at both the regional and subregional levels include total trips by persons and vehicles by mode and purpose; travel times and cost by mode and trip purpose; vehicle miles and vehicle hours of travel; average speed by mode and facility type; measures of system capacity versus travel demand by mode and facility type; trips to and from major subareas (such as the CBD) by mode and trip purpose; average length by mode and trip purpose, etc.

Another type of system evaluation commonly used was an economic analysis such as the benefit-cost analysis. In this type of analysis, facility cost and transportation cost by both the public and private sector were estimated. Comparisons were then made of the benefits derived from decreased travel distance and travel time and the cost of providing the proposed facilities and service.

Performance measures of accessibility provided by the highway and/or transit system to various subareas as well as general measures of accessibility to population, employment, and other land use activity were also developed by some studies. Many forms of analyses were developed in various studies to evaluate the impact of various land use plans and policy elements. Incorporated in many of the studies were evaluations of the impact of various public policies regarding the transit systems, parking facilities, sewer policies, open space, land use control for commerical and industrial development, etc.

From the analysis of alternative land use and transportation plans, one of the alternatives or a next plan developed from several alternatives was selected for implementation.

d. Phase IV: Implementation and Continuing Planning - Most of the 3-C transportation studies are complete through the first three phases of the study process and are now in the implementation and continuing planning phase of the study.

5. Data Sets and Formats

Many reports, technical memoranda and tabulations, and summaries of data are produced through the 3-C Planning Process. The 3-C Planning Process dates back to the early 1960s in most urban areas and was used in some studies begun in the mid-1950s. In that time period, there have been many studies and updates of inventory data. Also, significant changes have taken place in the technology used in the planning process so that the original models developed in many studies have been revised and reapplied to develop more reliable future forecasts and provide better analytical data for the evaluation of transportation problems. Because of the dynamic nature of the planning effort in many areas, problems can occur in the evaluation of published reports and tabulations of data. In many cases, detailed documentation of current practices and forecasts, which may differ substantially from those previously documented, are either not available or exist only in the form of technical memoranda with limited distribution. Thus, efforts to utilize transportation planning data must be accomplished through staff of the local 3-C planning agency.

a. Reports

- Annual Report - Each of the 3-C studies is required to prepare an annual report. This report contains a summary of the current planning activity and the surveillance program as developed in the operations plan for the individual study. Reports are also developed for many of the study areas when major reviews and plan reevaluations are made. The major review is generally performed at five-year intervals and the plan reevaluation at ten-year intervals unless the annual review indicates a need for more frequent examination.

- The Operations Plan - This plan for each study in the continuing phase describes the organizational structure, scope of the continuing planning and the methodology and procedures used in the study. The operations plan is revised when significant changes occur in the study operations.

- The Unified Work Program - This report is developed annually by most 3-C study areas and describes the allocation of funds for the planning activity.

- The Action Plan - Each state has developed an action plan describing the organizational structure and processes to be followed in the development of Federal-aid projects from initial system planning through design.

- Study Reports - In addition to numerous technical reports generated by each study, several summary reports are typical to most studies:

  - Base Year Findings Report - This report presents in a summarized and graphic form the results of the data collection phase of the study.

  - Model Development Report - This report contains a description of the development and validation of the models used in the study.

  - Forecast Report - This report contains a description of the land use, land activity and travel forecast.

  - Transportation Plan Report - This report describes the procedures used to develop and evaluate the various transportation and land use alternatives, and the resulting plan or plans developed from this analysis.

- Capital Improvements Plan - This is the short and long range dollar budget for implementing each phase of the plan. It is from this budget, when adopted, that state and local funds are allocated for transportation projects.

b. Computer and Other Data

Most of the 3-C studies have compiled the following types of data:

- Existing and Forecast Land Use and Land Activity Data by Traffic Zone - In most studies, there is a tabulation of the base year data described previously. This data is updated under the procedures described for the operations land. The forecast data is generally developed for short-term projections and for the target or design year. The short-term projections would be a 5 or 10 year projection and the long-term projection for 15 to 20 years.

- Transportation Facilities - Base inventories of the existing highway and transit facility and travel demand are also upgraded annually under the continuing phase of the transportation study. This would include traffic counts on highway facilities, patronage, and revenue data for the transit system and an update of the inventory of transportation facilities. In addition to this information almost all studies will have developed short-term and long-term travel demands. These area travel demands, based on the forecasted land use and land activity data, are assigned to future transportation networks to provide approximations of the future demand for all major transportation facilities. Data available from these procedures would include area-to-area travel demand by trip purpose and mode, total travel demand generated by subareas, vehicle miles and vehicle hours of travel by facility type and subareas, total travel demand on each segment of the highway and transit system and the travel speed on each segment of the highway network.

This generalized discussion is intended to serve as a guide to air pollution control personnel who may be participating in air quality maintenance planning. It should be recognized that in many urban areas the data required for air quality maintenance planning may not be readily available, or will require reformatting, or even reanalysis. It may be expected that, over time, the 3-C process will include compatible inputs, analysis, and products that can be used for comprehensive environmental planning.

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APPENDIX A

PROJECTING AND ALLOCATING EMISSIONS AND/OR AIR QUALITY

PROJECTING AND ALLOCATING EMISSIONS AND/OR AIR QUALITY

The following sections describe the methodology for projecting and allocating emissions and/or air quality in AQMAs. This approach maintains the identity of the individual source types contributing to the future air quality, so that control measures developed as part of the maintenance plan can be directly related to their impact on the future source types and distribution. The methodology assumes:

- The future emissions of all source types can be projected using available economic projection factors on a county basis. A methodology will be available to project county emissions by these source types for the years 1975, 1980, 1985 (Booz-Allen/EPA).
- The projected county emissions can be allocated to a more detailed spatial distribution required by some air quality modeling techniques using traditional local planning inputs. The allocation method for each source category is discussed in the following sections.
- The projected emissions can be related to ambient air quality using available modeling techniques (to be defined by EPA).

A. UTILIZING TRADITIONAL PLANNING DATA AND CONCEPTS

Methodologies for projecting countywide emissions and methodologies for relating emissions to ambient air quality are to be reproduced in detail elsewhere in the Guidelines Series. The following discussion will focus on procedures for utilizing traditional planning data or concepts to redistribute or allocate projected emissions to a subcounty area.

The local 3-C planning agency is a prime source for land use and transportation data and should be requested to assist in the collection and application of the best available data. In many regions, a subarea plan (county plan) may contain more detailed data to evaluate problem areas than the composite regional plan. However, these detailed data may be based on assumptions that conflict with the regional 3-C plan. Before proceeding with these data, the 3-C planning agency should be asked to comment on the uncertainties in them.

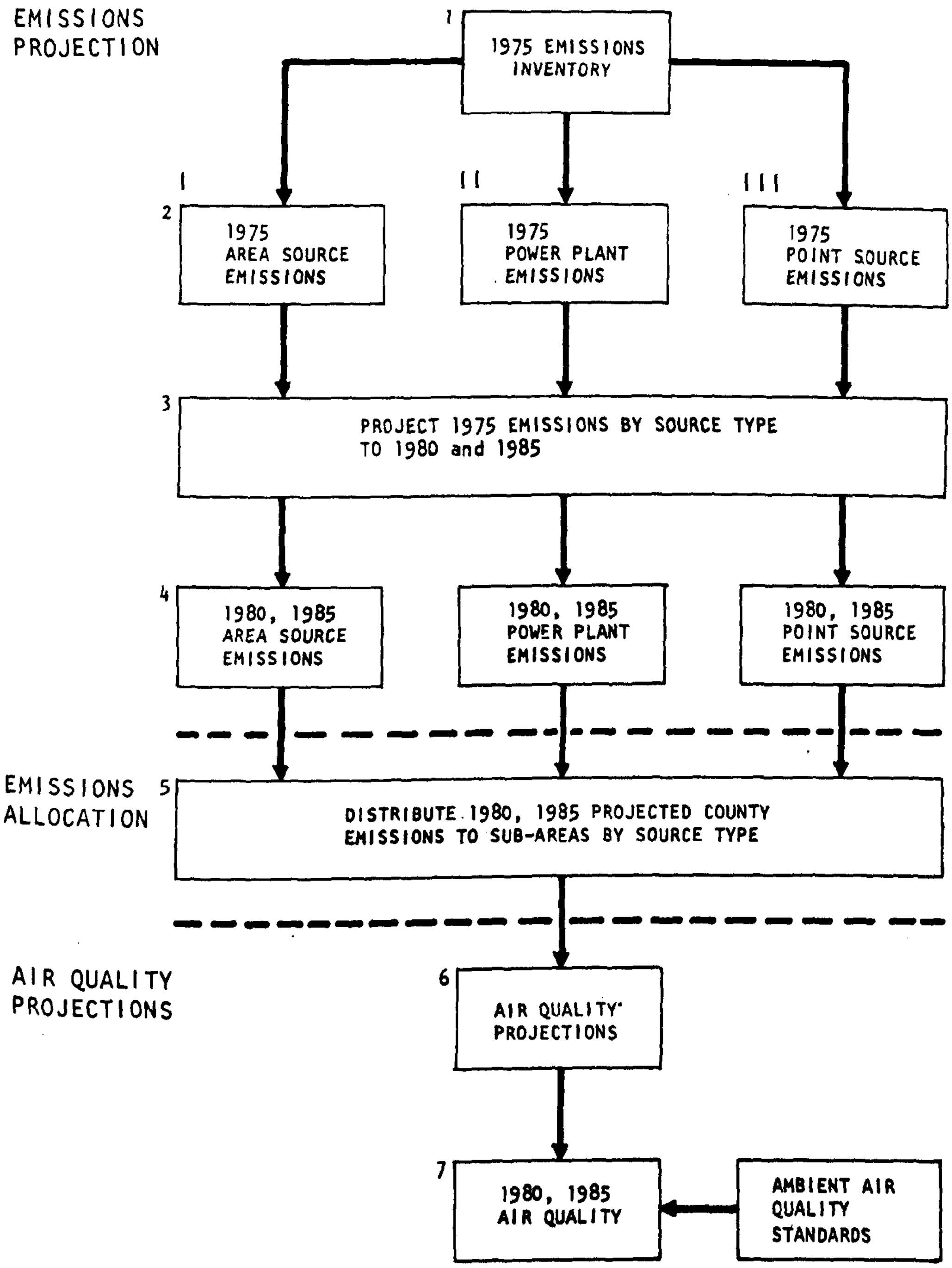
B. DETAILED METHODOLOGY

The following paragraphs discuss the detailed methodology for projecting and allocating emissions and/or concentrations of: total suspended particulates (TSP); and sulfur dioxide (SO_2); and carbon monoxide (CO); total hydrocarbons (HC; oxides of nitrogen (NO_x); and photochemical oxidants (O_x).

1. Particulates and Sulfur Oxides

Figure A-1 illustrates the methodology for projecting and allocating emissions (concentrations) of total suspended particulate and sulfur dioxide. As discussed in the general work flow plan, the concept of the methodology is to maintain the identity of the significant sources to the extent possible so that their individual and composite impact on emissions or air quality can be determined. Therefore, the methodology diagram illustrates that the emissions projections and emissions allocations of area sources, power plants, and point sources are to be performed independently. All of the point and area sources emissions may be displayed on a base map of the AQMA (or county). If an air quality projection method is available which accepts all such sources (see Appendix D), the allocated emissions can be immediately input to such a model to determine air quality for the time period of interest. If such a model has not been calibrated for the study area, a simple Gaussian-type model can be used to independently calculate the point

FIGURE A-1
TOTAL SUSPENDED PARTICULATES
AND SULFUR DIOXIDE
1980, 1985
EMISSIONS AND AIR QUALITY



source concentration isopleths and the area source concentration isopleths. These can be superimposed to produce the composite concentration isopleths for the area.

A more detailed discussion of the emissions projection and allocation methods for each source type follows.

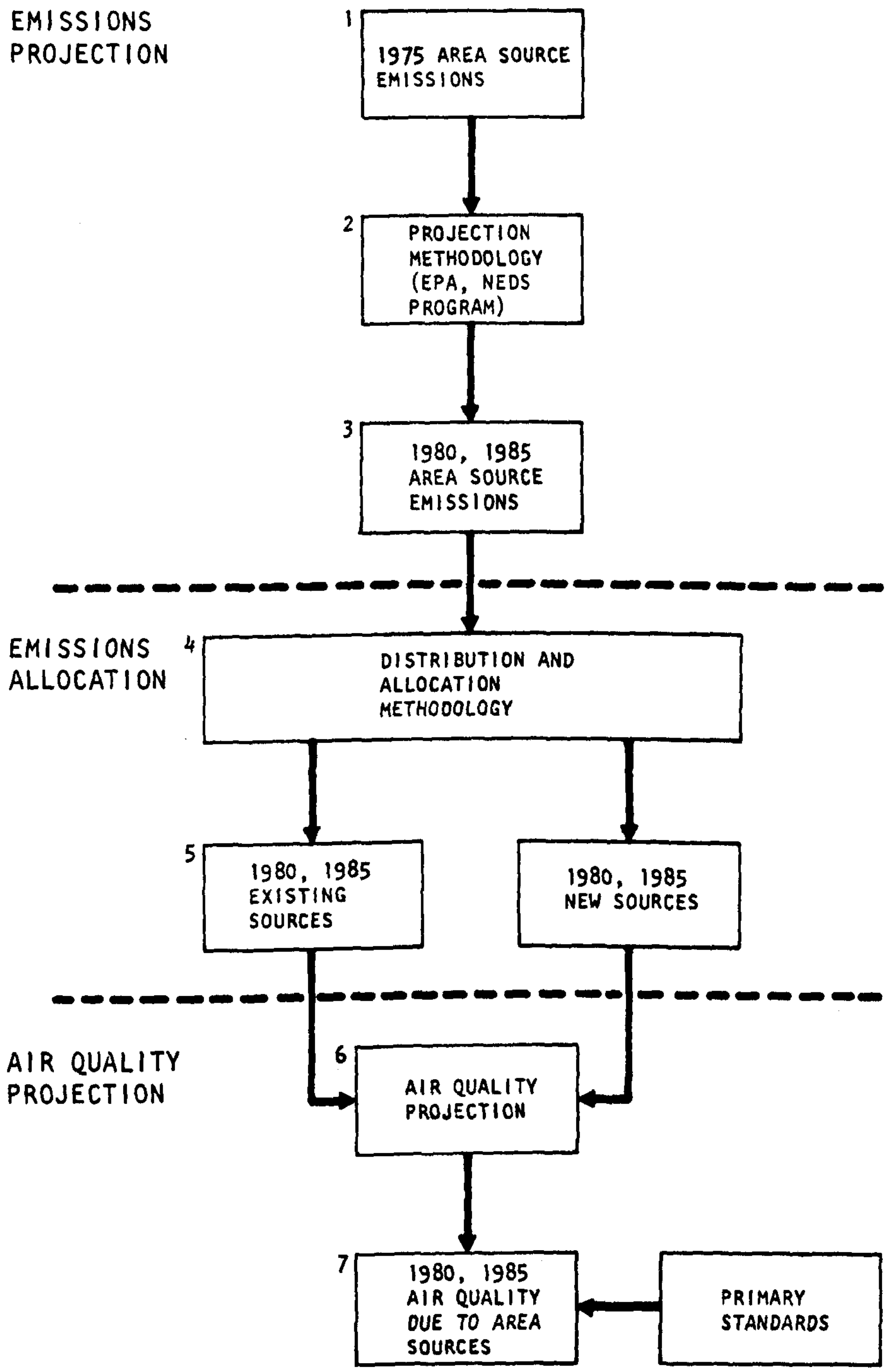
a. Area Source Emissions -- Figure A-2 illustrates the steps of the "Area Source Emissions Projection and Allocation Procedure."

Steps 1-3 - A methodology for projecting area source emissions on a county basis for 1980 and 1985 is currently being prepared under a contract to EPA by Booz-Allen. The 1970 NEDS data is used as base year values. The countywide totals by type are then factored to 1980 and 1985 based on expected county growth rates. In the absence of county growth rates by type for the forecast years, BEA statistics for the area can be used. Since the existing data (1970) does not reflect the emission reductions expected to result from the SIP, the 1980 and 1985 totals will be reduced to compensate for the reductions expected.

Steps 4-5 - These area source emissions can be distributed to a grid network within the county using the CAASE (Computer Assisted Area Source Emissions) technique and software package currently being prepared for EPA. This technique would have to be modified to project the demographic distribution factors using available land use plans or associated socioeconomic data. If time or funds do not permit this modification, the basic output for the existing inventory and conditions can be adjusted manually to reflect growth and development plans or data.

Since most available land use forecasts are generalized, some judgements must be made regarding the nature of new development indicated. To allocate the projected countywide total emissions to the grid system,

FIGURE A-2
AREA SOURCE EMISSIONS AND AIR QUALITY



changes in the existing land use must be quantified. The first task should be to determine where new commercial, industrial, and residential development most likely will occur within the forecast period. This should be indicated on the grid system used. Next, the total number of grids within each county by land use type should be determined for both 1980 and 1985. For residential and commercial emissions, total emissions can then be averaged over total area. While this will tend to neglect densities of development, it should be suitable for identifying approximate ranges of emissions.

To allocate industrial area source emissions, two rates should be developed for each county; one for light industry and one for heavy industrial development. Many areas differentiate between these two categories on their land use plans. Since this is not always true, some judgement will be required to indicate what type of development may be expected. In lieu of observed rates for varying industrial types, a ratio of 5 to 1 should be sufficient to identify problem areas. Thus while one grid of light industry might be allocated one ton of TSP per year, an adjacent grid of heavy industry would receive five tons per year.

Step 5 - Wherever possible, the new source emissions should be distinguished from those sources which existed in 1975 (and their growth to 1985) for the purpose of maintenance measure evaluation. This step is only applicable if county level growth rates have been used to project the emissions. If BEA statistics are used, new sources will normally be underestimated in outlying areas and overestimated in the urbanized core of the AQMA. This is primarily attributable to the low existing pollutant levels in the areas within AQMAs where the growth potential is most prevalent.

Steps 6-7 - Area source concentration isopleths can be computed using any of several Gaussian-type diffusion models that accept the grid network data produced by CAASE. These include AQDM and Grifford-Hanna. The modified "roll-back" or "roll-forward" technique may also be used where air quality data is available. EPA is currently preparing guidelines on available air quality projection techniques.

b. Power Plant Emissions -- Figure A-3 illustrates the steps of the Power Plant Emissions Projection and Allocation Procedure.

Steps 1 and 2 - Because of power plant siting regulations and detailed permit requirements, the location and general characteristics of proposed power plant emissions are known approximately ten years in advance. Source growth and control factors can therefore be obtained for this category.

Step 3 - Existing power plant emissions and their projected growth should be distributed independently from the new source emissions for the purpose of control plan development. Although the new power plant's location may already be planned, it may affect the location of other new major sources in the area.

Steps 4 and 5 - Since power plant emissions come from very tall stacks, these sources must be considered independently of other point source types. Proportional air quality modeling techniques should not be applied to power plant emissions unless some factor is included to account for the effect of emission height on local concentrations. EPA will recommend the diffusion modeling techniques to be applied. In many cases, existing power plants have already been modeled.

c. Point Source Emissions -- Figure A-4 illustrates the steps of the Point Source Emissions Projection and Allocation Procedure.

Steps 1, 2, and 4 - A methodology is currently being prepared for EPA to project emissions on a county basis. The projected emissions

FIGURE A-3
POWER PLANT EMISSIONS AND AIR QUALITY

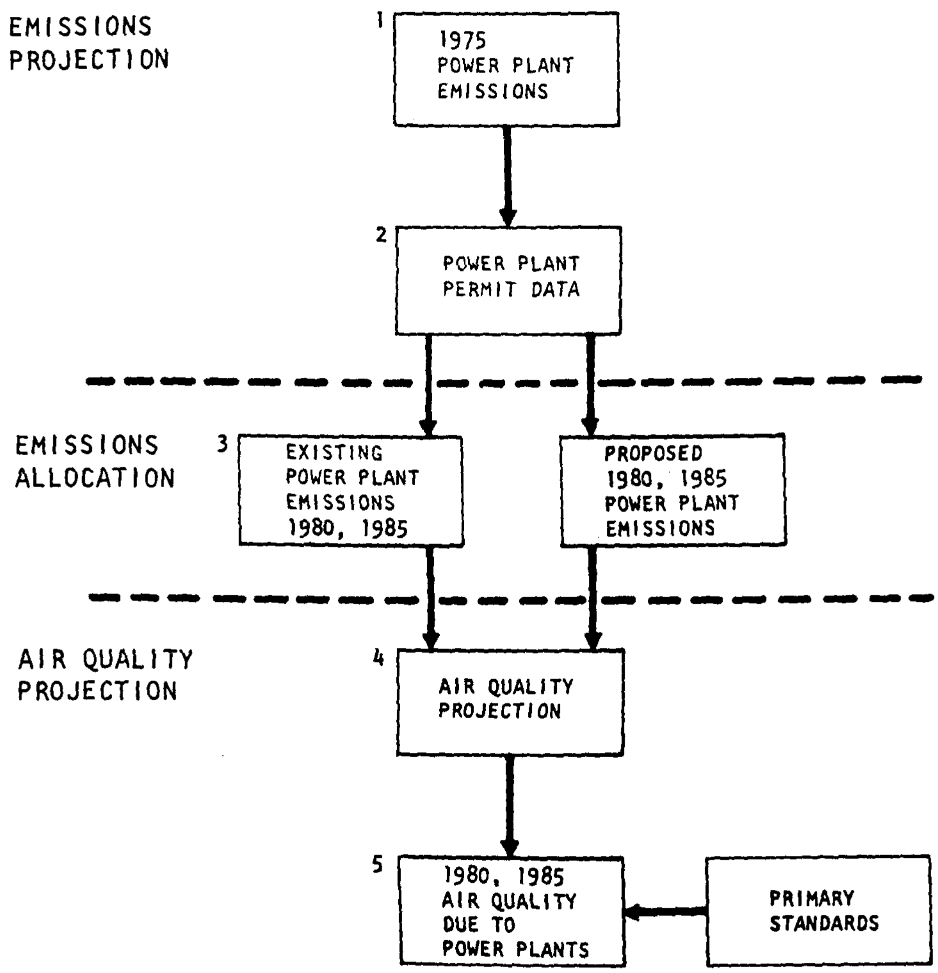
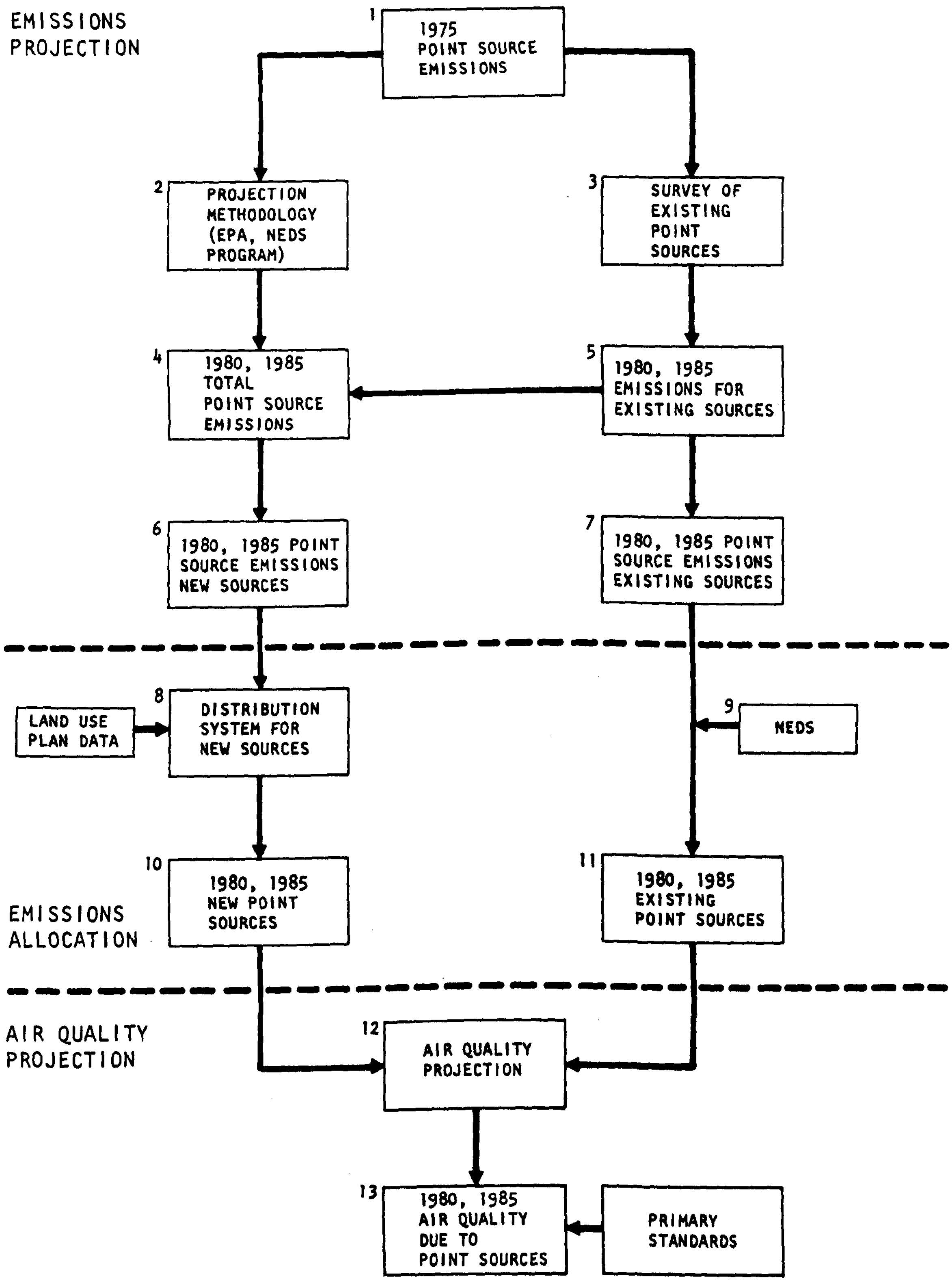


FIGURE A-4
POINT SOURCE EMISSIONS AND AIR QUALITY



will be based on industrial growth statistics by source category (such as SIC code or SCC code). For plan preparation purposes, the total emissions must be separated into at least the following categories:

- Existing sources - current (1975)
- Existing sources and growth at existing sources (1980, 1985)
- New sources (1980, 1985)

Therefore, a survey procedure is suggested (Steps 3, 5, 6, and 7) to determine the expected growth at existing sources.

<u>Steps 3, 5, 6, and 7</u> - Survey existing sources to determine the following:

- Existing operating capacity
- Existing operation as a percentage of maximum existing operating capacity
- Expansion plans (next 10 years)
- Control plans
- Opinion of possible growth of this particular industry type in the area and where in the area (county) the resources are available to support such a new facility

The Plan Revision Management System (PRMS) has a software package which will sort the National Emissions Data System (NEDS) inventory data for an AQCR to determine those sources which contribute 80 to 90 percent of the total emissions for a given pollutant. This list can be further sorted by county and source type (SIC code or SCC code) to provide a list of existing significant sources to be surveyed. Experience with several AQCRs for which such lists have been compiled indicates that there are probably no more than 30 to 50 such sources for any one pollutant in an AQMA and probably no more than three to five such sources for any one county. Therefore, it appears feasible to perform such a survey within the time constraints of AQMA plan preparation. It is recommended that a local planner or regional planning agency perform the actual survey. Item 5 of the survey will then assist the planner in distributing the new sources as proposed in Step 8.

Items 1 to 4 of the survey can be used to estimate the fraction of the total emissions (from Step 4) which are due to existing sources and their attendant growth. This can be subtracted from the total projected emissions (Step 4) to obtain the new source emissions (Step 6).

Steps 8 to 11: Emissions Allocations - The existing point sources and their attendant growth (Step 7) can be located by referencing the NEDS Inventory (Step 9). The stack parameters associated with each source should be retained (see NEDS) for input to the air quality projection model (Step 12).

The "new source" emissions (Step 6) can be distributed by one of the following methods using the survey results (Step 3) and land use plan data or techniques:

a. A weighting system that evenly distributes the emissions among those industrial zones (see county zoning plans) which in the opinion of the survey and the regional planning agency would be most likely to attract new manufacturing.

b. A weighting system that evenly distributes emissions based on an "industrial growth plan." Some urban areas, for example Philadelphia, have prepared industrial growth plans to encourage new development in the most "appropriate" areas. Such plans may be used to locate new sources if it appears reasonable to the planning agency.

c. An informal emissions allocations procedure further restricting the location of significant sources to those "most probable" location areas in (a) and (b) above not projected to be significantly close to the standards levels before inclusion of the new source emissions. The basic assumption behind this allocation procedure is that new sources will not be allowed to locate in an area such that the provisions of the AQMP will be violated.

The rationale for distribution of emissions using this system would be as follows:

New point source emissions will be a small fraction of the total emissions contributing to the ambient concentrations in the area. New source performance standards will control the amount of emissions from any one source and will discourage the location of "heavy polluters" in urbanized areas. If total point source emissions are projected by source category in a county and the projected emissions of existing sources is subtracted from this total by source category, the residual emissions (those due to new point sources) will indicate the amount of new source emissions which could come from any one source within that category. For example, if SO_2 residual emissions for the SIC code containing sulfuric acid plants is greater than the allowable emissions process weight curve, there will be more than one new source of SO_2 to locate in the county. An examination of the planned industrial areas in the county which would have the facilities to support a new, major SO_2 source would probably reveal that no more than two or three sites could possibly support a new "heavy industry" of this source type. The concentration isopleths for all area sources, power plants, and existing point sources should be superimposed to produce the concentration pattern "due to all sources except the possible new significant source(s). All areas within a given percent the standards could be identified as "potential problem areas." Two conditions could then be evaluated the "most probable" and the "worst-probable" case.

The "most probable" case would be that the new sources will not be placed in any potential problem area. The emissions could then be evenly distributed to those sites which are not in problem areas. The "worst-probable" case would be to allocate the emissions to one or more problem areas and determine if the standards will be exceeded. If the standards are exceeded by this case, the AQMP could provide a control to prevent the growth from occurring at this location.

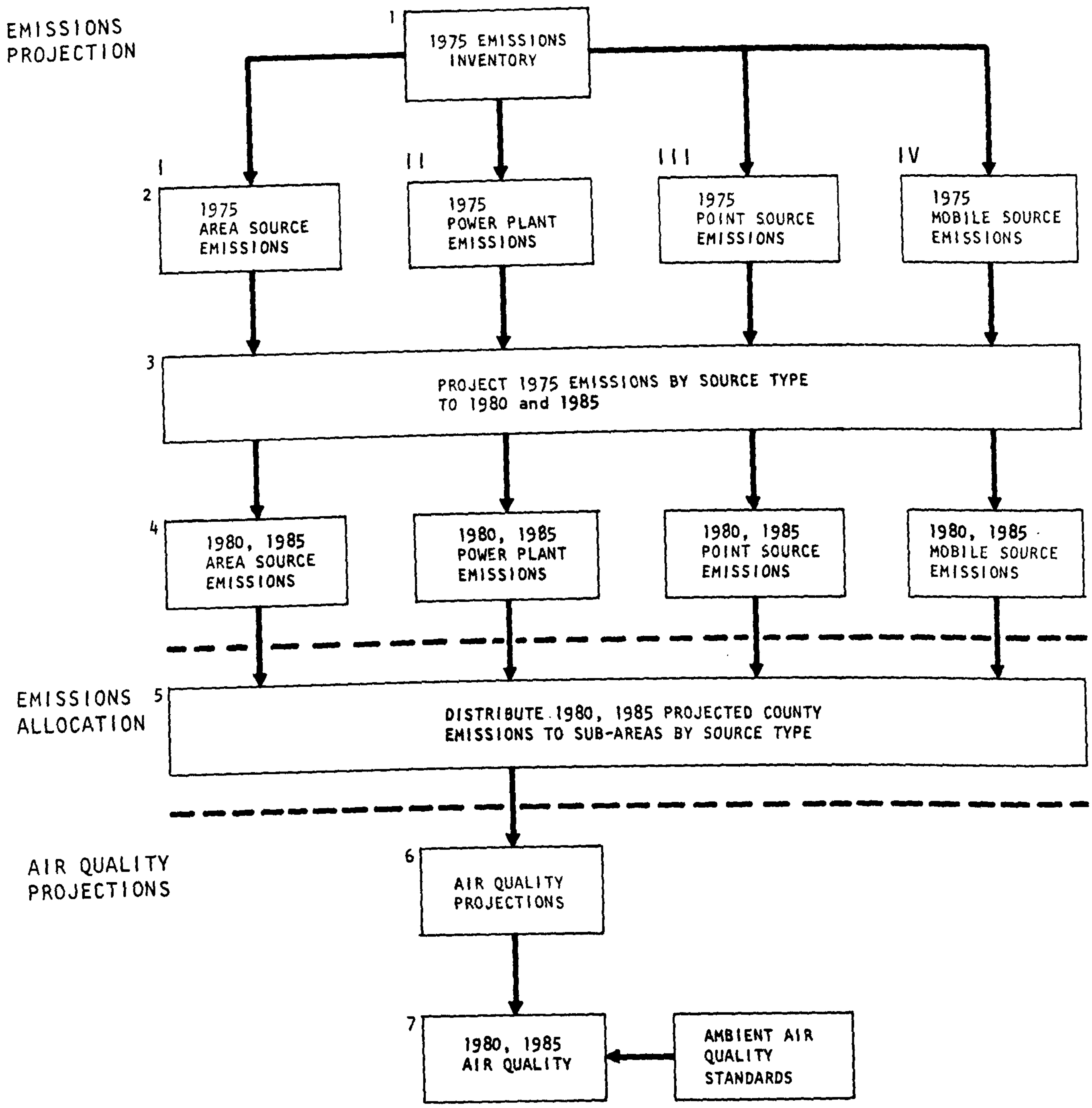
Steps 12 and 13: Air Quality Projection - It may not be desirable or necessary to complete the detailed emissions allocation procedures in Steps 8 through 11 above if new point source emissions are insignificant. The total point source emissions (Step 4) and the simplified distribution system for new sources could be used as input to an air quality model.

2. Carbon Monoxide, Hydrocarbons, Oxides of Nitrogen and Photochemical Oxidants

Figure A-5 illustrates the steps of the Methodology for Emissions Projection and Allocation of Carbon Monoxide, Total Hydrocarbons, Oxides of Nitrogen and Photochemical Oxidants. The initial designation criteria implies that most AQMAs designated for any of these pollutants will be Transportation Control Plan (TCP) AQCRs. It is also assumed by the definition of a maintenance plan, that the TCPs will be able to meet the standards by the 1975 or 1977 attainment dates. In the transportation control plan AQCRs, mobile sources of these pollutants currently account for 60 to 90 percent of the total emissions of CO, HC, and NO_x. Therefore, a fourth source type category projection and allocation scheme is added to the methodology requirements. However, area sources, power plants, and points sources are still retained as significant sources of emissions.

If CO standards are met by 1975 or 1977, then they will not be exceeded by 1985 on a regional basis. This hypothesis is based on a comparison of the emissions control curve, which shows an 80 to 90

FIGURE A-5
CARBON MONOXIDE, HYDROCARBONS
AND OXIDES OF NITROGEN
1980, 1985
EMISSIONS AND AIR QUALITY



percent reduction in vehicle emissions between 1980 and 1985, and the maximum regional growth estimates for any urban area ($\sim$5 percent).

These pollutants may exceed the standards in sub-AQCR areas where urban congestion and/or traffic congestion is projected to occur at levels exceeding the regional growth rates.

If mobile source emissions are reduced by between 50 and 90 percent of their baseline (1970-1972) emissions levels, and coincidentally, area source or stationary source emissions are not controlled, these secondary source types may represent between 30 and 60 percent of total emissions by 1980 or 1985. Therefore, problem areas within the AQMA may represent mobile source congestion, or uncontrolled stationary source growth, or a combination of source problems.

The emission projection and allocation methods for area, point, and power plant sources above are still applicable. However, since the standards for CO and oxidants and the guidelines for hydrocarbons are short-term values, the air quality projection steps must incorporate a means of relating the annual emissions and/or concentrations to short-term values. This may require that the emissions projections be converted to short-term (i.e., for CO--1-hour and 8-hour, and for hydrocarbons--6:00 to 9:00 average values).

a. Mobile Source Emissions -- In the discussion above it was noted that problem areas due to mobile source emissions will be found only where congestion or unaccounted for growth occurs. This is due to the significance of the speed factor which increases greatly as low average speeds or congestion is approached. This indicates that mobile source problems will be "hot-spot" problems. The data base and allocation methodologies must be capable of determining these "hot-spots." In most cases, the data base and projection techniques are available to perform these evaluations, however, it is likely that the techniques are too costly and time consuming to be performed within the timeframe for air quality maintenance and plan development.

In the following discussion of methodology some simplified techniques are suggested for obtaining the required projections, however, the assumptions upon which the analysis is based should be carefully considered.

It is recommended that these assumptions be reviewed on an annual basis and should they become invalid, the AQMP should be flexibile enough to incorporate these changes.

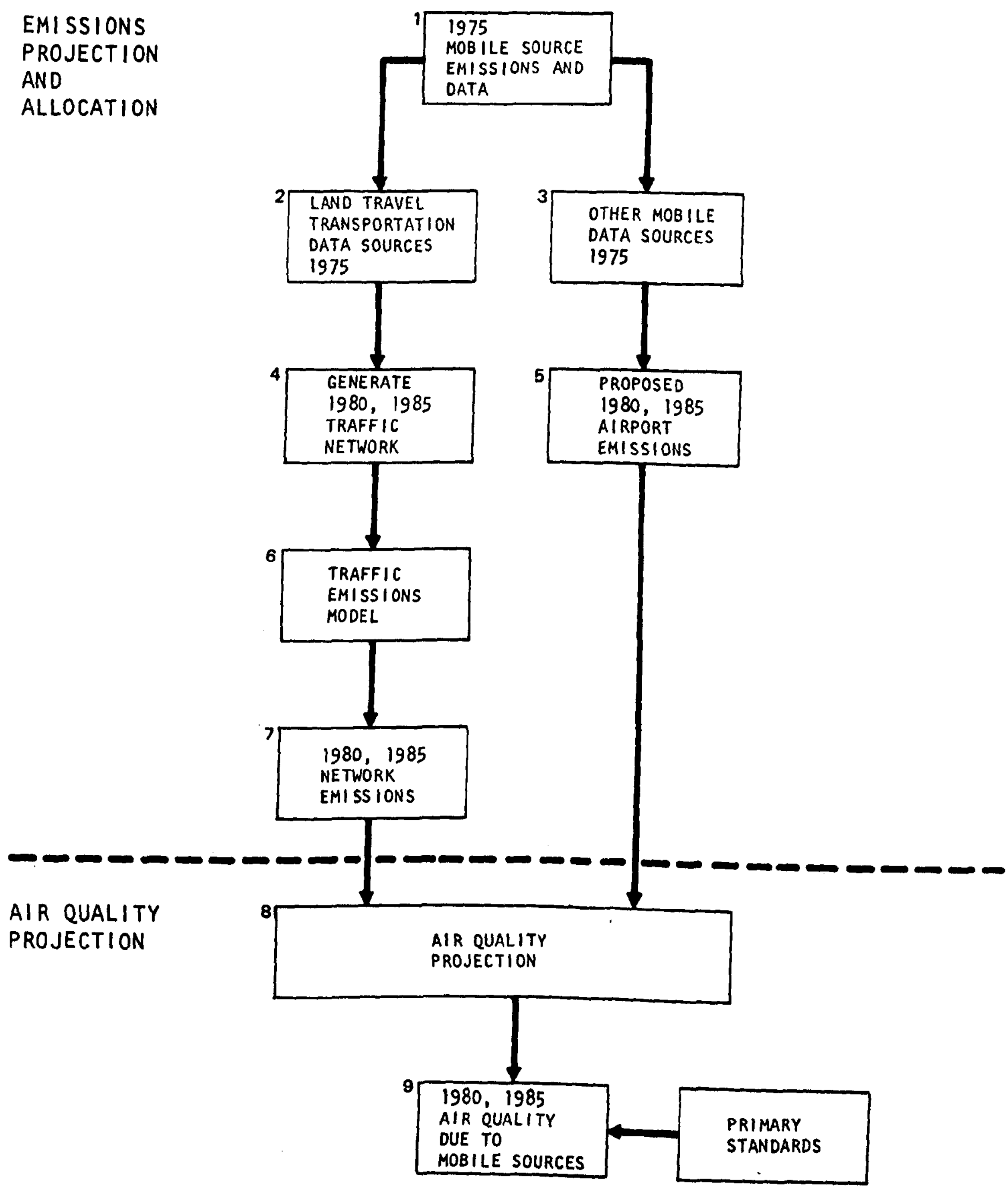
Figure A-6 illustrates the steps of the basic concept of the Mobile Sources Emissions Projection and Allocation

Steps 1 to 3 - The mobile source inventory should be available in Appendix C format (40 CFR 51) for all transportation control plan areas. This inventory must be allocated to the AQMA(s) and divided into motor vehicle emissions and other mobile source emissions such as airports and significant centralized transportation systems.

Step 4 - In all AQMAs that exceed the population of 50,000, a 3-C transportation plan is available in some form. The data available in these plans is discussed in detail elsewhere in this report. The significant data element of this plan for vehicle emissions is the traffic network assignment. In order to accurately assess the "hot-spot" problems, the detailed network assignment for the year of interest must be obtained. This may not be available and some method of interpolation between available data and the year of interest must be used. However, linear interpolation would not be reliable between, for example, a 1970 network and a year 2000 network because of the change in distribution pattern expected. A procedure for obtaining an approximation for the year of interest is as follows:

FIGURE A-6

CO, HC, AND NO_X
1980, 1985 MOBILE SOURCE EMISSIONS
PROJECTION AND ALLOCATION PROCEDURE



- Obtain the network assignment which most closely relates to the year of interest

- Request the 3-C transportation agency to determine whether sketch planning techniques or macro-level analysis techniques could be used to estimate the changes in the network to the level of accuracy desired for analysis. At the regional level, the following tools have been utilized to estimate macro-scale changes:

  - "A Methodology for Estimating Macro-Level Travel Demand in Baltimore Metropolitan Area" - a method presented for calculating regional VMT for a number of transportation actions. The results indicate that the greatest change in VMT is brought about through restraints and non-capital intensive actions. The tool was developed for EPA, working cooperatively with the 3-C process in Baltimore.

  - "CAPM (Community Aggregate Planning Model), Federal Highway Administration, unpublished report (1973)," - a method of calculating regional VMT given an estimate of vehicle trip end density, arterial and freeway spacing, and speed limits. The calculations can be done by hand, but a computer program is available to do the work in a few seconds. The tools have been used in a few urban areas. There are some problems with the mode choice component of the model.

- If the sketch planning techniques are not appropriate, request the 3-C planning agency or other professional familiar with both the regional characteristics and the tools to be applied, to prepare a link-node assignment for the year of interest, suitable for input to an emissions or air quality model.

Step 5 - Project the airport emissions for the year of interest using the land use plan or current information available from the 3-C planning agency, such as the FAA grant application.

Step 6 and 7 - Several emissions models have been used to calculate emissions directly from network data. These include the APRAC 1A (SRI model) and the SAPOLLUT model (which is not part of the Federal Highway

Administation (FHWA) program battery). The TASSIM study which was reviewed for its utility in this methodology is described in Appendix C. This study method simplified the traffic network before calculating emissions. The assumptions inherent in this simplification may greatly affect the accuracy and spatial distribution of emissions resulting from its application. However, TASSIM is readily available and fairly simple technique to apply.

Step 8 - Air quality projection techniques are available for carbon monoxide and include such models as APRAC 1A (SRI), Gifford-Hanna, and TASSIM. Other modeling techniques are currently under review by EPA and will be described in the guidelines for analysis.

Air quality projection techniques for reactive hydrocarbons, NO_x, and photochemical oxidants are poorly defined at this time and are not available for subarea analysis. The forthcoming EPA guidelines will provide some interim method for analysis until the current studies of these reactive pollutants are available and generally applicable. Regionwide rollback of total hydrocarbon emissions appears to be the only available technique for oxidant and NO_2 evaluation.

APPENDIX B

A REVIEW OF THE STATE-OF-THE-ART QUANTIFYING THE RELATIONSHIP OF LAND USE AND TRANSPORTATION TO AIR QUALITY

A REVIEW OF THE STATE-OF-THE-ART QUANTIFYING THE RELATIONSHIP OF LAND USE AND TRANSPORTATION TO AIR QUALITY

A. REVIEW OF RELATED STUDIES

If the process for relating land use and transportation plans to air quality is to be used to prepare or evaluate the air quality maintenance plans, all of the techniques and data required to provide the information described above must be available and generally applicable. A review of several studies or models that have attempted to relate land use and/or transportation plans to air quality was performed to determine the utility of the study techniques or results to the preparation of air quality maintenance plans. These studies include:

- The Hackensack Meadowlands Air Pollution Study (Environmental Research and Technology)
- Air Pollution/Land Use Planning Project (Argonne National Laboratories)
- A Report on Guidelines for Relating Air Pollution Control to Land Use and Transportation Planning in the State of California (Livingston and Blaney)
- The Transportation and Air Shed Simulation Model (TASSIM) Reports, DOT-OS-30099 and SOT-OS-20099-4, March 1974. (Harvard University)
- The Baltimore Regional Environmental Impact Study (BREIS), March 1974)

The Hackensack Meadowlands Air Pollution Study was developed by Environmental Research and Technology, Inc., to provide a general methodology for considering air pollution in the formulation and evaluation of alternative urban plans and applied the methodology to alternatives developed for the New Jersey Meadowlands area. The Air Quality for Urban Industrial Planning (AQUIP) model was developed; this model uses a set of submodels requiring detailed data for land use, emission factors, meteorology and ambient air quality.

The Air Pollution/Land Use Planning Project was completed by the Argonne National Laboratory. The objective was to investigate the utility of various land use parameters in describing the air quality impacts of land use plans, using the Chicago region as a test. The tests were made for manufacturing and residential/commercial land uses.

Guidelines for Relating Air Pollution Control to Land Use and Transportation Planning in the State of California were developed by Livingston and Blaney. The purpose was to integrate the goal of achieving and maintaining air quality with the land use and transportation planning process in California metropolitan regions. The primary concept is one of allocating allowable emissions to subareas within air basins.

The Transportation and Air Shed Simulation Model (TASSIM) was developed at Harvard University. The study was designed to develop a model that would integrate existing urban transportation models, vehicle emissions factors, and a simple air diffusion model to analyze air quality effects of various transportation policies. The model was applied and calibrated in the Boston area, using a district level "spider" network, representing the average characteristics of the facilities represented by the network.

The Baltimore Regional Environmental Impact Study (BREIS) evaluated the environmental impacts of the proposed urban interstate highway system in the City of Baltimore. All environmental analyses were performed including air quality. The study was performed by Alan M. Voorhees and Associates, Inc. for the Interstate Division of Baltimore City.

The review of each of these studies is given in Appendix C of this report. In general, no generally applicable model or technique is available that will meet all of the information requirements discussed above. The models or studies listed above could serve as a core to a community specific process or model. However, all such models require extensive data bases which are not generally available.

B. SUMMARY AND CONCLUSIONS

The review of the studies and methodologies listed above, and the techniques described suggest the following conclusions regarding the state-of-the-art in relating land use to air quality and its application to air quality maintenance planning:

1. General Conclusions

a. Land use can be quantified. However, the available techniques require detailed area-specific data bases.

b. Procedures do exist for the conversion of detailed land use and activity data to pollutant emissions. However, the procedures are specific to the study area for which they have been generated and the results imply that these procedures would need to be developed on an area-specific basis.

c. Data allocation procedures do not exist for disaggregating pollutant emissions data. However, the disaggregation of projected (long-term) pollutant emissions is dependent upon detailed land use and activity data that may not be available.

d. Several procedures exist to relate land use and/or transportation data to air quality. However, they are specific to the area for which they have been developed and would require considerable effort to develop the required data bases in other areas.

e. No generally applicable procedure currently exists for projecting the long-term air quality impact of land use within the level of detail and accuracy required for the preparation of air quality maintenance plans.

2. Emissions Calculations

a. Techniques are available to calculate emissions given detailed process data for each source.

b. Techniques are not readily available or generally applicable for converting land use or activity data directly to the process data necessary for emissions calculations.

3. Emissions Projections

a. Short-term (1 to 5 years) emissions projections techniques assume little or no change in past trends. Application of any of these techniques requires careful consideration of the assumption and generalities used to simplify the techniques in order to interpret the results.

b. Long-term emissions projection techniques are available for projecting regionwide emission totals, given a detailed existing emissions inventory and reasonable regional growth factors. However, existing long-term growth factors are not accurate indicators of the change in emissions and should only be used as "indicators" of a possible problem.

c. Long-term projection techniques for traffic and transportation network data are available that given the geographic detail necessary to show significant carbon monoxide problem areas within an AQMA due to these mobile sources. However, these techniques are very costly to implement and require detailed data base development that may include land use and activity projections (Land Use and activity projection models are referenced in Appendix C).

d. Long-term emissions projection for small area (sub-county) for stationary sources (other than power plants) is dependent upon detailed knowledge of the future location of specific sources. These specific data are not currently available.

Assumptions can be made to estimate the probable location of future stationary sources within the AQMA; however, emissions projections based on these assumptions would not be sufficiently accurate to make subarea planning decisions without careful surveillance and evaluation of these assumptions as new information becomes available. These emissions projections could be used to indicate possible or "most probable" problem areas.

4. Air Quality Diffusion Models

a. Diffusion models are currently available to project carbon monoxide (CO), total suspended particulates (TSP) and sulfur dioxide (SO_2) for any geographic levels of detail for which emissions data are available. The accuracy of these projections is dependent upon (1) the accuracy of the emissions data, ambient air quality, and meteorological data used to calibrate and validate the given model and (2) the degree to which the area topographic and meteorological characteristics fit the model assumptions.

b. Diffusion models are not currently available to represent the air quality concentrations of any of the secondary pollutants such as reactive hydrocarbons (HC), nitrogen oxides (NO_x) and oxidants (O_x).

The state-of-the-art in emissions projections and air quality projections are summarized in Tables 2 and 3, respectively. It is noted that microscale emissions and air quality projection techniques are dependent on the ability to project growth at that level of detail.

TABLE 2

STATE-OF-THE ART SUMMARY

EMISSIONS PROJECTIONS TECHNIQUES

	Level of Detail or Geographic Scale								
	Microscale			Subarea			AQMA (or regional)		
Pollutant-Source	N	S	L	N	S	L	N	S	L
CO-Mobile	x	x	?	x	x	x	x	x	x
CO-Stationary	x	x	?	x	x	?	x	x	x
HC-Mobile	x	x	?	x	x	x	x	x	x
HC-Stationary	x	?	o	x	x	?	x	x	x
NO_x-Mobile	x	x	?	x	x	?	x	x	x
NO_x-Stationary	x	?	o	x	x	?	x	x	x
TSP-All	x	?	o	x	x	?	x	x	x
SO_2-All	x	?	o	x	x	?	x	x	x

N--Now (1975)

S--Short term (to 1980)

L--Long term (to 1995 or beyond)

o--Not available

?--dependent on detailed data base projection

x--currently available

TABLE 3

STATE-OF-THE ART SUMMARY

AIR QUALITY PROJECTION TECHNIQUES

	Level of Detail or Geographic Scale								
	Microscale			Subarea			AQMA (or regional)		
Pollutant	N	S	L	N	S	L	N	S	L
CO	X[3]	X[3]	X[3]	X[2]	X[2]	?	X[2]	X[2]	X[2]
HC	0	0	0	0	0	0	X[1]	X[1]	X[1]
NO_x	0	0	0	0	0	0	X[1]	X[1]	X[1]
O_x	0	0	0	0	0	0	X[1]	X[1]	X[1]
TSP	X	X	?	X	X	?	X	X	X
SO_2	X	X	?	X	X	?	X	X	X

[1]Proportional models, i.e., roll back or roll forward

[2]Subarea and microscale models--Gaussian models, statistical models, climatological models, etc.

[3]Microscale CO--Line source models, etc., dependent on traffic assignment projection data.

N--Now (1975)

S--Short term (to 1980)

L--Long term (to 1995 or beyond)

0--Not now available

?--Dependent on data base availability

X--Currently available

APPENDIX C

REVIEW OF SELECTED STUDIES RELATING LAND USE AND TRANSPORTATION TO AIR QUALITY

I. THE HACKENSACK MEADOWLANDS AIR POLLUTION STUDY -- ENVIRONMENTAL RESEARCH AND TECHNOLOGY, OCTOBER 1973.

A. Study Purpose and Scope

The purpose of this study was to (1) develop a general methodology for considering air pollution in the formulation and evaluation of alternative urban plans; and (2) to apply this methodology to the planning alternatives developed for the New Jersey Hackensack Meadowlands District. In addition, a planning guidelines document was produced to enable urban planners to introduce air pollution considerations into the planning process.

B. Analytic Techniques

The Air Quality for Urban Industrial Planning (AQUIP) System developed and applied in this study consists of a set of submodels or routines that perform the following:

- Preparation of input data descriptive of land use or transportation plan
- Conversion of these data into pollutant emissions data.
- Prediction and display of mean ambient pollutant concentrations within the area of interest.
- Evaluation and ranking of the plan with respect to other plans through analysis of air quality contours and the computation of quantitative measures of impact.

Utilizing these submodels and techniques, the following can be evaluated:

- The compliance with ambient air quality standards
- The impact of regional air quality levels

- The degree of impact in specific receptors or land use categories that are especially sensitive to the effects of pollutants

- An indication of ways to modify the plan(s) to improve air quality

LATRAN is the submodel which processes the land-use and transportation data. The data are independent of grid size and land use is allocated by geographic coordinates and land use zones. Activities are designated as point source, line source, or area source generators for input to the dispersion model. Land use activity and intensity data are converted to emissions using a set of conversion factors, emission factors, and activity parameters based on data specific to the Hackensack plan. A set of default parameters was also developed (specific to Hackensack data) for use when data is missing or incomplete. The air quality dispersion model used (MARTIK) to convert these emissions to air quality is a modification of Martin and Tikvart as used in the Air Quality Display Model (AQDM). The modifications were made to improve accuracy and to treat line sources directly. Approximation techniques were used to save computer time. The SYMAP software was used to display the model output. This displays concentrations as intensity shadings across the area of interest.

The air quality impact subroutine then performs the following comparisons on a pollutant-specific basis based on the output from MARTIK:

- Compare maximum concentrations to ambient air quality standards (AAQS).

- Determine percentage influence of background concentration of total air quality within each plan.

- Determine the "average" regional air quality.

- Determine the "average" exposure of critical receptors and land use categories to pollutant concentrations for the average or worst meteorological conditions.

C. Model Application

The sample analysis was performed for the Hackensack Meadowlands Planning District, a four by eight mile area near the densely developed lower Manhattan area. Four plan alternatives for 1990 were evaluated and ranked. The pollutants evaluated were TSP, SO_2, CO, HC, and NO_x for annual, summer, and winter averages. The analysis was for regional impact only (microscale impacts were beyond the scope). The sample analyses concluded that:

- The background concentration contribution for the Hackensack area was so significant that land use planning on a regional scale would be ineffective for abatement of regional air pollution levels.

- The analysis of impact of alternatives showed significant difference among spatial patterns due to:

  - Percent mix of land use
  - Relative location of land use activities
  - Relative intensity of land use activities

  The observed spatial differences were especially sensitive to the percent mix of manufacturing and transportation related land use.

- Percentage open-space did not have a significant impact on regional air quality.

D. Conclusions and Recommendations

The application results were evaluated and a guidelines document was prepared that can be "generally applied to the land use and transportation planning process for the consideration of air pollution" in ranking alternative plans. The guidelines should be applied to other planning situations only for consideration of regional scale air quality. Detailed analysis would require the application of the complete AQUIP system and the development of the associated detailed data bases.

Some general conclusions resulting from the analysis are:

- It is important to evaluate and rank plans on the basis of pollutant concentration rather than emissions because:

  - Air quality standards are related to concentration levels.

  - Meteorological conditions are critical in determining capacity of a region to assimilate local source emissions (i.e., to determine conditions under which planned land use developments will exceed or comply with AAQS).

  - Meteorology is critical in determining levels of background pollutant concentrations transported into and out of the planning region.

- Regional air quality considerations are good for making broad estimates of the relative air quality impact of alternative plans but are totally insufficient for the level of detail required to form the basis for evaluating subarea planning alternatives.

- Regional scale air pollution considerations are not applicable to the explanation or solution of microscale problems (i.e., CO over short time periods and small distances is more likely to be determined by localized influence or short-term extremes in meteorological conditions).

- The regional scale air pollution considerations are appropriate within the planning process to improve regionwide air quality and reduce exposure to the general population and high risk groups within the general population to high concentrations.

- If total concentrations do not exceed AAQS and if the variation in total regional impact among plan alternatives is less than 15 percent, the planner can be neutral in the choice of a plan with regard to regional air quality considerations.

- If background air quality concentrations exceed 60-70 percent of total regional concentration, land use planning is not an effective abatement strategy for regional problems.

- Plan design factors having a primary influence on regional air quality concentrations and spatial pattern are:

- Percent mix of land use (manufacturing and transportation dominate)
- Location of land use
- Intensity of land use (clustering)

- Local topographic and meteorological conditions have a major influence on air quality patterns.

The following recommendations for further study were made by ERT based on the results of the study:

- Refinements in emissions data, especially activity indices and projection indices, are required.
- Further development of default parameters is needed.
- Further calibration of the air quality model (MARTIK) is required. Meteorological effects studies are needed for model validation.
- A software interface between AQUIP and the computerized data base of air pollution agencies is needed.
- "Rapid estimation techniques" for evaluation and ranking of plans need to be refined.
- Extend AQUIP to the microscale.
- Perform sensitivity analysis and development guidelines for impact.
- Air quality needs to be examined in relation to other environmental and planning issues, (i.e., water quality, solid waste, cost/benefit, etc.).

E. Data Requirements

To complete the entire AQUIP sequence, detailed land use intensity or activity, emission factors, meteorological and topographic, ambient air quality, and conversion of default parameters are needed. Accuracy is greatly reduced as any of these data are missing.

F. Model/Calibration

Existing ambient air quality and meteorological data were used to develop simple ratios of existing to projected data to calibrate the model. Where meteorological or topographic conditions vary significantly from the Meadowlands conditions, the model would require extensive recalibration.

G. Model or Study Status

AQUIP is operational for the Hackensack planning region only and is currently operational on the ERT computer only.

H. Applicability to Other Areas

Based on the characteristics of the Hackensack land use plans, the following can be said: (1) some new routines would be required to reflect the appropriate planning assumptions of new planning development. However, the overall AQUIP procedures and subroutines are sufficiently general to be applied wherever data are sufficient to operate them, (2) the explicit quantitative results are less generally applicable as they are representative of the meteorology and topography of the Meadowlands. Any variation from these conditions must be considered; and (3) AQUIP can be used as a projection tool as well as a diagnostic tool, (i.e., it can be used to evaluate strategies).

II. A REPORT ON GUIDELINES FOR RELATING AIR POLLUTION CONTROL TO LAND USE AND TRANSPORTATION PLANNING IN THE STATE OF CALIFORNIA

A. Study Purpose and Scope

The study purpose was to prepare guidelines for integrating the goal of achieving and maintaining air quality with the land use and transportation planning processes in California metropolitan regions. The initial idea was to develop guidelines for preparing air pollution elements in local general plans. However, this idea was dismissed because of the regional nature of the air pollution problem resulting in several technical and administrative problems. Instead, a combination regional/subarea approach to integrating air quality goals into the planning processes was suggested as a solution.

The process consists of six steps: (1) compiling detailed inventories of air polluting emissions in subareas of air basins, (2) designating maximum emissions allowable in each subarea, (3) project subarea emissions likely to be generated by sources indicated in land use and transportation plans for future years, e.g., 1985 and 1995, (4) evaluate and revise the plans so that the maximum emission limits are not exceeded, (5) adopt and implement the plans, and (6) monitor public and private development through a refined environmental impact assessment process. The key to the process is the concept of allocating allowable emissions to subareas within air basins. The premise is that the emission limits will be set up so that air quality standards will be met if plans and projects conform to the limits. An appeal process is suggested to allow deviations in those cases where technical information is available to ensure that air quality standards will not be violated.

B. Analytic Techniques

1. Land Use Model

- At least three sectors of land use would be modelled: manufacturing, residential, and commercial.
- Land use inventories and projections by planning subarea would be required.
- Useful source variables to be inventoried and projected as far as possible are: acreage, residential density, employment density, nature of uses, production level, fuel consumption, location with respect to transport facilities, and other physical or socioeconomic variables, as well as amounts of emissions.

2. Data Allocation or Disaggregation Technique

- The analyses proposed for this study are geared to a planning subarea basis, so data would be allocated or disaggregated by planning subarea.

- No grid with receptor points is specifically mentioned, but might be used in the monitoring process which is suggested.

- Land use would be given in terms of acreage for use with emission density factors of emissions per acre in stationary source area source emissions calculations; no specific area size is mentioned in connection with mobile source area source emissions calculations.

3. Previous Emissions Inventories

- Existing inventories for counties and air basins are too general for detailed air quality planning; suggests that Basin Coordinating Councils compile planning subarea emissions inventories.

- Five major pollutants covered in 1970 inventories: organic gases, particulate matter, oxides of nitrogen, sulfur dioxides, and carbon monoxide.

- Four source groupings used in breakdown of emissions by source in 1972 inventory: process losses, fuel combustion, waste disposal by burning, and mobile sources classified by point and area sources.

4. Emissions Inventory Development -- The study suggests that total emissions inventory be composed of three separate inventories: (1) point sources, (2) stationary source area sources, and (3) mobile source area sources. Point sources are defined as any stationary source that emits more than 100 tons per year of any pollutant within an urban place with a population over one million or more than 25 tons per year in a less populated area (high emitters). Area sources, all other stationary sources (low emitters), are aggregated on an area basis; mobile sources, also treated on an area basis, are aggregated on an area basis.

- Point Sources:
  - Point sources emissions inventory information can be obtained directly from emissions data or indirectly using standard emissions factor on source parameter data collected by previous inventories and disaggregated by planning subareas.
- Stationary Source Area Sources:
  - Emission density factors would be developed for various land use categories.
  - Development of emission density factors would be based on nature and intensity of land use data on existing sources; types of nature and intensity of land use data are: residential or employment density, nature and level of production, nature and level of fuel consumption, location with respect to transport facilities, and other physical and socioeconomic variables.
  - The emission density factors would be multiplied by acreage devoted to each existing land use in a planning subarea to get detailed stationary source area source emission inventories for planning subareas.
- Mobile Source Area Sources:
  - Emissions inventories by planning subarea would be derived by multiplying vehicle-miles traveled information by appropriate emissions factors.
  - Emissions factors for transportation systems have been developed already.
  - Vehicle-miles traveled information from transportation plans would be in link format and would have to be aggregated by planning subarea.
  - Separate calculations would be needed for the different modes (auto, bus, train, truck, ship, and aircraft).
- Total Inventory:
  - Total emissions inventory in each planning subarea would be determined by combining the three inventories.

5. Emissions Model:

- Emissions model consists of the methodology used in developing the inventory.

- Future emissions would be projected for 1985 and 1995 based on current or modified emission or emission density factors and projections from land use and transportation plans of: (1) either point source emissions or source parameter data, (2) area source acreage by land use category, (3) vehicle-miles traveled.

- Modifications to emission factors would reflect future technology, changes in fuel usage, motor vehicle emissions controls, etc; modifications to emission density factors would reflect all of the above plus changes in nature and intensity of land use parameter distributions of future sources.

- Modifications of factors and projections would be made as new data becomes available.

- The National Emissions Data System is a computer program to facilitate emissions calculations for point and area sources; could be used after emissions inventory information is put into the necessary format.

6. Air Quality Model:

- No sophisticated validated air quality model is presently available to predict values in California air basins.

- The study recommends that the initial program use the proportional model with provisions for deviation from the model where technical information is available to ensure that ambient air quality standards not be exceeded by the proposed deviation; recommends usage of a more refined model for the continual program, if and when such a model (or models) is developed, calibrated, and validated for individual California air basins.

- The basic relationship of the proportional model is:

$$\frac{\text{Maximum Concentration of pollutant m base year in air basin}}{E_m \text{ base year in air basin}} = \frac{\text{Air quality standard m}}{E_m \text{ allowable in air basin}}$$

where:

E_m is the emissions of pollutant m; the output item is the E_m allowable in the air basin.

- The air quality modeling assumption implicit in the proportional model is that the worst ambient air quality concentrations in the air basin are roughly proportional to the total amount of emissions in the basin.

7. Air Quality Impact Model:

- The control method proposed is a proportional rollback of this form:

$$\frac{E_m \text{ in planning subarea in 1970}}{E_m \text{ in air basin in 1970}} = \frac{E_m \text{ allowable in planning subarea}}{E_m \text{ allowable in air basin}}$$

where:

E_m is the emissions of pollutant m; the output item is the E_m's allowable in planning subareas.

- The air quality impact modeling assumption implicit in the control method is that reducing emissions by a constant proportion in all planning subareas will result in roughly that proportion improvement in air quality to the region in general and to the worst concentrations in particular.

C. Application

The applications would be to the air basins of the State of California.

D. Study Recommendations/Conclusions

The study recommends a regional/subarea approach to integrating air quality goals into land use and transportation plans, rather than the development of separate air pollution elements to local general plans and regional transportation plans.

The study also recommends using the proportional model for modeling air quality and rollback as a control method, with provisions for allowing deviations from emissions limits where an adequate case can be made for the deviation not interfering with attainment or maintenance of air quality standards.

The study recommends separating stationary sources into high emitters and low emitters and treating the former as point sources, using point source emission factors, and the latter as area sources, using emission density factors. Mobile sources are treated as area sources, but emissions are based on emissions/VMT factors.

The study recommends using more refined models as they are calibrated and validated for California. Periodic updating of emission and emission density factors is also recommended.

E. Data Requirements

Land use plan parameters: covered under "Land Use Model" transportation plan parameters: vehicle-miles traveled, possibly speed and other traffic flow characteristics emission factors: point source emission factors based on process weight, energy consumption, etc. (available); emission density factors for low emitter stationary source area sources (need to be developed); emission factors per vehicle-mile traveled and possibly speed, by mode (available or soon to be available).

F. Validation or Calibration

The proportional model has so far proven to be as reliable as would be derived from a more complicated method. However, more refined models calibrated or validated for individual air basins in California would be desirable. Currently research is underway to develop such models in the San Francisco Bay Area, in the South Coast Air Basin, and in San Diego.

G. Model or Study Status

The study presents a set of recommended guidelines, application results have not been published.

H. Applicability to Other Areas

The guidelines recommended are applicable to any area.

III. THE TRANSPORTATION AND AIR SHED SIMULATION MODEL (TASSIM) REPORTS, DOT-OS-30099-3 AND DOT-OS-30099-4, MARCH 1974

A. Study Purpose and Scope

The purpose of this study was to develop a model that integrates existing urban transportation models, vehicle emission factors, and a simple air diffusion model to analyze the air quality effects of various transportation policies. The model was calibrated and applied for the Boston area, disaggregated into 122 subareas to simulate the air quality effects of various transportation controls, land use controls, and stationary source policies. The model structure and several model applications are described.

B. Analytic Technique

The TASSIM computer technique is composed of three separate programs, each of which have two or more sub-programs.

1. TASAQD Program -- The TASAQD program is a simplified version of the Air Quantity Display Model (AQDM) which models air pollutant concentrations in each subarea resulting from individual large point sources. The basic simplification is the substitution of a single typical stability class.

2. TASSIM Program -- The TASSIM program contains the following seven sub-programs.

- TRGEN - Forecasts total person trips made to and from each sub-zone. This submodel uses the trip generation equations and zonal land activity data typical to most urban transportation studies.

- TRIPAL - Uses the zonal productions and attractions developed by TRGEN and performs trip distribution, mode split and network assignment to a composite highway and transit district or "spider" network.

- EMIT - Calculates auto emissions based on the network assignments and speeds and combines them with non-mobile area emissions to produce air quality surfaces for the region and determines the frequency with which the Federal standards are exceeded in each of the subareas. The diffusion model used for mobile and area sources in this subprogram is a Gaussian vertical distribution (Honna-Gifford model).

- MODSPT - Adopts the mode split models developed in the urban transportation study to the district level composite highway and transit network to produce estimates of transit person and auto trips for various pricing, level of service, and control policies.

- TRPDST - Adopts the gravity model for person trip zonal distribution to the district level network.

- SKIMT and JAY - Calculates the interdistrict impedance using a modificaton of the "Moore" minimum path model. Highway only and combined highway-transit network interdistrict impedances are calculated and used as input to the mode split model.

- DIAL and DIALT - Assign transit trips to the transit subnet and uses a version of the parallel probabilistic assignment algorithm to assign auto person trips to the composite auto-transit network.

3. TASMAP Program -- The TASMAP program generates maps portraying the geographical concentrations or concentration changes using the data developed by the diffusion models.

C. Application

The models described above were calibrated for the Boston regional area and applied to test the effect on air quality by:

- Reducing vehicular emissions

- Applying various prohibition and licensing schemes to auto trips

- Increasing auto occupancy

- Reduction of transit fare

- Performance improvements of highway and/or transit systems
- Controlling urban development patterns
- Reducing stationary source emissions

The regional and subarea air quality for 122 subregions were evaluated for the total pollutants, TSP, SO_2, CO, HC, and NO_x, and the change in these pollutants with the various policies and system changes listed above.

D. Study Recommendations and Conclusions

The application for the Boston area permitted an analysis of a wide variety of factors that would affect the air quality. The TASSIM model contains submodels for trip generation, trip distribution mode split, assignment, composite highway and transit network representation, point source emissions, area source emissions and mobile source emissions, as well as a diffusion model. It also provides for analysis at the subarea level as well as the regional level. Because the model chain contains all submodels which are executed very economically in sequence, the effect of policy decisions on the entire model chain can be analyzed for a large number of policy considerations at the subregion as well as the regional level.

Some general conclusions resulting from the analysis were:

- It is very important to consider the total effect of localized air quality control policies since an improvement of air quality may occur in one subarea but may be reduced in other subareas.
- Reducing vehicle emissions to the level set forth in the 1970 Clean Air Act is an extremely effective technique for improving air quality in the metropolitan area.
- The spatial distributions of emissions, and not just the metropolitan-wide aggregate of emissions, must be considered in order to effectively evaluate the effects of individual policies or combinations of various policies.

- It is very difficult to generalize about the effectiveness of point source controls because the relationship between point source and concentrations vary widely due to the local meteorology, topography, and the location of large point sources.

- An evaluation of the cost and effectiveness of various policies indicate some of the control strategies analyzed produced small improvements in air quality at relatively large cost.

E. Data Requirements

To apply the TASSIM model requires:

- Subarea, interarea travel times and trip interchange

- Inventories of stationary emissions

- Meteorological parameters

- Vehicle emission rates

- Social-economic characteristics of the population for the calibration and application of the trip generation and mode split equations

- Person trip generation equations (usually developed as part of the transportation planning process)

- A "Gravity Model" trip distribution procedure. ("F" and "K" factors developed as part of many of the transportation planning process)

- A "Mode Split Model" to be applied to person trips distributed by the gravity model

F. Calibration

The models for trip generation, trip distribution, and mode split developed as part of the transportation planning process, were used with 1970 census land activity data and employment data, and the forecasted air quality compared favorably to the monitoring data collected in the area. If the trip generation, trip distribution, mode split models, interarea travel times, trip interchange, and inventory of stationary sources are available, the model could be calibrated for other metropolitan areas.

G. Model or Study Status

The TASSIM model is operational, and FORTRAN decks of the programs have been executed on an IBM 370/145 and 370/165.

H. Applicability to Other Areas

The TASSIM model is designed to use data and models developed by many of the urban transportation studies. If person-trip generation equations, gravity type distribution models, and post-distribution mode split models are available, the TASSIM model could be calibrated and applied. In some cases substantial modification would be required to the TASSIM model to accommodate the models generated by the transportation study. The model would be applied at a 100 to 200 subregion area level. These subregions would probably be combinations of the 600 to 1000 transportation planning zones to facilitate the model calibration data developed in the transportation study at the zone level.

The model uses a district level spider network in which all highway and transit facilities are represented by direct connection between district centroids. These "links" are encoded with average characteristics of all the transportation facilities they represent. For the mobile source emissions, the number of vehicles assigned to the link and the adjusted speed assigned to the link are used to calculate the emission of all facilities represented by this link. They are prorated to the two subareas connected by the link based on the square root of the area of the subregions. With this technique it is difficult to identify the unique characteristics of specific facilities and the effect traffic volume would have on the operating speeds of individual routes.

IV. AIR POLLUTION/LAND USE PLANNING PROJECT, PHASE II, FINAL REPORT, VOLUME II, ARGONNE NATIONAL LABORATORY, CENTER FOR ENVIRONMENTAL STUDIES, MAY 1973.

A. Study Purpose and Scope

The general purpose of the project was to examine relationships between air quality and land use guidance and control practices. The specific objective of the work was to investigate the utility of various land use parameters in describing the air quality impacts of land use plans. The Chicago metropolitan region was used as the test region.

B. Analytic Techniques

The methodology envisioned for predicting the air quality impacts of land use plans from various land use parameters, a part of which is investigated involved:

- A land use model to forecast growth or change in land use based on rates of change in land use, employment, and productivity for the different kinds of manufacturing land uses, changes in housing stock and population for residential land use, and changes in square footage of floor space for commercial land use.

- An emissions model based on either emission density factors (emissions per acre) or other emission factors to relate emissions to land uses.

- An air quality model to determine air quality levels in the region, assuming knowledge of quantity of emissions. The air quality model used was the Air Quality Display Model.

The work described examined the feasibility of developing useful emission factors for an emissions model. Only one pollutant was examined as a test case-particulates.

Separate analyses were conducted for manufacturing land use and for residential/commercial land use.

For manufacturing land use, two methods of developing emission factors were tried. The first method was to develop emission density factors. Four sets of emission density factors, based on mean, median, and "best fit" representations of source inventory data were tried. The usefulness of each set of emission density factors was determined by seeing how well the air quality representation obtained using the factors compared to the air quality representation obtained using the point source emissions data.

The second method was to test the feasibility of using some combination of the following parameters-number of employees, process weight, fuel consumption as well as acres of land-to forecast emissions of manufacturing activities. Linear regression was used as a method of analysis. Statistical tests such as correlation coefficients were used to judge usefulness of parameters for prediction.

For residential/commerical land use, the observation was made that for the test pollutant, particulates, that emissions were a direct function of fuel consumption and therefore, that it was sufficient to be able to predict fuel consumption. The land use parameter used for prediction of residential fuel consumption was mean energy use per dwelling unit, by dwelling unit category. The land use parameter used for prediction of commercial fuel consumption was mean energy use per thousand square feet by commercial size category. Analysis of variance was used to determine the breakdowns of dwelling unit categories and of commercial size categories that were significant.

C. Application

The test analyses were performed on data from the Chicago Metropolitan Air Quality Control Region. The primary data sources used were emission inventories collected by the City of Chicago and the State of Illinois Environmental Protection Agency and land use data on a square-mile basis collected by the Northeastern Illinois Planning Commission.

D. Conclusions

- None of the four sets of emission density factors tested predicted air quality deterioration from manufacturing land use sufficiently well. Thus, the emission density concept was rejected.

- One of the linear regression models tried to predict manufacturing emissions on the basis of number of employees and acres of land. As these two parameters are easier to predict or more likely to be predicted in most land use planning than the other two parameters being examined, the model was an effort to determine if they were sufficient to predict manufacturing emissions. They were not. The linear regression model based on all four parameters, however, was sufficent. An attempt was also made to see if number of employees and acres of land could be used to determine the other two parameters, process weight and fuel consumption. If the latter two could be determined from the former two, input would then be available for prediction of emissions from the four parameter model. However, the results were inconclusive.

- For prediction of residential emissions, the breakdown of dwelling unit categories that was determined significant was between light residential (less than or equal to twenty dwelling units per building) and heavy residential (more than twenty dwelling units per building). For prediction of commercial emissions, the breakdown of commercial size categories that was determined significant was between light commercial (less than or equal to 20,000 square feet per building) and heavy commercial (more than 50,000 square feet per building). Mean energy use per dwelling unit or per thousand square feet were determined for each category and were found useful predictors of emissions.

E.,F.,G. Data Requirements, Model Calibration, Model or Study Status

The Argonne project terminated before a methodology or model for predicting air quality impacts of land use plans from land use parameters was developed.

H. Applicability to Other Areas

The approach taken by the project is applicable to other areas. However, the specific research results for the emission model cannot be assumed applicable to other areas, as they reflect data specific to the Chicago region.

V. BALTIMORE REGIONAL ENVIRONMENTAL IMPACT STUDY (BREIS) -- ALAN M. VOORHEES AND ASSOCIATES, INC., MARCH 1974.

A. Study Purpose and Scope

The purpose of BREIS was to evaluate the regional environmental impacts of alternative land use and transportation policies in the Baltimore region. Several environmental analyses--air, noise, water, solid waste, socioeconomic, and traffic--were performed for a 1970 base year plus three 1980 alternatives and four 1995 alternatives for the highway system.

B. Analytic Techniques

The Urban Systems (USM) land use model was first used to determine regional development data for each of the alternatives. Next, a series of transportation models were used to determine trip generation, modal split, and traffic assignments for each alternative.

An emissions model was developed to calculate motor vehicle emissions by link and by trip ends (for cold start and hot soak emissions) from the output of the transportation models. Emissions of CO, HC, and NO_x were summed to the regional planning district level and further summarized by county and for the entire study area. Comparison of emissions from different alternatives indicated the effect of the highway system on automotive emissions and the trend in emissions over time (1970, 1980, and 1995).

Emission data for stationary sources and non-automotive mobile sources were obtained from available inventories. These were projected by a two-step procedure. First, controls that would be applied to individual point sources in the future and to area source categories were estimated. Then, the controlled emissions were increased by use of appropriate growth factors from the Urban Systems model data or U.S. Department of Commerce projections to account for growth. The two partial inventories were combined to show the differences in total emissions by alternative and the contribution of motor vehicle emissions in each case.

C. Model Application

For pollutants other than CO, maximum projected concentrations were simply estimated by proportional reduction with the emissions data. For carbon monoxide, the APRAC-1A urban diffusion model was used to determine maximum CO concentrations for each alternative. Areas of high suspected concentrations were found by using the grid-point version of that model. Then, receptor points were specified in the areas indicated by the grid-point version to have high background levels, and the synoptic version with the street-canyon subroutine was used to estimate maximum 1-hour and 8-hour concentrations alongside the major streets in those areas.

D. Conclusions and Recommendations

The results of this study have been used by Federal agencies to assess the regional impact of alternative land use and transportation policies. Because the traffic data was prepared at link level it has been possible to perform minor level CO analysis as well for assessment of highways at the project level. Further applications will be completed for the efforts of transportation control strategies and energy consumption. The local decisionmakers are utilizing the results to further evaluate alternative policies.

E. Data Requirements

The procedure applied in Baltimore served to update the 3-C transportation plan as well as to provide a regional environmental assessment. Thus, the activity allocation model and the travel simulation models required input data at the zonal level (approximately equal to 2-5 square miles) as part of the overall process. The air quality and other environmental assessments were conducted at a more aggregate level.

F. Model Calibration

The land use and transportation models were calibrated according to standard practice. The CO model was calibrated on limited receptor sites.

G. Model or Study Status

The BREIS study is essentially complete; however, ongoing analysis will further refine the data and the procedures.

H. Applicability to Other Areas

The approach is readily applicable to those areas that have a quantified land use model and/or a comprehensive update of the transportation modeling process. It can be used to evaluate alternative plans as well as incremental plan changes.

APPENDIX D

AIR QUALITY MODELS

AIR QUALITY MODELS

The following is a brief summary of the current state-of-the-art models that might be utilized. These can be broadly categorized as Emission Models and Dispersion Models.

1. EMISSION MODELS

Emissions models are usually simple in form. Their product often takes the form of emissions maps of the community which show pollutants, in terms of tons per day, discharged on a subarea basis. By this means, areas overburdened by pollution can be identified for purposes of abatement and avoidance of adding to an existing problem by appropriate planning and zoning measures.

Emissions modeling usually begins by surveying the various sources of air pollution within each subarea including stationary, mobile, refuse, and industrial combustion or evaporation loss sources. The volume of daily fuel burned or chemicals subject to evaporation processes is obtained. Research-produced emission factors are used which correlate the amount of pollutants produced per unit of fuel or chemical; they are multiplied times the above volumes to obtain the daily contaminant production. Pollutant tonnages from all sources are cumulated to discover the total weight of each pollutant being produced in the subarea. The final result is usually expressed in tons per square mile.

2. DISPERSION MODELS

Four major groupings of dispersion models are currently in use. The first type is a statistical model in which air pollution levels are correlated with an emission inventory and meteorological data for a given region. This type of model may be used for pollution-episode forecasting provided that there is ample data.

A second type is the "box model" in which the pollutants in a volume of air enclosed by a given area on the ground are assumed to be uniformly mixed. The concentration of pollutants within this box are then given by the rates of emissions at the ground area and transported by horizontal wind through the box. Transport by wind out of the box is air at the pollution concentration in the box. Transport by wind into the box is air at the pollution concentration of the neighboring box just upwind. This model has been used with some success for pollution predictions given a suitable emission inventory. Depending on resolution requirements, a region may be divided into several such boxes. Major problems are the assumption of uniform mixing with the box and the usual lack of knowledge of the altitude of the temperature inversion, if any.

The third, and currently the most popular, grouping is the Gaussian plume type. These models give the pollutant concentration as a normal Gaussian distribution in directions crosswise to the wind. The standard deviation for these distributions is provided as a function of travel time or distance from the source and the current meteorological conditions (especially wind speed, terrain roughness and the strength of incident solar radiation). Such distributions have been developed for point, line, and area sources (see especially the work of Pasquill, Gifford, and Turner). Such models are widely used for simple pollution calculations for single sources. More recently, a large number of workers has developed sophisticated computer programs for integrating the pollution concentration of the plumes from many such sources (as might comprise a region or city) to obtain the total pollution level at a single location or a set of isopleths. A major drawback of this model is that it is valid only for a relatively short period during which both the wind speed and meteorological conditions remain constant. Moreover, the model becomes invalid at zero or low wind velocities (in which one such model resorts to the box model).

The fourth grouping of models may be termed "analytical." In such models, an attempt is made to solve the fundamental equations governing air flow diffusion of pollutants. The preceding two groupings of models presuppose a single solution to these equations and hence are limited inherently in their range of applicability and accuracy. Moreover, the use of an analytical model is less dependent on the availability of detailed meteorological data (e.g., wind fields). Information on terrain features is required instead.

Another major advantage of the analytical type of model is that chemical changes to the emitted pollutants can be introduced in a natural way. (This cannot be done in a Gaussian plume model). Thus the formation of photochemical oxidants can be modeled. Unfortunately, models of the chemistry of the formation of photochemical oxidants are still in the research stage. Such models developed to date have been used only with partial success.

The following Evaluation of Some Climatological Dispersion Models is extracted from the User's Guide for the Climatological Dispersion Model, EPA-R4-73-024, December 1973. This evaluation provides an excellent review of dispersion models available for evaluation of TSP, and SO_2 air quality.

Simple models to estimate carbon monoxide air quality were described in the Guideline for Designation of AQMAs. More sophisticated approaches include the EPA-ARAC (a model which incorporates the Stanford Research Institute Model for CO, and Gifford-Hanna Models. These models, incorporated in three of the studies summarized in Appendix B, are:

- The Hackensack Meadowlands Study - used Gifford-Hanna (modified)
- The BREIS study used SRI model (HPRAC 1A)

- TASSIM used a modified Gifford-Hanna approach

Models to project ambient concentrations of reactive hydrocarbons, NO_x, and photochemical oxidant are in the development stages and are not currently available or generally applicable.

AN EVALUATION OF SOME CLIMATOLOGICAL DISPERSION MODELS

by

D. Bruce Turner*, John R. Zimmerman*, and Adrian D. Busse*

ABSTRACT

Six different dispersion models were used in a climatological mode of application with point source and area emission data to calculate annual (1969) sulfur dioxide and total suspended particulate matter for the New York Air Quality Control Region. Two of the models, the Air Quality Display Model and the Climatological Dispersion Model, use joint frequency distributions of wind direction, wind speed, and stability class as meteorological data. The Climatological Dispersion Model (single stability) requires only a wind direction frequency and harmonic mean speed for each direction. The other three models: Gifford '72, Modified Hanna, and Modified Hanna Including Source Height; require only mean annual wind speeds for climatological application.

Simple models are as highly correlated with measurements as are the more complex models, explaining 70% of the sulfur dioxide variance and 40% of the particulate variance. For SO_2, root mean square errors for the best complex model are 52; those for the simple models are 56 to 59. The standard deviation of the measurements is 72. For particulates, root mean square errors for the complex model are 16; those for the simple models are 19 to 40. The standard deviation of the measurements is 23.

It is difficult to achieve results surpassing those of the simple models. Of the two more complex models, the AQDM and the CDM, the CDM yields smaller errors with means and maxima nearer those of the measurements. Evaluation of models should include comparison of results with those from simple models applied to the same data.

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*On Assignment from the National Oceanic and Atmospheric Administration, Department of Commerce

INTRODUCTION

Six different dispersion models were used to calculate annual (1969) sulfur dioxide and total suspended particulate matter for the New York Air Quality Control Region. Two of the models, the Air Quality Display Model and the Climatological Dispersion Model, use joint frequency distributions of wind direction, wind speed, and stability, as meteorological data. The Climatological Dispersion Model applied for a single stability requires only a wind direction frequency and harmonic mean speed for each direction. The other three models based upon ideas of Gifford and Hanna (1971, 1972) require only mean annual wind speeds for climatological application. These are referred to as: Gifford '72, Modified Hanna, and Modified Hanna Including Source Height.

The emission inventory, measured air quality data, meteorological data, and climatological estimates of pollution concentration using the Air Quality Display Model were obtained from EPA's Air Quality Management Branch. Emission estimates for 1969 for both pollutants for 854 area sources varying in size from 1 km^2 to 100 km^2, and for 674 point sources were included. Estimates of stack height, stack diameter, stack gas exit velocity, and stack gas temperature were also included for the point sources. A stability wind rose (joint frequency distribution of wind direction, wind speed, and stability class) was available for La Guardia Airport based on the 3-hourly observations during 1969. These observations are routinely available in computer compatible form (punch cards or magnetic tape).

Each of the models was used to calculate mean annual concentrations of sulfur dioxide at 75 locations and total suspended particulate matter at 113 locations. These estimates were compared with mean annual concentrations based upon measurements.

DESCRIPTION OF MODELS

1. Air Quality Display Model (AQDM)

The AQDM, a climatological model based on ideas of Martin and Tikvart (TRW Systems Group, 1969; Martin and Tikvart, 1968; and Martin, 1971), considers the joint frequency distribution of wind direction to 16 points, wind speed in 6 classes, and stability categories in 5 classes. Computations for a receptor point are made by considering the contribution of each point and area source to this receptor. Separate calculations are made for each speed class - stability class combination for the wind direction sector about the receptor that contains the source. For area sources a modification of the virtual point source method is used. Estimation of area source heights are assumed to be effective height of the area source. The effective height can be different for each area source. Holland's plume rise equation (Holland, 1953) is used to estimate the effective height of point sources. A feature of the AQDM is that a source contribution file consisting of the partial concentration of each receptor due to each point and area source is retained at the end of the computation. This is primarily used as input to control strategy studies.

2. Climatological Dispersion Model (CDM)

The CDM described in detail by K. L. Calder (1971) has been applied to air quality estimates for Ankara, Turkey, and St. Louis (Zimmerman, 1971, 1972) for the Committee on Challenges of Modern Society. Although similar in many respects to the AQDM, the CDM contains several distinct features. In the CDM, area sources are calculated using the narrow plume hypothesis (Gifford and Hanna, 1971) applied for winds within a sector (Calder, 1971) which involves an upwind integration over the area sources. Emission rates at various upwind distances, using an expanding scale, are averaged over an arc within the sector. A power law for the vertical wind profile which is a function of stability is used to extrapolate surface winds to the source height. Estimation of effective height of point sources is by Briggs plume rise (Briggs, 1969). The total concentration at each receptor is the sum of 32 concentrations. These concentrations are those from point and from area sources for each of the 16 wind directions. These values are retained and are useful in plotting direction contribution pollution roses. The running time of the CDM is about 73% of that required by the AQDM.

3. Climatological Dispersion Model (Single Stability)

Whereas both the AQDM and the CDM are applied for 5 different stabilities and 6 wind speed classes within each stability class, this model performs the calculations for a single stability and further reduces the computations by using a single wind speed for each of the 16 wind direction sectors. The single wind speed is a harmonic mean of the average speed for each wind speed class weighted for its frequency. The running time of this single stability version of the CDM is about 30% of that required by the CDM.

4. Gifford '72

Drs. Frank Gifford and Steve Hanna of NOAA's Atmospheric Turbulence and Diffusion Laboratory in Oak Ridge, Tennessee, have been active in developing simple dispersion models for estimating concentrations (Gifford and Hanna, 1971; Hanna, 1971). In a recent manuscript (Gifford and Hanna, 1972), they have suggested use of

$$\chi_A = C \frac{\bar{q}}{\bar{u}} \qquad (1)$$

where χ_A is the concentration in μgm^{-3} of the pollutant of interest due to all area sources for a particular averaging time, C is a dimensionless constant, $\bar{q}$ is an average area emission rate in $\mu gm^{-2} sec^{-1}$ in the vicinity of the receptor, and $\bar{u}$ is the mean wind speed in m sec^{-1}. Both $\bar{q}$ and $\bar{u}$ are for the same averaging time as the concentration, χ_A. They suggest that the values of C are 50 for sulfur dioxide and 225 for particulate matter. Concentrations at this receptor from point sources for the same averaging time should be added to the concentrations from area sources. These can be determined from an appropriate point source model. Without firm direction from the manuscript of Gifford and Hanna as to what area about the receptor should be used to obtain average area emissions, the authors selected an area after an investigation which will be described later.

5. and 6. Modified Hanna

Since emissions close to a receptor at about the same height as the receptor have a greater influence than emissions at greater distances, it was felt that an improvement to the above Gifford '72 model could be made which would eliminate the use of the rather arbitrary constant C, and would also eliminate the difficulty of not knowing just which area should be considered in determination of the average area emission rate. The model can be expressed as:

$$\chi_A = \frac{1}{\bar{u}} \sum_i k_i \bar{q}_i + b \qquad (2)$$

where i is an index referring to a range of distances from the receptor, $\bar{q}_i$ is the average area emission rate for this range of distance about the receptor, $\bar{u}$ is mean wind speed as before, b is background concentration of the pollutant considered beyond the last distance considered in the summation, and the coefficient, k, is determined from:

$$k_i = \int_{x_l}^{x_u} \frac{2}{\sqrt{2\pi}\ \sigma_z} \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] dx \qquad (3)$$

where x_l and x_u are the lower and upper limits of distance of the i th range, σ_z is a dispersion parameter dependent upon distance and representative of mean stability conditions for the period of interest, H is a single effective height of emission for the pollutant considered for area sources in the region under consideration. In general, the value of b will be the concentration of the particular pollutant at the boundaries of the region considered, i.e., the boundary of the emission inventory. Note that the k's are dependent only upon the mean meteorological conditions and the height of emission and, therefore will be constant for a given distance range, and independent of receptor location. On the other hand, the $\overline{q_i}$'s are determined for different distance ranges about each receptor and, therefore, are dependent upon receptor location.

Model 5, referred to as the Modified Hanna, is applied with H=0. This is the same in concept as that of Steve Hanna (1971). The only difference is that in this model sources are considered for ranges of distance without regard to direction variations. For this model the values of k can be determined analytically.

Model 6, referred to as the Modified Hanna Including Source Height, uses a mean value of effective height of emission for each pollutant. For this case the values of k are determined by numerical integration.

Both Models 5 and 6 can be considered as further simplifications to the CDM and CDM (single stability) models since another liberty has been taken, that of calculating emissions for various distance ranges instead of in each wind direction sector.

APPLICATION OF THE MODELS TO THE NEW YORK REGION

With each of the models, calculations of ground level concentrations of both sulfur dioxide and total suspended particulate matter were made. Measurements of sulfur dioxide were available at 75 locations and of particulate matter at 113 locations.

As indicated, the AQDM was applied to the data for this area by the Air Quality Management Branch. A background of 35 μgm^{-3} was added to each calculated value of particulate concentration before comparing with measurements. A background of 35 was also added to each calculated value of particulate matter by the CDM before comparing with the measurements.

For applying the CDM for a single stability, Table 1 lists the frequencies and the harmonic mean wind speeds for each direction. The model was applied for three different single stabilities. The values used for the σ_z parameter most closely approximate those corresponding

TABLE 1

Frequencies and Harmonic Mean Wind Speeds for Each Direction

SECTOR	$f(\theta)$	$\bar{u}$ (θ) (m sec^{-1})
NNE	0.088	3.65
NE	0.054	2.98
ENE	0.076	3.27
E	0.084	3.53
ESE	0.036	2.82
SE	0.010	2.04
SSE	0.014	2.78
S	0.025	3.54
SSW	0.117	4.00
SW	0.044	2.93
WSW	0.062	3.27
W	0.075	3.72
WNW	0.071	4.73
NW	0.086	4.43
NNW	0.082	3.90
N	0.075	4.12

TABLE 2

Dispersion Parameter Coefficients and Exponents

	$\sigma_z = a\ x^b$					
Range of x (meters)	C Stability		C/D Stability		D Stability	
	a	b	a	b	a	b
<500	0.1120	0.9100	0.1078	0.87645	0.0856	0.8650
500-5000	0.1014	0.9260	0.1725	0.80072	0.2591	0.6869
>5000	0.1154	0.9109	0.3546	0.71611	0.7368	0.5642

to Pasquill's C, D, and something between C and D (Pasquill, 1962; Turner, 1967) so the notation: C, D, C/D is used to designate these. The coefficients and exponents for various downwind distances from the source, x, for these three stabilities used to determine σ_z from:

$$\sigma_z = ax^b \tag{4}$$

are given in Table 2.

For application of the Gifford '72 model, the mean wind speed for La Guardia Airport for the year 1969 as given by the Local Climatological Data (Environmental Science Service Administration, 1969) of 11.6 miles per hour (5.1852 m sec^{-1}) was used. As indicated, Gifford (1972) is not clear as to the size of the area that should be considered for averaging area emission rates. Therefore, three distances were selected: 3, 5, and 10 km. Using the emission rates for the area sources on the 1 km basis previously prepared as part of the CDM run, a computer calculation was made to determine average emissions for both SO_2 and particulate within circles centered on each receptor for radii corresponding to the three above-mentioned distances. If the center of a 1 km source square was within the circle, it was included in the averaging; if the center was outside, it was not included. After determining the average emission rate for the three different radius circles, the linear correlation coefficient of measurements of concentration as a function of average emission rate was determined for both pollutants. This appears on the left side of Table 3. From these results, the average emission rates for circles with a radius of 10 km were selected for use in applying the Gifford '72 model. At a later time the average emissions for larger circles and the corresponding correlation coefficients were determined. These appear in the right hand portion of Table 3.

Since Gifford indicates that the values of the factor C of 50 for sulfur dioxide and 225 for particulate matter were determined without consideration of any background values, no background was added to the estimates from this model before comparing with measurements. Comparisons of this model were made with measurements for both: estimates from area sources only, and estimates from the area sources using this model with estimates of concentration due to point sources as determined from the CDM model added to the area estimates. (After noting the results achieved with this model, a background of 35 was added for particulate matter estimates for an additional comparison.)

In applying the Modified Hanna Model to this region, six ranges of distances were used as shown in Table 4. From intermediate results punched on cards during the determination of the average emission rates for various sized circles, it was simple to determine the average emission rates for the 5 annular areas. For application of the Modified Hanna Including Source Height (Model 6), the average emission heights

TABLE 3

Linear Correlation Coefficients of Measured Air Quality Data with Average Emission Rate of Circles of Given Radius about Each Receptor

Pollutant	Number of Receptors	Radius of Emission Area (km) 3	5	10	20	30	40
Sulfur dioxide	75	0.73	0.79	0.81	0.85	0.78	0.70
Particulate matter	113	0.61	0.64	0.63	0.63	0.63	0.60

TABLE 4

Limits of Integration and Corresponding Values of k from Equation (3)

i	x_l km	x_u km	k_i Model 5 $H = 0$	Model 6 $H = 10$ Particulate	$H = 30$ SO_2
1	0	3	163.468	50.331	30.715
2	3	5	12.264	12.133	11.844
3	5	10	19.344	19.183	18.993
4	10	20	23.551	23.053	22.97[illegible]
5	20	30	16.085	15.580	15.555
6	30	40	12.589	12.120	12.110

of 30 meters for sulfur dioxide and 10 meters for particulate matter were chosen as representative of effective heights of emission for the New York region. (One could apply this model using different effective heights of emission for various receptor locations, but only one height for each pollutant was used here.) Using values of the dispersion parameter, σ_z, corresponding to C/D stability the k_i's were determined by integrating analytically over appropriate distance ranges for use in Model 5 and using the σ_z's for C/D stability and the above emission heights, numerical integrations were performed to determine the values of the factors, k_i for use with Model 6. These are also shown in Table 4. Values of background concentration, b, of 0 and 35 were used for sulfur dioxide and particulate matter respectively in equation (2).

STATISTICS USED FOR EVALUATION

To evaluate the various models, 12 different statistics were used. One of these was the mean concentration for all stations. Considering the error for each location to be defined as the calculated concentration from the model minus the measured concentration, the root mean square error and the mean absolute error were determined. As an indication of the range of errors at the individual measurement locations, the largest negative error (underestimate), the largest positive error (overestimate), and the range of errors (the largest positive error minus the largest negative error) were tabulated. Linear correlation coefficients, the variance of the correlation (the square of the correlation coefficient) and the slope and intercept of the least squares line of regression between model estimates and the measured values were also calculated.

Because of its importance to the meeting of air quality standards, the error at the location with the highest measured concentration is of interest as well as the maximum estimated concentration at any of the measuring station locations.

RESULTS

The results of the comparison of model estimates with measurements are given in Table 5 for sulfur dioxide and in Table 6 for particulates. In addition to comparing the calculated AQDM estimates with measurements, the Air Quality Management Branch had used the measured air quality data to calibrate the AQDM. Considering the calculations without background as the independent variable, the measurements as the dependent variable, least square lines that are forced to have an intercept of 0 for sulfur dioxide and 35 for particulate matter were determined. The slope and intercepts for these lines are given in Table 7. Using the equations of these lines, "calibrated" concentration estimates were determined from the calculated concentrations. This was done similarly for all other models. The comparisons of these estimates with the

TABLE 5. NEW YORK - SULFUR DIOXIDE

MAX MEAS = 350

	MEAN (MEAS =135)	NUMBER	RMSE (STD DEV OF MEAS =72)	MEAN ABSOLUTE ERROR	LARGEST NEGATIVE ERROR	LARGEST POSITIVE ERROR	ERROR RANGE	LINEAR CORREL. WITH MEAS.	VARIANCE	SLOPE	INTERCEPT	ERROR AT POINT OF MAXIMUM MEAS.	MAXIMUM ESTIMATED CONC. AT A MEAS. POINT
1 AIR QUALITY DISPLAY MODEL (AQDM)	211	75	121	92	-87	310	397	0.89	0.79	0.45	31	112	566
	(116)	(75)	(37)	(28)	(-117)	(74)	(191)	(0.89)	(0.79)	(0.82)	(31)	(-97)	(310)
2 CLIMATOLOGICAL DISPERSION MODEL (CDM)	138	75	52	37	-118	166	284	0.84	0.70	0.66	35	-101	368
	(115)	(75)	(44)	(32)	(-143)	(121)	(264)	(0.84)	(0.70)	(0.79)	(35)	(-143)	(307)
3 CDM (SINGLE STABILITY)													
3A CDM (D STABILITY)	206	75	124	89	-112	332	444	0.84	0.71	0.41	40	13	577
	(112)	(75)	(45)	(33)	(-153)	(114)	(267)	(0.84)	(0.71)	(0.76)	(40)	(-153)	(313)
3B CDM (C STABILITY)	94	75	56	46	-128	96	224	0.82	0.67	0.73	56	-119	307
	(101)	(75)	(55)	(45)	(-122)	(118)	(240)	(0.82)	(0.67)	(0.68)	(56)	(-101)	(329)
3C CDM (C/D STABILITY)	139	75	64	45	-115	188	303	0.84	0.70	0.55	49	-56	423
	(107)	(75)	(49)	(39)	(-125)	(109)	(234)	(0.84)	(0.71)	(0.72)	(48)	(-125)	(324)
4 GIFFORD '72													
4A AREA ONLY	54	75	82	72	-175	29	204	0.81	0.66	1.07	67	-175	180
	(91)	(75)	(63)	(54)	(-151)	(125)	(276)	(0.81)	(0.66)	(0.63)	(67)	(-54)	(304)
4B WITH CDM POINT ESTIMATES	79	75	59	50	-137	49	186	0.85	0.72	0.97	48	-137	219
	(107)	(75)	(48)	(38)	(-118)	(115)	(233)	(0.85)	(0.72)	(0.72)	(48)	(-64)	(294)
5 MODIFIED HANNA													
5A AREA ONLY	279	75	330	178	-145	1232	1377	0.77	0.60	0.16	80	1153	1503
	(77)	(75)	(77)	(65)	(-152)	(188)	(340)	(0.77)	(0.60)	(0.58)	(80)	(63)	(413)
5B WITH CDM POINT ESTIMATES	305	75	348	193	-120	1270	1390	0.78	0.62	0.16	76	1191	1541
	(81)	(75)	(73)	(61)	(-145)	(189)	(334)	(0.78)	(0.62)	(0.60)	(76)	(62)	(412)
6 MODIFIED HANNA INCL. SOURCE HEIGHT													
6A AREA ONLY	102	75	58	45	-151	190	341	0.84	0.71	0.62	62	49	399
	(96)	(75)	(57)	(46)	(-151)	(170)	(321)	(0.84)	(0.71)	(0.66)	(62)	(26)	(376)
6B WITH CDM POINT ESTIMATES	127	75	56	38	-126	225	351	0.86	0.74	0.59	50	87	437
	(105)	(75)	(48)	(37)	(-131)	(157)	(288)	(0.86)	(0.74)	(0.71)	(50)	(11)	(361)

TABLE 6. NEW YORK - PARTICULATE MATTER

MAX MEAS = 169

	MEAN (MEAS = 82)	NUM BER	RMSE (STD DEV OF MEAS =23)	MEAN ABSOLUTE ERROR	LARGEST NEGATIVE ERROR	LARGEST POSITIVE ERROR	ERROR RANGE	LINEAR CORREL. WITH MEAS.	VARI- ANCE	SLOPE	INTER- CEPT	ERROR AT POINT OF MAXIMUM MEAS.	MAXIMUM ESTIMATED CONC. AT A MEAS. POINT
1 AIR QUALITY DISPLAY MODEL (AQDM)	102	113	36	28	-51	115	166	0.62	0.39	0.38	43	5	199
	(77)	(113)	(21)	(15)	(-60)	(54)	(114)	(0.63)	(0.39)	(0.62)	(34)	(-48)	(136)
2 CLIMATOLOGICAL DISPERSION MODEL (CDM)	74	113	22	16	-63	68	131	0.61	0.37	0.63	35	-48	135
	(76)	(113)	(22)	(15)	(-62)	(74)	(136)	(0.61)	(0.37)	(0.59)	(37)	(-43)	(141)
3 CDM (SINGLE STABILITY)													
3A CDM (D STABILITY)	88	113	28	21	-60	98	158	0.64	0.41	0.42	45	-6	165
	(74)	(113)	(22)	(17)	(-67)	(65)	(132)	(0.64)	(0.40)	(0.57)	(40)	(-39)	(132)
3B CDM (C STABILITY)	58	113	31	26	-78	59	137	0.57	0.32	0.69	42	-71	126
	(69)	(113)	(28)	(21)	(-74)	(104)	(178)	(0.57)	(0.32)	(0.46)	(50)	(-40)	(171)
3C CDM (C/D STABILITY)	69	113	25	19	-73	75	148	0.61	0.37	0.54	45	-43	142
	(71)	(113)	(25)	(19)	(-72)	(82)	(154)	(0.61)	(0.37)	(0.50)	(46)	(-37)	(149)
4 GIFFORD '72													
4A AREA ONLY	40	113	53	47	-117	46	163	0.63	0.40	0.35	68	-56	151
	(64)	(113)	(30)	(24)	(-83)	(42)	(125)	(0.63)	(0.40)	(0.47)	(51)	(-50)	(147)
	[75]	[113]	[33]	[27]	[-82]	[81]	[163]	[0.63]	[0.40]	[0.35]	[56]	[-21]	[186]
4B WITH CDM POINT ESTIMATES	51	113	47	40	-111	59	170	0.63	0.40	0.32	65	-44	164
	(68)	(113)	(27)	(21)	(-79)	(38)	(117)	(0.63)	(0.40)	(0.49)	(48)	(-52)	(143)
	[86]	[113]	[36]	[28]	[-76]	[94]	[170]	[0.63]	[0.40]	[0.32]	[54]	[-9]	[199]
5 MODIFIED HANNA													
5A AREA ONLY	80	113	41	30	-77	177	254	0.64	0.40	0.28	59	61	281
	(62)	(113)	(31)	(25)	(-81)	(80)	(161)	(0.64)	(0.40)	(0.47)	(53)	(-16)	(184)
5B WITH CDM POINT ESTIMATES	92	113	45	32	-71	190	261	0.64	0.40	0.27	57	73	294
	(66)	(113)	(28)	(22)	(-78)	(74)	(152)	(0.64)	(0.40)	(0.48)	(50)	(-20)	(178)
6 MODIFIED HANNA INCL. SOURCE HEIGHT													
6A AREA ONLY	56	113	31	26	-80	25	105	0.66	0.43	0.72	41	-58	129
	(66)	(113)	(28)	(22)	(-77)	(68)	(145)	(0.66)	(0.43)	(0.49)	(49)	(-23)	(172)
6B WITH CDM POINT ESTIMATES	67	113	25	19	-71	37	108	0.62	0.39	0.63	39	-53	141
	(73)	(113)	(24)	(18)	(-69)	(55)	(124)	(0.62)	(0.39)	(0.54)	(42)	(-39)	(159)

TABLE 7

Equations of Least Squares Lines (y=a+bx)
Used to Determine Calibrated Concentrations

Model	Sulfur Dioxide b	Sulfur Dioxide a	Particulate Matter b	Particulate Matter a
1. AQDM	0.5478	0	0.6162	35
2. CDM	0.8330	0	1.0630	35
3a. CDM (D Stability)	0.5429	0	0.7452	35
3b. CDM (C Stability)	1.0790	0	1.4956	35
3c. CDM (C/D Stability)	0.7653	0	1.0637	35
4. Gifford '72				
A. Area only	1.6909	0	0.7430	35
B. With CDM point estimates	1.3435	0	0.6557	35
5. Modified Hanna				
A. Area only	0.2746	0	0.6063	35
B. With CDM point estimates	0.2676	0	0.5512	35
6. Modified Hanna Including Source Height				
A. Area only	0.9435	0	1.4594	35
B. With CDM point estimates	0.8265	0	1.1717	35

measured concentrations are reported in Tables 5 and 6 in parentheses with each model. Note that the "calibrated" estimates are compared with the same measurements used for determining the calibration equations, not with independent data. Although the development of the coefficients for the Gifford '72 should not require the addition of a background concentration, the estimated values from this model were also tested after adding a background of 35 μgm^{-3} to the particulate values. These results are reported in brackets in Table 6.

Models 1 and 2 (both AQDM and CDM) each require joint frequency distributions of wind direction, wind speed, and stability. For the CDM (single stability) only the frequency and mean speed for each direction (Table 1) are required. For the last three models only the mean annual wind speed is used although the effects of the point sources, that are added in, have used the joint frequency distribution information.

Considering first the results for sulfur dioxide, for the mean concentration for the 75 locations, Model 2 with 138, Model 3c with 139, and Model 6 b. with 127 are all close to the mean of measurements of 135 μgm^{-3}. Note that calibration causes all models to underestimate the mean. For the root mean square error, Model 2 with 52, Models 3b and 6b with 56 are examples. Six of the 11 models have a RMSE less than the standard deviation of the measured values, 72 μgm^{-3}.

As expected, calibration reduces the root mean square error but in some cases only slightly. The smallest mean absolute errors are from Model 2 with 37 and Model 6 b with 38. Calibration reduces the mean absolute error. The range of errors is lowest, 186 (-131 to 49), for Model 4 b. Note that all correlations are quite close, ranging from 0.77 to 0.89. The error at the point of the maximum measurement varies from an underestimate of 175 μgm^{-3} to an overestimate of 112 μgm^{-3}, ignoring the huge overestimates of Model 5. Model 3 a. with an overestimate of 13 μgm^{-3} has the least error. Calibration causes Model 6 b's overestimate of 11 μgm^{-3} to be smallest. The maximum estimated concentration at a measurement point ranges from 180 μgm^{-3} to 577 μgm^{-3} (again ignoring Model 5) with Model 2's estimate of 368 closest to the measured maximum of 350 μgm^{-3}. Calibration improves some estimates of the max, notably Model 6 b. with 361.

In the results for the particulate matter (Table 6) for the mean concentration, the 80 μgm^{-3} from Model 5 a is closest to the mean of all measurements of 82. Models 3a, 2, and 5b also are close. Calibration improves the means from most of the models. For the root mean square error, only Model 2 with 21 is less than the standard deviation of measured particulate values of 23 μgm^{-3}. With calibration, Models 1, 2, and 3a have RSME less than 23. For the mean absolute error, Model 2 with 16 μgm^{-3} is the smallest. With regard to the largest errors, the models are not greatly different if Model 5 is excluded. Model 2 has the smallest error range, 131. Generally calibration doesn't have too much effect on the range of errors. The correlations are not greatly different for the various models ranging from 0.57 to 0.66 although they are poorer than those for SO_2. The variance is about half those for SO_2: 0.32 to 0.43 for particulate, 0.60 to 0.79 for SO_2. This may be due, in part, to the difficulty in obtaining a reliable emission inventory for particulate matter and in obtaining representative measurements. The error at the point of maximum concentration is a slight overestimate of 5 μgm^{-3} for Model 1 and a slight underestimate of 6 μgm^{-3} for Model 3a. For the maximum concentration at any measurement point, Model 3a with 165 and Model 4b. with 164 are near the maximum measured at any sampling station of 169. Generally, calibration does not greatly improve the estimate of the maximum. An exception is Model 3b. whose calibrated maximum is 171.

CONCLUSIONS

There is no one model that is superior in all statistics. The AQDM (Model 1) overestimates concentrations. Although we feel that the use of the Holland plume rise equation contributes to this overestimation, it is not the only cause. Many measurements of air quality are needed in order to calibrate the AQDM. This results in a low error but also, in this case, results in underestimated concentrations for both the mean and the maximum.

The CDM (Model 2) gives a good estimate of the mean and maximum for SO_2 in this test, but somewhat underestimates the particulate concentrations, particularly the maximum. It should be noted that this is without a calibration, therefore no extensive measurement network was required to obtain the result.

The CDM (single stability) with the dispersion parameters given by the C - D stability class (model 3c) gives a better estimate of the mean of all stations than of the other statistics. The errors are somewhat larger than the full model. Like the CDM Model, the CDM (C/D stability) overestimates the SO_2 maximum concentration but underestimates the particulate concentration.

The Gifford '72 Model underestimates both the mean concentrations and also the maximum SO_2 but produces a good estimate of the particulate maximum for this test region. Although the errors are somewhat larger than with the other models, they are not greatly different considering the degree of simplicity of this model over the preceding ones. The addition of a background of 35 μgm^{-3} for the particulate estimates improves the results of this model in most statistics with the exception of the maximum concentration at any measurement point.

The Modified Hanna Including Source Height seems to be an improvement over the Gifford '72 Model with regard to means and errors but does not perform as well on the maxima, overestimating SO_2 and underestimating particulate. Note that there is a relatively close correspondence between the CDM (C/D stability) and Model 6b in nearly all statistics and for both pollutants.

Simple models using only mean annual wind speeds and emissions do quite well compared to the more complex models. The input and the calculations are simple. They do have limitations when trying to use the results to apply control strategies. For the simple models at each receptor there are two concentration estimates available: that due to point sources and that due to area sources. Of the more complex models (1 and 2), these data indicate a preference for the CDM over the AQDM.

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APPENDIX E

ANNOTATED BIBLIOGRAPHY OF ACTIVITY ALLOCATION PROCEDURES

Batty, Michael. Recent Developments in Land Use Modeling: A Review of British Research. Urban Studies. June 1972.

This paper is primarily a discussion of the development and application of Lowry-type models in England. These models have dominated British research and have been strongly influenced by A.G. Wilson's entropy-maximizing framework. Wilson's framework, which explicitly identifies spatial interaction in terms of stocks and flows of activities, provides a strong theoretical basis for refinements of the original Lowry model. Building on Wilson's work, British researchers have devised several constraint procedures which are consistent with Garin's matrix solution of the Lowry model.

Several Wilson-Garin-Lowry models with constraints have been tested at the subregional and town levels in Britain.

Batty reviews the current research undertaken in England to address the following problems:

- The static equilibrium nature of model projections
- The lack of feedback between the population and service sectors and the basic sector
- The slow convergence of the constraints procedure under model Modification I
- The basic-service definitional problems
- Improved parameter estimation techniques
- The optimum level of aggregation for the model (both in terms of level of analysis and level of data)

Batty concludes that the Wilson-Garin-Lowry formulation is flexible enough to allow for the solution of the above problems and the incorporation of other model refinements as current research introduces them.

Berry, Brian J. L. The Retail Component of the Urban Model. Journal of the American Institute of Planners. May 1965.

The author analyzes work done in Chicago to identify the structure of retail markets in an urban area. He concludes that the correct ecological units for measurement of retail market areas are not transportation zones or census tracts, since they cut across market boundaries. Larger analysis units, however, are more likely to capture the effects of the retail business center on its market area. The most useful definition of market area is seen to be the area in which a constant rate of accumulation of trips with distance holds.

The author employs factor analysis to determine the nature of the interdependencies among variables indicative of the size and complexity of the retail centers. Variables tested include functions, establishments, total center area, shopping center area, ground floor area, area of trade area, median income, social class, family class, total competition, planned competition, unplanned competition, ribbon competition, discount competition, and population density.

The results of the factor analysis suggest that the number of functions and their size are highly related to the population of the market area area and the position of the retail centers in a hierarchy. Other independent factors, which are identified by factor analysis, are population of the trade area and the independent variables above are regressed by Berry to produce estimates of retail market area size for planned and unplanned centers.

Chapin, Stuart F., Jr., and Shirley F. Weiss. A Probabilistic Model for Residential Growth. Transportation Research. December 1968.

Chapin and Weiss view urban land development as a dynamic process involving priming actions such as the building of expressways and major industrial parks which promote secondary actions such as the opening of shops or the choice of residential locations. The authors have focused their efforts on the study of residential land use conversion and have determined that the most influential factors in this process are marginal land not in use, accessibility to work, and assessed value.

A Monte Carlo simulation technique (linear form without replacement) is adopted by the authors to distribute the expected level of new housing units to grid cells on the basis of attraction probabilities. Assessed values are used in computing the initial attraction probabilities, while density and housing value constraints are imposed to modify these initial probabilities. Ten density-value classes for subdivided and raw land are considered by the model.

After each simulation period, the attraction probabilities for each grid cell are modified according to anticipated new priming actions and the effects of the land market in the previous development period. The model developed by Chapin and Weiss allocates discrete household units, and the number of these units to be allocated in each simulation period is exogenously specified.

The model is applied to Greensboro, North Carolina, for the years 1948-1960 with three-year simulation periods. The results indicate that the model may be used as a tool for investigating the effect of different land use development policies on residential location patterns. In the future, the authors are hoping to develop submodels which simulate human values and behavior patterns in order to better understand the primary influences on location decisions.

Cripps, E. L. and D. H. S. Foot. A Land Use Model for Subregional Planning. Regional Studies. December 1969.

Wilson's entropy-maximizing approach has been applied in a Lowry-type model to several regions and towns in England. This paper is a full description of the application of such a model to the Bedforshire multinodal subregion.

The model, which strongly resembles the Urban Systems Model, is calibrated and applied in order to allocate population and service employment to 130 zones. Plots of actual and estimated activity are included in the paper as well as statistical indicators of the fit. From the trip tables produced by the model, desire lines of spatial interaction are examined to ensure that trips between selected towns are adequately simulated.

In general, the authors find that the model is able to produce the existing activity structure of the subregion within a reasonable margin of accuracy and that the small-area projections made by the model are sensible. However, the authors note the limitations of the static equilibrium form of the model in describing the process of urban growth and development.

The activity allocation model applied in Bedfordshire has a second shortcoming cited by the authors. The model treats locational factors after the decision to move has been made. The authors contend that there is a need for behavioral submodels which simulate the motivation to move itself. They reveal that such work is already done by A.G. Wilson using the same framework as the Bedfordshire model, and they conclude that such research represents the proper focus for future modeling of locational decisions.

Evaluation of Regional Economic Effects of Alternative Highway Systems. Curtis C. Harris Associates, Inc. FHWA Report, January 1973.

This report summarizes the development and application of a national econometric model which projects population, employment, income, investments, consumption, and government expenditures by 1973 OBE regions. The model contains system sensitive components which may be used to evaluate the effects of alternative transportation systems on regional activity levels. These components are embodied in the transport shadow prices which are derived by solving a linear programming algorithm for each industry.

The transport shipping costs developed by Harris include truck and rail operating costs. The treatment of these costs is of particular interest because the future location of basic employment may be influenced by the level of truck and rail service.

The calculation of rail rates is based on the mark-up of out-of-pocket costs incurred by the carrier. Out-of-pocket costs include terminal and line haul expenses averaged over an extended time period. These costs do not include equipment depreciation rates and overhead expenses. The mark-up factors which reflect revenue to out-of-pocket ratios for each region, are derived from the Annual ICC publication, Procedures for Developing Rail Revenue Contribution by Commodity and Territory.

The methodology for developing truck operation costs which are sensitive to highway system changes relates ICC average operating costs per mile at specific speeds to the TRANSNET network. The ICC operating costs are adjusted to reflect the type of road and terrain and penalties for driving through or around major urban areas. Five highway types are considered:

- Limited access - divided toll
- Limited access - divided free
- Other divided
- Principal through highways
- Local connectors

These types are further divided into four speed categories depending upon the terrain.

The speeds associated with the TRANSNET network reflect composite automobile-truck speeds. Therefore, TRANSNET speeds are adjusted to reflect average truck speeds by the following formula:

$$TS = .771S$$

where:

TS = Average truck speed, including stops

S = TRANSNET composite speed

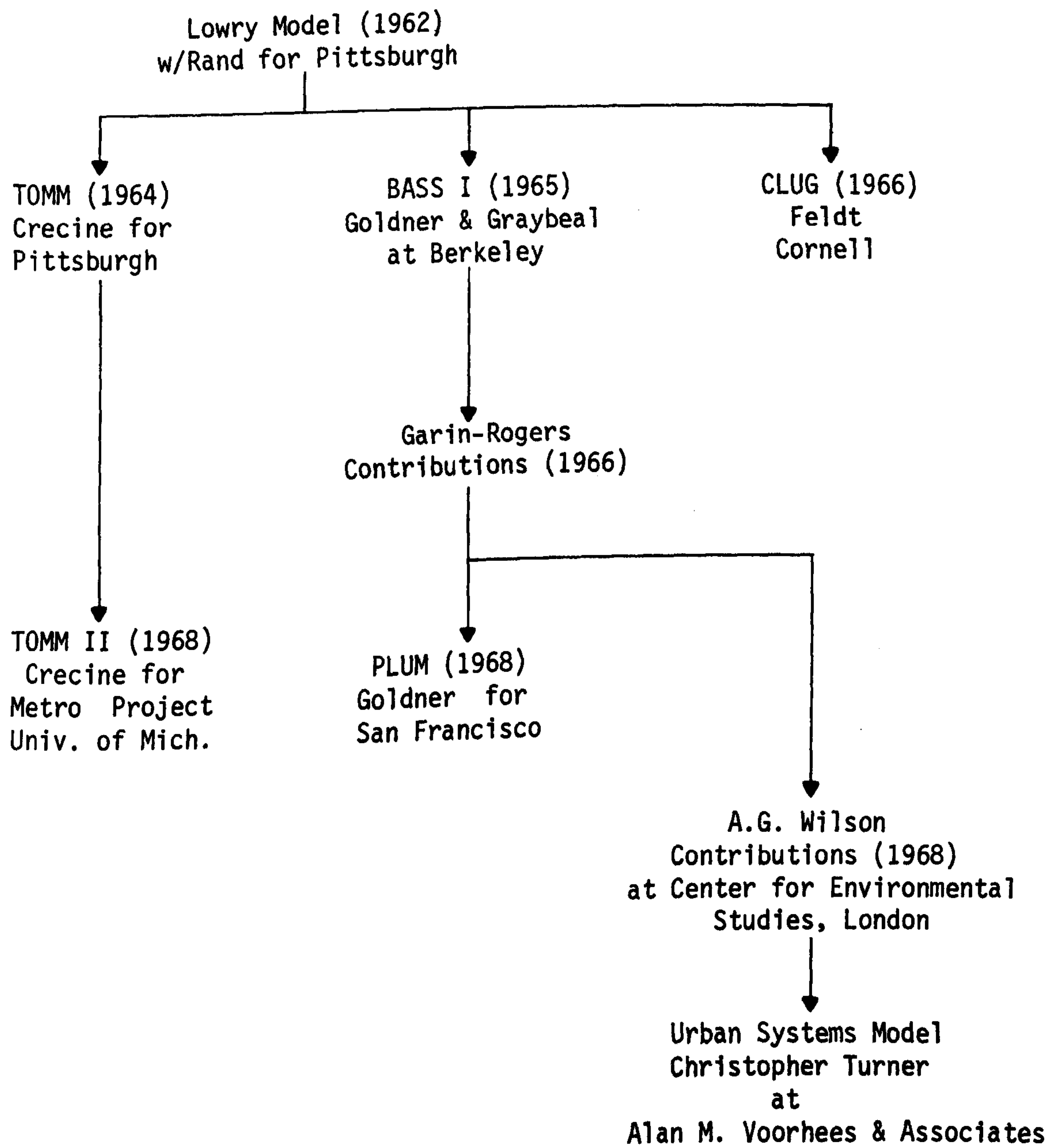
The truck operating cost per vehicle mile is calculated for each state on the basis of the ICC cost-speed data and the TRANSNET link truck speeds. The cost per vehicle-mile is then used in TRANSNET to compute the minimum truck cost path between OBE regions.

In order to account for the friction of traveling through or around urban areas, TRANSNET imposes time penalties, depending on the size of the city. In the Harris study, these penalties are increased by two minutes for truck travel and are converted to costs using the ICC median hourly truck operating costs.

By substituting truck costs for speed and time data in TRANSNET, the Harris study has developed a methodology which is sensitive to the changes in the highway system. For example, truck operating costs may be decreased by the upgrading of a highway or the building of a bypass around an urban area. The major assumption that is made in developing the truck cost methodology is that motor carrier rates will actually adjust to reflect such improvements in the highway system.

Goldner, William. The Lowry Model Heritage. Journal of the American Institute of Planners, March 1971.

This article is a review of the basic Lowry model and its descendants. The structure of Lowry's original model is discussed, and tables of the Pittsburgh calibration parameters, allocation weights, and minimum service employment thresholds are presented. The subsequent theoretical and operational revisions of the Lowry model discussed by Goldner are summarized in the following tree:



Under the aegis of A. G. Wilson, the Lowry model has been applied at the subregional and town scale throughout England. Empirical work with the model in England has contributed meaningful improvements to the original form.

Goldner maintains that the differences among Lowry-type models are reflected in the following considerations:

- Treatment of the time dimension
- Degree of disaggregation
- Handling of development constraints
- Definition of the areal units
- Number of variables considered
- Calibration and evaluation techniques

Goldner examines each of the Lowry model descendants with respect to these model considerations.

Goldner concludes that the "promise of meaningful operationally" which characterizes the original Lowry model has inspired a host of variants developed for various planning applications. Although many Lowry descendants in America have failed to reach operationally, British modelers have applied the model at "conceptual, experimental, and operational levels."

Illinois River Basin Pilot Project. Argonne National Laboratory. January 1973.

The socioeconomic/land use mathematical model (SELUM) which was developed in conjunction with the Illinois River Basin project is similar to the trend analysis technique used in Missouri. The methodology suggested for projection and allocation of state activity levels involves the identification of subregions in the state. These subregions are defined on the basis of activity growth patterns over time, i.e., fast, stagnant, and independent. Trend projections of activity are then made by subregions, counties, and municipalities.

The Illinois activity allocation methodology assumes that the more aggregate projections are most accurate. Therefore, county trend projections are normalized to the appropriate subregional projection, and municipality totals are normalized to the adjusted county projections.

The most attractive feature of this simple state projection and allocation methodology is its flexibility and ease of utility. Data requirements are small. Data for several points in time are the only requirement for the projection of any activity. In addition, the processing of data is greatly facilitated by the package of manipulation and analysis programs developed for the Illinois project.

Kilbridge, M. D., Robert P. O'Block, and Paul V. Teplitz. A Conceptual Framework for Urban Planning Models. Management Science. February 1969.

The authors present a framework for classification of urban planning models which emphasizes the basic characteristics of the model rather than the application. The basic elements which are evaluated for twenty major models are:

- Subject (land use, transportation, population, and/or economic activity)
- Function (projection, allocation and/or derivation)
- Theory (i.e., market theory, location theory, gravity theory, etc.)
- Method (econometric, stochastic, mathematical programming, or simulation)

The authors also address the problems inherent in model building efforts including the lack of adequate data and urban theory to support the construction of models which accurately reflect urban phenomena.

King, Leslie J. Models of Urban Land Use Development. Models of Urban Structure. Lexington, Massachusetts, Lexington Books, 1969.

This paper is a summary of methods for classifying urban development models, as well as an evaluation of the most influential models which have been constructed. The author reviews the model classification schemes suggested by Harris, Kilbridge, et. al, Wilson, and Lowry, and then introduces his own systems analysis framework. This framework involves a ranking of models based on the level of abstraction which characterizes the model. The ranking continuum ranges from empirical observations to simulation techniques to mathematical analyses.

Empirical observations include such "models" as Burgess' concentric zone theory and Hoyt's sector hypothesis. Simulation techniques include both gaming models and Monte Carlo simulations. King describes the most famous urban gaming models, such as CLUG, METRO, and CITY, and summarizes the uses of Monte Carlo techniques in model building. The most abstract technique, that of mathematical analysis, is used in many urban development models, and the author describes the general algorithms of POLIMETRIC, EMPIRIC, and Lowry-type models. Several normative models are discussed, including the Herbert-Stevens linear programming formulation, and significant stochastic approaches are reviewed briefly. The final recommendations of the author are addressed to agencies of small metropolitan areas and these include:

- Delineate specific goals with respect to land use development
- Implement (even a simple linear regression) forecasting model
- Consider participation in an urban simulation game

Model for Allocating Economic Activities into Subareas in a State. Alan M. Voorhees and Associates, Inc. McLean, Virginia. Report for the Connecticut Interregional Planning Program. May 1966.

A differential shift model is developed to allocate manufacturing employment, population, and service employment by type to small areas. The model is a set of simultaneous equations with independent variables which include lagged dependent variables, holding capacities, and accessibilities. The differential shift, which is the dependent variable for each activity type, is added to the proportional share of state growth term in the net change in small area activity over the forecast interval. The model is applied in distributing activity to 169 Connecticut towns, while a second set of similar models is applied to distribute activity from towns to 804 traffic zones.

Readings in Economic Geography. Smith, Robert H. T., Edward J. Taaffe, and Leslie J. King (eds.). Chicago, Rand-McNally and Company, 1968.

This book is a collection of classical and modern readings in location theory. The sections of most interest with respect to the development of a state activity allocation model involve discussions of Central Place Theory.

In an early section, Brian J. L. Berry and Allan Pred discuss W. Christaller's classical formulation of Central Place Theory. Christaller maintains that regions are characterized by a system of central places whose arrangement is ordered on the basis of three competing principles; namely, marketing, administration, and transportation. Christaller also hypothesizes that the range of a good is determined by the size of the center, the income of the consumer, subjective economic distance and the quantity and price of the good.

John E. Brush presents results of an empirical study of Southwestern Wisconsin which support many tenets of classical Central Place Theory.

The settlements or trade centers in the study area are ranked as hamlets, villages, or towns, according to the number of trade functions which they perform and their spatial location. Brush concludes that trade centers in Southwestern Wisconsin are distributed in a radial-circular fashion, supporting the central place hypotheses of Kolb rather than those of Christaller. Brush maintains that trade center hierarchies in America differ from those in Europe and Africa. However, he concludes that it may be possible to formulate hierarchy guidelines which are applicable to similar regions in America.

Two other articles dealing with applications of Central Place Theory are of special interest. A set of general equations is presented by Berry and Barnum to summarize the fundamental characteristics of central places. Specifically, the relationships between the trade area, the population served, and population densities are plotted for four regions. In a second article, Barry, Barnum, and Tennant's application of Central Place Theory to Southwest Iowa suggests that factor analysis is a useful tool for determining the hierarchy of central places.

A Review of Operational Urban Transportation Models. Peat, Marwick, Mitchell, and Company. Final report submitted to FHWA, April 1973.

This document is a summary of operational urban transportation procedures including five major activity allocation models: PLUM, USM, EMPIRIC, Accessibility-Opportunity, and UPM. The comparison of activity allocation models is preceded by a discussion of the appropriate evaluation criteria and these are considered to be:

- Conceptual structure
- Solution method
- Policy sensitivity
- Level of detail
- Transferability
- Man-machine interface

Each of the five models is evaluated with respect to these criteria. The major advantages and disadvantages of each model, as cited in the report, are summarized below.

PLUM or the Projective Land Use Model is a static equilibrium Lowry-type model with a deductive theoretical base. PLUM provides an option for highly disaggregate output (if stratified input data is available) and a land use accounting system is integrated into the structure of the main model. Submodels are also available in the PLUM package for the projection of socioeconomic data. PLUM suffers from the same disadvantages as other Lowry models in that the basic-service employment split is difficult to determine and the model requires exogenous allocation of forecast year basic employment by small areas.

In many respects, the USM or Urban Systems Model is similar to PLUM. It also is a Lowry-type, static equilibrium model, and therefore has a tight, theoretical structure. However, the USM has a simple and more clearly defined calibration process than PLUM due to its repeated application and modification in Britain. The USM does not contain an explicit land use accounting procedure, nor is the current form of the model able to produce disaggregate activity types. The general limitations of Lowry-type models are discussed above. These drawbacks are also applicable to the USM.

EMPIRIC is a completely different type of model from the preceding two in that its theorectical base is, at the same time, quite loose and flexible. The basic structure of the model is a set of 3-15 simultaneous equations, depending on data availability and desired disaggregation of the output. The dependent variables in these equations represent changes in shares of activities over the forecast interval. The estimation of coefficients for the model variables is a complex procedure which requires a highly trained analyst. However, the package of data manipulation programs which accompanies the basic model facilitates the calibration process. EMPIRIC activity output is generally disaggregated, i.e., population by income group and employment by SIC group, and subordinate models are available for projecting land consumption and socioeconomic variables.

The Opportunity-Accessibility Model has a similar structure to that of the basic modules of PLUM and the USM. The model has been used primarily in allocating trip ends for transportation studies in urban areas. Because of its principal use as an impact analysis tool, its input data requirements are relatively small, and its output is of an aggregated form. Its simplified structure precludes the testing of non-transportation policies, an option which is available within the other four models. Transferability of the model is limited, since it is not actively supported by a staff effort.

The UPM or Urban Performance Model is a time-dependent model with an attractive conceptual structure based on utility theory. The model is principally noted for its use of "opportunity" and "quality" measures which provide a simple and effective framework for the evaluation of urban area projections. Some UPM forecasting options have not been fully tested, however, and the calibration process is not well defined. Therefore, the utility of the UPM in terms of producing urban area projections is as yet unknown.

STAM Socioeconomic and Land Use Data File. West Virginia Department of Highways. March 1972.

West Virginia is developing a comprehensive 1970 socioeconomic and land use data base as part of a Statewide Traffic Assignment Model Study. The socioeconomic variables which are being collected at the 778 zone levels can be allocated to the following seven categories:

- Population
- Auto Registration

- Employment
- Indices of Productivity
- Education
- Indices of Community Structure and Accessibility
- Recreation Index

Work sheets and detailed instructions for implementing the data collection process are provided in the West Virginia Manual.

A Summary of the Urban Systems Model. Alan M. Voorhees and Associates, Inc., McLean, Virginia. January 1974.

The Urban Systems Model (USM) is a Lowry-type model which incorporates the entropy-maximizing formulation developed by A. G. Wilson.

The model consists of an integrated set of activity system submodels which distribute population and service employment to small areas in a metropolitan region as a function of:

- The transportation cost (in terms of time or money) of traveling to the small area
- The intrinsic attractiveness of the small area to population or service employment
- The competitive attractiveness of all other such small areas
- The activity holding capacity of each small area

Assuming regional projections of population, primary and service employment, and a small area distribution of primary employment, the USM operates iteratively to distribute increments of employment from work place to residential locations and of service demand from residences and work places to service centers. This iterative procedure converges on the regional population and service employment control totals. After regional convergence is attained and small area holding capacities are satisfied, small area densities, accessibilities, and market potentials are calculated for each activity.

In addition to the calculation of the aforementioned indices, the USM has the optional capbility of calculating the following environmental indices:

- Level of sewer service per resident and per primary employee
- Level of water service per resident and per primary employee
- Mobile source emissions (i.e., highway and transit) by district
- Mobile source air pollution exposure indices (i.e., highway and transit) by district
- Noise pollution exposure levels from large stationary sources (e.g., airports) by district

The USM is a static equilibrium model, which is operated recursively (generally in ten-year periods) to predict activity distributions for future points in time. The temporal dimension is treated implicitly in the model via the usage of logged residential and service employment attraction indices. The model may also be applied in a semi-dynamic form to distribute the growth in activity during the forecast interval.

The USM has been calibrated and applied in the North Central Texas (Dallas-Ft. Worth) and Baltimore regions, is being calibrated for Kalamazoo, Michigan, and is also be adapted for application at the statewide level in Connecticut.

Correlation coefficients (R^2) and root mean square error are calculated by the USM and provide statistical measures of the overall quality of calibration results. The calibration procedure also provides a comparison of the actual and estimated levels of population, service employment, and total employment by small area. Analysis of the North Central Texas calibration results show close correlation between actual and estimated population, service employment, and total employment and a good bit between the actual and estimated distributions of percent work trips against travel cost.

Wilson, A. G. Entropy in Urban and Regional Modeling. London, Pion Limited, 1970.

This reference represents a synthesis of the work done by Wilson in developing an entropy maximizing approach to spatial interaction within an urban system. Wilson addresses the specific relationship of the entropy-maximizing approach to transport models and locational analyses.

The gravity model, which has usually been derived thorugh analogies with Newtonian mechanics, is derived by Wilson using a statistical approach. The basic gravity model he produces is shown to be applicable in a variety of transport flow situations.

In addition, Wilson demonstrates that the entropy-maximizing approach can be applied to locational models which describe macro-system movements. For example, the location of retail activity and residences may be ascertained via Wilson's approach. However, the author concedes the maximum entropy approach is probably not suitable in projecting discrete industrial locations.

Wilson also discusses the close relationship of the entropy-maximizing approach to input-output economic models and utility-maximizing systems and concludes that the theory is quite adaptable in the field of urban and regional modeling.

Wilson, A. G. Models in Urban Planning: A Synoptic Review of Recent Literature. Urban Studies. November 1968.

The paper presents a systems framework for the design and implementation of planning models. Wilson presents the following hierarchical relevance tree for planning:

<u>Policy</u>

- Action
- Goals
- Evaluation

Design

- Plan Formulation
- Design Techniques
- Problem Formulation

Understanding

- Systems Models
- Techniques

The author suggests that the most current model building efforts belong to the Understanding stage, but that the future development and application of models should involve both the Design and Policy levels.

Wilson proposes that the following basic questions be addressed during the model development phase:

- What questions is the model trying to answer?
- Which concepts are measurable?
- What variables are at least partially controlled by the planner?
- What level of analysis and disaggregation will be used?
- How will time be treated in the model?
- What behavioral theories will the model represent?
- What techniques are available for implementing the theories?
- What relevant data are available?
- How is model to be calibrated and tested?

Wilson delineates the following urban systems and discusses the most recent modeling work in these areas:

- Spatially aggregated population
- Spatially aggregated economic
- Residential
- Workplace
- Physical infrastructure
- Economic activity
- Transport
- Social services

The remainer of the paper is a review of recent modeling contributions in each of the Policy and Design categories of the planning relevance tree.

Wisconsin Place Classification for Transportation Planning. State of Wisconsin, Department of Transportation, Division of Planning. January 1973.

Wisconsin has developed a framework for ranking activity centers via a composite index of economic importance. Activity centers are classified by the following six identifiers:

- Urbanized area
- Metropolitan center
- Regional center
- District center
- Area center
- Special center

The classification procedure is based on the activity center ranking as determined by the following variables: full valuation, sales tax, population, employment, selected services, retail sales, and wholesale trade.

The place classification methodology has been applied in ranking Wisconsin activity centers in 1966 and has been updated for 1970. These rankings have been used in determining the level, location, and type of airports and highways needed in the prime market centers of the state. It is anticipated that the place classification will also be useful in the development of a statewide development and/or land use plan.