EPA-450/3-74-020-a

AIR QUALITY FOR URBAN AND INDUSTRIAL PLANNING

by

John C. Goodrich, Scott T. McCandless,
Michael J. Keefe, William P. Walsh, and Alan H. Epstein

Environmental Research & Technology, Inc.
429 Marrett Road
Lexington, Massachusetts

Contract No. 68-02-0567

EPA Project Officer: John Robson

Prepared for

ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, N. C. 27711

March 1974

This report was furnished to the Environmental Protection Agency by the Environmental Research & Technology, Inc., in fulfillment of Contract No. 68-02-0567. The contents of this report are reproduced herein as received from the Environmental Research & Technology, Inc. The opinions, findings, and conclusions expressed are those of the author and not necessarily those of the Environmental Protection Agency. Mention of company or product names is not to be considered as an endorsement by the Environmental Protection Agency.

Publication No. EPA-450/3-74-020-a

PREFACE

This Final Report for EPA Contract No. 68-02-0567, Air Quality for Urban and Industrial Planning (AQUIP: Extension) is divided into three parts. Part 1 presents a summary of work undertaken, including sections describing the proposed scope of work for each of the three major tasks for the study, together with a summary of the actual work undertaken and an explanation of deviations, if any, from the intended scope of work. The detailed findings of Tasks 1 and 2 are found in Parts 2 and 3 of this Final Report, respectively; the detailed findings for Task 3 are found in a separately bound report entitled, A Guide for Considering Air Quality in Urban Planning. The report on Task 3 is available free of charge to Federal employees, current contractors and grantees, and nonprofit organizations - as supplies permit - from the Air Pollution Technical Information Center, Environmental Protection Agency, Research Triangle Park, North Carolina 27711; or, for a fee, from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

PART 1

SUMMARY OF WORK UNDERTAKEN

TASK 1 DEVELOPMENT OF IMPROVED EMISSIONS PROJECTION ACTIVITY INDICES

The general approach to this task was to be based upon the most recent point and area source inventories compiled for the development of state implementation plans by the Environmental Protection Agency (EPA) and its Basic Ordering Agreement (BOA) contractors with emphasis on a large statistical sample drawn from the industrial point source inventories. Such data were to be divided into specified land use categories and subcategories. Activity indices were to be derived empirically from the relationships between activity levels and fuel use or process emissions. Because of the massive data-handling requirements, computer data processing was to be used. Determination of activity indices provides factors for estimating current emissions which can then be used as a basis for projecting activity indices for future time periods. This task emphasizes determination of current activity indices, but also establishes the procedures for projecting activity indices. These projections may involve detailed assumptions concerning changes in emission control regulations, industrial processes, fuel switching, productivity, consumer preferences, and many other factors affecting the relationship between land use and resultant air quality

Subtasks proposed included the following:

1-a Defining principal land use categories and specifications for statistical validity.

1-b Collecting 1970 implementation plan point and area source inventories, particularly those available in machine readable format. Conducting supplementary surveys of particular industrial, utility and commercial sources, and surveys of planning and governmental agencies

1-c Compiling and processing the available data using standard tabulation and statistical computer programs.

1-d Analyzing the data and deriving activity indices for current emissions estimation.

1-e Developing the methodology for projection of activity indices for future emissions estimation.

1-f Documenting the data, methodology, and derived activity indices

1-g Incorporating the resulting activity indices into the AQUIP System (an acronym standing for Air Quality for Urban and Industrial Planning).

Early in the study the following were ascertained relative to data for Task 1:

1) Data from the National Emissions Data System (NEDS) inventories for the 1970 Implementation Plan (IPP) information was not available in sufficient quantity and appropriate form for our study. The availability of this data had been stressed as a necessity for successful completion of the project.

2) The only data available in computer form was the point source inventories for certain states from BOA contractors; there were significant problems of confidentiality, making it difficult, if not impossible, for EPA to release this data to us for our use in the study. Moreover, most of the states were not in a position to release the data at the time due to litigation over the question of confidentiality.

Accordingly, it was decided to obtain data for New Jersey and Massachusetts directly from the states since ERT already had worked with agencies in these states. As documented in the monthly progress reports, this process resulted in (1) significant delays, (2) unexpected efforts in data gathering, verifying, and manipulation, and (3) certain redirection of subsequent subtasks relying upon these data.

By reducing the desired sample number and relying upon national indicators of floor space per employee for industrial firms, the initial data-gathering was concluded with the hope of maintaining sufficient detail of information to carry out Task 1. Efforts that would have otherwise been devoted to supplemental surveys and literature searches (Subtask 1-b) were instead concentrated on coding, keypunching and data preparation. Emphasis was placed on industrial point source data to the exclusion of area source data or other types of point source data.

The activity categories to be investigated were broadly defined as "industrial" (Subtask 1-a); this was to be narrowed according to the distribution of Standard Industrial Classification (SIC) contained in the final sample obtained.

Unfortunately, errors and missing information were found in the data. Field trips to each of the major data sources in Massachusetts and New Jersey were then necessary to obtain supplementary information. Time was spent in the New Jersey Department of Environmental Protection, Bureau of Air Pollution Control Office, reviewing printouts of point source emission rates, employment, fuel consumption and process rates. A review of Bureau of Air Pollution Control questionnaire files was needed to supply information not currently stored in computer data banks. Likewise, in Massachusetts a review of Department of Public Health source questionnaires was made to supplement data in existing printouts.

It became clear as the technical work was concluded that the data analysis of Task 1 would yield less than the desired statistical sample and analysis results because of the data-gathering problems of Subtask 1-b. Therefore, the documentation stresses the approach, problems, opportunities and recommendations for further work, and de-emphasizes concrete statistical conclusions. This re-orientation resulted from problems in obtaining requested data and has been consistently documented in the progress reports.

When all Massachusetts data was identified and received and the status of all New Jersey data determined, definition of the required tabulations and statistical computer routines was begun. As a part of the previous AQUIP study[1] computer algorithms for comparing fuel use, emissions, floor space and employment by SIC had been partially developed and, since the changes in Subtask-1b required that data be coded, a form compatible with this software was used. The software requirements for Subtasks 1-c and 1-d were, thus, simultaneously formulated.

After initial computer analyses were performed for both the New Jersey and Massachusetts data, errors corrected, and the final computer runs performed, the interpretation of statistical analyses (Subtask 1-d) was brought to the disappointing and abbreviated conclusion that the accuracy and completeness of the data were not sufficient to derive activity indices at the level of detail anticipated.

The projection methodology (Subtask 1-e) was most affected by data-gathering delays. Preliminary work began with a literature survey and comparison of information with the initial Hackensack study[1] and concluded with the postulation of the kinds of information and decisions necessary for emission projection. Given the late start for this subtask, the disappointing results of Subtask 1-d (necessary as an input to Subtask 1-e), and the lack of other readily usable information, no definitive results were forthcoming from this subtask.

Work related to documentation (Subtask 1-f) is contained in Part II of this Final Report. The small degree to which information was shown to be statistically conclusive and, therefore, documentable, and the inability to incorporate revised activity indices into AQUIP to any great degree (Subtask 1-g) has been a function of the disappointing results of Subtask 1-d which came ultimately from the data gathering problems of Subtask 1-b. Moreover, the necessity of concentrating on a specific source category—industrial point sources—due to time and budget constraints precluded the examination of activity indices which might have been more appropriate for other source categories.

TASK 2 DEVELOPMENT OF A METHODOLOGY FOR INCORPORATING COST DATA INTO THE EVALUATION OF THE AIR POLLUTION IMPACT OF LAND USE PLANS

The general approach to this task was to focus on collecting and assembling the results of EPA-sponsored studies on source control costs and on evaluation of economic impacts of various control strategies. ERT was to examine the data available and formulate a framework for presenting such data relative to land use plans, developments, or facility designs. Parameters to be examined were expected to include land use zone cost indices per unit emission control

Subtasks proposed included the following:

2-a Surveying of literature and federal contract research efforts to compile source air pollution control cost data and data on costs and economic impact of implementation plan control strategies.

2-b Developing a methodology for including cost data in the evaluation of land use plans.

2-c Compiling representative cost data to test and demonstrate the techniques for a hypothetical application.

2-d Documenting results of the test and demonstration and making recommendations for incorporation of the cost data base and methodologies into the AQUIP system for planning use.

The research showed that existing data and literature were sparse but that reasonable methodologies could be developed for including cost data in the evaluation of land use plans. Literature pertinent to the economic implications of air pollution may generally be categorized into three distinguishable areas of concern:

1) The tradeoff of economic activity with air quality.

2) The functional relationships of emission control costs and damage costs to air quality.

3) Cost/benefit analyses associated with the control and damage costs of air pollution for a given level of economic activity as a function of land use strategy.

The findings of Subtasks 2-a and 2-b determined the depth possible in demonstrating the methodology. Accordingly, work on the hypothetical application of the methodology (Subtask 2-c) concentrated on a review of the literature on air pollution damage functions. Documentation of the methodology (Subtask 2-d) was done in the form of Part III of this Final Report, entitled "Cost Effective Planning for Acceptable Air Quality."

TASK 3 PERFORMANCE OF LAND USE - AIR POLLUTION IMPACT SENSITIVITY STUDIES

The proposed approach to this task was to utilize the AQUIP System to carry out certain sensitivity analyses. ERT was to use the existing land use data base for the Meadowlands, and, in addition, incorporate the improved activity indices resulting from Task 1. Several planning agencies were to be contacted to identify a set of specific and meaningful small area and facility design alternatives. On the basis of such alternatives, ERT would specify the number of scenarios or case studies and trade-off parameters to be modeled. Air quality would be projected for each of these scenarios and the results correlated with changes in different design parameters.

Subtasks proposed included the following:

3-a Identifying case studies, land use configuration alternatives, and facility design choices to be included in the sensitivity analysis.

3-b Defining the parameters and scope of specific sensitivity analyses.

3-c Preparing inputs for the AQUIP System appropriate to each sensitivity study.

3-d Running the AQUIP System and processing resulting air quality as a function of parameters described in Subtask 3-b.

3-e Documenting results in the form of guidelines of general applicability for planners.

Visits to planning agencies in New Hampshire, New York, New Jersey, and Massachusetts indicated the specific need for a document containing guidelines dealing with air pollution for planners. Accordingly, such a guidelines document became the main goal of Task 3, with the sensitivity studies a major contributor to this final product. This guidelines document is a separately bound report, entitled "A Guide for Considering Air Quality in Urban Planning."

ERT conducted several interviews of planning agency personnel projected to be potential users of the findings of any air quality planning guidelines. ERT initiated a dialogue with these professionals concerning the goals, methods and data to be used in the study procedure and attempted to determine which tools and format the intended beneficiaries of the investigations would prefer to see developed. By acquainting potential users of the guidelines document with the early stages of data collection, it was hoped that the guidelines might be more usefully tailored to the needs of such users.

In addition to the air quality agencies in Massachusetts and New Jersey, as well as EPA, four regional planning agencies were interviewed: Southern New Hampshire Regional Planning Commission (Manchester, New Hampshire), Central Massachusetts Regional Planning Commission (Worcester, Massachusetts), Tri-State Regional Planning Commission (New York City), and the Hackensack Meadowlands Development Commission (Hackensack, New Jersey).

The information obtained from speaking to these agencies can be summarized as follows. Traditional planning agencies appear to be relatively ignorant of the relationships between planning practices and air quality. While each knew that transportation vehicles and industries are the primary sources of air pollution emissions, the concept of planning for air quality was a new one. Each agency seemed eager to have some capabilities in the area of planning for air quality. Motives among the agencies for wanting these capabilities were diverse, however. Some saw AQUIP as a tool for use in zoning, public hearings, or transportation planning. Each agency wished to have the study provide a simplistic approach to air quality planning. The planners seemed much more interested in receiving a manual that would provide a cookbook methodology for studying air quality than a semi-theoretical discussion of air quality parameters. Specifying land uses by SIC code (Standard Industrial Classification) was universally accepted as desirable since both land use planners and air quality agencies were familiar with them. Other parameters received mixed reactions as being acceptable indices. Some preferred floor area, etc., as a means for projecting emissions activity. Each agency was anxious to see the guidelines document to be produced.

Subtask 3-a required the identification of "case studies, land use configuration alternatives, and facility design choices to be included in the sensitivity analyses." As described in greater detail in the guidelines document,[2] these were chosen to be the following.

Case Study No. 1

Relative effects on annual average air quality resulting from clustered versus dispersed area sources. Land use configuration alternatives: (1) clustering, and (2) dispersal. Facility design choices: (1) single area source, and (2) four dispersed area sources.

Case Study No. 2

Relative effects on annual average air quality of clustered versus dispersed point sources. Land use configuration alternatives: (1) clustering, and (2) dispersal. Facility design choices: (1) single point source, and (2) four dispersed point sources.

Case Study No. 3

Relative effects on air quality of clustered versus dispersed sources in a worst-case situation. Land use configuration alternatives: (1) clustering, and (2) dispersal. Facility design choices: (1) one point source and one area source, and (2) one point source and four dispersed area sources.

Highway Sources

Facility design choices: (1) elevated, (2) depressed, and (3) at-grade.

Subtask 3-b required the definition of "the parameters and scope of specific sensitivity analyses." As described in greater detail in the guidelines document, these were chosen to be the following.

Case Study No. 1

Comparison of annual average air quality for a concentrated area source with annual average air quality for four smaller dispersed area sources having the same total source strength. Parameters included:

1) Meteorological Conditions - annual stability wind rose for Newark, New Jersey.
2) Source Strengths - (a) area source of 4,000 grams/sec, (b) four dispersed area sources, each emitting 1,000 grams/sec.

Case Study No. 2

Comparison of annual average air quality for a concentrated point source with annual average air quality for four smaller, dispersed point sources having the same total source strength. Parameters included:

1) Meteorological Conditions - annual stability wind rose for Newark, New Jersey.

2) Source Strengths - (a) point source of 4,000 grams/sec, (b) four dispersed point sources, each emitting 1,000 grams/sec.

Case Study No. 3

Comparison of worst-case air quality for a concentrated point source and a concentrated area source with worst-case air quality for the same concentrated point source and four dispersed area sources. Parameters included:

1) Meteorological Conditions (identical for both source configurations) - (a) high stability, (b) low wind speed, and (c) southwest wind.

2) Source Strengths - (a) point source of 5,000 grams/sec, and area source of 4,000 grams/sec; (b) point source of 5,000 grams/sec, and four dispersed area sources, each emitting 1,000 grams/sec.

Highway Sources

Discussion of worst-case air quality for different highway designs under different meteorological and traffic conditions. Parameters included:

1) Meteorological Conditions - (a) stability, and (b) wind speed.

2) Highway Designs - (a) elevated, (b) depressed, and (c) at-grade.

3) Source Strenth Dependence on Traffic Characteristics: (a) volume, (b) speed distribution, and (c) vehicle year and make mix.

Subtask 3-c required the preparation of "inputs for the AQUIP System appropriate to each sensitivity study" while Subtask 3-d required the running of the AQUIP System and the processing of "resulting air quality as a function of parameters described in 3-b." The revised scope of the sensitivity studies led to the decision to use them in illustrating an important factor in planning for air quality: the influence of source configuration for both stationary and highway sources. For this purpose, the most effective use of the AQUIP System (Subtasks 3-c and 3-d) lay in using the diffusion modeling capability, MARTIK (based upon the EPA Martin-Tikvart Model), independently of the rest of the system. For describing the influence of source configuration on highway sources, results obtained from the ERT numerical simulation model, EGAMA (developed by Dr. B. A. Egan and Dr. J. R. Mahoney),were used. EGAMA is not part of the AQUIP System, but its results have been found to be most useful in determining the impact of alternative highway configurations on air quality.

The improved activity indices resulting from Task 1 were not available to the sensitivity studies on account of data limitations. This precluded the incorporation of such improved indices into the existing land use data base for the Meadowlands. The processed air quality results for the sensitivity studies are depicted graphically in the guidelines document. As discussed above, the guidelines document itself represent the results of Subtask 3-e.

REFERENCES FOR PART 1

1. Willis, B. H. et al. The Hackensack Meadowlands Air Pollution Study, Summary Report and Task Reports, Tasks 1-5, prepared for the State of New Jersey, Department of Environmental Protection, Trenton, 1973.

2. Epstein, A. H. et al. A Guide for Considering Air Quality in Urban Planning, prepared for USEPA, March 1974, Contract No. 68-02-0567.

PART 2

TASK 1 REPORT

DEVELOPMENT OF IMPROVED EMISSIONS PROJECTION ACTIVITY INDICES

by

John C. Goodrich
Scott T. McCandless
Michael J. Keefe
William P. Walsh

TERMINOLOGY

Because the terminologies of several different professions are used in this task report, often in unfamiliar ways, this brief discussion of terminology is presented to show the context within which different terms were used.

The basic land use and transportation planning units of intensity of use - such as square feet of industrial plant space - are called the activities or the activity level. The parameters which translate the activity levels into demand for fuel for heating purposes are called activity indices; for instance, BTUs (British Thermal Units of heat demand) per square foot for industrial plant space.

A distinction has been made between fuel-related and nonfuel-related activities or sources of emissions. The fuel-related sources use fuel for:

1) Heating area, for example, heating a building in the winter. The amount of heat required and the fuel consumed is a function of the temperature or the number of degree-days (the sum of negative departures of average daily temperature from 65°F). This fuel use is that required for heating, or space heating (or cooling).

2) Raising a product to a certain temperature during an industrial process. The amount of fuel consumed is a function of the activity and is generally not related to outside temperature. This fuel use is that required for process heating, or nonspace heating.

3) Space heating and process heating. The sum is sometimes referred to as total heating fuel use.

The area to be heated for space heating purposes and the amount of the year it will be heated (a function of the schedule, such as 250 days per year for an industrial plant) help determine the heating requirements for an activity. If the activity requires process heat as well, the total heating requirements will be the sum of the space heating requirements and the non-space heating requirements. The percent of the total allocated to either type is called the percent space heat or the percent process heat.

The total heat requirement determines the demand for fuel. Different activities are more apt to use one fuel than another; the propensity to use particular fuel or fuels (the fuel use propensity) determines the actual fuel used to satisfy the heat requirement.

Different types of activities may have varying activity indices or percent space heat or fuel use propensities; for instance, each industrial category in the U. S. Census 4-digit Standard Industrial Classification (SIC) may have a unique value. However, we may know information only by broad industrial groups comprising aggregates of the 4-digit classification (e.g., 1-digit or 2-digit SIC codes). Using the value applied to the larger or broader group for the smaller or more detailed group, when the unique value is not known, has been termed a default parameter in these studies.

Emissions from sources that do not result from the burning of fuel; for example, evaporation from a refinery storage tank, are termed separate process emissions or process emissions. Note the distinction between process heating related or combustion emissions and separate process or non-combustion emissions. Although the combustion of fuel is involved, transportation emissions have been considered as process rather than fuel emissions in this study for simplicity, since they do not vary with heating degree days.

INTRODUCTION TO PART 2

The Environmental Protection Agency (EPA) and the New Jersey Department of Environmental Protection (NJDEP) sponsored a study, commencing in 1970, addressed to their mutual concern for improving future air quality through the planning of land use and transportation activities. The two fundamental objectives of the Air Quality for Urban and Industrial Planning (AQUIP) study were: (1) to develop a broadbased methodology for considering air pollution in the formulation and evaluation of alternative urban plans; and, (2) to demonstrate this methodology in detail by applying it directly to the planning alternatives developed for the New Jersey Hackensack Meadowlands District.[1]

One of the major goals of the AQUIP study was to develop a methodology to aid planners in determining air pollutant emissions directly from land use and transportation activity data. Procedures traditionally used to estimate emissions from land use and transportation planning data often emphasize empirical derivation of emissions indices as a one-step function of "activity categories (e.g., activity times and index yields emissions). In the AQUIP study, however, a multistep approach was developed so that: (1) all assumptions and constraints involved in transforming the levels of activities into emissions could be examined; and (2) procedures for updating the information which the planner does not directly input could be specified.

In response to the study objectives a five-step procedure was formulated in the AQUIP study as shown in Figure 1.

<u>Step 1 - Activities</u>. For each land use or transportation planning category identified for analysis, the "level of activity" is specified, such as 10 dwelling units per acre for residential density.

<u>Step 2 - Activity Indices.</u> For each category of activity, "default parameters" for determining fuel requirements are developed, such as 10 BTUs (British Thermal Units of heat demand) per hour per square foot of residential floor area.

<u>Step 3 - Fuel Use</u>. For each category of activity (and geographical subregion of the study area) default parameters for the "propensity"

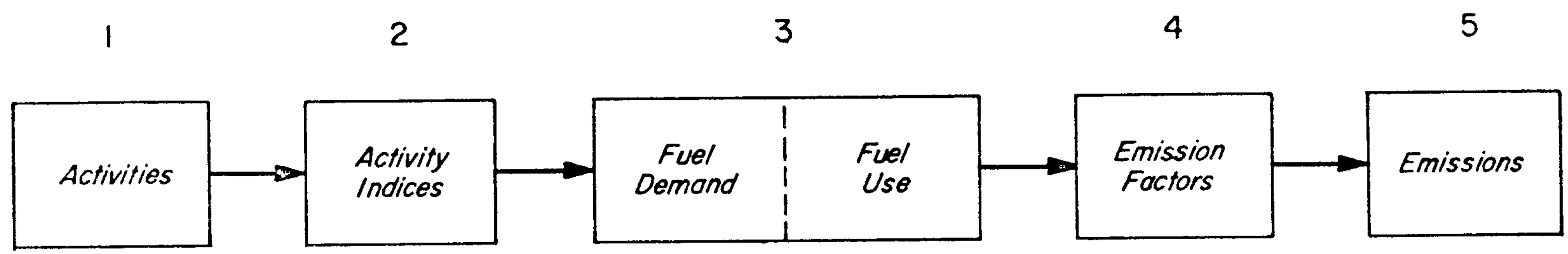

Figure 2-1. Five-step Procedure for Determining Emissions.

to use different fuels are applied to the fuel requirements, such as the degree to which oil is used (65%) rather than natural gas (25%) for home heating.

Step 4 - Emission Factors. For each category of activity, engineering estimates of fuel and nonfuel (process) related "emission factors" are developed and applied directly to fuel use and process rates to determine emissions, such as 10 lbs of particulates per 1000 gallons of fuel oil burned.

Step 5 - Emissions. Emissions calculated from fuel and process sources are adjusted for season of the year, based on temperature variation (degree-days) and default parameters representing the percent of fuel used for "space heating" purposes.

Of particular importance in the AQUIP study was the application of these five-step procedures in two distinct and consecutive phases. In the first phase current planning data and current fuel use are correlated to produce projecting indices - the default parameters. In the second phase these projecting indices are modified to reflect future time periods and are applied to planning data so as to generate future fuel demand and emission levels. Current data on fuel use and emission factors are likewise used to predict future information when better estimates are not known. The first phase analysis provides the majority of the default parameters to be used in the second phase in conjunction with the planner's own inputs.

The application of the emissions projection methodology to the Meadowlands plans showed that the five-step procedures were workable and, in fact, quite adaptable to the land use considerations that were encountered. In particular, the development of a "conversion factors catalog" and sets of "default parameters" demonstrated that the planner need input only planning-related data to use a tool such as the AQUIP System.

However, it was found that the planner must specify data he does not normally deal with, such as the sizes of developments in terms of their heating requirements, and the types of manufacturing operations anticipated. Furthermore, the level of detail available for empirically deriving the default parameters was unsatisfactory for discerning between related activities; this was particularly true for deciding fuel use and determining process-related emissions. Consequently, the greatest need for further work was shown to involve the empirical derivation of activity indices and default parameters.

Activity indices as shown in Figure 2-1 are the basic factors used to convert land use activities to either fuel combustion or process emissions. This is precisely the area, however, for which it was shown in the previous AQUIP study that there is the greatest lack of data, and for which there is the greatest need for detailed and accurate data (fuel use data and emissions factors are generally readily available from EPA).

The objective of Task 1 of the current AQUIP Extension Study was, therefore, to define, collect and process activity data so as to derive improved activity indices for the AQUIP System.

In previous studies (including the AQUIP Study) it has been demonstrated that one of the principal variables in determining existing and future air quality levels is land use. This is because land use dictates emission source characteristics in terms of both the levels of activity and the activity indices. In order to develop the desired activity indices for land uses, it is necessary to define the land use categories to be studied and to arrange these categories in a manner that facilitates statistical analysis.

Of the major categories of emission sources we determined that industrial point sources most warranted development of activity indices that could be readily used in the planning process.

The two largest contributors to source emissions have been shown to be transportation and industry. Most other source categories are either relatively insignificant or have been studied to some extent. Since research was already being supported by EPA in regards to transportation sources and emission patterns, it was decided in conjunction with the project officer to concentrate the efforts of Task 1 of the AQUIP Extension on industrial sources. For several years research with respect to air quality has focused on mobile sources. As a result, there are several documents now in publication that enable one to calculate existing vehicle emissions and to forecast emissions from given numbers and types of transportation vehicles for future time periods[2]. It was also decided that the air quality impacts of transportation systems are both very specialized and usually localized. This being the case, major transportation studies should be accompanied by individual air quality assessments based on much more specific and detailed data than that which could be collected, analyzed, and organized in the AQUIP Extension Study. In addition, transportation sources cannot reasonably be grouped as a land use for air quality considerations. Transportation systems are products of other land uses and activities, but the variables which affect pollutant emission from mobile sources are not at all similar to the variables that affect emissions from point sources. Accordingly, land use and transportation need to be treated as separate, but interdependent emission sources.

Quasi-public activities, such as incinerators and power plants, are point sources which warrant individual analysis. Such activities do not lend themselves well to statistical analysis since designs, capacities and, therefore, emissions, may differ radically. Generally, the relatively small number of such emission sources makes this individual assessment feasible.

Other sources may generally be considered insignificant on a regional scale. Although it is obvious that commercial and residential facilities have a space heating function, the levels of emissions due to the space heating needs are both small and fairly predictable using current information[3]. These sources do, however, need to be considered as inducers of transportation sources.

The previous AQUIP study concluded that industrial sources are of special significance because of the uncertainty as to the amount of fuel required for process heating and the incidence of separate process emissions. Efforts to develop a statistical sample of the propensity to use fuel for process heating by industrial category, based upon the existing emission inventories, were not successful in the previous study. It was possible to divide the industrial SIC codes into only two major categories of "relatively clean" and "relatively unclean" industries. The clean industries were assumed to operate fewer hours per year and use a greater percentage of their fuel for space heating.

A separate study of process emissions corresponding to the industries proposed for the New Jersey Hackensack Meadowlands was made as a part of the previous study. With the exception of possible sources in the chemical and petrochemical and primary metals area, the SICs proposed for the Meadowlands were not found to be significant separate process emitters.

There were some potential emissions of particulates and hydrocarbons from selected industries. These were accounted for by adding an arbitrary best-estimate percentage of the fuel-burning emissions to the fuel emission estimates, since no information was available on process rate. The Meadowlands planners felt that there would be no petrochemical or primary metals smelting operatins in the Meadowlands.

As a result of missing data, the concept of "default parameters" was developed in the previous study. If information is desired according to a detailed industrial classification for the propensity to use different fuels and the data is only available in aggregate form for all industries in the region, a default parameter is used to assign the industry-wide factor to each individual industry. If, at a later date, specific information for an industry is available, it can be used in place of the default parameter.

As a result of the previous AQUIP Study, it was clearly evident that the activity indices required better specification. It was hypothesized that industrial point source emissions are a category particularly in need for further study and that such sources would probably lend themselves to some reasonable statistical analysis. These hypotheses were based on the fact that industries have several inherent similarities that should make planning for air quality a reasonable undertaking. The industrial activity indices that were considered the statistical analysis were:

1) Employment
2) Floor area
3) Process weights (or production rates)
4) Fuel use
5) Hours of operation
6) Classification by product

The fact that industries are conveniently organized by type of activity is probably the factor that makes this system of emission projection seem most feasible. The U. S. Census Standard Industrial Classification (SIC) codes aggregated land uses into numerical groupings by product. It was hypothesized, therefore, that industries with similar process emission characteristics are grouped together. These same SIC codes were chosen as the common denominator since they are familiar to both planning agencies, as a tool to classify land uses, and to air pollution control agencies as a classifier of point source activities.

The following chapters present the data used, analysis of emissions data, and discussion of projecting future emissions.

DATA USED IN THE STUDY

In order to derive activity indices for emissions estimations, a substantial data base is required. The original scope of work specified that EPA would provide the desired data. It was intended that the EPA data collected for the National Emissions Data System (NEDS) would provide sufficient data to perform statistical analyses. Early in the study, however, it was discovered that the EPA data could not be made available.

Much of the information in the NEDS files is confidential material. Although its nature is limited to pollutant-related statistics, industries are very sensitive about releasing any information to their competitors. Likewise, some industries are reluctant to have figures on emissions and fuels available to groups and organizations that may lobby against the interests of the industries. EPA was not able to provide the general data files without ensuring that the confidence of the contributing industries would not be violated. Accordingly, the General Counsel of EPA decided that the data files would not be released during the course of the study. Without these data the entire AQUIP Extension Study was threatened.

After consulting with the project officer, the consultant elected to apply directly to several state air quality agencies for the data required for the study. The constraints of budget and time limited the number of state air quality agencies that could be petitioned for information. It was decided that two reasonable sources of emissions data would be Massachusetts and New Jersey, since both were familiar with the contractor. Massachusetts data was filed in the Boston Office of the Massachusetts Department of Public Health, only a few miles from the consultant's office and through previous contracts in the state, a working relationship with Massachusetts officials had been established. New Jersey had been the site of the previous AQUIP study, and was therefore considered an appropriate state from which emissions data could be solicited.

The consultant requested a fairly comprehensive set of data from both states, including point source information for each of the following categories:

1) SIC code for each point source
2) Employment of the point source

3) Annual operating hours of the source
4) Fuel use by type and amount of fuel
5) Percent of fuel used for space heat
6) Product process rate
7) Floor area of the point source building.
8) Emmission rates for sulfur dioxide (SO_2), total suspended particulates (TSP), carbon monoxide, (CO), hydrocarbons (HC), and nithogen oxides (NO_X).

As in previous air quality studies, the air quality agencies from each of the states were assured that all data used would be confidentially handled. All point sources were, accordingly, coded to a source number, and reference to the sources is by number and SIC codes only. Since all data was supplied by the two states and since only EPA will review results there was no loss in confidentiality of the data.

Although each of the states was quite cooperative, assembling the relevant data presented some unavoidable problems. The consultant had hoped to expedite the data-gathering process by securing the relevant materials in the form of computer tapes or computer card decks, but this was not possible. In each case compiling the data inventory involved obtaining clearances to examine state air quality data and extracting the appropriate information by hand from existing printouts and questionnaire files. In many cases, accumulating the data required large amounts of time for cross-referencing and for normalizing the inputs into congruent sets of units. In its final form the data inventory reflects the problems that were encountered. Major shortcomings of the data set include problems in the following areas:

Percent space heat or process heat data was not available for New Jersey. Findings in this area are, therefore, extrapolated from Massachusetts data alone. Employment figures for the point sources from both states were fragmented. (In some cases the consultant does not feel confident that employment figures supplied are entirely accurate either, but the figures obtained from the state agencies were used without review.) Floor areas for the industries were not available. Since floor areas were not available from the industries, they were derived using employment figures and a table which estimates unit floor areas per employee by SIC code. This obviously means that where point source employment is unknown floor area is also missing.

After screening and computer runs to organize the material, the final form of the data consisted of some 5500 computer cards which outline information (although fragmented and incomplete) for some 868 point sources of industrial emissions. Of these, 555 sources were from Massachusetts and 313 from New Jersey. This included point sources with a wide range of SIC code numbers, however. The final working file of data was trimmed to include only manufacturing industries - those whose SIC codes begin with the digits "2" or "3". Table 2-1 shows the two-digit classification for such manufacturing industries. The analysis concentrated on the general area of industrial sources, whle institutional, commercial, and all other sources which were presumed to be relatively minor were excluded from subsequent analysis. This decision left at least some statistical input for each of a total of 644 manufacturing point sources.

Management of the data collected presented the study with the prodigious tasks of recording, keypunching, checking, sorting, aggregating and analyzing. The consultant made use of its electronic data processing capabilities to record, compile, aggregate, and tabulate the various point source statistics. The data management capabilities of the algorithms used are as follows:

1) For each point source the statistical analysis program produces a summary, by source, of identifying information such as source identification number and the following parameters of interest.

SIC code
Number of employees
Operating hours/year
Gross plant area (sq.ft.)
Enclosed floor area (sq.ft.)
Percent process heat (e.g., nonspace heating fuel use)

Missing data, if any , is so indicated. Also, supplementary information is generated as follows: For each type of fuel, the amount of fuel, the corresponding BTUs supplied and the percentage of the total BTUs supplied by this fuel, are so indicated. Table 2-2 shows the parameters in terms of their computer algorithms.

Also, for the same fuel-use data, given the total BTUs supplied (by all fuels), the total process heat BTUs and the total space heat BTUs are computed (if the percent process heat is known); the corresponding BTU/hour

TABLE 2-1

TWO-DIGIT STANDARD INDUSTRIAL CLASSIFICATION (SIC)

CODES FOR MANUFACTURING

Industry Type	SIC
Food products	20
Textiles	22
Apparel	23
Lumber and wood	24
Furniture	25
Paper products	26
Printing and publishing	27
Chemical	28
Petroleum	29
Rubber and plastics	30
Leather products	31
Stone, clay and glass	32
Primary metals	33
Fabricated metals	34
Machinery	35
Electrical machinery	36
Transportation equipment	37
Professional, scientific precision-made instruments	38
Miscellaneous manufacturing	39

TABLE 2-2

PARAMETERS EXAMINED

general parameters	PROC. RATE PERC. PROC. HEAT HOURS/YEAR
heat content parameters	FUEL BTU/HR FUEL BTU/HR-EMPL FUEL BTU/HR-ENC.*
(Broken down by Process, Space and Total heating, where TOTAL = PROCESS + SPACE)	
fuel emission parameters	FUEL AMT/HR FUEL AMT/HR-EMPL FUEL AMT/HR-ENC*
(Broken down by pollutant: SO_2, Particulates, HC, CO, NO_x)	
separate process emission parameters	PROC AMT/HR PROC AMT/HR-EMPL PROC AMT/HR-ENC*
(Broken down by pollutant; SO_2, Particulates, HC, CO, NO_x)	

*BTU/hour per unit enclosed floor space
AMT/hour per unit enclosed floor space

(BTU divided by operating hours/year), BUT/HR-EMPL (BTU/HR per employee), BTU/HR-ENC. (BTU/hour per unit enclosed floor area) are also computed for the process heat and space heat portions of total BTUs. Note that if such variables as percent process heat, operating hours/year, number of employees, or enclosed floor area are missing, the related categories will not be created or shown.

Emissions data are also analyzed; the amounts of fuel ('FUEL...) and/or separate process ('PRØC...') emissions, by pollutant, are given. Additional parameters such as AMOUNT/HR, AMT/HR-EMPL, AMT/HR-ENC may be computed and printed, for both fuel and process emissions but only if certain variables, as mentioned in the previous paragraph, are not missing.

For compatibility with the data sets from the previous AQUIP study, summary data may also be given for FUEL BTU/HR-GRØ., FUEL AMT/HR-GRØ., PROC AMT/HR-GRØ, where GRØ is the gross plant area.

2) The statistical program will also aggregate or group, by 4-digit SIC codes, the total sample size, the number of non-missing data, the mean and the standard deviation of all of these variables. The mean and standard deviation are determined as follows, where each of the 42 parameters examined (e.g., PROCESS FUEL BTU/HR) is symbolically represented as X_L, L = 1,...,N:

$$\bar{x} = \frac{\sum_{L=1}^{N} x_L}{N}$$

and

$$\sigma = \sqrt{\frac{\sum_{L=1}^{N} (x_L - \bar{x})^2}{N - 1}} = \sqrt{\frac{\sum_{L=1}^{N} x_L^2 - N\bar{x}^2}{N - 1}} ,$$

To conserve storage of data in the computer files, the sums Σx_L and Σx_L^2 are formed, by point source (N is the number of sources per SIC). It is apparent that Σx_L and Σx_L^2 may be determined by the following iterative procedure:

For the k^{th} source,

$$\sum_{L=1}^{k} x_L = x_1 \quad ,k=1$$

$$\sum_{L=1}^{k} x_L = x_k + \sum_{L=1}^{k-1} x_L \quad ,2 \leq k \leq N \tag{1}$$

$$\sum_{L=1}^{k} x_L^2 = x_1^2 \quad ,k=1$$

$$\sum_{L=1}^{k} x_L^2 = x_k^2 + \sum_{L=1}^{k-1} x_L^2 \quad ,2 \leq k \leq N. \tag{2}$$

The means and standard deviations of all relevant variables (see Table 2-2) are computed, using these intermediate sums, and a tabulation of all parameters, with nonzero means is then given; this includes the total sample size, the number of non-missing data, the mean and the standard deviation of all parameters, by activity code (SIC).

3) The statistical program can also truncate the activity codes to a specified number of characters (LENGTH-X) and reaggregate the total sample size, the number of valid data, the mean and the standard deviation, according to these truncated activity codes. In this way, statistics are determined at the 1, 2, and 3-digit SIC levels. The statistical program performs this function in the following way:

Given that Nm is the number of sources for the m^{th} truncated activity code, and $\bar{x}m$ and σm are the corresponding mean and standard deviation, respectively,

$$\bar{x} = \frac{\sum_{m=1}^{J} N_m \bar{x}_m}{N} \tag{1}$$

where

$$N = \sum_{m=1}^{J} N_m$$

intermediate sums (by activity code):

ΣN_m

$\Sigma N_m \bar{x}_m$

$$\sigma = \sqrt{\frac{\sum_{m=1}^{J} \{(N_m - 1) \sigma_m^2 + N_m \bar{x}_m^2\} \quad N\bar{x}^2}{N - 1}}$$

intermediate sum:

$$\Sigma \{(N_m - 1) \sigma_m^2 + N_m x_m^2\}$$

where there are J sets of parameters (activity codes) per truncated activity code.

A tabulation of these variables, similar to that described above for 4-digit SICs, will then be produced.

4) The statistical program also determines the percent of total BTU satisfied by each of the possible fuels. In calculating the percentage of total BTU, by fuel, the following relationships are used:

Given that $btu_j = \Sigma\, btu$ (for all fuels)

and $f_j = \frac{btu}{btu_j}$ (by fuel),

for all N sources,

$$F_{1,J} = f_J$$

$$F_{L,J} = \frac{F_{L-1,J} \cdot BTU_{L-1,J} + f_J \cdot btu_J}{BTU_{L-1,J} + btu_J}, \qquad L=2,3,\ldots,N$$

$$P_{L,J} = 100 \cdot F_{L,J}, \qquad L=1,2,\ldots,N$$

where

L = source number

j - activity code number

$F_{L-1,J}$ and $BTU_{L-1,J}$ are the fraction of the previous total BTU, by fuel, (up to and including the L-1st. source) for activity code number J and that total BTU, respectively; f_J and btu_J are the fraction of the total BTU, by fuel, for the present source and that total BTU, respectively.

BTU for activity code J, for each fuel, is then calculated as:

$$BTU_{1,J} = btu_J$$

$$BTU_{L,J} = btu_J + BTU_{L-1,J}, \quad L = 2,3, \ldots ,N$$

5) The statistical program took 320,000 bytes of capacity on an IBM 360/75. In the course of the study the program was used in some seven individual operational runs. Typical run time was between 10 and 15 minutes. The following pages give illustrative examples of example input data (Figure 2-2) and a data coding sheet (Figure 2-3).

```
PARAMETERS          HACKENSACK FOLLOW-ON
 &INPUT
 JC=12, ASTAT=.TRUE.,
 QNAM=' S O2',' PARTIC',' C O',' HYDROC',' N OX', QUNIT=5*' TONS/YR',
 NFF=4, FNAM='COAL','RES. OIL','DIS. OIL','NAT. GAS',
 FUNIT='TONS/YR',2*'KGALS/YR','MCUFT/YR', CFACT=26.,152.,142.,1100.,
 &END
RESET
SRCE                1970 MASSACHUSETTS & NEW JERSEY POINT SOURCES
POINT     2001
    1     3111
    2 1970        10                  4460.         6583  50.
    3              .        158.         .            .
    4    1       12.          .          .            .          .
99999
POINT     2002
    1     3111
    2 197000000140             0062440.       0087600095.
    3              .     0000630.        .            .
    4    10000049.            .          .            .          .
99999
POINT     2003
    1     3999
    2 197000000020             0011220.       0030000100.              2.
    4    2         .          .          .  0000002.          .
99999
POINT     2004
    1     3271
    2 197000000025             0023850.       0045500100.
    3              .     0000164.        .            .
    4    10000012.            .          .            .          .
99999
POINT     2005
    1     3443
    2 197000000053             0044732.       0020000100.              3.
    4    2         .          .          .  0000003.          .
99999
STATISTICS          3 & 4 DIGIT SIC'S
PARAMETERS          TRUNCATE TO 2 DIGITS
 &INPUT LENGTH=2, &END
STATISTICS          2 DIGIT SIC'S
PARAMETERS          TRUNCATE TO 1 DIGIT
 &INPUT LENGTH=1, &END
STATISTICS          1 DIGIT SIC'S
ENDJOB
```

Figure 2-2. Example of Input Data.

BASIC POINT SOURCE DATA

273

73 SEQ. NO. 80

	COLS	
	1-5	PØINT
SOURCE I.D.	11-18	
NAME	21-44	
ADDRESS	46-70	

FORMAT 1 - PLANT DATA (1 CARD)

	COLS	
	5	1
ACTIVITY CODE	11-18	
MUNICIPALITY, AND COUNTY CODE	21-30	
UTM X-COORDINATE, Km EAST	31-36	
UTM Y-COORDINATE, KM NORTH	41-46	
BASE ELEVATION (FT. ABOVE SEA L.)	51-56	
ZONE, AND OPTION CODE	65-70	

FORMAT 2 - OPERATIONS DATA (1 CARD)

	5	2
YEAR TO WHICH DATA APPLIES	7-10	
NUMBER OF EMPLOYEES	11-18	
GROSS PLANT AREA, ACRES	21-28	
ENCLOSED AREA, SQ. FT.	31-38	
OPERATING SCHEDULE (HRS./YEAR)	45-50	
PERCENT PROCESS, FUEL USE	51-55	
PROCESS RATE (UNITS: - - - - - - -)	61-68	

FORMAT 3 - FUEL USE DATA (1 CARD)

	5	3
EMISSION CODE FACTOR	9-10	
FUEL #1 _______________	11-18	
2 _______________	21-28	
3 _______________	31-38	
4 _______________	41-48	
5 _______________	51-58	
6	61-68	

FORMAT 4 - EMISSIONS DATA (1 OR 2 CARDS)

		FUEL EMISSIONS	SEP. PROC. EMISSIONS
	5	4	4
	10	1	1
EMISSION TYPE			
#1 _______________	11-18		
2 _______________	21-28		
3 _______________	31-38		
4 _______________	41-48		
5 _______________	51-58		
6	61-68		

99999

Figure 2-3. Data Coding Sheet.

ANALYSIS OF THE EMISSIONS DATA

Using data and procedures described in the preceding chapter, the relationship of industrial categories (SIC code) to fuel and process emissions for SO_2, TSP, CO, HC, and NO_X was to be analyzed. In terms of fuel emissions the relationship of employment and floor area by SIC code to the demand for space heating and total BTU demand was to be examined. Likewise, any propensity to use different fuels was of interest as this might vary by SIC code. As previously mentioned, several constraints existed in examining the data. First, the distinguishing of emissions between fuel and process was possible only for the New Jersey sample. On the other hand, the variable "percent process heat" was available for the Massachusetts sample only. This parameter is necessary to distinguish between space heating and process heating uses of fuels. Finally, the sample sizes were not very good at the 3-4-digit SIC level. In fact, the sample sizes were not very good at the 3-digit or 2-digit levels as well. This made it quite difficult to analyze very many subsamples or to perform meaningful statistical tests.

Table 2-3 shows the results of the analysis at the 4-digit level for certain of the Massachusetts data. The first column shows the SIC code and the second column the total sample size for each of the SIC codes. The next two columns show the mean for the parameter "percent process heat" and the variance for that parameter as defined in the preceding chapter. The next three columns show the sample size, mean and variance for the parameter space heating in terms of BTUs per hour per employee. The following three columns show the same variables for the parameter total heating BTUs per hour per employee. The next six columns show the same variables, respectively, for the parameters space heating BTUs per hour per square foot, and total heating BTUs per hour per square foot. The final four columns show the propensity to use different fuels by SIC code. It can be clearly seen that for the Massachusetts industries contained in the sample, residual oil was by far the most commonly used fuel.

For industry group SIC 20, the data is shown at the 4-digit SIC level with the first code being SIC 2010. A sample of only one existed here and, therefore, no variance or analysis can be shown. For SIC 2013 a sample size of five existed. The percent process heat is shown to be 88% with a variance of seven. The space heating BTUs per hour per employee is shown to be 3617 with a variance of 1972. The total BTUs per hour per employee is 30540

TABLE 2-3 MASSACHUSETTS 4-DIGIT SIC FUEL DATA

SIC Code	% Process Heat			Space Heat BTU/hr/empl.			Total Heat BTU/hr/empl.			Space Heat BTU/hr/ft^2			Total Heat BTU/hr/ft^2			Percent Fuel Use			
	Mass. Sample Size	Mean	Variance	Sample Size	Mean	Variance	Sample Size	Mean	Variance	Sample Size	Mean	Variance	Sample Size	Mean	Variance	R-Oil	D-Oil	N-Gas	Coal
2010	1	100			--	--	1	59790	--				NA	NA	NA	100			
2013	5	88	7	5	3617	1972	5	30540	9285	5	11	6	5	95	29	100			
2026	2	74	20	2	25150	28920	2	76570	52920	2	50	58	2	153	105	100			
2033	1	68		1	9585	--	1	29950	--	1	11		1	35		100			
2012	2	88	18	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	100			
2052	1	NA		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	100			
2062	3	95	5	1	20800	--	1	416000	--	1	144		1	887		99.22	0.78		
2071	4	59	9	4	21560	15040	4	50440	32920	4	42	29	4	97	64	100			
2084	1	0	--	1	77840	--	1	77840	--	1	44		NA	44		100			
2085	2	70	28	2	11490	4686	2	55680	36880	2	6	3	2	30	20	100			
2086	1	55		1	14710	--	1	32700	--	1	20		1	44		100			
2087	1	64		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	100			
2094	2	94	6	2	10720	10610	2	171500	15170	2	18	18	2	283	251	100			
2095	2	100			--	--		--	--				NA	NA	NA	100			
2098	1	100			--	--		--	--				NA	NA	NA	100			
2099	1	100			--	--		--	--				NA	NA	NA	100			
201	6	90	8	5	3617	1972	5	35410	14540	5	11	6	5	95	29	100			
208	5	52	33	4	28880	32780	4	55470	28160	4	19	18	4	37	14	100			
209	6	98	4	2	10720	10610	2	171500	15170	2	18	18	2	283	25	100			
20	30	77	27	19	16950	19280	20	78910	91670	19	26	25	19	148	197	99.5	0.5		
2818	2	60	42	2	18340	10130	2	74100	53260	2	71	39	2	285	205	100			
2821	10	92	19	2	20690	10610	2	81490	84160	2	35	18	2	138	143	100			
2834	1	100			--	--		--	--				NA	NA	NA	100			
2812	1	100			--	--		--	--				NA	NA	NA	100			
2851	5	81	42	1	56630	--	1	59610	--	1	83		1	87		100			
2891	2	94	6	2	29640	11820	2	721900	483600	2	29	12	2	715	479	100			
28	21	87	27	7	27710	15670	7	259200	375000	7	50	29	7	337	347	100			
3069	13	73	24	8	36290	31800	8	75940	34440	8	64	56	8	133	60	99.38	0.62		
3111	14	84	19	8	45250	60850	8	147900	119600	8	102	136	8	332	268	98.24		1.04	0.72

with a variance of 9285. For many of the industries shown in this sample, information on floor area in terms of square feet was obtained from a U. S. Department of Transportation publication[4] which relates employment to square footage by 4-digit SIC. Accordingly, the means and variances shown in the columns for BTUs per hour per square foot are directly proportional to the means and variances shown in the columns for BTUs per hour per employee; the only variation is that introduced by the varying square feet per employee by 4-digit SIC as contained in the DOT publication.

In Table 2-3, only three 4-digit SIC categories were shown to have a sample size greater than 10. These are SIC 2821 with a sample of 10, SIC 3069 with a sample of 13, and SIC 3111 with a sample of 14. In each case some variance is shown for the parameter percent process heat, varying between 19% and 24%. For SIC 3069 and SIC 3111 a sample size of eight exists for the BTU per hour variables. For the space heating BTUs per hour per employee and per square foot variables, significantly high variance is seen relative to the mean. In the case of SIC 3111 the variance is actually higher than the mean. On the other hand, for the variables total BTUs per hour per employee, and per square foot, the variance is reasonably good, particularly in the case of SIC 3069. For these SIC codes and for others which were examined, this type of pattern often existed, leading to the tentative conclusion that the information on total fuel use and, therefore, BTU demand, is probably more reliable and accurate than the parameter percent process heat.

One would expect to find fairly good correlation between employment and the heat demand for that number of employees, or between square footage of plant area and the heat demand for that square footage. In other words heat demand in BTU/hr/employee or BTU/hr/square foot should not vary significantly from plant to plant within the same industry and climate. However, better correlations were found with total fuel demand than with the demand for fuel heating. This may be explained by the inaccuracies for the variable percent process heat: when the percent process heat shows very little variance, then the relationship between space heating BTUs per hour and total heat BTUs per hour is shown to be quite good. This is true, for example, for SIC 2071 with a sample size of four.

On the 3-digit level SIC 201 shows the same information as SIC 2013 because the only valid information at the 3-digit level comes from that particular 4-digit SIC. On the other hand, SIC group 208 includes the information from SICs 2084, 2085 and 2086. Here it is found that for a sample size of four the variance for space heating BTUs per hour is greater than the mean, whereas for total BTUs per hour it is approximately one-half the mean. This may be due in large part to the very large variance seen in the percent process heat variable.

At the two digit level there is a sample size of 30, a fairly large variance for percent process heat for SIC 20, and, again, variances greater than the mean for both space heating BTUs and total heat BTUs.

Finally, if one looks at the variable space heating BTUs per hour per square foot for all the 4-digit SICs shown in Table 2-3, one sees a variation in the mean from 6 to 102 BTUs per hour per square foot, although this should be a fairly uniform number if the data were accurate and the reporting of the percent process heat, in particular, were accurate. In the full sample there is even greater variation as exhibited by the variance to the mean. This was to have been the base variable in the sense that if anything could be thought to be uniform in terms of these parameters, it would be the amount of heat required to heat "X" number of square feet of floor space. The fact that one sees so much variation at the 4-digit level makes both the use of this sample size and the reporting of the parameter "percent process heat" in particular, suspect. The relatively good results shown for the variable total heat BTUs per hour underlines the weakness in this data.

Table 2-4 shows the entire sample for SIC 20 for Massachusetts. It shows the variables percent process heat, space heating BTUs per hour, total heating BTUs per hour, and employment. The data shown in Table 2-3 was derived from this information. Figures 2-4, 2-5 and 2-6 show the plots of the variables space heating BTUs per hour, and total heating BTUs per hour vs. employment. This information was plotted to examine graphically the variance so as to provide better insight into the analysis of the information shown in Table 2-3.

Figure 2-4 shows, on semilog paper, space heating BTUs per hour vs. employment; whereas Figure 2-5 shows total heating BTUs per hour vs. employment. Finally, for the center area of the scale, Figure 2-6 shows on normal graph paper total BTUs per hour vs. employment. Again, the variable total BTUs per hour exhibits better correlation than does the variable space heating BTUs per hour, although intuitively the reverse would be expected.

TABLE 2-4 MASSACHUSETTS TOTAL SAMPLE FOR SIC 20

SIC Code	Percent Process Heat	Space Heat 10^5 BTUs/hr	Total Heat 10^5 BTUs/hr	Employment
2010	100		90.0	150
2013	97	2.2	75.0	250
2013	90	5.2	52.0	200
2013	81	28.0	140.0	700
2013	80	7.6	38.0	125
2013	90	9.0	91.0	200
2026	60	91.0	230.0	200
2026	88	23.0	200.0	500
2033	68	24.0	75.0	250
2042	N/A	N/A	N/A	N/A
2042	N/A	N/A	N/A	N/A
2052	N/A	N/A	N/A	N/A
2062	95	100.0	2100.0	500
2062	N/A	N/A	N/A	N/A
2062	N/A	N/A	N/A	N/A
2071	62	32.0	84.0	100
2071	50	180.0	360.0	500
2071	55	27.0	59.0	200
2071	70	52.0	174.0	1109
2084	0	200.0	200.0	262
2085	50	46.0	92.0	310
2085	90	4.3	43.0	52
2086	55	37.0	82.0	250
2087	N/A	N/A	N/A	N/A
2094	90	7.3	73.0	40
2094	98	1.9	93.0	58
2095	100	N/A	N/A	50
2095	N/A	N/A	N/A	N/A
2098	N/A	N/A	N/A	N/A
2099	N/A	N/A	N/A	N/A

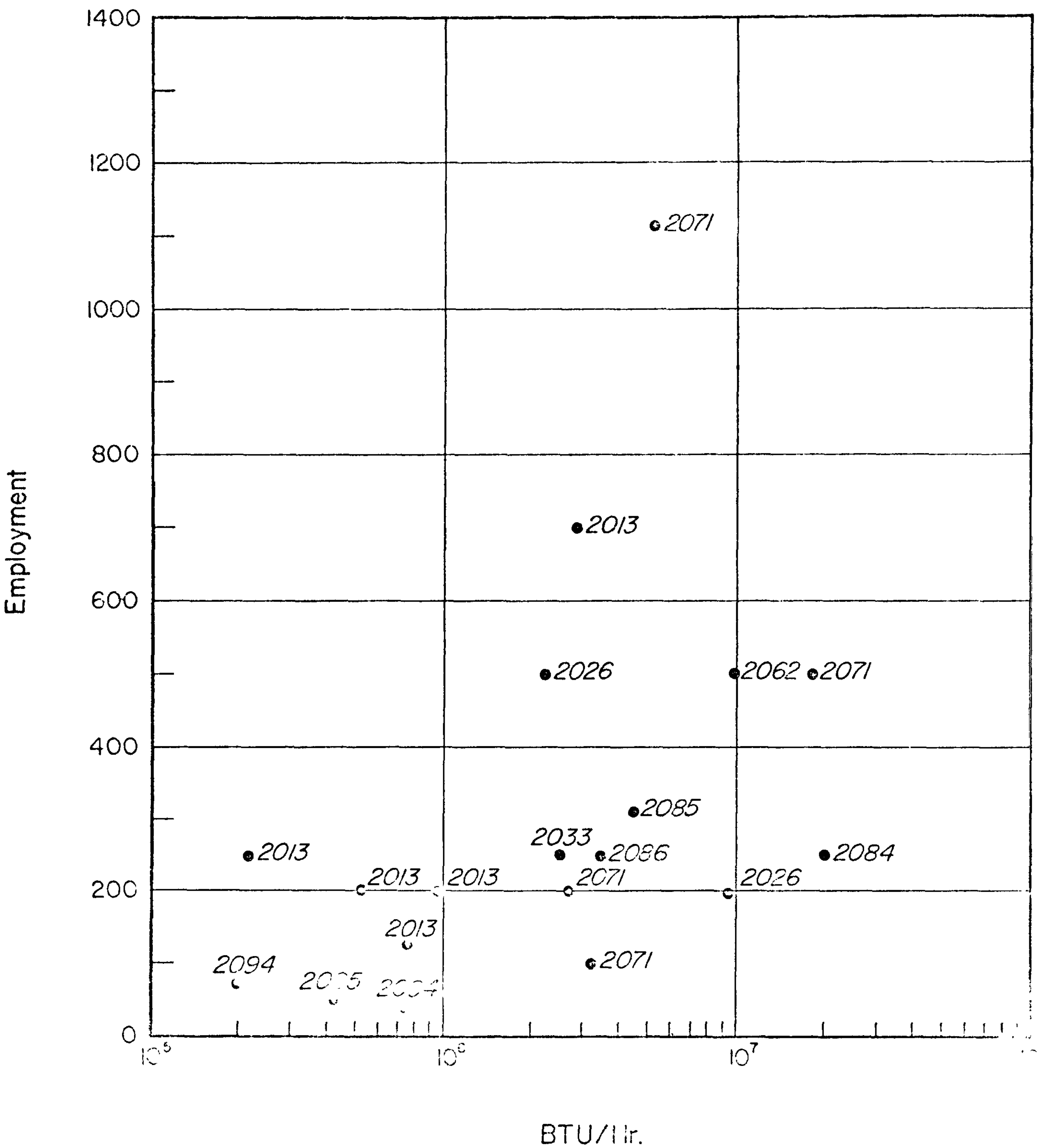

Figure 2-4. SIC 20 Space Heating BTUs Per Hour vs. Employment

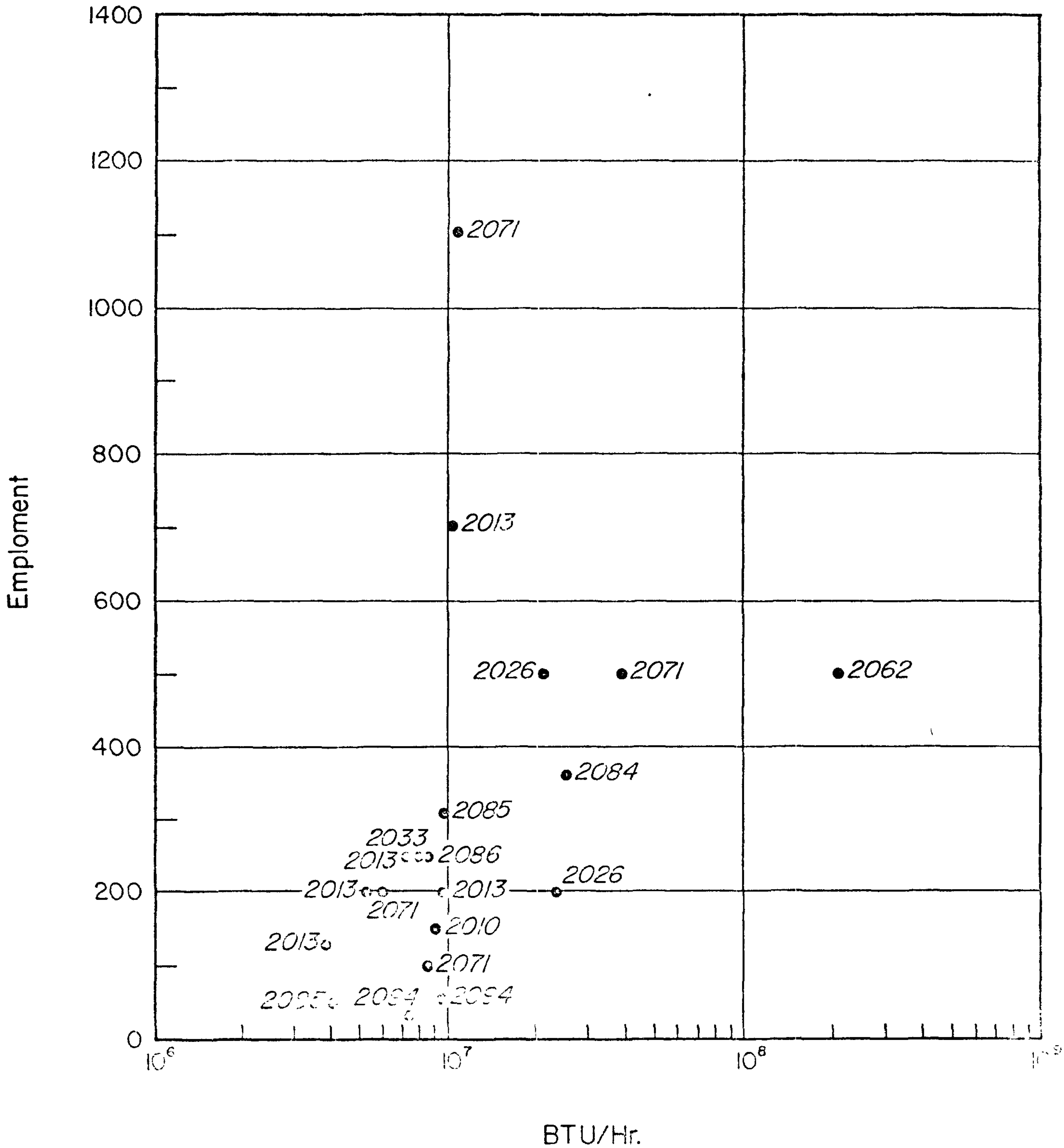

Figure 2-5. SIC Total Heating BTUs Per Hour vs. Employment

8133

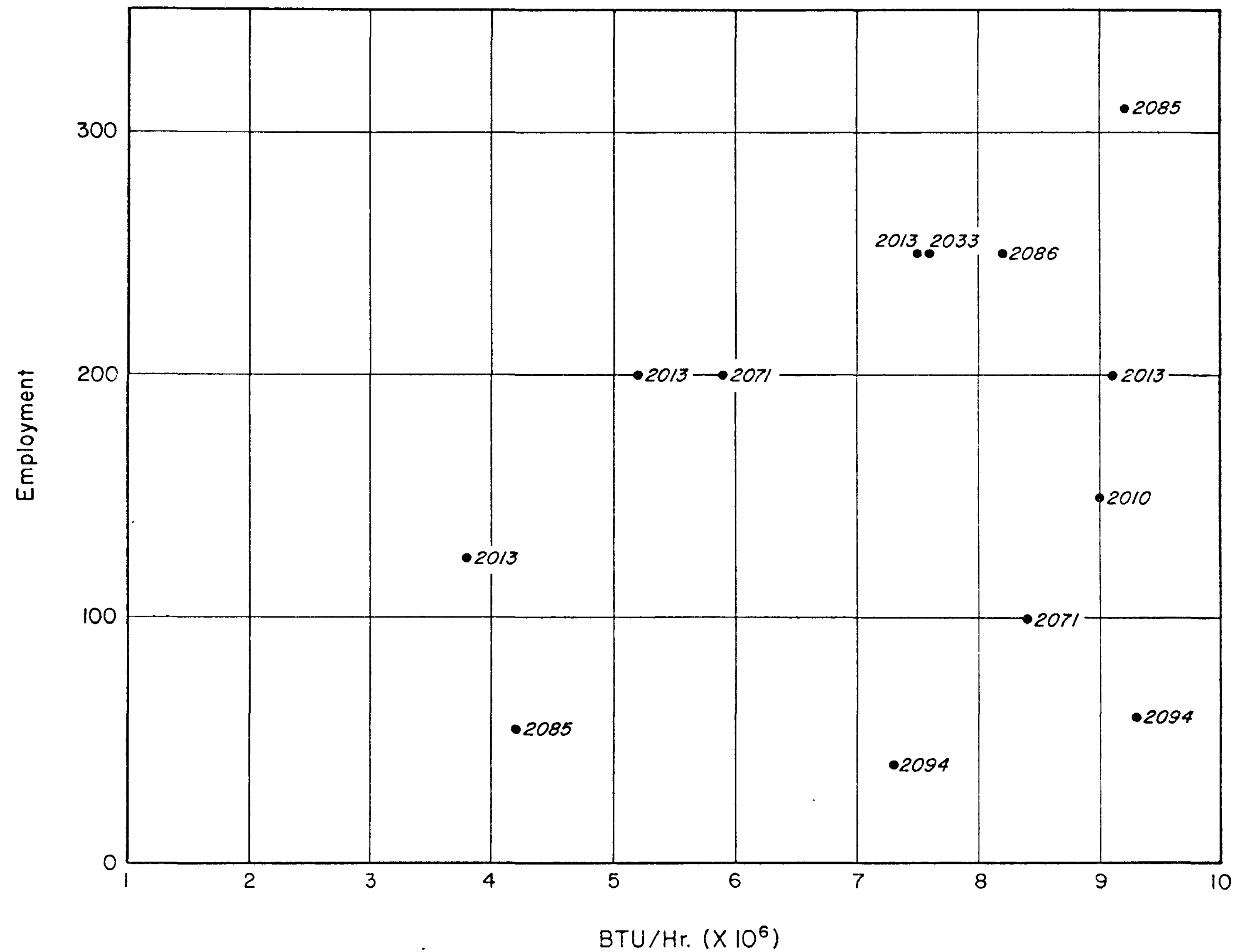

Figure 2-6. Detail of SIC 20 Total Heating BTUs Per Hour vs. Employment.

Interestingly, in Figure 2-6, based only on a sample size of four, SIC 2013 shows a decent fit between the four data points, giving a nearly one-to-one correlation between total heat demand and employment. The fit for SIC 2085 and SIC 2071 is not quite as good but is also promising, as is the case for SIC 2094.

In summary, based on the information in Tables 2-3 and 2-4, as well as Figures 2-4, 2-5 and 2-6, there seems to be some promise for finding good fit between the variables under investigation. However, the sample sizes and the lack of detailed information about how the data were originally determined makes it impossible to prove or disprove any usefulness in these correlations.

The next set of information examined was the 4-digit SIC data for New Jersey for fuel and process emissions per hour per employee and per square foot. The data for SIC 28 at the 4-digit and 3-digit levels are shown in Table 2-5, for emissions per hour per employee, and Table 2-6 for emissions per hour per square foot. In each case, the first column shows the sample size, mean and variance for total heating BTUs per hour per employee. The remaining 10 columns show the mean and variance for SO_2, TSP, CO, HC and NO_X, respectively. For each SIC code the first line shows the fuel emissions and the second line shows process emissions. Immediately preceding the SO_2 mean column in parentheses are found the sample sizes for the fuel and process emissions. At the 4-digit level SIC 2818 has a total sample size of 10 with valid data for nine sources for fuel emissions and seven for process emissions. The mean for total heating BTUs per hour per employee is shown to be 222,000 with a variance of 134,000. Referring to Table 2-3 for SIC 2818 in Massachusetts, there was a sample size of two and a mean of 74,000 total heating BTUs per hour per employee with a variance of 53,000. This does not agree favorably with the 222,000 mean shown for the New Jersey sample, but is quite characteristic of the results that were found for all SIC categories.

Looking at the emissions per hour per employee for fuel emissions, the variance is greater than the mean for SO_2 and is less than the mean for the other four pollutants. For TSP and CO in particular, the variance is one-third to one-quarter of the mean. For the process emissions, based on a sample size of seven, only NO_X shows a variance greater than the mean. At the 3-digit level for SIC 281 for a sample size of 19 the total

TABLE 2-5 NEW JERSEY SIC 28 EMISSIONS PER HOUR PER EMPLOYEE

SIC Code	NJ Sample Size	Total BTU/hr/emp			Lbs/hr/employee										
		Sample Size	Mean x 10^3	Variance x 10^3	Sample Size	Mean SO_2 x 10^{-6}	Variance x 10^{-6}	Mean TSP x 10^{-8}	Variance x 10^{-7}	Mean CO x 10^{-9}	Variance x 10^{-8}	Mean HC x 10^{-7}	Variance x 10^{-7}	Mean NO_x x 10^{-6}	Variance x 10^{-6}
2810	1	1	1020.00	--	(1) (1)	143.00	--	4580.00 8470.00	--	--	--	137.00	--	145.00	--
2813	2	2	462.00	51.00	(2) (2)	117.00 101.00	19.10 142.00	3420.00	48.90	203.00	28.6	43.90 510.00	6.61 721.00	91.70	9.45
2815	1	1	139.00		(1)	36.60		1100.00	--	--	--	18.30	--	27.50	--
2818	10	9	222.00 74.00	134.00 53.00	(9) (7)	92.40 78.40	137.00 152.00	10700.00 733.00	2470.00 138.00	1280.00 2340.00	344.00 619.00	27.40 --	18.90 --	41.70 121.00	29.40 321.00
2819	7	6	363.00	381.00	(6) (5)	84.70 794.00	108.70 1068.00	2686.00 6610.00	291.70 840.00	67.80 35600.00	11.00 7960.00	34.00 363.00	30.30 813.00	72.90	76.70
2821	8	4	191.00	258.00	(3)	46.30	66.90	1010.00	135.00	203.00	32.00	19.00	28.10	38.20	56.10
2874	4	3	26.06	13.29	(3) (1)	4.50	2.46	147.40 6.24	5.97 0.00	6.93	1.202	3.29	1.94	4.30	1.83
2841	5	4	101.60	32.20	(4)	20.79	14.80	617.00	40.30	33.60	6.73	10.90	7.39	17.00	8.63
2842	1	1	27.94	0.00	(1) (1)	--	--	200.00	0.00	--	--	2.50 255.00	0.00 0.00	5.50	0.00
2843	1														
2844	1														
2851	3	3	40.52	55.42	(3) (3)	9.81	15.10	300.00 7.63	43.40 1.32	-- 74.90	-- 12.90	3.81 6420.00	6.61 10700.00	8.01	10.92
2889	1	1	121.00	0.00	(1) (1)	36.40 6.33	0.00 0.00	870.00 246.00	0.00 0.00	175.00	0.00	14.90 1840.00	0.00 0.00	20.90 26.90	0.00 0.00
2891	2	1	72.75	0.00	(1)	17.50	0.00	558.00	0.00	--	--	7.97	0.00	14.30	0.00
2892	4	3	234.00	156.00	(3) (2)	86.60	71.80	10800.00 21.30	1790.00 3.02	5720.00	567.00	36.60	28.40	59.70 93.60	43.10 132.00
2899	29	23	649.00	1090.00	(23) (16)	62.20 51.00	91.50 182.00	2200.00 5730.00	283.00 2080.00	125.00 182000.00	32.00 72000.00	95.10 48.00	200.00 120.00	79.10	103.00
281	21	19	329.00	291.00	(19) (15)	92.20 314.00	110.00 670.00	6560.00 3100.00	1700.00 560.00	650.00 13000.00	237.00 3400.00	36.50 190.00	32.40 521.00	61.50 56.50	53.10 220.00
284	8	5	86.84	43.16	(5) (3)	16.60	15.80	533.00 316.00	40.00 54.80	27.00 97000.00	6.02 16700.00	9.27 85.10	7.40 147.00	14.70	9.08
289	35	27	582.00	1018.00	(27) (18)	63.20 45.40	87.30 172.00	3100.00 5100.00	620.00 2000.00	740.00 161000.00	240.00 68600.00	85.40 42.70	185.00 114.00	74.50 10.40	96.00 44.10

TABLE 2-6

NEW JERSEY SIC 28 EMISSIONS PER HOUR, PER SQUARE FOOT

SIC Code	NJ Sample Size	Total BTU/hr/emp Sample Size	Total BTU/hr/emp Mean x 10^3	Total BTU/hr/emp Variance	SO_2 Mean x 10^{-9}	SO_2 Variance x 10^{-9}	TSP Mean x 10^{-10}	TSP Variance x 10^{-10}	CO Mean x 10^{-11}	CO Variance x 10^{-11}	HC Mean x 10^{-10}	HC Variance x 10^{-10}	NO_x Mean x 10^{-9}	NO_x Variance x 10^{-9}
2810	1	1	1020											
2813	2	2	462	51	167 144	27.3 203	489	69.9	28.9	40.9	62.7 729	9.44 1030	131	13.5
2815	1	1	139		53.5		160				26.7	401		
2818	10	9	222	134	355 302	526 584	4110 282	9500 532	493 900	1320 2380	105	72.7	161 466	113 1230
2819	7	6	363	381	21.3 199	27.3 268	67.5 166	73.4 211.8	1.7 896	2.76 2000	8.56 91.5	7.6 204.7	18.3	19.3
2821	8	4	191	258	78.5	113.5	171	229	34	54.2	32.3	47.6	64.8	95.1
2831	4	3	26.06	13.29	9.83	5.83	32.1 1.36	13.06 0.0	1.51	2.62	7.19	4.25	9.46	4.0
2841	5	4	101.6	32.29	31	22.1	92.1	60.1	5.02	10	16.37	11	25.4	12.8
2842	1	1	27.94	0.0			2.6	0.0			3.25 332	0.0 0.0	7.16	0.0
2843	1													
2844	1													
2851	3	3	40.52	55.42	14.3	22	43.8 1.16	63.5 1.932	1.09	18.9	5.57 9390	9.6 15700	11.7	15.9
2889	1	1	121	0.0	37.8 6.56	0.0 0.0	90.3 25.5	0.0 0.0	18.2	0.0	15.5 1910	0.0 0.0	21.7 27.9	0.0 0.0
2891	2	1	72.75	0.0	17.3	0.0	55.2	0.0			7.89	0.0	14.2	0.0
2892	4	3	234	156	866	781	10800 21.9	17900 30.21	5720	5670	366	284	597 936	431 1320
2899	29	23	649	1090	64.5 53	95 190	228 595	294 2150	13 18000	33.2 75000	98.6 49.8	207 125	82	107
281	21	19	329	291	206 242	400 432	2140 200	6820 400	250 770	940 2000	64 136	67 400	103 232	103 871
284	8	5	86.84	43.16	24.8	23.6	78 47.2	59 81.8	4.02 25000	8.9 110	13.7 191	11.2	21.7	13.8
289	35	27	582	1018	152 47	337 178	1400 530	6020 2030	647 167	2410 71200	125 44.3	224 118	136 104	227 441

BTUs per hour per employee shows a mean of 329,000 with a variance of 291,000. Again, for fuel emissions only SO_2 shows a variance greater than the mean. However, for process emissions a larger variability is shown with SO_2, HC, and NO_X all showing variances greater than the mean. One would expect that the process emissions would show greater variability than the fuel emissions.

Table 2-6 shows the comparable data for emissions per hour per square foot. Again, at the 4-digit level the numbers are directly proportional to those shown in Table 2-5, since the square footage data is based upon the U. S. DOT relationship of employment to square feet at the 4-digit level.

For those SICs that end in 9, such as 2899 or 289, the data would be expected to show additional variation because the industrial categories themselves are aggregations of disparate industries. If one examines SIC 289 it is seen that for a sample of 27, the mean for total heating BTUs per hour per employee is 582 with a variance of 1018. For fuel emissions both SO_2, HC, and NO_X show variances greater than the mean, whereas for process emissions one also sees that SO_2, HC and NO_X show variances greater than the means.

Looking at the table as a whole, the data is more complete for SO_2 and TSP, less so for NO_X, and inadequate for CO and HC. This is to be expected since the initial thrust of point source emission inventories in states such as New Jersey was for stationary fuel sources and pollutants, particularly SO_2 and TSP.

The fuel emission variability for SO_2 is from 4 to 143 for the mean. The actual variability for the whole sample is much greater as shown by the variance. Some of this variability can be attributed to the use of different fuels, whereas other variability would be attributed to the non-correlation of fuel use with employment; e.g., a disproving of the hypothesis TSP varies from a mean of 147 to 10,700, showing a much greater variability, which may reflect the use of control equipment as well as the parameters mentioned for SO_2. Information for process emissions is more incomplete and, as expected, the variability much higher. It was not expected that process emissions per hour per employee or per square foot would show very good correlation or that any meaningful information could be determined by SIC code.

Figure 2-7 shows the plotting of SO_2 fuel and process emissions per hour vs. employment for SICs 2810, 2813, 2815, 2818, 2819 and 28121. For fuel emissions all but three of the sampled industries shown used 100% residual oil. The percentages of residual oil vs. other fuels are shown on the graph for the three other sources sampled. With the exception of these three sources, a good correlation between fuel emissions and employment would be expected, since fuel emissions should correlate well with total BTUs per hour and vary with space heating BTUs per hour only insofar as percent process heat varies. A fairly good correlation is shown for SIC 2818 and SIC 2819, the two 4-digit SICs with a reasonable sample size. Insufficient data exists for an analysis of the process emissions in Figure 2-7. There are two data points for SICs 2818 and 2819.

In summary, as in the case of the Massachusetts data, no definitive conclusions can be reached because of the sample sizes. However, where the samples are reasonably good the variance relative to the means for the fuel emissions seems reasonable. This is borne out by the information shown in Figure 2-7. The expected variability and lack of information for process emissions relative to fuel emissions was also found.

The variance between the SIC categories seems high enough to make the analysis by SICs worthwhile. In other words, the variation shown in the means at the 4-digit SIC level is quite high relative to the variance from the mean for any particular SIC. As a result further research in this direction should prove valuable in determining useful indices. In particular, it is seen that the variances relative to the mean at the 3-digit level for SIC 281 are quite high relative to the variances at the 4-digit level for the SIC 281 series.

Table 2-7 summarizes the BTU per hour parameters analyzed at the 2-digit and 1-digit SIC levels for the Massachusetts sample. The first column shows the SIC code; the second, the sum of the New Jersey and Massachusetts samples for each SIC category; the third column, the Massachusetts sample; the fourth column, the percent process heat; the next three columns, the sample size, mean and variance for space heating BTUs per hour per employee; the next three columns, the sample size, mean and variance for space heating BTUs per hour per square foot; and, the last three columns, the sample size, mean and variance for total BTUs per hour per square foot. It shows the same type of information as Table 2-3 except at the 2-digit rather than the 3-digit and 4-digit levels.

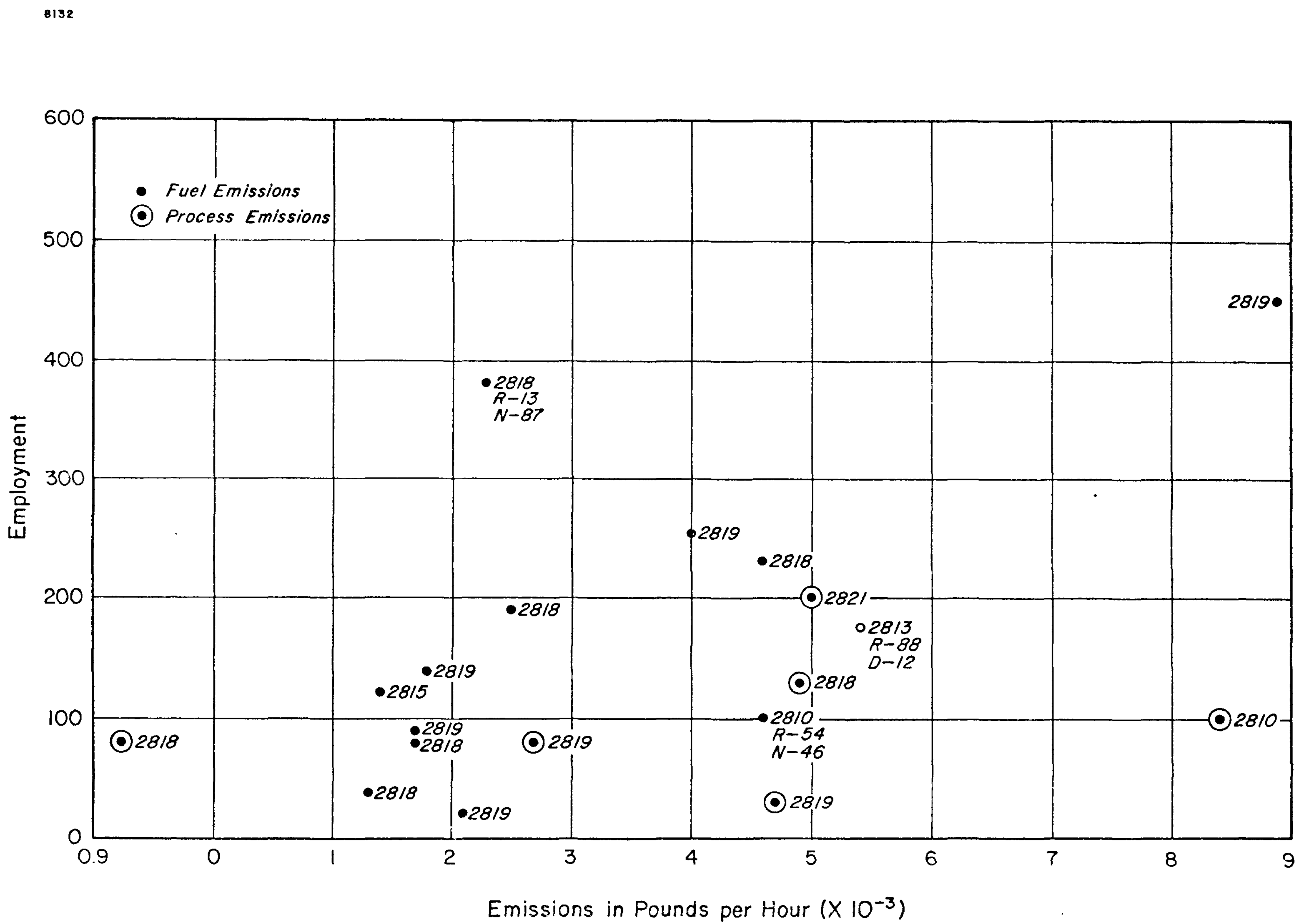

Figure 2-7. SIC 28 Emissions vs. Employment.

TABLE 2-7. MASSACHUSETTS 2-DIGIT SIC FUEL DATA

SIC Code	Total Sample Size	Mass. Sample	Percent Process Heat	Sample Size	Mean	Variance	Sample	Mean	Variance	Sample	Mean	Variance
2	305	150	88	36	20750	18760						
3	339	189	81	37	40770	46240						
est avg	644	339	(85)	73	(30000)	NA						
19	2	2	75	1	7486		1	49		1	98	
20	50	30	77	19	16950	19280	19	26	25	19	148	197
21	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
22	44	34	98	2	24670	1918	2	87	29	2	245	158
23	6	6	57	2	18690	14470	2	104	129	2	125	100
24	6	5	100				NA	NA	NA	NA	NA	NA
25	8	8	100				NA	NA	NA	NA	NA	NA
26	42	28	90	4	33650	26500	3	36	15	3	315	326
27	22	16	90	2	4844	2555	2	16	0.3	2	21	4
28	102	21	87	7	27710	15670	7	50	29	7	337	347
29	25	2	50	NA	NA	NA	NA	NA	NA	NA	NA	NA
30	27	20	80	9	36880	29800	9	64	52	9	131	57
31	25	25	83	10	39530	55350	10	88	124	10	272	268
32	43	13	94	2	119100	137400	2	184	219	3	332	307
33	50	22	78	NA	NA	NA	NA	NA	NA	NA	NA	NA
34	32	27	72	7	41310	30350	7	73	45	7	157	141
35	45	38	85	1	47830		1	139		2	74	92
36	20	12	65	4	35684	19250	4	94	72	4	114	58
37	8	NA	NA	4	NA	NA	NA	NA	NA	NA	NA	NA
38	8	6	54	1	5287		1	9		1	15	
39	35	26	89	3	32640	31200	3	52	45	3	72	29

No systematic findings can be made; the BTUs per hour and per employee vary quite a bit with some fairly high variances. In fact, it is not clear whether one introduces more accuracy by using 2-digit indices than would be found with a single index for manufacturing as a whole. The variability between 2-digit SICs is high for both the total heating BTUs per hour and the space heating BTUs per hour. Thus, it is not just a matter of inaccurate reporting of the percent process heating variable.

Table 8 shows the propensities to use different fuels: residual oil, distillate oil, natural gas and coal for both the Massachusetts sample and the New Jersey sample for 1-digit and 2-digit SIC categories. From an examination of Table 2-8, it is clear that variation in geography and supply of fuels rather than SIC code predominate. There is a much higher propensity across the board for SIC categories to use residual oil in Massachusetts than in New Jersey. However, it should be noted that the lowest percent residual oil occurs for SIC 34 in both New Jersey and Massachusetts, and that in all cases in New Jersey where the percent of residual oil is over 90, the percent of residual oil in Massachusetts is over 99%. It is difficult to examine the fuel propensities in much greater detail because of the high dependence upon residual oil for all industries sampled in both states.

Table 2-9 shows fuel and process emissions per hour per employee on a 2-digit SIC level for both New Jersey and Massachusetts data. The New Jersey data is an extension of Table 2-5 but at the 2-digit rather than the 3-digit and 4-digit levels. The Massachusetts data shows aggregated fuel and process emissions since no breakdown could be determined from the sample. The numbers in this table were used to derive the industrial emissions in the Task 3 Report.[5] Both the fuel and process emissions from the New Jersey data were used as a guide as to whether an industry was an A, a B, or a C classification and, further, whether it were a B-, a B, or B+ subclassification. Where insufficient data for a particular pollutant was available from the New Jersey data, the Massachusetts information was used but less reliability was attached to it. Finally, for certain SIC categories (particularly SIC 23 and SIC 25) default information was used, based upon other parameters in the table, with a general caveat that such industries were of the cleaner variety.

In general, it was found that at the 2-digit level the variances are quite high relative to the means although in the case of TSP the variances

TABLE 2-8 PROPENSITIES TO USE DIFFERENT FUELS

SIC Code	Mass. Sample Size	Percent Fuel Use R-Oil	D-Oil	N-Gas	Coal	NJ Sample Size	Percent Fuel Use R-Oil	D-Oil	N-Gas	Coal
2	150	97.8	0.1	1.9	0.2	155	57.85	1.62	36.15	4.37
3	189	94.4	1.0	4.5	0.1	150	63.72	3.49	30.59	2.20
(avg. 2-3)	339	(96)	(1)	(3)		305	(60.25)	(2.5)	(33.5)	(3.25)
19	2	100				0				
20	30	99.5	0.5			20	95.58		4.31	0.11
21	NA	NA	NA	NA	NA	0	NA	NA	NA	NA
22	34	89.0		10.5	0.5	10	59.15		40.85	
23	6	89.3	3.9	6.8		0	NA	NA	NA	NA
24	5	NA	NA	NA	NA	1	100.			
25	8	96.0			4.0	0	NA	NA	NA	NA
26	28	99.8			0.2	14	89.05		10.95	
27	16	100.0				6	53.77	3.44	42.80	
28	21	100.0				81	60.07	2.82	25.29	11.82
29	2	NA	NA	NA	NA	23	45.88	1.23	52.89	
30	20	99.3	0.7			7	57.17		42.83	
31	25	98.6		0.8	0.6	0	NA	NA	NA	NA
32	13	78.3	0.9	20.8		30	63.61	6.03	30.36	
33	22	97.8	1.3	0.8	0.1	32	57.80	1.62	33.41	7.17
34	27	51.1	6.3	42.6		5	30.61		69.39	
35	38	99.8	0.2			7	77.25	0.44	22.31	
36	12	100.0				8	99.61		0.39	
37	NA	NA	NA	NA	NA	8	64.39	8.88	26.72	
38	6	100.0				2	31.26		68.74	
39	26	100.0				9	90.89	0.48	8.63	

R-Oil = Residual Oil
D-Oil = Distillate Oil
N-Oil = Natural Gas

TABLE 2-9. EMISSIONS PER HOUR PER EMPLOYEE

SIC		Total Sample Size	SO_2 Mean $\times 10^{-6}$	SO_2 Variance $\times 10^{-6}$	SO_2 Sample	TSP Mean $\times 10^{-8}$	TSP Variance $\times 10^{-7}$	TSP Sample	CO Mean $\times 10^{-8}$	CO Variance $\times 10^{-8}$	CO Sample	HC Mean $\times 10^{-8}$	HC Variance $\times 10^{-7}$	HC Sample	NO_x Mean $\times 10^{-8}$	NO_x Variance $\times 10^{-8}$	NO_x Sample
			Lbs/employee-hrs														
20	NJ-Fuel -Proc.	20	165.0	470.0	17	4850.0	1360.0	17	30.0	115.0	17	668.0	1830.0	17	12700.0	35400.0	17
						2120.0	226.0	4									
	Mass.	30	21.6	27.6	21	685.0	264.0								8.0	28.2	
22	NJ-Fuel -Proc.	10	22.9	29.9	5	723.0	645.0	5	4.6	10.2	5	483.0	8470.0	5	3190.0	3530.0	5
						7.3	1.5	4	14.6	29.1	4	3280.0	1400.0	4			
	Mass.	34			2												
23	NJ-Fuel -Proc.	0															
	Mass.-Fuel -Proc.	6	7.3	1.4	2										63.4	89.7	2
24	NJ-Fuel -Proc.	1	5.6		1	139.0		1							418.0		1
	Mass.	0															
25	NJ-Fuel -Proc.	0															
	Mass.	0															
26	NJ-Fuel -Proc.	14	540.0	1450.0	11	13500.0	3590.0	10	150.0	400.0	11	1960.0	4520.0	11	38500.0	93100.0	11
						8770.0	1070.0	4				6130.0	11100.0	4			
	Mass.-Fuel -Proc.	28	38.0	39.4	4										105.0	175.0	
27	NJ-Fuel -Proc.	6	4.6	6.0	6	147.0	23.8	6			6	11.2	19.7	6	479.0	689.0	6
												69600.0		1			
	Mass.-Fuel -Proc.	16	2.9	2.8	2												

TABLE 2-9 (continued). EMISSIONS PER HOUR PER EMPLOYEE

28	NJ-Fuel	81	61.7	88.8	61	3550.0	1050.0	61	54.7	207.0	61	115.0	12800.0	61	5620.0	7490.0	61
	-Proc.		123.0	421.0	45	3160.0	1280.0	45	7550.0	43600.0	45	5560.0	28200.0	45	2360.0	12900.0	45
	Mass.-Fuel	21	119.0	200.0	7							10.9	28.8	7	35.4	93.7	7
	-Proc.				6	39.7	9.7					24900.0	18400.0				
29	NJ-Fuel	23	877.0	1360.0	21	24300.0	2590.0		54.5	156.0		6360.0	10900.0		63600.0	67400.0	
	-Proc.		6800.0	27300.0	16	89000.0	12600.0		243000.0	882000.0		341000.0	1270000.0		957.0	2640.0	
	Mass.-Fuel																
	-Proc.																
30	NJ-Fuel	7	17.5	17.1	6	527.0	48.4		2.7	6.7		131.0	158.0		1820.0	1680.0	
	-Proc.				3	152.0	15.5					2570.0	2660.0				
	Mass.-Fuel	20	20.8	7.8	9							1930.0	5780.0		1.8	5.3	
	-Proc.		67.7	135.0	4							51600.0	59100.0				
31	NJ-Fuel	0															
	-Proc.																
	Mass.-Fuel	25	61.0	59.7	10	198.0	62.6								7.6	20.5	
	-Proc.				7				9.3	24.7		20000.0	13900.0				
32	NJ-Fuel	30	78.0	148.0	20	2350.0	454.0		22.2	51.1		480.0	668.0		7020.0	12400.0	
	-Proc.		28.6	72.9	17	11900.0	2010.0					8.5	33.1		113.0	465.0	
	Mass.-Fuel	13	81.8	41.6	3	323000.0	56000.0										
	-Proc.				3	2350000.0	405000.0										
33	NJ-Fuel	28	52.8	94.7	19	950.0	122.0		177.0	767.0		236.0	253.0		3370.0	3380.0	
	-Proc.		2.1	6.1	13	5320.0	521.0		26100.0	94200.0		16.3	58.8				
	Mass.-Fuel	22	1100.0	2910.0	7	25500.0	5330.0		178000.0	472000.0		4290.0	9460.0		51300.0	136000.0	
	-Proc.																
34	NJ-Fuel	5	5.3	5.6	5	225.0	13.5					80.1	55.7		766.0	993.0	
	-Proc.				3	415.0	67.2					19400.0	20900.0				
	Mass.-Fuel	27	17.1	14.7	7							105.0	277.0		69.2	115.0	
	-Proc.				9	2.7	0.8		2.7	8.0		2780.0	3820.0		927.0	1880.0	

TABLE 2-9 (continued). EMISSIONS PER HOUR PER EMPLOYEE

35	NJ-Fuel	7	25.5	43.8	7	768.0	731.0	6.4	16.9	109.0	161.0	2060.0	3390.0
	-Proc.				5	360.0	72.1			1640.0	3140.0		
	Mass.-Fuel	38	13.0	16.3	2								
	-Proc.				12					5120.0	10400.0	1590.0	5410.0
36	NJ-Fuel	8	23.3	41.3	4	217.0	27.2	2.0	4.0	23.9	38.1	542.0	917.0
	-Proc.				1	8.0				970.0			
	Mass.-Fuel	12	7.3	4.8	4							34.6	69.2
	-Proc.				2					580.0	175.0	1060.0	1490.0
37	NJ-Fuel	8	[illegible]	8.1	5	309.0	23.2	0.4	1.0	39.8	28.2	807.0	612.0
	-Proc.		1.0	2.3	5	46.5	9.7			1770.0	2480.0		
	Mass.	0											
38	NJ-Fuel	2	1.2	1.6	2	40.6	3.7	17.7	25.0	77.9	99.7	89.3	126.0
	-Proc.				1			1170.0					
	Mass.-Fuel	6	4.5		1								
	-Proc.				1					7500.0			
39	NJ-Fuel	9	21.3	28.6	8	578.0	823.0			87.0	116.0	1510.0	2100.0
	-Proc.				3	69.2	120.0			3530.0	5930.0		
	Mass.-Fuel	26	13.4	5.5	3					9350.0	9370.0	71.7	124.0
	-Proc.				11								
2	NJ-Fuel	155	255.0	783.0	122	7900.0	1900.0	54.7	204.0	1640.0	5230.0	19100.0	46500.0
	-Proc.		1570.0	12700.0	74	21800.0	6820.0	57100.0	413000.0	78700.0	592000.0	1640.0	10100.0
	Mass.-Fuel	153	40.2	92.2	38	378.0	197.0			2.0	12.4	25.4	74.8
	-Proc.				23	12.8	5.0	2.5	11.9	33500.0	78500.0		
3	NJ-Fuel	104	42.0	93.3	76	1080.0	2540.0	51.6	384.0	226.0	402.0	3320.0	7030.0
	-Proc.		10.2	43.4	51	5390.0	1270.0	6680.0	47600.0	1860.0	6410.0	37.6	268.0
	Mass.-Fuel	189	32.4	40.1	39	24900.0	15500.0			464.0	2780.0	23.8	65.0
	-Proc.		142.0	1030.0	56	129000.0	93800.0						

are in general less than the mean. Both the incidence and the accuracy of process emission data are quite variable and no definitive conclusions can be reached. Again, the more traditional point source pollutants, SO_2, TSP and secondarily NO_x, show a more complete set of information. Examples of the overall variability and unreliability of the data at an aggregated level can be seen by examining the 1-digit figures at the bottom of the table. For SIC 2 under SO_2, a value of 255 x 10^{-6} lbs/employee-hour for fuel emissions and 1570 x 10^{-6} lbs/ employee-hour for process emissions is found; however, the sum of those, as exhibited in the Massachuestts total data, is only 40 x 10^{-6} lbs/employee-hour. For SIC 3 the fuel emissions are 42 x 10^{-6} lbs/employee-hour and the process 10 x 10^{-6} lbs/employee-hour whereas for Massachusetts the aggregated number is 32 x 10^{-6} lbs/employee-hour and for those sources where separate process emissions were available the mean was 142 x 10^{-6} lbs/employee-hours. For SIC 2 the same kind of findings are exhibited for TSP, whereas for SIC 3 Massachusetts values are of an order of magnitude greater than the New Jersey ones.

Although reasonable results were not expected at such an aggregated level, the variability that was found was quite disappointing. Moreover, if one examines SIC 20 for SO_2 one sees that fuel emissions are 165 x 10^{-6} lbs/employee-hour from New Jersey data and total emissions 21.6 x 10^{-6} lbs/ employee-hour Massachusetts data. In both cases the variances are greater than the means. In general, there were too few 2-, 3- or 4-digit categories that had enough information or showed similar findings to be able to make either positive or negative conclusions about the accuracy or usefulness of the different comparisons.

Accordingly, it was not fruitful to use this information to project future emissions or to update the activity indices of the AQUIP System.

PROJECTING FUTURE EMISSIONS

The previous AQUIP study pointed out that current data should be used as much as possible to develop the future inventory as shown in Figure 2-8. For the purpose of consistency, sources in the current inventory should be carried forward to the future time period and only the most significant new sources added as point sources; other sources should be added as area sources. Regional and national projective data and "control totals" as to fuel use, population, and employment should be used in conjunction with the most reasonable activity indices. Many of these indices, such as the heating demand per square foot, need not vary greatly from region to region, except with variation in temperature. Others, such as propensity to use different fuels, are highly a function of current uses in the particular region. Fairly reasonable estimates can be made of the number of hours of operation for each type of facility and for process heat for all land use categories except industrial. Lack of information and tremendous variation in this variable, as experienced in the point source inventory, affected the results of the previous study. Finally, with uncertainty in international fuel supplies, even one to two years in the future, it was virtually impossible to make reasonable estimates by land use category for 1990 as to fuel usage. In using the activity indices determined in the previous AQUIP study, the planner is constrained by the national and regional availability of fuel-use related data.

The projection of fuel consumption for 1990 made in the previous AQUIP study was based largely on national trends. Little information is available on the different regional areas such as the New York metropolitan area. Furthermore, it was beyond the scope of the previous AQUIP study to undertake a detailed regional fuel projection analysis. Several nationwide projections are available, the results of which are inconsistent with each other. The majority of these projections were made before 1965 and all projections make assumptions that are suspect.

An elaborate system was set up in the previous AQUIP study to project percent process heating, schedule, fuel use propensity and process emissions for existing New Jersey industrial sources to 1990. Indices derived from current activity data for the individual source as well as data on current employees, enclosed space and gross plant area were requested for each

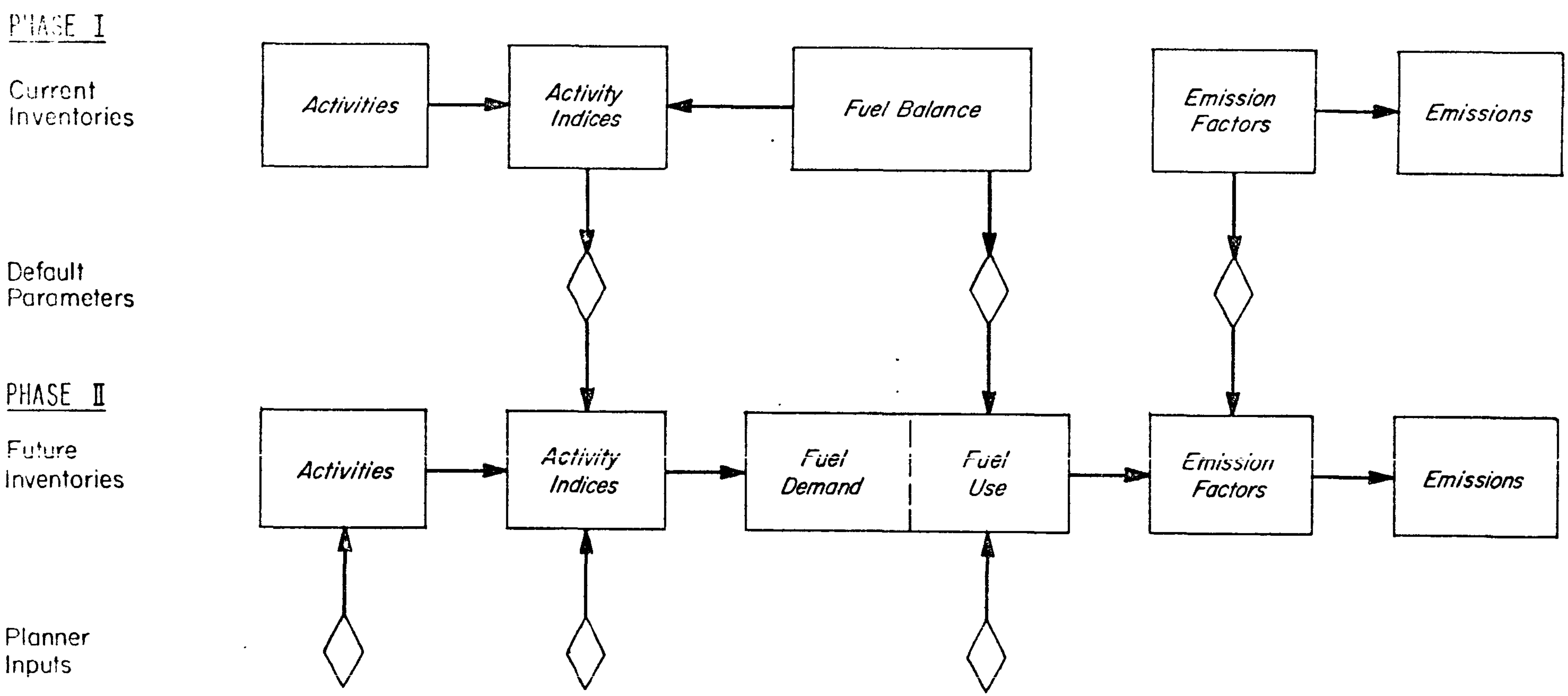

Figure 2-8. Two-phase Procedure for Projecting Emissions.

industrial source in the inventory. The data obtainable for a large number of sources were the number of employees; therefore, this parameter was used as the major projection variable. The availability of this parameter (and the unavailability of other parameters) was confirmed in the AQUIP Extension Study.

For each point source the number of BTUs for space heat per hour per employee was derived in the previous AQUIP study. It was assumed that this parameter would not vary significantly by industrial category; however, when summaries were made by industrial category, wide variation was found and no statistical conclusions could be drawn. This is, no doubt, due in part to the inaccuracy in the percent process heat variable from which the amount of space heating vs. process heating is derived. Again, similar findings have occurred for the AQUIP Extension study, although the data base has been larger.

Information was determined on the ratio of 1980 to 1969 employment by county and SIC code from the New Jersey Bureau of Labor and Industry in the previous AQUIP study. Many assumptions had to be made because of the categories of SIC codes for which the data are available and the labor market areas (cutting across county boundaries) for which information was assembled. It was intended in the previous AQUIP study to project 1990 space heating directly in BTUs per hour using the employment ratios and any assumed change in the BTUs per hour and employee index. This would then be combined with a new projection of percent process heat to yield total BTU heat demand for a source for 1990. Accordingly, information on current percent process heat was used to develop an index of percent process heat by SIC. This parameter yielded two broad categories of industrial use. It was therefore concluded in the previous AQUIP study that present information was not sufficient to carry through the analysis as intended.

Initially, our intentions in the AQUIP Extension study were to improve upon the data and to relate indices contained within the basic categories of economic, geographic and demographic factors to emissions associated with industrial activities. Intuitively, this approach is sound for residential and commercial activity where heating of homes and transportation are the principal activities which generate emissions. Here one could expect a high degree of correlation between such indices as "floor space," "number of dwelling units," "number of occupants," "degree-days," "passenger miles," etc., and emission levels. In fact, suitable and accurate relationships have been derived by applying regression techniques to actual observations for such variables. In such cases the fuels burned, the technology of heating and the technology of the combustion engine were fairly uniform throughout the area and range of observations made. Furthermore, the technology of emission control associated with the technology of heating and transportation were also fairly uniform.

Relative to industrial activity, one would expect that for any industry (described by an SIC code) similar relationships between such indices as "floor space" or "employment" and emissions might also pertain, provided there was uniformity in:

1) Technology of supplying power and heat
2) Technology of the processes (manufacturing and production)
3) Technology of emission controls applied

Unfortunately, such a constraining condition is rare within any industry or group of industries. For example, if today one were to select any industry that has the facility to supply its own power and heat, one will find a vast spectrum of fuels burned and applied technology. Figure 2-9 depicts schematically the range of possibility involved in this one instance. Figure 2-10 illustrates in a similar way a limited range of possible process variations in petroleum refining with just a small number of applied technologies. As a consequence, one would expect to find for any respectable sample of facilities within any one industry a large variance between activity indices which are purely demographic, geographic and economic in character and emission levels. This is especially true when one takes into consideration the vast array of emission-generating processes involved. Indeed, observations associated with the analyses of variance recently undertaken by others[3] have vindicated this expectation.

As the aforementioned realizations become more apparent, the plan for simply relating activity indices to emissions by regression analyses was augmented to include constraints of power generation technology, process technology (particular to a given industry) and applied emission control technology. In accomplishing these investigations we would expect to:

1) Establish relations between economic productivity, demographic and geographic variables and emissions for each industrial element

	Fuel		Energy Generation Technology			Emission Control Technology
	0.5% Coal					
	0.51% Coal					
	1-2% Coal					
	2% Coal					No SO_2 Control
	Deashed Coal		New	Wet Bottom		"No Recovery" SO_2 Control
Burn	0.5% Resid	in a	Available	Dry Botton	Boiler With	"Recovery" SO_2 Control
	0.5-1% Resid		Oil Converted	Oil Fired		Additives and "No Recovery" SO_2 Control
	1-2% Resid		Gas Converter	Gas Fired		Additives and Recovery SO_2 Control
	2% Resid					Additives only
	Light Fossil Fuel					
	Gas					

{ } means "select any from set enclosed"

FIGURE 2-9. PERMUTATIONS OF POWER GENERATION - A SAMPLE.

Process Technology → **Emission/Effluent Control Technology**

{Crude Distillation with} {
- Catalytic Cracking
- Hydrocracking
- No Catalytic Cracking

} and {
- Gas-Oil Hydrotreatment
- Rheniforming Hydrotreatment
- Catalytic Reforming
- LPG Processing
- a) Deethanizing
- b) Depropanizing
- Alkylating Facilities
- Hexane by-production
- Hydrogen by-production

} with {
- Flaring
- No Flaring
- H_2S Recovery
- No H_2S Recovery
- Mercaptan Scrubbing
- No Mercaptan Scrubbing
- Vacuum-gas Column Contactors
- No Vacuum-gas Column Contactors

}

{ } means "select any from set enclosed"

FIGURE 2-10. PETROLEUM REFINING VARIATION - A SAMPLE (as codified by SIC) employing similar energy-generating and process technology.

2) Establish relations between applied technology and emissions for the industrial elements considered.

These observations would assist in establishing trends in the effects certain technologies might have in either augmenting or alleviating emissions and would form the quantitative basis upon which the forecasts of future emissions might be derived by planners. Furthermore, such studies would also entail predictions relative to the qualitative changes in emissions that would be likely as a consequence of application of more advanced technology.

Our intentions were to establish models that would employ available economic and technologic information as well as an appropriate analytical framework for such models. The analytical framework depends mainly on a multiple regression approach wherever the data permit. For the purposes of formulating structural models, the number of data observations were to be developed on a geographical basis for use in the regression models. Since consistent and comparable data on emissions and other related variables would probably not be available for any time periods of significant duration, the analysis to be carried out in this regard would be chiefly a cross-section one on a spatial basis, rather than a time series against the two objectives previously mentioned: (1) structural relations to explain the correlation between emissions and related indices and technologies, and (2) prediction of future emissions for use in planning formulations.

Development of forecasts would be carried out in two stages with respect to quantity and to type. The latter would have to be developed separately from the regression models since the models cannot be used in predicting changes in composition or technology on a qualitative basis.

As previously mentioned, the analytical approach which was envisioned involves fitting regression equations by the least-squares method of estimation for different types of emissions. The success of this approach depends upon the number of independent observations (at least ten) that can be collected on a cross section basis for each type of emission within the individual industries to be considered.

A search for available information within various industry classifications that contained the distinction required relative to activity indices, process technology, power technology and emission control technology, proved disappointing.[6] All indications pointed toward a rather extensive program of data-gathering by such means as interviews and questionnaire mailings since the existing data bases were so incomplete and inconclusive. Since neither time nor resources had been budgeted for this purpose, investigations in this regard were curtailed. This direction appears to hold considerable promise and such research should be supported.

Having worked with the 1970 Implementation Plan emissions data provided by the states has given the consultant some insight into the kinds of data required to plan for urban and industrial air quality. While there is sufficient information available to hypothesize planning procedures, the quantity and quality of existing data are useful for only tentative conclusions. It is suggested that future studies work within the framework of this AQUIP Extension study, but that future results are now limited by the availability of pertinent data. With this in mind, it is suggested that the type of data inventory shown in Table 2-10 is necessary for further studies of this nature.

Item 1

A point source code number is necessary for data handling since confidentiality is important in dealing with emissions factors. Such a code number would be used as a mechanism for storage and retrieval by computer systems, of relevant air quality data. A numerical code could be used at either the state or national level. A national coding of alphabetical and numerical figures would prove to be most useful. For those states that already have their own coding systems conversion to a national system would be relatively simple. For mapping purposes x and y coordinates in some standardized coordinate system would also be asked for.

Item 2

SIC codes are currently used in Implementation Plan data. Any reasonable data file would incorporate SIC codes as a means of grouping point sources by both land use and point source characteristics. In future work, however, the use of SIC codes could

TABLE 2-10

INVENTORY OF AIR QUALITY PLANNING DATA
FOR IMPLEMENTATION PLAN QUESTIONNAIRES

1.	Point Source Code Number (assigned by air quality agency)			MA-1234
2.	Standard Industrial Classification Code Number(s)			2431
3.	Year to Which Data Applies			1970
4.	Employment of the Point Source			215
5.	Annual Hours of Operation			6000
6.	Floor Area of the Point Source (square ft.)			40,000
7.	Annual Fuel Use	Coal (tons)	a.	0
		R. Oil (10^3 gal.)	b.	155
		D. Oil (10^3 gal.)	c.	0
		Nat. Gas (10^6 ft^3)	d.	20
8.	Percent of Fuel Used for Space Heating			60
9.	Degree Days at Point Source			4000
10.	Process Weight Rate (pounds per hour)			100
11.	Solid Waste Rate (pounds per hour)			0
12.	Percent Fuel for Incineration of Solid Waste			0

		13. Space Heat Emissions Tons/Yr		14. Separate Process Emissions Tons/Yr		15. Solid Waste Emissions Tons/Yr
SO_2	a.	43.0	a.	0	a.	0
TSP	b.	12.0	b.	0	b.	0
NO_x	c.	6.4	c.	2.1	c.	0
HC	d.	8.2	d.	12.2	d.	0
CO	e.	2.4	e.	3.1	e.	0

be greatly expanded. In this particular study the inventory of manufacturing point sources was relatively small. This made it necessary to use 2-digit SIC codes to group industries with simlar point sources. These 2-digit groupings are in large part responsible for large variances because of the tremendous diversity within 2-digit SIC groupings. Future work should be done with a sufficient base of data to fully use the SIC coding system.

The SIC codes for industries could be used on a 2-, 3-, or 4-digit basis depending on the size of the data base. The 2-digit codes which have been used in this study (e.g., SIC 23) identify major industry groups such as "manufacturers of food and kindred products." At this stage there was only enough information to compile a marginal statistical sample for most industrial groups. With an expanded set of point sources and with increased data completeness, 3-digit codes (e.g., SIC 231) which identify subgroups within an industry, or even the 4-digit codes which specify industries by specific products (e.g., SIC 2311 meat packing plant) could be used. As the code became more detailed so should it be expected that air quality planning parameters would become more accurate.

Item 3

The year to which data applies is merely a "bookkeeping" measure. Since data will be solicited and checked periodically some means of insuring consistency in time periods is required.

Item 4.

Employment is one of the two major units for quantifying activity indices in the planning process. Production rates, population, and economic growth are all dependent upon employment to some measure, yet Implementation Plan data fails to give employment by point source. In the course of this study the employment figures provided relatively major data management problems. It was necessary to seek employment estimates from multiple sources. In some cases questionnaires from the sources outlined the employment figures. In other cases it was necessary to petition state agencies, such as the New Jersey Department of Commerce and Labor for employment figures.. These figures, when available, were of questionable reliability for several reasons. First of all, the employment may or may not correspond to the time period for which the Implementation Plan data is valid. Secondly, the employment may not correspond directly to the point source (i.e., a manufacturer may produce two or more products at different locations within the state but the state agency will list employment by corporation, rather than by point source). All the variables dependent upon employment were affected by the quality of the employment figures that had to be used in the study. Statistical analysis categories that were affected by employment figures include the following:

1) "FUEL BTU/HR-EMPL" - the activity index which indicates a propensity to consume energy. (This might also be phrased as a unit demand for fuel in BTUs per manhour.)

2) "FUEL AMT/HR-EMPL" - is the activity index which describes the unit propensity to emit pollutants in pounds of pollutant per manhour for space heating.

3) "PROC AMT/HR-EMPL" - is the activity index which describes the unit propensity to emit pollutants from industrial processes, in pounds of pollutant per manhour.

Briefly, then, three major projection indices are directly affected by the quality of employment data.

Item 5

Annual hours of operation are presently included in Implementation Plan data. Operation hours are necessary to calculate unit time figures for projection. The primary projection units (grams per employee hour and grams per enclosed floor area hour) require some means of time normalization. The annual hours of operation provide this means.

Item 6

Floor area is the only index, other than employment, that can currently be used to quantify emissions into a systematic unit grouping for planning calculations and projections. Implementation Plan data are void of floor areas, however. In fact, preliminary investigations show that there are no figures on floor area available from any source. This directly affects the remaining set of activity indices.

1) "FUEL BTU/HR ENC" - is the fuel demand per unit time and floor area.

2) "FUEL AMT/HR ENC" - is the unit propensity to pollute per unit time and floor space for space heating.

3) "PROC AMT/HR ENC" - is the unit propensity to emit industrial process emissions per unit time and floor space.

Since no floor area data were available to input directly into statistical analysis, rather than abandon consideration of floor area as a useful tool in calculating and projecting emissions, floor areas were synthesized from employment numbers. While this provided some unit activity indices incorporating floor area, it must be realized that all floor area data is limited by the quality and availability of employment figures (since it is derived from employment). Where employment is missing, floor area is missing; where employment is not accurate, neither is floor area; but even with reasonable employment data, floor area validity cannot be assumed. Average floor height could also be obtained so that heating demand reflects building volume as well as floor space.

Item 7

Annual fuel use is currently included in Implementation Plan data. Since fuel use is a major variable in pollutant emissions its inclusion in data files is imperative. Current detail in providing fuel data is adequate, however.

Items 8 and 12

The allocation of fuel use is particularly relevant to planning for air quality. The knowledge of how a fuel is used helps project the level of emissions by specifying the combustion characteristics and also by providing a means for estimating related plant activities. Traditionally, air quality inventory data has included percent process heat and percent space heat as the two means of fuel use. It seems that probably three categories of fuel use may be warranted.

1) Percent Space Heat Fuel has generally been estimated in the past. The quantities of fuel required for space heating should be fairly predictable and generally unrelated to SIC code. Space heat is dependent upon enclosed floor area and heated volume for the most part.

2) Percent Process Heat Fuel has generally been taken to be the total annual fuel consumption less the space heating fuel. This process fuel use has been the index for estimating process heating emission levels. The process heating emissions are those that may be expected to differ from industry by SIC codes. The greater the fuel use the greater the process emissions that are anticipated.

3) Percent Incineration Fuel is not currently a data file variable. In many cases solid waste may play a large part in total point source emissions, yet the use of fuel for incineration is unquantified. While this may be unimportant on the large scale it may be quite important for local considerations where solid waste disposal is a significant element.

Item 9

Degree days are not available from Implementation Plan data, yet are a necessary element in projecting space heating requirements. Given the number of degree days and the floor area of a plant, a reasonable space heating fuel estimate can be made. The accumulation of degree-day data would be relatively easy. By knowing the location of each point source, degree-days for each point source could be determined using data from the weather service and from local distributors.

Item 10

Process Weight Rate is currently included in Implementation Plan data inventories. This information is useful in forecasting process emissions. Its current use and availability is adequate.

Item 11

Solid Waste Rate is necessary for projecting solid waste incineration emissions. Assuming that certain similar products have certain similar wastes, it can be seen that as process emissions are characteristic of industries (by SIC code), so are solid waste emissions by product. It must be realized, however, that not all facilities with similar production activities can be expected to have similar solid waste characteristics; some may have all wastes trucked away, some may burn all wastes, and some will be somewhere between the two extremes. Solid waste, then, becomes an independent variable for which data is required.

Items 13, 14 and 15

Space heating emissions and separate process emissions are currently catalogued in Implementation Plan data. There is, however, no current classification for solid waste emissions, or they are recorded as process emissions. Where there are process emissions there is no means for distinguishing which of the emissions are due to separate process and which are due to solid waste burning or incineration. Stack parameters - height, exit velocity, temperature, etc. - would also be useful information for diffusion studies.

REFERENCES FOR PART 2

1) Willis, B. H., et al, The Hackensack Meadowlands Air Pollution Study, Summary Report and Task Reports, Tasks 1-5, prepared for the State of New Jersey, Department of Environmental Protection, Trenton, 1973.

2) See the following: Kircher, D. and D. Armstrong. An Interim Report on Motor Vehicle Emissions Estimation, USEPA, Office of Air Programs, October 1972; and Compilation of Air Pollutant Emission Factors, USEPA, Office of Air Programs, Publication No. AP-42, February 1972 and April 1973.

3) See the reports produced for the Land Use Planning Branch, Office of Air Programs, by Argonne National Laboratories, 1970-1973.

4) See Estimating Land and Floor Area Implicit in Employment Projections, Vols. 1 and 2, U. S. Department of Transportation, Federal Highway Administration, 1970.

5) Epstein, A. H., et al, A Guide for Considering Air Quality in Urban Planning, prepared for USEPA, March 1974, Contract No. 68-02-0567.

6) See the following reports by the Hudson Institute: "Study on the Corporation Environment, 1975-1985," and "Energy and Energy Fuels,"

PART 3

TASK 2 REPORT

COST-EFFECTIVE PLANNING FOR ACCEPTABLE AIR QUALITY

by

Alan H. Epstein

SUMMARY

This document presents a methodological approach to planning for and evaluating the impact of land use on air quality. The planning process is viewed as a series of sequential steps in which the economic implications of planning decisions are evaluated in terms of their dollar value impact on air quality. In this way postulated plans may be designed to be compatible with both air quality criteria and various development preferences. In addition, because running tallies of both benefits fostered by a given plan and the resultant costs of air pollution control and damage are kept for each planning option considered, alternative plans may be conveniently compared and ranked according to how effectively, from a cost standpoint, each utilizes the air resource.

The material presented is divided into three distinct but closely interrelated chapters. The first chapter discusses the essential concepts with which the methodology attempts to deal. The second chapter presents the methodology itself, and the third chapter provides some application guidelines.

It is not intended that this document, of itself, be sufficiently comprehensive to enable the planner to implement the concepts presented. Rather, it is expected that considerable effort will be required to fully research individual areas of concern so that information sufficent to apply the methodology is compiled. Furthermore, because specific applications of the methodology are heavily dependent upon available site specific data, the general technical and operational capabilities of the individual planner or planning group, and the ever present constraints of time and money to do detailed planning studies, it is anticipated that both the level of detail and degree of sophistication of individual applications will be widely varied.

It is intended that this document, with its suggested analyses, be used as a guide by the planning community in making and evaluating planning decisions. It is hoped that sufficient ingenuity will be brought to bear in the application of the concepts presented so that each use of this methodology represents an accurate appraisal of actual physical and economic phenomena.

INTRODUCTION TO PART 3

BACKGROUND AND PROBLEM DEFINITION

Because the urban planning process offers a fundamental means of *controlling long term air quality, it is necessary that the planner be able* to evaluate alternative land use plans in terms of their relative air pollution impact.

The air quality of given regions or sub-regions depends upon two sets of phenomena:

1. The assimilative capacity of the air environment for pollutant material
2. Pollutant emission characteristics.

The capacity of a given air environment for atmospheric pollutants is determined by ambient meteorological, topographical, climatological, chemical, and biological conditions. In general, very little functional control can be exercised over these phenomena on a regional scale. Consequently, it does not appear practical to postulate a regulatory program of air quality based upon the specification of desired conditions of naturally occurring physical phenomena.

Pollutant emission characteristics include the quantity of pollutants released to the atmosphere, the physical location of emission sites, and source types (e.g., mobile, stationary, elevated, and depressed sources). These characteristics are determined from the specification of land use type, level of activity or process rate, types and amounts of fuels used, source controls, and activity schedules.

Because pollutant emission characteristics are directly derivative from the specification of the mix, locations and intensities of land use, it is evident that the urban and transportation planning process offers an effective means of controlling long term air quality. Furthermore, both analytical techniques and empirical data for estimating the relationships between land use and air quality have reached the point of making air quality impact-land use planning a practical tool in helping to manage urban growth and development

For the planning process to effectively accommodate the requirements of an expanding population within a limited air resource, it is necessary that the planner be able to differentiate between and evaluate alternative plans in terms of their relative air pollution impact. The problem then is how to apply existing analytical techniques and data for quantifying the impact of land use on air quality to an evaluative methodology for estimating how effectively the air resource is used.

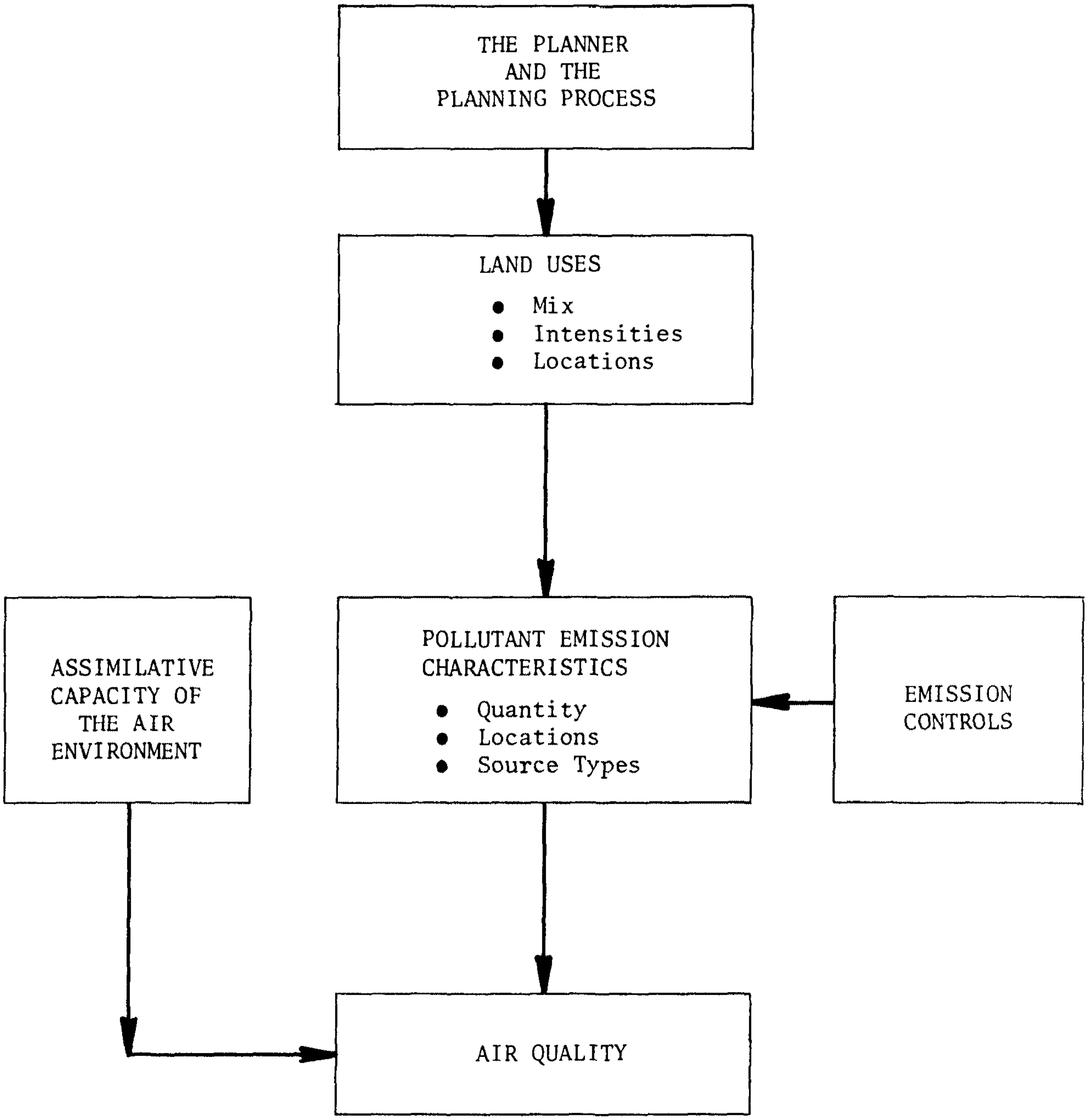

Figure 3-1: The Dependence of Air Quality on Land Use - Shows how the planning process can contribute to the determination of air quality and suggests that the planner needs a way of evaluating the consequences of planning decisions in terms of air pollution impact.

THE ECONOMICS OF AIR POLLUTION

Cost implications provide the most tangible and immediate means of evaluating the air pollution impact of alternative land use plans.

Air pollution may be viewed as the result of using the atmosphere as a waste disposal medium for the urban processes supporting the economic structure of a region. Because the air resource is not limitless, it is apparent that a means of evaluating the effectiveness of 'spending' this resource is important to the decision making processes which prescribe urban growth and development. The ideal measure of effectiveness would be a single quantitative indicator which is generally applicable to the spectrum of planning variables as an optimization parameter. On this basis, cost effectiveness is the obvious comparison of proposed alternative land use strategies relative to their air pollution impact, as well as to the other constraints within which the planner must operate.

There are three broad areas of economic concern identifiable within the scope of a cost effective approach to evaluating regional air pollution impact. They are:

1. The trade-off between air quality and those urban activities which determine regional economic viability
2. The costs incurred in controlling pollutant emissions
3. The costs of damage resulting from expected air pollution levels.

Their interrelationship with the planner and the planning process may be represented as shown in Figure 3-2.

The first of these is important to the planning process because it defines attainable limits for proposed land uses in terms of both air quality and whatever measure of economic viability the planner chooses. Federal and state air quality standards and regulations have, in effect, placed constraints on the mix, intensities, and locations of the various land use categories, particularly those involving heavy industry and motor vehicular transportation. These constraints require the planner to reconcile the pressures for economic development, with their anticipated impact on air quality, to a level of detail encompassing the spatial allocation of both the sources and receptors of air pollutants.

Collectively, the cost of controlling pollutant emissions and the cost of air pollution damage define the total cost of air pollution for a given land use plan. Evaluation of total cost relative to the flow of benefits inherent in the land use configuration which gives rise to these benefits is the basis for determining the relative air quality impact cost effectiveness of alternative plans.

Quantification of allowable limits to preferred land uses and cost effective evaluations of alternative proposed land use plans generated within these limits may be taken as the initial and final steps in a methodological approach to cost effective air quality impact land use planning. Subsequent sections of this chapter discuss individual aspects of air pollution economics as they pertain to land use planning, and subsequent chapters outline the methodology indicated above and present a set of guidelines for its application.

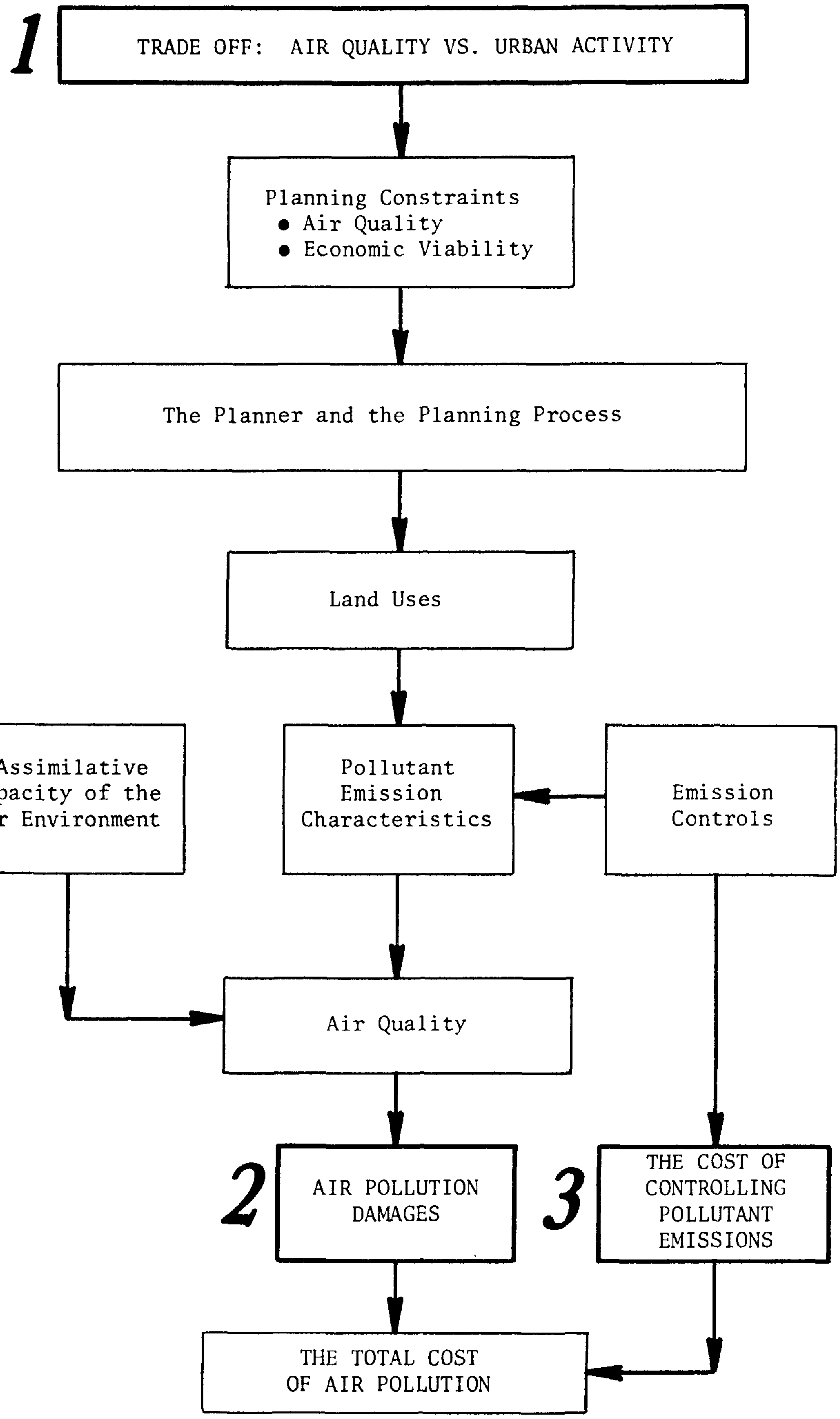

Figure 3-2. The Economic Implications of Land Use Planning in Terms of Air Pollution Impact - Shows how three basic economic concerns may be combined to provide both constraints to and a means of evaluating land uses in terms of air pollution impact.

Trade-Off: Air Quality vs Economic Viability

Because land use activities which promote a healthy regional economy tend to degrade regional air quality, there is a trade-off between these two basic planning goals.

It has long been recognized that activities which are conducive to a healthy economy can, and often do, result in unwanted side effects. Known in economic linguistics as external diseconomies, these effects generally demonstrate a positive correlation with the level of their causal activity. Air pollution is an outstanding example of an external diseconomy because it is the unwanted result of urban activities which ultimately exist to enhance the quality of urban life. Further, it generally increases as the levels or intensities of these activities increase. The result of this cause and effect relationship on a regional scale is an overall decrease in air quality as a function of increasing urban activity.

Given that some general inverse relationship exists between air quality and economic potency, the planner must at the outset reconcile these opposing planning goals. On the one hand, severely curtailing those activities which are major contributors to air pollution may provide for good air quality but may, at the same time, so severely limit both productivity and mobility that the regional economic base may be eliminated. On the other hand, vigorous pursuit of an effective and vital economic base may cause air quality to be unacceptable. It is essential that the planner be able to quantitatively establish these extremes at the outset so that both good air quality and an effective economic base are 'built-in' to proposed land use schemes.

Considering the reliance upon the combustion of fossil fuels as the major source of energy, there will always be some level of urban activity beyond which acceptable air quality is simply unobtainable. It should be recognized however, that emission controls offer considerable latitude in specifying activity types and levels which meet air quality criteria. As indicated in the accompanying figure, control strategies have the effect of either increasing the capacity of a given environment for urban activity at a given level of air quality (control strategy C_1), or increasing the level of air quality for a given level of urban activity (control strategy C_3), or some combination of the two (control strategy C_2).

Unfortunately, there are some very real economic constraints associated with the degree of emission controls that a given land use strategy can tolerate. For example, if a plan is proposed which attempts a very high level of emission control (in order to allow, for instance, for high industrial employment), it may become economically impossible for certain of the activities which are being relied upon as potential employers to survive on a competitive basis. The next section discusses in further detail the effects of emission controls and air pollution damage in terms of achieving regional economic viability.

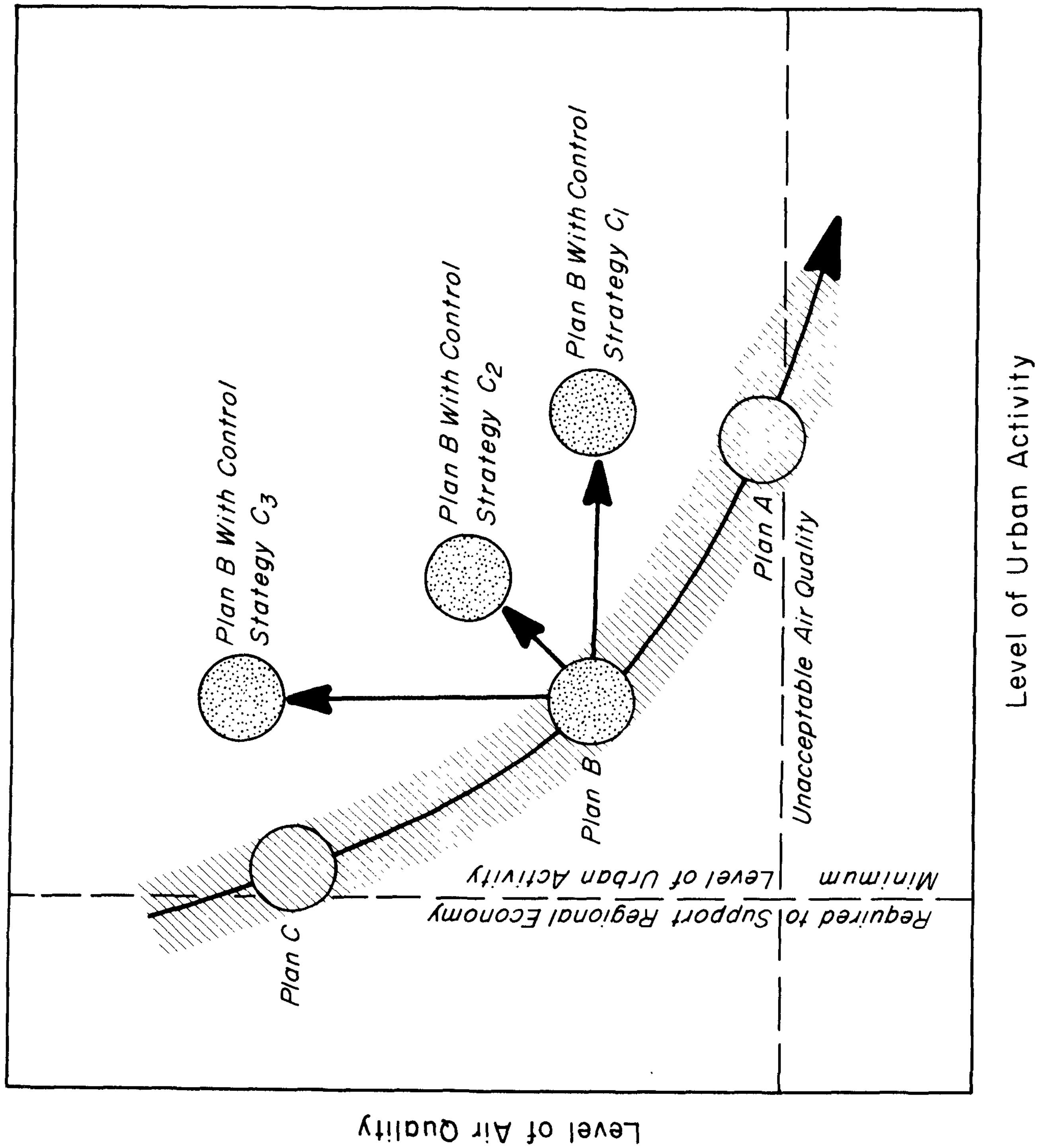

Figure 3-3. The General Relationship of Level of Urban Activity to Air Quality - Shows the options available to the planner in terms of both air quality and urban activity through the specifications of emission control strategies.

The Cost of Achieving Ecomomic Viability in Terms of Air Pollution Impact

For a given land use configuration, the cost optimum level of attainable air quality may be determined from the combination of costs resulting from the implementation of various control strategies and the corresponding costs resulting from air pollution damage.

The cost of achieving regional economic viability in terms of air pollution impact may be defined as the return received (e.g., in regional employment) for each dollar spent on air pollution. Quantification of this parameter for alternative proposed land use plans may be used as the basis for performing cost effective evaluations and consequent ranking of the alternatives in terms of their relative air pollution impact. It is therefore essential to be able to determine the total cost of air pollution for each of the proposed alternatives which have been postulated to provide for both regional economic viability and acceptable air quality.

As indicated in the accompanying figure, the total cost of achieving a given level of air quality for a given land use plan is the sum of the costs resulting from controlling pollutant emissions and the corresponding costs resulting from air pollution damage. Ideally, the planner should attempt to attain, for each of the proposed alternatives, that level of air quality which results in the minimum total cost of air pollution. This would require specification of an emission control strategy which provides for the cost optimum level of air quality. However, as a result of satisfying either basic planning constraints or the requirements of legislated air quality regulations, it may well be that the planner has had to specify emission controls as an integral part of one or more of the alternative plans. If this is the case, and if the control strategy is such that it becomes impossible to operate at the cost optimum air quality level for that land use plan, additional emission controls should not be specified. The point is that the planner should always attempt to operate as close to the minimum total cost as possible for each plan considered because the utility received is inherent in the specification of the plan.

By the same token, a plan which does not operate at the minimum total air pollution cost should not necessarily be abandoned. If the utility received from the plan is high, the cost effectiveness evalution may indicate that it is the most desirable alternative. Again, it is not the total cost of air pollution which is the indicator of relative worth, but rather the air quality cost effectiveness. This is the most critical concept involved in the economic evaluation of air pollution impact and its importance cannot be overstressed. Assuming that it is necessary to spend air quality to buy economic viability, it is essential that the maximum return be realized for the damage that is done.

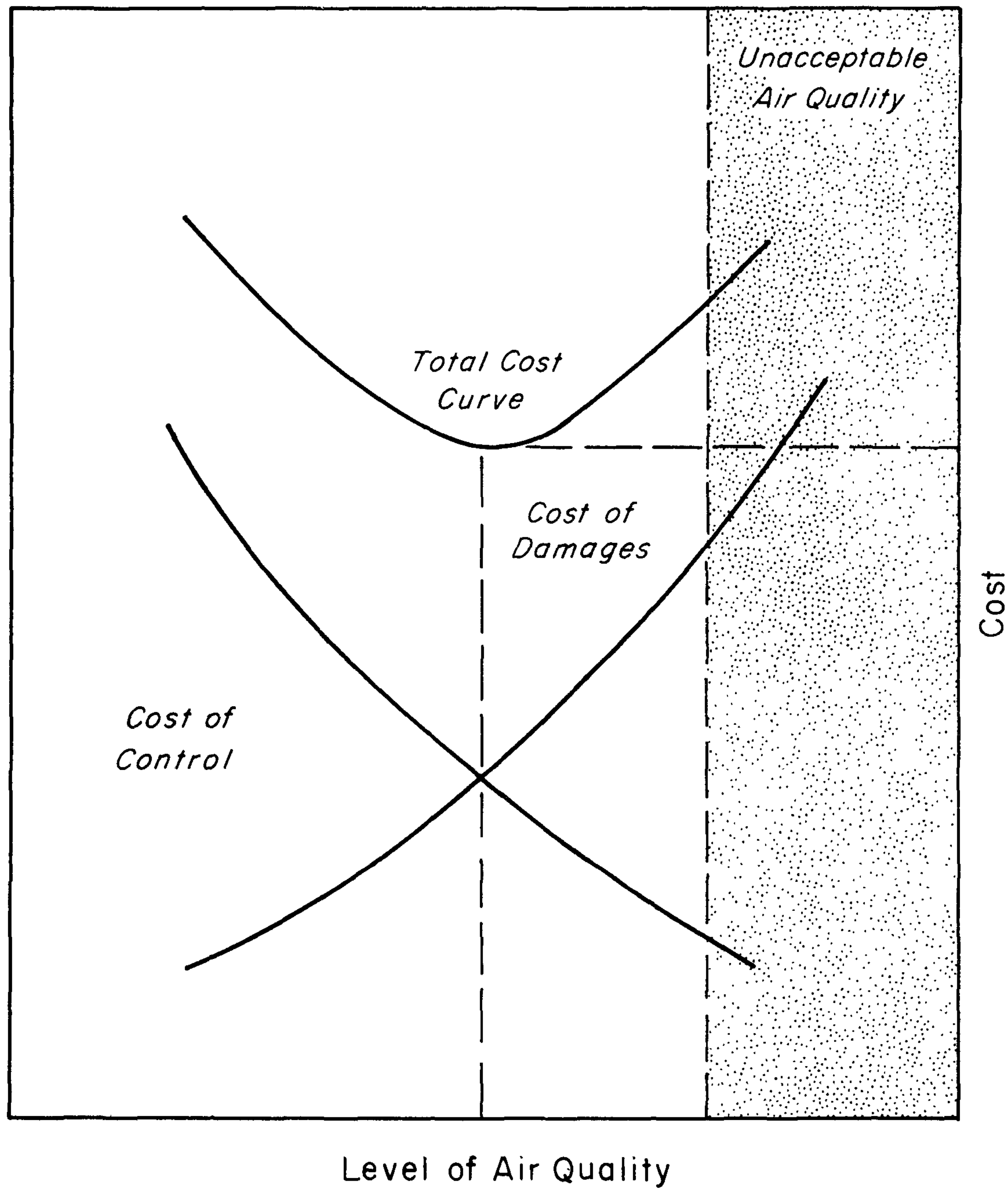

Figure 3-4. The Total Cost of Air Pollution - Shows how the curves of control and damage costs for a given plan combine to form a total cost curve the minimum of which determines the cost optimum level of air quality.

8034

The Cost of Controlling Pollutant Emissions

The cost of air pollution control is the economic indicator defining the aggregate ability of the public, corporate, and ultimately the individual sector to supply clean air.

Legislated air pollution control strategies and standards effectively shift some of the direct cost burden of air pollution from the individual to the corporate and public sectors. That is, rather than the individual having to bear the direct burden of air pollution damage, public and corporate facilities are required to assume the responsibility for air pollution control. Other things being equal, internalization of air pollution costs results in a decrease in net productivity. In turn, the ability to shift this burden back to the individual will generally determine the viability of public and corporate facilities within the structure of the regional and national economy.

For the public sector, the cost of controlling air pollution results from the combined costs of directly controlling pollutant emissions from municipally owned sources (i.e. power plants, incinerators, public transportation facilities, etc.) and from the costs of operating and maintaining air pollution control and regulatory services and facilities (e.g. enforcement, research and development, monitoring, information services, litigation, etc.) In as much as these facilities are publicly owned, the cost of pollution control is generally passed on to the individual in the form of increased taxes or usage rates.

Air pollution control strategies and regulations will have a significant effect on the corporate sector as well. The final effect of pollution control on quantity of output, facility location, profits, and consequently prices will generally depend upon a) pricing policy of the industry in which the individual firm is located, b) the direct cost of abatement in terms of equipment required to meet emission standards and the operating and maintenance costs of that equipment, c) the structure of the industry (other than pricing policy), d) the demand elasticity for the firm's product and, 3) the structure of the market. In order to counterbalance the effects of internalizing pollution costs, individual firms will try to shift as much of the burden resulting from the decrease in productivity as is possible to the individual in the form of higher prices.

Ultimately of course, the largest burden of air pollution control costs will be borne by the individual. While direct cost increases to the public and corporate sectors do not, in general, translate dollar for dollar to price and tax increases to the individual, for purposes of establishing a <u>relative</u> system of accounts to perform cost effective analyses of alternative <u>land use</u> plans, these cost increases are sufficient. The justifying assumption for this statement is that the factors defining multiplier effects in the regional economy will not be significantly altered by differences in growth options. The cost of controlling pollutant emissions may then be defined in terms of direct costs to the corporate and public sectors.

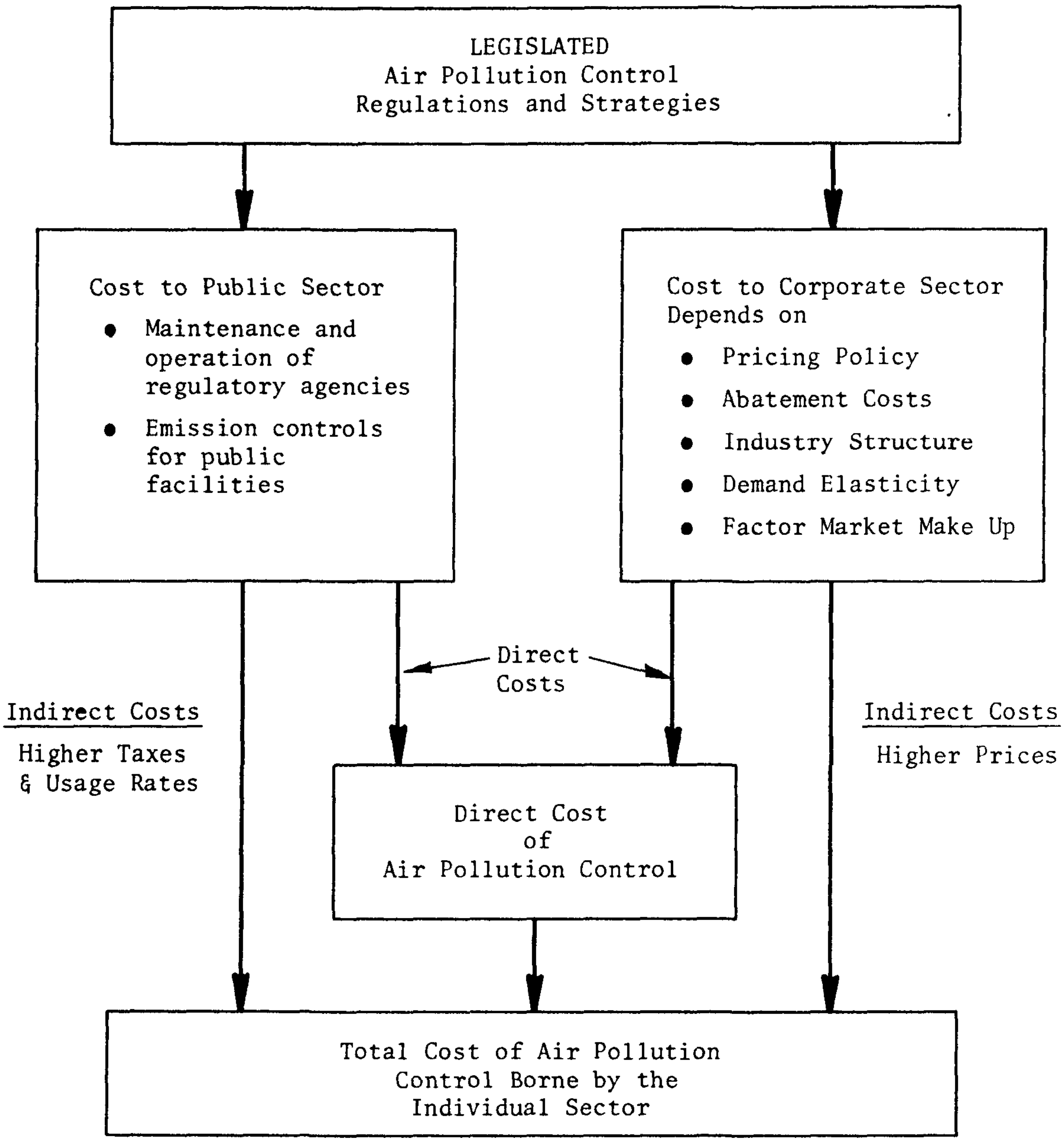

Figure 3-5. The Cost of Controlling Pollutant Emissions - Shows how the individual costs of pollution control may be considered for purposes of defining the total cost. The ability of the individual sector to support this burden may then be viewed as the aggregate ability of society to supply clean air.

8040

The Damage Function

Air pollution damage functions define the extent of aggregate dollar value damages attributable to polluted air.

The total nation-wide cost of air pollution damage for 1968 has been estimated at approximately 16 billion dollars. This figure, while admittedly a rough approximation, nevertheless, demonstrates that air pollution damages are both quantifiable and significant. More recent studies have estimated national damage costs ranging upwards of 300 billion dollars, indicating a more complete understanding of the effects of air pollution as well as a broader range of analytical capabilities with which to define its economic consequences. As the body of knowledge concerning the effects of polluted air continues to grow, it is expected that damage estimates will increase even further.

Existing studies into the construction of air pollution damage functions have postulated the following indicators as those best suited to establish the deleterious effects of polluted air:

- Health Costs
- Materials Damage
- Property Devaluations
- Vegetation Damage
- Soiling Costs
- Animal Losses
- Asthetic Effects
- Litigation Expenses

Of these, sufficient data exists only for attempted quantification of the first four. Even for these categories, data limitations have prevented construction of reliable empirically based damage functions. Those postulated to date are pro forma representations of indicated trends generated through multivariate statistical analyses. In addition, it has not as yet been possible to postulate an aggregate damage function of all pollutants. Rather, damage functions are currently expressed by pollutant.

Data limitations notwithstanding, information currently available to estimate per capita damage costs as a function of pollutant concentrations is sufficient to indicate the comparative air pollution impact of alternative land use schemes, particularly for the industrial pollutants, i.e., SO_2 and particulates.

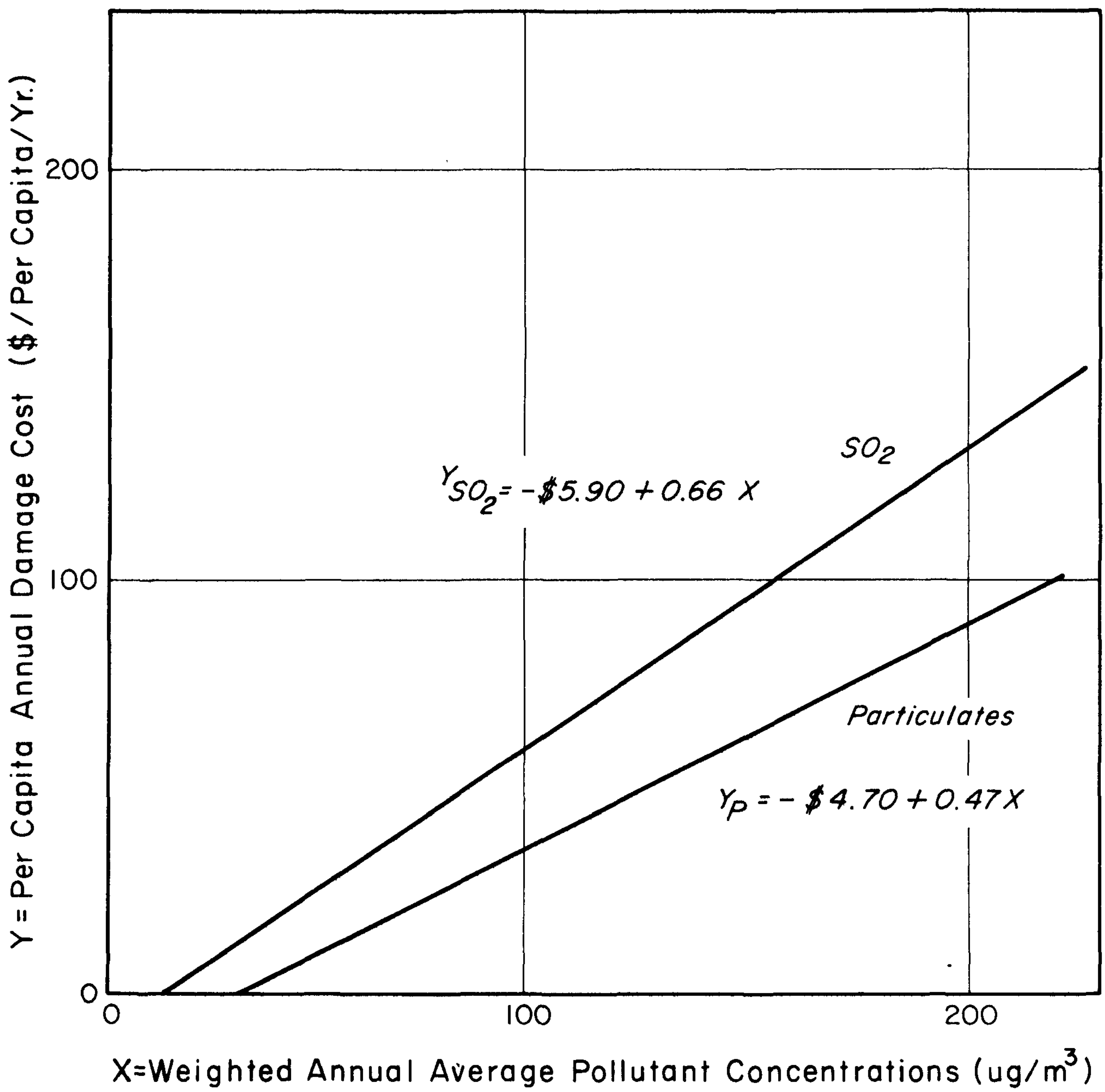

Figure 3-6. Pro Forma Damage Functions for SO_2 and Particulates - Show the effect of pollutant concentrations on annual per capita damage costs.

8035

LITERATURE SURVEY AND EVALUATION

Although a considerable amount of material is available concerning each of the various aspects of air pollution economics, a comprehensive methodological approach to cost effect air quality impact planning is not available on a level commensurate with both the requirements and constraints of existing planning practices.

Available literature relative to the economic implications of air pollution may be categorized into the three individual areas of concern indicated previously:

1) The trade off of air quality with urban activity
2) The damage functions
3) The cost of controlling pollutant emissions.

Information relevant to the first area of concern is fairly abundant and relatively easy to obtain. Unfortunately, much of the available literature is descriptive in nature and, for the most part, reflects efforts to implement various control strategies for existing land use configurations. The outstanding examples of implemented studies in this area, and those for which the preceding generalization does not apply, are referenced in the accompanying table.

In terms of documented studies attempting to establish empirically based damage functions, very little has been accomplished to date. Conceptually, this area has been relatively well defined; however, difficulties in compiling data have as yet precluded the availability of anything but pro forma representations. It is anticipated that extensive research efforts currently under way will provide more suitable information.

Since the adoption of the Clean Air Act, considerable effort has been spent on defining the costs to be incurred in controlling pollutant emissions. Much data is already available and this is being supplemented on an almost daily basis.

As discussed in the Summary, it is not expected that the application of the concepts presented here be accomplished through consideration of this document alone. Because of a multiplicity of factors involving site specific concerns of individual areas, the capabilities and limitations of various planning groups, the availability of representative data, and the relative position that air quality occupies within the priority structure of a given state, region, or municipality, it is anticipated that extensive literature and agency surveys will be required of potential users. It is therefore suggested that references cited in the accompanying table be obtained and examined as a first step in performing such surveys.

TABLE 3-1. REFERENCE MATERIAL

1. "The Arizona Environmental and Economic Trade-Off Model." Columbus, Ohio: Battelle Laboratories, September 1972.

2. Barrett, L.B. and T. E. Waddell. Cost of Air Pollution Damage: A Status Report. E.P.A. Publication No. AP-85, February 1973.

3. Benedict, H.M. and R.E. Olson. Economic Impact of Air Pollutants in Plants, Annual Report, Vol. I. Irvine, California: Stanford Research Institute, August 1970.

4. Crocker, Thomas D. Urban Air Pollution Damage Functions: Theory and Measurement. Riverside, California: University of California, June 1971.

5. "Demonstration of a Regional Air Pollution Cost/Benefit Model." TRW Systems Group, EPA Contract No. PH 22-68-60, McLean, Va., July 1971.

6. "The Economics of Clean Air." Annual Report of the Administration of EPA, U.S. Government Printing Office, Washington, D.C., 1972.

7. "Environmental Quality." The Third Annual Report of the CEQ, Washington: Government Printing Office, 1972.

8. "Environmental Quality." The Fourth Annual Report of the CEQ, Washington: Government Printing Office, 1973.

9. Fogel. "Comprehensive Economic Study of Air Pollution Control Costs for Selected Industries and Regions."

10. Peckham, Brian W. "Bibliography of Literature Relating to the Economic and Legal Aspects of Air Pollution." Chapel Hill, North Carolina: University of North Carolina, September 1971.

11. Purdom, P. Walton. Environmental Health. New York: Academic Press, 1971.

12. Ridker, Ronald G. Economic Costs of Air Pollution. New York: Frederick A. Praeger Publishers, 1967.

13. Williamson, Samuel J. Fundamentals of Air Pollution. Reading, Massachusetts: Addison-Wesley, 1973.

14. Wolozin, Harold. The Economics of Air Pollution. New York: W. W. Norton and Co., 1966.

A METHODOLOGICAL APPROACH TO COST EFFECTIVE AIR QUALITY IMPACT LAND USE PLANNING

SCOPE AND OBJECTIVES

The methodology presented here attempts to provide an analytical framework for considering the economic implications of air quality impact land use planning.

Current concern about the environment has fostered attempts to improve urban air quality. The major focus of these attempts has been on emissions control through fuel utilization and waste gas cleansing devices. Unfortunately, this type of approach recognizes neither the problems of planning for long term air quality, nor basic questions related to the economics of air pollution. The methodology presented here combines some of the most significant aspects of air pollution economics with an existing air quality impact planning process to form a "bare-bones" procedural outline for:

1. Making preliminary planning decisions involving acceptable amounts of heavily polluting land uses in terms of both air quality and one or more planning goals considered representative of economic viability

2. Evaluating alternative proposed land use plans in terms of how effectively they use the air resource to obtain stated planning goals.

In order that a cost effective planning and evaluation scheme for air quality be of practical value to the planner, it must be both easily applicable to a variety of planning situations and sensitive to time and budgetary constraints imposed on all planning exercises. Most especially it must be flexible in scope, tolerant of a variety of operating variables, simple to implement, and compatible with existing data and techniques for relating land use to air quality.

The ultimate objective of this methodology is the improvement of the decision making process concerned with the growth and development of urban configurations in terms of air quality. The intention here is not to put forth a dogmatic planning procedure but rather to provide a quasi-analytical framework within which the planner can accomodate and evaluate the effects of special characteristics of individual study areas. This is neither a mechanism for producing ideal land use schemes nor a means of attaining pollution free air. It is instead a planning aid and management tool for conserving the air resource in the face of severe pressures for economic development and given the restrictions of a fossil fuel energy supply and an imperfect emissions control technology.

Because this document is very conceptual and does not provide for the actual application of the methodology presented, Table 3-2 may prove useful to those who might wish to attempt an application. It presents the general objectives of the methodology and indicates what these objectives translate to in terms of scope of application. It represents, therefore, a concise statement of the intended utility of the methodology. Additional comments on application may be found in the third chapter.

TABLE 3-2. SCOPE AND OBJECTIVES

Objectives of the Methodology	Implications to Scope of the Methodology
1) To anticipate and evaluate the air quality and economic implications of planning decisions.	1) Must recognize and include quantification of air quality and economic criteria.
2) To be compatible with existing data and air quality and economic analytical techniques.	2) Must allow for a range of sophistication and detail.
3) To recognize and accommodate the specific concerns of individual planning areas.	3) Must be tolerant of a variety of operating variables over a range of physical scales.
4) To accommodate both the operational capabilities and limitations of individual planning groups.	4) Must be sensitive to time and budgetary constraints.

CONCEPTUAL DESIGN

Conceptually, the methodology aims at establishing the most effective use of the air resource from among alternative proposed land use plans which accomodate both air quality and economic development criteria.

In addition to the general problem of defining appropriate state and regional planning control strategies in compliance with the requirements of legislated air quality criteria, a very practical problem facing most communities is planning for the future to accommodate anticipated or desired growth. Government environmental regulations and citizen group activities have caused many communities to re-evaluate the process by which growth is achieved, so that environmental quality is now as much a concern as the more traditional problems of housing, employment, crime, and tax base. Consequently, planning decisions involving the magnitude and direction of community and regional growth must be cognizant of both economic and air quality constraints and should be based upon the effectiveness of air resource utilization.

Generally, economic constraints to planning options will appear in the form of minimum increases of industrial, commercial, and residential land uses necessary to accommodate existing and anticipated or desired changes in the economic, social, and political structure of a given study area. Factors to be considered in establishing this 'lower bound to growth' should therefore include the existing land use configuration, indicated development trends, physical characteristics of the area which either tend to promote or inhibit certain types of development, specific political or legislative requirements, and the development preferences of the existing population.

Air quality constraints to planning options are somewhat less difficult to define than economic constraints. In most cases these air quality constraints will be legislated federal or state standards. In addition to absolute limits of individual pollutant concentrations, these may also involve incremental limits, to either emission densities or pollutant concentrations, over fixed values. In any event, these constraints will translate to maximum amounts of industrial, commercial, and residential land uses which can be tolerated within a given study area.

Together, the upper and lower bounds to growth, as established through a consideration of air quality and economic constraints, provide a range of land use types and intensities from which preliminary development options may be specified. Designing within these limits will enable proposed plans to effectively accommodate both economic and air quality requirements. However, there are any number of combinations of land use mixes and intensities which may be permitted in a given area so that most often a series of alternative configurations will be postulated. An evaluation of the alternatives, defining how effectively each makes use of the air resource, provides a basis for indicating the preferred direction and magnitude of area growth. This evaluation is accomplished by performing a simplified relative cost effectiveness analysis.

The following section discusses the implementation of these concepts within the planning process.

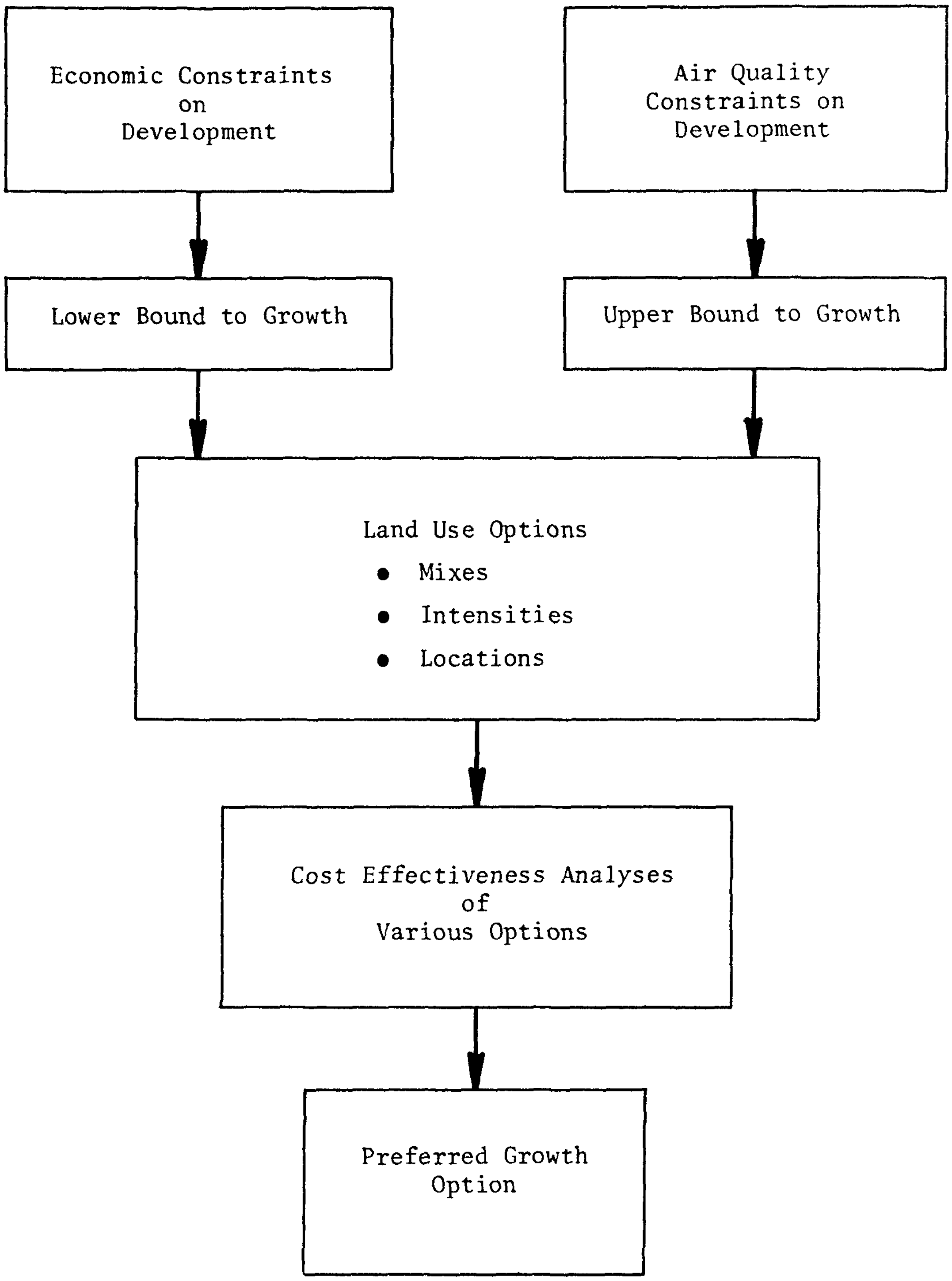

Figure 3-7. Conceptual Methodological Design - Shows how air quality and economic development constraints are used to establish preferred growth options.

8037

PROCEDURAL DESIGN

The procedural design of the methodology is effectively a step-wise sifting process in which economic and air quality constraints are sequentially applied to possible growth configurations and the residuals are evaluated in terms of their relative air pollution impact cost effectiveness.

Translating the conceptual design of the methodology, as defined in the previous section, into a practical, operational planning tool requires delineation of a procedural set of working steps. Ideally, these steps are individual operations which apply the current body of relevant information to specific planning concerns and do so in a chronological sequence which eliminates less promising plans early on and examines the residuals in further detail. As indicated in the previous section, an Air Quality Impact-Land Use Planning Process has already been defined and documented. The process is outlined, by its component steps, in the accompanying figure. It is the foundation upon which the procedural design of the methodology is laid.

Establishing the upper and lower bounds to growth, as required by the conceptual design, is accomplished by performing Steps 1 through 3 of the Air Quality Impact-Land Use Planning Process (denoted by the dashed line). These steps represent a 'quick and dirty' means of defining the trade-off between air quality and the pollution generating activities which generally support the economic structure (i.e., industry and transportation). The output of Step 3 is in the form of a series of preliminary alternative plans, specified in terms of types and amounts of industry and transportation. Each of these preliminary plans has been generated within the limits set by stated air quality and economic criteria.

Steps 4 and 5 of the Air Quality Impact-Land Use Planning Process develop and refine preliminary designs into 'final' land use plans and provide a statement of expected pollutant concentrations and their relative spatial distributions within the planning area. This information is applied to census tract data (or its equivalent) to obtain per capita air pollution damages from pollutant specific damage functions. The total cost of air pollution damage for the planning area is then the sum, over all census tracts, of the total damage in each tract.

The cost of controlling pollutant emissions is determined from the combination of costs fostered by controls imposed to limit pollutant emissions in excess of federal emission requirements and the cost of operating state, regional, and/or municipal control and regulatory agencies. Together, damage costs and control costs define the total cost of air pollution for a given land use plan. By iterating on control strategies and working back through the Air Quality Impact-Land Use Planning Process, it is possible to define, for each land use configuration proposed, the cost optimum level of air quality. Emission controls should be specified to obtain this level as far as possible.

The total cost of air pollution is then used as the denominator in a ratio of the dollar value of benefits received from a given plan to its air pollution costs. This ratio represents the relative cost effectiveness of that plan. Comparison of this value with those derived for other plans establishes a preferential ranking of all alternatives considered.

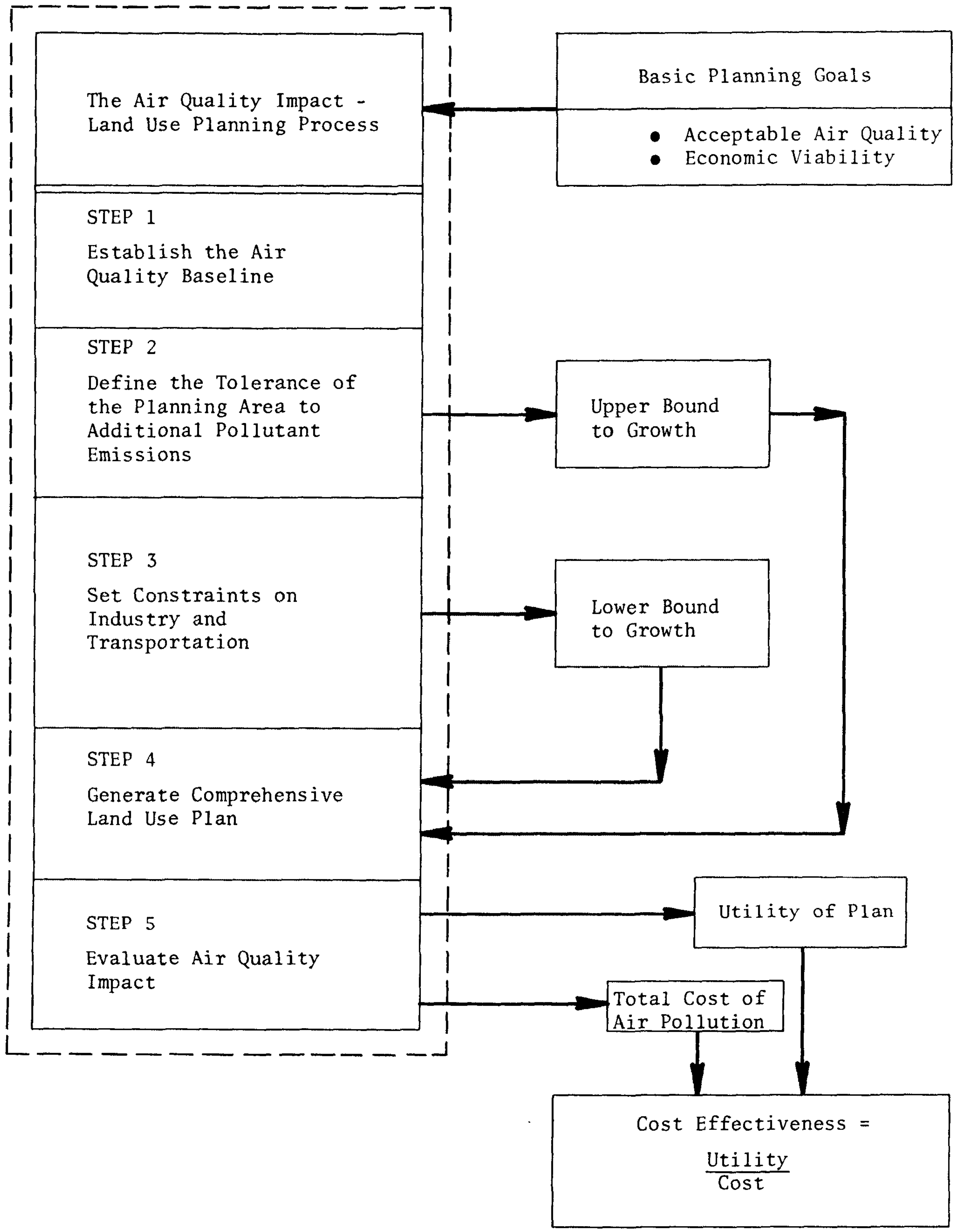

Figure 3-8. Procedural Methodological Design - Shows how the implementation of the methodology interfaces with the Air Quality Impact-Land Use Planning Process.

APPLICATION GUIDELINES

The methodology presented is applicable to a variety of planning situations over a range of physical scales each subject in its turn to a variety of operating variables.

As indicated previously, the methodology presented is a loosely structured framework within which planning decisions are formulated and evaluated in terms of how effectively the air resource is used to obtain stated planning goals. Because planning exercises are invariably site specific, and because the special concerns of individual planning areas are extremely difficult to address in a generalized context, application of the methodology to a specific problem requires that preliminary decisions relative to physical scale, operating variables defining utility, and data requirements be made. Generally, these three concerns will dictate both the scope and levels of detail of specific analyses required within the generalized procedural framework.

The physical scale over which the methodology may be applied is considerable, ranging from macroscale studies involving several hundreds of square miles to microscale studies of perhaps a square mile or less. In the macroscale case the primary focal point of analytical studies is the definition and evaluation of the aggregate effects of all land uses within a given study area, in terms of both their economic and air pollution impacts. By definition these are regional scale planning exercises and are particularly effective for establishing general development preferences in terms of over all land use types, intensities, and relative locations. Microscale studies will usually involve the design and placement of individual facilities within a given study area. In many cases, it may be desirable to use such studies as a tuning mechanism for regional scale exercises. For example, after defining an acceptable regional configuration, alternative subregional and local development options may be examined and evaluated within that regional context.

In choosing a physical scale which is appropriate for a given study, it is important that the scope of impact of various planning options be recognized. The environmental consequences of a regional scale planning decision may be limited to the microscale. By the same token, the economic implications of microscale development options will often be regional in nature and might therefore require an iteration on the macroscale scheme.

Once a physical scale has been chosen, it is necessary to structure the work study programs defining utility (benefits) and non-utility (costs). The first consideration in doing this should involve the specification of operating variables.

The number and types of operating variables available to represent the utility of a given plan are as varied as the connotative meaning of the word 'utility.' Any single planning goal or objective, or any combination of goals which can be quantified, and to which a dollar value assignation may be made, is fair game. These variables may be either positive or negative, although any plan which demonstrates a net negative utility in terms of a combination of variables defining stated goals is, by definition, less than useless and should be summarily rejected. Optimally, operating variables should be specified so as to be mutually independent, and therefore directly additive on a dollar value basis. It must be noted here that the evaluation of alternative plans in terms of their relative air quality cost effectiveness is meaningless unless the same operating variables are used to define utility for each plan.

The variables which may be used to define non-utility, or costs, appear in two basic sets:

1) Expressing the costs of air pollution damage

2) Expressing the costs of air pollution control.

The operational definition of the damage function is limited by lack of extensive available data. As indicated in the section entitled The Damage Function, the present definition would involve the summation of health, vegetation, property devaluation, and soiling costs. The costs of air pollution control are more varied and will be more site specific in nature. For this reason, a bit more creativity can be brought to bear in their operational definitions for a given study. In either case, it will usually be the availability of empirical data which will dictate the variables to be used.

Because the validity of any quantitative evaluation scheme is critically dependent on the validity of the data used, it is important that comprehensive regional or locally specific data be used in defining the operating variables. If this type of information is unavailable, serious consideration should be given to a redefinition of utility for that series of planning options. Where a redefinition cannot retain the intended meaning of utility, pro forma data representations may be used. However, even where relative evaluations will suffice, results derived from these data should be closely scrutinized.

It should be painfully obvious at this point that an actual application of the entire methodology will require a considerable effort. Furthermore, there appears to be a general reluctance on the parts of both the planning and economic communities to accept the validity of a cost effective approach to air quality planning. However, it would be unreasonable to assume that a cost effective approach to allocating perhaps our most precious resource can be dismissed without further scrutiny.

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-450/3-74-020-a	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Air Quality For Urban and Industrial Planning		5. REPORT DATE March 1974
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) John C. Goodrich, Scott T. McCandless, Michael J. Keefe, William P. Walsh, & Alan H. Epstein		8. PERFORMING ORGANIZATION REPORT NO. ERT Document No. P-434
9. PERFORMING ORGANIZATION NAME AND ADDRESS Environmental Research and Technology, Inc. 429 Marrett Road Lexington, Massachusetts 02173		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 68-02-0567
12. SPONSORING AGENCY NAME AND ADDRESS Environmental Protection Agency Office of Air Quality Planning & Standards Research Triangle Park, N.C. 27711		13. TYPE OF REPORT AND PERIOD COVERED
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES Prepared in cooperation with the New Jersey Department of Environmental Protection, Office of the Commissioner, Labor and Industry Building, Trenton, N.J. 08625

16. ABSTRACT

This Final Report presents a summary of work undertaken, including the proposed scope of work for each of the three major tasks, a summary of the actual work undertaken, and an explanation of any deviations from the intended scope of work. The report also contains the findings of Task 1, the development of improved emissions projection activity indices; and Task 2, the development of a methodology for incorporating cost data into the evaluation of the air pollution impact of land use plans. The results of Task 3 are presented in a separate report entitled "A Guide for Considering Air Quality in Urban Planning", EPA-450/3-74-020.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Land Use Planning & Zoning Local Governments County Governments Regional Governments State Governments Air Pollution Control		
18. DISTRIBUTION STATEMENT Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 87
	20 SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)