AN ABSTRACT OF THE THESIS OF

John August Jaksch for the Master of Science
(Name) (Degree)

in Agricultural Economics presented on August 8, 1969
(Major) (Date)

Title: EFFECTS OF AIR POLLUTION ON RESIDENTIAL PROPERTY VALUES IN TOLEDO, OREGON

Abstract approved: Herbert H. Stoevener

The main hypothesis of this paper was that air pollution represents an economic cost to the community affected; the incidence of such costs will be discounted in the land values of the community. The main objective of this study was to estimate empirically the effect air pollution would have on land values through a regression model explaining residential property values in Toledo, Oregon.

The empirical base of the study was the actual sales of residential property over a six and one-half year period (June 1961 to December 1967) in Toledo, Oregon. The source of air pollution in the study area came from a pulp and paper mill. Particulate fallout (dustfall) was used as a measure of air quality.

Two regression models were developed to explain property values:

Model 1

$$Y_1 = -.86533.4080 + 21.8264X_1 + -79499.7692X_2 + 115557.8900X_3$$
(9.0541) (9440.4432) (15981.8592)

$$+ 5615.1596X_4 + .0130X_5 + -277.0269X_6$$
(2452.3249) (.0068) (153.7133)

Model 2

$$Y_2 = -.17470.8590 + 9.4779X_1 + 1393.6180X_2 + 17678.2332X_3$$
(1.0465) (1216.8155) (2051.6368)

$$+ .0013X_5 + -29.4746X_6$$
(.0009) (19.7786)

where Y_1 = market price of the residential property expressed as price per acre in dollars.

Y_2 = market price in dollars of the residential property.

X_1 = size of the house in square feet.

X_2 = size of the lot in acres.

X_3 = a measure of the depreciation of the housing unit (expressed quantitatively between 0.00 and 1.00).

X_4 = the number of bedrooms in the housing unit.

X_5 = the quarterly, total manufacturing payroll (in millions of dollars) of Lincoln County.

X_6 = a measure of air quality (expressed in dustfall, tons per square mile per month).

The standard error of the coefficients are in parentheses. Model 1 had a multiple correlation coefficient (R^2) of 0.6079. Model 2 had an R^2 of 0.7076.

All coefficients in the models were significantly different from zero from one to 30 percent. In Model 1 X_6 (air quality) was significantly different from zero at ten percent; in Model 2 it was significant at 20 percent. In Model 1 it was found that a ton per square mile per month increase in dustfall would cause property values to decline by $277.03 per acre. In Model 2 it was found that a similar increase in dustfall would result in a decline in property values of $29.47 per market transaction.

All the signs of the coefficients were as expected, except X_2 (lot size) in Model 1 which had a negative instead of a positive sign. Statistically this was explained by the manner in which the dependent variable was expressed in Model 1. X_4 (number of bedrooms) was deleted from Model 2 because it was not significant.

The models have application in quantifying the economic costs of air pollution; in the setting of standards; in the setting of emission charges. The specific models given here are limited to the study area within Toledo. The general form and content of the models, however, have applicability to other study areas.

One of the assumptions made in developing these models was that people are aware of the costs of pollution. To the extent that they are unaware of some of them, the results obtained from this study should be interpreted as minima in the estimates of the costs of pollution.

Effects of Air Pollution on Residential Property Values in Toledo, Oregon

by

John August Jaksch

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

June 1970

APPROVED:

____
Associate Professor of Agricultural Economics
in charge of major

____
Head of the Department of Agricultural Economics

____
Dean of Graduate School

Date thesis is presented ______ August 8, 1969 ______

Typed by Gwendolyn Hansen for ______ John August Jaksch ______

ACKNOWLEDGEMENTS

The author is indebted to many persons for advice and assistance in the preparation of this manuscript. In particular, debts of gratitude are due to:

Dr. Herbert H. Stoevener for his patience, guidance, and consultation as the major professor,

my wife, Carol, for continued encouragement, thoughtfulness, and sacrifice throughout the conduction of this study,

the Oregon Agricultural Experiment Station for support of the costs of research, and stipend support from September 1966 through December 1967; U. S. Public Health Service for stipend support from January 1968 to date (fellowship number 5 F3 AP 38, 677),

the staff members, in particular Dr. Roger G. Peterson and Dr. Fred L. Ramsey of the Department of Statistics for their help and advice in the statistical analysis; Dr. Richard W. Boubel, Department of Mechanical, Industrial, and Nuclear Engineering, for the advice, suggestions, and aid on questions of air pollution and in obtaining air quality data; Dr. William P. Lowry, Department of Atmospheric Science, for his advice and assistance on questions of meteorology and in the preparation of isopleth maps for estimating air quality upon a given piece of property,

the county officials and employees of Lincoln County, Oregon and to the employees of Pioneer National Title Insurance, Co. for their cooperation during the collection of the data for this study,

Robert Percy, Assistant Laboratory Director, Oregon State Sanitary Authority, for his help during the collection of data on the particulate fallout stations maintained by the Oregon State Sanitary Authority.

TABLE OF CONTENTS

Chapter		Page
I.	INTRODUCTION	1
	The Problem	1
	The Objectives	2
II.	A THEORETICAL FRAMEWORK	4
	Introduction	4
	Literature Review	4
	Reasons for Using the Real Estate Market to Study the Economic Affects of Air Pollution	10
	Derivation of the Economic Model	17
	Introduction	17
	Characteristics, Assumptions, and Definitions of the Real Estate Market	19
	The Economic Model	21
III.	THE EMPIRICAL PROCEDURE	36
	The Study Area	36
	Derivation of the Economic Model Used in Toledo, Oregon	40
	The Statistical Model	44
	Price of the Residential Property	45
	Size of the House	49
	Lot Size	50
	Depreciation of the Housing Unit	51
	Number of Bedrooms	52
	Quarterly Manufacturing Payroll	54
	Air Quality	55
IV.	AIR QUALITY ANALYSIS	56
	Introduction	56
	Air Quality	56
	Method of Dustfall Collection and Analysis	61
	Data Limitations in Using Particulate Fallout as an Indicator of Air Quality	64
	The Preparation of the Dustfall Data for Inclusion in the Regression Model	68

Chapter		Page
V.	STATISTICAL RESULTS	80
	The Results of the Regression Models	80
	Size of the House	82
	Lot Size	83
	Depreciation of the Housing Unit	85
	Number of Bedrooms	85
	Quarterly Manufacturing Payroll	86
	Air Quality	86
	Selection of the Final Regression Models	88
VI.	THE APPLICATIONS OF THE MODELS	92
	Introduction	92
	Applications and Limitations of the Models	92
	Regrets with Respect to the Model and the Data	100
VII.	SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS	103
	Summary	103
	Conclusion	107
	Recommendations	109
BIBLIOGRAPHY		113

LIST OF TABLES

Table		Page
1.	Initial Estimating Equations for Residential Property Values.	81
2.	Second Initial Estimating Equations for Residential Property Values: Model 2.	89
3.	Estimates of Decreases in Property Values for Given Reductions in Air Quality: Model 1.	95
4.	Estimates of Decreases in Property Values for Given Reductions in Air Quality: Model 2.	97

LIST OF FIGURES

Figure		
1.	Hypothesized relationship between price of residential property and air pollution.	24
2.	Hypothesized relationship between price of residential property and air quality.	26
3A.	Indifference curve analysis of an increase in air quality.	27
3B.	Hypothesized relationship between an increase in air quality and a change in price of residential property.	27
4.	The study area. (Map adapted from a map prepared by the Oregon State Highway Department.)	39
5.	The study area and the location of the dustfall stations. (Map adapted from a map prepared by the Oregon State Highway Department.)	59

EFFECTS OF AIR POLLUTION ON RESIDENTIAL PROPERTY VALUES IN TOLEDO, OREGON

I. INTRODUCTION

The Problem

As of late land use planning, out of necessity, has received increased attention in connection with urban problems. Particularly this has been true with respect to the increased emphasis of planning for a better tomorrow with more livability in one's environs. One of the items receiving increased attention along these lines, especially in just the last decade, is the deteriorating state of air quality. Air pollution represents cost placed upon the community. It is a cost to the extent the consumer may be required to clean his house more often; or a loss of utility because one's view of the scenery may be impaired by a pall of smoke. Because of this many people hold that air pollution has a detrimental effect upon the residential properties exposed to it. Such a recognition is not new. Alfred Marshall, in his Principles of Economics (13, p. 804) proposed the leveling of a "fresh air rate" upon the property owners. The monies collected would have been spent by a local authority for pollution control. Marshall felt that much of the tax would be returned to the property owner through increased valuation of the property site. However, the evidence of such effects are not well quantified. For the most part such evidence has been limited to the general observations of most urban land economists and real estate appraisers that, in most instances, air pollution makes an affected site less desirable to live upon. This may cause a decline in the demand for the land, and, therefore, a decline in its value. The amount and to what extent other factors may contribute to this decline is generally not known.

Given the lack of quantification, the problem within this study is to estimate empirically the anticipated effect that air quality will have on land values. The study will make use of actual real estate transactions for the period June 1, 1961 to December 31, 1967. Thus the main hypothesis of this paper is as follows: Air pollution represents an economic cost to the community affected; the incidence of such costs will be discounted in the land values of the community. The higher the value of the land, the more indication there is of a more prosperous community. The value of the land in essence then is a reflection upon the overall economic activity of the community. Air quality is one of the economic variables determining the level of economic activity.

The Objectives

One of the objectives of this study will be the development of an economic model, and a corresponding regression model, to explain residential property values in Toledo, Oregon. Particular emphasis will be given to the development of a model which will explain associated changes in an air quality parameter with changes in property values. In effect, therefore, one will be quantifying the costs of air pollution as reflected in property values. A secondary objective of the study will be to establish the importance of, and to gain insight into other property characteristics which establish residential property values in a small town such as Toledo, Oregon.

A third and final objective of the study will be the inclusion of suggestions to pollution control and other regulatory agencies. These suggestions will be given with respect to the location of the sampling stations in order that they might be better used for economic analysis.

Chapter II of this paper will be devoted to the economic framework upon which the study is based. Chapters III, IV, and V will detail the empirical investigation. Chapter III explains the area of study, and details the derivation of the final economic and regression models. Chapter IV discusses the limitation of the air quality data, and the modifications and statistical preparation it had to undergo for inclusion in the general regression models. Chapter V gives the statistical results of the general regression models. Chapter VI explains the applications to which these models may be put. Chapter VII gives the summary, conclusions, and recommendations.

II. A THEORETICAL FRAMEWORK

Introduction

The first section of this chapter will deal with a review of the relevant literature. A second section will explain the advantages in the use of the real estate market to determine the economic consequences of air pollution. A third section will present the theoretical framework under which the market operates, and the assumptions associated therewith. From this framework a general land value model for residential property will be derived which can be empirically tested.

Literature Review

The economic literature concerning air pollution is scarce, but there is a large body of literature in the more developed field of water resources. The two fields of air and water resources are closely related in many respects, and there are many analogies and comparisons which can be drawn between them. Therefore, research done in water resources can be indicative of similar research which could be done in the field of air resources. Knetsch (11), for example, studied the consequence of proposed TVA reservoir projects upon land values. Using multiple regression equations, Knetsch derived a model explaining the relationship between land values around existing reservoirs and factors thought to determine such values. This method provided a basis for the estimation of land values if the project were constructed. A similar method was used to determine the value of the same land if the project were not constructed. The differences between the estimates of the two regression models could be attributed to the influence of the proposed reservoir project. It was found that for those cases examined near existing reservoirs the increases in land values were substantial, and were due mainly to the value of the project as a "recreational and amenity resource." Knetsch concluded that the results and methods developed in the research should have relevance to planning and repayment policies, management and operating decisions, and the assessment of the impact of other kinds of public investment.

Brigham (4) investigated residential land values in Los Angeles County and concluded that urban land value can be expressed as a function of only a few variables: the value of a particular urban area site is functionally related to its accessibility to economic activities, to its amenities, to its topography, to its present and future use (i.e., industrial, commercial, or residential), and to certain historical factors that affect its utilization. Brigham found serious measurement problems in dealing with these variables. (For example, he found that there were several different proxies for the accessibility and amenity indices, and that these proxies werefrequently highly intercorrelated.) These variables were then used to fit multiple regression equations to a sample of land values in Los Angeles County. The sampling method involved extending arbitrary rays from the Civic Center to the county boundaries. Each block a ray passed through was considered an observation, and the average appraised value per square foot for the block was ascertained. If a block included two or three types of land uses--for example, residential and commercial properties--this fact was noted, and subsequently individual samples of each were obtained.

It was found that most of the independent variables were inter-correlated with one another, in different degrees, which made it difficult to appraise the significance of the regression models. When the highest inter-correlations were removed, the regression coefficients were consistent with a priori expectations and exceeded their standard errors by fairly wide margins. And it was found that the regression coefficients were stable from ray to ray. This suggested other factors were at work which were not included in the model. Brigham concluded that the study should be extended (after certain improvements) to other cities to gain insight about the way parameters might change in cities of different sizes, with different rates of growth, and so forth.

Cresing, Davis, and Jackson (5), using a methodological approach similar to Brigham's, did a study of the urban property market of Pittsburgh. Essentially their paper dealt with zoning and externalities. However, their research was not helpful to this study in this specific regard. It was helpful to the extent of giving insights into the economic variables that one might wish to look at in the forming of an economic model. Empirically their study was helpful in giving ideas as to what market transactions to include, or to exclude, from the sample; how to quantitatively express some variables for inclusion within the model; and possible trouble spots that one might wish to avoid.

The Ridker (18) study is the only study known which attempts to measure the real effect of air pollution upon property values. The study consisted of a time series and cross-sectional analysis of the impact of pollution on property values in St. Louis, Missouri.

In the cross-sectional study the difficulty of obtaining information on each house or household was overcome through the use of neighborhood characteristics. Each neighborhood was defined as being a census tract. The advantages of using census tracts were that the tracts tended to be homogeneous with respect to income and other socio-economic variables. The unique characteristics associated with each household would tend to wash out using the neighborhood data.

A regression equation containing 12 independent variables was then developed to explain the variations in property values. The independent variables contained an index of air pollution, median number of rooms, percent of all housing units built from 1950 to March 1960, houses per square mile, distance in time from the central business district, accessibility to major through streets, school quality, percent of workers in blue collar occupations, persons per unit, percent of units occupied by non-whites, a dummy variable indicating whether the tract was in Illinois or Missouri to account for differences in property taxes, and median family income in 1959. The index of air pollution was based on milligrams of sulfur trioxide per 100 square centimeters per day, averaged for one year. The regression coefficient of the air pollution variable indicated that for every increase of .5 milligrams sulfur trioxide per 100 square centimeters per day there would be a decrease of $245 in value for the property effected.

Time-series analysis usually cannot be used in the study of the cost of air pollution, because there is usually not enough variation in air pollution over time. If a specific situation should arise in which the air pollution level does change over time very rapidly, and when a suitable control area as a basis of comparison is available, then a time-series analysis might be feasible. Such was the opportunity in a middle-class neighborhood in St. Louis when a plant that had just been taken over by a metal fabricating firm began emitting "choking, nauseous gases."

Two studies were done, one in the affected area, the other in a control area, as similar to the affected area as could be obtained. The control area was selected to assess the effect that pollution had on property values apart from changes in the general market conditions that occur over time. Results of the analysis show a depreciation in house values of $1,000 per house covered by the specific nuisance. A rough estimate of the total loss in the neighborhood, based upon the number of dwelling units in the affected areas, was $765,000. Ridker felt such results should be interpreted with caution. The specific air pollution episode occurred in 1962. If the two study areas were comparable they should not have been significantly different prior to 1962, but should have been after 1962. The two areas were significantly different in 1963 and 1964, but they were also significantly different in 1959 and 1960 when the pollution did not exist. The same phenomena which existed in those two years could also have existed in 1963 and 1964. If this were the case, then the fact that the two areas were significantly different in 1963 and 1964 would be irrelevent from the standpoint of air pollution having caused such significance difference.

Ridker felt that a great many assumptions underlied his time-series study. So many in fact that he felt little confidence could be placed in the final results. Essentially, because of the lack of some data, and the lack of time available to obtain and apply additional data, Ridker concluded that the principal values of the study lie not in the numerical findings, but in the illustration of the time-series approach and its difficulties.

All of the studies discussed above have made a contribution in the preparation of the Toledo study. But only one, the Ridker study, specifically attempted to measure the impact of air pollution upon residential property values. To this extent then, the Ridker study was the most helpful.

Reasons for Using the Real Estate Market to Study the Economic Affects of Air Pollution

This section will discuss the fact that air pollution is an external diseconomy, and as such the current market mechanism fails to impose the costs of pollution upon the decision making unit responsible for it. There will also be a discussion of three potential methods of measuring the costs of pollution. In the words of Ridker the first method is called the direct affects of pollution or "the cost of pollution in the absence of adjustments" (18, p. 15); the second method could be called the cost of pollution with individual adjustments allowed; the third method could be called the estimating of the costs of pollution via market effects. Reasons will be given why the first two are abandoned, and attention is focused on the third method.

Most economists within the United States would view a well-functioning, competitive market system as the most efficient method to allocate resources in accordance to consumer wants. In theory, if the markets are highly competitive and if the producers and consumers are attempting to maximize benefits to themselves, then resources are allocated for the maximization of social welfare given the existing income distribution. In such a market the costs and benefits of a decision or act would fall upon the decision unit performing or instigating the act. In actuality economists have long recognized that the market will often prove ineffective in making the performing unit be fully accountable for the economic consequences of its decision making.

These economic consequences are called technological external diseconomies, and may be defined as follows: A technological external diseconomy exists where a particular action by a decision unit (government, business, households, and individuals) produces uneconomical results--higher costs, or less valuable production--and the costs of the action are transferred from the economic decision unit pursuing the action to a managerially independent unit by a technical or physical linkage between the units, and not by a market transaction. These costs may take the form of an actual outlay of money, a reduction in income or utility, or the foreclosure of some opportunities (10, p. 78).

When a technological externality exists one can say that resource allocation could be disturbed. That is, the decision unit imposing the external diseconomy would incur higher profits than if it was forced to internalize the costs of the diseconomy. The opposite would exist for the receiving unit. Its profits would be lower because it is forced to take into account the costs of the diseconomy. If one is dealing with households or individuals as the receiving unit instead of another firm, then one could say that the marginal social costs imposed upon society by the diseconomy are greater than the marginal private costs incurred by the decision unit in the execution of the decision. The differences between the two costs are not taken into account in the normal operation of the market, again leading to a possible misallocation of resources. In this study attention will be directed to this latter situation.

Air pollution is an externality, a technological external diseconomy to be exact. Like most natural resources used in waste disposal the costs are for the most part external to the emitter. Given the acceptance of the discussion above, it soon becomes evident that additional mechanisms may be needed, in addition to the market, to force decision makers to take into account such costs. Social institutions now existing to augment the market in resource allocation when externalities exist include: the courts and the judicial process; the local, state and federal governments and their use of police and legislative powers to establish regulatory agencies. To operate effectively, however, social institutions need adequate information. Particularly, to effectively handle the making of and implementation of decisions about air pollution, social institutions need information about its economic costs. The fact that such costs are not always handled within the market system means that the costs must be measured in some other way. There are potentially three methods of estimating such costs.

The first method to be discussed is the direct costs of pollution (18, p. 15-20), that is, the costs of pollution in the absence of adjustments to the pollution by the individuals affected. This method is beset by measurement difficulties, particularly when there are no market reflections whatsoever of the losses incurred. In essence, what this method does is to avoid including costs of adjustments or market effects. To the extent that such adjustments are used to alleviate the damages caused by air pollution, biasness will result. That is, if all direct costs have been measured, these biases will overstate the costs of air pollution. Unless the net effect of adjustments is to reduce the associated costs, then the adjustment would not have been undertaken. Failure to take into account the adjustments, and the reduction in air pollution damage brought about by the adjustments, will result in an overstatement of the actual air pollution damage. It is quite evident from this that one should consider individual adjustments.

One is now brought to the second method outlined by Ridker for the measurement of air pollution costs (18, p. 20-23). The effects of air pollution will cause individuals and firms to make adjustment to lessen the immediate effect of air pollution. One could move from the affected area, paint the house more often, and so forth. Such adjustments to the immediate impact of pollution can be costly. In reality no matter what the individual does he suffers a loss of utility. He may be able to cut his losses, but he can not completely eliminate them.

One of the biggest problems associated with this method is again one of measurement. Any relation between air pollution and the cost of adjustment to it must be based upon data specifically gathered for this purpose. Each possible adjustment that will minimize the effects of pollution on a given object must be identified. In essence, one must in using this method seek to identify all of the effects of pollution damage. This approach of looking only at individual adjustments understates the costs of pollution. This will be explained in more detail below.

The third method outlined by Ridker in estimating pollution costs is the market effects (18, p. 23-28). The only complete way to measure social losses occurring with air pollution is to go beyond individual adjustments and to take into account social interactions (the effect of one person's actions upon another). One of the more important interactions in this case would be the effects which can occur because people are linked together by their purchases and sales in different markets. The fact that one person is not directly affected by pollution does not necessarily mean that he won't be at least indirectly affected by the altered market behavior of another who is directly affected.

For the most part such market effects represent transfers of benefits or costs between economic units rather than an additional set of consequences not taken into account by the second measurement strategy discussed above. A good example of this would be a case that happened in Los Angeles. As air pollution increased in Los Angeles, spinach and orchid growers at first bore the brunt of the costs of not being able to produce in the area. However, to the extent that their prices rose as a consequence of the decreased production, some of the losses were transferred from the producers to the consumer (18, p. 24). The market, therefore, tends to spread the consequences of pollution among individuals.

The spreading of the consequences of the pollution in all probability means that the estimates of the costs of pollution based upon the second method of measurement understate the true costs of pollution. The reason for this is as follows: The second method includes only the costs of the individual's adjustments, and makes no attempt to look at the costs that may have been transferred to those who were not initially affected by the pollution. Therefore, to the extent these transferred costs are not included in the second method, the estimates of the costs of pollution are understated. Only if the pollution costs could not be transferred would the second method yield accurate results.

Even if one were to try to obtain estimates of the costs of air pollution based upon market data, spreading effects still complicate the actual measurement problem and the interpretation of the meaning of the estimates. There is one market, however, which does have the potential to reflect the aggregation of the majority of the effects of air pollution. This would be the real estate market, the procedure of measurement used in determining the costs of pollution in this study.

In theory it is held that if the land market were to work perfectly, the price of a piece of land would equal the sum of the present discounted stream of net benefits derivable from it. The hypothesis of this paper is that air pollution represents a cost, the incidence of which will be reflected in land values. If air quality deteriorates and some of the costs associated with air pollution rise (one has to clean or paint his house more often), or benefits from the use of the land decline (one can no longer see the mountains) then the market price of the property will be discounted in the market to reflect the consumers' valuation of such changes. Therefore, estimates of air pollution costs can be obtained by observing the changes in property values with changes in air quality.

The advantages of using this method of measurement are as follows: The supply and location of land is fixed; the pollution sources located upon the land are relatively fixed; the meterlogical conditions within the air shed over the land are comparatively stable from one year to the next. With these conditions, it is less likely that the incidence of air pollution can be shifted to other markets, as would be the probable case if markets other than the land markets were used to estimate pollution costs.

While this approach to measurement does have its advantages, it is not without its problems. One of the problems is that the market does not always operate perfectly. At any one point in time one cannot always be sure just what is being discounted in the property value. That is, for air pollution to have an observable effect upon property values, buyers and sellers must know of its consequences.

Derivation of the Economic Model

Introduction

Essentially what this section will do is to present a development of the hypothesis stated in the prior section. This hypothesis says that air pollution represents a cost, the incidence of which will lie in land values. From this one would infer that air pollution acts as a depressant on property values.

In an attempt to explain the hypothesis logically, this section will detail the characteristics of residential properties and the buyers of these properties, and list the assumptions and definitions associated therewith. There will be a development of a framework which will provide an explanation as to how certain characteristics providing utility can enhance residential property values, and why air pollution as a disutility may depress the property values. The framework, or model, as it initially will be developed is a general one in nature. That is, the framework will detail many economic variables which one might wish to initially examine in attempting to explain variations in residential property values.

Perhaps it should be stated now that all potential areas of study are different from each other. This is true not only in what data is available, but also in economic and other characteristics as well. The variables to be discussed may be modified with respect to any given area of study. The discussion should not be taken as containing a complete listing of all variables which could potentially be examined. The study of a given area might suggest or lend itself to other variables to be studied which might not be mentioned here.

Characteristics, Assumptions, and Definitions of the Real Estate Market

Each piece of property has certain unique characteristics from which utility is derived by its user, or for which he is indifferent. Examples of such characteristics would be the location of the property, the improvements upon the property, and so forth. These characteristics, since they have use for the consumer, have a value for which he is willing to pay. To the extent that they may be empirically determined, these characteristics can be used in a regression model to provide estimates of residential land values. But there are characteristics of property which do not provide utility to the user. Examples of these would be excessive noise, poor location, and air pollution. These are items which he could do without. Since these items do not provide utility to the potential user, they would be discounted by him in the price of the property.

For the residential property buyer the buying of property is not an everyday occurrence. For many people it is a once in a lifetime transaction. The buying of the property will usually represent a huge sum out of one's total lifetime income. It is this total income (present and future) which places limits upon the total amount of property that one can buy.

In this paper residential property is defined to be an improved piece of property located within the city limits of any given town.

By improved it is meant that the property has city water, sewage, and garbage disposal; has a single family residence located thereon; and possesses other characteristics from which utility can be derived.

Price is usually thought of as being the quantity of money exchanged for the last marginal unit of a homogeneous product. Since a homogeneous product is not being dealt with here, the use of the term price of property or value of property has to be definitionally modified. Before this is done it would perhaps be best to give the assumptions made in this paper concerning price or value of residential property.

It is assumed that buyers bid for the residential property, and attempt to maximize the net benefits arising from it. It is assumed that the seller will accept the highest bid offered for the property. The bid price will reflect the consumer's valuation of the net benefits arising from the property characteristics.

Given these assumptions, residential property value is defined as the total amount of discounted consideration paid by a consumer after giving deliberation to the alternatives--such as the satisfaction derivable from the property, the opportunity costs of having invested his money elsewhere, and the costs of owning the property (interest, taxes, maintenance, depreciation, and so forth).

Because there are so many buyers in the real estate market, each with his own unique desires and wants, there is created, for the purposes of this analysis, a representative buyer. Since this study is limited to only single family residences, it would not be unreasonable to assume that the buyers of such property, as a class, possess, very broadly, similar desires and wants. A representative buyer then is defined as a buyer who would possess such group characteristics.

As already mentioned, in part, it is assumed that the amount of money which the representative buyer would spend upon a given piece of residential property is a function of his lifetime income, or preferably, expected permanent income. Permanent income is defined as the expected value of the consumer's expected future receipts (7, p. 20).

Property value has been defined to be inclusive of land and its improvements. There will be no attempt in this paper to separate the effects of air pollution on improvements from its effects on land. This assumption appears reasonable when one views the fact that when most people buy residential property they consider the land and the improvements upon it as an integral unit. It is in this light and consideration that residential property and the value of residential property were defined.

The Economic Model

The last sub-section stated that residential property value is a function of many characteristics which provide utility or disutility to the representative consumer. The consumer attaches a value or cost to each, respectively, and then tries to maximize those items providing utility. In the discussion of the general model to follow, attention first of all will be focused on the role air pollution has in determining the value of the property. Consideration then will be given to the other characteristics one might desire to look at in the formation of a general economic model for the determination of residential property values. These characteristics are empirically measurable in most instances, and full recognition is given to the fact that some satisfaction is derivable from the property which cannot be measured.

Stated previously was the fact that air pollution is an external diseconomy, and as such represents a discommodity to the consumer in that less is preferred to more of it. The higher the degree of air pollution the more are the direct costs which the property owner must bear (one has to clean or paint his house more often for example). Not only does the deterioration of air quality increase the costs associated with the use of the property, but it also cuts down on the benefits derived from the property (one can no longer see the mountains because of the decreased visability due to air quality deterioration). In the last section and in the last sub-section of the current section, it has been established that if the market were to work perfectly, which has been implicitly assumed via the assumptions and definitions previously given, residential property value would be equal to the sum of the present discounted stream of net benefits derivable from it. This would imply that if the buyers are aware of the consequences caused by air pollution they will discount the increased costs and loss of benefits in their valuation of the property, causing it to decline. Whether potential buyers and sellers know that air pollution caused the effects is immaterial. All they need know is that the effects exists, not what specifically causes them. The implication of this then is that the incidence of the costs of air pollution will ultimately be discounted in the values of the properties subjected to it. Such costs may be estimated by observing the changes in property values with changes in air quality over space or time.

It has just been stated that an underlying assumption of this reasoning is that buyers are aware of the effects of air pollution. However, to the extent that they are unaware of some of them, the methods outlined here will produce results which should be interpreted as minima in the estimates of the cost of air pollution.

For illustrative purposes, the hypothesized relationship between air pollution and residential property prices or value is shown graphically in Figure 1. On the vertical axis is measured the price of a given piece of land. Air pollution is measured on the horizontal axis. This relationship illustrates that as air pollution increases, the price of the land will decline.

So far the hypothesized relationship between air pollution and

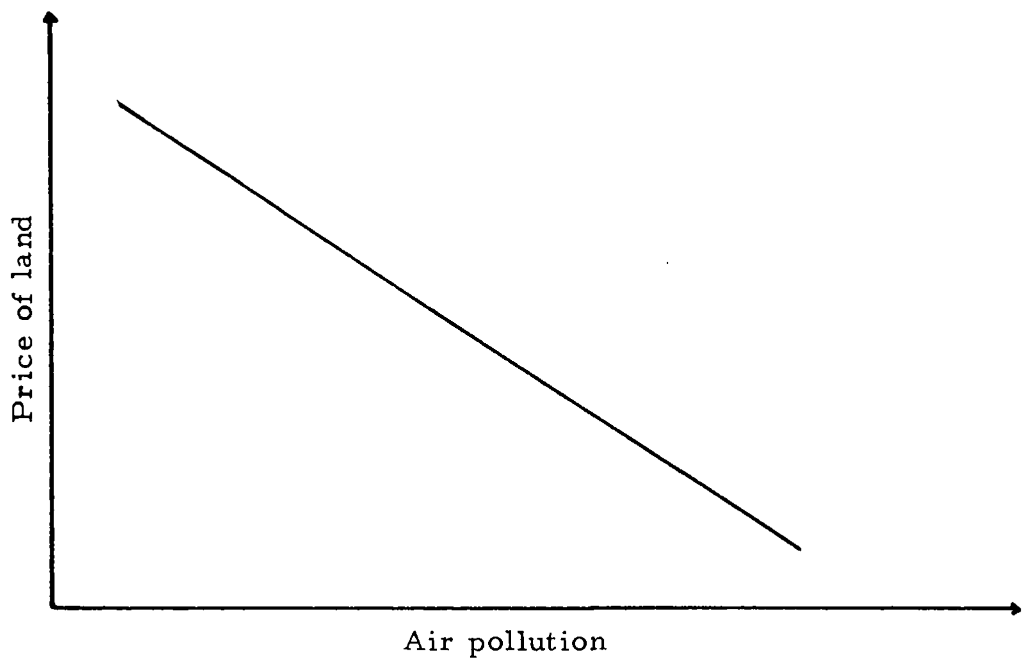


Figure 1. Hypothesized relationship between price of residential property and air pollution.

residential property value has been theoretically explained. The next problem to which attention must be directed is how this relationship is expressed in the market place. To do this will require the use of the converse of the arguments heretofore given. It has been explained in some detail that, given the assumption that the market works perfectly, the increased incidence of air pollution will be discounted in the valuation of the property by any potential buyer. One can in a similar manner argue that increases in air quality will result in the increased valuation of a given piece of residential property. Reference is given to Figure 2 which illustrates this concept. Price of a given piece of property is on the vertical axis and increases in air quality on the horizontal axis. This illustration says just the opposite of Figure 1: As the quality of air increases so will the price of the piece of property. Air quality is thus defined as a commodity, more of it being preferred to less.

Attention now is directed at Figures 3A and B. Figure 2 is reproduced as Figure 3B, with the assumptions and relationships given with respect to Figure 2 remaining unchanged for Figure 3B. In Figure 3A air quality is shown on the horizontal axis, and money is shown on the vertical axis. I^0 and I' are indifference curves between money and air quality held by our representative buyer. It is assumed that money and air quality are commodities, and, for reasons to be given later, the marginal utility of money is constant.

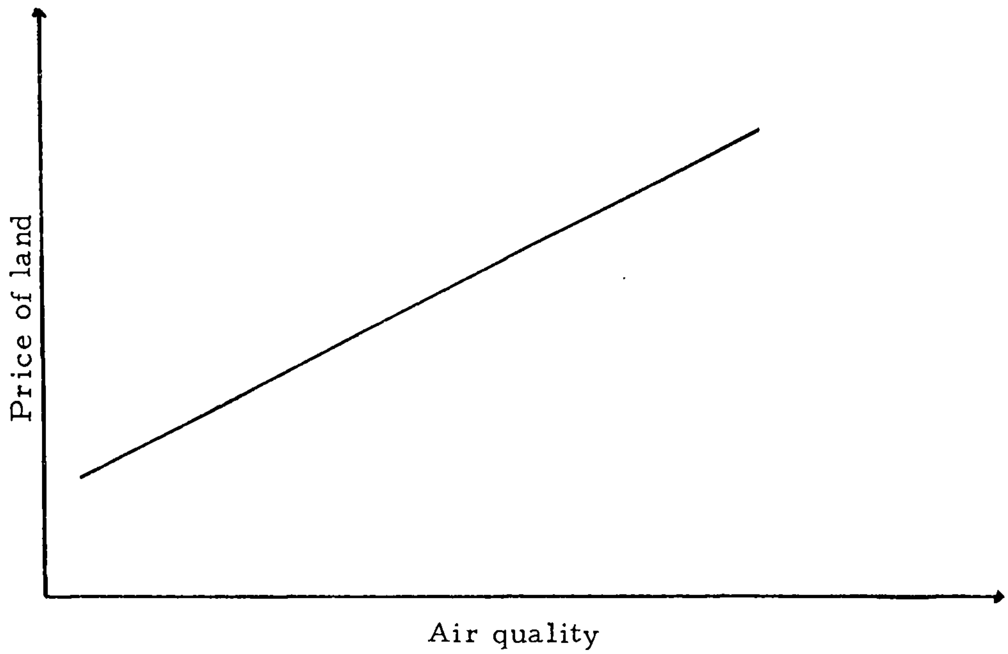
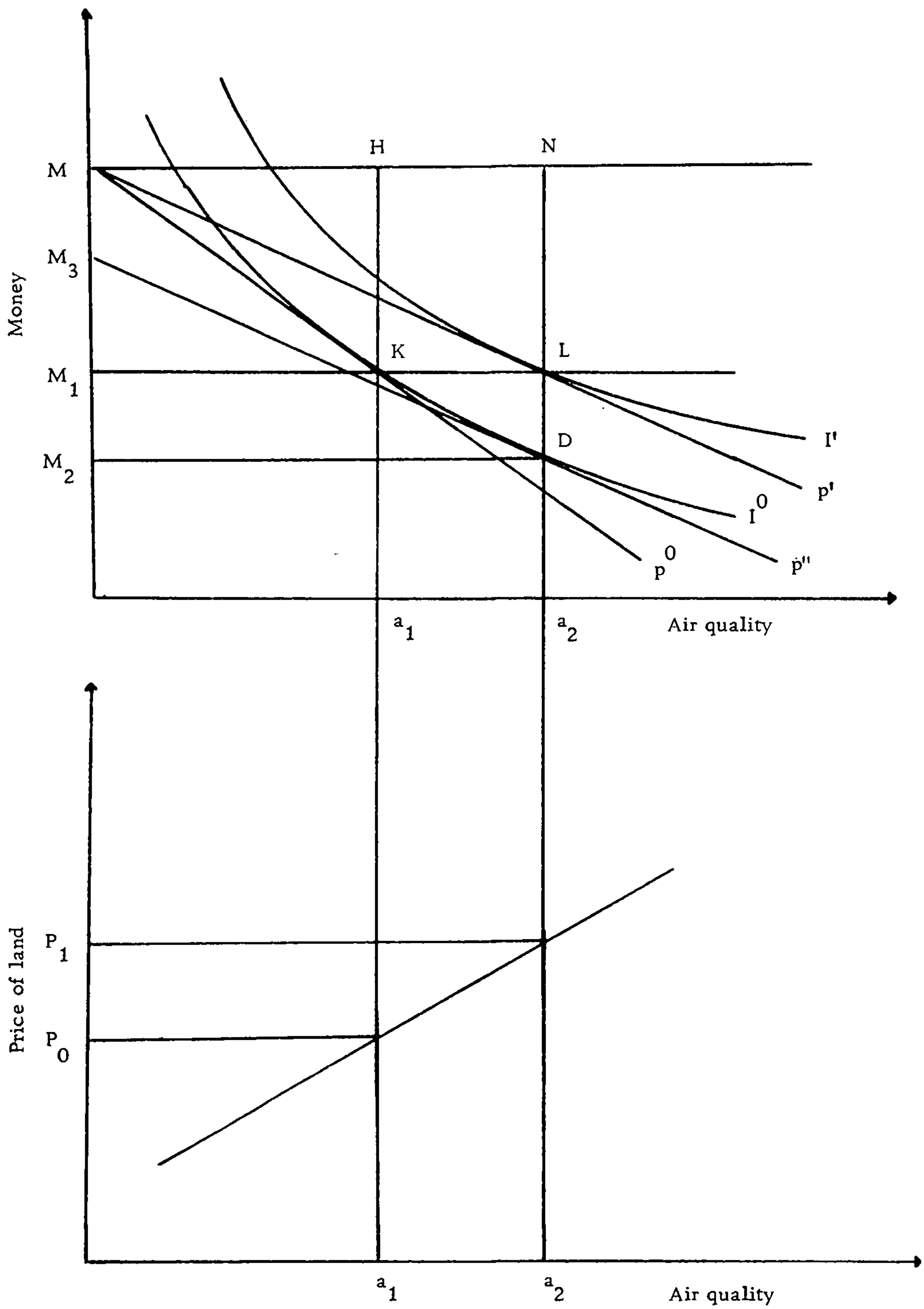


Figure 2. Hypothesized relationship between price of residential property and air quality.


Money
M
M3
M1
M2
H
N
K
L
D
I'
p'
I0
p0
p''
a1
a2
Air quality
Price of land
P1
P0
a1
a2
Air quality

The indifference curves are of the usual shape for a choice between two commodities. The usual assumptions about the indifference curves hold: utility is constant for movements along an indifference curve; a higher indifference curve is preferred to a lower indifference curve (I' is preferred to I^0); the indifference curves do not intersect. OM is defined as the consumer's permanent income. The total amount of money to be spent upon any given piece of property by the potential buyer is a function of his permanent income. The buyer will attempt to maximize the utility arising from the use of the property given the constraint imposed by his permanent income. The price offered for clean air by the potential buyer is given by the slope of the line p^0, which touches the indifference curve I^0 at K, the point at which utility is maximized. MM_1 would then be the amount of money which a consumer would pay to have air quality a_1 (at the time he buys the property) which is reflected in price P_0 (Figure 3B) that he offers for the property.

What does all this say? Essentially that, with the assumptions that have been made, the market works perfectly in evaluating the effects of air pollution up until the time of sale. What happens if air quality improves, say from a_1 to a_2? To examine this question let it be assumed that the potential, representative buyer has bought a given piece of residential property at price P_0 and air quality a_1. Suppose now that air quality changes from a_1 to a_2, and the change is permanent enough to be noticed by all concerned. The consumer would increase his utility or satisfaction from K to L by moving to a higher indifference curve. Since he has already committed himself in the market he would pay nothing for the increased utility. When he entered the market the present owner of the property was willing and did pay a price p^0 to obtain air quality a_1. Now a_1 has changed to a_2, which means the owner is obtaining increased air quality without paying additional for it. Since he is now receiving cleaner air this would imply that the price of air quality has been lowered for him from p^0 to p'. But if he were now entering the market the present owner, as seen by Figure 3A, would have been willing to pay up to L D (M_1 M_2) to obtain the increase in air quality. (For distances larger than LD the consumer would be on a lower indifference curve; for distances less than LD the consumer is placed on a higher indifference.) The consumer is obviously better off at L, and the consumer (owner) has been able to obtain this position without cost to him. The increase in air quality will be capitalized into the value of the property for which the next potential buyer of the given piece of property must pay. Further discussion on this subject will follow later.

Conceivably the owner of the property could be taxed for his gain in such a way as to make him no better or worse off for the change in air quality. To do this one would draw a line parallel to p' and tangent to D. This is done with p'' in Figure 3A. One notices that the amount of the tax ($M M_3$) is equal to the amount of money ($M_1 M_2$) the owner would have been willing to pay for the increased air quality. This is because of the assumption of the constancy of the marginal utility of money made earlier. This assumption is not unjustified when one thinks of the fact that of the total amount of money paid for the property, the price paid for air pollution remains but a small part of the sum total. Thus the fact that the marginal rate of substitution between air quality and money remains unchanged by the reduction of income is not unreasonable.

If one calls LD consumer surplus arising to the present owner because of a change in air quality, the next question to be asked is what happens to it ? The present owner of the property will not realize this capital gain until such time as the property is sold. (Obviously of course there would be intermediate benefits arising from the increased air quality, such as not having to paint the house as often, but this should be reflected in the property value.) Other buyers would begin to bid up the price of the property to obtain the consumer surplus. This would continue until the consumer surplus is bid away, and the change in air quality would become reflected into the value of the property at a higher price, P_1 as shown in Figure 3B. Thus the market has evaluated the change in air quality for those coming into the market at any given moment up to and until such time a commitment is made. In essence the new buyer is paying for what he is getting, given the assumptions made. One can of course reverse the above process to analyze deterioration in air quality, or increases in air pollution.

What conclusions may now be drawn from all of this? A buyer committed in the market place will initially take into account the quality of the air at the time of purchasing the property, and discount it accordingly. To this extent the market works perfectly, in theory, in evaluating the effects of air pollution at the time of sale. After the purchase has been made the property owner may stand to benefit or lose by increases or decreases in air quality. The market fails to take this into account and compensate or tax those who benefit or lose via a change in air quality. Such benefits or losses will not be realized in a monetary sense by the present owner until the property is sold.

Increases in air quality followed by resulting increases in the price of a given piece of property, other things being held constant, will only allow people with higher incomes to purchase property in the given area. Just the opposite would happen with decreases in air quality. The price of the property would become less, allowing people with lower incomes to purchase it. This could explain, in part, why many of the polluted areas of the cities have developed into slum areas populated only by those with lower incomes.

Air pollution is only one variable which determines the value of the residential property. The remainder of this section examines other variables which one might wish to include in the economic model. Again attention is called to the fact that the question of what to include, or not to include, is peculiar to the given area of study.

The variables to be studied can be grouped into three broad classifications: characteristics specific to the property, neighborhood characteristics, and locational characteristics. Given the fact that the property has associated with it certain characteristics which provide utility or disutility, each of the following variables is a characteristic which can either enhance or depress property values.

Turning now to those characteristics which are specific to residential property one might wish to include within the model such things as the number of bedrooms, the quality, and the size of the housing unit; and the size and the topography of the property upon which the housing unit is located. With the acceptance of the fact that more of a good is preferred to less, it would not be too hard to accept the fact that at a given value a per unit increase in house size, the number of bedrooms of the house, or the quality of the housing unit will increase the value of the property.

A larger lot size would likewise be expected to enhance property value. The reason for this is that the smaller the lot size the more crowded the neighborhood. Most potential buyers would feel this to be a most undesirable consequence. A larger lot size would enhance the consumer's neighborhood, and thereby would increase the value of the property. One might want to develop a topographical index to take into account the material and physical characteristics of a particular site for similar reasons. A site located on an elevated position which provides a view could enhance the value of the property more than if the same piece of property were located upon level ground.

Next one might want to take into consideration the neighborhood characteristics associated with the property. Here one might want to examine such things as the quality of public services and the level of taxes used to support them (especially if the area of study covered more than one taxing district from which services are obtained), persons per housing unit, houses per acre, and the crime rate in the area. Economic theory would lead one to assume that the level and quality of public services, along with the taxes to support them, would be capitalized in the value of the property. It is not too hard to accept the fact that the better the public services provided, the higher the value of the property so affected. School quality would be a prime example of this. It is quite obvious that families having children would prefer to live in an area having better school quality. This would tend to enhance property values. In a similar vein most people would prefer to live in an area experiencing a lower crime rate. This too would increase the demand for the property causing it to increase in value. But there is another side to the coin. Increased school quality and lower crime rates, for example, will likely mean higher property taxes, or cuts in other services in order to finance these items. If property taxes are used as a method of financing these increased public services, then this could lead to an ever increasing tax burden upon the land, which could depress property value. If other services are cut to finance these services, then others who desire these services would be discouraged from participating in the market in this area. This too could conceivably depress land values.

Persons per housing unit would be a measure of population density in a given area (as would the number of housing units per acre). Higher values of this variable would usually be associated with more children in the neighborhood, and thus increased noise, wear and tear upon the property, and higher taxes for schools. Thus higher values of this variable would cause property values to decline.

The number of housing units per acre would also be a measure of crowding within a given area. Higher values of this variable would usually be associated with more people in the neighborhood, and as a result more noise and congestion. Thus higher values of this variable would also cause property values to decline.

Finally in examining the locational characteristics of the property, one might wish to include in the economic model as a variable the distance from the center of the major shopping district, and highway accessibility. Shopping is something which every potential buyer has to do. The closer he is to a major shopping district the less time he has to take to get there, and the cheaper it is to get there if he has to drive. Thus one would expect that the greater the distance between a given piece of property and a shopping district, the more land value would be depressed. A similar argument would lie with the second variable. The farther the property is located from a major access route, the more depressed the value of the property.

III. THE EMPIRICAL PROCEDURE

The Study Area

This section will contain a brief description of the study area. There will be a brief discussion as to the manner in which the area of study was selected within the city limits of Toledo. The section will be concluded by a discussion of the advantages and disadvantages of using Toledo as a study area.

The area of study centers within the city limits of Toledo, Oregon (estimated 1967 population 3,010[1]). The City of Toledo is located on the Yaquina Bay, 13 water miles and six road miles from the Pacific Ocean. The town is located on U. S. Highway 20 which connects it to the Willamette Valley 40 miles to the east. It is served by two motor freight lines, Southern Pacific Railroad, one bus line, and the Port of Toledo (assessed valuation of $23,043,741 in 1967[2]). In addition, Toledo has the usual city facilities and services such as fire and police departments, sewer, industrial and domestic water services, and so forth. Assessed valuation for Toledo in 1967

---

[1] Obtained from the State of Oregon, Division of Planning and Development.

[2] Obtained from the records of the Lincoln County Assessor in Newport, Oregon.

was $14, 353, 538,[3] the highest of any town in Lincoln County.

The economic geography of the area is oriented toward lumber and wood products, pulp and paper manufacturing, sports fishing, tourism, and recreation. However, the economy of Toledo itself is more oriented toward lumber and wood products and pulp and paper manufacturing than toward sports fishing, tourism, or other recreational activities. In fact Toledo boasts of itself as having the "industrial hub of the Central Oregon Coast." But more specifically, one of the first things to be noticed when entering Toledo, via Highway 20 from either the east or the west, is the large white plume being emitted from the 290 foot stack from the three recovery furnaces of Georgia-Pacific Corporation's (G. P.) pulp and paper mill. This, together with the company's plywood mill, offers continual year-around employment for approximately 1, 000 employees, and provides economic stability in a county characterized by seasonal fluctuations of employment. Several other mills in the area offer additional employment, but G. P. is the largest employer.

The kraft mill represents a 40[4] million dollar investment, and has a capacity of approximately 1, 000 tons of paper per day. It started operations in December of 1957. For the area of study (see

---

[3]Obtained from the records of the Lincoln County Assessor.

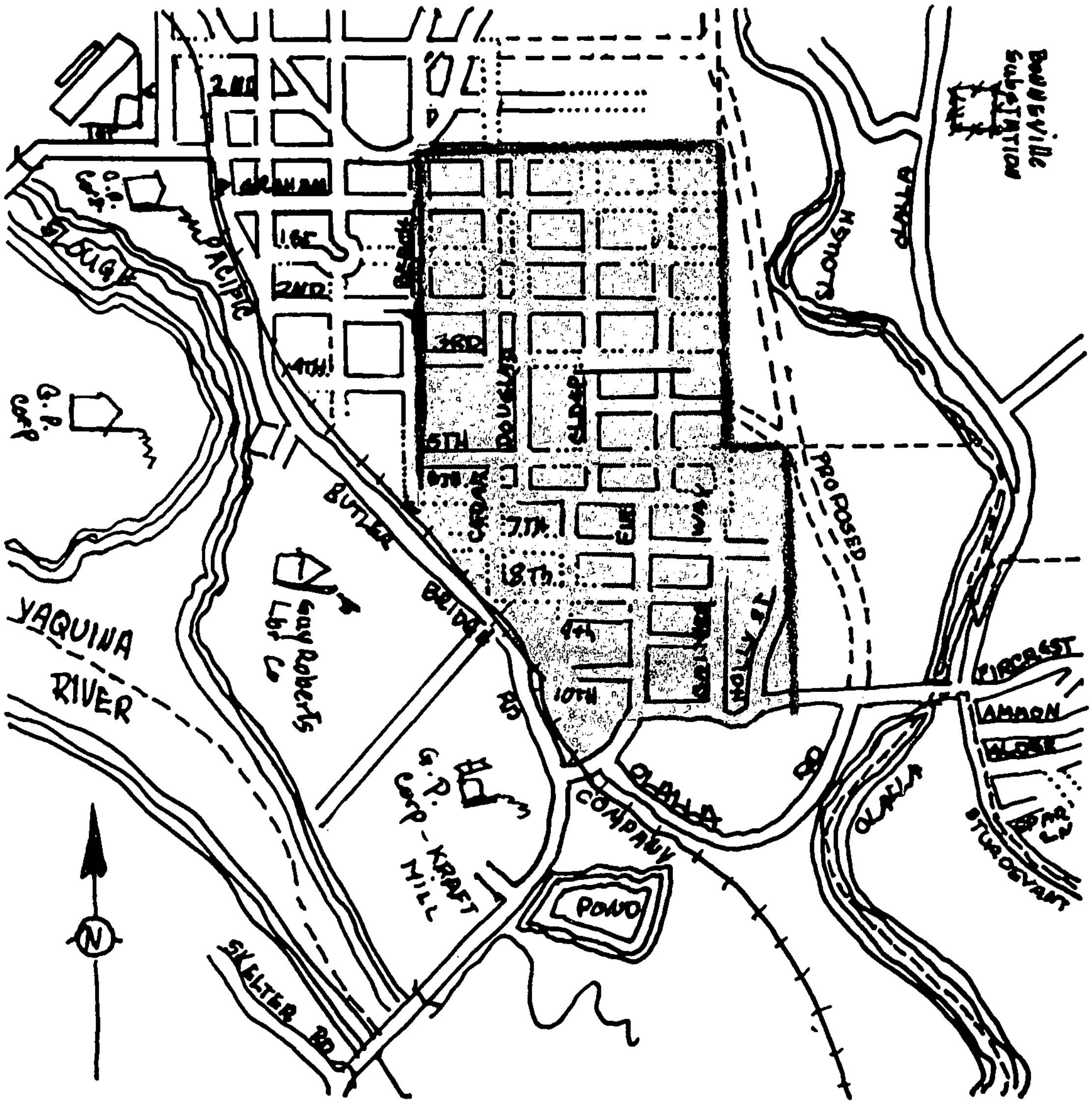
[4]Obtained from the Lincoln County Assessor.

the shaded area in Figure 4) the kraft mill represented the only major source of air pollutant emissions. The shaded area of Figure 4 was made up entirely of residential property with very little vacant, unimproved land.

The boundaries of the shaded area of study in Figure 4 were determined principally by the location of the air quality stations, since this was the major variable of interest. The boundaries were established specifically by the ease with which isopleth lines could be drawn as between the stations. These lines were then used to make isopleth maps in order to estimate the air quality for a given piece of property at the time of sale. The details of this procedure will be given in the next chapter.

The use of Toledo as a study area had the following favorable characteristics. First, the source of pollution for the area was principally from only one emitter. A second advantage was that the area consisted for the most part of single family, residential housing units. This led to the homogeneity of the study area. And third, the area was close to the campus of Oregon State University, and therefore transportation between the study area and the campus was easily facilitated.

The principal disadvantage of the study area had to do with the data obtainable. Because of the smallness of the study area much of the statistical information which would have existed for larger areas



TOLEDO
Lincoln County
Oregon

Scale: 1 in. = 953 ft.

Figure 4. The study area. (Map adapted from a map prepared by the Oregon State Highway Department.)

were not available. This would include income parameters, employment data, and retail sales for the town, among others.

Derivation of the Economic Model Used in Toledo, Oregon

The last chapter presented the development of a general economic model to explain property values. This section is more specific. Within it there will be given the economic model developed for Toledo, and the reasoning leading to such development.

Because of the nature of the study area, many of the variables which were mentioned in the last section of the last chapter were excluded in the final determination of the economic model to follow. The study area was within one taxing district. For this reason such things as school quality, the quality of other governmental services, and tax rates need not be included within the economic model. These items would be the same for the entire study area. The town was so small that crime rates were thought to be inconsequential. The compactness of Toledo, and the lack of any really major shopping district, made it unnecessary to include in the function variables measuring distances to the central area of shopping or to the major access route of Highway 20.

The six and one half years which the study covered would empirically have made it most difficult to obtain the number of persons per housing unit at the time of any given sale. As one will remember from the last chapter, this variable was a measure of the population density within a given area of study. However, it was felt that even if the variable could have been obtained it would have added nothing to the explanatory power of the economic model, or any resulting statistical model. Higher values of this variable would be associated with larger families, and consequently with more wear and tear upon the property. As will be seen in the discussion to follow, this is taken care of by the depreciation variable.

The number of houses per acre also was not included in the final economic model. As mentioned in the last chapter, this variable was a measure of crowding within a given area. Higher values of this variable would be associated with more people, noise, and congestion. As will be seen in the presentation to follow, this is taken care of by a variable measuring lot size.

Most of the residential area of Toledo, and all of the study area, is located upon a ridge of hills overlooking a small valley. This meant that the terrain upon which the study area is situated was fairly uniform throughout. Thus it was felt that nothing would be added to the explanatory power of the economic model by including a topographical index.

After careful examination of the characteristics of the town, and particularly the given area of study, the following economic model explaining residential property values was derived,

$$Y = f(X_1, X_2, X_3, X_4, X_5, X_6), \tag{3.1}$$

where Y = market price of the residential property.

X_1 = size of the house in square feet.

X_2 = size of the lot in acres.

X_3 = a measure of the depreciation of the housing unit (expressed quantitatively between 0.00 and 1.00)

X_4 = the number of bedrooms in the housing unit.

X_5 = quarterly, manufacturing payrolls in Lincoln County.

X_6 = a measure of air quality (expressed in dustfall, tons per square miles per month).

The economic implications behind the inclusion of each of the variables in the economic model (with the exception of X_5) have been discussed in the last chapter. Nothing would be gained by repeating it here. With respect to X_5, however, it was felt that there needed to be included within the model some measure of economic activity for the period of study. A higher level of economic activity within a given area would be indicative of more payrolls and jobs within the area. This would tend to attract people to the region, creating more demand for the property, which would tend to push it up in price. Expressing the variable quarterly would take account of the seasonal fluctuations in economic activity that the region might have.

Before proceeding to the next section and the statistical model, perhaps it would be best to discuss certain matters. It is often difficult in doing economic research to determine where economic theory ends and statistics begins. Reconciliation between what economic theory tells one to include in the model, and what statistically is desirable is often not easy. This is particularly true in the picking of and the expression of the variables to be used. In economic theory one would desire to include in the economic model as many variables as he feels will adequately explain residential property values. Statistically one would desire all the independent variables to be as important as the primary independent variable of interest, which in this study is air pollution. When this is done, it is reasonably likely that the primary variable will not prove to be significant only because it happened to be correlated with some more important variable that was left out (18, p. 120). It was with these desired requirements in mind that the economic model above, and the statistical models to follow were formed.

A final matter to be given attention before proceeding to a discussion of the statistical model is the type of analysis undertaken in this study, and why. This study made use of cross-section analysis and used property characteristics as explanatory variables within the economic and statistical models. The reasons were as follows: The only data available for the study area was property characteristics. Time-series analysis requires significant variation in the independent variables from one year to the next. Property characteristics would not give this type of variation. They would remain fairly constant from one year to the next at any given site. This situation, for one, suggested the use of cross-sectional analysis.

Another reason for the use of cross-sectional analysis comes out of the assumptions made in the last chapter. It was assumed that the market value of residential property was determined by the demand for the net benefits arising from the property to all potential buyers, and not the demand of the current owner-occupant. Within the residential property market, assuming the market works perfectly and that there is no discrimination, the determinents of the demand for the residential property (total income, distribution of income, family size) are assumed constant in cross-section data (18, p. 118). This study was interested in explaining the value of residential property available to the same class of potential buyers. To accomplish this, the study should be done in terms of differences in the characteristics of the property. In this study this was done. The next section is a discussion of the statistical models.

The Statistical Model

The considerations of the last section lead to the two regression models of the following form:

$$Y_1 = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5 + B_6X_6 + u, \quad (3.2)$$

and

$$Y_2 = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5 + B_6X_6 + u, \quad (3.3)$$

where Y_1 = market price of the residential property expressed as price per acre.

Y_2 = market price of the residential property.

u = a random error term, about which the usual statistical assumptions are made.

And where X_1 through X_6 are defined as in the economic model (3.1) given above.

Attention is now focused upon the dependent and independent variables included in the statistical models. The expected statistical relationship of the independent variables to the dependent variables will be given. The method of data collection, the inherent limitations of some of the independent variables, and some of the decisions made during their collection will be discussed.

Price of the Residential Property

This variable was expressed in two ways. Each separate expression then became the dependent variable of the two models given in 3. 2 and 3. 3 above. As a rule, the value of a residential lot may be expressed without explicit reference to any units of measurement, as was done with Y_2. When units of measurement are to be considered explicitly, as they are with Y_1, these units may be expressed in either terms of frontage in feet, or an areal unit such as square feet or acreage.

The advantage of having the dependent variable expressed on a per acre basis, and consequently the use to which the separate model given in 3. 2 will be put, is that one can vary one of the variables (the air pollution one for example), holding the others constant, and observe associated changes in the dependent variable. These changes then may be extropolated quite easily to the entire study area, or for any segment thereof. This also could be done if the dependent variable was expressed without reference to areal measurement. That is, if one varied one of the independent variables in 3. 3 he would get associated changes in the value of the lot without reference to areal measurement. However, the use of 3. 3 for extropolation to the entire study area would be more difficult than a similar use of 3. 2. The use of 3. 2 requires only that the total acreage within the study area be calculated. This is a fairly easy task when compared with the method of extropolation that would have to be used with 3. 3. Here to extropolate to the entire study area would require one to obtain the total number of separate units of property within the study area. A more detailed discussion of the uses of these models will be given in Chapter VI.

The boundaries of the study area, from which property sales were taken, were more or less determined by the location of the dustfall stations maintained by the Oregon State Sanitary Authority. The location of these stations may be seen in Figure 5 on page 59 (Stations 5, 6, and 8). The area of study is shaded in Figure 5. To expedite matters in the beginning, the boundaries of the study area were established by drawing circles one quarter mile in radius about Stations 5, 6, and 8. The basic assumption in the use of this method was that each station was very roughly indicative of conditions over an area of this size (12, p. 2-41). Later, isopleth maps were developed for the area to estimate dustfall at any location.

All market sales in the study area were determined by reviewing the warranty deed abstracts and contracts as kept by a title insurance company in Newport, Oregon, the county seat of Lincoln County. One of the first questions that had to be answered was whether to take a complete enumeration of all sales within the area, or set up some sampling scheme. It soon became evident that land sales in the area were not of a sufficiently large number. Thus a complete enumeration of all sales in the area was made. By the time some of the sales were eliminated, for various reasons given below, there were in the end 98 observations out of total market transactions of 118.

The price of each transaction was inferred from the amount of the internal revenue stamps, which by law then had to be affixed to the deed. These stamps were sold only for the amount of cash involved in each transaction. If the cash involved represented a down payment upon the property, and a mortgage was given for the remainder of the purchase price, then this was accounted for by adding the mortgage to the cash down payment. Contract sales were included at the contract price.

Since the study concerned itself only with the residential property, market sales of vacant lots (of which there were 11) were excluded. Also excluded were sales between relatives and estate sales, unless such sales (based upon prior sales of the property) occurred at a reasonable market price. Sales also had to be excluded where no internal revenue stamps appeared upon the deed. Without the internal revenue stamps it was almost impossible to infer the purchase price of the property, unless, as in some rare instances it was, such information was recorded on the property tax records maintained for the property. Usually the stamps would not be affixed to the deed for two reasons: One was that they were not purchased, which was a violation of federal law. Another reason was that they would not be affixed to the deed until after the deed was recorded. The explanation for this would be the desire of the buyer and seller not to have the purchase price of the property known. This was the biggest problem in collection of land sales for Toledo, and thus caused many of the sales to be discarded.

In the title insurance company office the deed abstracts were grouped together by the names of the subdivisions in the study area. The properties not located in a subdivision were assigned arbitrary numbers by the company to facilitate in their location. From the deed abstract the property's locational description was obtained. The locational description was used to locate the property upon section maps obtained from the county assessor. Each piece of property for property tax purposes had a tax code, or account number, imprinted upon the maps. Once the property was located upon the map one had the tax code, which was then used to obtain the property tax records for each piece of property sold. From these records were obtained the property characteristics described in the last section: size of the house, lot size, depreciation of the housing unit, and number of bedrooms.

Size of the House

This is a housing unit characteristic and was expressed in square feet. This variable measures only the number of square feet in the base of the house. No provision was made to include the additional living space that might have been obtainable from an upstairs or basement. Reasons for this approach are given below. Statistically this variable was expected to have a positive relationship with the price of the property.

A decision which had to be made at the time the data for this variable was collected was with respect to the amount of square feet to include for each housing unit. The main reason for failure to include the additional amount of living space that an upper story or basement might have provided was the manner in which the data was presented upon the tax, or appraisal, cards. While provisions were made upon the cards to include an "attic or upper stories," there were in many instances no attempts made to state the square feet existing within the unit. This was particularly true when appraisal had to be done without admittance to the home for actual interior inspection. It could not be determined from the cards whether an upper story was a full upper story, half upper story, or what. Since the assessor used the number of square feet in the base of the structure in estimating the value of the house in most instances, then it seemed best to do likewise for this study. Almost all of the dwellings within the sample area were of one story. To the extent that on a few sales the square feet in the house could have been understated, it was felt nothing would have been added to the study by subjectively estimating the area contained in the upper story or basement. This would be particularly true when the characteristics and uses of the upper story or basement could not have been determined.

Lot Size

This variable was expressed in acreage, and included the total amount of land in each sales transaction. The variable was introduced as a specific property characteristic. The basic assumption for its inclusion was that a larger tract of land provides more utility to the potential users of the land. As was pointed out in the last chapter, a smaller lot can be suggestive of crowding not only for the owner-occupants upon the given lot, but also for the neighborhood as a whole. Therefore, it was thought that the lot size should have a positive relationship with property values.

Depreciation of the Housing Unit

This variable was inserted specifically as a housing characteristic. It was an estimate by the county assessor to express in a quantified form the condition of the dwelling with respect to physical depreciation and functional obsolescence. Physical depreciation and functional obsolescence are treated together upon the appraisal cards, and are expressed as "percent good" instead of the "depreciation of the housing unit" as the variable has been labeled here.

Physical depreciation in the appraisal sense is referred to as the actual wearing out of the structure due to use. Physical depreciation, or physical deterioration as it is also called, can be measured in most instances by estimating the costs of restoration and repairs (16, p. 113).

Functional obsolescence is referred to as the inadequacy of design, architecture, and layout of the structure. Some examples of functional obsolescence would include inadequate plumbing for the number of bedrooms (one bath in a four bedroom house), and an inadequate heating plant. Functional obsolescence can be measured by estimating the cost required to correct the situation (16, p. 113).

The variable was expressed within the models between 0.00 and 1.00. The higher the number the better the condition of the dwelling. For example, if the number inserted for this variable for a given observation was 0.99, then for all intents and purposes the dwelling would be in almost perfect condition. This variable was expected to have a positive relationship to the dependent variable.

Number of Bedrooms

This variable was included as a measure of a characteristic of the housing unit. The model already has one variable specific to the housing unit (the amount of square feet in the house). However, the model did not have a variable specifying the structional arrangement of the housing unit. To be more specific: A housing unit quite large in square feet, but containing say only two bedrooms would in many instances be of less value than a comparable house with three bedrooms. This variable was expected to have a positive relationship to the dependent variable.

Before ending the sub-sections pertaining to the discussion of the property characteristics included in the statistical models, perhaps it would be best to detail some of the decisions that had to be made concerning these variables. State law requires that all property be re-assessed by the counties in which it is located every six years.

The area of study was re-appraised in 1960 to 1961, and again in 1966. Prior to 1960 accurate assessment records were not maintained. In most instances, this gave two sets of property characteristics to work with for each observation. A decision had to be made as to which of the two sets of characteristics were to be used for a given observation. That is, property characteristics could change between the years of re-appraisal. A decision had to be made as to when to shift from the property characteristics contained on the 1960-1961 appraisal cards to the data contained on the 1966 cards. The decision was made more or less arbitrarily. In those instances where a change had occurred in a property characteristic, and the property had been re-appraised for it, the newer appraisal card was used. In those instances in which this was not done, or in those cases where the only change in property characteristics from one appraisal date to the next was in the depreciation factor, then the end of 1963 was determined as the breaking point. That is, sales in 1961, 1962, and 1963 had attached to them the property characteristics existing upon the 1960-1961 appraisal cards. Sales in 1964, 1965, 1966, and 1967 had attached to them the property characteristics existing upon the 1966 appraisal cards. The end of 1963 was chosen as the breaking point, because this was the mid-point between the two appraisal years.

Quarterly Manufacturing Payroll

This variable is a measure of the total manufacturing payroll for Lincoln County expressed quarterly. The variable was included in the economic model as a measure of economic activity in the area. Statistically the variable would also act as a time trend variable, explaining some of the variations in property values which were due to time alone and would not as a result be accounted for in the other variables. This variable was expected to have a positive relationship to the dependent variable.

It was felt, quite early in the study, that all the variation in residential property value in the study area could not be explained using the property characteristics discussed above as explanatory variables. Because of the length of time the study covered, some variation would be due to time itself. It was thought that one way to attempt to account for this statistically would be to have a measure of economic activity within Toledo. (The economic reasons for inclusion of this variable were discussed in the last section.) Total payroll for Toledo was initially desired for this purpose, but it was not available. However, payroll data was available for Lincoln County from the Oregon State Department of Employment.[5] The question which had to be answered of course was how could the county data be made more closely representative to the Toledo conditions. From the 1960 federal census it was obtained that approximately 55 percent of Toledo's work force was employed in manufacturing (19, p. 138). From the State Department of Employment there was obtained the total manufacturing payroll for Lincoln County,[6] and this was used as a proxy for conditions in Toledo. Quarterly data was used to take into account seasonal fluctuations that might occur within a given year, or from year to year.

Air Quality

This was the variable of principal interest, and it was expected to be negatively related to residential property values. A detailed discussion of the collection, limitation, modification, and statistical preparation of this variable for inclusion in the final regression models will be given in Chapter IV.

---

[5] A state law prohibits the Department of Employment from letting any private individual or group use its records, even in aggregate form, to determine the employment characteristics of any given geographical area. This law prohibited the obtaining the payroll data for Toledo.

[6] This information was obtained from their quarterly publication: Oregon Covered Employment and Payrolls of Industry and County. This publication was prepared by the Research and Statistics Division of the Department of Employment. The study used the quarterly data inclusive from June 30, 1961 through December 31, 1967.

IV. AIR QUALITY ANALYSIS

Introduction

The first section of this chapter will discuss the methods of expressing the air quality variable within the regression models. The assumptions behind these methods of expression will be given. The way in which the data for the air quality variable was obtained, and the problems encountered in obtaining it will be presented. The second section will be a brief discussion of the actual method of dustfall collection. This will be followed in the third section by a presentation of some of the limitations inherent in using dustfall (particulate fallout) as an indicator of air quality. The chapter will be concluded with the fourth section in which there will be a detailed presentation of the preparation of the dustfall data for inclusion within the regression models.

Air Quality

As stated at the close of the last chapter, the air quality variable was the variable of principal interest in this study. It was expected to be negatively related to property values. For use in the regression models, the variable was expressed in two ways: One method of expression was the simple average of dustfall for the month of sale and the two months preceding the month of sale. This was expressed in units of tons per square mile per month. The reason for using the three month period was an effort to take into account how a potential buyer would utilize information as it relates to actual conditions. As it was stated in Chapter II, whether potential buyers and sellers are aware of the consequences of air pollution is immaterial. All they must know is that the effects exist, not what specifically causes them. The basic assumption of this approach was that which has happened in the more recent past will be reflected in a person's actions more than that which has happened some time ago. The second method of expressing the variable was a weighted average of dustfall for the three month period in tons per square mile per month. The month of sale was weighted by a factor of three. The two months prior to the sale were weighted by two and one, respectively. The reasons for using the weighted average were the same as those given for the first method of expression.

The collection of the air quality data, of all the data collected, took the most time, was the most difficult to obtain, and was the hardest to adequately develop for use in the statistical model. The air quality data for the most part was obtained from the Oregon State Sanitary Authority.

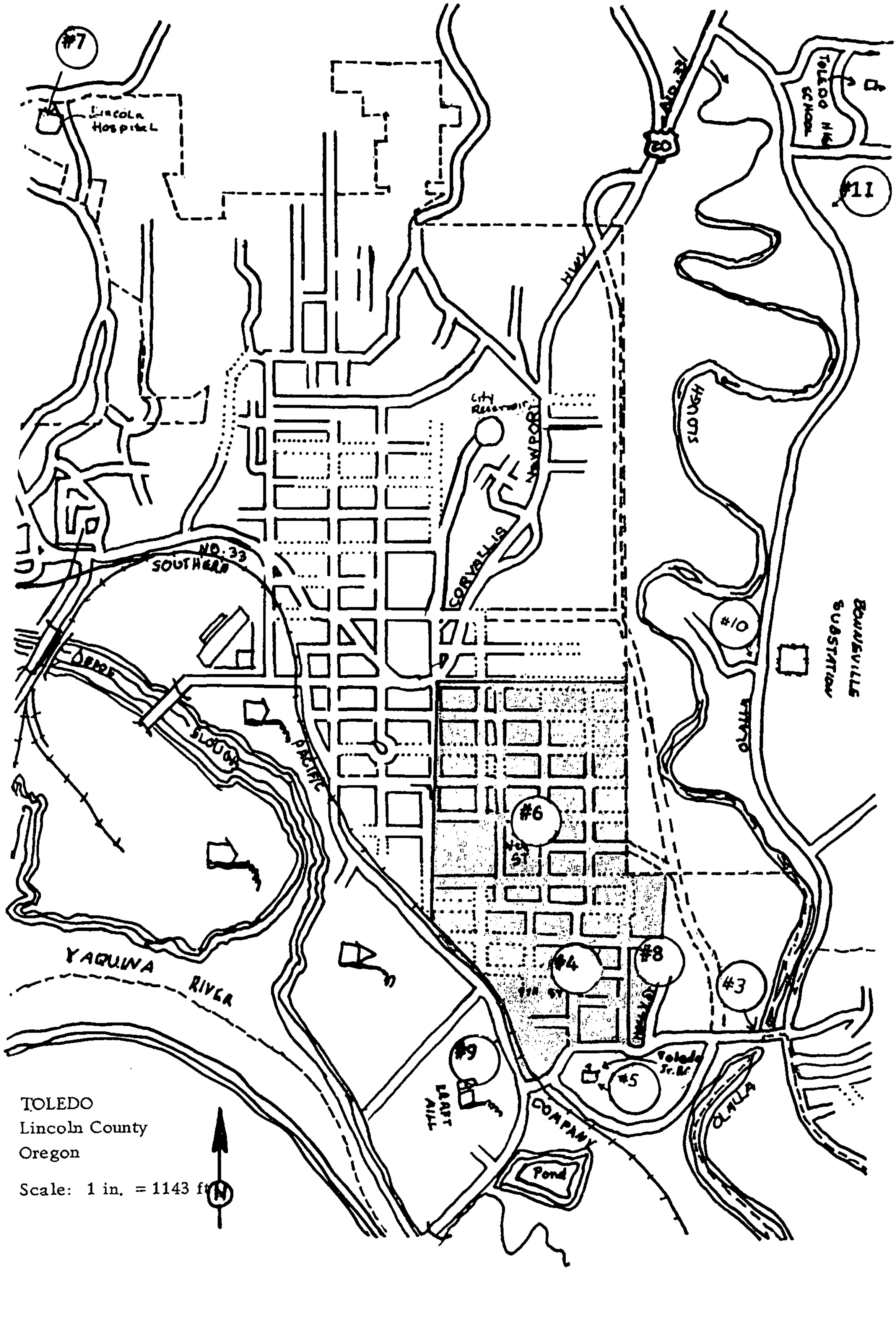
The only air quality data which the Oregon State Sanitary Authority had of a continuous nature for Toledo was dustfall. While other methods of air quality measurement had been run within the

Toledo area, they were of such a sporadic nature as to be useless for utilization within this study. The Oregon State Sanitary Authority had four dustfall stations in operation in Toledo. They were Stations 5, 6, 7,[7] and 8, and their approximate locations are shown in Figure 5.[8] The stations served three essential purposes in this study. They gave the only continuous measurement of air quality within the area. Their location established the boundaries from within which the property sales were to be taken. The dates of their continuous operation established the period of time over which the study would be conducted (June 1, 1961 to December 31, 1967). All of the stations were in continuous operation for the period of study, with the exception of Station 8 which began operation in January of 1965. It is obvious that the more stations there are the better the estimate of existing air quality on a piece of property at the time of sale. Statistical methods had to be employed to estimate monthly dustfall data for Station 8 back through

---

[7]Station 7 is used by the Oregon State Sanitary Authority as a background station. A background station is used to estimate what the level of dustfall would be in a given area in the absence of industrial or other unnatural contamination.

[8]The approximate locations of all dustfall stations were determined by the visual location of the station upon the property where possible. Where visual observation was not possible, then addresses had to be relied upon. In some cases no exact address could be given, and the station's location was described by a landmark or structure known to local residents. In these cases their knowledge was sought in locating the stations.



TOLEDO
Lincoln County
Oregon

Scale: 1 in. = 1143 ft.

April of 1961. The methods undertaken to do this will be discussed within the last section of this chapter.

In concluding this section let it be said that it was initially thought the only air quality data available was that obtainable from the Oregon State Sanitary Authority. Looking at Figure 5 one will see the shaded study area, and located within and without the study area are other dustfall stations besides those of the Oregon State Sanitary Authority. These other dustfall stations are labeled as Stations 3, 4, 9, 10, and 11. Where did they come from? Data was missing from Station 8, and an attempt had to be made to formulate a regression model to estimate the missing data. It was desired to include in such a model, as one of the explanatory variables, meteorlogical data. Specifically what was desired was prevailing wind direction which plays an important role in the amount of dustfall being deposited in a given area. It was in a search for such data, which for the Toledo area was found not to be available for a continuous period of time, that these additional stations maintained by Georgia-Pacific were learned of. The monthly records kept on the stations were finally obtained from the evidence of a tried civil complaint case in the Circuit Court of Lincoln County.[9] The finding of this data gave more stations

---

[9] Vernie Hansen, executrix for the estate of Ross N. McElwain and Edith McElwain vs. Georgia Pacific, a corporation. (Case no. 23257.) Judgement handed down August 9, 1968.

in and around the study area with which to work.

Method of Dustfall Collection and Analysis

For quite some time dustfall, or particulate fallout, has been used as an indicator of air quality in the United States. Dustfall is one of the more easily measured pollutants. In essence it is a measure of the amount of material that settles out of the air and is entrapped in a collecting container. The specific intent of this measure then

> . . . is to describe the mass rate of fall of particulate matter under the conditions of each test. It measures the quantity of material which will settle on horizontal surfaces, and consequently is useful in describing one phase of community dirt--that material which must be swept from porches, steps, automobiles or other unsheltered locations (9, p. 375).

As far as is known there have been no studies conducted which attempt to correlate particulate emissions and hydrogen sulfide, and other odorous gases being emitted from kraft mills. The recovery furnace of a kraft mill is the largest single source of particulate emissions. Hydrogen sulfide and other odorous gases emit from many points within the production process including the recovery furnace. The recovery furnace is one of the most expensive pieces of equipment in the mill process line. It is usually the last unit to be expanded, because expansion means the installation of a new unit. Therefore, to increase production the furnace is often operated outside its designed capacity, leading to an increase in the emissions of hydrogen sulfide and other odorous gases (8, p. 31). To the extent that such operations are beyond the designed capacity of the recovery furnace and exceed the designed operating efficiency of the air pollution control equipment attached to the furnace, then it is possible that increased particulate emissions could also result and contribute to the particulate fallout within the affected area.

In Oregon dustfall samples are usually collected in polyethylene type sample containers. This type of jar will be required in the future according to proposed changes put out by the Oregon State Sanitary Authority (17, p. 3), but during the period of this study other non-reactive material could have been used, such as glass and stainless steel (14, p. 1). As far as is known, however, only polyethylene containers were used for dustfall collection in Toledo.

The sampling container is usually exposed at a desired location for a period of 30 days with the watertight cover removed. Allowance of plus or minus two days is permitted in the setting out and, or collecting the sample jars. The Oregon State Sanitary Authority's standards provided that distilled water may be added as a collection solution. Isopropyl alcohol may be used as antifreeze where necessary, and algacide (Dowicide B) may be added when needed. At the end of the sampling period, the watertight lid is replaced upon the jar. The sample is then analyzed in accordance with the Oregon

State Sanitary Authority's procedures (14, p. 2-4), which are similar to the American Society for Testing and Materials' procedures (2). Total particulate weight and volatile and non-volatile solids were determined gravimetrically (measured by weight). Analysis for specific ions were usually performed, particularly with respect to calcium, chloride, and sulfate. Such analysis can be used to trace the source of the fallout. That is, kraft mills emit calcium, chloride, and sulfate compounds. An increase in these ions, above normal background level, could be indicative of the source of the increased pollution. All units of measurement were expressed in tons per square mile per month.

Regarding the stations maintained by Georgia-Pacific, the period of exposure, or sample period, was the same as the Oregon State Sanitary Authority's stations with respect to the number of days. Laboratory analysis followed the directives put out by the National Council for Stream Improvement. Chemical analysis of the sample for specific ions included obtaining calcium, chloride, and sulfate. Results were expressed in tons per square mile per month. It did not seem to make any difference to either party (the Oregon State Sanitary Authority or Georgia-Pacific) that the laboratory procedures used by Georgia-Pacific might have been different from those used by the Oregon State Sanitary Authority. Both considered their results comparable to each other, and thus this study did likewise.

With respect to the selection of the sampling site there are several specific rules. In general it is recommended that the sampling site have a free exposure such that the sampling jar will collect the sample by gravity settling only. The site should be selected in such a way as to eliminate any undue contamination caused by local sources. It should be free from interferences caused by adjacent walls, structures, or other higher objects. Accessibility to the station is desirable, but freedom from tampering is even more important.[10]

Data Limitations in Using Particulate Fallout as an Indicator of Air Quality

The measurement of particulate fallout is subjected to many possible errors, not only in the collection and laboratory analysis, but also in the interpretation of the results. There are many things which may influence particulate fallout. These would include such things as the rate of emission from any given source, wind direction and speed, precipitation, thermal air currents, air eddies produced by the terrain or construction in the vicinity, and other conditions (9, p. 372).

---

[10] If one should desire a more detailed discussion of any of the items presented above, then he should consult the following citations in the bibliography: (14, p. 1-4) and (9, p. 372-7).

Most of the material collected in the dustfall container is larger than 20 to 40 microns in diameter. Anything above ten microns in diameter will usually settle out of the air rapidly. Therefore, one can usually expect that the sample results will be indicative of the scale of industrial and domestic activity in a given area, based on the combustion of fuel and processes involving coarse dust emissions. Thus a comparison over a period of time of certain stations at given locations can be indicative of the success or failure of pollution abatement activities directed at reducing excessive emissions. However, dustfall results reported from other areas of the United States are not comparable to fallout results reported from Oregon stations. The reasons for this are two fold: Particle fallout varies as between areas, and Oregon's particulate fallout appears to be bigger than that found in other parts of the nation. So big in fact that much of it fails to pass through a 20 mesh screen (3, p. 4). Most methods of analysis (American Society for Testing and Materials (2) and the Air Pollution Control Association (9)), except Oregon's, require as the first step that the sample solution be strained through a 20 mesh screen. Thus, secondly, the methods of analysis for Oregon are based largely on observations and experience in the state.

Particulate fallout results will not serve as a measure of the total dust content existing in the air, and as such cannot describe the general atmospheric particulate loading within a community.

However, the three measures of particulates--suspended particulate, particulate fallout, and soiling index--are closely interrelated. Thus it can be expected that if one is reduced, the others will also (20, p. 9). That is, a greater or lesser loading of the atmosphere will be reflected in a correspondingly greater or lesser particulate fallout.

Georgia-Pacific and the Oregon State Sanitary Authority had different starting and stopping dates for their sampling periods. That is, all the stations maintained by the Oregon State Sanitary Authority started on one day, and all the stations maintained by Georgia Pacific would start on a different day. Sample periods for both network of stations were more or less 30 days. Statistically the difference in starting dates and stopping dates for the sample periods were not corrected for in the use of the stations. The reason was as follows: particulate fallout cannot be determined for any one day of the sampling period. In essence the results obtained give the total dustfall for a 30 day period. On any one of these days most of the dustfall could have fallen with little falling on the remaining days.

Before concluding this present section, perhaps some word should be given with respect to the specific effects of pollution from kraft mills. The potential effects of pollution emissions from kraft mills are numerous. However, in many instances very little is known about such effects, or the occurrences are too few to be conclusive. The effects of particulate fallout are mostly physical or chemical in nature. With respect to human health, particles of larger than ten microns in size are practically all removed in the nasal passages. It has already been stated that most particulate fallout is in the 20 to 40 micron size range. Thus particulate fallout in itself could not be classified as a health hazard. However, it might be indicative of other contaminants which might cause harm. For example, increased dust-fall could be indicative of increased suspended particulate smaller than two or three microns which can penetrate deep into the lungs and cause damage.

It is generally concluded that health hazards from concentrations of gases found within an area of kraft operations is not of significant consequences (1, p. 69). However, most people would agree that hydrogen sulfide, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide all have an unpleasant odor, and tend to "red-flag" most kraft mills.

Within the near vicinity of kraft mills it is not uncommon to hear of complaints about the fallout from the recovery furnaces and lime kilns. Vegetation damage has been attributed to fallout and sulfur dioxide. (Vegetational damage is evident in Toledo.) Particulate matter can be an important factor in the corrosion of metals and damage to other materials (8, p. 2). Damage to structural materials and painted surfaces have been reported from saltcake, lime dust, and various sulfur containing gases. The employees' car washing operation that can be seen at most mills is enough to attest to managements' awareness of the problem. Also, lead base paint may be blackened in the presence of sufficient concentrations of hydrogen sulfide under specific conditions.

In conclusion, most of the particulate emissions into the air from kraft mills do no more damage than contribute to the general dirtiness of the surrounding area. Most of the larger particulate matter settles near the plant site, while the smaller particles may be carried for several miles. If these finer particles remain suspended in the air, they contribute to visability interference, sky darkening, and may help to carry odors longer distances.

The Preparation of the Dustfall Data for Inclusion in the Regression Model

Attention is again focused upon the data obtained from the stations maintained by Georgia-Pacific. Data on some of the stations were obtained from September of 1961 through December of 1967. By the end of December of 1967 Georgia-Pacific was in maintenance of 13 stations. However, the data obtained did not have all 13 stations back to 1961. During the period 1961 to 1967 some stations were added, the location of some were changed, and some were deleted.

While there was data on some of the stations going back to 1961, only the data for 1965, 1966, and 1967 could be used. The reason for this was as follows: In approximately May of 1966 Georgia-Pacific discovered that it had made an error in the calculation of its data. The data for all these stations are turned over to the Oregon State Sanitary Authority. Georgia-Pacific issued a summary sheet to them with correct calculations for the years 1965 and part of 1966. Nothing was said about the 1961 through 1964 data. Was it in error also? An attempt was made to find out. Several experts[11] tried to reconcile the wrong 1965 data to the correct 1965 data in order to check the 1961 to 1964 data, and to correct it if needed. There were substantial variations of over 100 tons per square miles per month, high and low, as between the corrected and incorrect data. Thus rather than run the risk of using wrong data, the 1961 to 1964 data was discarded. Only the Oregon State Sanitary Authority's stations were used in estimating dustfall in this period. Of the 13 stations available from Georgia-Pacific's network of dustfall stations, five (Stations 3, 4, 9, 10, and 11 in Figure 5) were selected for two reasons. There was a minimization of missing data due to vandalism, storm damage, or loss of the sampling report in the court records. Missing data from these selected stations was only seven out of 180 observations for the three years. The missing data for these stations

---

[11] In this particular situation the aid of Dr. Richard W. Boubel, Professor of Mechanical Engineering at Oregon State University, was sought. He in turn sought the aid of the National Council for Stream Improvement.

was estimated by taking the yearly average of the dustfall at that station and substituting that figure for the missing month. If the yearly average appeared out of line (too high or too low) with other stations, whose monthly observations were available for the given month, then the average of the dustfall for the month prior and the month subsequent to the missing month for the given station was used. These stations were also picked because of their location, and the ease with which they could be used in the drawing of the isopleth maps.

Leaving the Georgia-Pacific stations for the moment, attention is now focused upon the methods used in estimating the missing data for the Oregon State Sanitary Authority's stations. In brief, Station 8 had to be estimated from December of 1964 back through April of 1961. Station 7 had to be estimated for April, May, June, and July of 1961.

How was this to be done? What additional information was needed to do this? It was mentioned in the last section how weather may affect dustfall and dustfall distribution. In the setting up of a model to estimate the missing data, it was deemed desirable to try to take the conditions of weather into account as variables. In this respect it was particularly desirable to take into account wind direction and velocity for each month of observation. The data desired was not available. It was not available at the airport; the Coast

Guard kept observations for only two years; the Oregon State Department of Forestry kept such observations only for the fire season; the Oregon State University Marine Center was just getting started in the keeping of such records. Failure to obtain data at these sources resulted in turning to Salem, where daily weather observations for that area were kept back through 1960. It was thought by one expert[12] that while hourly or daily wind direction might vary considerably in Salem from that which might be observed in Toledo, the average quadrangular monthly wind direction in Salem would not be materially different from possible observations in Toledo. An attempt was made to try and determine a relationship between the quadrant in which the prevailing wind direction for any given month was blowing, and the level of dustfall for Stations 5, 6, and 8 taken together. An attempt was also made to do the same thing as between the four seasons of the three year period as well. A relationship was not found. If there had existed such a relationship, however, a statistical model might have been developed using Stations 5 and 6, wind direction, and velocity to predict Station 8.

With the failure to obtain the meteorlogical data, it soon

---

[12] With respect to the use of meteorlogical data in the attempt to form a statistical model to estimate the missing station, and later in the drawing of the isopleth maps, the aid of Dr. William P. Lowry, Assistant Professor of Biometeorology at Oregon State University, was sought.

became evident that a statistical model would have to be formed with the data available. Attempts to do this were very experimental and involved much trial and error. It was quite obvious that the Georgia-Pacific data, which was good only from 1965 to 1967, could not be used to estimate the missing data of 1961 to 1964. Thus about the only thing that could be done was to regress Station 8, the station having the missing data for 1961 to 1964, on Stations 5 and 6.

The first question which had to be answered was what model to use. There was nothing to suggest that anything but a linear model should be used. Thus initially a model of the following general form was used,

$$Y = B_0 + B_1X_1 + B_2X_2 + u \qquad (4.1)$$

where Y = dustfall of Station 8 in tons per square mile per month.

X_1 = dustfall of Station 5 in tons per square mile per month.

X_2 = dustfall of Station 6 in tons per square mile per month.

u = random error term, about which the usual statistical assumptions are made.

A stepwise regression procedure was used. Actual dustfall from all three stations for the period 1965, 1966, and 1967 was used to compute 4.1. If one or more of the observations from any of the stations were missing for any month within this period, then that month would be discarded as an observation. This resulted in 30 usable months as observations out of a total possible 36 months for 4.1. Stations 5 and 6 were chosen for inclusion in this model as independent variables, because they were in the immediate vicinity of Station 8.

The results of this model were as follows:

$$Y = 17.4847 + \underset{(.0642)}{.1310X_1} + \underset{(.0534)}{.0560X_2} \tag{4.2}$$

The standard error of the coefficients are shown in parentheses. The coefficient of X_1 was significantly different from zero at the ten percent level. The coefficient of X_2 was significant from zero at the 40 percent level. The multiple correlation coefficient (R^2) was 0.2425. The conclusion derived from this model was that there was still much variation to be explained.

Several graphical plots of the residuals were made to see if the form of the model itself was adequate. These included plotting the residuals against the predicted values of the dependent variable, the plotting of the residuals against the independent variables, and the plotting of the residuals in a time sequence plot (6, p. 86-92). In all cases there was nothing to indicate that the form of expressing the model was in any manner inadequate.

Some additional plots were tried to see if any relationship or additional ideas could be obtained. These plottings consisted of plotting the dependent variables, and the independent variables against each other. This led to use of dummy variables (plus one if the actual observation from the dustfall station was greater than a reference level, and minus one if it was equal to or less than the reference level, with the latter value being changed for each of several regression runs), and cross-product terms within the model.[13] However, this too proved to be unsatisfactory, because of the limitations which the use of the dummy variables put upon the values that the dependent variable could take.

Having failed in the attempt to obtain a satisfactory prediction model for Station 8 using the methods discussed above, there was no choice but to go back to the use of 4.1. Up to now Station 7 had not been used within the model, because it was located some distance from Station 8. The only other step left was to expand 4.1 to include Station 7 as an explanatory variable, and see if the results for the model improved. The expanded model is shown as follows:

$$Y = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + u \qquad (4.3)$$

where X_3 = dustfall of Station 7 in tons per square mile per month.

And where Y, X_1, X_2, and u are as defined in 4.1.

---

[13] The model was of the form: $Y = B_0 + B_1X_1 + B_2X_2 + B_3X_1X_2 + u$, where the variables were as defined in 4.1.

The results of this model were as follows:

$$Y = 13.6397 + \underset{(.0669)}{.1746X_1} + \underset{(.0561)}{.0183X_2} + \underset{(.2055)}{.3836X_3} \qquad (4.4)$$

The standard error of the coefficients are shown in parentheses as they will be in all models to follow. The coefficient of X_1 was significantly different from zero at the two percent level. The coefficient of X_2 was not significant. The coefficient of X_3 was significantly different from zero at ten percent. Again actual dustfall data was used in computing 4.4 as it was in the rest of the models to follow. There were 30 usable months of observations out of a total possible 36 months. The multiple correlation coefficient was 0.3316.

It was apparent that given the data available, 4.4 was the best prediction equation for Station 8 that could be obtained. Thus 4.4 became the final prediction equation for the missing observations of Station 8.

A third model was developed to estimate tons of dustfall for those months for which data from Station 5 was missing. A model of the general form of 4.3 was used with the following changes: X_1 instead of Y was regressed on X_2 and X_3. The variables remained as defined in 4.3. The results of the model were as follows:

$$X_1 = 23.3904 + \underset{(.0707)}{.4127X_2} + \underset{(.3085)}{-.3900X_3} \quad (4.5)$$

The coefficient of X_2 was significant from zero at one percent, and X_3 was significant from zero at 30 percent. The model was computed from 74 monthly observations for the three stations out of the total possible 83.[14] The model was used to estimate seven missing observations for the period of April 1961 through December 1967. The R^2 was 0.3272.

A fourth model was developed to estimate tons of dustfall for the observations of Station 6 that were missing. The basic model was the same as that used in 4.5 with the following exception: X_2 was regressed on X_1 and X_3. The definitions of the variables again remained unchanged. The results of the model were as follows:

$$X_2 = 7.5051 + \underset{(.1346)}{.7863X_1} + \underset{(.4242)}{.6228X_3} \quad (4.6)$$

The coefficient of X_1 was significant from zero at one percent; X_2's coefficient was significant from zero at 20 percent. Again 74 actual observations were used in the computation of the equation. This equation was used to estimate two missing observations for Station 6 for the period April 1961 to December 1967. The R^2 was

---

[14] Air quality data through June of 1968 was used in computing 4.5, and in 4.6 and 4.7 to follow.

0.3323.

A fifth and final model was developed to estimate tons of dustfall for the missing observations of Station 7. Again everything was the same as in 4.3 and 4.5 except X_3 was regressed on X_1 and X_2. The results were as follows:

$$X_3 = 10.4773 + -.0564X_1 + .0473X_2 \qquad (4.7)$$
$$(.0446) \qquad (.0322)$$

The coefficient of X_1 was significant from zero at 30 percent, and the coefficient of X_2 was significant from zero at 20 percent. Seventy-four actual observations were used in the computation of 4.7. The model was used to estimate eight missing observations for Station 7 from April 1961 through December 1967. The R^2 was 0.3325.

The general conclusion that may be reached concerning the above equations (4.4 through 4.7) is that there is a lot of variation that the models are not taking account of. However, with the data available these equations were the best that could be devised.

The next step was to devise a method of estimating the dustfall on each piece of property for the month of sale, and the two months prior to the sale. Of course it would have been ideal had there been a dustfall bucket located on each observation. But there was not. There were eight dustfall stations for the period of 1965 to 1967 and three stations for the 1961 to 1964 period which could be worked with. One method of estimating dustfall upon a given observation which could have been used (and was in certain instances), would have been the weighting of each observation by its distance from each dustfall station. The station nearest the observation would be given the greatest weight. The biggest advantage of this method was its simplicity. The biggest disadvantage of the method was that there were limits placed on the dustfall value any piece of property could take. These limits would be set by the high and low dustfall values of any two stations of the group of stations used. As a result this gave some very unusual predictions at times.

The other alternative, which was predominately used in this study, was the making of isopleth overlays, and using these to estimate dustfall for an observation at some points in time. The method of constructing these was as follows: Straight lines (axes) were drawn connecting any two stations together, say Station A and B. The amount of distance between A and B in inches upon a sectional map was measured, and then divided into the difference in dustfall between A and B. This rate of change was then plotted upon the axis. This was done for all stations. Connecting lines between equal amounts of dustfall on each of theaxes were drawn. The resulting product was called an isopleth overlay. Isopleth overlays were constructed for each month of the study period. The basic assumption of this method was that the rate of change of tonnage was constant along any one axis. In reality of course this was not true. But the assumption had to be made to devise a method of measuring dustfall.

The estimation of dustfall upon a piece of property was done by placing the isopleth overlay upon a sectional map and using the connecting lines to estimate the dustfall. Where possible the isopleth lines were rigorously adhered to in estimating dustfall. In the few cases where they could not be adhered to,[15] the weighting formula described above was used. The results obtained from these methods were then used in the main statistical models given in Chapter III. The results of these regression models are given in the next chapter.

---

[15] Usually this would occur when a property sale would be located upon the fringes of the overlay, and not enough connecting lines could be drawn to obtain a reasonable estimate of dustfall upon the property.

V. STATISTICAL RESULTS

The Results of the Regression Models

In Chapter III there were given two regression models for the estimation of property value (Models 3.2 and 3.3). Model 3.2 expressed the dependent variable as market price per acre; Model 3.3 expressed the dependent variable as market price. In this section 3.2 will be designated as Model 1; 3.3 will be called Model 2. From Chapter III it will be remembered that there were two ways of expressing air quality in the two models: as a three month weighted mean, and as a mean of three months. Within each model, the model containing the weighted mean of the three monthly observations will be designated by A; the model containing the unweighted mean of the three monthly observations will be designated by B. The scheme of things as just described may be seen in Table I. The discussion to follow will be on a variable by variable basis rather than a model by model basis.

As just mentioned, each of the four models have the same independent variables with the exception of the expression of the air quality variable. These variables are as follows: market price of the residential property expressed as price per acre in dollars (Y_1); market price in dollars of the residential property not

Table 1. Initial Estimating Equations for Residential Property Values. (Standard errors of the coefficients in parentheses)

Variables	Model 1 A	Model 1 B	Model 2 A	Model 2 B
Sample Size	98	98	98	98
Constant	-84809.4970	-86533.4080	-17090.7060	-17225.0680
X_1	21.9241 (9.0737)	21.8264 (9.0541)	8.9631 (1.1730)	8.9391 (1.1669)
X_2	-79992.6992 (9469.9206)	-79499.7692 (9440.4432)	1385.9034 (1224.2090)	1428.1144 (1216.7036)
X_3	113979.8370 (15972.3622)	115557.8900 (15981.8592)	17286.8475 (2064.8018)	17476.9146 (2059.7747)
X_4	5499.9239 (2454.9512)	5615.1596 (2452.3249)	313.1510 (317.3599)	329.2397 (316.0606)
X_5	.0127 (.0068)	.0130 (.0068)	.0011 (.0009)	.0011 (.0009)
X_6	-257.6872 (153.6112)	-277.0269 (153.7133)	-23.7154 (19.8578)	-30.8093 (19.8109)
R^2	0.6061	0.6079	0.7079	0.7110

expressed on an areal basis (Y_2); size of the house in square feet (X_1); size of the lot in acres (X_2); a measure of the depreciation of the housing unit (expressed quantitatively between 0.00 and 1.00) (X_3); the number of bedrooms in the housing unit (X_4); the quarterly, total manufacturing payroll (in millions of dollars) in Lincoln County (X_5); a measure of air quality (expressed in dustfall, tons per square mile per month) (X_6).

In the discussion of the variables in this section, particular attention will be devoted to their individual statistical significance and the signs of the coefficients. The next section will discuss what is considered to be the best predicting models of the two submodels of Model 1 and Model 2.

Size of the House

Size of the house in square feet (X_1) was significantly different from zero at the two percent level for Model 1; it was significant at the one percent level for Model 2. For both models the variables were positively related to the dependent variables as expected. The estimates of the coefficients of this variable were biased to some extent by the inability to obtain the square feet existing in some of the upper stories of a few houses.

At first glance the coefficients for Model 1 in Table 1 might appear to be exceedingly high. However, it should be remembered that the dependent variable was expressed as an areal unit, and thus all of the independent variables of Model 1 must be viewed in this manner. The dependent variable of Model 2 was not expressed on an areal basis, but as the market price for each i^{th} observation. And thus all of the independent variables of Model 2 must be viewed likewise. In Model 2, the coefficients of the variable under discussion were comparable with the replacement cost, or appraisal value, of a medium home (Class R1-5) and a fair home (Class R1-4)[16] as figured by the county assessor (15, p. 16-21).

Lot Size

Size of the lot in acres (X_2) was significantly different from zero at the one percent level in Model 1; it was significant at 30 percent in Model 2. In Model 1 the sign of the coefficient was opposite from that originally anticipated. In Model 2 it was positive as anticipated originally.

The latter situation would tend to support the contention that a larger lot would be preferred to a smaller lot in offering more

---

[16]The coefficient was approximately $.35 a square foot over the appraisal cost per square foot of an R1-5 home. It was $1.35 a square foot higher than the appraisal cost per square foot of an R1-4 home. Most of the houses in the study area were classified as R1-4 or R1-5. The average size house sold in the study contained 967 square feet. The comparative appraisal costs above were figured for a one story house containing 960 square feet.

spacial area upon which to live and possibly a less crowded neighborhood. With respect to the negative sign associated with the coefficient of Model 1, it could be concluded that this contention has failed. The view could be taken that the consumer would rather take the additional money that would be spent on the larger piece of property and use it on something else. Since he has a utility function containing many preferences, it could be taken that another item within that function ranked higher than the desire for a larger lot. Thus he would accept a smaller piece of property and use the money saved to obtain the more desired item. Another, more probable reason, however, could be statistical. From observation it was noticed in the study area that usually the smaller pieces of property would have the same type of house and other property characteristics as the larger pieces of property. The market price of the smaller property unit was not that much less than the larger property. This would mean that, for expression in the regression model, the market price of the smaller unit would be spread over a smaller areal measurement resulting in a higher price per acre. It could be concluded, therefore, that lot size was not that important as a component of property value as such. The reason that the coefficient was positive in Model 2 was the fact that the dependent variable was not expressed in areal units, and also because the more expensive improvements were located upon the larger lot. However, these results do not cause a rejection of the hypothesis made earlier that a larger lot is preferred to a smaller lot.

Depreciation of the Housing Unit

The depreciation of the housing unit (X_3), expressed quantitatively between 0.00 and 1.00, was significant from zero at the one percent level in both Models 1 and 2. The signs of the coefficients were as expected. This would seem to support the thoughts expressed earlier that a better quality home would be expressed in a higher price for the property unit.

Number of Bedrooms

The number of bedrooms in the housing unit (X_4) was significant from zero at the five percent level in Model 1; it was not significant at all in Model 2A, and significant from zero at 40 percent in Model 2B. It is not known why the variable was significant in one model and not in the other. The only thought which can be offered on the subject is that the simple correlation coefficient between the size of the house (X_1) and the number of bedrooms was .4561. In Model 2 it is possible that X_1 could have picked up enough variation to have made X_4 insignificant. In Model 1 perhaps more variation, or larger amounts of variation, was introduced because of the expression of the dependent variable in areal units.

The signs of the coefficients in both models were as expected. This would tend to support the contention that more bedrooms add value to a home, and would be expressed in the market price of the property unit.

Quarterly Manufacturing Payroll

The quarterly manufacturing payroll (X_5) was significant from zero at ten percent in Model 1; it was significant from zero at 30 percent in Model 2. The signs of the coefficients were as expected. In view of the fact that the quarterly payroll was expressed in the models in millions of dollars, the size of the coefficients in the models appear to be quite satisfactory.

Air Quality

The air quality variable (X_6) was expressed in two ways: as an unweighted and as a weighted mean of three monthly observations. The coefficient associated with Model 1A (expressed as a weighted mean) was significant from zero at the ten percent level. The coefficient associated with Model 1B (expressed as an unweighted mean) was also significant from zero at ten percent, but with a higher t value than Model 1A (1.802 as compared to 1.678, respectively). The coefficient of Model 2A was significant from zero at the 30 percent level; the coefficient of Model 2B was significant from zero at 20 percent.

In both Models 1 and 2 the coefficient most highly significant from zero (at the ten and 20 percent level, respectively) was the variable expressed as an unweighted mean of the three months period. This could support the contention that the consumer does not place the most emphasis upon the month of sale in his evaluation of the air quality.

The signs of the coefficients in all four models were as expected. This would tend to support, and not result in a rejection of, the major hypothesis of this paper: air pollution as an externality does represent an economic cost to the community affected; the incidence of such costs are discounted in the residential property values of the community.

A priori nothing could be said with respect to the size of the coefficients. As far as was known there were no other studies which measured air quality in the manner of this study. And even if there were, the results from this study were unique to Toledo as was explained earlier.

The fact that the level of significance from zero for Model 1B and Model 2B was at ten and 20 percent, respectively, was gratifying. This was especially true in comparison with the Ridker study. There his air quality variable was significantly different from zero only at the 30 percent level (18, p. 136).

Selection of the Final Regression Models

From the last section it was seen that there were two basic models distinguished by the expression of the dependent variable. There were two variations of each of these models differentiated by the manner in which the air quality variable was expressed within each. Besides the air quality variable there were five other variables all significantly different from zero at 30 percent or at a higher probability level. The exception to this was X_4 (the number of bedrooms) in Model 2. Thus before the final selection of the regression equation for Model 2 could be made, another run had to be made eliminating X_4.[17] The results are shown in Table 2. The levels of significance from zero for each of the variables are as follows:

X_1 (house size) significant at one percent;

X_2 (lot size) significant at 30 percent;

X_3 (depreciation) significant at one percent;

X_5 (manufacturing payroll) significant at 20 percent;

X_6 (air quality) significant at 30 percent in Model 2A, and significant at 20 percent in Model 2B.

---

[17] It was rather arbitrarily decided that any variable that was not significantly different from zero at the 30 percent level or higher (higher level of probability that the estimated coefficient would be significantly different from zero) would be discarded from the final prediction equation. Another run had to be made for Model 2 (eliminating X_4) to obtain the final prediction equation.

Table 2. Second Initial Estimating Equations for Residential Property Values: Model 2

(Standard error of the coefficient in parentheses)

	Model 2	
Variables	A	B
Sample Size	98	98
Constant	-17328.6680	-17470.8590
X_1	9.4754 (1.0517)	9.4779 (1.0465)
X_2	1354.3269 (1223.6154)	1393.6180 (1216.8155)
X_3	17487.1487 (2054.5050)	17678.2332 (2051.6368)
X_5	.0012 (.0009)	.0013 (.0009)
X_6	-22.9036 (19.8380)	-29.4746 (19.7786)
R^2	0.7048	0.7076

A choice now had to be made between Model 1A and 1B as shown in Table 1, and between Model 2A and 2B as shown in Table 2 for the selection of the final regression models. Where more than one method was available to express a given variable in a model, the criterion used to discriminate between the methods in such cases was to choose the method of expression having the highest level of significance. Where this did not discriminate, the highest R^2 and lowest standard error of Y would be looked at. In light of this, Model 1B and Model 2B were chosen over Model 1A and Model 2A as the final regression models.

Model 1B was chosen because the three months unweighted average of pollution had a higher level of significance (higher t value as explained in the last section) than the weighted average. The R^2 of this model was slightly higher and the standard error of Y was lower. Model 1B, hereafter to be called Model 1, is shown below. The standard error of the coefficients are in parentheses. The definitions of the variables remain the same as given at the first of the last section.

$$\dot{Y}_1 = -86533.4080 + \underset{(9.0541)}{21.8264X_1} + \underset{(9440.4432)}{-79499.7692X_2} + \underset{(15981.8592)}{115557.8900X_3}$$

$$+\underset{(2452.3249)}{5615.1596X_4} + \underset{(.0068)}{.0130X_5} + \underset{(153.7133)}{-277.0269X_6}$$

The R^2 is 0.6079. All variables are significant from zero at at least ten percent. Specific levels of significance for each variable may be obtained from the discussion of Table 1 given in the last section.

Model 2B was chosen for the exact same reasons that Model 1B was chosen. Model 2B, hereafter to be called Model 2, is shown below. Again the standard error of the coefficients are in parentheses. The definitions of the variables remain the same as given in the last section.

$$Y_2 = -17470.8590 + \underset{(1.0465)}{9.4779X_1} + \underset{(1216.8155)}{1393.6180X_2} + \underset{(2051.6368)}{17678.2332X_3}$$

$$+ \underset{(.0009)}{.0013X_5} + \underset{(19.7786)}{-29.4746X_6}$$

The R^2 is 0.7076. All variables are significantly different from zero at at least 20 percent, with the exception of X_3 (lot size) which is significant at 30 percent. The specific levels of significance for each variable may be obtained from the discussion about Table 2. The next chapter will discuss possible applications of these models.

VI. THE APPLICATIONS OF THE MODELS

Introduction

In this chapter there will be a discussion of some of the economic applications, and the general uses to which the models might be put. Some of the statistical and practical limitations inherent within the models will be given. There will be an analysis of some of the economic implications which the predictions of the models might have. The chapter will conclude by giving the regrets which were held with respect to the study.

Applications and Limitations of the Models

Model 1 may be used in the prediction of a market price per acre of any given piece of developed residential property in the study area. The varying of one independent variable at a time would allow for the prediction of a change in market price for the property per associated changes of the independent variable. Such variations of the independent variables could be used to ascertain what the affects of certain changes in property characteristics would have on the price of the property. The most important independent variable (from the standpoint of the major hypothesis of this study) of the model was air quality. The coefficient of this variable in Model 1 says that for every ton per square mile per month increase in particulate fallout the value of the property decreases $277.03 per acre.

Certain limitations have to be taken into account in the use of Model 1. These limitations are applicable equally to Model 1, under discussion here, as well as to Model 2, the discussion of which will follow. These models are applicable only to improved residential property. They were not developed for vacant and unimproved land, and hence cannot be used to predict their values. The models are unique to Toledo, of course, but they are also fairly unique to the specific area of study within Toledo. That is, the area of study was fairly well developed with older homes built mostly in the 1925 to 1945 period. While the same type of regression model, with the same variables included, might be used for a newer development within the city, it would seem unwise to use the model given here, with these coefficients, for such purposes. One way to get around this would have been to include the newer and older sections of the town together in one study area. It was not by design that this was not done. The selection of the study area, and the resulting limitations it imposed upon the uses of the models, more or less came about by chance, because the air quality measurements only covered this area.

The prediction of residential property values resulting from specific changes in air quality, the other independent variables of the model being held constant, must take into account the normal background level of the ambient air. For example, say it was estimated that the average dustfall for a three month period was 25 tons per square mile per month. Assume that normal background for the area was ten tons per square mile per month. This would leave 15 tons per square mile per month to be substituted into the models.

Attention is now focused upon the estimates of decreases in property values for given deteriorations in air quality. Table 3 displays such relationships. Column 1 of Table 3 shows associated deteriorations in air quality (increases in dustfall) and property values on a per acre basis; Column 2 shows the associated deterioration in air quality and property values for the 77 nonduplicating observations from the study area (duplicate sales of the same piece of property are eliminated); Column 3 shows the decrease in property values per decrease in air quality for the entire study area. The predictions of Column 3 were overstated to the extent of not being corrected for the unimproved vacant lots within the area. Since most of the land within the area was improved, such overestimation was considered minimal.

As an example in the use of Table 3, assume that there is a change in air quality to such an extent that the potential buyer and seller notice it. Looking at Table 3, assume that quantification of the air quality change shows a deterioration in air quality (increase in dustfall) from 15 tons per square mile per month to 20 tons, net of background. This would result in a decreased value of the affected residential property of $1300 per acre for a five ton increase in dustfall ($4,200 decrease in value per acre at 15 tons, $5,500 decrease in value per acre at 20 tons).

Table 3. Estimates of Decreases in Property Values for Given Reductions in Air Quality: Model 1.

Deterioration in air quality in dustfall tons per square mile per month	Column 1 Decrease in property value per acre [a]	Column 2 Decrease in property values, total acreage for all non-duplicated observations [c]	Column 3 Decrease in property value for the entire study [c]
5	$1,400	$25,400	$134,800
10	$2,800	$50,000	$269,500
15	$4,200	$76,200	$404,300
20 [b]	$5,500	$101,600	$539,100
25	$7,000	$127,000	$673,900

[a] Net of background, which in Toledo during the period of this study was ten tons per square mile per month.

[b] Mean dustfall for the 98 observations was 31.58 tons. Net of background thus becomes 21.58 tons. Thus 20 tons could be considered the average air quality in Toledo for the period of study.

[c] Rounded to the nearest hundred dollars.

Attention is now turned to Model 2. The applications of this model are similar to those discussed with respect to Model 1 above. It can be used to predict the selling price of any given piece of property in the study area having certain characteristics. In order to observe the associated affects upon the dependent variable, certain variables within the model may be held constant while others are allowed to vary. Again, as in Model 1, the air quality variable may be changed to show decreases in air quality and the resulting declines in property values. The coefficient of the air quality variable in Model 2 says that, for every ton per square mile per month increase in dustfall, property values per market transaction will decline by $29.47. Attention is now focused upon such changes.

As a reminder, the restrictions placed upon Model 1 also hold for Model 2. Deteriorations in air quality and property values using Model 2 are shown in Table 4. Again it is assumed that the changes in air pollution are enough to be noticed by buyer and seller. The air quality figures given in Table 4 are again net of background. Column 1 shows the decreases in property value associated with the declines of air quality per each transaction in the market. Column 2 shows the same thing for the study area.[18]

Now that there have been estimated associated changes in air quality and property values, what good are these estimates? Such changes may be read in either of two ways: as social costs or social

---

[18]This model has not been extrapolated to the entire study area, because of the difficulty of determining the number of lots which are in the same ownership, and which would, therefore, count as one market transaction at the time of sale.

benefits. The former results from deteriorations in air quality (reading down the columns of Tables 3 and 4). The latter is associated with improvements in air quality (reading up the columns of Tables 3 and 4).

Table 4. Estimates of Decreases in Property Values for Given Reductions in Air Quality: Model 2.

Deterioration in air quality in dustfall, tons per square miles per month[a]	Column 1 Decrease in property value per individual market transaction[c]	Column 2 Decrease in property value for all non-duplicating observations[d]
5	$150	$11,300
10	$290	$22,700
15	$440	$34,000
20[b]	$590	$45,400
25	$740	$56,700

[a] Net of background, which in Toledo during the period of study was ten tons per square mile per month.

[b] Mean dustfall for the 98 observations was 31.58 tons. Net of background this leaves 21.58 tons. Thus 20 tons could be considered the average air quality in Toledo for the period of study.

[c] Rounded to the nearest tens of dollars.

[d] Rounded to the nearest hundred dollars.

The central theme of this study has been that increases in air pollution represent a cost through increased damage to paint, soiling of clothes, furnishings, and through increased cleaning costs;

through decreased visability; and possibly through the increased incidence of respiratory diseases. Such increased costs are private costs incurred to the user of the property. The incidence of such costs are ultimately discounted in the value of the property subjected to the pollution.

To the extent air pollution is reduced, private benefits result to the user of the land. The incidence of such benefits will ultimately lie in the property values, and will be realized by the user of the property when he sells the land. This improvement of the air quality does not come about without a cost. Other scarce resources would have to be sacrificed in order to improve the quality of the air. Such sacrifices would include, among other things, the need for more pollution control equipment; a cut back in the production of paper in order to reduce emissions. It was unfortunate that current available data did not permit a comparison between the benefits derivable from an increase in air quality, and the resulting costs which would have to be incurred to bring it about. In other words, are the benefits to the area resulting from an increase in air quality enough to make it worth while to incur the costs to bring it about? If it were, then it would be desirable to increase air quality to the point where the marginal social benefits derived from a unit reduction in air pollution were equal to the marginal costs of bringing it about. This study only gives half of what is needed to determine this. That is, from the study there are obtained from Model 1 the marginal social benefit (cost) of $277.03 per acre resulting from a unit decrease (increase) in dustfall of one ton per square mile per month; or from Model 2 a $29.47 marginal social benefit (cost) per market transaction resulting from a unit decrease (increase) in dustfall of one ton.

It should be kept in mind that an increase (decrease) in air quality will have other benefits besides just the estimated increases (decreases) of residential property values given here. Property values other than those for single-family dwellings would also rise, adding substantially to the benefits (costs) given in Tables 3 and 4.

There are other practical applications to which these models may be used. The Lincoln County Assessor since the appraisal of 1960 has been giving district depreciation allowances from ten percent to 50 percent within the study area. This results in a reduction of the appraisal value of the property. Such depreciation has been given because of the presence of industrial activity resulting from the kraft mill, such as air pollution. It would be quite interesting at the time of the next appraisal to determine the dustfall prevailing in the different areas, estimate the decline in property values resulting from the given dustfall, and compare these values with the assessor's estimate of the decline of property values due to district depreciation.

In a more general sense, the fact that residential property values were influenced greatly by increases in air pollution would have significant implication for industrial planning, location, and development. This would hold true not only for Toledo, but for any other place where such a model might be developed. Results from these equations could suggest alternatives which may be more appropriately compared when specific information is available on the effects of varying levels of air quality.

Within this framework, management and operation decisions may be benefited, via more complete information, if a method is devised to reflect the costs of pollution to the emitting unit. Also, because of potential for capital gains resulting from air quality improvement to the owner of the land, there are further implications of the findings to tax such gains.

Regrets with Respect to the Model and the Data

In the development of a study of this nature things occur which are often wished otherwise. This study was no exception. Such occurrences are now discussed.

There were three regrets with respect to the air quality data: It was most unfortunate that some method could not have been derived to have corrected the Georgia-Pacific dustfall data that was in error. If the dustfall data had been correctible, then the isopleth overlays would have been that much more accurate. It was disappointing that no meteorological data existed which could have been used in the estimation of the missing dustfall stations. It was felt that, given how meteorlogical conditions affect the distribution of dustfall, a better predictive equation for the missing stations could have been estimated if such data had been obtainable. It would also have been most helpful if the dustfall stations could have been set up in such a way as to have lent themselves better to economic analysis. This will be taken up in the next chapter.

The principal regret with respect to the property characteristics was concerned with the variable measuring the amount of square feet within the housing unit. The variable was biased by the inability to include the square feet in the upper stories and basement. For reasons already given in Chapter III such an omission was not considered too detrimental to the predictive ability of the model. However, because of the omission the estimate of the coefficient of the variable was not as accurate as it might have been. The problem could have been solved by an inside inspection of each of the houses containing upper stories.

The models could also perhaps have been more accurate in their predictive abilities if total monthly payroll for the City of Toledo could have been used, instead of the county-wide quarterly data that was used. It was disappointing that a state law prohibited the obtaining of such data.

It would have been desirable, from the point of view of this study, if the study area could have been expanded to include newer subdivisions. The fact that there were not enough dustfall stations to do so limits the general applicability of the model to older residential sections of Toledo.

It would have been most desirable if enough dustfall stations had been available in order to have developed an additional model for the commercial area of the city. It would have been most interesting to see if air pollution has a negative effect upon land values in this sector of the real estate market.

VII. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The main hypothesis of this paper was that air pollution represented an economic cost to the community affected, and that the incidence of such costs were reflected in the land values of the community. Thus the main objective of this study was to estimate empirically the hypothesized effect that air quality would have on land values in Toledo, Oregon.

The empirical basis to test the hypothesis and obtain the objectives was furnished by actual sales of residential property within the city limits of Toledo. The economic geography of the area was oriented toward lumber and wood products, and pulp and paper manufacturing. The study area within the city limits was homogeneous, and limited to single-family residential housing. There was only one major source of pollution to which the study area was subjected. This came from a pulp and paper plant. Particulate fallout (dustfall) was used as a measure of air quality in the study area. It was obtained from the Oregon State Sanitary Authority, and from evidence submitted in a civil suit. Specific property characteristics were obtained from the Lincoln County Assessor.

Two models were developed to explain property values. The final regression equations resulting from the analysis of 98 sales of residential property from June 1961 through December 1967 are as follows:

Model 1

$$Y_1 = -86533.4080 + \underset{(9.0541)}{21.8264X_1} + \underset{(9440.4432)}{-79499.7692X_2} + \underset{(15981.8592)}{115557.8900X_3}$$

$$+ \underset{(2452.3249)}{5615.1596X_4} + \underset{(.0068)}{.0130X_5} + \underset{(153.7133)}{-277.0269X_6}$$

Model 2

$$Y_2 = -17470.8590 + \underset{(1.0465)}{9.4779X_1} + \underset{(1216.8155)}{1393.6180X_2} + \underset{(2051.6368)}{17678.2332X_3}$$

$$+ \underset{(.0009)}{.0013X_5} + \underset{(19.7786)}{-29.4746X_6}$$

where Y_1 = market price of the residential property expressed as price per acre in dollars.

Y_2 = market price in dollars of the residential property.

X_1 = size of the house in square feet.

X_2 = size of the lot in acres.

X_3 = a measure of the depreciations of the housing unit (expressed quantitaively between 0.00 and 1.00).

X_4 = the number of bedrooms in the housing unit.

X_5 = the quarterly, total manufacturing payroll (in millions of dollars) of Lincoln County.

X_6 = a measure of air quality (expressed in dustfall, tons per square mile per month).

The standard error of the coefficients are in parentheses. Model 1 had a multiple correlation coefficient (R^2) of 0.6079. Model 2 had a multiple correlation coefficient of 0.7076.

The findings with respect to the air pollution variable were as follows: In Model 1 it was found that a ton per square mile per month increase in particulate fallout would cause property values to decline by $277.03 per acre. In Model 2 it was found that a similar increase in particulate fallout would result in a decline of property values of $29.47 per market transaction.

All the coefficients of the independent variables were significantly different from zero from one to 30 percent in both models. The only exception to this was the variable measuring the number of bedrooms in the housing unit (X_4). In Model 2 it was not significant at all, and consequently was deleted from this model. In Model 1 the air quality variable was significantly different from zero at ten percent; in Model 2 it was significantly different from zero at 20 percent.

All the coefficients of the independent variables had the expected positive or negative relationship with the dependent variable. The only exception to this was in Model 1 where the lot size had a negative relationship instead of the expected positive relationship to the dependent variable. Statistically this was explained by the manner in which the dependent variable was expressed.

The general contention throughout this thesis has been that air pollution represents an economic cost. These costs are ultimately reflected in a discounting of the value of the affected property. Thus these models have general application in the determination, or estimates, of the marginal social benefits (costs) resulting from a unit decrease (increase) of air pollution. Methods of measuring and determining such costs must be available if methods of taxation, or other schemes, are to be devised to impose the costs of such pollution upon the emitter. Or, in a similar manner, to tax the property owner for benefits accruing to him from a unit decrease in air pollution.

Methods of estimating the marginal social costs must be known in the setting of air pollution standards. The standard would ideally be set at a level where the marginal social benefits of an increase in air quality are equal to the marginal social costs incurred to bring it about. Emission charges can be used as a management tool to approximate an efficient level of standards by forcing the firm to take into account the marginal social costs of pollution.

In addition, models of these types could be used for industrial planning and development. The prediction of the effects of air quality changes on land values is an important consideration in industrial site selection for efficient resource allocation.

Conclusion

The hypothesis of this paper was that air pollution does have an economic cost to the community affected; the incidence of such costs will be reflected in the land values of the community. The findings of this study do not cause a rejection of this hypothesis.

The value of land reflects the overall economic activity of the community. Air quality is but one of the economic variables determining the level of economic activity. Air quality is becoming an economic good as other scarce resources have to be sacrificed in order to improve the quality of the air; or adjustments may have to be made to a lower level of air quality. Air pollution represents a cost through damage to paint; soiling of clothes, furnishings, and the extra cleaning costs associated with this; decreased visibility; and the increased incidence of respiratory diseases. All these represent social costs. The property affected by air pollution will be discounted in the market to reflect peoples' valuation of these changes and costs.

An underlying assumption of the above conclusions is that people are aware of the costs of air pollution. To the extent that they are unaware of some of them, the results obtained from this study should be interpreted as minima in the estimates of the costs of air pollution.

With respect to the air quality variable there are some limitations that might be kept in mind. It is possible that the air quality variable may be picking up some variations in other variables not included in the model. For example, particulate fallout, the method of measuring air quality in this study, might be picking up a noise factor associated with the mill, which, like particulate fallout to some extent, would become more intense as a function of distance from the mill.

In both Model 1 and Model 2 the coefficient of the air quality variable was negative in sign as expected, and significantly different from zero at ten and 20 percent, respectively. Model 1 states that for every ton of dustfall increase per square mile per month, everything else held constant, property values would decline by $277.03 per acre. Model 2 says that for the same increase in dustfall the value of the property per market transaction would decline $29.48. The average size of the lots sold in this study per observation was 0.2294 of an acre. Using Model 2 this would indicate an average decrease in property value of $128.49 per acre for each ton of increase in dustfall, or a difference from the value given by Model 1 of $148.54. The fact that a relatively minor change in the specification of the models leads to considerably different estimates of the air pollution effect upon residential property values indicates that the numerical estimates from these models must be used with caution.

The equations derived from this study are limited in their specific applications. In essence, they may be used only upon developed residential property in Toledo.

Recommendations

This section is broken into two parts. The first part will deal with suggestions to the pollution control agencies in the placement of sampling stations. The second portion of the section will be dealing with recommendations for future research.

The study of air pollution is no longer strictly a technician's job. It is becoming more and more interdisciplinary. The role of the economist is becoming more important as attempts are made to place monetary values upon the effects of air pollution. In order to estimate the cost of air pollution, via the method outlined in this study, an estimate of air quality is needed. The placing of air sampling stations is most important in obtaining an accurate estimate of air quality. Attention is now turned to methods of locating the dustfall stations in order that they may be more useful in economic analysis.[19]

---

[19] Particulate fallout is not the only method of determining or estimating air quality within an area. However, since dustfall stations were the only means available for estimating air quality within Toledo, the comments within this section are more or less directed toward their use.

The dustfall stations in Toledo were located under the following general classification: source surveillance or study, background sampling stations, and general area monitoring. Some of these stations were initially established because of complaints concerning some given source of pollution. With respect to Toledo, each station appeared to have been placed for a specific purpose with no attention being given to the possible co-ordinated use of all the stations (including the privately maintained stations). Such a method of placement made the drawing of isopleth overlays (used to estimate dustfall upon any given piece of property at the time of sale) difficult.

It would be helpful, and would extend the usefulness of the data collected from these stations if the following procedure had been followed. This method is a modification of the methods outlined by the Air Pollution Control Association (9, p. 373). The principal modification is in the number of stations and the criteria to be used in placing them.

The best procedure in the establishment of each dustfall station is to locate them at sites which represent as nearly as possible the fall of particulate matter within the area without duplication. For use in drawing isopleth maps, the stations should be located in a square. A minimum of five stations should be used, with each of four stations on the corners of the square, and the fifth station located in the center of the square. Additional stations above the minimum number, the location of the stations within the sample area, and the distance between the stations should be a function of the meteorological and economic conditions existant within the area.[20]

It would be desirable to have at least one meteorological station within the sample area to determine the variations in weather that occur over time. Meterological conditions can very much influence the distribution of particulate fallout. It is desirable, therefore, that meterological conditions within the sample area be as homogeneous as possible. This is particularly true with respect to prevailing wind direction and speed, which probably have the most influence on dustfall distribution within the area. To the extent that terrain or other conditions might prohibit such homogeniety, more meterological and dustfall stations might have to be established and suitably located to take this into account.

The number, location, and distances of the stations from each other would be a function of the economic situation, with respect to property values, existing within the sample area. That is, decreases in property values for increases in air pollution would be more for higher valued, more developed properties than for less developed, lower valued properties. From an economic standpoint, it would be desirable

---

[20] What follows is applicable to any sampling network, not just dustfall stations.

to have a more accurate measure of air pollution for the higher valued properties than for the lower valued properties, because of the potential for higher economic losses on the former. Thus more stations located closer together should be placed in areas of higher property values to obtain more accurate measurements of air quality.

Turning now to recommendations for future research. The results of this study suggest certain directions which future research might profitably take in attempting to understand the effects of pollution upon the value of the land. These would include the development of models to explain the effects of air pollution upon commercial, industrial, and agricultural lands.

Clearly the type of model outlined here should be pursued further. The cross-section study should be repeated and tested in other towns having similar characteristics as Toledo. For until the model is tested again, no one can be sure of the relationships hypothesized therein.

The model used here has given estimates of the social benefits (costs) resulting from a unit decrease (increase) in air pollution. This is only half of the picture. Future research would be beneficial in determining the marginal cost of bringing about a unit reduction in air pollution.

BIBLIOGRAPHY

1. American Association for the Advancement of Science. Air Conservation Commission. Air conservation. Baltimore, Horn-Shafer, 1965. 324 p. (Publication no. 85)

2. American Society for Testing and Materials. 1964 book of A S T M standards. Part 23. Industrial water; atmospheric analysis. Philadelphia, 1964. 758 p.

3. Boubel, Richard W. Associate Professor, Oregon State University, Dept. of Mechanical Engineering. An analysis of errors involved in dustfall determination. Paper presented at the Pacific Northwest International Section, Air Pollution Control Association, Seattle, November 3-4, 1966. 10 numb. leaves.

4. Brigham, Eugene. The determinents of residential land values. Land Economics 41:325-334. 1965.

5. Cresing, John P., Otto A. Davis and John E. Jackson. Urban property markets: some empirical results and their implications for municipal zoning. The Journal of Law and Economics 10:79-99. Oct. 1967.

6. Draper, N. R. and H. Smith. Applied regression analysis. New York, Wiley, 1966. 402 p.

7. Friedman, Milton. A theory of the consumption function. Princeton, National Bureau of Economic Research, 1957. 239 p.

8. Harding, E. I. and J. E. Landry. Future trends in air pollution control in the kraft pulping industry. Gainesville, Florida, 1966. 8 p. (Florida. University. Florida Engineering and Industrial Experiment Station. Technical paper no. 361)

9. Herrick, Robert A. Recommended standard method for continuing dust fall survey. Journal of the Air Pollution Control Association 16:372-377. 1966.

10. Kneese, Allen V. and Blair T. Bower. Managing water quality: economics, technology, institutions. Baltimore, John Hopkins University, 1968. 318 p.

11. Knetsch, Jack L. The influence of reservoir projects on land values. Journal of Farm Economics 46:231-243. 1964.

12. Magill, Paul, Francis Holder and Charles Ashley (eds.). Air pollution handbook. New York, McGraw-Hill, 1956. Various paging.

13. Marshall, Alfred. Principles of economics. 8th ed. London, MacMillan, 1927. 858 p.

14. Oregon. State Sanitary Authority. Air Quality Control. Particle fallout collection and analysis. Portland, Jan. 30, 1964. 4 p.

15. Oregon. State Tax Commission. Cost factors for residential buildings, 1960. Salem, 1960. 64 p.

16. Oregon. State Tax Commission. Manual of appraisal methods for real property. Salem, 1957. 201 p.

17. Oregon-Washington Air Quality Committee. Criteria for particle fallout objective and standards. Portland, Oregon, State Sanitary Authority, April 1969. 13 p.

18. Ridker, Ronald G. Economic costs of air pollution. New York, Praeger, 1967. 214 p.

19. U. S. Bureau of the Census. U. S. census of population: 1960. Vol. 1. Part 39. Characteristics of the population: Oregon. Washington, D. C., 1963. 332 p.

20. U. S. Public Health Service. Bureau of Disease Prevention and Environmental Control. Interstate air pollution study phase 2 project report. Vol. 8. A proposal for an air resource management program. Cincinnati, National Center for Air Pollution Control, 1967. 132 p.