F I N A L R E P O R T

ESTABLISHING AND VALUING THE EFFECTS OF IMPROVED VISIBILITY IN EASTERN UNITED STATES

by

George Tolley
Alan Randall
Glenn Blomquist
Robert Fabian
Gideon Fishelson
Alan Frankel
John Hoehn
Ronald Krumm
Ed Mensah
Terry Smith

The University of Chicago

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PROJECT OFFICER: Dr. Alan Carlin
Office of Health and Ecological Effects
Office of Research and Development
U.S. Environmental Protection Agency
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T A B L E O F C O N T E N T S

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Section 1

INTRODUCTION

1.1 SUMMARY OF PROJECT OBJECTIVES

While visibility is receiving increasing attention, it is still relatively neglected as an attribute of the environment whose worth is important. Visibility is a pervasive and inescapable phenomenon which is subject to both general and periodic deterioration. The effects are significant to the individuals affected, and extremely large numbers of people are affected. The relative neglect of visibility as a subject of investigation appears to be due not to its lack of importance, but rather to the fact that it is more difficult to value than many other environmental attributes. Visibility is not explicitly bought and sold, and the consequences of poor visibility are not as overt as illness and death. Yet visibility affects the quality of life and is potentially important to well-being.

Valuing visibility raises methodological questions to which recent contributions have been made. The present effort utilizes and develops these contributions, enhancing their validity and accuracy. Previous work on visibility has concentrated on sparsely populated areas of the West. The present research, concerned with visibility in the Eastern United States, deals with larger numbers of people under a wider variety of circumstances. People in urban and rural areas are affected in the course of daily living, and a variety of special activities centering on recreation and related activities are particularly sensitive to visibility conditions.

Three major objectives have been accomplished by the research contained in this Report. The first and most important result is the establishment of a visibility value function. This function is the Project's basic contribution to the analysis of visibility policy effects. Research was directed not at measuring the value of current visibility or any other specific value, but rather at estimating the value of policy-induced <u>changes</u> in visibility. The generality of the visibility value function permits estimation and comparison of benefits from any set of policy alternatives.

The benefits of a visibility policy depend upon the extent of improvement, on initial visibility conditions and their geographic distribution, and upon social and economic characterisrics of people in various regions. Benefits are a function of these variables in the visibility value function. Changes in socioeconomic characteristics of the population will occur over time as well as policy-induced visibility changes. The visibility value function accounts for the separate and joint effects on benefits of changes in these variables over time.

The second major objective was to identify particular activities likely to be influenced by visibility and to measure the value of visibility to households in producing these activities. Recreational swimming and enjoyment of residential views are among the wide range of activities investigated. Visibility value functions for individual activities were derived. The individual activity functions compliment the aggregate function in several important ways. Theoretically, they are based upon information derived from transactions in ordinary markets or from activity in implied markets. An important result is that these studies corroborate the findings from the aggregate function, which is based upon hypothetical behavior in contingent markets. First, the activity functions consistently establish positive values for improved visibility in individual markets. One example is that property values are observed to increase with improved visibility. Secondly, the magnitudes of benefits in individual markets are plausible in relation to aggregate benefits.

The third major contribution of Project research was to establish a rigorous and operational method of aggregating visibility policy benefits over the entire Eastern U.S. From the beginning it was recognized that the visibility value function, based upon contingent valuation, would be the basis for measuring aggregate policy benefits. This is because it was not feasible to develop individual value functions for all markets in which visibility is important.

The basic problem was to use a limited amount of information obtained from contingent markets in six cities to measure visibility valuation in the entire eastern U.S. Approximately 800 expressions of willingness to pay were obtained for five visibility programs. Each program covered a specific geographic area and offered a specific change in visual range.

An early empirical approach was to estimate a separate willingness to pay function for each program in each city. Several aggregation problems resulted. First, there was only one eastern U.S. policy program to use (along with the endowment point) to fit the eastern bid curve. This was inadequate. Secondly, there was no satisfactory way to estimate willingness to pay for improvements at different distances from the bidder. One would have to resort to an expedient like "average improvement over all eastern states" as an argument of a city's eastern U.S. bid function. Thirdly, estimation of policy benefits required adding values derived from local bid functions and values derived from eastern U.S. bid functions. This was rather arbitrary in that local visibility improvements and distant visibility improvements were treated as separate goods, rather than as a single good which yields different service flows at different distances.

These difficulties were overcome by pooling all observations and estimating a single function directly applicable to all bids, both local and region-wide.

The resulting visibility value function permits direct aggregation of all policy benefits based upon parameter values derived from a quite limited but carefully chosen set of contingent market observations.

The spatial index is the feature of the visibility value function that produces direct aggregation of policy benefits. The index expresses willingness to pay for visibility in any location as directly related to the number of square miles of improvements and inversly related to distance. Thus, the benefits of a policy in a state in a particular year are a function of policy-induced improvements in all states that year. Estimates of policy benefits take account not only of the size but also of the complicated and changing spatial distribution of visibility improvement over time.

This report is a summary of a 32-month effort aimed at arriving at estimates of the value of improved visibility for the Eastern United States. The project was carried out under a Cooperative Agreement with the Environmental Protection Agency, with active day to day participation by the staff of the Resource Analysis Group of the Committee on Public Policy Studies of the University of Chicago and the staff of the EPA, including Dr. Alan Carlin and others. Austin Kelly of the University of Chicago and James Ciecka of DePaul University served as consultants to the project.

The project was completed in two phases. The basic phase ran from Month 1 through Month 17, during which time detailed methodology was developed and visibility situations examined for the Chicago area. The supplementary phase of the project, running from Month 8 through Month 32, was devoted to examining six additional metropolitan areas and six non-urban cases.

1.2 ECONOMIC EFFECTS ON VISIBILITY

1.2.1 Economic Effects: Introduction

The history of visual air quality in the eastern United States is essentially a history of economic development of the region. The relationship between economic development and visibility has changed over the years in response to changing technology, energy prices and other factors. A requirement of effective visibility policy is to alter the direction of these occurrences optimally.

Measurement of policy effects requires a knowledge of historical trends. Policy evaluation requires that regulatory rules be modelled in proper relationship to other factors, so that their partial effect on visibility may be isolated.

1.2.2 Visibility in the Eastern United States Since World War II

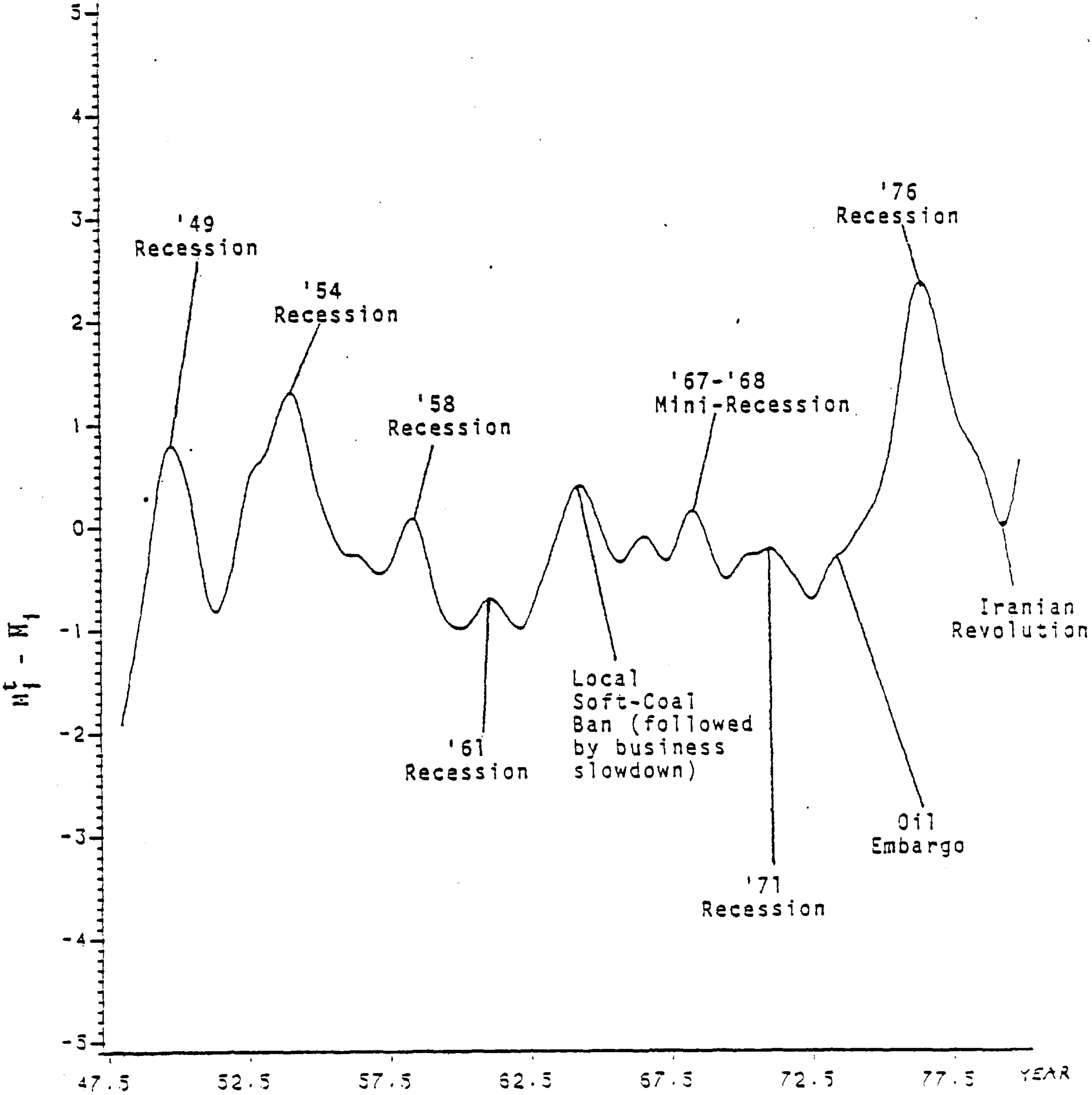
Examination of the path of visibility in the twentieth century provides many insights into the short and long term factors which influence pollution and visibility in the eastern United States.

Visibility trend data were initially used in the scenario-setting of the contingent valuation (CV) portion of this study. Examination of the data immediately raised a difficult question: Just what is typical visibility in these urban areas: Median visibility over the last four years was used, buy a satisfactory answer to the question still requires some knowledge of the history of visibility and its determinants in these cities.

Fig. 1-1 shows a seasonally-adjusted time-series of visibility in Chicago. The vertical scale represents the difference between the month's median visibility and the average median for the particular month over the entire series. While this method is flawed, in that seasonal shifts have occurred in the pattern of visibility, it is nevertheless useful in showing the distinguishing features of the trend line, which has been smoothed somewhat using a modified spline routine. Fig. 1-2 through 1-4 repeat the exercise for Atlanta, Boston, and Cincinnati. Fig. 1-5 presents all four cities simultaneously, to aid in regional comparisons. The major features are presented below. In Fig. 1-5 the vertical, broken lines occur at the midpoints of business troughs, while the first solid vertical line occurs at the time of the OPEC oil price hikes of 1973-1974. The second solid vertical line occurs at the Iranian Revolution, which was accompanied by another round of oil cutbacks and price hikes. It is important to note at this point that substitute fuels respond to oil price hikes, as demand for them increases. Fig. 1-6a shows a deflated (1972 dollars) schedule of several fuel prices, in energy equivalents, as well as a quantity-weighted composite of all mineral fuel prices in the United States since 1950. It is clear that economic activity and relative factor prices influence pollution and visibility. Any projections of future trends should carefully consider these effects. As an example, Fig. 1-7 shows the trend of visibility at O'Hare Airport in Chicago. This series is interesting in that more

FIGURE 1-1

Median Visibility at Chicago-Midway:
Difference From Sample Mean



Source: National Climate Center
Bureau of Labor Statistics

Note: Recessions are drawn at local troughs

FIGURE 1-2

Difference From Mean Monthly Vis.
City = Atlanta

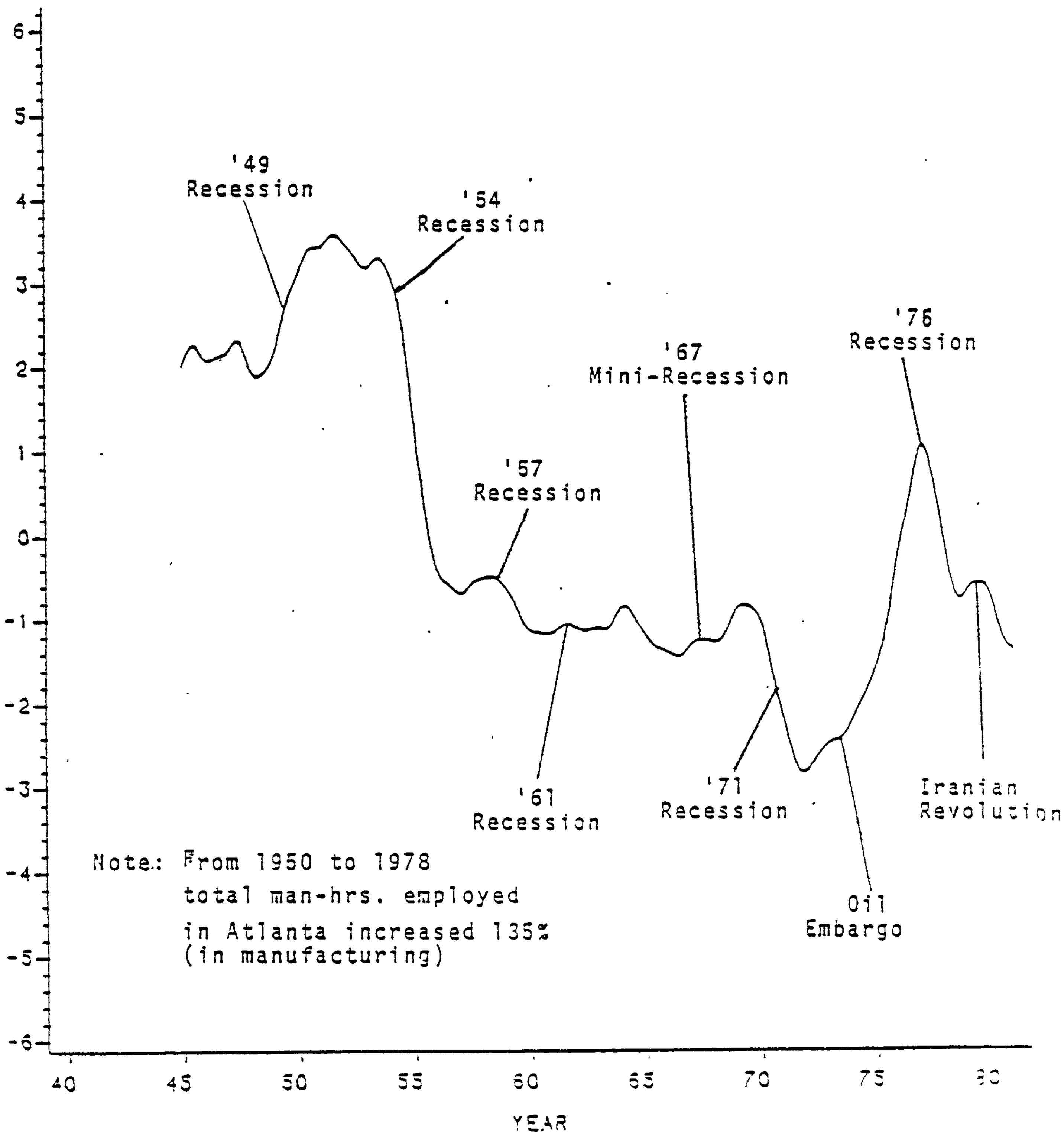


FIGURE 1-3

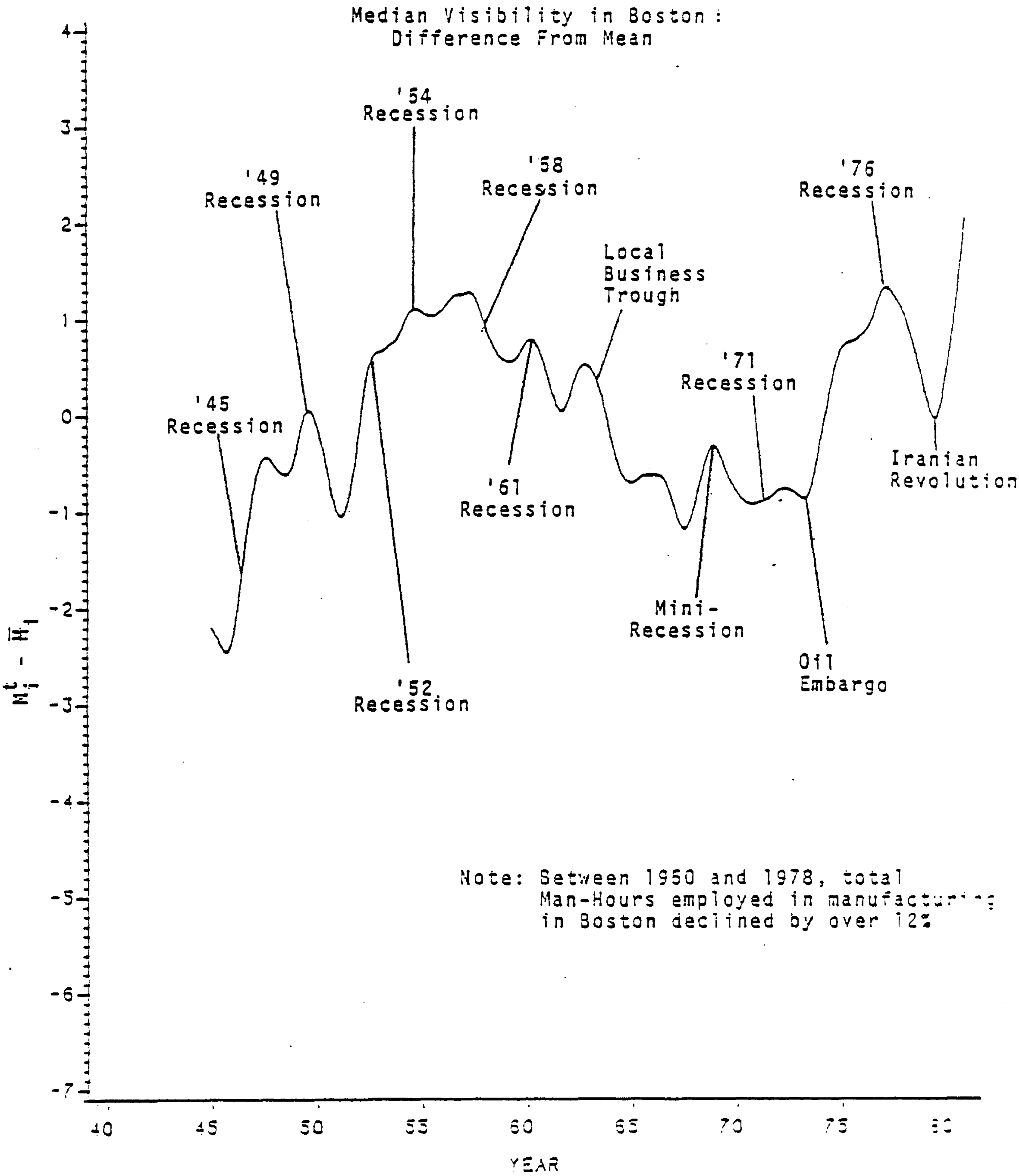

Median Visibility in Boston: Difference From Mean
'54 Recession
'49 Recession
'58 Recession
'76 Recession
Local Business Trough
'71 Recession
'45 Recession
'61 Recession
Iranian Revolution
Mini-Recession
Oil Embargo
'52 Recession
Note: Between 1950 and 1978, total Man-Hours employed in manufactur
in Boston declined by over 12%
YEAR
40
45
50
55
60
65
70
75
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7

FIGURE 1-4

Monthly Median Visibility in Cincinnati:
Difference from Month's Sample Mean

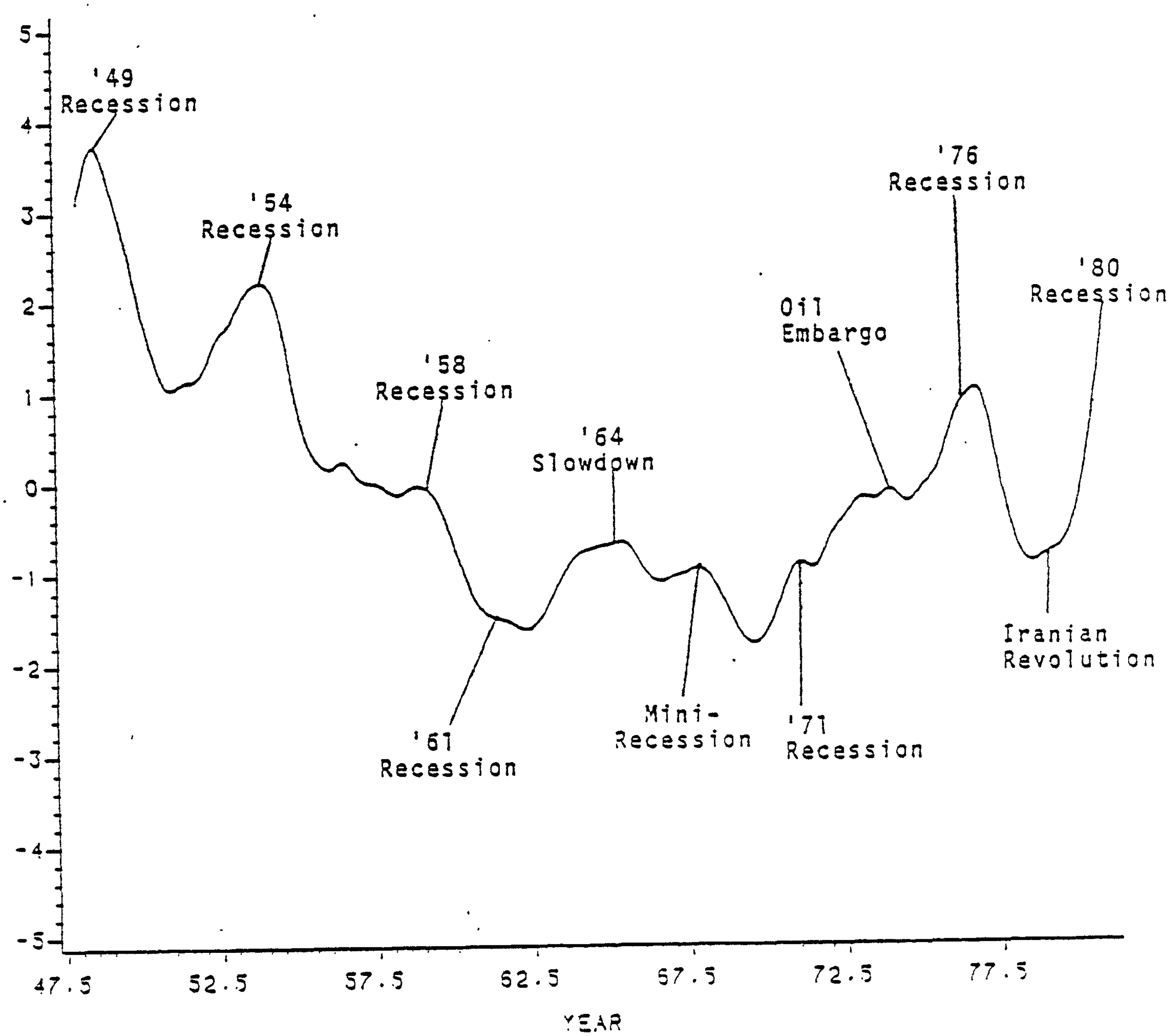
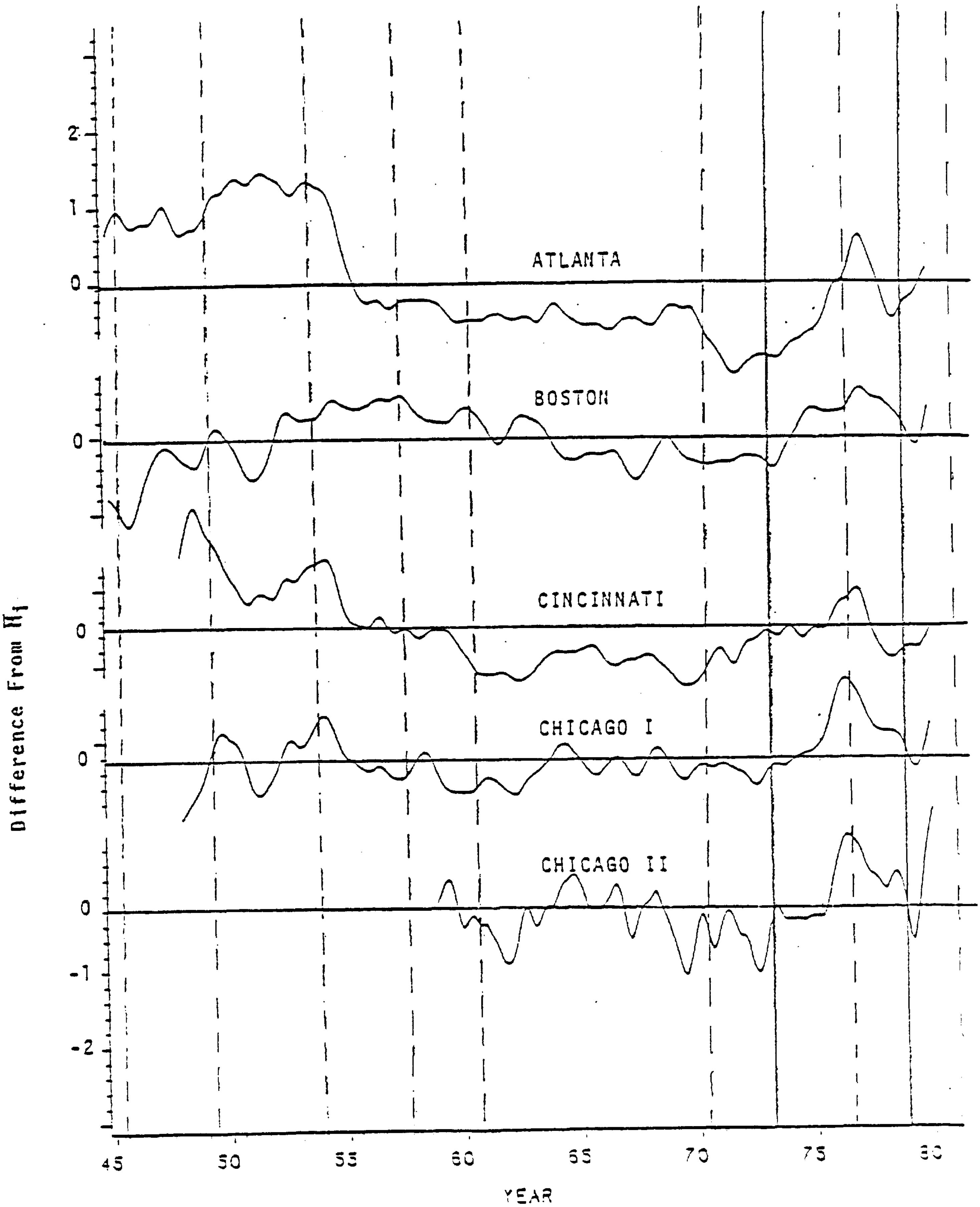


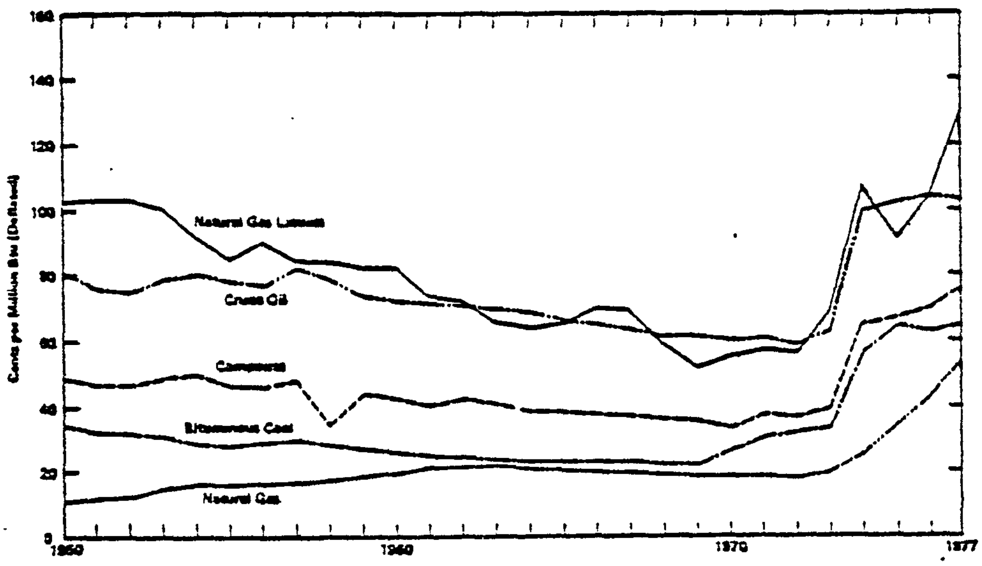
FIGURE 1-5



LEGEND: Broken vertical lines are U.S. Recessions. First solid line occurs at oil Embarco. Second occurs at Iranian Revolution.

FIGURE 1-6a

Prices of Domestically Produced Mineral Fuels



Source: Bureau of Mines and Energy Information Administration.

The deflated (real) composite price of U.S. fossil fuels declined at an annual rate of 0.9 percent from 1950 through 1973. Since 1973, this price has increased at a rate of 17.9 percent per year.

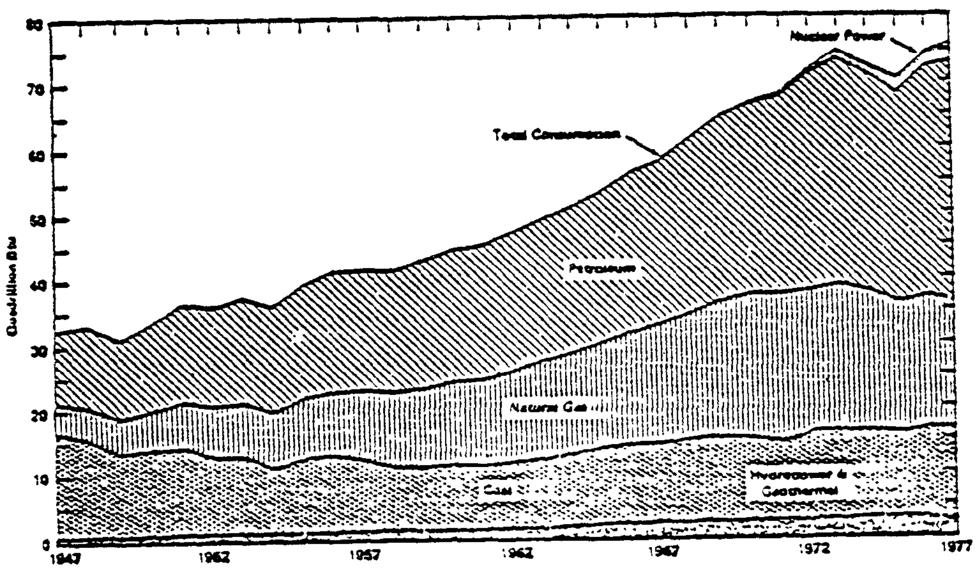
The average real domestic crude oil price decreased 1.1 percent per year between 1950 and 1973, then jumped 58.3 percent in 1974. During the 1975–1977 period, crude oil prices grew at an annual rate of 1.2 percent.

Real natural gas prices increased from 1950 through 1973 at a rate of 2.5 percent per annum. In 1974 this price rose 15.4 percent, and then from 1975 through 1977 increased at an annual rate of 7.4 percent.

Real bituminous coal prices fell an average of 0.1 percent per year between 1950 and 1973, then increased 64.7 percent in 1974. From 1975 through 1977, the annual growth rate for bituminous coal prices was 4.9 percent.

FIGURE 1-6b

Energy Consumption by Primary Energy Type



Source: Bureau of Mines and Energy Information Administration.

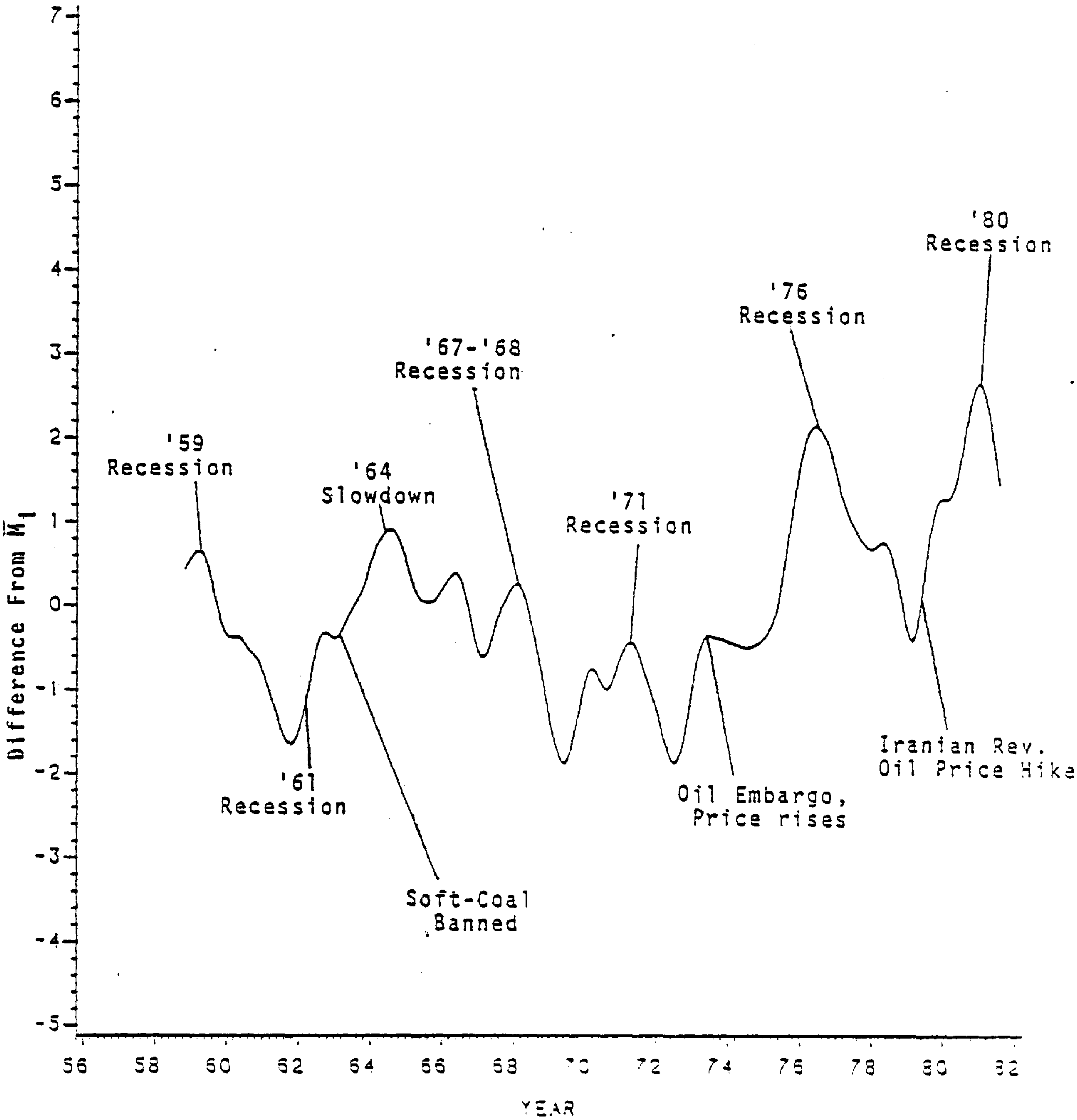
Between 1947 and 1973, consumption of energy in the United States increased at an annual rate of 3.2 percent. During this period, petroleum and natural gas consumption grew at annual rates of 4.3 percent and 6.4 percent, respectively.

During 1974 and 1975, total U.S. energy consumption fell 2.7 percent per year, but then increased in 1976 and 1977 by 5.3 percent and 2.0 percent, respectively. Petroleum consumption in 1974–1975 decreased 2.3 percent annually, and then increased an average of 6.2 percent per year in 1976 and 1977. Natural gas consumption declined 3.1 percent annually from 1974 through 1977.

Coal consumption declined 3.9 percent annually from 1947 to 1959, then increased 3.0 percent per year through 1977. In 1947, coal, natural gas, and petroleum held 46.6 percent, 13.9 percent, and 34.9 percent, respectively, of total U.S. energy consumption. In 1977 those shares were 18.4, 25.7, and 46.7 percent, respectively.

FIGURE 1-7

Monthly Median Visibility at Chicago-O'Hare:
Difference from Sample Mean, by Month, 1958-1981



Sources: National Climatic Center
Bureau of Labor Statistics

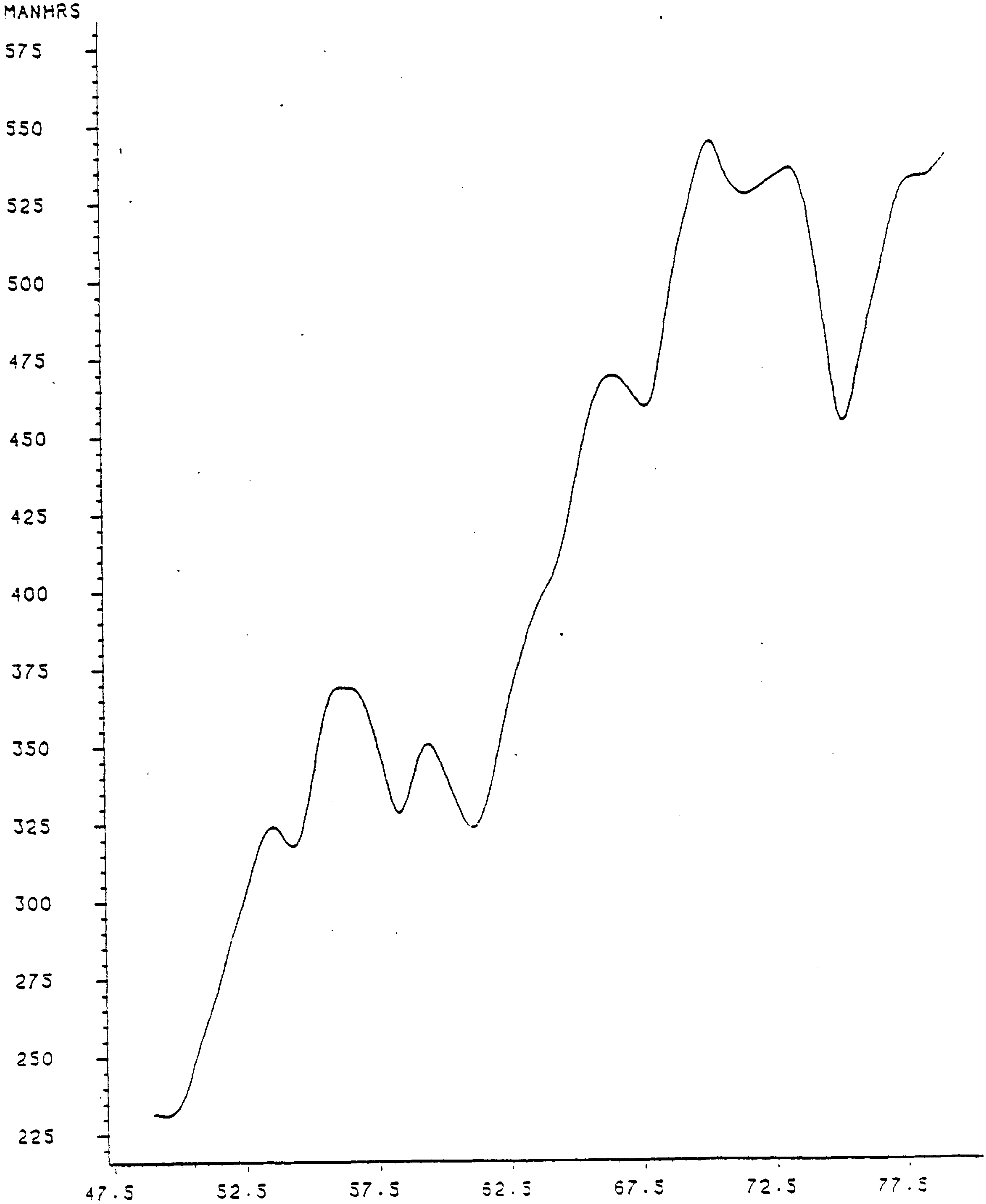
Note: Recessions are drawn at the <u>local</u> troughs recent levels are available, and have been added to the plot. The recession of 1975-1976 increased visibility. Following this is the recovery into 1978, when visibility fell once again. In 1979, the oil price hikes again increased visibility, and the 1980 recession followed soon thereafter. The quick recovery from this recession is seen at the end (September 1981) of the series, and we are confident that additional data would again reflect the business downturn beginning in the final quarter of 1981.

This kind of historical analysis is primarily intended to explain the short-run peaks and valleys of the observed series, but the method is equally valid for longer time periods. As an illustration, the plot of median visibility in Atlanta should be compared with the plot of employment in manufacturing industries for the same city (Fig. 1-8). Atlanta was chosen because of its dramatic pattern of growth. During episodes of rapid growth in the 1950's, and again in the early 1970's, Atlanta's visibility declined appreciably. No doubt this was also influenced by regional growth in general as well as local growth. In almost all cases, a decline in employment was matched closely with an increase in visibility. More precise econometric estimates of the effects of legislation, fuel prices, and business cycles will aid in the prediction of policy benefits, especially as more refined estimates of future fuel prices are developed. The effects of legislation on visibility, and pollution in general, are difficult to measure, as the 1970's also saw so much economic turmoil. Persons should be cautioned against the indiscriminant use of two-year comparisons of pollutant levels, as a look at these graphs clearly shows that the choice of end points can be made to produce almost any trendline of pollution.

The best that can be said of typical visibility is that it is the level of visibility which exists with a typical level and rate of growth of economic

FIGURE 1-8

ATLANTA MAN-HOURS (THOUSANDS)
Total Manufacturing



activity, typical fuel prices, wages, and prices of other production inputs, and typical weather conditions. It is clear that it is neither valid nor informative to base policy oriented pollution projections on trend data assembled from spot readings taken several years apart. It is hoped that more reliable projections will be made through careful econometric estimation procedures.

1.3 DEFINITION AND MEASUREMENT OF VISIBILITY

Visibility is rooted in human perception. As atmospheric conditions change, the human perception of distance, clarity, color, texture and contrast change. An adequate notion of visibility, as related to atmospheric quality, involves (1) relationships between atmospheric conditions and those atmospheric quality attributes which are objectively measurable with scientific instruments, and (2) relationships between measurable quality attributes and human perceptions of visual quality.

Visibility traditionally has been defined as the relative distance at which an object can be seen under the prevailing conditions; i.e., as the visual range. Husar et.al. (1979) define visibility as the maximum distance at which an observer can discern the outline of a black object. According to Trijonis and Yuan (1978) the procedure commonly used to determine visibility is to observe markers against the horizon sky, e.g., buildings or mountains during the daytime and unfocused, moderately intense light sources at night. Markers are chosen whose distance from the observation point is known. Prevailing visibility is the greatest visibility that is met or exceeded around at least 50 percent of the horizon circle. The procedure has two limitations. The measurement of visibility is affected by the visual acuity of the observer and the quality of objects observed. The latter leads to a systematic underestimation of daytime visibility because the objects are rarely black as required by the definition. There is an even greater problem with measurement of nighttime visibility because of the variation in intensity of the light sources. This lack of standardization makes accurate comparisons of visibility among different sites difficult, especially for nighttime visibility. There seems to be reasonable confidence in comparison of daytime visibility among sites probably because less variation in the characteristics of target objects is suspected. Visibility is the good that individuals value, measured in this Report in miles.

Natural scientists who are concerned with the relationship between visibility and pollutants have found it convenient to study the "bad"--haziness or lack of visibility. Haziness is increased by the presence of light scattering and absorbing aerosals and gases and is proportional to their concentration in the air. Trijonis and Yuan measure haziness by the extinction coefficient (B), which is inversely proportional to visibility (V) in the following way:

$$(1\text{-}1)\quad B = 24.3/V ,$$

where 24.3 is the Koschmieder constant, V is measured in miles and B has the units $(10^4 \text{ meters})^{-1}$. The relationship means that in a uniform atmosphere with extinction coefficient equal to $x(10^4 \text{ meters})^{-1}$, a black object against the horizon sky will be reduced to the threshold level of contrast for the human eye at a distance of 24.3/x miles. It is the extinction coefficient that is used to determine the causes of haziness. Both the extinction coefficient and visibility are used to describe air quality patterns and trends.

In addition to visual range, important components of human perception of atmospheric visual quality include color and texture. These concepts can be measured objectively as contrast, color and lightness, using scientific instruments. Formulae have been developed to combine these concepts into a single parameter called color contrast (Malm, Leiker, and Molenar). Research in which personal interview subjects rated carefully calibrated color slides and actual scenes for visual quality has established that the relationship between color contrast and perceived visual quality is linear and statistically significant. Other factors such as scenic beauty serve as shifters, leaving the essential linear relationship between color contrast and perceived visual quality intact.

Several prominant patterns and trends are reported by Trijonis and Yuan. First, visibility is rather low in the Northeast, ranging from 8 to 14 miles typically. In the Southwest, visibility ranges from 30 to 80 miles. Second, visibility is fairly uniform throughout the Northeast in that visibility is only 2 or 3 miles less in urban than nonurban areas. Third, there is a seasonal pattern in that visibility is now typically 2 to 3 miles lower in the summer quarter than the rest of the year, especially for non-metropolitan (urban/suburban and nonurban) locations. Fourth, over the period 1953 to 1972, visibility declined in the Northeast, -2 percent for metropolitan areas. It appears most of the decline occurred early in the period.

Trijonis and Yuan explain the deterioration in visibility by an increase in sulfates in the atmosphere. Sulfates tend to occur in the particle size range of 0.1 to 1 micron, which is the size range that is optically most important. Despite the fact that sulfates comprise only 15 percent of the aerosal mass, they account for approximately 50 percent of the reduction in visibility in the Northeast. Through multivariate analysis of the extinction coefficient Trijonis and Yuan find contributions to total extinction as follows:

Component	Contribution
Sulfates	49%
TSP*	16%
Blue-sky scatter (background)	5%
Nitrates	2%
Unaccounted for	28%

*TSP is total suspended particulate other than sulfates and nitrates.

The conclusion that sulfates are the primary cause of visibility reduction is robust with respect to six different data sets and linear and nonlinear specifications. Physical modeling which relates sulfate reductions in one area of the Northeast to visibility in the other areas of the Northeast--a distributional concern--has been supplied by D.M. Rote of ANL, and is used in the policy simulation chapter of this report.

1.4. OUTLINE OF THE REPORT

Section 2 is "Expressed Willingness to Pay for Visibility." This is the first major empirical part of the Report. Analysis is based upon data drawn directly from contingent markets in six eastern cities.

The most important literature on contingent valuation is reviewed in 2.1. Important extensions of this literature are made in design, reported here, of a contingent valuation research project carried out in Chicago. The project made a fundamental contribution to the main results of this Report.

In 2.2 it is argued that geographically dispersed visibility improvements are substitutes. Empirical support provided for the theoretical argument. This work was fundamental to the development of the contingent valuation instrument and the visibility value function, which are the key elements of Section 2 research.

Alternative econometric approaches to estimating the parameters of the visibility value function are discussed in 2.3. Tobit estimation, discussed in 2.3.2, is applied to a contingent valuation study at Indiana Dunes State Park. Tobit and probit specifications are compared with ordinary least squares in 2.3.3, in an application to National Park Service data.

The visibility value function is presented and analyzed in 2.4. Drawing upon the theory of household production, it is an empirical statement which summarizes the information gathered from the contingent valuation work. Aggregate policy benefits by state are derived by substituting mean state values for each of the variables in the function.

Section 3 is the second major empirical part of the Report: "Secondary Data Analysis of Visibility Valuation." "Secondary Data" includes information such as prices and quantities determined in ordinary markets. The term also denotes information about behavior in implicit markets, such as increased probability of accident while driving at a slower speed under reduced visibility conditions. This can be interpreted as in increased price of safety.

A brief description of each topic, and corresponding empirical results, are given in 3.1. Section 3.2.1 analyzes visibility effects on outdoor swimming. A theoretical model of visibility demand is developed and tested by means of several regression specifications. In 3.2.2 and 3.2.3 the effects of changing visibility on television viewing and baseball attendance are analyzed. The theoretical foundation of these studies is the idea of visibility as a productive input which households use to produce services that yield satisfaction. Relevant theory is developed in the Conceptual Appendix.

Section 3.3.1 reports the development of statistical procedures for analyzing Hancock Tower visitation, and estimates of consumer surplus from improved visibility The Hancock analysis is continued in 3.3.2. Results of contingent valuation and analysis of secondary data from the Tower are found to be in close agreement with contingent valuation results of the kind reported in Section 2. This comparison greatly strenghtens confidence that can be placed on both types of analysis employed in this Report. In this study of the value of residential view quality and atmospheric visibility, property value and contingent valuation estimates of visibility were found to be compatible. Benefits estimates of improved view quality and visibility are reported.

A model of consumer behavior under visibility constraints on air travel is developed in 3.5.1, and a framework is provided for measuring the net costs of lowered visibility on air travel in 3.5.2. The relationship between visibility and highway accidents on metropolitan Chicago is examined in 3.5.3. Underlying the quantitative estimates is a behavioral theory of choice in which drivers are assumed to balance the risks of injury or death against travel objectives. Consumer surplus estimates of visibility benefits are reported.

Section 4, "Use of Results to Estimate Benefits for the Eastern United States," shows how the visibility value function can be used to derive dollar estimates of policy benefits. Four alternative illustrative policies are analyzed. Each policy produces a set of state-by-state visibility improvements to the year 2000, as determined by the Argonne long range transport model. More stringent policies produce greater visibility improvements, which are distributed unequally among the states. The benefits received by a state are seen to depend not only upon local improvements but also importantly upon improvements in all other states as well. Benefit estimates for each eastern state in 1990 under the four hypothetical scenarios are presented.

Section 2

EXPRESSED WILLINGNESS TO PAY FOR VISIBILITY

2.1 OVERVIEW OF SECTION 2

The major objective of Section 2 is to formalize an aggregate visibility value function. This function is the central contribution of Project research to the measurement of region-wide visibility policy benefits.

In Section 2.2, a general theoretical framework of visibility valuation is developed. It pertains both to the contingent valuation work of Section 2 and the analysis of secondary data in Section 3. The theory and practice of contingent valuation are then reviewed. Project contributions to this literature are explained in detail. The empirical data used in the Project were gathered in conformity to the framework established in the section.

Section 2.3 is an investigation of econometric approaches to data analysis. Section 2.4 presents the visibility value function and its underlying rationale.

2.2 ALTERNATIVE CONTINGENT VALUATION APPROACHES

2.2.1 Overview of Section 2.2

The basic problem addressed in this Section is the gathering of reliable data on maximum willingness to pay for visibility improvements by the contingent valuation (CV) approach. Sections 2.2.2 and 2.2.3 give a critique of the current state of CV literature, stressing issues that need special care in visibility valuation. This is followed by a general theoretical model of household production of visibility services, 2.2.4, in which visual air quality and purchased goods are productive inputs. The household production model and regional economic theory--spatial economics--underlie the content of the CV instrument. Section 2.2, therefore, addresses the two basic issues: what information is needed and how most effectively to obtain it.

2.2.2 The Process by Which Atmospheric Visibility Acquires Economic Value

2.2.2.1 The Conceptual Model

Atmospheric visibility is desired by households not so much as a commodity for direct consumption but rather as an input into the production of things (variously called "commodities" or "activities") which yield satisfaction. Thus, the "new" demand theory of Lancaster and the household production approach of Becker are both relevant. Stoll, building on the work of Lancaster and Becker, developed a conceptual model of the process by which environmental resources yield satisfaction, and applied it to the analysis of wildlife-related outdoor recreation. The following is a modification of Stoll's approach, specifically designed to recognize the nonrival character of the good, atmospheric visibility.

Assume that the household seeks to maximize the satisfaction it derives from the *characteristics* provided by the *activities* it produces. Activities are produced by combining *time* with exclusive, priced goods, and nonexclusive and/or nonrival goods. Thus both time and goods serve as *inputs* into activity production. The process of producing activities is constrained by the household's activity production function (a mathematical depiction of its consumption or household production technology) and by constraints on available time and income. Assuming, as does Becker, that time may be traded for wages, these two constraints may be combined into a "full income constraint."

Symbolically, the process may be depicted as one in which the household maximizes

(2-1) $$U(c_1 \ldots, c_m, \ldots, c_M)$$

Subject to

(2-2) $$\sum_{j=1}^{B} \left(\sum_{n=1}^{N} p_n x_{jn} + T_j \bar{r}_{B+1} \right) \leq S$$

(2-3) $$w_{jk} = W_k \qquad k = 1,2,\ldots,L$$

(2-4) $$z_j = z_j(x_{jn}, T_j | w_{jk}, E) \qquad j = 1,2,B,\ldots,J \quad n = 1,2,\ldots,N$$

(2-5) $$c_m = c_m(z_j, w_{jk}) \qquad m = 1,2,\ldots,M$$

(2-6) $$z_j \geq 0$$

where c_m are characteristics; z_j is an activity; $z_1, \ldots, z_B$ are nonwork activities, and $z_{B+L}, \ldots, z_j$ are work activities; x_n is a purchased input whose unit price is p_n; w_k is a nonrival good; $\bar{r}_{B+L}$ is the unit wage rate for the highest-marginal-wage work activity available; S is full income; W_k is the total initial endowment of nonrival good; and E is a vector of determinants of the household's activity production technology at a given point in time.

Constraint (2-2) is the full income constraint; (2-3) is a constraint on availability of nonrival goods; (2-4) is a household activity production function; and (2-5) is a characteristic production function depicting how activities yield characteristics. To repeat, it is characteristics which provide satisfaction. Note that w_{jk} enters both eqs. (2-4) and (2-5). In (2-4) the important point is whether w_{jk} is present in at least the threshold quantity necessary to permit production of z_j, in (2-5), it is recognized that, given that a z_j is produced, the amount of characteristics it provides depends upon the quantity of w_{jk} available for use in its production.

The level of satisfaction that the household enjoys may vary with full income, prices of purchased goods, wage rates, production technology, and the endowment of nonrival goods. Activity production technology in the form of human capital may be acquired by the household and may depreciate over time. The endowment of nonrival goods, e.g., atmospheric visibility, at any location is determined jointly by background conditions and the aggregate activities of mankind and thus may be influenced by public policy. By choice of location, the household may influence the endowment of nonrival goods available to itself.

Solution of the household's maximization problem yields implicit prices (or opportunity costs), π_m, for the various characteristics, c_m. Since these π_m depend on a particular household's activity production function and full income constraints, they are , in principle, different for each household. Furthermore, the π_m are affected by those factors that influence the household's activity production technology and its full income, the endowment of nonrival goods, and the price of purchased goods.

The conceptual model of the consumption process has a number of interesting attributes.

1. It recognizes both the role of time in the consumption process (eq. (2-4)) and the consumer's choice in allocating marginal units of time between work and nonwork activities (eq. (2-2)).
2. The role of activity production technology (eq. (2-3)) permits explanation of changes in consumption bundles in the absence of changes in tastes, prices of purchased goods, or endowments of nonrival goods.

A change in activity production technology (e.g., the acquisition of some specialized consumption or leisure skill) may be sufficient to change the π_m, c_m, and x_{jn}. Indicators of household activity production technology would be expected to prove useful in explaining variation in the WTP for W_k (e.g., atmospheric visibility) across households.

3. The two-step relationship between goods, activities and characteristics (eq. (2-4) and (2-5)) permits more complete understanding of the relationship between goods which are substitutes or complements in consumption, and the reasons why goods enter and exit the marketplace (Lancaster.) If it is charactertistics which are demanded, if various activities produce different (but, in some cases, overlapping) vectors of characteristics, and if changes in activity production technology change the amounts of the activities which may be produced from given quantities of purchased and nonrival goods, then the process by which changes in prices or activity production technology lead to substitution among activities and perhaps the total elimination of some activities may be completely understood. A set of general hypotheses may be developed along these lines, testable in specific natural resource and environmental contexts.

Thus, the model incorporates the possibility of substitutes and complements for visibility. In the production of safety characteristics for aviation, navigation instruments may be excellent substitutes. In the production of view characteristics for valued vistas, the only available substitute, photographs taken by another at a time when visibility was better, may be quite poor substitutes.

4. These concepts may be used to more precisely define activity value, expected activity value, option

value, the expected activity value for the non-risk-neutral individual and existence value, In our context, if one or more valued characteristics may be derived from one or more activities which are produced using only w_k, their value is the pure existence value for w_k,

This model of the process through which the household derives satisfaction from a non-rival endowment such as ambient visibility is useful for several purposes:

-it permits the derivation of welfare impacts, in consumer's surplus terms, of changes in the endowment of a non-rival good, ambient visibility;

-in so doing, it provides a conceptual linkage between contingent valuation methods, analyses of behavioral choices, and valuation methods which use observations from the markets in goods whose demands are systematically related to the demand for visibility;

-it identifies the relevant categories of variables for use in bid equations to explain variation in individual WTP for improvements in ambient visibility, thus increasing the likelihood that regularities in WTP can be documented;

-with its focus on the role of nonrival endowments in the production of activities which yield satisfaction, it provides a conceptual focus for a major section of our research effort: analysis of the relationship between ambient visibility and the observed activity production behavior of individials. This research is a major, original contribution of our project. Previous projects have, for the most part, confined their attention to contingent valuation and the analysis of relationships between property values and ambient air quality (of which visibility is one characteristic).

2.2.2.2 Welfare Impact and Consumer's Surplus

The following model derives expressions for the consumer's surplus value of the welfare impacts of changes in the endowment of environmental goods. These expressions are conceptually straightforward but quite lengthy. So, for expository purposes, we will revert to a simpler model in this section in which utility is a function of the endowed level of nonrival amenity (ambient visibility) and a vector, $\underline{X}$, of ordinary, priced goods,

$$U = U(W,\underline{X}) \tag{2-7}$$

From this point, the valuation methods may be devised by either of two approaches.

1. The Income Compensation Function Approach

Define Y as the numeraire value of $\underline{X}$. The utility function, implicit in prices, $\underline{P}$, may then be represented as

$$U = U(W,Y) = U[\underline{P}(W,Y)] \quad , \tag{2-2}$$

where W is taken as initially fixed to the individual.

Using the income compensation function, $\mu(W|W^*,\bar{Y})$, which represents the least amount of the numeraire the individual would require with W to achieve the same level of utility as with W* and $\bar{Y}$, a system of partial differential equations may be derived for various reference levels of W,

$$\frac{\partial \mu(W|W^*,Y)}{\partial W} = P[W,\mu(W|W^*,\bar{Y})] \cdot \tag{2-9}$$

For a change in visibility from W' to W", where $U(W',\bar{Y}) < U(W'',\bar{Y})$, the Hicksian compensating measure of the welfare impact for the individual's willingness to pay (WTP), is

$$\text{(2-10)} \qquad WTP = \int_{W'}^{W''} P[W,\mu(W|W',\bar{Y})]dW.$$

An equivalent measure, the individual's willingness to accept (WTA), is

$$\text{(2-11)} \qquad WTA = \int_{W'}^{W''} P[W,\mu(W|W'',\bar{Y})]dW.$$

That is, both WTP and WTA are defined as areas under (different) Hicksian compensated demand curves for W. WTP and WTA may be directly observed using any technique which permits estimation of the respective indifference surfaces passing through

$$\text{(2-12)} \qquad U'(W',\bar{Y}) = U'(W'',\bar{Y} - WTP), \text{ for WTP, and}$$
$$U''(W'',\bar{Y}) = U''(W',\bar{Y} + WTA), \text{ for WTA.}$$

Most contingent valuation (CV) methods, (including direct questions, checklist questions, iterative bidding, and various experimental formats) are designed to estimate (2-12). The theory is direct, undemanding in terms of the analytical assumptions needed, and easily applied. The most serious challenge in empirical application concerns data quality. Most CV methods are in principle susceptible to some kind of strategic behavior. WTP and WTA data may also be disturbed by outside influences. The principal challenge in implementation of CV methods is to minimize (1) opportunities for strategic behavior and (2) the incidence of noise in the data set.

2.2.2.3 The Expenditure Function Approach

An alternative formulation of the same problem posits the utility function (2-7), in which $\underline{X}$ is a vector $(x_1,...,x_i,...x_n)$ of ordinary, private (i.e., exclusive, divisible, and nonrival) goods. Maximizing (2-7) subject to a budget constraint, $\sum_i p_i x_i = Y^0$, generates a set of Marshallian demand functions,

$$x_i = X_i(\underline{P},W,Y^0). \tag{2-13}$$

The possibility that W is an argument in the demand for private goods (c.f. eq. (2-4) and (2-5)) suggests that market data, prices and quantities taken, for x_i may be used to reveal the welfare impact of changes in W. Let us explore this possibility. First, we establish the theoretical equivalence of the expenditure function and income compensation function approaches. Then, we consider the implementation of the expenditure function approach.

The utility maximization problem yields ordinary demand equation (2-13). The dual of the same problem minimizes expenditure, $\sum_i p_i x_i$, subject to the constraint that utility must be at least equal to some specified level, U. Solution to the problem

$$\min \sum_i p_i x_i$$

$$\text{s.t.} \quad U = U(\underline{X},W)$$

yields the expenditure function. Considering a proposed change in the availability of a nonrival good from W' to W", where $U'(\underline{X},W') < U''(\underline{X},W'')$, the relevant expenditure functions are, respectively,

(2-14) $E'(\underline{P},W,U')$ and
$E''(\underline{P},W,U'')$.

The derivative of any expenditure function with respect to any price, p_i, yields a Hicksian compensated demand function for x_i. For the expenditure functions (14), the compensated demand functions are:

(2-15) $$x_i^{h'} = \partial E'/\partial p_i = E'_{p_i}(\underline{P}, W, U') \text{ and}$$

$$x_i^{h''} = \partial E''/\partial p_i = E''_{p_i}(\underline{P},W,U'') .$$

The inverse Hicksian compensated demand curves for W are given by

(2-16) $$-\partial E'/\partial W = E'_w \; (\underline{P},W,U') \text{ and}$$

$$-\partial E''/\partial W = E''_w \; (\underline{P}, W, U'') .$$

Thus, the compensating and equivalent measures of the welfare impact of the proposed change are respectively,

(2-17) $$WTP= -\int_{W'}^{W''} E'_w \; (\underline{P},W,U')dW, \text{ and}$$

(2-18) $$WTA= -\int_{W'}^{W''} E''_w \; (\underline{P},W,U'')dW.$$

Eq. (2-17) is, of course, equivalent to eq. (2-10) and similarly eq.(2-18) is equivalent to (2-11). This alternative formulation, however, offers the prospect of empirically estimating WTP and WTA without directly observing (relevant points on) indifference surfaces expressed in (W,Y) space. Instead, under favorable conditions, it should be possible to estimate WTP and WTA via appropriate manipulation of readily accessible market data for private goods, x_i, expressed in forms suitable, initially, for estimating (2-13). A number of techniques have been developed to use this approach. Examples include methods which analyze travel costs, property values, and hedonic prices.

Let us now consider the conditions under which these various approaches may be effective.

2.2.2.4 Comparison of Approaches

a) Separable utility functions. If the utility functions is strongly separable in W, i.e.,

$$(2\text{-}19).\qquad U(\underline{X},W) = U_x(\underline{X}) + U_w(W),$$

then the demand functions for x_i will all be of the form

$$(2\text{-}20)\qquad x_i = x_i(\underline{P},Y),$$

that is, completely independent of the level of W. Certain commonly used functional forms for utility functions (e.g., the Cobb-Douglas and CES forms) have this property, and Freeman (1979) argues that some important classes of environmental amenities may in fact be separable. In such cases valuation methods based on the expenditure function approach are without prospects, and valuation will be performed with CV methods or not at all.

b) Nonseparability of x_i and W. In many cases, demands for x_i may not be spearable from W, as in eq. (2-13). If such a system of demand equations has been estimated and it satisfies the Slutsky conditions for integrability, it may be possible to solve for the underlying expenditure function. If it is, eq. (2-17) eq. (2-18) can be estimated and the value of W at the margin, of the welfare impact of a nomarginal change from W' to W", can be estimated by implicit pricing methods. However, it is generally necessary to impose additional conditions on the problem in order to solve the system completely (Maler, 1974). Two, often benign, assumptions that are useful are (1) weak complementarity and (2) the existence of a perfect substitute.

Weak complementarity occurs if when the quantity of x_i demanded is zero, the marginal utility of W is zero (Maler, 1974). In such cases, when W increases the demand for x_i shifts out, and the value of W" - W' is approximated by the integral between $x_i(\underline{P}, W'', Y)$ and $x_i(\underline{p}, W', \bar{Y})$. This valuation approach can be operationalized as long as demand curves approximates the integral between Hicksian compensated demand curves (Willig, 1976; Randall and Stoll, 1980).

The assumption of weak complementarity provides the basis for the travel cost method of valuing recreation amenities (Clawson and Knetsch, 1966; Stevens, 1966) and the land value method of valuing increments in air quality, view quality, and other residential amenities (Freeman, 1974; Brown and Pollakowski, 1977). It should be noted, however, that Maler (1977) expresses doubts as to whether the weak complementarity assumption is satisfied in the housing market or (by extension) in other markets frequently used for implicit valuation of non-marketed goods.

A second approach is operational if we can suppose that some good x_i is a perfect substitute for W. If some x_i and W are perfect substitutes, while W and $\underline{X}^j$ (x_i is not in $\underline{X}^j$) are independent in the utility and demand functions, the marginal demand price of W reduces to the price of x_i multiplied by the substitution ratio between x_i and W (Maler, 1974; Freeman, 1979.

This idea suggests that if there exist some x_i which counteract the effects of pollution so that x_i are perfect substitutes for improvements in W, expenditures on x_i provide evidence of the value of W. If the elasticity of substitution between x_i and W is less than infinite, this method would underestimate the value of W. While this method has promise, we have yet to find published studies demonstrating its successful application in empirical research.

c) Hedonic Prices.

Assume first that x_i and W are not separable in the utility function. Second, assume that x_i can be defined in terms of a vector of characteristics $\underline{C}_i = (c_{i1}, \ldots, c_{in})$. Third, assume that a purchaser, j, of good x_i can vary $\underline{C}_i$ by choosing a particular unit, x_{ij}. That is, x_i is not the usual homogeneous good but a bundle of attributes as are houses and automobiles. Finally, suppose that one of the characteristics in $\underline{C}_i$ is c_{iw}, the amount of W enjoyed along with x_i. Therefore, as the consumer selects, for example, a given house or car, the amount of residential air quality he enjoys along with his house or the amount of safety he enjoys along with his car is also determined. For any unit of x_i, say c_{ij}, its price, $p_{x_{ij}}$, is

$$p_{x_{ij}} = p_{x_i}(c_{ij1}, \ldots\ldots, c_{ijw}, \ldots\ldots, c_{ijn}), \quad (2\text{-}21)$$

where p_{x_i} is the hedonic price function for x_i. If p_{x_i} can be estimated from observations of the prices $p_{x_{ij}}$ and the characteristics $\underline{c}_{ij}$ of different x_{ij}, then the price of any x_{ik}, $k \neq j$, can be calculated from a knowledge of its characteristics. The implicit price of the characteristic, c_{ijw}, for individual j can be found by differentiation:

(2-22) $$p_{c_{ijw}} = \partial p_{x_i} / \partial c_{ijw}.$$

Under favorable conditions, it is possible to use information in the implicit price function to identify the demand for c_{iw}, that is, the demand for W if W is enjoyed only as a characteristic of x_i. Assume the individual purchases only one unit of x_i (or, if more than one unit, only identical units) and the utility function is spearable in x_i and $\underline{X}^j$ (x_i is not in $\underline{X}^j$) so that the marginal rate of substitution between any pair of x_i is independent of $\underline{X}^j$. Then, depending on the form of the characteristic demand function (Rosen, 1974), it is possible to estimate the inverse demand curves for W. In such a case, the integral between the inverse demand curves for W' and W" would approximate the intetral between the appropriate Hicksian compensated demand curves (Willig, 1976; Randall and Stoll, 1980).

In the brief period since publication of Rosen (1974), many attempts to use hedonic prices to value nonmarketed goods have been initiated. Applications have included many aspects of residential amenities (e.g., airport noise, Abelson, 1979), and work place safety (Thaler and Rosen, 1975). An literature is emerging to identify and catalog the analytical difficulties this approach encounters.

The priminary advantage of methods which use the expenditure function apporach is data quality. Such methods use data sets of actual transactions. CV methods, by definition, will never enjoy that advantage. However, that does not mean that the estimated values for W derived from expenditure function approaches are necessarily valid or, for that matter, superior to estimates using CV methods. When X and W are strongly separable in the utility function, these methods cannot be used. When (nonseparable) relationships between X and W are not of the most simple kinds, the analytical assumptions will be violated to a greater or lesser degree, with corresponding deleterious effects on the validity of the value estimates for W. Thus, while the data base is, in a sense, real, the stringent analytical assumptions necessary to derive the value of W from observations in the market for X provide more than enough opportunities for bias or noise to intrude. Our empirical research plan, therefore, provided opportunities for replication of value estimates with both CV methods and methods which use various expenditure function approaches.

2.2.2.5 Econometric Specification of the Model

Herein, let us explore the implications of the above model for the specification of econometric equations to explain individual WTP for y_k. The model implies that the satisfaction derived from a change in the ambient level of visibility will be influenced by:

(1)--the array of activities produced using visibility; the characteristics these activities provide; and the array of activities which do not use visibility as an input, but which provide (some of) the characteristics provided by visibility-using activities.

(2)--the prices of purchased inputs used in production of the activities discussed immediately above. Taking a long time horizon, one would also be concerned with the availability at a particular time of purchased inputs which may enter and/or exit the marketplace and with changes in input quality. In the static time frame, these would not be considerations.

(3)--in a cross-section of households spatially arrayed across the land surface, the array of Y_k, endowments of nonrival goods, would be expected to vary; and this variation will influence the productivity of the activity production process. This suggests a focus on nonrival goods, in addition to air quality, which are used in production of visibility-using and nonvisibility-using activities which provide (some of) the same characteristics.

(4)--the marginal opportunity cost of time to the household.

(5)--the household's activity production technology in general and in particular as it applies to visibility-using activities and, non-visibility-using activities which provide (some of) the same characteristics. Technology can be expected to vary across households and one important subset of technology, the things that contribute to visual acuity, may vary within the household. In general, activity production technology may be acquired and many depreciate, which is important in a longitudinal time frame, but not in the static time frame.

(6)--the household's preferences across characteristics. Economics has made little headway in using information about preferences to explain individual household demand for purchased goods, or household valuation of nonrival goods. The revealed preference approach by-passed the fundamental question by taking it as axiomatic that purchases reveal preferences. Time-series analyses of demand often resort to the use of crude trend variables which are presumed to correct for secular changes in tastes (and anything else which may not be properly accounted by the other, more precisely defined, independent variables). One could argue that a significant trend variable should lead to the rejection of the hypothesis that the model is adequately specified.

Becker has shown that, under certain plausible assumptions about caring within the household, the household acts as though it is seeking to maximize a single preference function. Stigler and Becker have argued that, since economics has made such poor positive use of the notion of preference (for the most part, being satisfied with negative uses such as using it as an all-purpose copout to explain away otherwise inexplicable results), progress might best be sought by assuming that preferences are constant across households and across time periods, thus ascribing behavioral differences to differences in opportunity sets and activity production technology.

If the above-mentioned factors influence the satisfaction derived from changes in the level of atmospheric visibility, WTP for these changes is influenced, in addition, by

(7)--household full income.

(8)--the competing demands within the household, which may influence the marginal and total WTP for characteristics that may or not be provided by visibility-using activities versus WTP for characteristics always provided by non-visibility using activities. If this latter group of characteristics is treated as a numeraire, then we are speaking of those things that influence the marginal rate of substitution between the numeraire and the group of characteristics that may or may not be provided by visibility-using characteristics.

In summary, eight cataegories of variables which may influence WTP have been identified. Of these, we may a priori assign low priorities to categories (2) and (6): (2) on the grounds that unit prices of homogenous purchased goods used along with visibility to produce characteristics are unlikely to experience much variation in a static cross-section; and (6) on the basis of the Stigler-Becker argument which suggests an emphasis on inter-household variations in activity production technology rather than preferences.

In the light of the preceding conceptual analysis, let us now consider the variables traditionally used to explain variations in individual WTP. To what extent do these variables capture precisely the kinds of factors thought to influence WTP? Are the traditional variables addressed to a single factor or to multiple factors. If to a single factor, is the underlying relationship clear, unambiguous and fully specified? If to multiple factors, are the various underlying relationships between these factors and WTP unidirectional. (If not, a priori expectations will be unclear, and the interpretation of results will be ambiguous.) Are there variables and relationships that the conceptual model suggests are likely of importance, but which are ignored by the traditional variables?

Below, the traditional variables are listed and for each, its interpretation in terms of the factors identified by the conceptual model is explored.

Traditional Variable	Category of Factors Influencing WTP
Income	--(7), i.e., income addresses the notion of "full income," but incompetely, since it ignores the relationships between current income, work and wealth.
Education	--(5), presumably, better education assists the acquisition of activity production technology (APT), but this relationship is unclear. Formal education may be of little use in the acquisition of outdoor APT's, and the time spent gaining it may have come at the cost of time which would otherwise be spent acquiring outdoor APT's. -- Education may be a better indicator of acquired technology useful in handling CV exercises.
Age	--(5), presumably. However, advancing age implies the depreciation of certain APTs while it may permit the acquisition of others. For specific APT's, the relationship between age and technology has yet to be conceptualized. -- if the program (e.g., to improve visual air

	quality) is seen as one which requires the passage of time, in order to achieve its full effectiveness, advancing age may indicate shorter time horizons (a problem our model does not explicitly address) or pessimism about the speed and effectiveness of program implementation.
Race/Ethnicity Sex	--(5), if R/E or Sex determines propensity to acquire certain APT's. Does it? Which ones? --(1), if overt or subtle descrimination removes some x's or z's from opportunity sets.
Household Size	--to some extent, an indicator of (8).
Unemployed	--(4), if it indicates a temporary change in the marginal opportunity cost of time. If unemployment is voluntary, it indicates something more permanent about the respondent's MOC of time. --(7), temporary change in full income. --(5), if unemployment frees up time for the acquisition of APT's.
Rural/Urban	--(3), a crude indicator. --(5), if R/U residence indicates something

	about opportunities to acquire APT's. In this context R/U for the first two decades of life may be a better APT indicator than current R/U residence.
	--(1), perhaps some xs are available in R but not U, as vice-versa.
	*--Unfortunately, R/U may indicate different beliefs about the state of nature with respect to markets in environmental goods: R may feel environmental goods should be free and available in virtually unlimited quantities, while U may not object to paying for restricted quantitives.
Location of residence	--(3), perhaps a little better indicator than R/U. However, location is unlikely to identify all of the respondents enjoying a particular Y_k.
	--(5), e.g., Florida residence increases the travel component in the activity production function for downhill skiing.
	--(1). Maybe some X's are unavailable in some localities.

*These are considerations of how effectively a respondent uses a CV instrument to reveal his true WTP, not the value of his true WTP.

Water/Fish/Swim/Boat (From RFF water quality instrument)	--(5). However, it is crude, since it fails to distinguish among e.g. different fishing APTs. (A sociologist has identified 5 classes of trout fishermen; perhaps he means people possessing 5 categories of trout fishing APTs.)
Walk along the Ridge? (From U.C. Indiana Dunes instrument)	--(5); but, which APT's? --(4), maybe: Marginal opportunity cost of time is low enough to permit walking.
Binoculars? (From U.C. Indiana Dunes instrument)	--(5)? Actually, it indicates the decision to purchase a specific x.
Environmentalist	--(6), an "attitude" to the sociologist. --(5), to a Stigler-Becker economist. But which APT's do respondents associate with the word "environmentalist? (After all, it is self-reported?)

To summarize, these traditional variables provide the following qualities of information in each of the 8 categories:

(1) Almost nothing. Every variable which may be interpreted in terms of (1) has at least one other interpretation. None is yet specific to any particular category of x's, z's, or c's.

(2) Nothing about input prices, but in a static, cross-sectional variation in input prices may not be especially significant.

(3) Very little. Only R/U and Location address this issue, and both are very blunt proxies.

(4) Very little. Only Unemployment and "Walk along Ridge?" address this issue. The Latter, especially, is blunt.

(5) Several variables may address APT, but none is capable of addressing specific categories of APT's precisely and to the exclusion of other APT's.

(6) If you believe Stigler-Becker, (6) is a dead-end street, anyway.

(7) Income is addressed in money terms, but not full income terms.

(8) Only Household Size addresses (8), but it is a blunt indicator.

Further, many of the variables lack any clear *a priori* expectation as to the sign or magnitude of the coefficient, and any clear interpretation of empirical results in term of the conceptual model. This occurs in the cases of variables which say address two or more of the categories, and variables which address, e.g. category (5), but in no clearly-conceived my (e.g. Education, Age, R/E, R/U).

2.2.2.6 Review and Summary

The discsussion thus far suggests that many previous CV exercises may have encountered at least some of the following problems (or, at least, may have been suspected of being susceptible to some of them):

1. Strategic bias: There is agreement that scope for strategic bias exists but little evidence to suggest that strategic behavior is *prevalent*.

2. Conservative/cautious initial response. That is, the kind of unsure and unconfident initial reaction to new and radically different hypothetical markets which may be the cause of WTP understatements noted by Bishop and Heberlein.

3. Unsatisfactory bid equations.

   a. small samples.

   b. bids, themselves, may be poor quality data.

      (i) the good being bid for may be incompletely perceived, or perceived differently across respondents.

      (ii) respondents may have difficulties arriving at what is, for them, the optimal bid.

   c. poor specification of bid equations.

      (i) independent variables poorly defined.

      (ii) independent variables imprecisely measured.

      (iii) poor selection of independent variables, resulting from inadequate conceptualization of the process through which environmental goods acquire value.

Of the 8 categories of variables which the conceptual model suggests as likely to influence WTP for atmospheric visibility, five seem especially important. Let us consider these five categories of variables, attempting to identify and define variables appropriate for observation and use in WTP equations.

Full Income (7): Annual value of household consumption is important, i.e., annual household disposable income corrected for saving or dissaving. However, gross annual household income is most readily observed. Also important is net worth, since especially in higher age groups, consumption is financed in part by dissaving.

Marginal Opportunity for Cost of Time (4): The expected wage rate for one additional hour of work weekly is important. The question must be worded carefully, to ensure that respondent does not interpret it to mean "the reservation price for an additional hour of work."

Competing Demands on the Household Budget (8): Household size is important. It is also desirable to know the life cycle stage of the household (young children, college students, aged dependents, etc.).

Endowments of Nonrival Goods (3): Of particular importance is the definition of bundle of nonrival goods available for consumption jointly with atmospheric visibility.

a. big city/town/rural non-farm/farm.

b. coastal/mountains, hills/flatlands.

c. some indication of the variety and aesthetic quality of the vistas encountered in the course of normal activity (at home, at work, commuting, shopping, local recreation). Secondary evaluation based on, say, zipcode, is not good enough, since within a locality different residential addresses, workplaces, and patterns of activity will lead to different view exposures. More satisfying than secondary evaluation is the self-reported subjective evaluation, e.g. "in course of a typical week, would you say that the most attractive view to which you are regularly exposed are: spectacular? more pleasant views than most folks get to see regularly? ordinary views? worse than ordinary?

In a study-region-wide sample, it is useful to know whether the respondent is concerned primarily with his own locality, or whether his concern is geographically broader.

d. Do you expect to live here for the indefinite future?

or, do you expect you might move to a place selected because, among other reasons, it is scenically attractive?

or, do you expect you might move, but the decision would be unrelated to scenic concerns?

e. Do you usually vacation

--at home?

--at a place where

--you spend most of the time indoors?

-- . . . . outdoors, urban?

-- . . . . outdoors, rural?

-- . . . . outdoors at a place chosen.

among other reasons,for its scenic vistas?

Seasonal aspects of WTP for visibility, climatic aspects (temperature, cloud cover, snowfall, etc.--secondary data) are of interest in analyzing a broad cross-sectional sample.

Activity Production Technology (5): Activity production technology may, in concept, be observed directly,or indirectly via observation of purchased goods used (x's), activities produced (z's), or characteristics enjoyed (c's).

a. Direct observation of APT's.

--visual acuity (is it "too much" to ask respondent to submit to a simple eyesight test?).

--powers of observation: in the evening, if asked, do you think you could accurately describe visibility conditions during the preceding daylight hours?

--knowledge of what is being viewed:--identification of features of scenes, e.g. animal/bird/plant species, distant objects, geological formations, etc.

--identification of location of U.S. scenes represented in photographs.

--health and physical fitness (self-reported? enumerator evaluated?).Presumably this is a major element in APT's for vigorous outdoor activities which use visibility as an input.

--acquired skills: do you hold a pilot's license? have you ever been recognized (e.g. by winning a prize or selling your work) for landscape painting or photography? do you feel confident doing the following things: rock climbing or mountaineering; hiking through the back country; taking a good landscape photograph; walking/running/bicycling long distances; cross-country skiing?

b. z's produced

--list them all (data overload)

--indicate if you regularly engage in any activities in the following categories:

strenuous outdoor	--rural scenic (examples: hiking, biking, backpack).
	--urban scenic.
	--non-scenic (examples: tennis, team sports).
other outdoor	--rural scenic (examples: picnicking, sunbathing, flying, driving to enjoy scenery).
	--urban scenic.
	--non-scenic.
indoor view-oriented	--looking out the window.
	--looking at collections of landscape photography.

c. <u>x's bought</u>

--binoculars, cameras with telescopic lenses.

--equipment for activities which use visibility as an input (it could be a long list).

d. <u>c's provided</u>: Probably not much of value can be gained by getting a list of the visibility related characteristics from which respondents, derive satisfaction.

Visual. characteristics probably serve two purposes: (1) a source of aesthetic pleaure, and (2) an indicator of the health and comfort related aspects of air quality. Since it is important to isolate the visibility affects from the health and comfort affects, it may be useful to ask: indicate on this list the things you associate with atmosphere conditions depicted in the (worst case) set of photographs (list includes respiratory distress, poor color contrast, eye irritation, poor long distance visibility, poor ventilation in homes, etc. in addition to "placebo" and "decoy" items).

2.2.3 Strengths and Weaknesses of Contingent Valuation

For more than a decade contingent markets have been used to elicit individual valuations of unpriced (usually, nonrival and/or nonexclusive) goods and services. The basic idea is that the researcher constructs a model market in considerable detail and, in a survey or experimental setting, communicates the dimensions and characteristics of that market to the subject. The researcher specifies an increment (or decrement) in some good or service and invites the subject to make a conditional dollar-valued offer to buy (sell) the increment (decrement). The conditional offer is contingent on the existence of the model market as structured and communicated to the respondent; hence, the term contingent valuation. However, the exercise does not involve the actual exchange of goods and services for money.

Contingent valuation has several advantages, which seem likely to encourage its more general use. (1) Contingent markets may be inexpensively constructed and used by subjects (see, e.g., the argument of Brookshire and Crocker, 1981). Market structure and rules, and the quantity and quality dimensions of the good or service involved, may easily be manipulated in a conscious experimental design strategy; and such manipulations need not be limited to the currently observed range of market rules and quantities/qualities. (2) Contingent market data are generated in forms consistent with the theory of welfare change maeasurement (Bradford, 1970; Randall, Ives and Eastman, 1974; Brookshire, Randall and Stoll, 1980). (3) Contingent markets do not rely on the actual delivery of goods and services. Thus, their use is not limited to cases in which delivery is feasible and convenient to the researcher.

Other candidate techniques for valuation of unpriced goods do not enjoy all of these advantages. Indirect methods of inferring value data by observing actual markets in related goods (e.g., the travel cost, land value, and hedonic methods) have considerable failings with respect to points (1) and (2) above. The theoretical difficulties implicit in the restricitive assumptions required to yield value estimates from these kinds of observations should not be underestimated. Experiments with actual markets for exclusive but not customarily marketed goods may sometimes be contrived (Bishop and Heberlein, 1979). Perhaps more opportunities exist for incentive-compatible (Groves and Ledyard, 1977) laboratory experiments in which groups of subjects contribute toward the purchase of collective (i.e., nonexclusive and often, nontival) goods. However, these kinds of methods are adaptable for value-revealing purposes (as opposed to work with induced preferences, see Smith, 1977 and 1980) only in cases when the direct and side payments can be actually collected and the collective goods actually delivered--a restrictive condition.

The discussion thus far suggests that, if contingent valuation methods were generally accepted as accurate, there would be little reason to use other kinds of valuation methods in benefit cost analyses of programs that provide unpriced goods. However, it has generally been assumed from the outset that the accuracy and reliability of contingent valuation methods is minimal. Two blanket criticisms were raised: (1) “everybody knows” that hypothetical questions rarely enjoy accurate responses; and (2) “everybody knows” that where nonexclusiveness or nonrivalry are involved, strategic behavior is general, and the data collected are nothing but the pooled products of individual attempts to mislead the researcher.

In spite of the pervasive skepticism engendered by these sweeping criticisms, there has accumulated a body of evidence to the effect that considerable real information can be generated in contingent markets. In early applications, Davis (1963) and Randall, Ives and Eastman (1974) obtained results which were plausible and which did not fail certain (rather minimal) validation tests. The results of the last-mentioned study were later replicated by Brookshire, Ives and Schulze (1976) and Rowe, d'Arge and Brookshire (1980). Starting with Knetsch and Davis (1966) recreation demand analysts have consistently demonstrated comparability between the results of contingent valuation and travel cost methods. More recently, Brookshire _et al._ (1982) have demonstrated considerable consistency between results of hedonic analysis and contingent valuation.

Individual willingness to pay for nonexclusive or nonrival goods, as revealed in contingent markets, exhibits some regularities. Many researchers have found the theoretically expected relationships between individual bid and income (among others, Brookshire, Randall and Stoll, 1980; Mitchell and Carson), quantity of the good offered (Brookshire, Randall and Stoll, 1980) and the availability of substitute goods (Majid, Sinden and Randall). Socio-demongraphic and attitudinal variables are sometimes significantly related to bid (Brookshire, Randall and Stoll, 1980; Mitchell and Carson). These variables seldom account for a large proportion of the variance in individual bids. However, when individual observations are grouped in some way, to reduce the influence of outlying observations, much of the variance in bids across groups can be explained[1] (Brookshire, Randall and Stoll, 1980).

Nevertheless, some reasonable doubts about the accuracy and reliability of contingent valuation persist. (1) The possibility has been raised that contingent markets in general, or in particular formats may be susceptible to various biases. This line of thinking leads to a cataloging of potential biases and empirical testing to determine the presence if any of the identified biases in particular data sets[2] (Brookshire, Ives and Schulze, 1976; Rowe, d'Arge and Brookshire, 1980; Schulze, d'Arge and Brookshire, 1981). Some of these biases are merely problems to which all survey research is susceptible, and sound research procedures are routinely available for their avoidance (e.g., sampling and interviewer biases). Others are more interesting: "strategic bias," "hypothetic bias," "starting point bias," and "information bias." However, there is nothing compelling about the taxonomy developed by Brookshire and his associates. Grether and Plott (1979) develop a quite different taxonomy, in an attempt to explain apparent preference reversal; and Mitchell and Carson quarrel with several aspects of the Brookshire *et al*. discussion.

"Strategic bias" is fairly clear. It provides the basis for the mainstream economic analysis of nonexclusiveness and nonrivalry; and it is strategic bias the incentive-compatible mechanisms (Groves and Ledyard, 1977) are designed to thwart. The basic idea is that when the consequences of truth-telling are more costly to the individual than those of some prevaricating stretegy, truth-telling inevitably gives way to strategizing. Since most contingent markets provide disincentives for free-riding, the most likely strategy is for an individual to bid in a way which exaggerates the difference between his true bid and his expectation of the sample mean bid, so as to move the sample mean bid toward his true bid. Pervasive behavior of this kind would increase the variance of a sample of bids, in the extreme producing a bimodal distribution. Given a minimum acceptable bid of zero (for an increment in a positive-valued good) but no *a priori* maximum limit, such behavior would bias sample mean bids in an upward direction.

"Information," "starting point" and "hypothetic" biases are not so clear. In the hands of Grether and Plott (1979) these concepts merge to become Theory[3] 8: the notion that, in the absence of good reasons to care about the consequence of their responses, subjects minimize investment in information processing and decision making by clutching at any "anchor" provided in the question format. As it turned out, Grether and Grather and Plott experimentally rejected Theory 8 by finding that introducing real incentives (reasons to care about consequences) did not diminish apparent preference reversal. In contingent valuation, there is little evidence of the general occurrence of "information" and "starting point" bias. Rowe, d'Arge and Brookshire (1980) claim to have found both kinds of bias in a single data set, but that finding appears to be the exception rather than the rule. The interpretation of "information" bias is controversial, since significant changes in the information provided to respondents must change the quantity/quality definition of the good being offered or the structure of the contingent market. Thus, a finding that changes in information generate changes in bids can seldom be unambiguously interpreted as a finding of bias. Often, it shows a rational response to a change in the situation posited, and provides more reason for comfort than alarm.

While Schulze, d'Arge and Brookshire (1981) argue that "hypothetic" and "strategic" biases are opposite sides of the same coin--contingent markets which give subjects less reason to care are susceptible to "hypothetic" bias while those that offer more reason to care are susceptible to strategic influences --Mitchell and Carson attempt a more subtle distinction. They suggest that both kinds of bias can be simultaneously minimized by constructing realistic contingent markets but reassuring subjects that actual bids will not be collected during the experiment.

"Hypothetical bias," if it occurred, would increase the variance of bids. Given a lower limit of zero for acceptable bids but no upper limit, its influence would also be in the direction of overestimating true sample mean bid.

(2) A second attack on the efficacy of contingent markets focuses directly on the size of the value estimates obtained. Mitchell and Carson appear to be stating that conventional wisdom when they claim that contingent markets generally overestimate the true sample mean value of the nonexclusive and/or nonrival good under consideration. However, there is surprisingly little evidence to support this position. Bohm (1972) found a small upward bias when payemnts were hypothetical, but Mitchell and Carson question his interpretation of the evidence. Babb and Scherr (1975) found no evidence of bias in either direction. Brookshire et al (1982), in a comparison of hedonic and contingent valuation results, found good correspondence. A close examination of their analysis suggests that, if the contingent valuation results deviate at all from the true values, that deviation is almost surely on the downward side. Bishop and Heberlein (1979) compared contingent valuation results with those of a willingness-to-sell experiment in which actual exchange was consumated. They reaffirmed that contingent willingness to sell (in situations where selling is not customary or morally acceptable in the real world) leads to substantially larger value estimates than contingent willingness to pay--a well-established finding. Of more interest, they also found that contingent willingness to pay yielded considerably lower value estimates than actual willingness to sell--a finding which they interpret as showing that contingent WTP substantially underestimates true value.[4]

The evidence seems to suggest that the conventional wisdom is unsupportable. There is almost no evidence that contingent WTP over-estimates true value, but there is some evidence to suggest underestimation.[5]

(3) A third source of doubts about the efficacy of contingent markets focuses not on mean sample bid but on the frequency of extreme bids. Starting with Randall, Ives and Eastman (1974) researchers routinely separate “protest bids” (that is, those zero WTP on infinite willingness to accept, WTA, bids which the subject identifies as a protest against some aspect of the contingent market structure) from the sample of bids prior to calculating the sample mean value estimate. The frequency of protest bids in various contingent markets has ranged from less than ten percent of all bids to more than fifty percent (Mitchell and Carson); so, it appears that the structure of contingent markets influences the quality of data obtained. While the literature contains less discussion of “high bids," most researchers find a few scattered respondents bidding a substantial fraction of annual income for increments in a single nonexclusive or nonrival good. While there exists no perfect test for strategic bids, most researchers take one of the following two courses: reject all bids above some arbitrary maximum, expressed as a dollar amount or a fraction of annual income; or reduce all high bids to the arbitrary maximum. The first approach arbitrarily treats all high bidders as dissemblers. The second grants some plausibility to high bids and, rather than disenfranchising high bidders, seeks to limit their influence on the sample mean bid. While we can be less certain that high bids are poor-quality data than we can about protest bids, contingent valuation researchers tend to treat both kinds of bids as unreliable and focus

their analysis on those bids which are identified as neither protest bids nor “too high."

This approach, incidently, parallels Smith’s (1980) discussion of his experiments, in which he treats zero-bidders as free-riders and endowment bidders as anti-free-riders (p. 396).

Let us attempt a very brief summary of what is now known about contingent markets.

1. Contingent markets are not incentive-compatible, but strategic behavior does not seem to be pervasive among human beings asked to contribute toward providing collective goods (Marwell and Ames, 1974; Smith, 1980; Sweeney, 1973). That does not mean that strategic behavior never occurs, just that there appears to be a substantial class of decision contexts in which a good many people do not behave strategically.

2. Contingent markets do not deliver the goods and collect the payments, but that does not necessarily render them wildly unreliable. The data sets collected via contingent valuation have, for the most part, performed fairly well in those quality tests which have been applied to them. This finding is consistent with the result of Grether and Plott (1979), who found that the introduction of real consequenses for their subjects did little to change decisions those subjects made in experimental contexts.

3. Contingent markets collect some “junk data”: protest bids, for sure, and presumably some of the high bids. However, they appear to collect a solid core of serviceable value data. These findings are entirely consistent with Smith’s (1980) experimental results.

4. Analyzing this solid core of serviceable data, we find no evidence that it consistently overestimates true value. If anything, the evidence

points to underestimation. In addition, individual bids are to some extent regular and predictable. In short, the solid core of data generated via contingent markets is neither fanciful nor random.

5. The structure of contingent markets does appear to have some (perhaps limited) influence on the value data generated. This ought not be surprising in principle--the performance of real-world and actual-experimental markets is influenced by their structure--but it is an appropriate subject for further investigation.

The remainder of this section reports some preliminary results of an experiment designed to explore two aspects of market structure: (1) the number of distinguishable commodities offered for bid and the sequence in which offered, and (2) the process in which bid data rea collected.

An extensive contingent valuation pilot study for the visibility project was consciously designed to permit, inter alia, experimental testing of the effect of contingent market structure on the characteristics of the bids generated. The general objective was to empirically explore the two apects of contingent market structure identified in the preceding paragraph. We proceed as follows. A conceptual framework is developed and specific empirically testable hypotheses are generated there from. Data collection procedures are briefly described. Analytical procedures consistent with the conceptual framework are introduced and used in hypothesis testing. Some preliminary results are presented and briefly discussed.

2.2.4 Conceptual Framework for Contingent Valuation

Consider a household which at any time is producing a simple activity γ_i selected from the vector $\underline{\gamma}''[\gamma_i]$. Its activity production function is

$$\gamma_i = \gamma_i(\underline{\chi_i}, q_i, \alpha), \quad 0 = \gamma_1(0, q_i, \alpha), \tag{2-23}$$

where $\underline{\chi_i}$ is a vector of priced goods with prices $\underline{p_i}$, q_i is an unpriced nonrival good and α is the household’s activity production technology. If π_i is the probability that the household is producing γ_i, and i is limited for convenience to the values 1, 2 and 3, and y refers to other goods, the indirect utility function is

$$v(p, q, \pi, \alpha, m) = \max u(\pi_1 \cdot \gamma_1 + \pi_2 \cdot \gamma_2 + \pi_3 \cdot \gamma_3, y) \tag{2-24}$$

$$\text{subj. to } y + \sum_{i=1}^{3} \underline{p_i}\, \chi_i = m,$$

$$\text{and} \quad \gamma_i(\chi_i, q_i, \alpha) = \gamma_i \quad .$$

Using duality and the expected utility property,

$$c(p, q, \pi, u) = \min y + \sum_{i=1}^{3} \underline{p_i}\ \underline{\chi_i} \tag{2-25}$$

$$\text{subj. to } \sum_{i=1}^{3} \pi_i\, u[\gamma_i(\underline{\chi_i}, q_i, \alpha), y] \quad .$$

Letting the utility function be specified such that $\partial u/\partial \underline{\chi_i}\big|_{\underline{\chi_i} = 0} < \infty$, there may exist prices $\underline{p_i}$ at which the household would choose to set $\underline{\chi_i}$ and γ_i equal to zero.

With the expenditure function defined, consider a change in the level of provision of nonrival good[6] q_i.

(2-26) $$\partial e/\partial q_i = -\gamma\pi_i \partial u/\partial \gamma_i \cdot \partial \gamma_i/\partial q_i$$

$$= \delta_i(p, q, \pi, \alpha, u) \leq 0 \quad .$$

While the conceptual framework for contingent valuation is often derived via an income compensation function approach (section 2.2.2.2), it is possible to proceed via the expenditure function. For the moment, suppress α (which is used below in the empirical analysis) and π (which is of more interest in analyses explicitly directly toward option price, (see Schmalensee, 1972, and Graham, 1981), so that

$$e(p, q, u) = e(p, q, \pi, \alpha, u).$$

At an initial situation (p°, q°), the household requires $m^\circ = e(p^\circ, q^\circ, u^\circ)$ to attain u°. If the level or provision of a single environmental good q_i changed to q_i', the minimum expenditure to attain u° would be

$$m' = e(p^\circ, q', u^\circ) \quad .$$

The welfare impact of that change, in compensating surplus terms (Randall and Stoll, 1980) is

(2-27) $$CS(q_i^\circ, q_i') = e(p^\circ, q', u^\circ) - e(p^\circ, q^\circ, u^\circ)$$

$$= e(p^\circ, q', u^\circ) - m^\circ \quad .$$

Locating $e(p^\circ, q, u^\circ)$ in the real plane with (p°, m°) as the origin, $e(p^\circ, q, u^\circ)$ describes the indirect version of the familiar Bradford (1970) bid curve.

Now consider in all three nonrival environmental goods, i = 1, 2, 3. For clarity, we express $q = (q_1, q_2, q_3)$ as

$$e(p, q, u) = e(p, q_1, q_2, q_3, u) .$$

For a change from $q^\circ = (q_1^\circ, q_2^\circ, q_3^\circ)$ to " $= (q_1', q_2', q_3')$,

(2-28) $$CS(q^\circ, q'') \equiv e(p^\circ, q'', u^\circ) - e(p^\circ, q^\circ, u^\circ)$$

$$= \int_{q^\circ \atop C(q)}^{q''} \partial e(p^\circ, q_1, q_2, q_3, u^\circ) | \partial q \, dq ,$$

where C(q) denotes some path from q° to q''.

Choosing a particular rectangular path from q° to q'', say $(q_1^\circ, q_2^\circ, q_3^\circ)$ to $(q_1', q_2^\circ, q_3^\circ)$ to (q_1', q_2', q_3°) to (q_1', q_2', q_3'), the line integral (2-28) can be transformed to the sum of several ordinary integrals,

(2-29) $$CS(q^\circ, q'') \equiv e(p^\circ, q'', u^\circ) - e(p^\circ, q^\circ, u^\circ)$$

(2-29.1) $$\equiv \int_{q_1^\circ}^{q_1'} \partial e(p^\circ, q_1, q_2^\circ, q_3^\circ, u^\circ)/\partial q_1 dq_1$$

(2-29.2) $$+ \int_{q_2^\circ}^{q_2'} \partial e(p^\circ, q_1', q_2, q_3^\circ, u^\circ)/\partial q_2 dq_2$$

(2-29.3) $$+ \int_{q_3^\circ}^{q_3'} \partial e(p^\circ, q_1', q_2', q_3, u^\circ)/\partial q_3 dq_3 .$$

An alternate rectangular path from $(q_1^\circ, q_2^\circ, q_3^\circ)$ to $(q_1^\circ, q_2^\circ, q_3^\circ)$ to (q_1°, q_2', q_3') to (q_1', q_2', q_3') results in the same aggregate valuation as in (2-29):

(2-30) $$CS(q^\circ, q'') \equiv e(p^\circ, q'', u^\circ) - e(p^\circ, q^\circ, u^\circ)$$

(2-30.1) $$\int_{q_1^\circ}^{q_1'} \partial e(p^\circ, q_1, q_2', q_3', u^\circ)/\partial q_1 dq_1$$

(2-30.2) $+ \int_{q_2^\circ}^{q_2'} \partial e(p^\circ, q_1^\circ, q_2, q_3', u^\circ)/\partial q_2 dq_2$

(2-30.3) $+ \int_{q_3^\circ}^{q_3'} \partial e(p^\circ, q_1^\circ, q_2^\circ, q_3, u^\circ)/\partial q_3 dq_3$

However, unless $\partial^2 e/\partial q_i \partial q = 0$, (249.1) ≠ (2-30.1), (2-29.2) ≠ (2-30.2) and (2-29.3) ≠ (2-30.3). Thus, we have

Proposition 1: The contribution of an increment in a single q_i to the value of an increment in the q vector from q° to q" varies with the sequence of valuation, unless $\partial^2 e/\partial q_i \partial q_j = 0$.

Further, if $\partial^2 e/\partial q_2 \partial q_1 > 0$ and $a^2 e/\partial q_3 \partial q_1 > 0$ (i.e. q_1 and q_2, and q_1 and q_3 are substitutes[7]) the contribution of q_1 to the value of an increment in the q vector will be greater, the earlier q_1 appears in the valuation sequence.

Identities (2-29) and (2-30) suggest that, in general, it is erroneous to value a change from q_i° to q_i' and a change from q_j° to q_j' independently and then calculate the value of a simultaneous change from $[q_i', q_j']$ by simple addition. Suppose q_1, q_2, and q_3 are substitutes. If we were to proceed as if the valuations of the individual changes were independent, we would measure

(2-31) $V(q^\circ, q'')$

(2-31.1) $= e(p^\circ, q_1', q_2^\circ, q_3^\circ, u^\circ) - e(p^\circ, q_1^\circ, q_2^\circ, q_3^\circ, u^\circ)$

(2-31.2) $+ e(p^\circ, q_1^\circ, q_2^\circ, q_3^\circ, u^\circ) - e(p^\circ, q_1^\circ, q_2^\circ, q_3^\circ, u^\circ)$

(2-31.3) $+ e(p^\circ, q_1^\circ, q_2^\circ, q_3', u^\circ) - e(p^\circ, q_1^\circ, q_2^\circ, q_3^\circ, u^\circ)$.

A well-conceived valuation would recognize the non-independence of q_1, q_2 and q_3 select a policy path (for example, the path in eq. (2.29)), and obtain

$$(2\text{-}32) \qquad CS(q^\circ, q'') \equiv e(p^\circ, q'', u^\circ) - e(p^\circ, q^\circ, u^\circ)$$

$$(2\text{-}32.1) \qquad \equiv e(p^\circ, q_1', q_2^\circ, q_3^\circ, u^\circ) - e(p^\circ, q_1^\circ, q_2^\circ, q_3^\circ, u^\circ)$$

$$(2\text{-}32.2) \qquad + e(p^\circ, q_1', q_2', q_3^\circ, u^\circ) - e(p^\circ, q_1', q_2^\circ, q_3^\circ, u^\circ)$$

$$(2\text{-}32.3) \qquad + e(p^\circ, q_1', q_2', q_3', u^\circ) - e(p^\circ, q_1', q_2', q_3^\circ, u^\circ) \; .$$

In (2-31) and (2-32), only lines (2-31.1) and (2-32.1) are equal. In the case of substitutes, (2-31.2) is larger in absolute value than (2-32.2) and (2-31.3) is larger in absolute value than (2-32.3). Thus we have

Proposition 2 : If $\partial^2 e/\partial q_i \partial q_j \neq 0$, the value of a change in the vector q is not equal to the sum of the independently estimated vales of the changes in the elements of the vector.

Further, if $\partial^2 e/\partial q_i \partial q_j > 0$ for all $i \neq j$, the value of a change in the vector q is less than the sum of the independently estimated values of the independently estimated values of the changes in its elements.

By identifying appropriate valuation and aggregation procedures, (2-29), (2-30) and (2-32) provide important restricitons on the design of contingent valuation exercises.[8] In addition, they provide an explanation for phenomena observed but not well explained in previously reported contingent valuation studies (e.g., Schulze et al., 1981b; and Walsh et al., 1978). In these studies, authors report with some surprise that environmental goods valued later in a valuation sequence are not valued as highly as had been predicted.

Competitive and complementary relationships arising from price changes are frequently observed. It is important to consider the possibility that competitive and complimentary effects are absent or weak for changes in non-rival goods. A possibility is the case where non-rival goods are additively separable in the utility function. In this case, Proposition 1 applies. Let preferences of an individual be represented by an additively separable utility function,

$$u = \sum_{i=1}^{I} \sum_{k=1}^{K} v_i(x_k, q_k) \quad ,$$

where $x_k=(x_{kg})$ is a G-dimensional vector of market goods, $q_k=(q_{kh})$ is an H-dimensional vector of non-rival goods, $k \varepsilon \{1,\ldots,K\}$ indexes subcategories of market and non-rival goods used in v_i, the v_i are each increasing and strictly concave with non-negative second-order cross partial derivatives, and $\partial q_k/\partial q_f=0$ for $k \neq f \varepsilon \{1,\ldots,K\}$. Let

$$e(p,q_1,\ldots,q_K,u) = \min_x px \quad \text{s.t. } u = \sum_{i=1}^{I} \sum_{k=1}^{K} v_i(x_k, q_k) \quad .$$

Then the following properties hold:

(1) For non-rival goods in different subcategories ($k \neq f$) the substitution relationship is competitive ($\partial^2 e/\partial q_{kh} \partial q_{fr} > 0$, all h and r).

(2) For non-rival goods in the same subcategory the substitution relationship may be either competitive, independent, or complementary ($\partial^2 e/\partial q_{kh} \partial q_{kr} \gtrless 0$, all h and r).[9]

Proposition 1 demonstrates that independence in valuation does not arise from additive separability. Indeed, the case of additive separability between non-rival goods results in unambiguous competitive effects.

Where additive separability cannot be assumed, competitive and complementary effects are both possible. Complementary effects may outweigh competitive effects. Less likely is the case where competitive and complementary effects just cancel and result in independence in valuation.

Given the implications of Proposition 1 it is useful to consider the empirical circumstances that may justify additive separability between non-rival tools. Below, we examine two possible cases: the first where an individual enjoys equivalent activities each affected by different sets of non-rival goods and the second where future use is uncertain. These illustrative cases are easily linked to common benefit cost contexts. Thus interpreted, Proposition 1 provides an a priori prediction of competitive effects.

Consider the first case where the household production technology for activity i is not specific to a particular site or region k. Market goods x_k, and non-rival goods q_k, available at site or region k, enter as inputs into the production technology and $a_{ik}=a_i(x_k,q_k)$ Within a given time period total activity production of type a_i is a simple summation over all visited sites or regions k, $a_i=\sum_{i=1}^{k} a_i(x_k,q_k)$. If preferences are defined over a similar time period (say, a month or a year) utility can be written

$$u = u[a_i,\ a(x,\omega)] \tag{2-33}$$

$$= u[\sum_{i=1}^{K} a_i(x_k,q_k), a(x,\omega)] ,$$

where a(.) is a vector of other activities, x is a vector of market goods, and ω is a vector of non-rival goods specific to a(.). If activities a_i are broadly defined and do not directly and strongly affect the enjoyment of other activities $(\partial^2 u/\partial a \partial a_i = \jmath \cdot$ (a constant)), then utility is approximated by

$$u = \sum_{i=1}^{K} a_i(x_k, q_k) + \jmath' a(x, \omega) \quad , \tag{2-34}$$

where $\jmath$ is a vector of ones conformable to $a(x,\omega)$. On grounds of convenience, additive separability as in eq. (2-34) is a common assertion in both economic theory and econonometrics (Deaton and Muelbauer). Moreover, in this case of equivalent activities over different sites or regions, additive separability has strong intuitive appeal. For instance, enjoyment of slack-water recreation at site k is not likely to be directly affected by water quality at site m; snowskiing activities at site n are not likely to be directly affected by the slopes available at site p.[10]

A second source of dominating additivity comes from the rationale underlying option demand and option price. Consider a simple case where an individual faces the future possibility of either recreating within the region of residence or visiting one of two unique but distant recreation areas. By unique we mean that activity production technology is peculiar to the recreation itself. For an easterner, candidate areas might be the Grand Canyon National Park or Yellowstone National Park; for a westerner, the Maine coast or the Florida everglades. If the areas are indeed distant and quite costly to visit relative to home region alternatives, the probability of future use is likely to be small and dominated by exogenous random elements rather than explicit individual choice. With probabilities of visitation parametric to the individual at the time of valuation, the expected utility model can be meaningfully applied.[11] Supposing the conventional additive utility structure over time, expected utility in future period t is

$$(2\text{-}35) \qquad u_t = u_t\left[\sum_{t=1}^{3} \pi_{tk} \circ z_{tk}(x_{tk}, q_{tk})\right] \quad ,$$

where $\sum_{t=1}^{3}$ denotes a lottery over the three described possibilities, k=1, 2, 3, and π_{tk} is the probability that in time period t recreational activity z_{tk} is chosen. For simplicity, suppose there is only one future period and that we can therefore suppress the notation t. Using the expected utility property,

$$(2\text{-}36) \qquad u = \sum_{k=1}^{3} \pi_k u[z_k(x_k, q_k)]$$

$$= \sum_{k=1}^{3} \pi_k u_k(x_k, q_k) \quad ,$$

where $\sum_{k=1}^{3}$ denotes arithmetic summation. Thus, the case of parametric uncertainty leads to additive independence between activities and respective non-rival goods by a fairly direct route.

Proposition 1 is straightforwardly translated into the two valuation contexts detailed above. In the context of equivalent activites at different sites or in different regions, let $v_1(.)=a_i(.)$ and let the $v_2(.),...,v_I(.)$ equal the respective I-1 elements of $a(x,\omega)$. Subcategory indexes conform to the site-or region-specific indexes of the market and

ition 1, then, non-rival goods used
erent regions are competitive in
me activity at the same site or
or complementary. To translate
n visitation, let K=3 , $v_i(.)=\pi_k u_k(.)$,
The subcategories index services specific
ivalent activities, non-rival goods
ions but may be either competitive,
thin the same region.

Table Page

stics of a given choice context can lead to
activities and categories of non-rival goods in the
additive separability between activities in the utility
independence in valuation. Quite the contrary. Given a
level of some non-rival good, an individual maintains
educed expenditure by shifting activity production
more productive activities and away from the relatively
thout direct complementary effects, activities
rival goods become relatively less productive. As individuals
y from these less productive activities, the value of associated
s declines. Thus, where non-rival goods are additively separable
onstrained expenditure minimization imposes strictly competitive
cross-qu ty valuation effects.

Propositions 1 and 2 provide the basis for a major empirical hypothesis to be tested in the experiment reported below. Nonindependence and the associated question of valuation sequence constitute one of the questions of contingent market structure. The other question concerns the process in which value data (individual bids) are collected.

The literature reports a variety of ways to collect bids. Published studies have used devices ranging from a single direct question (e.g., Hammack and Brown, 1974), iterative bidding routines (e.g., Randall, Ives and Eastman, 1974), checklists (e.g., Schulze _et al_. 1981b) and payment cards (e.g. Mitchell and Carson). Considering this array of devices, we identify two important dimensions of the value data collection process: (1) the extent to which it provides the opportunity to iterate toward the maximum WTP (i.e., the points of indifference between paying WTP and obtaining the good, and doing neither); and (2) the amount of value-relevant or price-relevant information provided in the format. The payment card device (Mitchell and Carson) provides information on the cost per typical household of various public programs now in effect. A modified payment card developed by the authors provides additional information on typical annual expenditures for various market goods. Considering these two dimensions of the value data collection process, we propose the set of hypotheses 2, below.

The experiment reported below was designed to test the following hypotheses.

Hypothesis 1: The estimated value to Chicago residents of a specified atmospheric visibility program for the Grand Canyon is greater if measured independently than if measured last in a sequence which first considers programs for Chicago and all of the U.S. east of the Mississippi.

This hypothesis is derived from proposition 1.

Hypothesis 2: (a) The quality of value data is improved by the use of devices which permit more opportunities to iterate toward maximum WTP.

(b) The quality of value data is improved by the use of devices which provide a greater quantity of value-relevant (or price-relevant) information to assist the respondent in decision making.

We offer no hypothesis concerning the trade off between opportunity to iterate and the provision of value-relevant information.

To operationalize hypotheses 2(a) and (b), measures of value data quality must be defined. We propose the following measures:

(i) The larger the solid core of serviceable value data in a data set, the higher its quality. That is, the higher the frequency of protest bids and "too high" bids, the lower the data quality.

(ii) Since strategic and hypothetical influences both seem likely to increase the variance of a value data set, lower variance in individual bids is taken as an indicator of a better data set.

(iii) Increased regularity and predictability of a value data set is taken as an indicator of better quality. Thus, data sets which yield better bid equations are taken to be of higher qualtiy.

(iv) Since the evidence appears to tilt toward the conclusion that contingent markets underestimate sample mean values, any data set which exhibits unusually low mean bid (relative to the other data sets) is taken as of poor quality.

2.2.5 Structure of Contingent Valuation Instruments

As described above, both region-wide and special, geographically limited contingent valuation studies were carried out. The region-wide or general study instruments were of modular design to facilitate pre-testing and the coordination of the general and special studies. There are seven basic modules to the general study instrument.

Module 1: Area Context Module

The area over which visibility improvements were offered were required to be clearly comprehended by each individual. For the research to provide, among other things, guidance as to sub-regional allocation of resources for air quality improvement, it was important to collect WTP data for improvements in visibility (i) in the individual's home sub-region, and (ii) in the whole study region. Thus, for different purposes, the area context differed increasing the burden of communicating the area context to subjects.

Since the eastern region is larger than the customary territorial range of individuals, a map card as well as a portfolio of photographs were used to convey the size and diversity of the region over which visibility is valued.

Module 2: Visibility Module

The nature of alternative levels of visibility can best be communicated via color photographs. This required a set of scenes representative of the area over which visibility changes were to be valued. For each level of visibility a set of the same scenes, with only the visibility different, was used. Some purely factual verbal material (on cards, and delivered orally) was used to quantify the visual range represented in each photo set. In order for WTP for visibility improvements in both the home sub-region and the whole study region to be elicited separately, separate photo sets were needed to represent both the sub-region and the entire East.

Module 3: Activity Module

Since we conceptualize $V_i(w_{jk})$ as the value of visibility as an input in the production of z_{ijk}, it had to be hypothesized that $V_i = f(z_{ijk} \ldots)$. To test that hypothesis, it was necessary to know the following:

1) the activities produced in the household,
2) the inputs, other than visibility, used in activity production,
3) the activity production technology used, and
4) whether <u>visual</u> air quality is the only air quality input used and, if <u>not</u>, whether visual air quality is used by the subject as an indicator of other aspects of air quality, For example, the individual may avoid strenuous outdoor sports on days of poor

> visibility, not because visibility *per se* is an important input, but because he treats poor visual air quality as an indicator of high pollutant concentrations which treatening respiratory stress.

The activity module was vital to the estimation of equation (3). In addition, the module served to sensitize the individual to the full variety of activities in which he might value visibility, thus eliminating possible sources of underestimation of V_i. A complete breakdown of all relevant activities would have been time-consuming and would have generated more data than could effectively be used in statistical analyses. Therefore, at the pre-test stage, considerable effort was allocated to devising and testing ways to more efficiently serve the basic purposes of this module.

Module 4: The Market Module

Contingent valuation established a hypothetical market and encouraged individuals to reveal their WTP by using that hypothetical market. Thus, the structure of hypothetical market was a major influence on the quality of WTP data. Major elements of this module described what was being purchased through the bid and the market rules regulating payment for and receipt of the good in question. To describe the good available for purchase, the general level of visibility as well as possible increments and decrements in visibility were portrayed in both photographs and narratives. Market rules provided assurance that the increment in visibility would be delivered if and only if the respondent was willing to pay. At the pre-test stage, alternative versions of the market module were developed and tested for their effect on bidding behavior.

Module 5: The WTP Data Collection Module

This module presented the fundamental WTP questions. In the Chicago research, questions were structured in several different ways. The first simply asked for a statement of WTP for some given improvement in visibility, the second used checklists of possible values from which a number representing maximum WTP was selected. The third used an iterative bidding format (e.g., Randall, et al, 1974). The fourth format presented information on relative tax prices of other public sector goods and then called for a statement of WTP for an increment in visibility. In this approach, the relative prices of other public programs served as reference points for the respondent.

Intensive pre-testing of WTP modules context was carried out. New WTP module designs were developed and tested. The most important modification to be introduced during the pre-test was the marginal bid question. Respondents bid first on local improvement, and then were asked how much they would add to their local bid to extend the improvement to the East and then to the entire U.S.

Module 6: Post-Bid Probing

With certain market rules and WTP formats, some individuals recorded a zero WTP which, in further questioning, turned out to be a protest against some aspect of the format rather than an accurate reflection of the value of the good offered. Probing of zero WTP's was, therefore, a routine element of the data collection schedule.

Even with protest bids eliminated, it has recently been shown that WTP data generated by individuals who are in some way uneasy with the market rules and WTP format exert a highly significant downward influence on mean WTP

(Brookshire, Ransdall, and Stoll). Thus, it was necessary to provide opportunities for subject to confidentially evaluate the WTP instrument for credibility/plausibility and their own responses as valid WTP indicators. These evaluations were taken into account in developing the CV instrument used in the six eastern cities.

Module 7: Socio-Demographic Data

This module collected an array of socio-demographic data used to estimate equation (3). It has been argued (Second Quarterly Progress Report, Exhibit C) that full income concepts are highly relevant to the processes through which individuals demand and hence value, visibility. Thus, questions have been included in the CV instrument to capture the concept of full income and collect the appropriate data.

Implementation of Contingent Valuation

Following completion of those special studies which were designed to serve as pre-tests and pilot studies for the general study, the general study instrument was finalized. A region-wide data set was assembled during the winter of 1981 and analysis was completed during by January 1983.

Special studies address key issues in the design of effective contingent valuation devices. Two objectives were served: (1) the selection of thoroughly tested contingent valuation devices for use in the general study; and (2) the generation of experimental data sets which permitted formal comparison of the effectiveness of contingent valuation devices under consideration for use in the general study and additional devices used in previous research. Thus, this phase of the research design was intended to permit advances in the implementation of contingent valuation.

Formal experiments compared alternative systems of disincentives for strategic and hypothetical biases, and alternatives WTP data collection formats. The latter effort tested the four basic formats identified above, a fifth format combining formats (3) and (4), and two experimental formats newly devised during the current research. The two new formats were, resepectively, an "interative bidding with budget breakdown and reiteration" format, and group decision format utilizing linked computer consoles.

This work permitted (1) the first rigorous test of hypotheses about the efficieincy of a wide variety of WTP formats, (2) the selection of one, well-validated, WTP format for use in the general study, and (3) by selecting for study some visibility values in specific markets, also examined via secondary data analyses, the completion of test for corroboration and replication of CV results with behavioral data.

In addition to formal experiments, a series of informal studies using open-ended questioning, content analysis, and similar techniques were used to explore a series of important issues in instrument design for the general study. The purpose of these informal studies was to gain an understanding of citizen's perceptions in order to permit more effective communication with the general study subjects, and to develop more effective ways of obtaining important and/or sensitive information. Informal studies explored:

___how citizens conceptualize visibility, and the effectiveness of color photographs in communicating visibility to them.

___whether visibility is best presented in typical or in frequency terms.

___the activities Z_{ijk}, for which visibility is an input; in what sense is it an input, i.e., in what ways does poor visibility hinder activity production; is it a major or minor input; is visibility used by citizens as an indicator of other air-pollution-related problems, e.g., respiratory stress; in order to reduce data collection time and data overload, can meaningful categories of activities be developed?

___are there effective ways to gather information about activity production technologies (e.g., acquired outdoor skills) and complementary inputs (especially, specialized consumer durables), again without data overload.

___particular versions of the wording of modules 4 and 5 can be examined for effectiveness of communication and comprehension.

___can the notion of full income (which includes income, the marginal wage rate, and wealth] be implemented without an unacceptable number of refusals to answer particular questions?

2.2.6 The Chicago Contingent Valuation Experiment

2.2.6.1 Basic Contingent Valuation Structure

Following a small-scale pretest, a major pilot study was conducted to generate contingent valuation estimates of the value of atmospheric visibility. This pilot study was conducted by personal interview in the city of Chicago and suburban Cook and DuPage counties. The basic instrument contained sections for collection of the following data:

--Indicators of attitudes toward environmental quality.

--Activities of respondent (categorized as indoor-outdoor, strenuous or otherwise, etc.); identification of activities for which the respondent had invested in acquiring specialized skills or knowledge; identification of activities which are avoided for health, etc. reasons; and identification of activities the respondent was more likely to do on days when visibility was unusually good, and those he was less likely to do on poor visibility days.

--Ownership of or access to, equipment which could be used in activities which also use visibility (e.g., cameras with telescopic lens, binoculars, etc.).

--Contingent valuation modules that describe three alternative levels of visibility in the immediate Chicago region; one alternative level in the much broader east-of-the-Mississippi region; and one alternative level at the Grand Canyon. Verbal descriptions and color photographs were provided. Visual range in miles were stated and contingent market rules were defined. Respondents were given the opportunity to re-examine all 5 bids and adjust any or all of them. Protesters were identified--for example, respondents who objected to citizens bearing the costs of environmental clean-up. Six interchangable CV modules were used, each differeing only in the process by which bids were collected.

--Time horizon, with respect to expected length of residence near Chicago or east-of-the-Mississippi.

--Homeowner or renter status, estimated rental value of home, and rental income from other residential real estate owned.

--Quality of view from the place of residence.

--Socio demographic information about respondent and other household members, including income, wealth, average and marginal wage, and income expectations, as well as age, sex, education, race, ethnicity, etc.

A randomized cluster sampling design was developed, with a cluster size of six and specific instructions that each CV module be used once and once only within a cluster. Sixty starting locations were randomly selected using a computer routine which (after eliminating high density neighborhoods where interviewers would have trouble gaining access to apartments) gave every citizen in the region an equal chance of having his residence selected as a starting location. Thus, the target sample size was a maximum of 60 (and a minimum of 50) interviews with each CV module, for a total of at least 300 and no more than 360 interviewers.

2.2.6.2 Alternative Formats

The six contingent valuation formats used varied only in the process via which WTP bids were collected. They were:

A_1 directly asked respondents to report their maximum WTP, as Hammack and Brown (1974) had done in a mail survey.

A_2 stated an amount, invited acceptance or rejection of the program at that price, and then asked maximum WTP. This format duplicated the procedure used by Bishop and Herberlein (1979) to collect contingent WTP.

A_3 was an iterative bidding routine similar to those previously used by Randall, Ives and Eastman (1974) and Brookshire, Randall and Stoll (1980), among others.

B allowed respondents to indicate their maximum WTP by checking the appropriate number on a checklist of possible numbers. This format had been used by Schulze _et al_ (1981b).

C_1 provided a payment card, as developed and used by Mitchell and Carson.

C_2 expanded the payment card concept to include typical annual household expenditures (by income group) on several categories of goods purchased in the private sector, as well as typical annual household costs of public programs.

As one progresses from A_1 to A_3, there is successively more opportunity to iterate toward the point of indifference between (1) paying the amount stated and taking the good and (2) paying nothing and foregoing the good. Formats C_1 and C_2 provide information on the current levels of household expenditure on other goods and public programs; C_2 provides a greater array of such information than C_1. Format B has been promoted by Schulze _et al_ (1981b) as speeding-up the data collection process relative to, say, A_3 and eliminating the possibility of starting point bias.

2.2.6.3 Results

A data tape containing results of 273 completed interviews was used. While the target was 300 to 360 interviews, a few aborted interviews had to be discarded and a few stragglers had not been completed, coded and added to the data set. All analyses reported below are based on this set of 273 observations.

Let us look first at the effect of value data collection format. Hypothesis 2(a) suggests that formats A_3, A_2 and A_1 are expected to generate value data of highest, medium and lowest quality, respectively. hypothesis 2(b) suggests that formats C_2, C_1 and B are expected to generate data of highest, medium and lowest quality, respectively. There is no _a priori_ hypothesis about relative value data quality across the two sets of formats.

All three A formats and format B generated noticeably more protest bids than the C formats (Ta.2-1). The differences in generation of high bids were not so noticeable. However, the C formats clearly generated a larger solid core of serviceable value data than the A and B formats. Examining this solid core (the 4 rightmost columns of Ta.2-1), we notice that formats A_2 and B produced notably lower sample mean bids, and C_2 produced notably higher sample mean bids than the others. Within the solid core, there is little to be observed with respect to dispersion of bids. If one considers for example the mean bid relative to its standard error, the formats do not perform very differently.

Since the format subsamples are small (fewer than 50 bids in every case, and as few as 31 solid core bids in the case of A_3), it is important to control for differences in household characteristics across the sub-samples OLS regression analysis was used for this purpose.[12] Two regression specifications suggest themselves for estimation: the familiar linear-in-levels specification (2-37)and an alternative specification (13) developed below.

The linear-in-levels specification posits

(2-37) $$WTP(q_j^\circ, q_j')_k = b_o + \Sigma b_i Z_{ik} + e \quad ,$$

where k=1, ..., K refers to individual households; Z_1 is a vector of descriptors of the household's endowments, consumption technology, etc.; b_l are estimated parameters; and e is the error term.

Since one would suspect that (2-27) is likely to be non-linear, an alternative non-linear specification was developed. Rearranging (2-27) and entering the vector of human capital endowments α, we obtain

$$(m + CS)/m = 3(p, q', \alpha, u)/e(p, q^\circ, \alpha, u).$$

If u can be approximated by a homothetic direct utility function, the above

TABLE 2-1

Value Data, Atmospheric Visibility, Chicago 1981, by Format.

Format	Sample Size (n)	Zero bids All (% of n)	Zero bids Protest (% of n)	High Bids[a] (% of n)	Mean Annual Willingness to Pay per Household (Stand. Error of Mean): Full Sample WTP9[c]	Full Sample WTP10[d]	Full Sample WTP11[e]	Solid Core[b] n	Solid Core WTP9[c]	Solid Core WTP 10[d]	Solid Core WTP11
A_1	47	15	15	21	278 (191)	300 (116)	380 (145)	37	250 (51)	250 (50)	236 (50)
A_2	45	24	18	11	140 (26)	136 (22)	157 (24)	35	156 (30)	147 (22)	171 (24)
A_3	45	22	18	18	312 (133)	299 (132)	329 (133)	31	222 (37)	210 (38)	240 (39)
B	46	22	15	24	98 (21)	88 (18)	150 (34)	36	121 (25)	109 (22)	152 (29)
C_1	45	8	2	13	296 (66)	250 (61)	322 (74)	42	210 (44)	186 (35)	234 (53)
C_2	45	4	0	16	425 (121)	446 (123)	560 (145)	42	283 (57)	324 (72)	456 (115)
TOTAL	273	17	11	17	258 (36)	253 (38)	316 (44)	221	227 (20)	218 (20)	271 (28)

[a] Definded as any bid amounting, on an annual basis; to more than 10 percent of SOL.

[b] High bids were reduced to 10 percent of SOL. In addition, 12 erratic bidders were removed from the sample.

[c] WTP to avoid a reduction in visibility from 9 miles to 4 miles.

[d] WTP to get an increment in visibility from 9 miles to 16 miles.

[e] WTP to get an increment in visibility from 9 miles to 30 miles.

equation can be approximated by a normalized version ε,

$$(m + CS)/m = \varepsilon(p,\ q',\ \alpha,\ \ell \mid q^{\circ}) \quad , \tag{2-37}$$

which describes the proportional reduction in minimum expenditures due to the change in q as a function of prices, subsequent q', household characteristics and an error term ℓ --all conditional on the reference level of q, q°. If (2-37) can be further approximated by a multiplicative form, the following log linear form can be specified:

$$\ln(1 + CS/m)_k = b_o \ \pi Z_i^{\,b_i} \ \exp(\Sigma b_j d_j) e \quad , \tag{2-38}$$

where d_j are dummy variables.

Results Of estimating models (2-36) and (2-38) for WTP11 are presented (Ta.2-2 and 2-3, respectively).

Household standard of living, respondent's age, a grade 12 or lower education, and the environmental index clearly influenced WTP11 in the expected directions (Ta.2-2). Using format A3 as a basis for comparison, only format C_2 appeared to generate significantly different solid core bids. Turning to the non-linear specification (Ta.2-3), we find the numbers of adults in the household and the wage rate exerting significant influence, along with several of the same variables which were influential in (2-36). How-ever, no format generated a sample of bids significantly different from A_3. Our conclusion is that, for the most part, the choice of format seems to exert statistically insignificant influence on the solid core bids.[13]

In summary, it is clear that formats C_1 and C_2 elicited fewer protest bids than the other formats. Beyond that, little else is yet clear with respect to hypotheses 2(a) and (b) and the performance of the alternative formats.

TABLE 2-2

Estimated Bid Equation, WTP11, Using Specification (11).

Dependent Variable: WTP11[a]				F RATIO	3.04
		DFE	180	PROS>F	0.0007
				R-SQUARE	0.1684
VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>|T|
INTERCEPT	1	172.4	112.7	1.52	0.127
SOL	1	3.9	2.4	1.58	0.115
RYOUNG	1	-90.1	63.9	-1.41	0.160
RSENIOR	1	-90.0	79.2	-1.13	0.257
QHIGHS	1	-82.2	59.9	-1.37	0.171
QGRAD	1	-40.6	81.1	-0.50	0.616
ENVIR	1	7.9	3.0	2.58	0.010
CITPAY	1	74.4	55.1	1.34	0.178
A_1	1	11.0	96.3	0.11	0.908
A_2	1	-52.2	91.8	-0.56	0.570
B	1	-51.0	97.3	-0.52	0.601
C_1	1	4.4	91.6	0.04	0.961
C_2	1	170.0	91.2	1.86	0.064

Independent Variables

SOL = Annual household income divided by the Lazear - Michael (1980) index of standard of living.

RYOUTH = 1 if age of respondent < 35 years.
= 0 otherwise.

RSENIOR = 1 if age of respondent $\geq$ year.
= 0 otherwise.

QHIGHS = 1 if highest level of education of respondent, head, or spouse of head of household is a high school diploma or less.
= 0 otherwise.

QGRAD = 1 if highest level of education of respondent, head, or spouse of head of household is one or more years beyond a bachelor's degree.
= 0 otherwise.

ENVIR = an environmental attitude index estimated for each individual on the basis of observations obtained in section 1 of the interview.

CITPAY = 1 if respondent stated that citizens should pay the cost of environmental improvement.
= 0 otherwise.

TABLE 2-2. Continued

A_1, A_2	
B, C_1, C_2	= 1 if an observation from a given format.
	= 0 otherwise.

[a]WTP11 is willingness to pay for an improvement in visibility from 9 to 30 miles. Sample includes solid core responses only.

TABLE 2-3

Estimated Bid Equation, WTP11, Using Specification (13).

Dependent Variable: Percent*

				F RATIO	2.53
		DFE	159	PROD F	0.0014
				R-SQUARE	0.2126

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB T
INTERCEPT	1	4.5771	0.00594	770.10	0.001
LNWAGE	1	0.0031215	0.00166	1.87	0.063
RYOUNG	1	0.0018667	0.00251	0.74	0.459
RSENIOR	1	0.0074137	0.00354	2.09	0.037
QHIGHS	1	-0.003111	0.00239	-1.30	0.195
QGRAD	1	0.0012065	0.00310	0.38	0.698
ENVIR	1	-0.0002132	0.000129	-1.64	0.101
CITPAY	1	-0.0003975	0.00220	-0.40	0.684
HA_2	1	0.0105	0.00305	3.45	0.001
HA_3	1	0.0103	0.00369	2.81	0.005
HC_1	1	0.0076425	0.00325	2.42	0.016
HC_2	1	-0.001909	0.0029	-0.65	0.516
HC_3	1	0.0625697	0.00330	0.77	0.437
A_1	1	-0.0009201	0.00386	-0.23	0.812
A_2	1	0.0035101	0.0037	0.93	0.349
B	1	0.0037209	0.00395	0.94	0.348
C_1	1	-0.001814	0.00371	-0.48	0.626
C_2	1	0.00065131	0.00364	0.17	0.858

LNWAGE = Natural log of the respondent's marginal wage.

HA_2 = 1 if household includes two members whose age is greater than or equal to 18 years.
= 0 otherwise.

HA_3 = 1 if household includes three or more members whose age is greater than or equal to 18 years.
= 0 otherwise.

HC_1 = 1 if the household includes one member of less than 18 years of age.
= 0 otherwise.

HC_2, HC_3 are similarly defined for households with 2, and 3 or more members less than 18 years of age.

See Table 2 for definitions of other included variables.

*Percent is the natural lof of $(m - \frac{WTP11}{m})(100)$.

Now we consider the valuation sequence. Question 10 considered an increment in Chicago-area visibility from a typical level of 9 miles to 18 miles. Q 12 considered a similar visibility improvement over the whole east-of-the-Mississippi region. Q 13 considered the visibility program offered in Q 12 plus a program to prevent a threatened visibility decline at the Grand Canyon. In the previous year, the authors had collected in Chicago 128 bids to prevent the decline in Grand Canyon visibility,[14] using formats A_3 and B. Adjusting for one-year's inflation, these two data sets permit a test of Hypothesis 1. Thus, we hypothesize that WTP to prevent the visibility decline at the Grand Canyon when measured independently is greater than when measured third in a sequence of three visibility programs.

Given a Chicago-eastern region-Grand Canyon valuation sequence, the Grand Canyon program was valued by Chicago residents at a little more than 10 percent of the value of a Chicago program (Ta.2-4). More interesting, a direct comparison of the independently measured value of the Grand Canyon program (GCBid, Ta.2-5) with the value of the same program considered third in a three-program sequence (WTP13 - WTP12, Ta.2-5) shows the mean value of the former was more than five times the mean value of the latter. A linear regression analysis (Ta.2-6) shows that GCBid and WTP13 - WTP12 are different, at a very high level of significance. Thus, the null version of Hypothesis 1 is emphatically rejected.

2.2.7 Conclusion

Our experiment permits a clear conclusion with respect to Hypothesis 1: the null version is rejected. In the light of Propositions 1 and 2, this indicates that to the individual, visibility programs in Chicago, the east-of-the-Mississippi region and the Grand Canyon are substitutes: not perfect substitutes, but substitutes nevertheless.

If the real world of policy is characterized by the simultaneous augmentation of several collective goods in one or more policy packages or programs, our conceptual Propositions 1 and 2 and our empirical test of Hypothesis 1 suggest the following conjecture. If these several collective goods are each valued independently and the independent values then summed to determine the value of the program, the value of the program is inevitably overestimated (except in the special case where the program elements are strong complements). This conjecture would seem to apply when $q = (q_i, q_j, q_k)$ is defined so that i, j and k are regions (as in our experiment) or goods with different characteristics, e.g., visibility, health-related air quality, and water quality. All that is needed is substitute relationships among the elements of the q vector.

We have much less to say about the effect of value data collection format. It is clear that the payment cards were helpful in reducing the incidence of protest bids. Eyeball evaluation of mean bids suggests that formats A_2 and B

TABLE 2-4

Incremental Mean Value (and Standard Error) of Regional and Canyon Visibility Programs

Format	Sample Size[a] (a)	WTP10 ($/year)	Regional Program; WTP12 - WTP10 ($/year)	Grand Canyon Program; WTP13 - WTP12 ($/year)
	29	382 (183)	161 (72)	30 (21)
A_2	31	139 (23)	14 (6)	9 (6)
A_3	27	375 (217)	29 (12)	12 (6)
B	32	103 (24)	26 (8)	20 (11)
C_1	29	251 (86)	21 (9)	39 (28)
	26	608 (206)	354 (181)	83 (76)
Total	174	298 (58)	95 (31)	31 (13)

[a] Protest bids eliminated; erratic bids (e.g., those which bid more for a less-preferred program) eliminated; "high" bids neither eliminated nor reduced.

TABLE 2-5

The Value of a Grand Canyon Program to Chicago Residents.

Format[a]	GCBid 1980[b] (adjusted)			WTP13 - WTP12 1981[c]		
	n	Mean	SE	n	Mean	SE
A_3	57	69.02	13.84	27	12.00	5.58
B	73	105.64	24.91	32	19.88	10.892
A_3 and B pooled	130	89.58	15.28	59	16.27	8.942

[a] Since the GCBid 1980 survey used only the A_3 and R formats, only the A_3 and B format results for WTP13 - WTP12 are shown.

[b] GCBid 1980 is an independent valuation.

[c] WTP13 - WTP12 is a valuation of the same program, obtained third in a three-program valuation sequence.

TABLE 2-6

Willingness to Pay for the Grand Canyon Program: Independent versus Sequential Programs.

Dependent variable: Annual WTP to avoid visibility decline at Grand Canyon		DFE: 152		F RATIO PROB>F R-SQUARE	4.41 0.0002 0.1689
VARIABLE[a]	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>|T|
INTERCEPT	1	26.8	27.5	0.97	0.331
SOL	1	1.3	0.9	1.43	0.152
RYONG	1	-3.5	21.8	-0.16	0.871
RSENIOR	1	-65.8	31.5	-2.08	0.038
RHIGH	1	52.5	24.0	2.18	0.030
RGRAD	1	63.6	36.2	1.75	0.081
Z1	1	-74.7	23.5	-3.17	0.001
CITPAY	1	54.0	19.2	2.80	0.005

[a]Variables are defined as before, except for Z1, which is defined as
Z1 = 1 if WTP13 - WTP12 (i.e., third in a three-program valuation sequence)
= 0 if GCBid 1980 (i.e., independent valuation)

seem to generate lower mean bids in the solid core, and C_2 seems to generate higher mean bids, than the other formats.

More generally, we believe the effect of data collection format is a useful subject for further study. We suspect that, within the set of well-designed contingent markets, format makes some limited difference. However, we would be hesitant to casually apply some lable (such as "information bias") to this effect. In real-world and actual-experiment markets, market structure has some influence, and logic suggests that it should. That same kind of logic should be applied to contingent markets.

Contingent markets generate a solid core of serviceable value data, but a persistent fringe of protest bids and suspiciously high bids require and have received close examination. We perceive substantial convergence between the kinds of results we obtained in this and previous studies and the results of, e.g., Smith (1980).

The research agenda has shifted from "contingent valuation (CV) must be assumed useless because it is not incentive-compatible" to "CV must have some merit <u>because</u> its results are consistent with those of hedonic methods"[15] (Brookshire, <u>et al</u>., 1982). On the immediate horizon, in recent CV and experimental work (Smith, 1980) we see some indication that CV may have merit simply because many people really do try to tell the truth much of the time. The stage now appears set for a further shift in the research agenda toward painstaking study of the effects of contingent market structure on the quality of value data generated. In this process, we might expect a further convergence of survey and experimental methods.

We can expect however that there are limits to truth-telling. While income tax liability is self-reported, the IRS finds the need to employ auditors, inspectors and systematic reporting procedures. The possibility must be entertained that if CV were widely and routinely used to gather data which directly influenced many public programs, and "everyone" knew it, more people would invest in strategic efforts to influence its results.

FOOTNOTES

1. This seems to be a typical finding when cross-sectional data are used. For example, changes in the aggregate level of consumer confidence have predicted the onset of the last six recessions and the onset of each subsequent recovery. However, individual consumption and saving decisions are not predictable on the basis of individual consumer confidence (Katona, 1980).
2. We find much of the discussion of "biases" in contingent valuation imprecise and not especially perceptive. It seems to us that a bias is a systematic influence, predictable in its occurrence and the direction of its impact on results. Many of the "biases" identified in the lieterature cited as merely possible sources of (*a priori* undetermined) observation error.
3. We wish they had used the term, conjecture.
4. We believe their experiment was subject to certain influences which would lead to overestimating the difference between contingent WTP and true value. Nevertheless, we believe these influences were insufficient to account for all of the observed differences between contingent WTP and actual WTS. Thus, it is our

position that Bishop and Heberlein's result may overstate the difference between contingent WTP and true value, but is unlikely to have misidentified its sign.

5. Why underestimation? We do not know for sure, but we conjecture that contingent markets may take basically unprepared subjects by surprise. While their instinct in such circumstances is probably to tell the truth, their unpreparedness and inexperience with such markets leads to a cautious and conservative response: in WTP markets, to "sit pat" (i.e. bid zero) or to bid conservatively. This conjecture is also consistent with the observed high bidding behavior of many respondents in contingent WTS markets. In that circumstance, the cautious response is to refuse to sell or to announce a high selling price.

   Since Bishop and Heberlein's (1979) experimental WTS market was highly unusual and new to its participants, we suspect that it was subject to the influence conjectured above. If so, that would account for some portion of the observed difference between experimental WTS and contingent WTP.

6. Small and Rosen (1981) address the difficulty introduced by lack of smoothness in the expenditure function when $x_i(p, q, \pi, a, u)$ approaches zero.

7. Substitute relationships are more likely to occur than complementary relationships, although both kinds of relationships are possible.

8. In a working paper, the authors show that these restrictions are not peculiar to contingent valuation but apply also to those procedures which seek to infer the value of q_i by analyzing the demand for x_i (see Freeman, 1979).

9. Proof of Proposition 1 follows from the comparative static properties of the additively separable utility function. A full proof is given in Hoehn.

10. In a similar context Domenich and McFadden characterize additive separability as a "good general working hypothesis" (p.40).

11. The context described corresponds fairly closely to Malinvaud's case of individual risks. Graham argues that in this case option price is a lower bound on the correct BC measure of value.

12. Subsequent analyses will use methods more appropriate to the distribution of WTP observations. Some analysts have successfully used tobit (e.g., Adams _et al_., 1980). We propose to use censored sample correction methods (see Gronau, 1974; Heckman, 1976 and 1979) to more closely analyze protest bids, "high" bids and "solid core" bids.

13. It happens that the subsample which used format C_2 had (by pure chance, so far as we know) mean household income some $5,000 higher than the whole sample. One hypothesis for further investigation is that the non-linear specification (13) better accounted for a possible non-linear relationship between income and bid.

14. This survey was a contribution to work, reported by Schulze _et al_ (1981b).

13. This position is logically supportable only if we accept the (untestable) premise that hedonic methods reveal true value.

2.3 ALTERNATIVE ECONOMETRIC SPECIFICATIONS

2.3.1 Overview of Section 2.3

Section 2.3 reports the results of early CV experiments in Chicago on Grand Canyon National Park. The main purpose of these experiments was to investigate the solution to an important econometric problem--the presence of a substantial number of zero valuations of visibility improvements in the DV data. Ordinary least squares regression estimates, frequently employed in econometric analysis, can bias the results when a limiting value (zero in this case) occurs in the data set. Accordingly, tobit and logit specifications were investigated.

The conclusion was that the empirical results were consistent with conceptual reasons for employing tobit analysis. Tobit analysis is designed for use in models in which the dependent variable takes on a limiting value (zero) or a non-limiting value of some specific (positive) amount.

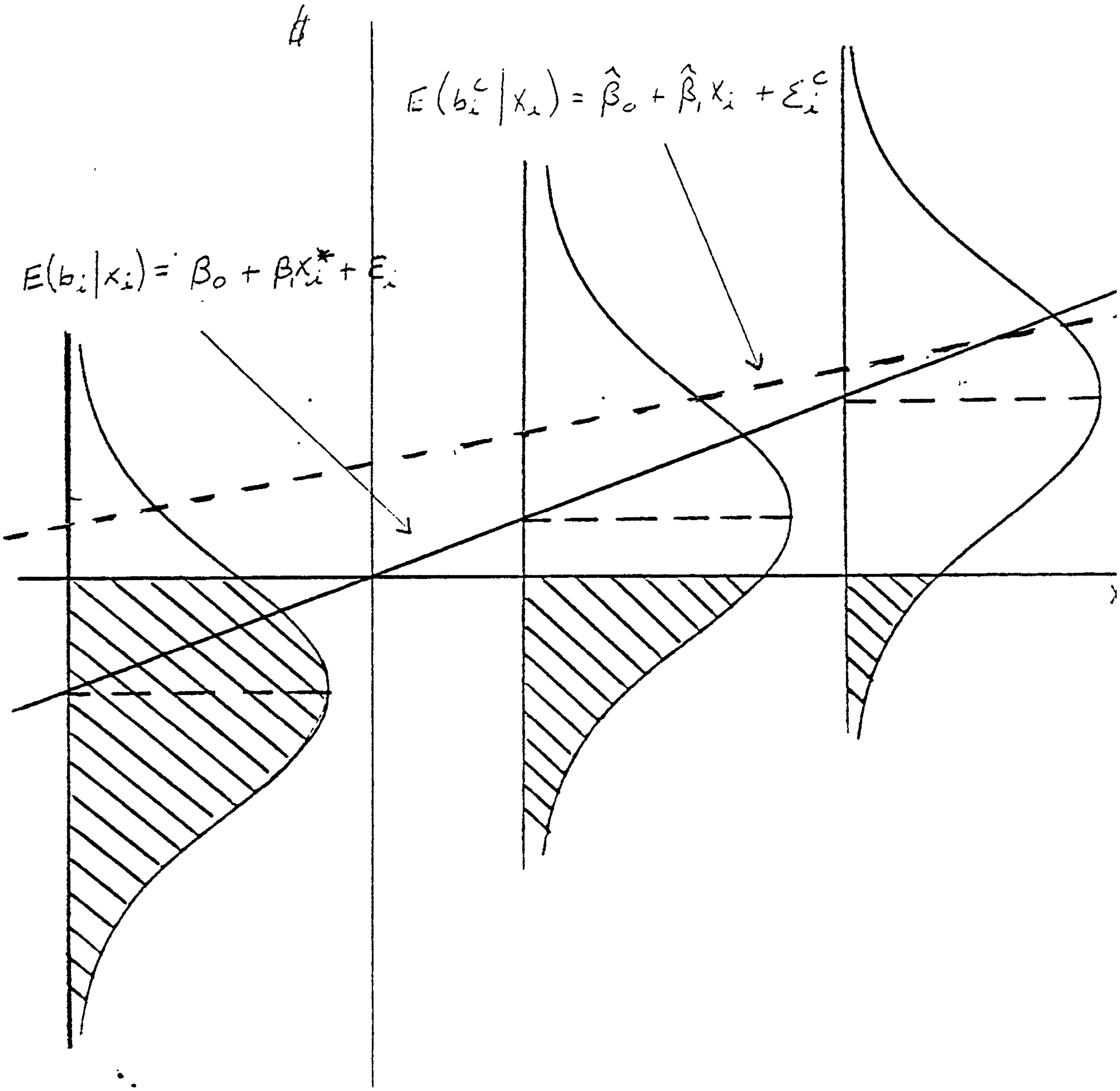
2.3.2 Tobit Estimation

2.3.2.1 Estimation When the Dependent Variable is Truncated

In the bidding game, an individual i's bid b_i, is elicited on the basis of some increment or decrement in visibility. Analytically then, the bid function becomes $b_i = \beta_o + \beta_1 x_i^* + \varepsilon_i$, where x_i is a vector of individual attributes including the represented level of visibility, and ε_i is a normally distributed random error term. As the increment of visibility x_{ij}, approaches zero, the distribution of the error term causes more and more of the b_i to fall on the negative side of the abscissa. With bids limited to the positive quadrant (no one pays a negative amount to get more visibility), the error term causes an accumulation of zero bids. The effect of such a limit causes the distribution to be truncated at zero. With truncation, ordinary least squares (OLS) estimators result in the regression line $E(b_i^c | x_i)$, the dotted line in Fig. 2-1. OLS tends to bias the estimation of β_o and β_1 and, in the illustrated case, cause $\hat{\beta}_o$ to be greater than β_o and $\hat{\beta}_1$ to be less than β_1. Because of OLS bias the statistical significance of $\hat{\beta}$ is reduced and the effect of an increase or decrease in the variable x_{ij} is underestimated. Truncation may therefore contribute to the usual problem of insignificant income effects or the underestimation of the rate at which bids increase with increments in visibility.

FIGURE 2-1

The Tobit Model with Lower Limit L = 0



To deal with the problem of truncation, tobit analysis was used. Tobit analysis uses the distribution of the error tern, e_i, and the number of zero bids as information in the estimation process. Depending upon the seriousness of the truncation problem, tobit analysis will improve estimates of the coefficients B_0 and B_1 in the bid function.

2.3.2.2 Tobit Analysis of Three National Parkland Study Experiments

This section presents results of the National Parkland Study’s (NPS) valuation of visibility. Previous analysis of the Chicago resident data were discouraging in that selected independent variables did not show a significant and systematic effect on individual bids. Bid functions estimated using ordinary least squares fit the Chicago data poorly. Because the independent variables of interest were consistently shown to be insignificantly related to the bids, tests of hypotheses regarding instrument design were impeded.

Results of a review of the concepts suggested tobit analysis as a potentially superior means of explicitly accounting for zero valuations. Reported below are the output of a tobit analysis.

The collaborative effort with NPS offered an opportunity for a contingent valuation experiment. Three different questionnaires were used: The AAA check-list, the AAA bidding game, and the CCC bidding game. The three CV formats were combined with a photographic display. The photographs represented five different levels of visibility, ranging from very poor at level A through intermediate levels B, C, and D to very good visibility at level E. Each of the three CV formats described level C as the current level of visibility. The CCC format elicited valuations directly from level C. Five CCC bids were elicited; (1) to improve Grand Canyon visibility from the current level C to level E, (2) to prevent a decline in Grand Canyon visibility from level C to level B, (3) to prevent a decline in Grand Canyon visibility from level C to level A, to improve regional visibility from level C to level E, and (5) to prevent a decline in regional visibility from level C to level A. The AAA formats described a decline in visibility to level C and elicited all bids as bids for improvements from level A. For visibility at the Grand Canyon, the AAA formats elicited three bids: bids for the improvements from A to b, A to C, and A to E. For regional visibility, the AAA format elicited bids for improvements from A to C and from A to E.

The bid function specified for the tobit analysis differed little from that used earlier in the ordinary least squares estimates. The variables in the bid function were:

ED	- The number of years of schooling completed by the respondent.
A2534	- A zero/one dummy variable. Equals one if the respondent's age is from 25 to 34 years and zero otherwise.
A3544	- A zero/one dummy variable. Equals one if the respondent's age is from 35 to 44 years and zero otherwise.
A4554	- A zero/one dummy variable. Equals one if the respondent's age is from 45 to 54 years and zero otherwise.
A55+	- A zero/one dummy variable. Equals one if the respondent's age is 55 or more and zero otherwise.
INC	- Income in thousands of dollars.
USTGC	- A zero/one dummy variable to indicate whether or not the individual has plans to visit the Grand Canyon, Equals one if yes, has plans, and zero otherwise,
PSTGC	- A zero/one dummy variable to indicate whether or not the individual has visited the Grand Canyon. Equals one if yes and zero otherwise.
SEX	- A zero/one dummy variable to indicate whether or not the sex of an individual. Equals one if male and zero otherwise.
PRIM	- A zero/one dummy variable to indicate whether or not the respondent is the primary income earner in household. Equals one if yes and zero otherwise.
CITPAY	- A zero/one dummy variable. Equals one if respondent believes that all citizens of U.S. should pay the cost of visibility impairment and zero otherwise.
USTPAY	- A zero/one dummy variable. Equals one if respondent believes that visitors to National Parks should pay the cost of preventing visibility impairment and zero otherwise.

POLPAY - A zero/one dummy variable. Equals one if respondent believes that polluters should pay the cost preventing visibility impairment. Equals one if yes and zero otherwise.

A priori notions regarding the sign attached to variables in the estimated bid equation were much the same as with the OLS test. ED, INC, and USTGC were expected to affect valuations positively. The effect of respondents' age, given the N.P.S. results, was expected to be negative. Age was entered as a dummy variable in order to test for non-linear effects of increasing years and to more accurately represent the actual responses elicited from respondents. No a priori notions were held regarding the estimated signs of PSTGC, SEX, PRIM, CITPAY, USTPAY, and POLPAY.

Dependent variables in the estimated bid functions are the five valuations elicited in each question. A valuation is identified by a four letter code (see Ta.2-7, 2-2 and 2-9). The first two letters indicate the area or region that could be affected by the bid; GC__indicates the Grand Canyon and RE__ indicates the regional parks as a whole. The second two letters indicate the increment in visibility for which a bid was elicited. For instance, __AB indicates a program that would shift visibility from level A to level B.

Bid functions estimated on the three sets of data are presented in Tables 1, 2, and 3, Examining the results overall, note first that the number of observations was similar in each case. Second, the number of zero bids tends to decline as the increment in visibility is increased. This tendency of zero bids is consistent with the conceptual framework justifying a tobit analysis. Third, average bids ($E(Y \; x=\overline{x})$) tend to increase as the increment in visibility increases. This trend in

TABLE 2-7

AAA Checklist Results
(|t| values in parentheses)

Dependent Variable	GCAB	GCAC	GCAE	REAC	REAE
# of OBS	57	57	57	57	57
# of Zero Bids	18	16	11	15	11
ED	-00962 (.87)	-.0518 (.46)	-.0159 (.14)	.0111 (.10)	.1593 (1.39)
A2534	-.4801 (.94)	-.0738 (.15)	.1346 (.27)	.0854 (.17)	-.3505 (.70)
A3544	-.3346 (.66)	.1243 (.25)	.6961 (1.40)	.1021 (.21)	.5452 (1.10)
A4554	-1.402 (2.33)	-.5974 (1.04)	-.2721 (.47)	-.5737 (1.00)	-.3461 (.60)
A55+	-1.174 (2.30)	-.8504 (1.67)	-.3812 (.79)	-.7858 (1.58)	-.5949 (1.21)
INC	-.0014 (.10)	.0091 (.62)	.0086 (.61)	.0003 (.02)	.0001 (.01)
USTGC	-.0164 (.04)	.0160 (.04)	-.0641 (.18)	-.1483 (.41)	-.2761 (.78)
PSTGC	-.4327 (1.27)	-.3482 (1.02)	-.0084 (.03)	-.1218 (.36)	.4593 (1.37)
SEX	-.0962 (.24)	-.0995 (.24)	-.0220 (.05)	-.0583 (.14)	-1.640 (.40)
PRIM	.4740 (1.16)	.0983 (.24)	-.4299 (1.05)	-.0065 (.02)	-.3068 (.74)
CITPAY	.8418 (2.57)	1.059 (3.16)	1.126 (3.38)	.9943 (3.00)	1.228 (3.61)
USTPAY	.4157 (.86)	.6953 (1.52)	.9206 (1.99)	.8151 (1.77)	.8951 (1.94)
POLPAY	-.1670 (.47)	-.2971 (.84)	-.3720 (1.07)	-.3801 (1.08)	-.2712 (.78)
Constant	2.142 (1.31)	.8227 (.48)	.1212 (.07)	.2006 (.12)	-2.095 (1.19)
$^1/_\sigma$	.1602	.0837	0.569	.1262	.0630
$P_v(Y>0 \mid x=\bar{x})$	.603	.579	.644	.628	.649
$E(Y \mid x=\bar{x})$	3.39	6.05	10.72	4.62	9.84
R^Z	.376	.365	.400	.350	.454

TABLE 2-8

AAA Bidding Game Results
(|t| values in parentheses)

Dependent Variable	GCAB	GCAC	GCAE	REAC	REAE
# of OBS	50	50	50	50	50
# of Zero Bids	7	6	6	4	3
ED	-.0069 (.09)	-.0880 (1.10)	-.033- (.42)	-.1334 (1.67)	-.1128 (1.43)
A2534	-.4590 (.84)	-.7812 (1.42)	-.6631 (1.23)	-.7476 (1.37)	-.9802 (1.83)
A3544	-.1252 (.21)	-.3248 (.54)	-.1437 (.24)	-.4026 (.67)	-.5212 (.88)
A4554	-.4361 (.63)	-.4460 (.65)	-.3113 (.46)	-.5435 (.80)	-.7563 (1.13)
A55+	-.3076 (.57)	-.4968 (.92)	-.4270 (.80)	-.3441 (.64)	-.5962 (1.13)
INC	-.0042 (.31)	-.0020 (.14)	-.0009 (.07)	-.0039 (.29)	-.0000 (.00)
USTGC	.3171 (.91)	.5507 (1.58)	.5613 (1.61)	.4882 (1.42)	.4256 (1.24)
PSTGC	.5567 (1.37)	.3284 (.79)	.2877 (.69)	.3650 (.89)	.3563 (.87)
SEX	.0184 (.04)	-.1421 (.34)	-.0739 (.18)	-.1465 (.35)	-.1596 (.39)
PRIM	-.1231 (.28)	.5664 (1.28)	.4318 (.98)	.6525 (1.50)	.5848 (1.35)
CITPAY	.8005 (2.31)	.7876 (2.29)	.7452 (2.17)	.7649 (2.24)	.6896 (2.03)
USTPAY	-.2291 (.48)	-.3464 (.74)	-.3689 (.80)	-.3836 (.82)	-.3351 (.72)
POLPAY	.5675 (1.41)	.8425 (2.07)	1.044 (2.53)	.9927 (2.42)	1.012 (2.47)
CONSTANT	.0241 (.02)	1.353 (.85)	.2194 (.14)	2.063 (1.30)	1.949 (1.23)
$1/\sigma$	.2205	.2012	.1708	.1863	.1689
$P_v(Y>0 \mid x=\bar{x})$	.721	.768	.766	.795	.809
$E(Y \mid x=\bar{x})$	3.44	4.31	5.04	5.05	5.81
R^2	.254	.381	.336	.420	.389

TABLE 2-9

CCC Bidding Game Results
(|t| values in parentheses)

Dependent Variable	GCBC	GCAC	GCCE	REAC	RECE
# of OBS	53	53	53	53	53
# of Zero Bids	9	7	12	7	9
ED	.2548	.2188	.2307	.2741	.3103
	(2.53)	(2.23)	(2.23)	(2.76)	(3.04)
A2534	.1269	.0455	-.1982	.1219	-.0268
	(.22)	(.08)	(.33)	(.22)	(.05)
A3544	-.4698	-.3478	-.4378	-.3902	-.4532
	(.79)	(.59)	(.74)	(.66)	(.77)
A4554	-.1444	.3124	-.4201	.0377	-.2329
	(.24)	(.52)	(.69)	(.62)	(.38)
A55 +	.0480	-.0223	-.1085	.0492	-.0593
	(.08)	(.04)	(.17)	(.08)	(.09)
INC	.0191	.0207	.0203	.0257	.0244
	(1.93)	(2.10)	(2.04)	(2.58)	(2.43)
USTGC	.5742	.1107	.7405	.5266	.6131
	(1.40)	(.27)	(1.79)	(1.29)	(1.49)
PSTGC	.1842	.1413	.3795	.2283	.2933
	(.45)	(.34)	(.92)	(.56)	(.71)
SEX	-.9014	-.4648	-1.063	-.9284	-.8774
	(2.09)	(1.11)	(2.42)	(2.17)	(2.05)
PRIM	1.197	.8802	1.315	1.179	1.240
	(2.67)	(2.00)	(2.87)	(2.64)	(2.76)
CITPAY	.5292	.3928	.4160	.4651	.3737
	(1.42)	(1.07)	(1.12)	(1.26)	(1.01)
USTPAY	.7941	-.8523	.8444	.8193	.9124
	(2.15)	(2.35)	(2.26)	(2.26)	(2.47)
POLPAY	.4938	.5590	.4092	.4685	.5294
	(1.45)	(1.66)	(1.20)	(1.39)	(1.56)
CONSTANT	-4.309	-4.222	-3.639	-4.663	-5.244
	(2.45)	(2.46)	(2.01)	(2.69)	(2.93)
$1/\sigma$	.1367	.0744	.1302	.1110	.1084
$P_v(Y>0 \mid x=\bar{x}$	.615	.611	.610	.659	.638
$E(Y \mid x=\bar{x}$	4.11	7.48	4.25	5.74	5.53
R^2	.518	.421	.506	.520	.510

valuations indicates an internal consistency among bids; on the average, people will pay more to get more. Finally, note that the R^2x100, the percentage of explained variation, ranges from a low of 25.4% on the GCAB bid of the AAA bidding game to 52.0% on the CCC bidding game. Relative to the OLS, tobit estimators seem to attain a better fit to the data. For the AAA checklist, tobit analysis does not appear to have improved our ability to discern significant decision variables. Results of the AAA bidding game appear rather similar to the checklist results. Results for the CCC bidding game (Ta.2-9) are substantially different from the other bid functions. Each of the _a priori_ expectations regarding the positive effects of variables is confirmed. Education (ED), income (INC), and planned visits (USTGC) each affect valuations positively and very significantly. Expectation regarding the age variables are not confirmed. With regard to the shift (dummy) variables,(CITPAY) retains a positive sign and is consistent across all three data sets. USTPAY is again significant and demostrates the same positive effect that it had on the AAA checklist bids. POLPAY is also significant and positively related to bids as it was in the AAA bidding game. Finally, a respondent's sex (SEX) and whether or not the respondent was the primary income earner (PRIM) both appear to affect valuation--a result unique to the CCC bidding game.

Two propositions may be stated. First, tobit estimators appear to utilize the information contained within zero valuations more effectively and therefore result in superior estimation of bid function parameters. OLS failed to discern any systematic relationships in the CCC data whereas the tobit analysis uncovered several significant relations between dependent and decision variables. The effectiveness of tobit is also noticeable in the rather sizeable R^2's. Second, if only an average bid is of concern, then the method of eliciting bids, whether bidding game or checklist, may not significantly affect results. However, a contingent valuation design that accurately describes the decision as well as forcing careful consideration of valuation will be more sensitive to individual variations. Such a design, therefore, may be more likely to permit discernment of systematic relation between individual dependent variables and individual decision variables.

The tobit procedure can glean information from some of the 0's. Tobit corrects biases that result from truncation of the dependent variable, but does nothing to solve the problem of individuals systematically refusing to participate in the bidding scheme. Thus, some of the 0's in the sample are informative, and some represent noise. Finding the right set of "Why 0 bid" questions is necessary to decide which observations should be deleted from the sample, and which 0's should be left in for the tobit estimation. A lower proportion of protesters among the 0 bids might explain why the tobit procedure was more successful than OLS in analyzing some sets of data.

2.3.3 Comparison of Empirical Results

2.3.3.1 Grand Canyon and Regional Park Visibility Programs

In the sections below the results of analyzing WTP data obtained by the Wyoming group for the NPS are presented. After removing invalid observations, about 85 percent of the NPS observations were left,* Of these, about 25 Percent were at the limit of the dependent variable (0 bids). Thus, a tobit model was chosen as the appropriate model for explaining the bid behavior. In a second stage, probit and OLS analyses were used.

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* The data for Albuquerque, Los Angeles and Denver were provided by the Wyoming group headed by William D. Schulze. The Chicago data were collected by us using methods identical to those used by the Wyoming group. The theoretical background for the survey and the results obtained by the Wyoming group can be found in Schulze, W. D. et. al. “The Benefits of Preserving Visibility in the National Parklands of the Southwest”, Office of Exploratory Research, U.S. EPA, Washington, D.C. (1981).

Ta.2-10, 2-2 and 2-12 are the most general relationships. All potentially relevant variables are included. We also allowed for non-linearities in income, age, education, and the electric bill. Income per family was restricted to a minimum of $5,000.

The common characteristics of the three tables are:

1) The "why zero" coefficient is negative as expected,but only the one that stands for "polluter should pay" and "other" is significant.

2) The non-white coefficient is negative but only barely significant.

3) Household size is mainly negative but is nowhere significant.

4) The quantitative variables which are assumed to have non-linear effects and are introduced by a linear and a quadratic term do exhibit non-linearity but mainly the coefficients are insignificant. Also the signs on the linear and quadratic terms are inconsistant across cities.

The possible combinations of coefficient and the implied effect are described below.

FIGURE 2-2

	Linear	Quadratic	Shape
1)	+	+	
2)	−	−	
3)	+	−	
4)	−	+	

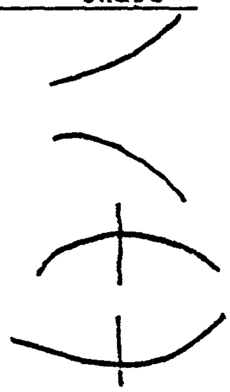

TABLE 2-10

Grand Canyon Visibility Value-Tobit
Dependent Variable-The Grand Canyon Bid
(|t| values in parentheses)

CITY	LA	DEN	ALB	CHC	ALL
Total Ob.	127	110	115	98	450
Valid Ob.	118	103	99	68	388
Limit Ob.	19	33	24	16	92
Urban Dummy	..0452	-.1334	-.4539	-.0243	-.0727
	(.14)	(.42)	(1.70)	(.08)	(.53)
Female Dummy	.4442	-.0324	.0403	.2607	.2029
	(2.03)	(.13)	(.17)	(.86)	(1.74)
NonWhite Dummy	.2605	-.5969	-.3099	-.0676	-.1477
	(.97)	(1.52)	(.99)	(.20)	(1.04)
Why 0-Not Significant Difference.	-3.439	-6.658	-.5214	-.1162	-1.054
	(.2)	(.01)	(.75)	(.10)	(2.43)
Why 0-Other	-1.205	-2.633	-1.352	-1.490	-1.448
	(4.27)	(6.00)	(4.22)	(3.76)	(8.90)
Education	1.162	-.2510	0.8872	-.3522	-.1319
	(2.01)	(.39)	(1.46)	(.48)	(.45)
$(Edu)^2$	-.0370	.0064	.0351	.0103	.0450
	(1.89)	(.29)	(1.63)	(.40)	(.45)
Age	..0515	-.0867	-.1329	.0950	.0135
	(.83)	(1.24)	(1.74)	(1.00)	(.39)
$(Age)^2$	-.0007	.0010	.0015	-.0012	-.0003
	(.98)	(1.15)	(1.64)	(1.07)	(.64)
Household Size	.0788	-.0784	-.0003	-.0916	-.0548
	(1.26)	(.82)	(.003)	(1.08)	(1.50)
Income	-.0612	-.0044	0.759	-.0040	-.0054
	(3.09)	(.20)	(1.45)	(.11)	(.48)
$(Income)^2$	.0009	.0000	-.0018	.0002	.0001
	(3.94)	(.10)	(1.66)	(.36)	(1.06)
Electric Bill	.0619	.0076	-.0311	-.0062	.0008
	(1.20)	(.73)	(1.57)	(.29)	(.14)
$(Electric\ Bill)^2$	-.0002	-.0000	.0003	.0000	.0000
	(1.62)	(.57)	(1.98)	(.33)	(.07)
Constant	-3.751	5.261	8.718	1.890	1.674
	(1.62)	(1.04)	(1.80)	(.33)	(.74)
$D(Y < 0 \mid x = \bar{x})$	.608	.486	.495	.476	.498
$E(Y) \mid x = \bar{x}$	5.59	2.13	4.53	9.87	5.95
LLF	-337	0224	-297	-249	-1026
R^2	.319	.297	.267	.096	.075
LA					-.194
					(1.1)
Den					-.480
					(2.67)
Alb					-.228
					(1.27)

TABLE 2-11

Grand-Canyon Visibility Study
Dependent Variable-The Regional Park Bid
(|t| values in parentheses)

CITY	LA	DEN	ALB	CHC	ALL
Total Ob.	127	110	115	98	400
Valid Ob.	118	103	99	68	388
Limit Ob.	23	39	90	21	113
(D) Urban	.2434 (.70)	-.3096 (.93)	-.8654 (2.94)	.2747 (.83)	-.1600 (1.11)
(D) Female	.3690 (1.65)	-.3506 (1.31)	.0394 (.15)	.1031 (.30)	.1513 (1.23)
(D) NonWhite	-.1237 (.40)	-.2854 (.72)	-.2455 (.70)	-.3008 (.77)	-.3037 (2.04)
Air Quality N.S.	-3.451 (.21)	-6.458 (.01)	-5.801 (.01)	-5.679 (.00)	-6.350 (.01)
Other	-1.402 (4.73)	-3.013 (5.88)	-3.116 (3.78)	-10.152 (.03)	-1.998 (9.65)
Education	.4351 (.78)	-.9061 (1.35)	-1.871 (2.80)	.2297 (.26)	-.7083 (2.36)
$(Edu)^2$	-.0129 (.69)	.0298 (1.30)	.0667 (2.83)	-.0102 (.34)	.0242 (2.35)
Age	.0921 (1.48)	.0512 (.72)	-.1500 (1.86)	.2228 (1.98)	-.0180 (.51)
$(Age)^2$	-.0012 (1.66)	-.0007 (.85)	.0016 (1.65)	-.0027 (2.01)	-.0004 (.85)
Household Size	-.0349 (.56)	-.0488 (.50)	-.0846 (1.03)	-.0648 (.67)	-.0121 (.34)
Income	-.0467 (2.32)	.0171 (.75)	.1150 (1.38)	-.0881 (1.22)	-.0080 (.69)
$(Income)^2$	.0007 (2.95)	-.0002 (.92)	-.0026 (2.05)	.0010 (1.69)	.0002 (1.28)
Elec. B.	.0267 (1.86)	.0082 (.77)	-.0417 (.89)	-.0270 (1.05)	.0020 (.32)
$(Elec.\ B)^*$	-.0002 (1.97)	-.0000 (.63)	.0005 (2.35)	.0003 (1.41)	.0000 (.70)
Constant	-4.719 (1.12)	7.009 (1.33)	16.762 (3.13)	-3.646 (.52)	5.510 (2.37)
$P(Y > 0 \mid x = \bar{x})$	.573	.438	.240	.009	.393
$E(Y) \mid x = \bar{x}$	5.086	1.418	1.756	.035	3.458
LLF	-364	-194	-273	-188	-783
D^2	.320	.350	.495	.463	.146
LA					.0903 (.49)
Den					-.3580 (1.88)
[illegible]					-.0352

TABLE 2-12

Grand Canyon Visibility Value-Tobit
Dependent Variable-The Plume Bids
(|t| values inparentheses)

CITY	LA	DEN	ALB	CXCH	ALL
Total Ob.	127	110	115	98	450
Valid Ob.	118	103	99	68	388
Limit Ob.	35	37	36	23	131
Urban (D)	-.0110 (.03)	-.3126 (.98)	-.4935 (.81)	-.0189 (.061)	-.2239 (1.60)
Female (D)	-.2236 (1.57)	.1147 (.44)	.0448 (.201)	.0820 (.201)	.1229 (1.03)
NonWhite (D)	-.2236 (.82)	-.9724 (2.25)	-.2670 (.81)	-.2388 (.70)	-.3313 (2.22)
Air Quality N.S.	-3.296 (.38)	-6.468 (.08)	-.1515 (.22)	-3.481 (.26)	-.7502 (1.68)
Other	-1.363 (4.7)	-2.335 (.57)	-1.292 (.375)	-1.569 (3.72)	-1.474 (8.86)
Education	-.6434 (1.12)	-1.298 (1.97)	-1.375 (2.18)	-.7034 (.94)	-.8716 (2.98)
$(\text{Education})^2$	.0201 (1.04)	.0445 (1.97)	.0528 (2.38)	.0217 (.93)	.0300 (2.97)
Age	.0511 (.82)	-.1040 (1.47)	-.1279 (1.61)	.0074 (.08)	-.0339 (.30)
$(\text{Age})^2$	-.0008 (1.03)	.0011 (1.34)	.0015 (1.54)	-.0001 (.10)	.0003 (.67)
Household Size	.0691 (1.09)	-.0378 (.34)	.0030 (.04)	-.1147 (1.29)	-.0197 (.55)
Income	.0282 (1.40)	.0136 (.64)	.0800 (1.45)	.0096 (.27)	.0141 (1.22)
$(\text{Income})^2$	-.0004 (1.64)	-.0001 (.57)	-.0018 (1.60)	.0000 (.10)	-.0002 (1.32)
Electric Bill	.0046 (.35)	-.0010 (.10)	-.0426 (2.03)	-.0039 (.17)	-.0060 (.99)
$(\text{Electric Bill})^2$	-.0000 (.2)	.0001 (.14)	.0004 (2.27)	.0001 (.43)	.0001 (1.30)
Constant	4.207 (.98)	12.305 (5.21)	11.846 (2.38)	5.938 (1.01)	7.587 (3.32)
$?(Y > 0 \mid x = \bar{x})$	.602	.435	.416	.463	.473
$E(Y) \mid x = \bar{x}$	2.580	1.579	3.345	3.041	3.239
LLF	267.7	206.9	263.4	109.3	980.3
R^2	.216	.255	.309	.129	.103
LA					-.0524 (.46)
Den					-.1547 (1.37)
Alb					.0454

Cases 1) and 2) never occurred. We consider the permissible range for case 3) to be to the left of the dividing line and *a priori* do not have expectations for case 4). Note that the turning points are at values of the independent variables that are $\hat{a}/2\hat{b}$ where $\hat{a}$ is the estimated coefficient of the linear tern and $\hat{b}$ of the quadratic term. Given the range of the variables, which is representative of the U.S. population, the estimated turning points in many cases are outside the range. The common conclusions for the three tables are related to the relevant range:

a) Education effect on the bid is positive although there might be a cut-off point (e.g. Ta. 2-9, Albuquerque 12 years).

b) Age effect is negative. It might be pronounced for ages above the cutting point. Thus for age the common picture is the right side of 3) and the left side of 4) in Fig.2-1.

c) Income has a similar effect as education.

d) The electric bill has a similar effect as income.

The final conclusion is related to the, question whether the observed behavior is the same in the four cities. The similarity is related only to the marginal propensities of the explanatory variables (city effects are accounted for by a city dummy variable). The answer is negative*. Searching for reasons for the insignificance of coefficients led to the possibility of multi-colinearity. This might arise due to the inclusion of both linear and quadratic terms and also due to potential expected (although non-linear) relationships between income on one side and education, age and race on the other side. One would also expect a positive relationship between income and the electric bill.

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*Based upon an F test on the residuals sum of squares (the Chow test).

Concerning city and variable results, we find that they are consistant. The consistancy is exhibited in the each city equation for each bid. The results are similar in nature. One might argue that this is to be expected since the explanatory variables are the same. While this is a fact,the consistancy of the estimated coefficients would not hold if the bids were not consistant. Hence, the three bids are not independent. Although each is expressed one at a time, they are motivated by the same reasons and affected by the same random errors. Thus, from the econometric point of view a "seemingly unrelated tobit model" is the appropriate model (does not exist).

2.3.3.2 Analysis of User Valuations

The analysis of user data is limited to those that visited or planned to visit the Grand Canyon. Thus, one expects them to be capable of better evaluating visibility in the western parks. The model and method of analysis are the same as the cities results reported above. The explained bid is for a specific improvement of visibility.

The various results presented in Ta. 2-13, 2-14 and 2-15 are strikingly consistent with this pattern of insignificance in the coefficient of "planned days at the Grand Canyon"; the coefficients of this variable are significant in almost all runs. Furthermore, the log likelihood ratio indicates that none of the probit runs is significant at the .05 level.[1]

Reviewing the probit analysis, neither rural residence, sex, nor race of the respondent is significantly related to the probability of a positive bid. Metropolitan location, specifically residence in Los Angeles, did in some cases affect the probability of a positive bid relative to residence in Albuquerque.[1] The coefficient for Denver (dummy) is always insignificant. Neither age nor education is significantly related to positive bids although.

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[1] The log likelihood ration in each probit runs is less than the critical y^2

TABLE 2-13

Coefficients of the Model Explaining Positive Bids

(Probit Analysis)

Dep.(3) / Indep	GCAB (14)[1]	GCAC (10)	GCAD (9)	GCAE (7)	RPBC (17)	GCPL (11)
Rural(D)	2.223 (5.44)[2]	2.780 (8.20)	2.635 (9.06)	2.530 (9.57)	2.660 (5.40)	2.358 (5.42)
Female (D)	.0738 (0.36)	-0.0459 (0.42)	0.0536 (0.44)	0.6032 (0.54)	-0.0042 (0.34)	0.6353)0.43)
Non-White (D)	.3705 (0.45)	0.1558 (0.48)	-0.0094 (0.49)	0.1440 (0.58)	0.8500 (0.52)	0.5359 (0.55)
Los Angeles (D)	1.229 (0.53)	1.073 (0.57)	0.9095 (0.58)	0.3987 (0.61)	0.8072 (0.47)	0.9781 (0.55)
Denver (D)	.1866 (0.37)	-0.2148 (0.44)	-0.3338 (0.44)	-0.6158 (0.51)	-0.2898 (0.37)	-0.097 (0.39)
Education (Yrs.)	.0055 (0.007)	-0.0077 (0.08)	-0.0033 (0.08)	-0.0190 (0.09)	0.0701 (0.071	-0.0082 (0.08)
Age (Yrs.)	-0.0049 (0.01)	-0.0013 (0.02)	-0.0063 (0.02)	-0.0043 (0.02)	0.0054 (0.01)	0.0042 (0.01)
Income ($1000.00)	-0.0118 (0.01)	-0.0148 (0.0;)	-0.00141 (0.01)	-0.0163 (0.01)	-0.0173 (0.01)	-0.0164 (0.0.)
Days Visited G.C. (#)	0.0578 (0.05)	0.2917 (0.16)	0.3036 (0.17)	0.2235 (0.161		0.1069 (0.08)
Planned Days To visit G.C. (#)	0.0983 (.07)	0.1169 (0.08)	0.0950 (0.09)	0.0560 (0.08)		0.0713 (0.07)
Constant	0.8025 (1.30)	0.7458 (1.58)	1.394 (1.65)	2.021 (1.70)	0.1978 (1.14)	0.3135 (1.4)
-2LLR	18.0	16.9	15.4	13.6	17.5	17.76

[1] Number in parentheses Indicates number of zero bids out of 147 cases.

[2] Standard errors noted in parentheses underlying estimated coefficients.

[3] GCAB = Improving the value of visibility in the Grand Canyon from level A to level B.
GCAC = As above from level A to level C.
GCAD = As above from level A to level D.
GCAE = As above from level A to level E.
RPBC = As above but for the regional parks from level B to level C.
GCPL = As above but for the Grand Canyon removing the plume.

TABLE 2-14

Bid Analysis Coefficients for Positive Bids

(OLS)

Indep. \ Dep.[1]	GCAB	GCAC	GCAD	GCAE	RPBC	GCPL
Rural (D)	0.4131 (0.79)	0.4180 (1.25)	0.645 (1.65)	0.1337 (2.51)	0.1189 (1.81)	-0.0892 (1.92)
Female (D)	-0.2600 (0.31)	-0.6547 (0.49)	-1.058 (0.65)	-1.514 (0.99)	-0.0119 (0.68)	0.1142 (0.75)
Non-White (D)	-0.4432 (0.37)	-0.8512 (0.58)	-0.9147 (0.77)	1.487 (1.17)	-0.9846 (0.80)	-0.8794 (0.88)
Los Angeles(D)	0.2001 (0.35)	0.4361 (0.55)	0.5371 (0.72)	0.5029 (1.1)	0.8181 (0.761)	0.2889 (0.83)
Denver (D)	-0.0135	0.1511 (0.65)	0.5096 (0.86)	-0.2747 (1.31)	-0.7337 (0.92)	0.8039 (0.99)
Education (Yrs.)	-0.0405 (0.07)	-0.0228 (0.12)	-0.0716 (0.15)	-0.1041 (0.23)	0.0040 (0.16)	0.0604 (0.18)
Age (Yrs.)	-0.0098 (0.01)	-0.0249 (0.02)	-0.0361 (0.02)	-0.0761 (0.04)	-0.0251 (0.02)	-0.0554 (0.03)
Income ($1000.00)	0.0076 (0.01)	0.0136 (0.01)	0.0240 (0.02)	0.0251 (0.03)	-0.0365 (0.02)	-0.0254 (0.02)
Days Visited G.C. (#)	0.0216 (0.04)	-0.0356 (0.06)	-0.0788 (0.081)	0.0171 (0.12)		0.0282 (0.09)
Planned Days To Visit G.C. (#)	0.0315 (0.04)	0.1042 (0.06)	0.2079 (0.07)	0.2816 (0.11)		0.2027 (0.09)
Constant	2.534 (1.09)	3.611 (1.73)	5.213 (2.27)	9.041 (3.46)	5.042 (2.39)	4.587 (2.62)
R^2	0.064	0.103	0.142	0.161	0.238	0.162

[1] See notes to Table 7.

TABLE 2-15

Coefficients of the Normalized Index of Bids

(Tobit Analysis)

Dep.[1] / Indep.	GCAB(14)	GCAC (10)	GCAD (9)	GCAE (7)	RPBC (17)	GCPL (11)
Rural (D)	0.3617[2] (0.47)	0.2614 (0.47)	0.2713 (0.47)	0.0899 (0.47)	0.3300 (0.50)	.0885 (.47)
Female (D)	-0.1186 (0.17)	-0.2266 (0.18)	-0.2708 (0.18)	-0.2375 (0.17)	-0.0257 (0.18)	.0981 (.17)
Non-White (D)	-0.1209 (0.21)	-0.2224 (0.20)	-0.1835 (0.20)	-0.1444 (0.21)	0.0428 (0.21)	-.1101 (.21)
Los Angeles (D)	0.3345 (0.20)	0.3444 (0.20)	0.3069 (0.20)	0.2051 (0.20)	0.4325 (0.20)	.2124 (.20)
Denver (D)	0.0045 (0.22)	0.1181 (0.22)	0.1467 (0.22)	-0.0360 (0.22)	-0.2019 (0.24)	.2065 (.22)
Education (Yrs.)	-0.0214 (0.04)	-0.0025 (0.04)	0.0073 (0.04)	-0.0089 (0.04)	0.0257 (0.04)	.0120 (.04)
Age (Yrs.)	-0.0065 (0.006)	-0.0092 (0.006)	-0.0112 (0.006)	-0.0136 (0.006)	-0.0036 (0.006)	-.0124 (.016)
Income ($1000.00)	-0.0013 (0.005)	0.0011 (0.005)	0.0023 (0.005)	-0.0001 (0.005)	-0.0156 (0.005)	.0096 (.001)
Days Visited G.C. (#)	0.0178 (0.02)	-0.0058 (0.02)	-0.0131 (0.02)	0.0077 (0.02)		.0111 (.02)
Planned Days To Visit G.C. (#)	0.0324 (0.02)	0.0487 (0.02)	0.0657 (0.02)	0.0630 (0.02)		.0625 (.02)
Constant	1.171 (0.54)	1.082 (0.59)	1.211 (0.61)	1.427 (0. 1)	0.734 (.57)	.9384 (.61)
$\frac{1}{\sigma}$	0.5965 (0.037	0.3881 (0.024)	0.2948 (0.018)	0.1966 (0.012)	0.2344 (.019)	.2588 (.016)
$P(Y>0 \mid X = \bar{x})$	0.833	0.043	.861	.865	.808	.816
$E(Y \mid X = \bar{x})$	1.77	2.80	3.92	5.95	2.49	3.867
R^2	0.073	0.112	0.148	.160	.143	.177

[1]See notes to Table 7.

[2]Coefficients estimated are $\frac{\beta}{\sigma}$

the age coefficient is at least consistently negative. The income coefficient is also consistently negative though insignificant. The number of days a respondent has spent at the Grand Canyon is close to being significantly related to positive bids. The number of days to be spent at the Grand Canyon in the future is not significantly related to a postive bid.

The OLS analysis attempts to estimate the behavioral structure of bids for those who bid a positive amount. Coefficients for the rural, race, metropolitan area, education, age, income, and days visited variables are consistently insignificant. The age coefficient, though insignificant, is again consistently negative. Planned days to be spent at the Grand Canyon is, however, significantly related to the magnitude of the bid. For each day planned, the bid on AC rises by 10¢, that on AD by 21¢, that on AE by 28¢ and that on the plume by 20¢. In each case, R^2's are very small.

Results of the tobit analysis are only slightly more revealing. As with the OLS, most coefficients remain insignificant. Age, however, is significantly negative with respect to the magnitude of bids. The income coefficient, where significant, is negative. Planned days to be spent at the Grand Canyon is in three out of four cases highly significant. Considering the equation as a whole, the R^2's again tend to be low. However, the predicted bids conditioned upon mean values for the independent variables are consistently increasing, as the conceptual structure of the bid curve would suggest. This consistency suggests that the bids were determined by a systematic method. Furthermore, predicted probabilities of a positive bid, conditioned upon mean values, tend

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[1]Albuquerque is defined to be the base city.

to correspond well with actual sample results. Thus, while the significance of the coefficients may not be very satisfying, the equations do seem to predict fairly well at average levels.

The Regional Parks tobit equation was also estimated for the case where the sum of past visits and sum of planned future visits to all Western Parks were the explanatory variables. The variable means are correspondingly 7.5 9.9 and they range from 0 to 80 and 0 to 60. The tobit equation does not change compared to the previous one. Also, the coefficient of the sum of past visits tends to be insignificant while that of future planned visits is postive significant. (-.0061 (.009) and .0223 (.008) respectively)

$$P(y>0|x=\bar{x}) = .776$$

$$E(y) \mid (x=\bar{x}) = 3.347$$

$$R^2 = .137$$

In the corresponding probit equation the visit variables have coefficients below their standard errors. The -2LLR is 14.9 with 10 D.F., which implies that the equation is not significant.

When analyzing the user survey we also looked at a model in which the answers for "Why a zero bid" were explicitly included as explanatory variables The coefficients of these variables (dummies) are always significant and negative. Thus obviously the R^2 is higher than in analyses without these variables. The explanation by other variables, mainly age and income, is some what better, although income never emerges as an important variable. The other socio-economic variables, including city effects,do not become more pronounced. The only exception is race. In several cases, being non-white results in significantly lower indexes (the tobit normalized coefficient); the coefficient of being non-white (dummy) is negative and significant.

The final run of the users survey data was an attempt to directly construct a bid curve. The variables to be explained are the differences in the bids, i.e., the vertical differences along the indifference curve in Fig. 2-3.

Future visits are important, although not always significant. The consistently significant variable is the height of the starting level of the bid. This is another clue for the consistency of the valuation of visibility.

Age is significantly negative while income has no effect. The same holds for education. City dummy variables and sex, race, rural-urban dummy variables have unstable coefficients. In most cases their standard error of estimate is larger than the corresponding coefficient.

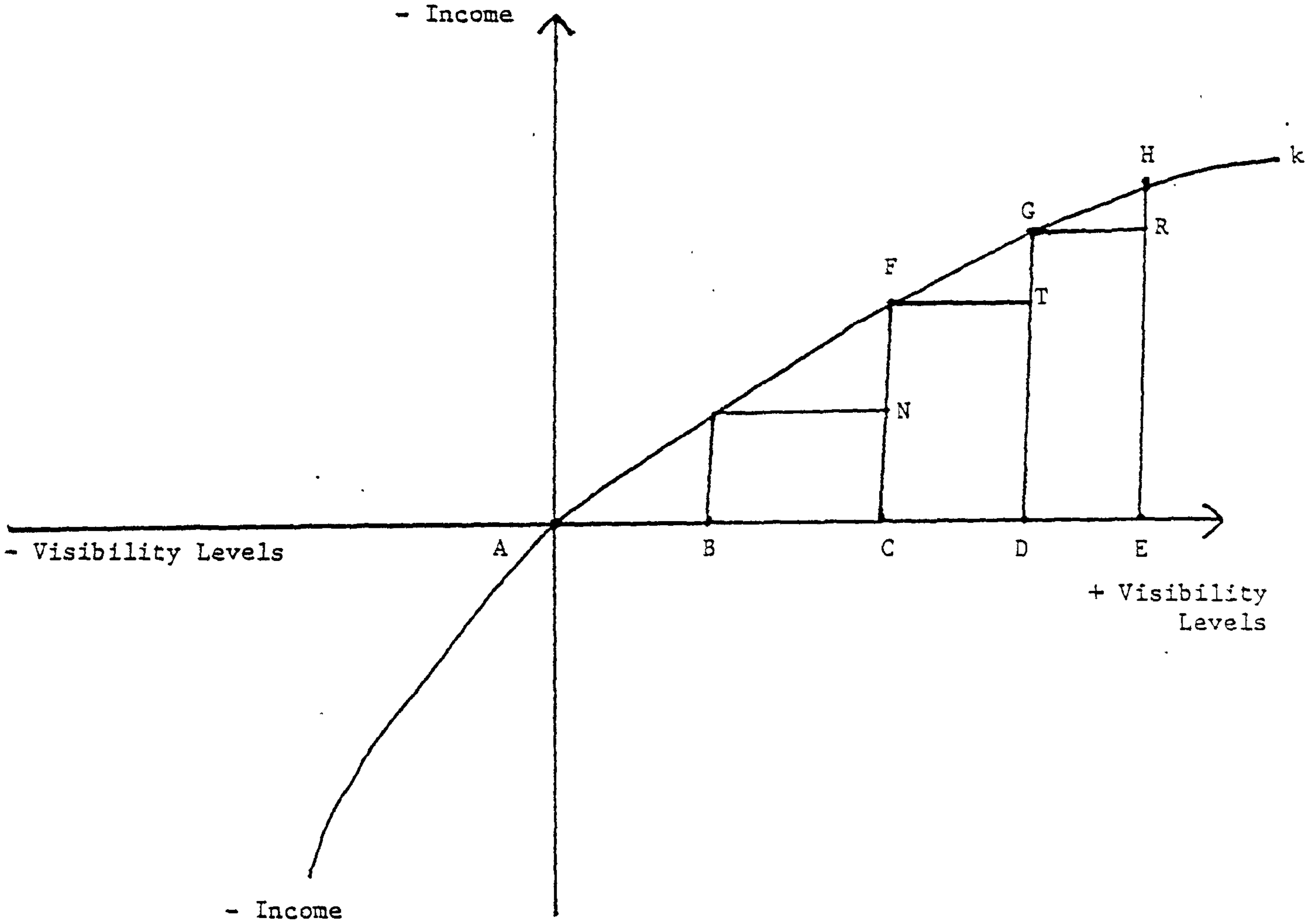
Overall, two observations can be made. First, the coefficient of the explanatory variables, with only an occasional exception, are insignificant. Second, predicted bids across increments in visibility are consistent. The implications that can be drawn are that the knowledge and perception of the population affected the quality of their answers. Those that have not been in the western parks and do not intend to be there in the future are likely to have less information about them than those that have either visitied or plan to visit.

Deficient information does not relate only to what one expects to see but mainly to the costs involved in getting there, the time required, the effort and effect of the weather on enjoyment. Those that have less information make decisions under greater uncertaintly where the distribution of perceptions they are drawing from is not stable.

The amount of information available differs depending upon whether they have already visited or plan to visit. The idea that these differences will cause their bids to change was tested by estimating separate relationships

FIGURE 2-3

The Bid Curve (AK)*



* In the analysis, the vertical segments FN, GT and HR are the explained variables.

for each group (Ta.2-16). The disadvantage with this approach is that the sample sizes are small, which is important given that we employ a maximum likelihood estimation procedure. Note the distance effect for Chicago. Hence, everything else the same, the information is low and the expected variance in the bids large (row 4 of Ta.2-16). On the other hand, comparison of means and variances of other population characteristics indicates considerable similarities (e.g., income, the last two rows of Ta. 2-16).

TABLE 2-16

Distribution of Bidders by Status
w.r.t. Visits to the Grand Canyon
(percent)

	LA	Denver	Alb.	Chc.	All
Visited	28.8	31.4	41.4	21.7	31.4
Plan to Visit*	80.5	71.4	74.7	68.1	74.4
Mean Bid	4.98	3.79	3.78	7.64	4.83
Std. Dev.	10.9	5.4	11.5	25.5	13.8
Mean Income	29.0	32.0	20.7	30.0	28.0
Std. Dev.	20.1	20.2	10.5	17.5	18.2

*Contains also those that visited in the past.

2.4 VISIBILITY VALUE FUNCTION

2.4.1 Overview to Section 2.4

The visibility value function was the concern of all of Section 2 research. The function embodies important results of this research and extends them in significant ways. The theory of household production, fundamental to the development of the CV instrument, was equally important to the development of the visibility value function. The importance of regional, or spatial economics was recognized from the beginning of the Project. However, the spatial dimension receives its most complete formulation in the work of Section 2.4.

The spatial problem was how best to use evidence from six cities to measure the value of visibility improvement in the entire eastern U.S. The earliest solution to the problem, as reported in Section 2.2 for example, was to regress measures of willingness to pay for each separate program on social and demographic variables . This would lead to a regression equation for each CV program in each city. For example, willingness to pay (WTP) for a ten mile improvement in Atlanta would be estimated separately from WTP for a twenty mile improvement in Atlanta. Similarly, there was no hypothesis about what a ten mile improvement in Atlanta would be worth to residents of Mobile, as distinct from Chicago’s WTP for the Atlanta improvement. WTP statements were modelled as if people regarded the East as a spatially undifferentiated area.

Spatial differentiation is introduced by the visibility value function in Section 2.4. It modelled WPT for regional improvements as directly proportional to the area of improvement in square miles and inversely proportional to distance from the improvement. This specification permitted valuations of different hypothetical programs in the CV exercise to be treated as data underlying a single demand curve. The implication for policy application in Section 4 was that a regional visibility policy, which produces numerous geographically dispersed improvements, can be evaluated by means of a single visibility value function. The spatial aspects of behavior and the substitute nature of visual air quality in different locations established in Section 2.1.4, were explicitly modelled. In addition, by pooling the data and estimating a single equation, more precise parameter estimates were obtained.

We have seen in the previous section that households were willing to pay less for visibility-improving program when presented at the end of a series of similar programs then when presented alone to the respondents. In this section a model is developed which accounts for this behavior and allows the construction of a general visibility value function which can be used to estimate aggregate benefits of a wide variety of policy scenarios.

A central feature of the model is its direct incorporation of spatial relationships into the empirical specification. In order to make meaningful statements about these spatial relationships an expanded data sample was gathered from the metropolitan areas in and around six major cities in the eastern United States. The iterative bidding game technique was again used for this purpose, although it was somewhat modified to reduce confusion found among some respondents. As before, a large amount of socioeconomic data and data on household participation in liesure activities were also gathered. More complete description of this dataset follows later in this section. First. we will develop more fully the conceptual framework that is used to analyze the problem at hand.

2.4.2 Visibility in Household Production

Visibility is primarily a spatially-distributed public intermediate good in the framework of household production and consumption, although there may be important effects from the direct entry of visibility into the utility functions of individuals as an amenity. In the household production analysis, visibility is combined with other factors of production such as scenery, eyeglasses, telescopes, and other human and physical capital such as astronomy classes or picture windows, to produce a service or “commodity” which enters into the utility function of the individuals.

The individual’s demand for visibility is, in this framework, formed by the vertical summation of the derived demand curves for visibility from each commodity. The market demand is the vertical summation over individuals of these demand curves, thus representing a second level of aggregation.

For the remainder of this analysis, the first level of aggregation, that of each individual over the array of utility producing commodities, will be summarized under the heading "visual services." Our goal is to explain variation in household demand for visual range (VR) based on the household’s stock of other inputs of production of visual services (VS), income, and current consumption of VS. This latter variable is important since the demand being measured is the marginal or net demand, given an initial endowment of VS and other goods and services.

To make sense of a household’s demand for increments in visibility we need to establish some way of quantifying VS which is consistent with economic theory. For our purposes it is not sufficient to say that a certain person in Chicago consumes visibility of, say, twelve miles, for this statement would ignore altogether how the value of these twelve miles might differ for, as an example, a poor-sighted individual in a basement apartment and a keen-sighted owner of a high-rise condominium with a spectacular view and a telescope mounted on the balcony. In addition, using local VR as a measure of a household’s consumption of VS would ignore completely the value of nonlocal visibility, which we have seen and will see again in this section has value to households as they have expressed by their willingness to pay for increments in nonlocal VR. This latter effect is of critical importance in the analysis of the social value of visibility improvements because sometimes areas receiving visibility protection might have few if any permanent inhabitants, and so a measure of VS which did not allow for nonlocal effects would place a zero value on these areas when our common sense tells us otherwise.

To get a better understanding of the spatial nature of VS we will draw an analogy from a more commonplace example of the same kind of economic structure, that of urban parks. If we require an estimate of the social value of an additional lakefront park in the City of Chicago, for instance, we would want to know where the park would be located, where the population is located, the current distribution of parks and park facilities, and lastly any unique site-specific features of the new park. We can abstract somewhat and think of each household as facing an array of parks distributed on a two-dimentional plane with the household at the origin. Each park has a certain amount of facilities and scenery, which can be thought of as a measure of quality, and each park has some unique characteristics. We should expect some basic properties to hold in this framework. First, it is reasonable to suppose that for a given park there are diminishing returns to quality. Second, the value of a given park to a given household will be negatively related to the distance between the residence and the park. Lastly, the value of the new park would be lower for households already in close proximity to parks than for households very distant from all parks, controlling for the other characteristics.

A measure of park consumption would then need to add all available park acreage, but only after weighting in some way each park according to its distance from the household and its quality. Similarly, a measure of visibility consumption should add together visibility in all places, but weighting each place's contribution by its distance, scenery, and quality. In particlular we define a function relating VS to these variables as

(2-39) $$VS_j = \sum_i VR_i^{\alpha_1} SM_i^{\alpha_2} D_i^{\alpha_3} SC_i^{\alpha_4} ,$$

where VS_j is household j's consumption of VS, VR_i is visual range in state i, SM_i is the area of state i in square miles, D_{ij} is the distance between household j and the center of state i, and SC_i is a measure of scenery in state i. The summation is done for the "continental" United States, including the District of Columbia. D_{ii}, the own-state distance is approximated by half the radius of a circle which would have area SM_i, or

$$D_{ii} = \tfrac{1}{2}\sqrt{1/\pi} \cdot \sqrt{SM_i} \qquad (2\text{-}40)$$

Although it might be possible to construct a proxy for SC , no such proxy is both convincing and readily available. Therefore, for the remainder of this analysis SC will be set equal to one for each state, equivilent to the assumption that each state has an equal amount of unique scenery. In addition, the following simplifications will be used:

1. All states west of the Mississippi River are combined into a single "super-state" centered near Denver.
2. The paramenters α_1 and α_2 from eq. (2-39) will each be fixed at unity.

The value of the remaining parameter α_3, the exponent on distance, will be estimated jointly with the vector of household characteristic parameters, as will be discussed below.

The current distribution of visibility as calculated by Trijonis is shown in Fig. 2-4. The isopleth map represents lines of equal VR at nonurban locations. Based on the data contained in this map, each state is assigned an initial level of VR. For additional information on this data and application of this distribution to the estimate of actual program benefits see the expanded discussion in Section 4 of this report.

2.4.3 Basic Properties of Visibility Valuation

Each household is assumed to have a well-defined, continuous, and mono-

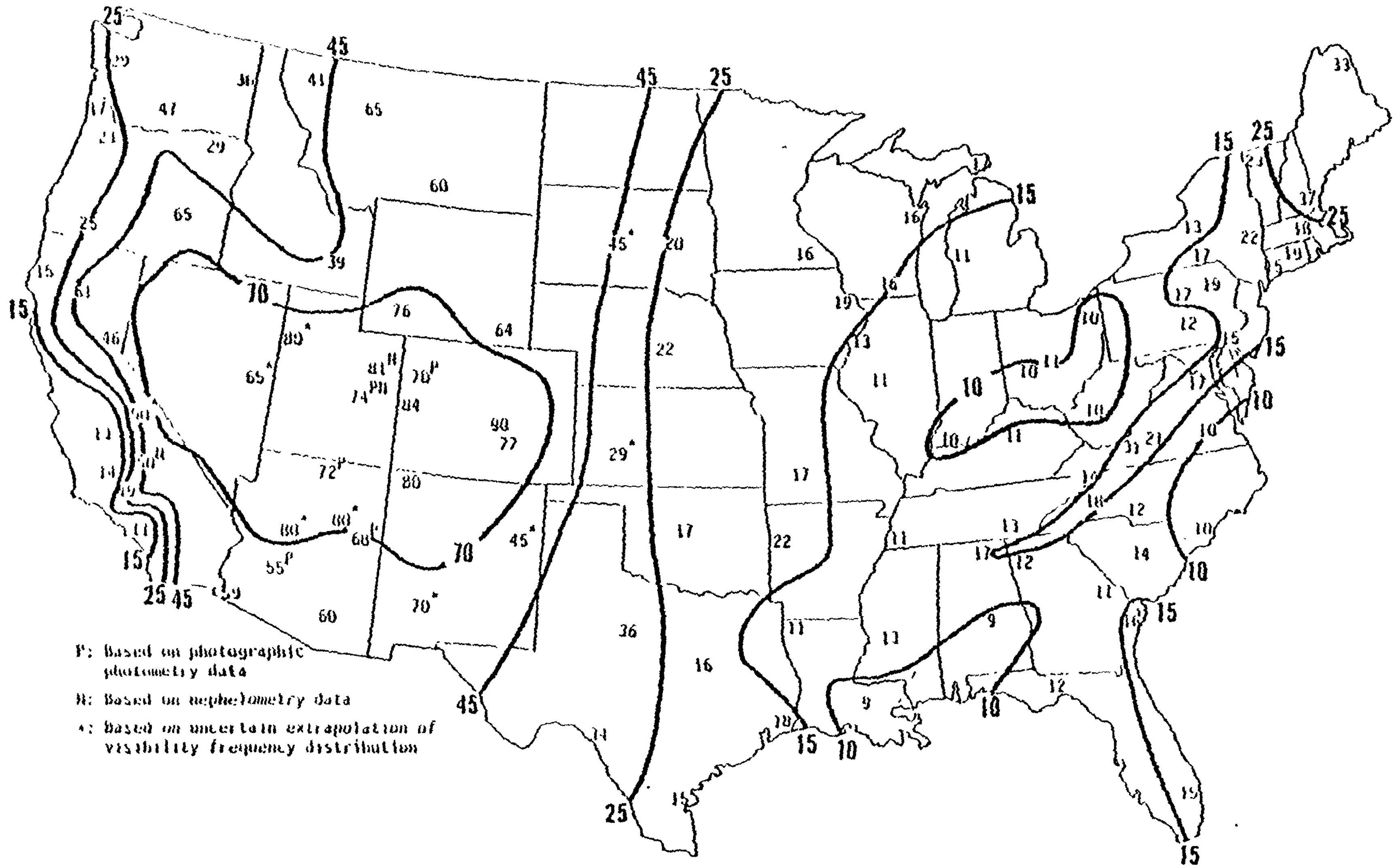


FIGURE 2-5. Median yearly visibilities and visibility isopleths for suburban/nonurban areas.

Source: Trijonis and Shapland, 1979

tonic increasing total benefit curve for VS. In Fig. 2-6a such a carve is shown. For a given household at a given moment, VS is fixed exogenously at VS^0. The total benefit at this level of VS is also shown in Fig. 2-6a. These two quantities determine the "endowment point" of VS and all other goods which we are measuring in dollar bundles along with the benefits of VS. These two lines become the axis for the marginal bid curve merely by rescaling the old axis. The only non-trivial point is that we do not know the original scale or the total benefit curve. All we can observe is the benefit from changing visibility from its present level as Fig. 2-6b for any individual.

Being a simple transformation of the total benefit curve, the marginal benefit curve, or bid curve, has the following properties:

Property 1: $BID(0)=0$
Property 2: $BID'(\Delta VS)\geq 0$
Property 3: $BID''(\Delta VS)\leq 0$
Property 4: Limit $BID'(\Delta VS)=0$ as $\Delta VS\rightarrow\infty$

It is important to note that some individuals will be at a point on their total benefit curve such that the slope of the bid curve is not significantly different from zero over the range of VS which is encountered by the respondent during the iterative bidding procedure. This does not imply, of course, that the individual does not value visibility, just that total benefits are some arbitrary constant over the relavent range.

As we have seen, for a given individual the marginal value of visibility (or VS) declines as total consumption increases. We might therefore expect that households in high VS cities bid less for increments in VS than do households in low VS cities, controlling for income and all the other fac-

FIGURE 2-6a

Total Benefit Function

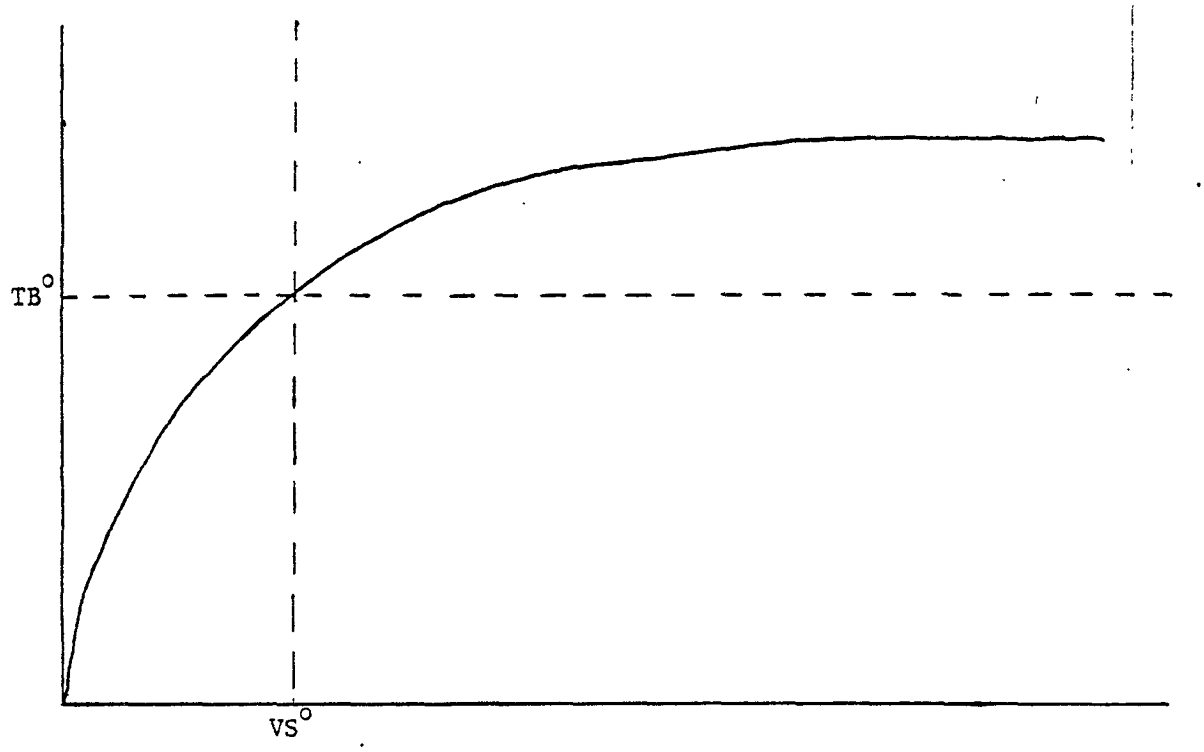
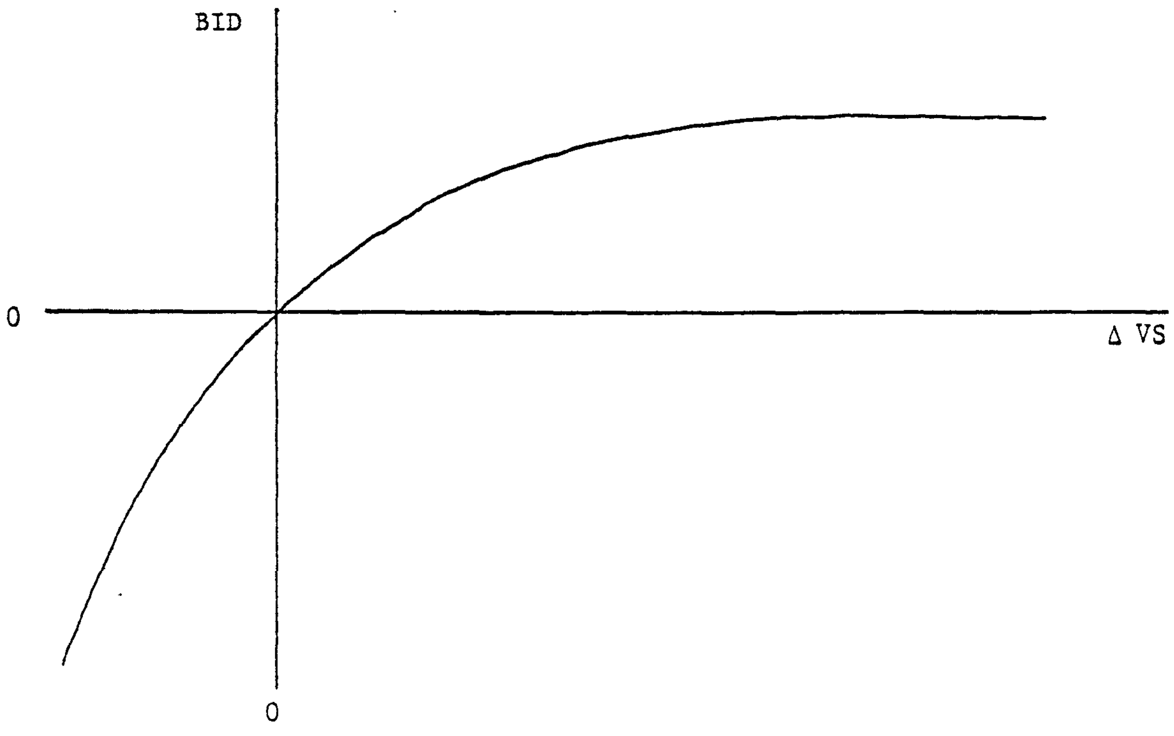


FIGURE 2-6b

Benefits of Changing Visibility from Present Level



tors. Such an expectation cannot be sustained, however, as long as the population is not homogeneous with respect to household demand for VS.

Once we acknowlege a heterogeneous population we must recognize that there will be some tendency of individuals to sort among the cities according to their demands for VS (and other amenities, of course). Thus, at the margin an extra mile of VR might be worth more to the average household in the high-VS city than the corresponding household in the low-VS city. This effect is reinforced by the additional tendency of households in low-VS cities to specialize their human and physical liesure capital in activities not visibility-intensive, such as indoor recreational facilities and training. Households in these areas might also spend resources on other factors of production, such as a residence with a glorious view of a nearby park or garden, as opposed to a household in a high-VS area investing in a residence with a view of a distant vista. Thus, even if the marginal product of VR is higher when the initial level of VR is low, it may be the case that the value of this marginal product may be rather low, especially in the short-run when households are even less able to adjust some other factors of production.

Since we will be examining a cross section of only six cities any estimate of this reduced-form effect of the level of initial visibility should be treated with some caution, although it remains an interesting and important parameter in the bid function.

2.4.4 The Visibility Value Function

We now turn to the empirical specification and estimation of the visibility value function (VVF). We require for this a functional form consistent with Properties 1-4 and capable of handling both continuous and discrete explanatory variables. This is not a simple matter. A normal OLS regression. even without an intercept term, will violate Property 1 if simple dummy variables are used. Also, a dummy variable for a discrete effect will not be correctly specified, since we know from Fig. 2-6b that a variable which tends to increase bids for positive changes in visibility will neccessarily tend to decrease (increase in absolute value) bids for negative increments in visibility.

What is needed is a functional form which has Properties 1-4 and which allows the bid curve to pivot around the origin with changes in the vector of explanatory variables while preserving these properties. Such a form is suggested by the "negative exponential growth" function, which we adapt as

(2-41) $$BID=[1-\exp(-\gamma\Delta VS)] \quad ,$$

which is monotonic increasing, passes through the origin, and has an upper limit of +1 (for all positive values of Y). This gives us our prototype bid function. We now need to include a rotational vector of household characteristics H, where

(2-42) $$H=(\alpha+\Sigma\beta_i Z_{ij}+u_j) \quad ,$$

so that H is a linear combination of these characteristics Z, and there is an unexplained household-specific rotational parameter u .

Our complete empirical bid curve is then given by the product of these two terms to form

(2-43) $$BID_j = [1-\exp(-\gamma\Delta VS_j)][(\alpha+\Sigma\beta_i Z_{ij}+u_j)]$$

where VS is given by eq. (2-44) below and BIDj is the willingness-to-pay (WTP) of household j. VS is given by changes in eq. (2-44) due to the program; α is a common intercept term (of rotation, not level of bid); Z is the vector of household characteristics with parameters B; u_j is the household-specific rotation of the bid curve.

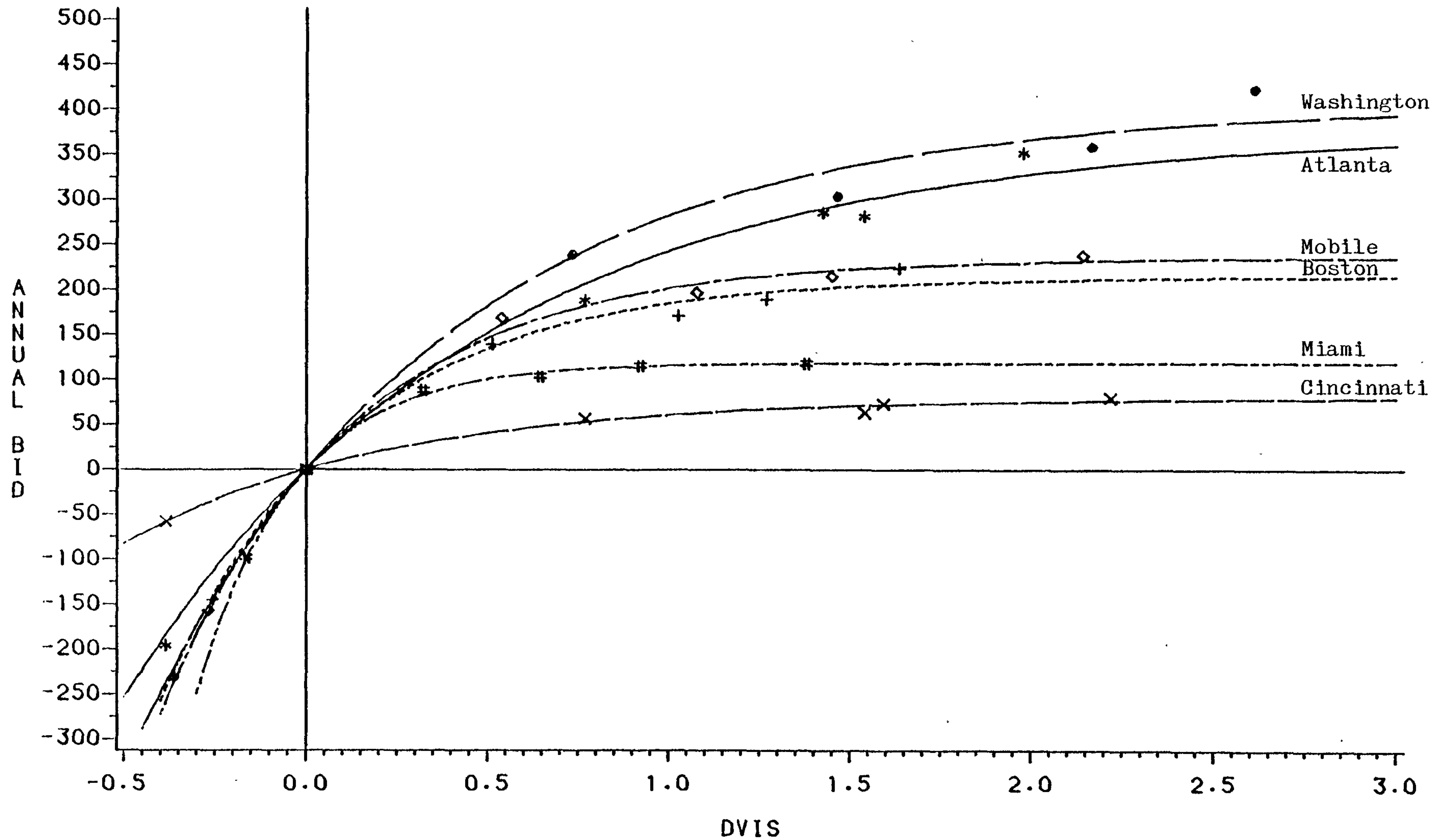
TO demonstate the properties of this function, a bid curve was estimated through each city's mean bids for the five programs. The non-linear regression was run once for each city, estimating only the α and the γ parameters. The hypothetical visibility programs are presented in Ta.2-17. The scenarios are the same in each city, but a given scenario represents different values of VS, depending on the other factors in eq. (2-39). (the parameters of which were estimated from preliminary maximum-likelihood regressions). In Ta.2-18 the initial value of VS, the value of VS for each program, and the mean bids for each program are presented for each city in the sample. The formula used to calculate VS for the empirical analysis is

(2-44) $$VS_j = \sum^{i} VR_i * SM_i * D_i^{-1.5}$$

where the exponent on the distance variable was estimated by a ML method jointly with the vector of household characteristics and the parameter γ, as discussed below. An important result of the derivation of VS is that some cities with very good local visibility conditions appear to have very poor quantities of VS since they have rather poor proximity to the other parts of the country. This is most notable in New England, where VR is the highest in the eastern U.S. but VS is calculated to be among the lowest. Since, in the eastern U.S., centrally located areas tend to have the lowest VR and the peripheral areas have the highest VR the estimated effect of initial VS will tend to be of opposite sign of that of the effect of local VR. If one believes that eq. (2-44) inadequately weights local effects then this will be the direction of change due to increasing this weight.

FIGURE 2-7

Marginal Bid Curves, by City



Note See text for derivation of bid curves

In Figure 3 the mean bids are plotted against VS as calculated in (6) for each of the six cities. For each set of points, a non-linear regression is fit of the form

$$\text{(2-45)} \qquad BID = [1-\exp(-\gamma\Delta VS)]*\alpha + e \ .$$

The figure shows the plot of the regression lines for each city. It should be emphasized that these city results are illustrative only. The visibility value function finally estimated applied a maximum likelihood approach to eq. (2-43) in which all cities were included in one regression, as will be discussed below.

We now turn our attention to the members of Z, their definitions, and the economic implications of each. Summary statistics of each of these variables can be found in Ta.2-19 for those observations which were used in the final regression i.e. excluding those households which did not report BID or one of the explanatory variables, usually income, and those who identified themselves as protesting the bid framework as strategic bidders. In addition, 21 persons who did not voluntarily identify themselves as one of these were dropped by the investigators for bidding substantially more than their available income, or for inconsistent answers coupled by interviewer reports of confusion.

The first variable we will consider has already been discussed at some length. This is VISENDOW, the initial level of VS as calculated in (2-44) above and reported in Ta.2-18. As discussed above, this variable will capture the net effect of the combination of the pure endowment effect from diminishing marginal utility, the sorting effect, the substitution effect, and the other complications discussed.

The second characteristic to be considered is that of income. A quadratic form is used to estimate the income effect, with a first order variable INCOME, in thousands of dollars, and a second-order term INCOME2, which is equal to INCOME squared. The parameter estimates on these variables (along with INCAGE discussed below) will be used to calculate a point estimate of

TABLE 2-17

Hypothetical Visibility Programs
as Presented to Survey Respondents

Program	Change in Visual Range	Area of Coverage
1	-5 Miles	Local*
2	10 Miles	Local
3	20 Miles	Local
4	10 Miles	Eastern U.S.
5	10 Miles	All U.S.

* Note: Local is defined as all land.area within 75-mile radius of the city center. East U.S. includes all land area east of Mississippi River. All U.S. includes all states except Alaska and Hawaii, and includes District of Columbia.

the income elasticity of demand for VS. This estimate is of interest because most researchers report or suggest that the income elaticity for environmental goods is greater than unity. This data provides a check on this hypothesis.

The number of persons in the household, HSLDSIZ, is important for two reasons having opposite expected signs, making the net effect ambiguous. The first effect is the public good effect within the household itself of the increments in VS. The respondent is asked to accept or reject a program at a given cost to the entire household. Since the good is non-rival, the respondent will sum as accurately as he can the marginal benefit functions of each household member to arrive at the household benefit function.

The other effect, however, works in the opposite direction. The actual disposable income available to the household for the programs is probably calculated by subtracting certain fixed or very inelastic costs from total

TABLE 2-13

Initial Levels of VS and Proposed Changes,
by City with City Mean Rids

	Atlanta	Boston	Cincinnati	Miami	Mobile	Washington
1980 Endowment	4.34	4.20	4.51	3.51	4.59	4.66
ΔVS_1^*	-0.02	-0.11	-0.11	-0.01	-0.03	-0.04
ΔVS_2	-0.02	0.05	0.11	0.01	0.02	0.15
ΔVS_3	0.21	0.24	0.34	0.11	0.15	0.35
ΔVS_4	0.26	0.41	0.56	0.14	0.20	0.57
ΔVS_5	0.21	0.17	0.22	0.16	0.21	0.22
BID_1	-195.92	-144.59	-57.48	-98.69	-156.40	-231.70
BID_2	188.39	138.94	56.94	88.47	168.00	238.36
BID_3	286.21	170.56	63.64	104.04	196.68	302.97
BID_4	281.42	188.79	73.53	115.53	214.52	358.14
BID_5	352.81	224.22	79.72	113.34	238.48	421.93

*Change from 1990 Base Case value.

income. These costs, such as food, clothing, etc. are likely to be correlated with household size, so that for a given money income the actual disposable income is reduced as household size increases. Thus the net effect is ambiguous.

Education, HOHED affects BID in two ways, although in this case the two act in the same positive direction. The variable is defined as the number of years of schooling of the head of household. The direct way that education affects BID is through the household production functions for various activities. In the human capital model, education enters the production function as an input. As long as education has a positive marginal product in production of these activities it will positively influence BID.

The other way that education affects BID is through its effect on household permanent income. So far we have looked at current income only. The now classic treatment by Milton Friedman of consumption as a function of transitory and permanent income gives us some guide to the effect of some of the explanatory variables. For a given level of current income, the more educated person will tend to have a higher permanent income, given quantities of other human and nonhuman capital. Thus we would expect BID to be positively affected by HOHED.

Age is a variable that combines permanent income and human capital effects. For many outdoor activities, youthfulness can be considered as an input in production, or at least as a cost-reducing factor. Thus, the direct effect of age would be to reduce the value of increments in visibility.

The permanent income effect also works in this direction. For a given money income, a middle-aged person will tend to have a lower permanent income than a young person, given the usual age-wage profile. Again, if the person is consuming out of permanent income then, in this example, the young person will have a higher WTP.

It is likely that the effects of income and age are not independent. In particular, the marginal propensity to consume VS out of money income may vary with age, aside from the independent effect of age on BID. To capture this effect an additional variable, INCAGE, is introduced which is equal to the product of INCOME and HOHAGE. This variable is included in the calculation of the income elasticity of demand along with the independent income terms.

Two additional variables enter the vector Z which arise partially out of permanent income considerations. These are race and sex. It has been shown that race and sex enter significantly into the earnings function of individuals. Nonwhites tend to earn less, even after controlling for other human capital variables; and the same is true for women. A special problem exists for female-headed households when children are present, especially among poorer households.

In the case of nonwhites, there is often a geographical separation from whites, and often the division is along central city/outlying area grounds. It is not clear what the net effects will be of these variables, but we can guess that the effects will be negative, based on the permanent income analysis. The variable FEM is a dummy for female-headed households (it should be noted that this includes households where both husband and wife are present and the wife responded and listed herself as “head of household”). The variable NONWHITE, also a dummy variable, represents any of the following groups: Blacks, Latinos, Asians, and Native Americans.

We have said that the household’s stock of human and physical capital influences BID by increasing the marginal product of VIS, but that VS may be high already because of the capital that BID is lower in households with large stock of these inputs. One item on the questionnaire asked the respondent to indicate whether or not the household owned or had access to such things as a private plane, binoculars, telescope, and others. To get a large enough sample to allow estimation of the effect of the physical capital ownership, these responses were pooled so that ownership of any of these specialized capital goods caused the dummy variable EQUIP to be set equal to one Otherwise this variable equals zero.

The view quality from the residence is treated as a special case of physical capital ownership. EXVIEW is a dummy variable which equals one if the respondent believes their view to be excellent or especially attractive, zero otherwise. Aside from the ambiguity resulting from the effect discussed in the preceeding paragraph, view quality is sugject to an additional caveat. A respondent who reports an excellent view might bid a low amount because VS consumption is already very high, or because they are insensitive to VS to begin with, and thus report a good view where other might not. Both of these possibilities are consistent with low WTP. Like EQUIP, EXVIEW cannot be signed a priori

Just as household size is important for the intra-household public good effect, so too will the number of activities participated in by the household be important to the household’s WTP for the visibility programs. The variable ACT is a crude measure of the household’s participation in various activities throughout the year. The respondent was handed a checklist of activities and asked to indicate those which the household takes part in during a normal year. The excercise was motivated both by the recognition of this intra-household and intra-individual public good effect across activities, and also for its usefulness in getting the respondent to think carefully about the various ways in which visibility entered into their household activities. Presumably, this aided in the accurate revelation of WTP's for the various programs. The variable ACT is just a count of the number of activites checked by the respondent on the list, each receiving equal weight.

One aspect of human capital which closely parallels the discussion of physical capital is the quality of eyesight. If we take extremes, a blind person will likely find changes in VS to be worthless, except insofar as they have indirect benefits such as saftey on commercial airplanes or crossing the street. On the other hand, a person with highly acute vision may find the marginal product of VR to be high in producing more VS, but can see so well already that the increase is of little value. The variable POOREYES is a dummy variable indicating an admission of poor eyesight on the part of the respondent.

The next set of variables addresses the ownership of residential property. The wording of the questionnaire emphasized that the BID would reflect the total cost of getting the program enacted. We recognize,however, that some individuals will not quite appreciate the meaning we are attatching to the word “all” and might believe that their property values might change if a local amenity changes the desireability of living in their city, or they might think that controlling pollution makes life in their city less profitable, thereby reducing property values. We could not be more explicit in steering any such persons away from these ideas, since the very suggestion might well have led to even more suspicion on the part of persons to whom the idea hadn’t occurred.

Aside from this potential flaw in the reported WTP’s, the ownership of property may well indicate real differences in economic value of visibility. If an owner-occupied home provides better opportunities for indoor substitutes for outdoor activities than does a rented apartment, then we should see such households bidding less. Also, if one own income-earning property, then the increase in tenant’s WTP may be partially collected by the owner. Thus, for a given change in visibility the property owner would be willing to pay more, reflecting someone else’s increased welfare. We do not, however, have to worry about double-couting of a single gain. To the extent that this indirect gain is important, the tenant will subtract an amount equal to the extra rent payments in the new equilibrium, so it is a pure transfer and will not affect the aggregate benefits as calculated in Section 4 of this report. The variable OWN signifies ownership of the housing unit occupied by the household, and the variable PROP indicates ownership of other residential property in the eastern U.S.

Finally, some geographic identifier dummy variables enter the analysis. The first of these is a dummy which equals one if the household is located in a rural area, named RURAL. There are several possible effects of a rural location on the bid function. First, a rural household might receive less benefits from an improvement in air quality centered in the middle of the city. Second, the general view quality may be higher in the rural area; having the effects discussed for EXVIEW. Third, cost-of-living differentials may result in a dollar buying more of other goods in rural areas than in the city, thus reducing BID for a given increase in welfare. This latter effect will also be important in the city-specific effects discussed below. The first and third of these effects tend to reduce bids while the second is ambiguous. Our hunch is that the negative effects will prevail.

In addition to the urban/rural dummy variable a set of four city-specific dummy variables will be used to help account for unexplained differences between cities. Only four can be used since one of the six city degrees of freedom has already been used up by the variable VISENDOW and the intercept uses another. The four cities with dummies are Atlanta, Cincinnati, Miami and Washington, with variable names A, C, M, and W respectively. Boston and Mobile remain as the base. Ta.2-19 gives the variable means for observations used in the regressions reported in section 2.4.5.

2.4.5 Empirical Estimation of Visibility Value Function

Eq. 2-43. has been estimated using a modified Gauss-Newton non-linear

TABLE 2-19

Variable Means for Observations Used in Regression

Variable	Mean
BID	108.704
DVIS	0.852
VISENDOW	3.754
INCOME	23.195
INCOME2	837.070
HSLDSIZ	3.177
HOHED	13.066
HOHAGE	45.391
INCAGE	1027.709
FEMHOH	0.395
NONWHITE	0.323
EQUIP	0.539
ACT	11.919
OWN	0.663
PROP	0.136
EXVIEW	0.491
POOREYES	0.226
RURAL	0.114
A	0.173
C	0.179
M	0.089
W	0.166

regression routine. Overall, between one-half and two-thirds of the variation of BID is accounted for by the explanatory variables, a high amount for cross-sectional survey data of this type. A point-estimate of the income elasticity of 0.539 is computed, holding all non-income variables at their means. This does not support the hypothesis that visibility is a luxury good, but rather that it is in the range of a normal good between zero and one. The first-order effect of income on BID is strongly positive as expected, but the negative second-order effect and the negative income-age interaction effect were somewhat larger than expected (although the direction was correctly forecasted). The negative interaction term confims the hypothesis that the marginal propensity to consume visibility does indeed decrease with age.

The above analysis takes account only of current money income, but as discussed above, stocks of human and nonhuman capital alter expected future income, thus having an effect on current consumption through the permanent income model. Turning to the human capital variables, we find an unexpected result. The estimate of the education parameter is negative, so that more educated person tend to bid less, holding the other variables constant. The explanation for this could be that education can have the same negative property discussed for the case of a good view, so that education, being more or less fixed as far as the individual is concerned, has already increased the productivity of leisure time so much that additions of VR have little additional value.

The variable HOHAGE must be considered jointly with the variable INCAGE. For very low income households, age actually increases WTP for VS, but as this declines until about an income of $9,000 per year the net effect becomes negative. This is not difficult to explain. As age increases, leisure time tends to increase, especially when one or more household members retire from the labor market. This reduction in the opportunity cost of time will shift out the demand curve for visibility and other leisure inputs. However, there will exist a negative correlation between income of these households and the amount of leisure time available. Thus, an older couple still working full time have a lower demand than if they retired, even though measured income is higher.

Nonwhites bid significantly less than whites, and females bid more than makes. We have no good explanation for the latter finding other than the possibility that women are less suspicious and conservative in responding to the (typcially female) interviewers than were men, although there doesn't seem to be any way for us to test this hypothesis.

Poor eyesight and ownership of specialized capital equipment did not have a clear effect, perhaps confirming our notion of the two underlying and opposing effects discussed earlier. As expected, participation in activities has a positive influence on bids, reflecting the non-rivalness of visibility within the household.

One of the dramatic results is the negative influence of view quality on bids. As discussed previously, it could be the result of diminishing marginal utility comgined with a fixed factor (view). Alternatively, the correlation could be spurious, reflecting the fact that people who are very satisfied with their present view are the ones who will not bid much. Thus, we may in part be measuring the same thing in two different ways. Both of these effects are probably important here.

The property ownership variables were of rather large magnitude, with home ownership having a negative impact and the ownership of other residential property having a positive effect. See the previous discussion of these variables for some possible interpretations of these results.

The package used to estimate the parameters in Ta.2-20 does not provide a confidence interval for estimated bids. It seems likely that Gamma and Alpha have

TABLE 2-20

Non-Linear Least Squares Summary Statistics
Dependent Variable BID

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
REGRESSION	22	130303017.02030957	5911864.41001407
RESIDUAL		140479409.60049038	44996.60781566
UNCORRECTED TOTAL		270782426.62079995	
(CORRECTED TOTAL)	3143	233630610.1008546	

PARAMETER (VARIABLE)	ESTIMATE
GAMMA	0.700
ALPHA	-472.606
VISENDOW	155.757
INCOME	14.797
INCOME2	-0.029
INCAGE	-0.172
HSLDSIZ	5.327
HOHED	-2.011
HOHAGE	1.586
EQUIP	4.417
EXVIEW	-67.139
BADEYES	12.065
ACT	5.175
PROP	97.183
FEMHOH	50.684
OWN	-138.736
RURAL	-41.049
NONWHITE	-78.691
A	139.928
C	-187.137
M	112.550
W	-17.078

a high degree of correlation, and errors in the Gamma estimate are largely offset by corresponding errors in Alpha. Standard errors are almost irrelevant in this case, as they are only assymptotically valid, and the function is degenerate for values of Gamma near 0. Because of this degeneracy, a direct test of the hypothesis Gamma = 0 is not possible; however, an indirect test of the hypothesis was carried by constraining the estimate of Gamma to be less than 0, and re-estimating the function.

The parameter estimates complete the specification of Equation (5)--the visibility value function. For an example of the uses of this function to estimate aggregate policy benefits see Section 4 of this report.

Section 3

SECONDARY DATA ANALYSIS OF VISIBILITY EFFECTS

3.1 OVERVIEW of SECTION 3

Section 3 is a related group of studies of the role of visual air quality in particular household activities. Swimming, Hancock Tower visitation, and baseball attendance represent active and passive outdoor recreation. Studies of view-oriented residences explore the relationship between view and visual air quality at the household residence. Auto and air traffic studies investigate the importance of visual air quality in basically non-recreational outdoor activities. Finally, the study of TV viewing establishes the role of visual air quality in influencing the choice between indoor and outdoor recreation.

These studies complement the contigent valuation work of Section 2 in several ways. First of all, the studies of Section 3 all pertain to particular markets, such as baseball attendance or TV viewing, whereas contingent valuation estimates total visibility value irrespective of the uses to which they are put. In each case the individual market studies demonstrated that people reveal an implicit willingness to pay for visibility improvement. Ideally, aggregate visibility benefits would be determined by both methods and compared in order to validate the results. While this is not feasible, nevertheless a judgment can be made concerning the plausability of the partial comparison that is possible.

Secondly, the value of visiblity improvements in these papers are estimated from historical records of completed activities. For example, the value of a one mile average improvement in visual range is estimated to be worth about 3 cents per person in attendance, including approximately 10,000 additional persons who would attend under the better visibility conditions. This result is derived from recorded time series information on attendance along with visibility and a number of other variables that effect attendance. People reveal the dollar value of their preference for visibility by their behavior in the face of actual visibility change .

Thirdly, the underlying theory of visibility valuation is the same for the market studies of Section 3 and the CV work of Section 2. The modeling and empirical estimation are quite different. Nevertheless, the common theoretical basis makes the two empirical approaches complimentary. Evidence that results are consistent strengthens our confidence in the results as well as the methods that have been developed to obtain them. The Hancock Tower study in 3.3 provides important directly comparable evidence concerning the two empirical approaches. The conclusion is that the hypothesis of a statistically significant difference between them is rejected.

3.2 OUTDOOOR RECREATION

3.2.1 Swimming

Swimming is one of the major summertime recreational activities available in the Chicago metropolitan area. With numerous beaches and over one hundred pools, the Chicago Park District alone has an annual attendance of many millions. Unfortunately for this analysis, admission to Chicago facilities is without charge, and no accurate records are kept of attendance as a result. Data for both beach and pool attendance were provided by the Wilmette Park District, which operates one of each type of facility just north of Chicago.

Visibility affects the demand for swimming in at least three ways. Consider the simple utility function:

$$U_P = U(H,Q,C,T) ,$$

where U_P is the utility generated by a pool visit, H is the perceived health benefits from swimming, Q is a measure of environmental quality, C is the level of thermal discomfort faced during the day, and T is the time spent at the pool. It is clear that all of these parameters are interrelated to some extent. For example, a hot day may cause an increase in photochemical smog, which may induce an individual to spend less time outdoors due to the decreased health benefits as perceived by the individual. The simple function is useful because it illustrates the mechanisms by which visibility may enter into the demand equation. The first of these mechanisms is the "pure-visibility" effect, and represents the amenity value of visibility in determining the overall utility generated simply by enjoying a nice day. The second is the "indicator" effect, which reflects the use made by individuals of visibility as an indicator of the presence of unhealthy air-pollutants. The indicator effect may be quite important in the Chicago area, as the public receives many warnings in the summer to avoid physical activity during periods of high ozone levels. These warnings may come to be associated with days in which visibility is poor, so that poor visibility may deter swimming for health reasons, even if the poor visibility is caused by harmless natural conditions.

The third way visibility enters the demand equation is through its effect on the transmission of ultraviolet radiation, which is responsible for tanning (and burning) the skin. Since many swimmers spend a great deal of time and money to get a tan (i.e., special lotions, etc.), any decrease in the ability to get a tan represents a real loss in utility.

To identify these effects from raw attendance figures requires an accurate treatment of thermal comfort. A precise, absolute definition of comfort is not possible, as it is a subjective evaluation which differs greatly among individuals. Auliciems (1) showed that four factors influence human comfort, that is, the proportion of individuals who respond negatively to the question, “Are you comfortable?“. These four factors are temperature, humidity, air movement, and thermal radiation, such as the infrared radiation from the sun. These factors interact with each other to yield a level of comfort: which is particular to the individual. The National Weather Service reports two indices which attempt to integrate these factors into a more useful measure than simply using temperature. These are the temperature-humidity index (THI) and the wind-chill index (WCI). Neither is particularly suited to this analysis for several reasons. The THI neglects the effect of the wind, since it was developed primarily to monitor factory conditions, and it does not respond to human comfort in a linear way. A THI reading of 65 implies that everybody is comfortable, while a reading of 70 corresponds to discomfort in 10% of the population, 75 corresponds to 50%, and 80 to virtually 100% discomfort. The WCI does not take into account humidity, as this factor is almost always negligible when compared to the wind effect outdoors in the winter. Also, the published formulas are inappropriate because they assume a normal amount of skin exposure and moisture, while in swimming the entire body is wet with most of the skin exposed to the wind. To account for temperature, humidity, and wind, a set of interaction terms is included in the regression, as well as the terms' independent effects. The fourth comfort-related factor, radiant energy, is assumed to be a simple linear function of cloud cover and visibility.

It is important to keep in mind that the true marginal decision variable is how much time to spend at the pool, or in the aggregate, how many person-hours are spent, and not how many people attend in a day, which is what we have data for here. At best, we can make some crude assumptions about average time spent at the pool and the average value of time of those who attend. Even so, it is questionable whether any reasonably accurate dollar value can be assigned to visibility in this particular case. What can be established, however, is the extent to which visibility plays a role, consciously or not, in the consumption decision of individuals. A decrease in attendance due to reduced visibility implies a decreased opportunity set and a reduction in utility to those who no longer attend as well as those who continue to attend. Assigning a dollar value based entirely on the reduction in attendance may also prove unsound due to the substitution into other, less visibility-elastic activities or even into more work and less leisure as the quality of leisure time is decreased.

3.2.1.1 Empirical Model

Two models are estimated using Wilmette data and surface weather observations at O'Hare Airport for the years 1977-1979. Swimming data are also available for

1980, and are used for prediction-verification. Due to the lack of data on certain important variables, such as wave height, water temperature, and pollution levels in the lake, the beach data are not used in this analysis. Rather, the emphasis is placed on the pool, which is a controlled environment not subject to closing unrelated to the weather.

The first model to be estimated assumes a simple, readily interpretable linear relationship. The relationship is of the form

$$P = \alpha + \beta_1 V \sum_{i=2}^{n} \beta \chi \quad ,$$

where P is daily pool attendance, V is visibility, and χ_i are other factors which effect attendance. Unbiased estimates could be achieved for the estimated parameters by taking first differences of all the variables, 364 days apart. However, with the limited dataset and the subtle quality of the effects being measured, first-differencing is highly undesireable. To account for purely temporal effects, a comprehensive set of dummy variables and functions are employed on a portion of the data, the results of which are compared with those obtained using first differences. In addition, the data are analyzed for each year separately in addition to the pooled regression to check for structural stability between years. Data for the year 1980 are included as an additional check on the parameter estimates.

A simple plot of attendance by date indicates a tendency for the attendance to fall in clusters. It is determined whether this is due to a simple clustering of days similar meteorologically, or whether there is a lagged relation among the data. The disturbances are examined for autocorrelation to see whether General Least Squares methods would be more appropriate than OLS estimators.

In addition to the linear model, a second model is used, of the form.

$$LOG(P) = \alpha + \sum_{i=1}^{n} \beta_i LOG(\chi_i) + \sum_{i=n+1}^{m} \beta_i \chi_i \quad ,$$

where the χ_i are expressed in log form, if continuous, or else left in levels if the relationship is best described by an exponential function, or if the variables are discrete. This model has the advantage that elasticities are estimated directly, but is not as straightforward and simple as the linear model.

3.2.1.2 Regression Results

Ta. 3-1 shows the results of the first regression model. The important points which led to this final regression are:

1. Day-of-week effects were minimal and not statistically significant. This includes a simple weekend/weekday dummy variable, which was also tried.
2. The linear model is not structurally stable. The values for the coefficients differ significantly for each of the three years in question. (F-ratio of 3.978. Separate year results are not reported here.) The pooled regression using all three years can be looked at as an “average” representation of the effects.
3. Lagged exogenous variables were not statistically significant, though their signs and relative magnitudes were as expected. In addition, the data showed no significant autocorrelation, using the Durbin-Watson method.

TABLE 3-1
Pool Attendance: Model 1

VARIABLE (units)	PARAMETER ESTIMATE	STANDARD ERROR	T-RATIO	PROB > T	
INTERCEPT	464633.7	350765.7	1.3246	0.1867	
RAIN (% of Day)	-1.061104	2.273052	-0.4668	0.3206	*
FOG (% of Day)	-0.051259	2.489467	-0.0206	0.4618	*
TEMP (°F)	543.921259	164.347770	3.3096	0.0006	*
WIND (MPH/10)	-292.932312	117.645255	-2.4900	0.0068	*
HUMIDITY (%)	57.678240	39.192380	1.4717	0.0713	*
CLOUD-COVER (%)	-4.782367	1.209490	-3.9540	0.0001	*
VISIBILITY (Mi./10)	1.852527	0.853752	2.1699	0.0156	*
$\sqrt{WIND}$	6511.505	2526.044	2.5777	0.0068	
TEMP-WIND **	3.943894	1.500730	2.6280	0.0092	
TEMP-$\sqrt{WIND}$ **	-84.489434	32.034411	-2.6375	0.0089	
HUMIDITY-WIND **	-0.192682	0.066548	-2.8954	0.0042	
TEMP.-HUMIDITY **	-0.434404	0.494560	-0.8784	0.3807	
COS(T) ***	3364.711	1648.974	2.0405	0.0425	
SIN (T) ***	-3488.21	2921.867	-1.1938	0.2338	
TTREND ***	-78,873748	54.698816	-1.4420	0.1507	

* One-tailed test	SSE	32258740	F-Ratio	25.51
** Comfort - Interaction Terms	Deg. of Freedom	220	Prob> F	0.0001
*** Time-Effect Terms	MSE	146630.6	R-Square	0.6349

164, 5, 6, & 7

The results of the final regression can be summarized thus:

1. Rain and fog effects are not well accounted for in a linear model. This is perhaps due to the discrete nature of these variables as they exist in our data set.
2. The model accounts extremely well for comfort-related effects, both independent and interaction terms are significant with the proper signs.
3. Visibility has a significant effect on attendance. The effect is not stable between years, but ranges between 1.24 and 3.73 persons per tenth-of-a-mile increase in visibility. When the data are pooled, an estimate of 1.85 is arrived at. The high of 3.73 was achieved in 1979, the year the model best fit the data.

The second model which was estimated was the log-log relationship. On the whole, this model was a disappointment, as some of the variables' effects were masked, or were not well accounted for in multiplicative relationships. Results from this regression are listed in Ta. 3-2.

While the log-log relationship expressed rain and fog effects in exponential form, which was found most appropriate, it seems to have been an inappropriate functional form for other variables. Temperature and wind have the anticipated effects, but cloud cover, humidity, and visibility have no significant effect. This model also has less overall explanatory power than the linear model ($R^2 = .5717$), and so the conclusions for this investigation rely heavily on the first model.

TABLE 3-2

Pool Attendance (Log): Model 2

VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	T-RATIO	PROB>T	
INTERCEPT	1338.153	10907.83	0.1227	0.9025	
RAIN	-0.040805	0.007502444	-5.4389	0.0001	*
FOG	-0.021650	0.008816437	-2.4556	0.0074	*
LOG(TEMP)	15.991371	1.486479	10.7579	0.0001	*
LOG(HUMIDITY)	-0.561598	0.594286	-0.9450	0.1728	*
LOG(WIND)	-0.663739	0.293846	-2.2588	0.0125	*
LOG(CLOUD-COV.)	-0.00686768	0.051006	-0.1346	0.4465	*
LOG(VISIBILITY)	0.025559	0.252146	0.1014	0.4597	*
LOG(TTREND)	-158.950272	1244.464	-0.1277	0.8985	
COS(T)	3.453727	5.731853	0.6025	0.5474	
SIN(T)	0.203768	10.422159	0.0196	0.9844	

* One-Tailed Test

SSE	435.025664	F-RATIO	30.04
DEG. OF FREEDOM	225	PROB> F	0.0101
MSE	1.933447	R-SQUARE	0.5717

3.2.1.3 Conclusions

1. An increase in ambient visibility levels of one mile will increase attendance from three to five percent. This represents an annual increase in attendance of between 1728 and 2880 persons.
2. The lack of day-of-week effects suggests a population consisting mainly of children and younger adults with a correspondingly low employment rate. Since environmental amenities are usually income-elastic, this would tend to yield a site-specific estimate which was below the average valuation over the entire population.
3. A large portion of the variation remains unexplained in the models used here. There is likely a large random element, due to reasons cited in number 1 above, but in addition, it appears that the inter-relation between the variables is a rather complex function, which can only be approximated by a linear relationship.

The remainder of the chapter presents the results of an investigation into the effects of visibility on common recreational and other activities. For the most part, we examine activities for which the relevant demand elasticities are unknown, and so benefit estimates of visibility changes are not possible. However, in the case of major league baseball attendance, estimates of demand elasticities have been made, for example, by Noll and Demmert.

General models of activity choice with visibility as an input into household production functions have already been presented in this report. For this reason, none are presented here. Instead, regression models are introduced, and the variables described. Following each are the results of one or more regression analysis with a brief discussion of the results. All of the activities measured were in the Chicago Metropolitan Area.

3.2.2 Television Viewing

With the aid of A.C. Nielsen's "Nielsen Television Index"* a dataset consisting of the total number of households using television at the hours of 1:00 P.M., 2:00 P.M., and 3:00 P.M., for each day during calendar years 1978 and 1979 was assembled. In addition, the number of households watching Chicago Cubs home games was determined. Due to the lack of lights at the stadium, all games take place between noon and around 4:00 P.M. These data are useful in the discussion of baseball attendance below.

Many factors undoubtably influence the number of television viewers. One for which we have little independent data is program quality. The choice of the early afternoon hours is partly an attempt to control for program quality, as there are relatively few changes in scheduling in this time period. Also, it enabled the comparison of the game and non-game days of the Cubs, as described above.

To examine the influence of visibility on television audiences, we separated its effects from other meteorological and temporal factors. The regression results are given in Ta. 3-3. The intercept, 31.86, represented an average Wednesday in May, meaning 31.86% of the 3 million households watching T.V. The effect of visibility is given by the two variables VIS15 and WKNDVIS. The effects of a one mile increase in visibility, assuming

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* Thanks are due to Maureen Gorman of NTI for her kind assistance in providing these data.

TABLE 3-3

Percent of Households Using Television, 1978-79

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>|T|
INTERCEPT	1	31.862665	1.407201	22.6426	0.0001
RA15	1	0.019619	0.005993813	3.2732	0.0011
SN15	1	-0.00618701	0.007097675	-0.8717	0.3837
WIN15	1	0.008701367	0.003107462	2.8002	0.0053
TCL15	1	0.016687	0.00402075	4.1501	0.0001
VIS15	1	-0.013373	0.003915276	-3.4157	0.0007
TEM15	1	-0.081347	0.014113	-5.7641	0.0001
FOOTBLSA	1	1.617240	0.764520	2.1154	0.0348
FOOTBLSU	1	6.678667	0.763180	8.7511	0.0001
FTBLHOL	1	5.454071	1.765358	3.0895	0.0021
CUBHOME	1	2.562305	0.534686	4.7922	0.0001
CUBAWAY	1	0.716211	0.530855	1.3492	0.1777
BLIZZARD	1	5.241333	1.123943	4.6633	0.0001
M	1	0.918224	0.471162	1.9489	0.0517
T	1	-0.320498	0.465496	-0.6885	0.4914
R	1	-0.073249	0.470864	-0.1556	0.8764
F	1	-0.283101	0.467240	-0.6059	0.5448
S	1	6.847284	1.241751	5.5142	0.0001
SU	1	12.259061	1.247545	9.8265	0.0001
M1	1	4.850261	1.004174	4.8301	0.0001
M2	1	2.067644	0.952657	2.1704	0.0303
M3	1	2.955393	0.806152	3.6660	0.0003
M4	1	1.445582	0.639560	2.2603	0.0241
M6	1	1.800524	0.620328	2.9025	0.0038
M7	1	2.639546	0.628826	4.1976	0.0001
M8	1	3.760193	0.627449	5.9928	0.0001
M9	1	2.744425	0.645459	4.2519	0.0001
M10	1	3.327091	0.739155	4.5012	0.0001
M11	1	2.894163	0.792583	3.6516	0.0003
M12	1	3.107789	0.854282	3.6379	0.0003
WKNDVIS	1	-0.00134655	0.007019629	-0.1918	0.8479
WKNDTEM	1	-0.104334	0.012805	-8.1482	0.0001
WKNDRA	1	0.017010	0.014474	1.1752	0.2403
WKNDSN	1	0.015358	0.015645	0.9817	0.3266

SSE	7584.145	F RATIO	49.41
DFE	689	PROB>F	0.0001
MSE	11.007467	R-SQUARE	0.7030

Source: A. C. Nielsen Co.

local linearity, is -.0134, meaning .134% of the 3 million households stop watching T.V. or around 4,000 households. The effect if that increase happens on a weekend is a further reduction of 400 households. The prime effect is very well estimated, with a t-statistic of -3.42, while the second is not, with a t-statistic of only -0.19. Overall, television appears to be highly seasonal, with a peak in January and a trough in the base month of May.

The day-of-week dummies acted as expected, with a large weekend increase. The weather variables also behaved as expected, with higher temperature and visibility causing less television watching, as people shift to outdoor activities, and with wind, clouds, and rain driving people indoors to the T.V. Snow had a negative effect, but was not precisely estimated.

In a further attempt to abstract from mere seasonal variation, 7-day first differences were calculated. The new regression is presented in Ta. 3-4. The variables prefixed with the letter D are the same as the previous regression, only having undergone first-differencing.

The results for visibility are still negative, but the effect is less precisely estimated, with only a 1.06 t-statistic.

TABLE 3-4

Percent of Households Using Television at 2:00 P.M. 1978-79:
7-Day First-Differences

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>|T|
INTERCEPT	1	0.063820	0.174468	0.3658	0.7146
D7RA	1	0.024183	0.007834551	3.0867	0.0021
D7SN	1	-0.000163412	0.007373556	-0.0222	0.9823
D7WIN	1	0.008463473	0.003586003	2.3601	0.0185
D7TCL	1	0.024703	0.004452127	5.5486	0.0001
D7VIS	1	-0.00419665	0.003943219	-1.0643	0.2876
D7TEM	1	-0.090849	0.015345	-5.9206	0.0001
D7FTBLSA	1	-1.629750	2.752302	-0.5921	0.5539
D7FTBLSU	1	-0.562519	2.791929	-0.2015	0.8404
D7CUBHOM	1	2.615677	0.528036	4.9536	0.0001
D7CUBAWA	1	0.695619	0.520638	1.3361	0.1819
D7HOL	1	1.373662	0.633384	2.1688	0.0304
D7FTBLHL	1	13.847987	1.597012	8.6712	0.0001
D7BLIZZ	1	4.136090	1.068155	3.8722	0.0001

SSE	15576.95	F RATIO	25.94
DFE	709	PROB>F	0.0001
MSE	21.970307	R-SQUARE	0.3223

3.2.3 Baseball

Two analyses were performed on baseball data. The first is an analysis of attendance data and relevant team information published for the Chicago Cubs during the 1978 and 1979 seasons. The second was an analysis of television viewing of the Cubs during the same two seasons. For both the same explanatory variables will be used.

The variables are all briefly described in Ta.3-5 with the results of the regression of attendance data. The results in Ta.3-6 are for the percent of Chicago metropolitan area households watching WGN Television at 2:00 P.M. during each game. Many similar and highly correlated variables were included in the regression. These include mainly statistics on team performance during the season, and opposing team characteristics. These results were not examined in detail. Instead, we merely noted the effects of visibility on attendance.

An increase in visibility of one mile increases gate attendance by approximately 125 people, although the effect is not precisely estimated. Interestingly, the effect of the same increase in visibility is to increase television watching of the Cubs by about 3,000 households, even though the total effect on television watching of all types is to decrease viewing by about 4,000 households. Perhaps picture quality is enhanced with the improved visibility. Whatever the case, both attendance and television increase.

Noll provided an estimate of the effect of ticket prices on attendance for an SMSA of population of around 3.5 million. Since Chicago has an SMSA of approximately 7 million, the effect is doubled, yielding a reduction in attendance of 380,000 persons per year for a one dollar increase in ticket price. Our measured visibility effect of 125 persons per game, multiplied by 81 games yields a total of 10,125 additional persons per year in gate

TABLE 3-5

Chicago Cubs Total In-Person Attendance, 1978-79

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB> |T|	VARIABLE LABEL
INTERCEPT	1	19137.39	60316800888	0.0000	1.0000	
M	1	1892.86	2421.542	0.7817	0.4362	MONDAY
T	1	-2010.47	1881.489	-1.0685	0.2878	TUESDAY
W	1	1438.35	1948.707	0.7381	0.4622	WEDNESDAY
F	1	-398.466013	2093.582	-0.1903	0.8494	FRIDAY
S	1	10936.11	1880.054	5.8169	0.0001	SATURDAY
SU	1	13464.3	1916.078	7.0270	0.0001	SUNDAY
M4	1	-10060.6	3186.865	-3.1569	0.0021	APRIL
M6	1	5966.58	2168.68	2.7512	0.0070	JUNE
M7	1	7907.502	3011.217	2.6260	0.0100	JULY
M8	1	10158.55	3905.221	2.6013	0.0107	AUGUST
M9	1	2512.577	4325.281	0.5809	0.5626	SEPTEMBER
DATE	1	-0.810883	38.412070	-0.2294	0.8190	LINEAR TIME TREND
LASTHOME	1	141.073569	167.978923	0.8398	0.4030	DAYS SINCE LAST HOME GAME
DOUBLE	1	3161.818	1845.086	1.7136	0.0897	DOUBLE HEADER
RA09	1	-33.978231	22.961630	-1.4798	0.1420	RAIN AT 9 AM
RA12	1	-25.077909	30.191844	-0.8306	0.4081	RAIN AT 12 NOON
RA15	1	15.898115	26.908620	0.5908	0.5560	RAIN AT 3 PM
TEM12	1	214.071109	82.563972	2.5928	0.0109	TEMPERATURE AT NOON
WINDOUT	1	1730.691	1503.111	1.1514	0.2523	DUMMY, EQUALS 1 WHEN WIND BLOWS OUT
VIS12	1	12.487959	14.521299	0.8600	0.3918	VISIBILITY AT NOON IN TENTHS OF A MILE
SOXPCT	1	-13109.2	17161.29	-0.7639	0.4467	SOX WINNING PCT
SOXPLAY	1	58050.9	60316800889	0.0000	1.0000	ZERO-ONE DUMMY
CHIFEST	1	-2027.13	3221.181	-0.6293	0.5306	DUMMY FOR CHICAGOFEST
IN RACE	1	3999.039	2317.196	1.7250	0.0874	DUMMY, ONE WHEN TEAM IN PENNANT RACE
CUBPCT	1	-19223.8	16608.63	-1.1575	0.2498	CUBS WINNING PCT
HMGMBK	1	-935.843864	312.870576	-2.9912	0.0035	GAMES BEHIND LEADER (CUBS)
SAMEDIV	1	-16637.5	14290.28	-1.1643	0.2471	1 WHEN OPPONENT IN SAME DIVISION
CPTCHERA	1	680.158836	405.725853	1.4003	0.1645	CUB PITCHERS ERA
VSSTAN	1	-998.082156	405.395244	-2.0562	0.0423	VISITORS STANDING IN DIVISION
VPTCH500	1	179.609536	176.324238	1.0186	0.3108	VISITING PITCHERS GAMES ABOVE 5
EQUALITY	1	-11718.5	13620.63	-0.8604	0.3916	DIFFERENCE IN WINNING PCT
EQUALSD	1	24302.13	15857.92	1.5325	0.1285	EQUALITY X SAMEDIV
KINGMAN	1	-3335.01	1724.915	-1.9334	0.0560	DUMMY, ONE WHEN KINGMAN PLAYED
YEAR79	1	8823.667	13533.4	0.6520	0.5159	YEAR DUMMY
CUBWIN10	1	1059.82	560.594588	1.8639	0.0652	NO. OF GAMES WON OF LAST TEN

SSE	2G10887601	F RATIO	12.76
DFE	101	PROB>F	0.0001
MSE	25850372	R-SQUARE	0.8155

TABLE 3-6

Chicago Cubs Television Audience, 1978-79:

Percent of Households

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB> |T|	VARIABLE LABEL
INTERCEPT	1	28.310590	27804381	0.0000	1.0000	
M	1	1.508206	1.116264	1.3511	0.1797	MONDAY
T	1	-0.333530	0.867315	-0.3846	0.7014	TUESDAY
W	1	0.336566	0.898300	0.3747	0.7087	WEDNESDAY
F	1	0.895605	0.965083	0.9280	0.3556	FRIDAY
S	1	4.545163	0.866653	5.2445	0.0001	SATURDAY
SU	1	5.355864	0.883259	6.0638	0.0001	SUNDAY
M4	1	-1.992947	1.469057	-1.3566	0.1779	APRIL
M6	1	2.428024	0.999702	2.4287	0.0169	JUNE
M7	1	3.579786	1.388088	2.5789	0.0114	JULY
M8	1	6.405515	1.800199	3.5582	0.0006	AUGUST
M9	1	5.339600	1.993835	2.6781	0.0086	SEPTEMBER
DATE	1	-0.018761	0.017707	-1.0595	0.2919	LINEAR TIME TREND
LASTHOME	1	-0.066878	0.077434	-0.8637	0.3898	DAYS SINCE LAST HOME GAME
DOUBLE	1	0.364654	0.850534	0.4287	0.6690	DOUBLE HEADER
RA09	1	0.001897492	0.010585	0.1793	0.8581	RAIN AT 9 AM
RA12	1	0.032381	0.013918	2.3266	0.0220	RAIN AT 12 NOON
RA15	1	-0.010960	0.012404	-0.8836	0.3790	RAIN AT 3 PM
TEM12	1	0.042599	0.038060	1.1193	0.2657	TEMPERATURE AT NOON
WINDOUT	1	0.370211	0.692893	0.5343	0.5943	DUMMY, EQUALS 1 WHEN WIND BLOWS OUT
VIS12	1	0.010100	0.006693918	1.5089	0.1344	VISIBILITY AT NOON IN TENTHS OF A MILE
SOXPCT	1	12.036824	7.910881	1.5216	0.1312	SOX WINNING PCT
SOXPLAY	1	110.357756	27804381	0.0000	1.0000	ZERO-ONE DUMMY
CHIFEST	1	-2.988367	1.484876	-2.0125	0.0468	DUMMY FOR CHICAGOFEST
IN_RACE	1	-0.115474	1.068163	-0.1081	0.9141	DUMMY, ONE WHEN TEAM IN PENNANT RACE
CUBPCT	1	-16.721749	7.656122	-2.1841	0.0313	CUBS WINNING PCT
HMGMBK	1	-0.520589	0.144225	-3.6096	0.0005	GAMES BEHIND LEADER (CUBS)
SAMEDIV	1	-7.081642	6.587425	-1.0750	0.2849	1 WHEN OPPONENT IN SAME DIVISION
CPTCHERA	1	-0.279615	0.223906	-1.2488	0.2146	CUB PITCHERS ERA
VSSTAN	1	-0.081824	0.223754	-0.3657	0.7154	VISITORS STANDING IN DIVISION
VPTCH500	1	-0.034274	0.081281	-0.4217	0.6742	VISITING PITCHERS GAMES ABOVE 5
EQUALITY	1	-10.780878	6.278732	-1.7170	0.0890	DIFFERENCE IN WINNING PCT
EQUALSD	1	9.484610	7.310063	1.2975	0.1974	EQUALITY X SAMEDIV
KINGMAN	1	0.592985	0.795138	0.7458	0.4575	DUMMY, ONE WHEN KINGMAN PLAYED
YEAR79	1	9.447361	6.238523	1.5144	0.1331	YEAR DUMMY
CUBWIN10	1	0.599823	0.262106	2.2885	0.0242	NO. OF GAMES WON OF LAST TEN

SSE	554.802019	F RATIO	7.18
DFE	101	PROB>F	0.0001
MSE	5.493089	R-SQUARE	0.7134

attendance per mile increase in visibility. Thus, the change in consumer's surplus associated with increase in visibility is at least 2.7 cents per person in attendance, or approximately $30,000 for a typical season's attendance. This benefit of a one mile visibility improvement represents somewhat less than one million dollars per year for baseball attendance in the entire U.S., assuming a homogeneous population.

three stand out. In the earliest study, Davis and Knetsch (DK) compared willingness to pay elicited in contingent valuation with a valuation derived through a travel cost model of demand. DK found the two estimates to be strikingly similar in magnitude. However, later work by Bishop and Heberlein (BH) suggested that the similarity found by DK might be misleading. Three of the BH results are relevant. First, travel cost valuations computed by BH were found to vary widely depending upon the choice of elements included in the cost of travel index that serves as price. Thus, a single travel cost estimate may be unreliable as a datum. Second, when compared to a range of travel cost estimates, the contingent valuation estimate lay close to the mean of the travel cost valuations. Third, both contingent and travel cost valuations tended to underestimate the BH datum of true value. In a third and most recent comparative study, Brookshire *et al*. found, in a manner consistent with a theory of individual versus market valuations, that valuations of visual air quality based on contingent valuation tended to lie below those based upon a rent gradient estimated on residential property prices. In light of the results of previous studies, two tentative conclusions can be drawn. First, contingent valuation performs at least as reliably as the operational, alternative valuation techniques. Results presented below tend to corroborate previous research.

3.3.1.1 Early Analysis of Hancock Tower Visitation

The Hancock Tower offered an unusual opportunity to determine the effects of visibility on the demand for view services. The view offered by the Tower is particularly sensitive to changes in visual range. Since an explicit price is charged and attendance is recorded it was possible to provide an estimate of the demand for Hancock Tower view services as a function of admission price, visibility, and a set of demand shifters. A mean per person consumer surplus of $2.12 in 1981 prices was computed from the aggregate demand estimate. Extrapolating this benefit estimate to cover the entire eastern United States is equivalent to assuming that identical viewing opportunities (as the Chicago urban landscape and skyline) exist in the entire eastern region. Assuming that similar experiences are obtainable in other areas of the region, then, given a homogeneous population, the aggregate consumer surplus is 275 million dollars in 1981 prices.

Early empirical analysis of Hancock Tower visitation completed four objectives. First, the error structures resulting from previously specified models were examined for non-random patterns and remedial estimation procedures employed where appropriate. Second, having selected appropriate estimation procedures, lagged groups of independent variables were tested for explanatory power. Third, the functional form of the specified equation was evaluated. Fourth, preliminary estimates of consumer surplus and revenue were computed for changes in visibility at the site.

The empirical analyses began with a demand equation specified in inverse exponential [IE] form. Such a functional form appeared most consistent with the color contrast results of Malm and Leiker. An examination of the error structure resulting from estimation in the IE form revealed a clearly non-random pattern. To remedy this difficulty, two steps were taken. First, the model was respecified in a simple linear form. The linear form was chosen since it can be viewed as a first-order approximation to more complex functional relationships. Second, a modified Cochrane - Orcutt (C-O)[1] procedure was used to allow for serial correlation errors and their effect on estimation. Combining the linear form with the C-O procedure resulted in an error structure approximating an i.i.d. process and, thus, appropriate for the computation of covariance statistics.

The second step in the empirical analysis was to check the explanatory power of lagged groups of variables. Conceptually, lagged variables could be important for two reasons. First, if the visiting population is fairly constant, extremely favorable visibility and weather conditions on a given day would tend to deplete the visitor stock for the nest. Within this context, lagged variables would tend to carry signs opposite to those of the respective comtemporaneous variable. Second, individuals may form expectations on the basis of past realizations of visibility and weather variable. In this context, the signs of lagged variables would depend upon the particular processes used to form expectations. Given this ambiguity, the net effect on the signs and significance of lagged variables cannot be determined *a priori*

To determine the empirical effect of lagged independent variables, F statistics (Chow type test) were computed to test several hypotheses. The basic form of the null hypothesis was : H_o - the lags x,y, and z do not contribute to variation in visitation. The set of variables lagged were VS1, VS2, RA, SN, CL, WIN, TEMP, and FG (see Ta. 3-7 for variable description).

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[1]See SAS AUTOREG procedure, SAS Institution, 1980.

TABLE 3-7

Statistic and Variable Descriptions
for Visitation, Weather and Visibility [1]

VARIABLE NAME	MEAN	STANDARD DEVIATION	DESCRIPTION
VST	955.12	710.77	Daily Ticket sales at Hancock Tower
VS1	12.55	13.94	Visibility in miles from H.T., 1st reading
VS2	16.28	15.42	Visibility in miles from H.T., 2nd reading
RP	0.7690	0.07659	Admission price divided by C.P.I.
RPI	916.91	9.23	Personal Income (National) divided by C.P.I.
M,TU,W, F,S,SU	0.14	0.35	Day of week dummy variables
TIME	270.50	151.41	Linear trend variable runs from 1 to 524
SNX	0.2169	0.6896	SINE Values with period of 365 days. Intended to pick up seasonal cycle
CSX	.01215	0.6922	COSINE Values with period of 365 days. Intended to pick up seasonal cycle
RA	0.0700	0.1950	Proportion of days with rainfall
SN	0.0719	0.2145	Proportion of days with snowfall
CL	0.4727	0.3262	Average cloud cover measured from 0 to 1.
WIN	10.82	3.983	Average windspeed in Knots
TEMP	50.72	22.09	Temperature in degrees Fahrenheit
FG	0.08715	0.2418	Proportion of days with fog

[1] Observations are for the period Iron 1/9/81 to 6/15/81.
Weather observations are for O'Hare Int. Airport.

The lags tested were lags 1,2,3,7,8 versus lags 1,2,7; lags 1,2,7 versus lags 1,7; lags 1,7 against lag 1; and lag 1 against an equation with no lags. The statistic used for testing was

$$F = (SSE_{H_0} - SSE_{H_1})(DFE_{H_1})/(SSE_{H_1})(DFE_{H_0} - DFE_{H_1}) \quad ,$$

where SSE_{H_0} is the sum of squared errors resulting from the regression without lags x,y, and z; DFE_{H_0} is the degrees of freedom associated with SSE_{H_0}; and SSE_{H_1} and DFE_{H_1} are analogous quantities for the regression with lags x,y,z included.

Ta. 3-8a and 3-8b exhibit the results of regressions computed with various sets of lagged variables. At the 5 percent level, Chow test computed from the given statistics failed to reject any of the null hypotheses involving lagged groups of variables. Hence, none of the lagged groups of variables are shown to contribute to the variation in visitation. Additionally, inspection of Ta. 3-8a and 3-8b shows that the lagged variables contribute little to the long run effects on visitation. For example, the combined effect of VS1 and VS2 in the regression with no lags differs little from the long run effects when lags are included. Similar results are apparent for other variables such as RP and PR1. With their effects neither statistically nor absolutely significant, lagged effects are provisionally rejected in favor of the more parsimonious contemporaneous equation.

With a satisfactory specification of demand for Hancock Tower visitation, consumer surplus and revenue changes were estimated for various percentage changes in mean visibility. Results appear in Ta. 3-9. For these

TABLE 3-8a

LAGGED VARIABLES AND THEIR LONG RUN EFFECT ON VISITATION

	LONG RUN COEFFICIENTS[1]					
	LAGS					
EXPLANATORY VARIABLES	1,2,3,7,8	1,2,7	1,7	1	NONE	NONE (US1 DROPPED)
ΣVS1[(2)]	-4.38	-3.90	-4.15	-1.77	2.49 (1.49)	——
ΣVS2	11.13	13.29	12.60	12.05	7.10 (4.63)	8.49 (7.17)
ΣRA	-445.83	-527.45	-462.84	-403.52	-535.89 (-5.87)	-541.86 (-5.94)
ΣSN	-188.07	-127.25	-69.83	-125.31	-175.38 (-2.07)	-183.07 (-2.16)
ΣCL	-143.02	-221.92	173.64	-226.86	-169.03 (-3.05)	-174.83 (-3.17)
ΣWIN	6.19	-11.92	6.52	1.92	2.26 (0.52)	2.00 (0.46)
ΣTEMP	1.81	2.08	0.81	3.26	5.70 (2.75)	5.16 (2.50)
ΣFG	-283.03	-271.74	-457.33	-317.19	-316.38 (-3.90)	-317.97 (-3.92)
RP	-1615.83 (-2.00)	-1752.92 (-2.23)	-1908.37 (-2.50)	-1360.15 (-1.79)	-1492.49 (-2.05)	-1376.04 (-1.85)
RPI	23.04 (1.98)	23.34 (2.05)	26.77 (2.38)	25.33 (2.29)	24.21 (2.21)	23.76 (2.17)
M	-6.44 (-0.09)	0.41 (0.00)	7.68 (0.11)	-9.30 (-0.13)	-13.59 (-0.19)	-11.90 (-0.17)
TU	-66.55 (-0.93)	-64.82 (-0.92)	-66.71 (-0.96)	-74.58 (-1.08)	-64.75 (0.94)	-63.62 (-0.93)
W	-29.26 (-0.47)	-37.70 (-0.62)	-43.20 (-0.72)	-67.97 (-1.14)	-60.14 (-1.01)	-56.92 (-0.97)
F	311.55 (4.95)	302.03 (4.91)	311.95 (5,15)	292.21 (4.92)	295.83 (4.98)	299.01 (5.06)
S	1071.55 (14.90)	1070.22 (15.18)	1074.62 (15.40)	1058.59 (15.35)	1063.66 (15.43)	1072.28 (15.62)
SU	319.21 (4.30)	315.91 (4.31)	320.65 (4.45)	314.64 (4.39)	315.99 (4.41)	321.99 (4.51)
TIME	1.73 (2.57)	1.77 (2.70)	1.99 (3.09)	1.69 (2.68)	1.71 (2.80)	1.61 (2.60)
SNX	-10.22 (-0.12)	16.38 (0.21)	14.16 (0.19)	-4.30 (-0.06)	29.20 (0.42)	14.81 (0.21)
CSX	-407.94 (-2.99)	-389.01 (-3.24)	-437.34 (-3.36)	-359.99 (-3.99)	-303.30 (-3.88)	-311.59 (-4.00)
INT	-19638.55 (-1.80)	-19777.28 (-1.35)	-22861.00 (-2.16)	-22078.96 (2.12)	-21086.09 (-2.04)	-20688.35 (-2.01)
ΣVS1+ΣVS2	6.75	9.39	8.45	10.28	9.59	8.49

t values given in parentheses

[1] Coefficients estimated using the SAS AUTOREG procedure with autocorrelation coefficients estimated at laggs 1 and 7.

[2] Σ indicates the sum of the coefficients of both contemporaneous and lagged values of the particular explanatory variable. For example, if lags 1 and 7 are included, ΣVS2 gives the sum of the coefficients estimated on the contemporaneous value of VS2 and the values of VS2 at lags 1 and 7.

TABLE 3-8b

Statistics for Regressions [1]

	LAGGED EXPLANATORY VARIABLES				
REGRESSION WITH LAGS	SSE	D.F.	R^2	p_1	p_7
1,2,3,7,8	62693407	464	.65	.31 (7.54)	.14 (3.39)
1,2,7	63477889	480	.64	.32 (7.66)	.15 (3.55)
1,7	64670558	488	.64	.32 (7.72)	.14 (3.35)
1	65825254	496	.62	.32 (7.72)	.13 (3.28)
NONE	67334226	504	.63	.32 (7.66)	.13 (3.26)
NONE (VS1 DROPPED)	67518458	505	.62	.32 (7.66)	.13 (3.16)

t values in parentheses

[1] Autoregressions estimated with autocorrelation coefficients estimated at lag 1(p_1) and lag 7 (p_7)

TABLE 3-9

Consumer Surplus and Revenue Estimates

Derived from Linear Demand Function [1]

CHANGE IN MEAN VISIBILITY ($\overline{VS2}$ = 16.28)	AVERAGE DAILY CHANGE[2]			
	CONSUMER SURPLUS	REVENUE	TOTAL	TOTAL
10%	26	28	54	19710
20%	52	57	109	39785
30%	78	85	163	59495
40%	105	113	218	79570
50%	133	115	248	90520

[1]Estimated from regression without interaction term as reported in Table 4. In dollars.

[2]Adjusted to current dollars using April 1981, C.P.I. of 266.8.

computations the regression "None (VSI Dropped)" of Ta. 3-8a was used along with the mean variable values given in Ta. 3-7. Revenue changes were included since, at this point, it is assumed that additional visitors are admitted to the Tower at close to zero marginal cost.

Caution must be taken against placing too much weight on the estimates Of Ta. 3-9. As Ta. 3-10 demonstrates, the response of individuals *to* changes in visibility is very likely non-linear. Ta. 3-10 gives results for two regressions. The first regression, "No Interaction," is entirely linear in the coefficients of all included variables. Note that the coefficient on visibility is rather small. The second regression, "With Interaction Term," includes two terms for visibility. The first is simply VS2. The second is

$$VST2 > 10 = VST \times D ,$$

where

$$D = 1 \text{ if } VST2 > 10 \text{ miles} ,$$
$$= 0 \text{ otherwise.}$$

The regression "With Interaction" clearly demonstrates a differential response to different ranges of visibility. When visibility is less than 10 miles the response in visitation to a one mile change in visibility is 23.91 versus the 8.49 person response of "No Interaction." When visibility is initially greater than 10 miles, the response to a one mile change in visibility is 9.6 (=23.91 - 14.31) and still greater than the 8.49 person response of "No Interaction." From these results, two implications can be drawn. First, non-linear forms should he explored for fit to the Hancock data; second, consumer surplus and revenue simulations performed with the "With Interaction" regression or other non-linear forms are likely to result in significantly larger estimates.

TABLE 3-10

TESTING FOR NON-LINEAR RESPONSE TO VISIBILITY

	REGRESSION RESULTS	
EXPLANATORY VARIABLE	NO INTERACTION TERM FOR US2	WITH INTERACTION TERM
INT	-20688.85 (-2.010)	-20640.20 (-2.00)
VS2	8.49 (7.17)	23.91 (3.47)
VS2 > 10	———	-14.31 (-2.27)
RP	-1376.04 (-1.85)	-.1416.66 (-1.90)
RPI	23.76 (2.17)	23.68 (2.17)
M	-11.90 (71.80)	-12.68 (-0.18)
TU	-63.62 (-0.93)	-59.36 (-0.86)
W	-56.92 (-0.97)	-45.23 9-0.76)
F	299.01 (5.06)	313.52 (5.26)
S	1072.28 (15.62)	1095.40 (15.74)
SU	321.99 (4.51)	344.40 (4.77)
TIME	1.61 (2.60)	1.61 (2.60)
SNK	14.81 (0.21)	21.20 (0.30)
CSX	-311.59 (-4.01)	-310.95 (-4.00)
RA	-541.86 (-5.94)	-540.29 (-5.95)
SN	-183.01 (-2.16)	-171.16 (-2.03)
CC	-174.83 (-3.17)	-183.05 (-3.33)
WIN	2.00 (0.46)	1.64 (0.38)
TEMP	5.16 (2.50)	5.24 (2.55)
FG	-317.97 (-3.92)	-307.89 (-3.81)
R^2	0.62	.62
SSE	67518458	66831464
DF	505.	504.

t values in parentheses

3.3.2 The General-Choice Model

The activity or action of record at HTO is not the enjoyment of viewing services but the number of individuals purchasing access to the viewing site. At any particular admission price, the quantity of access supplied is assumed to be perfectly elastic within the range of realized visitation. Given this perfect elasticity of supply, a demand function can be estimated through simple regression techniques and without reference to problems of simultaneity.

The demand for access to HTO may be thought of as derived from an individual's use of access in producing viewing services given the characteristics of the observatory, the city skyline, and environmental conditions including visibility. The most notable aspect of demand is that, at the individual level, it is discrete: an individual either accesses Tower services or does not. Borrowing from the relevant literate on discrete choice (Domencich and McFadden), aggregate demand can be represented by

(3-1) $$VST_t = N_t \pi \quad ,$$

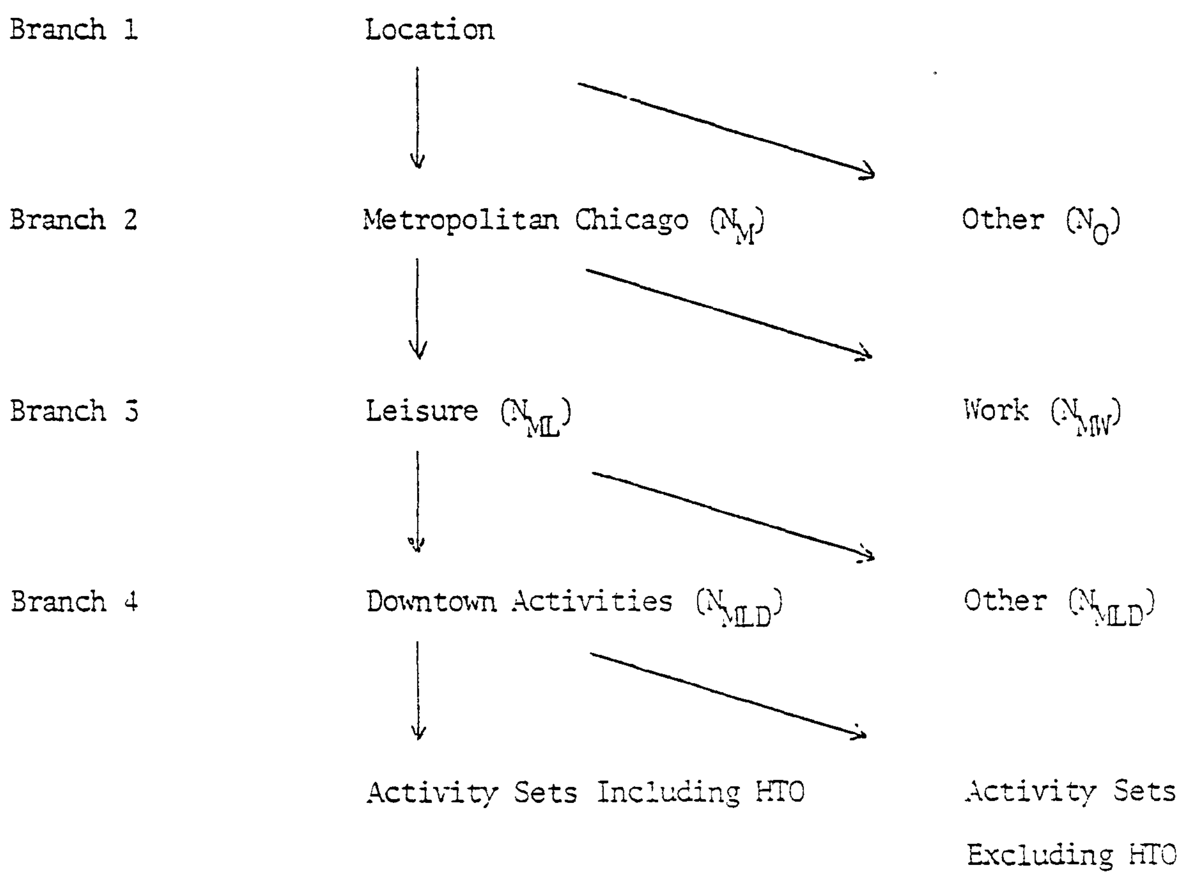
where VST_t is total visits on day t, N_t is a pool of potential visitors on day t, and π is the probability that an individual in N_t visits the HTO. More specifically, π is the probability that the utility gained by an individual through a set of activities that includes an HTO visit is greater than the utility of all sets of activities that do not include a visit to HTO.

Variables relevant to the determination of N_t and τ can be identified by considering the abbreviated “decision tree” (Domencich and McFadden) given in Fig. 3-1. On any particular day one can imagine that individuals sort themselves out over mutually exclusive activities as indicated by the direction of the arrows in Fig. 3-1. However, as the literature on discrete choice points out, the flow of information and choice is just the reverse of the sequence of actions. That is, individual choice begins at Branch 4 in Fig. 3-1. To make the Branch 3 decision between downtown activities and other alternatives, the individual must first select the optimal package of downtown activities. The decision at Branch 3 can then be made optimally by comparing the utility gained from the best set of downtown activities with the utility gained from the best set of alternative activities.

To identify variables relevant to choice, decisions represented in Fig. 3-1 are partitioned into those made in the longer run and those made in the short run. For example, choices above Branch 3 are likely to require major commitments of personal resources and be relatively fixed by long term contracts. For these long run decisions, the most important variables to the HTO visit choice are likely to be time series variables. Clearly, for the individual, relative prices contemporaneous to the long run decision may be inportant indicators of future relative prices. However, in the research problem at hand, this portion of the the individual's information set remains unobservable and must be relegated to an error term. Time series variables, however, are observable and are likely to be quite pertinent to long run individual planning. For instance, seasonal merchandizing sales and weather conditions are probably best judged by seasonal or other time series variables

FIGURE 3-1

Decision Tree for Choice of Activities



Specifically, for purposes of long run decisions, an individual can expect prices at downtown shopping areas to be relatively high in December but low in January; it is likely to be cooler in January than in July but whether January 1 or January 7 is colder is largely a matter of random occurrence. In addition, day of week effects may enter due to conventions of a 40 hour workweek and work scheduling. For the long run decisions of location and work/leisure choice, the information (potentially observable by the researcher) passed back up the decision tree therefore depends largely upon seasonal and other time series considerations. Thus, if decisions above Branch 3 are primarily long run decisions, we can write the pool of potential HTO visitors on day t at Branch 3 as a function

(3-2) $$N_{tML} = N_{tML}(s,d,e) \quad ,$$

where s is a vector of time series variables, d is a vector of day of week dummy variables, and e is an error term introduced for unknown price information used by individuals.

For individuals within N_{tML}, a decision regarding the day's excursion must be made. Assuming that the choice between downtown and other activities is fairly decisive and that variables specific to HTO contribute rather little to choice at Branch 3[1], the only variables affecting choice at Branch 3 that are also potentially observable by the researcher are local weather conditions. Entering these local weather conditions as a determinant of the visitor pool,

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[1] The assumption is not entirely unreasonable. Of the individuals sampled at HTO, 75 percent indicated that their visit HTO was only a sidetrip and apparently not crucial to their visit downtown.

we can write

(3-3) $$N_{tMLD} = N_{tMLD}(s,d,w,e) \; ,$$

where w is a vector of weather and environmental variables and e is again an error term introduced for unobservables.

It is at Branch 4 that we can begin to model individual choice and determine the relation between visitation, $N_{tMLDH}=VST_t$, and admission ticket prices. To begin, we assume that an individual maximizes a homothetic utility function subject to an excursion budget constraint prices, and environmental conditions. Maximization is conditional upon the HTO visit/non-visit choice[2] and we suppose that for all individuals the HTO visit is a sidetrip, an addition to an otherwise fixed itinerary. For a typical individual or group of individuals, conditional indirect utility funcitons are

(3-4) $$v_h(m-np_h) = v_h(p,w)(m-np_h)$$

if the individual visits the HTO and

(3-5) $$v_o m = v_o(p,w)m$$

if the individual does not visit the HTO where m is the excursion budget, p is a vector of prices of ordinary (continuous) market goods, w is again a vector of weather and environmental variables, n is the number of individuals within a typical visiting group, p_h is the price of admission, and np_h is the fixed cost of gaining access to HTO. Taking log transformations of (3-3) and (3-4), and letting $u_h = \ln v_h + \ln(m-np_h)$ and $u_o = \ln v_o + \ln m$, the probability that an individual i in N_{tMLD} visits HTO can be written

(3-6) $$\pi_h = \text{Prob}(\, u_h + \varepsilon_{hi} > u_o + \varepsilon_{oi} \,) \; ,$$

---

[2] Small and Rosen have suggested the conditional maximization process in dealing with discrete choice.

where z_{hi} and z_{oi} are the respective deviations of individual utility from the utility of the typical individual. Eq. (3-1) can now be written

$$\text{(3-7)} \qquad VST_t = N_{tMLD}\pi_h$$
$$= N_{tMLD}(s,d,w,e)\,\pi_h(p,w,m,n,p_h).$$

Assuming that z_h and z_o are extreme value or Weibull distributed, π_h can be written in terms of the cumulative logistic distribution (Domencich and McFadden):

$$\text{(3-8)} \qquad VST_t = N_{tMLD}(\, v_h(m-np_h)/(\, v_h(m-np_h) + v_o m\,))\ ,$$

where $\pi_h=(v_h(m-np_h)/(v_h(m-np_h)+v_o m)$.

To proceed further with specification, specific funtional forms must be applied to N_{tMLD}, v_h, and v_o. For present purposes the most tractable functional form is the general Cobb-Douglas (CD) form, $x^a\exp(b+cy+e)$ where x is a continuous variable, y is a dummy variable, e is a log-normally distributed error term, and a, b , and c are the coefficients of interest. Applying this general CD form to the aggregate demand equation in eq. (3-8) an estimable form is

$$\text{(3-9)} \qquad \ln VST_t = \ln A(s,d,w,p,e) + \ln(m-np_h) + \ln(v_h(m-np_h)+v_o m)\ ,$$

where A(.) is of the form $x^a\exp(b+cy+e)$. Because we have no information on the typical excursion budget or group size of individuals in X_{tMLD}, the log terms which include m are replaced by first order Taylor series approximations. The approximation to be estimated is

$$\text{(3-10)} \qquad \ln VST_t = a_1 + \ln A(s,d,w,) + b_1 p_h + \ln e\ ,$$

where again A(.) is of the general CD form, a_1 is a constant term, and p_h enters the equation in level form with coefficient b_1.

Given an estimate of eq. (3-10), it can be shown by direct intergretion that approximate total surplus is defined by estimated visits, $\widehat{VST}$, divided by the coefficient of admission price, $\hat{b}_1$. Thus, approximate average or expected surplus obtained per person visiting HTO is

$$\text{AVCS} = (\widehat{VST}/\hat{b}_1)\widehat{VST} \qquad (3\text{-}11)$$
$$= 1/\hat{b}_1 \quad .$$

Because the error bounds on $\hat{b}_1$ are straightforwardly calculated, AVCS is selected as the basis of contrasting demand-based valuation with contingent valuation in the HTO case.

3.3.3 The Contingent Valuation Experiment

During the Spring of 1981, a contingent valuation instrument was designed that would elicit the maximum willingness to pay (MWTP) for access to HTO[3]. During the summer of 1981, contingent valuations of visiting groups at HTO were recorded. Valuations were obtained under a variety of environmental conditions and, by the end of the summer, 319 usuable observations had been recorded.

Ta. 3-11 displays the results of the contengent valuation experiment at HTO. MWTP is the maximum willingness to pay elicited. ADMCOST gives the average actual cost of admission. Average SURPLUS per group is MWTP minus ADMCOST or an average of 3.93 dollars. Finally, average GROUPSIZE was 2.67 for groups during the summer of 1981.

TABLE 3-11

Results of the 1981 Contingent Valuation Experiment

at the Hancock Tower Observatory

Variable	Sample Mean[1]	Standard Error
MWTP	9.43	.428
ADMCOST	5.50	.199
SURPLUS	3.93	.314
GROUPSIZE	2.67	.115

[1] Number of respondent groups was 319. Means in this Table are computed for groups, not individual persons. Covariance between SURPLUS and GROUPSIZE is 4.59.

During the Spring of 1981, the HTO management apparently decided to experiment with well-publisized price variations in order to determine the relationship between price and attendance. For the purpose of estimating demand, the price variation was sufficient enough for a statistically significant estimate of the coefficient on admission price as shown in Ta. 3-13. By using the variable definitions given in Ta. 3-14, it is clear that the overall specification of the estimated equation (Ta. 3-14) paralleled the identification given in eq. 3-10. Relevant statistics for the secondary data are given in Ta. 3-15.

The coefficient of central interest is the coefficient on admission price, the variable PP. By inverting the coefficient and using the approximation formulas given in Mood, Graybill, and Boes (p. 181) for quotients of random variables, average surplus, AVCS, was computed and is presented in Ta. 3-16. In the same Table and computed using the same approximation formulas, the average from contingent valuation (AVCV) is also given. Given the fairly large sample sizes, a z statistic was computed for the difference between AVCS and AVCV and is also given in Ta. 3-16. Quite clearly, the z statistic indicates no statistically significant difference between the two means at conventional levels of significance.

The Hancock Tower Observatory in Chicago offered conditions suitable estimates of both a demand based valuation of access to the Observatory and a contingent valuation of access. Given the functional form developed for aggregate demand, average consumer surplus per person-visit to the Tower

TABLE 3-13

Regression Estimates of an Aggregate Demand for Access to HTO, March 15 to May 31, 1981

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>|T|
INTERCEPT	1	-33.479816	14.598137	-2.2934	0.0253
LNVIS	1	0.139551	0.054726	2.5500	0.0133
PP	1	-0.532835	0.192970	-2.7612	0.0076
MAR	1	0.327406	0.195630	1.6736	0.0994
MAY	1	-0.334280	0.125514	-2.6633	0.0099
M	1	-0.171819	0.181041	-0.9491	0.3464
TU	1	-0.348115	0.159548	-2.1819	0.0330
W	1	-0.126686	0.158907	-0.7972	0.4285
F	1	0.375736	0.158148	2.3758	0.0207
S	1	0.786929	0.158722	4.9579	0.0001
SU	1	0.271636	0.161977	1.6770	0.0987
RAIN	1	-0.926709	0.215838	-4.2935	0.0001
TSC	1	-0.00239967	0.001542321	-1.5559	0.1250
FOG	1	-2.295919	0.297832	-7.7088	0.0001
LNWIN	1	0.034347	0.128057	0.2682	0.7895
LNTMK	1	7.136954	2.612609	2.7317	0.0083
LNT	1	0.232934	0.116005	2.0080	0.0492
HAZE	1	-0.090610	0.395829	-0.2289	0.8197

SSE	7.601226	F RATIO	24.90
DFE	60	PROB>F	0.0001
MSE	0.126687	R-SQUARE	0.8759

DEP VAR: LNTVST

TABLE 3-14

Definitions of Variables Used in Estimating

Aggregate Demand

Variable[1]	Definition
LNVIS	Log of visibility where visibility is measured in miles.
PP	Price of admission to HTO in dollars.
MAR	Month of March dummy variable (March=1, 0 otherwise).
MAY	Month of May dummy variable (May=1, 0 otherwise).
M, TU, W, F, S, SU	Day of week dummy variables (No dummy variable entered for Thursday).
RAIN	Proportion of day in which rain fell.
TSC	Total sky cover in percent.
FOG	Proportion of day with fog.
LNWIN	Log of wind speed where wind speed is measured in mph/10.
LNTMK	Log of temperature where temperature is in degrees Kelvin.
LNT	Log of a time series variable beginning with 1 on March 15 and running consecutively through the intergers to 78 on March 31.
HAZE	Proportion of day with haze.

[1] All weather observations except visibility were recorded at O'Hare International Airport in Chicago. Visibility was recorded at HTO.

TABLE 3-15

Sample Statistics for Variables Used in

Estimating Aggregate Demand, March 15 to May 31, 1981

VARIABLE	MEAN +	STANDARD DEVIATION
LNTVST	6.58799580	0.89175811
LNVIS	2.56384683	1.12190785
PP	2.13141026	0.28411505
MAR	0.21794872	0.41552458
MAY	0.39743590	0.49253502
M	0.14102564	0.35030076
TU	0.14102564	0.35030076
W	0.14102564	0.35030076
F	0.14102564	0.35030076
S	0.14102564	0.35030076
SU	0.15384615	0.36313652
RAIN	0.11111111	0.25576565
TSC	69.35897436	32.98544737
FOG	0.06410256	0.20142130
LNWIN	2.40314246	0.37150081
LNTMK	5.65218864	0.02217227
LNT	3.39643141	0.91573362
HAZE	0.04273504	0.12436244
TVST*	931.61538462	567.76436101
VISB1**	20.26533862	15.42756495

* Total daily visits recorded at HTO.

** Visibility in miles recorded at HTO

* Number of observations equals 78.

TABLE 3-16

Estimates of Mean Per Person Consumer Surplus

Obtained by Access to the HTO

Mean per person surplus from aggregate demand estimate (AVCS):	$2.12
Variance:	.462
Mean per person surplus from contingent valuation estimates (AVCV):	$1.47
Variance:	.0120
Test statistic:	z = (2.12 - 1.47) / .688
Conclustion:	Do not reject null hypothesis of no significant difference between AVCS and AVCV.

embodied the most desirable statistical properties. On the basis of a comparison of average estimated surpluses, the hypothesis of a statistically significant difference between demand-based and contingent valuation was rejected. Thus, consistent with the results of other researchers, contingent valuation is shown to perform at least as well as the next best operational alternative in valuation.

3.4 VIEW-ORIENTED RESIDENCES

Clean air and attractive vistas are firmly established as valuable dimensions of environmetnal quality. Analysis shows that there are substantial benefits derived from clean air and that it is a valuable resource indeed. Typical is the housing market analysis of Bender et al. (1980) which shows that for a uniform 20 percent reduction in particulate concentration in Chicago the average household is willing to pay approximately $600 per year. Using a survey approach Brookshire et al. (1982) estimate that the typical household is willing to pay approximately $310 per year for a 30 percent reduction in pollutant concentrations in Los Angeles. Further analysis shows that attractive views yield benefits to which approximately 9 percent of some house prices in Sydney (Abelson, 1979) and 15 percent of some rents in Chicago (Pollard, 1977) can be attributed. Rowe et al. (1980) find that people will bid approximately $100 per year for clear, unpolluted vistas in the Grand Canyon National Park Area.

This study takes as its point of departure an earlier paper, "Visibility, Views and the Housing Market" which suggests that intensive analysis of view-oriented submarkets of the residential housing market would be productive. The objectives of this research are: (1) to measure the values of views and view characteristics including visibility using a survey instrument which establishes a contingent market for each; (2) to measure the values of views and view characteristics using a hedonic-demand analysis of housing consumption for the same group surveyed and (3) compare the contingent values from the survey and the implicit values from the housing market for individuals dwelling in view-oriented residences.

To insure comparability, a survey was conducted among Chicago residents of high-rise buildings along Lake Michigan. The survey instrument was designed to elicit contingent values for views, view characteristics and visibility and to get from the same individuals sufficient information to estimate the values of some of the same amenities from their housing consumption. An abbreviated bidding game was used to obtain contingent values. During the period May through September 1981, a team of interviewers collected 208 responses from residents of 10 high-rise buildings located mostly north of Chicago's Loop. Although further verification was warranted, the integrity of the data was well enough established that some results can be reported.

3.4.1 Contingent Values for View-Oriented Residences

3.4.1.1 Willingness to Accept Payment for No View

Residents of units with relatively unobstructed views of the lake and/or Loop were asked how much their monthly housing payments would have to be reduced for them to choose a unit with no views. Of those who responded, 92 percent replied that the amount would have to be greater than $50; only 8 percent replied that they would choose a viewless unit for a $50 reduction. The mean of the responses to the query about the minimum amount individuals would be willing to accept for loss of view is $169.39. It should be noted that this is average for only 40 percent of the sample and does not incorporate the 60 percent who bid zero, an infinite amount or did not respond.

3.4.1.2 Willingness to Pay for Lake View

Residents who do not have an unobstructed view of the lake were asked how much their monthly housing payment could be increased if they got a good lake view. Of those who responded, 52 percent replied that the amount could be more than $30; 48 percent replied that they would choose their current unit without a lake view if the amount was $30 or more. The mean of the responses to the query about the maximum amount individuals would be willing to pay for a lake view is $43.06.

3.4.1.3 Willingness to Pay for a Unit which Is Ten Floors Higher

All residents were asked how much their monthly housing payments could be increased if they got otherwise identical units 10 floors higher than their current units. Of those who responded 73 percent replied that the amount would have to be less than $30; 27 percent replied that they would choose the higher unit even if the payments increased by $30. The mean of the responses to the query about the maximum amount individuals would be willing to pay for the higher unit is $25.32. The average is based on responses from 79 percent of the 208 people surveyed.

3.4.1.4 Willingness to Pay for Better Visibility

All residents were asked how much their monthly housing payments could be increased if they got more days with better atmospheric visibility. This improvement in visibility was described by showing residents 9 color photographs which depict three Chicago lakefront vistas under visibility conditions of 3 miles, 13 miles and 30 miles. These ranges occur throughout the year and under current conditions there may be 12 consecutive days of 3 mile visibility. The specified improvement would reduce to four the number of consecutive days with only three mile visibility. All people surveyed responded and 65 percent replied that the amount their monthly payments could increase would be $10 or more; 35 percent rplied thay they would choose current visibility conditions if they were to pay $10 per month. The mean of the responses to the query concerning the maximum amount individuals would be willing to pay for the improvement in visibility is $14.27. The average is based on responses from 99 percent of the 208 people surveyed.

3.4.1.5 Implicit Value from the Housing Market

Using the same survey instrument containing the contingent valuation experiments, data on housing consumption and consumer characteristics were collected. Some tentative estimated can be made from a housing hedonic equation for renters. The housing hedonic equation is

$$\text{(3-12)}\quad \text{RENT} = \underset{(2.90)}{100.96} + \underset{(3.77)}{28.950}\ \text{TOTROOMS} + \underset{(1.98)}{83.918}\ \text{BATES} + \underset{(1.75)}{0.0816}\ \text{AREA}$$

$$+ \underset{(3.31)}{41.995}\ \text{CARPET} + \underset{(0.72)}{19.994}\ \text{DISHWASH} + \underset{(2.67)}{2.6219}\ \text{FLOOR}$$

$$+ \underset{(0.09)}{0.0139}\ \text{WARUN} + \underset{(1.53)}{0.21135}\ \text{LWARA}$$

$R^2 = .8537 \qquad F = 28.44 \qquad n = 48$

where RENT is monthly rent in dollars, TOTROOMS is total rooms, BATHS is number of bathrooms, DISHWASH is 1 if the apartment comes furnished with a dishwasher and 0 if not, FLOOR is the number of floors up the apartment is in the building, WARUN us square feet of total window area with unobstructed view, and LWARA is square feet of window area with an unobstructed view of Lake Michigan. Of the view-related characteristics, FLOOR is significant at the 2 percent level, LWARA is significant at the 14 percent level, but WARUN is not significant at any reasonable level.

Estimates based on this housing hedonic equation may be biased and imprecise since (1) relevant housing characteristics may have been omitted, (2) the functional form of the hedonic housing equation may be nonlinear, (3) the benefits might have to be estimated from demand equations and not directly from the average hedonic prices, (4) the remaining 160 residents may differ from the 48 in the sample, and (5) data errors may remain.

3.4.1.6 Implicit Value of a Unit which Is Ten Floors Higher

The value of height and the associated breadth of view is obtained by multiplying the coefficient of FLOOR by the 10 floor change in height. The value of the increase in height is (2.6219)(10) = $26.22 per month. This value is remarkably close to the contingent value of $25.32 from the bidding experiment.

3.4.1.7 Implicit Value of a View

The value of a lake or Loop view would be obtained by adding the products of the coefficients of WARUN and LWARA with their respective changes in window area. Performing the calculation gives an implicit value which is appromi-mately one-third of the average contingent value. However, the difference could be easily due to 44 percent of the contingents bids being excluded from the sample and the (perhaps overly) restrictive definition of WARUN.

3.4.2 Estimates of the Values of Views and View Characteristics

The similarity of the contingent and implicit values for height (10 floors up), the high response rate on the bidding experiment and the highly significant coefficients in the renters' housing hedonic equation are favorable to the use of contingent value of better visibility for policy analysis. Aggregation of individual values over the population residency in the view-oriented submarket would be straightforward, but it must be recognized that this subgroup has high annual incomes (the average is $33,000) and is well-educated (the average is some graduate work). Values of views and visibility from this submarket must be considered in the social value of improved air quality, but they are likely to be higher than those values of the entire population which is less oriented to views, view characteristics and visibility.

3.5 AIR AND AUTO TRAFFIC

3.5.1 Visibility and Air Traffic

Lowered visibility imposes costs on air travelers in many ways. If visibility falls below three miles, all traffic must operate under Instrument Flight Rules (IFR). All general aviation for flight training or recreation which is not IFR rated must terminate. The people engaged in general aviation lose the benefits gained from flying, aircraft rental operators lose revenue, and airports also lose revenue from landing fees. Those still engaging in aviation experience losses in waiting time since aircraft must maintain greater increments between each other under IFR conditions. Not only do travelers experience time costs in queuing, but also may miss connecting flights or appointments. Under lowered visibility, the probability or air accidents also increases. If visibility is poor enough to cause an in-flight diversion, the traveler's involved and airlines suffer losses. The nature of these costs are discussed in detail, and a formal economic model developed later in this section. This model captures consumer behavior under visibility constraints on air travel and provides a framework for measuring the net cost or benefits of lowered visibility on air travel.

In the next section, a generally used method of measuring the cost/benefit structure is outlined and critiqued. A formal model of utility maximization is presented. Finally, empirical estimates of visibility effects on total take-offs and landings at three Chicago area airports are presented and discussed within the context of the economic model.

One procedure used in estimating net benefits is to regress the affected variable on a vector of independent variables. In this case, air traffic counts would be regressed on visibility (possibly current and lagged), and a vector of other weather variables. The equation would resemble

$$(3\text{-}13) \qquad C_{it} = \alpha_o + \alpha_1 V_{it} + \underline{\alpha}_z \underline{W}_{it} + \varepsilon_{it} \quad ,$$

where C_{it} is traffic counts at the ith airport in period t. $\underline{W}_{it}$ and V_{it} are vectors of airport-specific weather and visibility variables in time t, and ε_{it} the stochastic error term. α_1 is taken to be the effect of changes in visibility on traffic counts. In log form α_1 is the elasticity of traffic counts with respect to visibility. Then an average value for a traffic count is determined and if α_1 = 10%, then a one percent change in α_1 would imply a 10 percent decrease in counts. So the number of counts lost times the average value is the cost of decreased visibility.

When presented in this way, several important points emerge. Besides the obvious problem is assessing the value of a count lost, α_1 is neither a supply nor a demand elasticity. It is an amalgam of supply and demand effects. Consider the simple supply and demand structure:

$$(3\text{-}14) \qquad C^D = \gamma_1 V_t + \underline{\gamma}_2 \underline{W}_t + \gamma_3 P_c$$

$$(3\text{-}15) \qquad C^S = \beta_1 V_t + \underline{\beta}_2 \underline{W}_t + \beta_3 P_c \quad .$$

Setting counts supplied (C^S) equal to counts demanded (C^D) yields a reduced form equation for the equilibrium counts (C_E):

$$(3\text{-}16) \qquad C_E = \left(\frac{1}{\gamma_3} - \frac{1}{\beta_3}\right)^{-1} \left[\left(\frac{\gamma_1}{\gamma_3} - \frac{\beta_1}{\beta_3}\right) V_t + \left(\frac{\underline{\gamma}_2}{\gamma_3} - \frac{\underline{\beta}_2}{\beta_3}\right) \underline{W}_t \right] \quad .$$

If eq.(3-13) and (3-14) were the true underlying structure of supply and demand, then $\alpha_1 = (\frac{1}{\gamma_3} - \frac{1}{\beta_3})^{-1} (\frac{\gamma_1}{\gamma_3} - \frac{\beta_1}{\beta_3})$; where γ_3 is the price elasticity of counts demanded, β_3 is the price elasticity of supply, γ_1 is the visibility elasticity of demand and β_1 is the visibility elasticity of supply, Clearly, interpreting α_1 as an elasticity is incorrect. In fact, α_1 cannot be shown to be an upper or lower limit of the true underlying elasticities since the sign of $(\frac{\gamma_1}{\gamma_3} - \frac{\beta_1}{\beta_3})$ is ambiguous.

Even if α_1 could be shown to be a limiting case of the underlying parameters, just multiplying α_1 times the count value does not give a true social cost. The count value chosen is usually an aircraft rental fee, or a plane ticket price. These are at best lower bound estimates of the true cost of the delays. They do not include the social cost due to inefficient allocation of resources.

In this section, the problems of infering social cost estimates from reduced form equations with no underlying structural model have been discussed. The importance of structural models in interpreting reduced form coefficients was shown.

3.5.2 A Model of Air Traffic Responses to Lowered Visibility

Air transportation is an input to a demand for location change. Y, or location changes, is the produced good directly entering the utility function. In meeting the demand for a Y, the individual choses the lowest cost combination of productive inputs. Among the possible combinations is air travel, either purchasing a ticket on a commercial airline or chartering a flight.

There is also a time input involved which is the trip to the airport, the time of the trip itself, and waiting time. Visibility affects the time componenet of air transportation by increasing the landing or takeoff queue. Consequently, the magnitude and direction of the visibility effects on purchased inputs can be analyzed. The purchased input on which the analysis focuses, in the aggregate, is the number of take-offs and landings per day in Chicago area airports. The model presented below develops a method of estimating the true social cost of visibility changes on Y by analyzing effects in the input, or counts, market.

Following Tolley (1972), the demand curve for Y is

(3-17) $P_y = F(Y)$,

where Y is produced according to

(3-18) $Y = Y(z,v)$,

v is the level of visibility which acts as a cost shifter. That is, changes in v affect the amounts of x needed to produce the same level of Y. From this framework the marginal cost of Y can be derived:

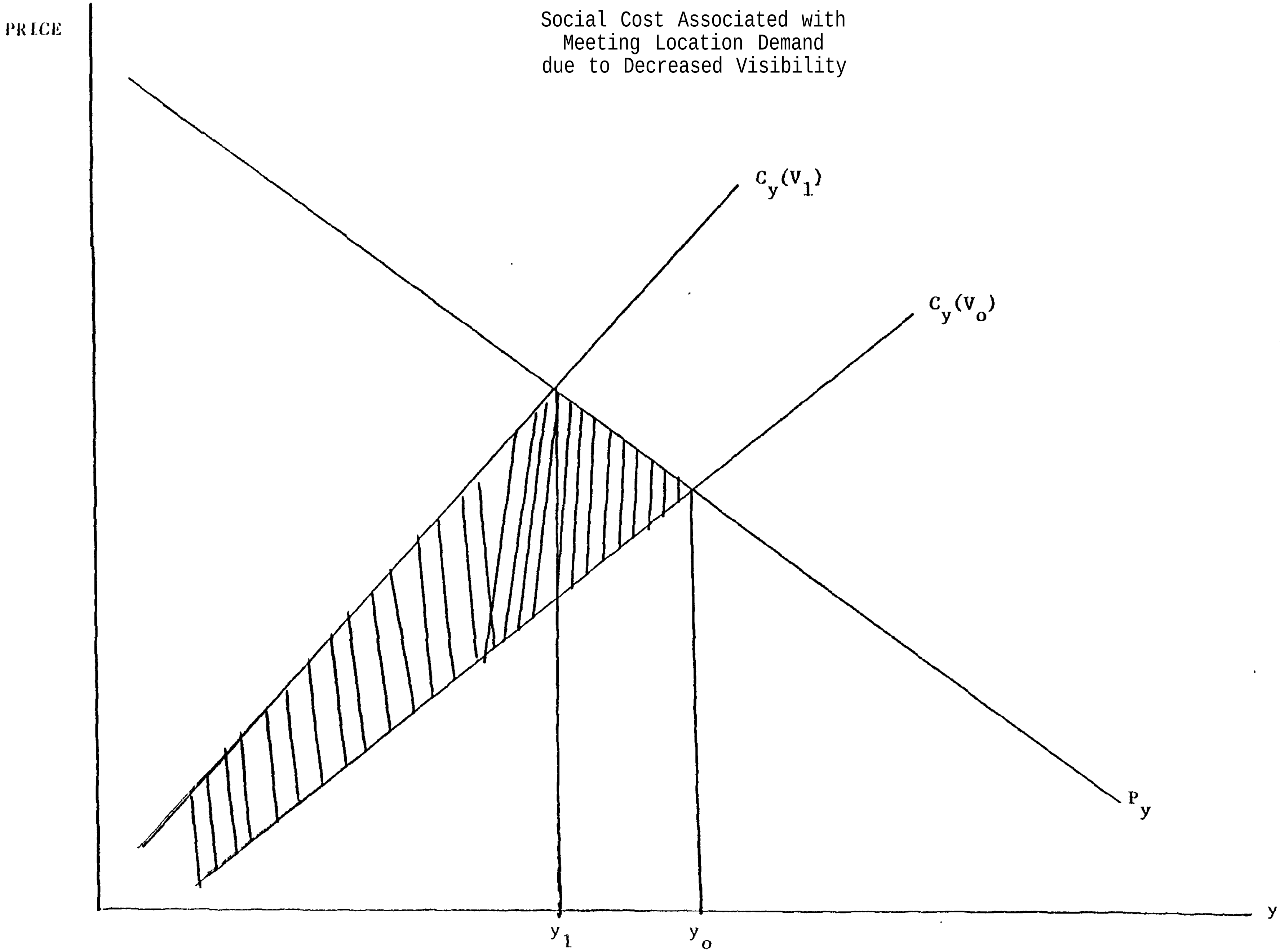
(3-19) $P_y = P_z \left(\frac{1}{y_z(z,v)}\right)$

The right hand side of (3) is the marginal cost of producing Y, and y_z is the marginal productivity of z in the production of Y.

The question to address is what are the costs associated with a decrease in visibility in the framework presented by eq. (3-17) and (3-19). Fig. 3-2 reproduced from the Tolley paper, shows that a decrease in visibility shifts the cost curve back, while leaving demand for Y unaffected. The social cost associated with this shift is the shaded area. The analytic solution of the area is

FIGURE 3-2

Social Cost Associated with
Meeting Location Demand
due to Decreased Visibility



$$(3\text{-}20) \qquad C_y(v) = \int_{Y_0}^{Y} P_y\, Y_{zv}\, dY \,,$$

where Y_{zv} is the effect on the marginal productivity of z of a change in v. In order to view this cost in the framework of a model for counts, this area must be transformed.

By substituting eq.(3-19) into eq.(3-20), this area is

$$(3\text{-}21) \qquad C_z(v) = \int_{z_0}^{z_1} P_z \frac{Y_{zv}}{Y_z}\, dz \,.$$

P_Z is the supply curve for z, and $\frac{Y_{zv}}{Y_z}$ can be viewed as the percentage change in z's marginal productivity resulting from the change in visibility.

The graphical analog to (3-21) is shown in Fig.3-3. P_Z is an upward sloping supply curve for 2. $D_Z(v_0)$ is the demand for z derived from the demand for Y under visibility v_0. $D_Z(v_1)$ is the demand for z at the lower visibility level v_1. The cast associated with this fall in demand is the shaded area in Fig.3-3. So, if P_Z were invariant to changes in visibility, the area ABC would be the associated social cost.

Now, consider the problem of a shift in P_t due to a change in visibility. The supply curve P_t can be viewed as the standard supply curve of an exhaustible resource. Fig. 3-4 presents the supply of counts curve for an airport. As p^*, the landing fee associated with this particular airport, the supply of counts is completely elastic up to $\bar{z}$, the technological or legal bound on the number of counts which can be supplied per period. The effect of decreased visibility is to add queuing time due to in-air stack ups

FIGURE 3-3

Social Cost of Supply Shift Transformed to the Input Market for Counts

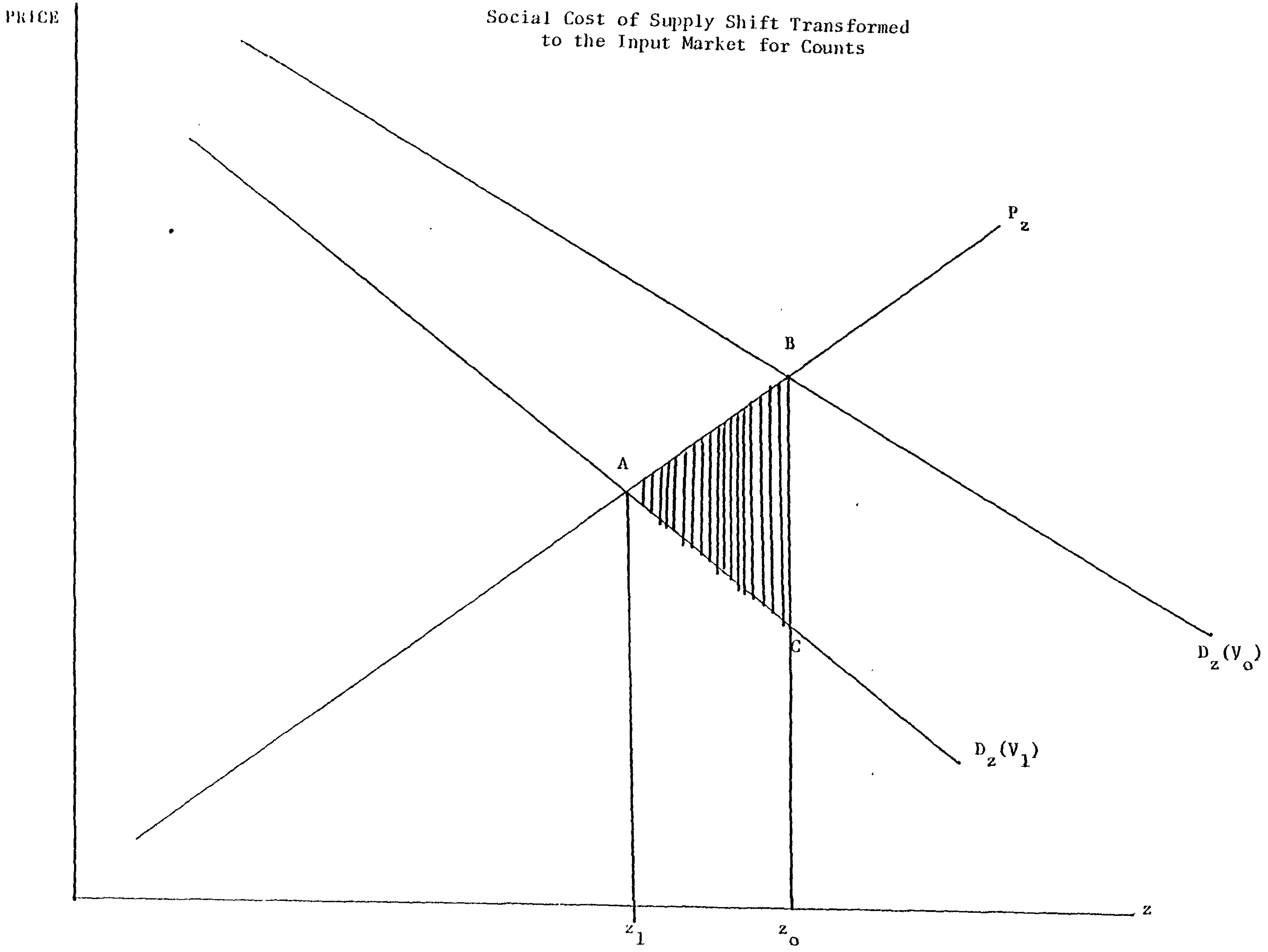
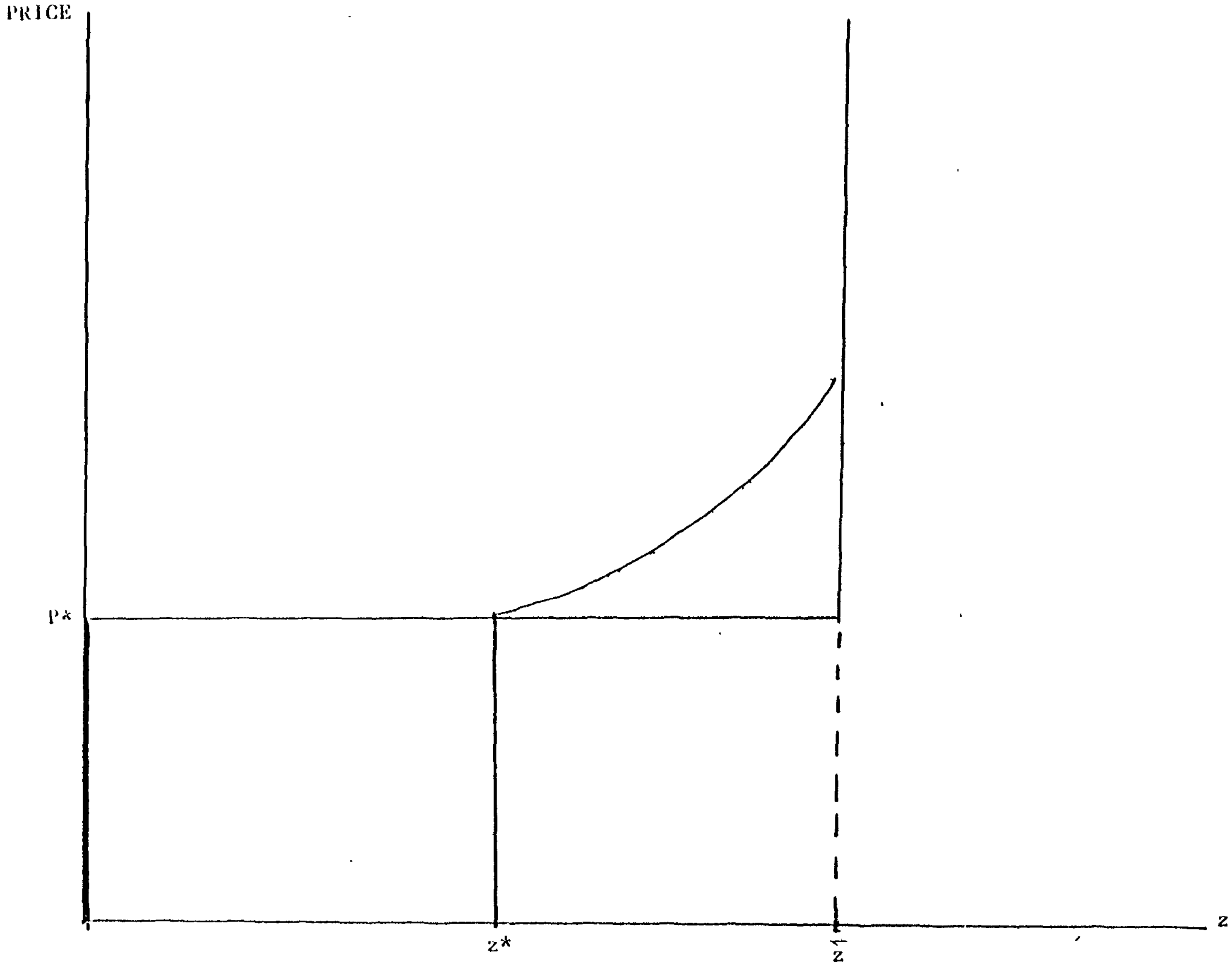


FIGURE 3-4

Supply Curve for Air Traffic Counts



and take-off delays. Thus, at some point z^*, the supply curve begins to slope upward reflecting this increased true cost. The effect of visibility changes is to shift z^* across the interval $(0,\bar{z})$ and thus shift the upward sloping portion of the supply curve.

The cost associated only with a shift in the supply of counts due to visibility changes is, as in the prior case of changes in costs of Y, the area between the two cost curves. Fig.3-5's shaded area is the cost associated with a shift of supply only. The complete cost is derived from a shift in the supply and demand for counts--which means combining the shaded areas.

Using the theoretical model constructed in the previous section, a framework for estimation can be developed. Consider the simple structural model below.

(3-22) $$C^D_{it} = \alpha_o + \alpha_1 P^D_{it} + \alpha_2 V_{it} + \underline{\beta X}_{it}$$

(3-23) $$C^S_{it} = \gamma_o + \gamma_1 P^S_{it} + \gamma_2 V_{it} + \underline{\delta X}_{it}$$

FIGURE 3-5

Cost Associated with a Supply Shift Only

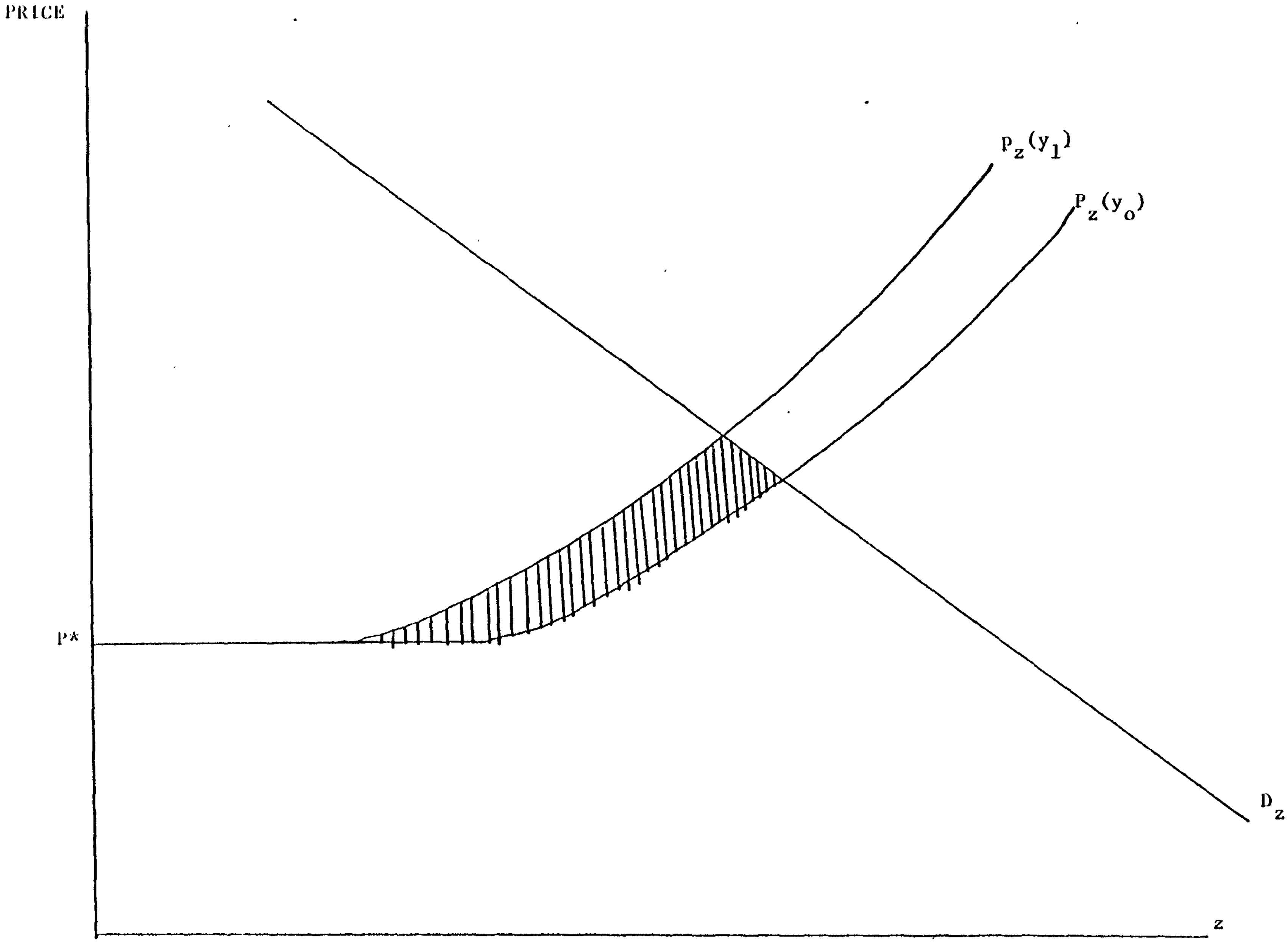
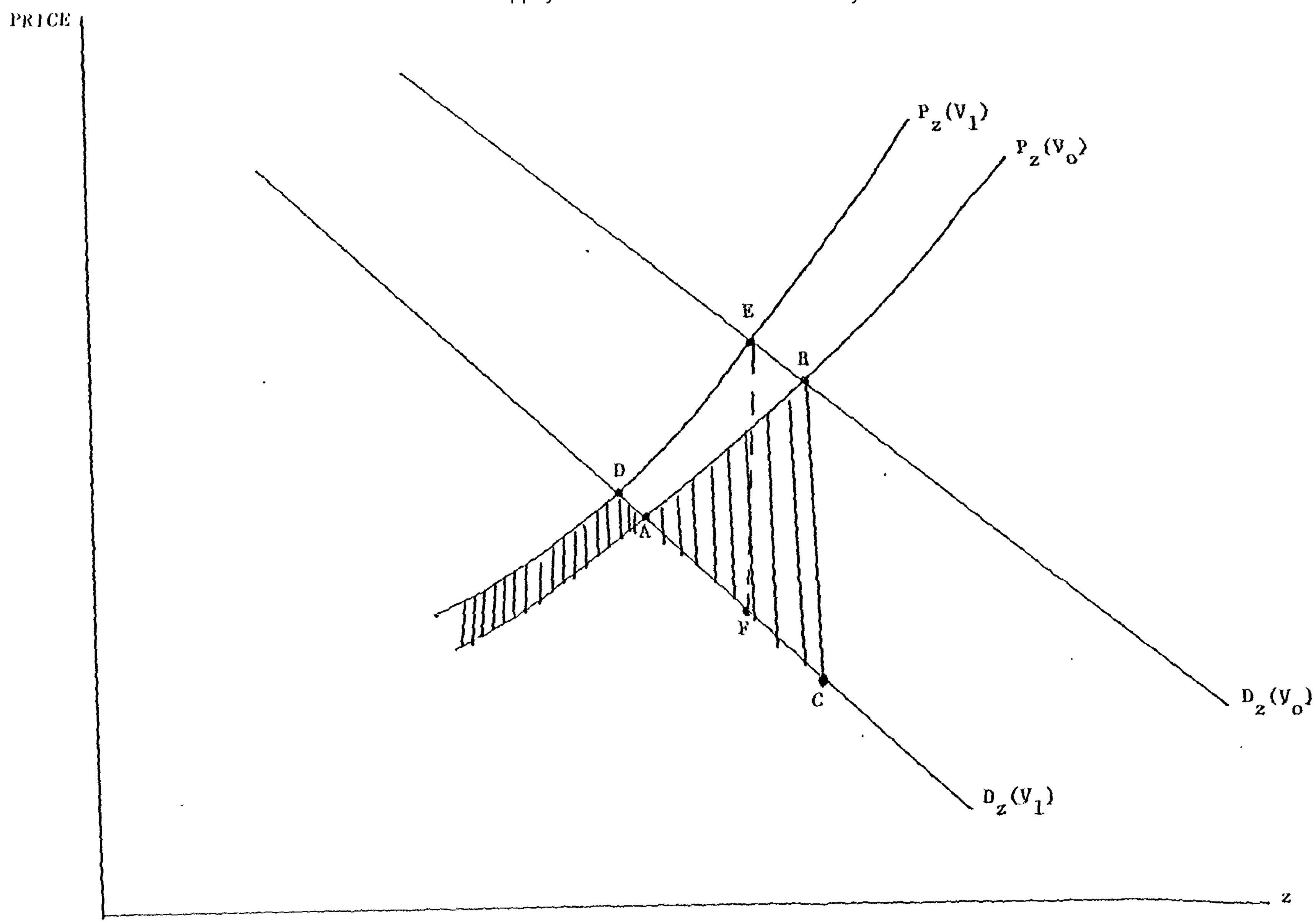


FIGURE 3-6

Social Cost Associated with Demand and
Supply Shifts due to Visibility Variation



Eq. (3-22) is the demand curve for counts. Counts demanded are specified as a function of landing fee and time costs (P^D_{it}), visibility (V_{it}), and a vector of other weather - related variables ($\underline{X}_{it}$) at airport i for time t. Counts supplied are also expected to be a different function of the same variables. Some of these parameters can be signed _a priori_. α_1 is expected to be negative since an increase in price decreases demand. α_2 expected to be positive since visibility decreases lower counts demanded by increasing time costs. γ_1 is the standard positive effect in supply of price increases. γ_2 is expected to be positive since decreases in visibility decreases the amount of counts supplied.

The reduced form equation for counts is

$$(3\text{-}24)\quad C_{it} = \frac{1}{\alpha_1-\gamma_1}\left[\left(\frac{\alpha_o}{\alpha_1} - \frac{\gamma_o}{\gamma 1}\right) + \left(\frac{\alpha_2}{\alpha_1} - \frac{\gamma_2}{\gamma_1}\right)V_{it} + \left(\frac{\beta}{\alpha_1} - \frac{-\delta}{\gamma_1}\right)\underline{X}\right].$$

The reduced form parameter associated with visibility, $\left(\frac{1}{\alpha_1-\gamma_1}\right)\left(\frac{\alpha_2}{\alpha_1} - \frac{\gamma_2}{\gamma_1}\right)$, is expected to be positive in sign, but the underlying structural parameters are unidentified. By making some assumptions about relative magnitudes of α_1 and γ_1, a range of values for α_2,γ_2 can be established for the cost-benefit analysis discussed in the previous section.

Ta.3-17 presents the results from a regression of total daily traffic counts at Aurora Airport on a vector of weather variables. Ta.3-18 defines each of the regression variables. All continuous variables are in logarithm. One drawback of the data is that weather conditions are available only for O'Hare

TABLE 3-17

Classical Least Squares Regression Estimates
of Total Traffic Counts for Aurora Airport

DEPENDENT VARIABLE: LTOTO

SSE	374.402890	F RATION	2279.71
DFE	645.	PROB > F	0.0001
MSE	0.580470	R SQUARE	0.9815

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T-RATIO	PROB > T
LVIS	1	0.413987	0.077050	5.3730	0.0001
LCL	1	-0.104677	0.044098	-2.3737	0.0179
LWS	1	-0.282124	0.085868	-3.2856	0.0011
LWD	1	0.006086538	0.037512	0.1623	0.8712
RA	1	-0.00882506	0.001742717	-5.0640	0.0001
SN	1	-0.00699878	0.001800427	-3.8873	0.0001
FG	1	-0.014861	0.001654214	-8.4838	0.0001
LTEM	1	0.398944	0.050810	7.8517	0.0001
M	1	3.923506	0.570428	6.8782	0.0001
T	1	3.994875	0.560049	7.1331	0.0001
W	1	4.033440	0.566187	7.1239	0.0001
R	1	4.077325	0.559592	7.2862	0.0001
F	1	4.125296	0.571374	7.2200	0.0001
S	1	3.862951	0.571230	6.7625	0.0001
SU	1	3.739265	0.568384	6.5788	0.0001

TABLE 3-18

Regression Variable Definitions

LVIS	Visibility at O'Hare International Airport (in Logarithms)
LCL	Ceiling at O'Hare International Airport (in Logarithms)
LWS	Wind Speed at O'Hare International Airport (in Logarithms)
LWD	Wind Direction at O'Hare International Airport (in Logarithms)
RA	Discrete Variable indicating presence of rain at O'Hare
SN	Discrete Variable indicating presence of snow at O'Hare
FG	Discrete Variable indicating presence of fog at O'Hare
LTEM	Temperature in degrees Fahrenheit at O'Hare (in Logarithms)
M	Monday dummy for day of week effects
T	Tuesday dummy for day of week effects
W	Wednesday dummy for day of week effects
R	Thursday dummy for day of week effects
F	Friday dummy for day of week effects
S	Saturday dummy for day of week effects
SU	Sunday dummy for day of week effects

International Airport. Thus, to the extent that weather conditions vary across airports, this analysis will be in error. However, all airports fall within a 20 mile radius of the Chicago Loop area, so major weather changes are unlikely. Landing fees over the sample are also unavilable. The regression equation estimate is

(3-25) $$C_{it} = \alpha_o + \alpha_1 LVIS_t + \alpha_2 LCL_t + \alpha_3 LWS_t + \alpha_4 LWD_t + \alpha_5 RA_t + \alpha_6 SN_t + \alpha_7 FG_t + \alpha_8 LTEM_t + \underline{\beta}\, \underline{D}_t + \varepsilon_t \;,$$

where $\underline{D}_t$ is a vector of day of week dummies and ε_t is the white noise error term. The high value of the F-statistic and R-squared in Table 3 inidcates that the regression has high explanatory power over the sample. The visibility parameter is positive, as expected and quite precisely estimated. All parameters are of the expected sign except for that associated with LCL. The negative value indicates that as the ceiling increases, traffic counts fall. Wind direction effects are small and imprecisely estimated. However, it is included in the regression to capture differential runway capacity effects at multiple runway airports.

Ta.3-19 presents the estimates for DuPage County Airport. Again, the visibility coefficient is positive in sign and precisely estimated. Its value of .392 is quite close to the visibility coefficient at Aurora of .413. The negative effect of ceiling height again occurs, and the effect of wind direction is larger than at Aurora but is imprecisely estimated. The high F-statistic and R-squared values again indicate a good fit.

TABLE 3-19

Classical Least Squares Regression Estimates
of Total Traffic Counts at DuPage County Airport

DEPENDENT VARIABLE: LTOTO

SSE	90.172072	F PATIO	3270.19
DFE	319.	PROB > F	0.0001
MSE	0.282671	R-SQUARE	0.9935

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T-RATIO	PROB > T
LVIS	1	0.391728	0.076608	5.1134	0.0001
LCL	1	-0.104518	0.043144	-2.4225	0.0160
LWS	1	-0.485604	0.084391	-5.7542	0.0001
LWD	1	-0.037855	0.036887	-1.0263	0.3055
RA	1	-0.00582789	0.001709277	-3.4096	0.0007
SN	1	-0.012183	0.001735787	-7.0189	0.0001
FG	1	-0.012260	0.001619163	-7.5715	0.0001
LTEM	1	0.299262	0.049938	5.9927	0.0001
M	1	6.328694	0.562298	11.2550	0.0001
T	1	6.443391	0.551889	11.6751	0.0001
W	1	6.393385	0.557940	11.4589	0.0001
R	1	6.498858	0.5500934	11.7961	0.0001
F	1	6.499807	0.562287	11.5596	0.001
S	1	6.615916	0.563341	11.7441	0.0001
SU	1	6.526664	0.560167	11.6513	0.001

Ta.3-20 reports the regression coefficients for Chicago's Meigs Field. The visibility effect is positive as before, but is smaller at .25 than the other airports where it was around .4. Ceiling effects are still negative, but wind direction effects, while small, are more precisely estimated than at other airports. Again, all other signs are as expected.

This section has reported on the estimated effects of visibility for three airports in the Chicago area. All of the regression equations have very good explanatory power as indicated by their R^2 and F-statistic values. Visibility effects are strongly positive, and precisely estimated at all sites. The next section attempts to bound the range of supply and demand elasticities of visibility by referring to the structural model presented at the beginning of the section.

As eq.3-24 showed, the parameter associated with visibility in the reduced form regressions is an amalgam of prior elasticities and the true underlying elasticities of visibility. This section examines the values of these visibilities under several polar assumptions in order to determine a reasonable range for the true visibility elasticities.

Ta.3-21 presents the values of α_2, the demand elasticity of visibility, and γ_2, the supply elasticity of visibility at the three airports under alternative assumptions about the relative price elasticities. As Ta.3-21 shows, if the demand and supply curves are unitary price elastic or price inelastic, then the visibility elasticities are on the order of .4 or below. That is, a one percent decrease in visibility would yield at most a .4

TABLE 3-20

Classical Least Squares Regression Results of
Total Traffic Counts for Meigs Field

DEPENDENT VARIABLE: LTOTO

SSE	127.117252	F RATIO	1491.54
DFE	316.	Prob > F	0.0001
MSE	0.402270	R-SQUARE	0.9861

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T-RATIO	PROB > T
LVIS	1	0.250323	0.089207	2 8061	0.0053
LCL	1	-0.096790	0.051904	-1.8648	0.0631
LWS	1	-0.055751	0.100681	-0.5537	0.5801
LWD	1	0.063096	0.044101	1.4307	0.1535
RA	1	-0.00825438	0.002051089	-4.0244	0.0001
SN	L	-0.00495015	0.002105944	-2.3506	0.0194
FG	1	-0.012995	0.00194284	-6.6889	0.0001
LTEM	1	0.273146	0.059633	4.5805	0.0001
M	1	3.716479	0.671756	5.5325	0.0001
T	1	3.866213	0.659868	5.8591	0.0001
W	1	3.885791	0.667383	5.8224	0.0001
R	1	3.835062	0.659811	5.8124	0.0001
F	1	3.930859	0.673699	5.8347	0.0001
S	1	3.274191	0.672222	4.8707	0.0001
SU	1	3.159501	0.669603	4.7185	0.0001

TABLE 3-21

Sensitivity of Visibility Elasticity
Estimates to Price Elasticity Assumptions

	PRICE ELASTICITY ASSUMPTIONS					
AIRPORT	$\alpha_2 = \gamma_2$ $\alpha_1 = -.1$ $\gamma_1 = .2$	$\gamma_2 = 2\alpha_2$ $\alpha_1 = -.1$ $\gamma_1 = .2$	$\alpha_2 = \gamma_2$ $\alpha_1 = -.1$ $\gamma_1 = -.9$	$\gamma_2 = 2\alpha_2$ $\alpha_1 = -1$ $\gamma_1 = 1.9$	$\gamma_2 = \alpha_2$ $\alpha_1 = -10$ $\gamma_1 = 11$	$\gamma_2 = 2\alpha_2$ $\alpha_1 = -10$ $\gamma_1 = 11$
AURORA	$\alpha_2 = .083$ $\gamma_2 = .083$	$\alpha_2 = .05$ $\gamma_2 = .1$	$\alpha_2 = .4$ $\gamma_2 = .4$	$\alpha_2 = .25$ $\gamma_2 = .5$	$\alpha_2 = 45.5$ $\gamma_2 = 45.5$	$\alpha_2 = 29.89$ $\gamma_2 = 59.77$
DUPAGE	$\alpha_2 = .08$ $\gamma_2 = .08$	$\alpha_2 = .05$ $\gamma_2 = .1$	$\alpha_2 = .35$ $\gamma_2 = .35$	$\alpha_2 = .24$ $\gamma_2 = .48$	$\alpha_2 = 43.12$ $\gamma_2 = 43.12$	$\alpha_2 = 28.3$ $\gamma_2 = 56.6$
MEIGS	$\alpha_2 = .05$ $\gamma_2 = .05$	$\alpha_2 = .03$ $\gamma_2 = .06$	$\alpha_2 = .23$ $\gamma_2 = .23$	$\alpha_2 = .15$ $\gamma_2 = .30$	$\alpha_2 = 27.5$ $\gamma_2 = 27.5$	$\alpha_2 = 18.0$ $\gamma_2 = 36.0$

percent decrease in traffic counts demanded or supplied. However, if price elasticities are very large in absolute value, then the visibility elasticities are also quite large. For the type of traffic at these airports, one would expect to find a price elasticity which was quite small, thus implying small visibility effects. However, notice that by eq. 3-24, whatever the price elasticity is, given these results, visibility effects will be large in absolute value.

3.5.3 Visibility and Traffic Accidents

The automobile has become a way of life in industrialized societies, and closely associated with this fact is the annual increase in reported highway casualties in the major cities. The Department of Transportation (1981) reports there were 45,212 fatal accidents and 51,083 fatalities due to roadway usage in the U.S. in 1979. The number of motor vehicles involved was 64,754 and the accident rate was 3.35 fatalities per 100 million vehicle miles. For Illinois there were 2,017 fatalities and the accidnet rate was 3.2.

The number of accidents is affected by those factors which determine travel demand and travel behavior as well as by driving conditions. Several studies of traffic accidents exist which consider accidents to be the result of the demand and supply of motor vehicle travel under various conditions. Peltzman (1975) developed a model of driver behavior and analyzed fatal accident rates to estimate the impact of national highway safety policy in the U.S. The time series analysis of national data covered the period 1937-1972 and his cross-section analysis of state data covered 1962, 1965, 1967, and 1970. He explicitly recognized drivers' utility maximizing use of safety inputs including those supplied exogenously. Peltzman incorporated into his study the earlier research by safety scientists who focused almost exclusively on driving conditions for the effect of traffic density and the like. Ghosh, Lees, and Seal (1975) modeled drivers as trading off safety and low fuel consumption rates for savings of time in choosing their utility maximizing speed of travel. As part of their analysis they estimated a production function for casualties on British motorways using monthly data for the period January1972 to March 1974. The evidence indicates that relevant factors include driver characteristics and driving conditions including weather.

In addition to the research which centers on driver behavior, there is considerable research on the contributions of vehicle and roadway design, and driving conditions to traffic accidents. In Blomquist (1977), a search to identify factors affecting seat-belt productivity found that vehicle speed, alcohol consumption, week-end and night driving, small cars, and high-speed travel on non-interstate highways each tend to increase the probability of a fatal accident.

Fatal Accident Reporting System 1979 gives facts and figures which quantify the gross (as opposed to partial) effects of these and other factors on the number of fatal accidnets. One of the relevant characteristics of the 1979 fatality profile is that an overwhelming majority of fatalities occured during clear weather conditions. According to the Department of Transportation (1981), only fourteen percent of the fatalities were associated with inclement conditions. With rain-slick or ice-slick roads being the worst weather conditions, one would not expect atmospheric visibility to be dominant. However, it is identifiable and measurable.

Measuring the benefits of better visibility can be accomplished by: (1) estimating the physical damage caused by poor visibility, and (2) placing a dollar value on that damage. Our analyses showed that while improvements in visibility lead to decreases in nonfatal accidents, it also resulted in an increase in the probability of fatal accidents. It was also found that a unit improvement in visibility resulted in cost saving of 9.45 million dollars (1980 prices).

In this study we examine the effects of weather (rain, snow, ice, fog), visual range (visibility) and the seasonal variables on highway accidents in Cook and DuPage counties in the Chicago SMSA. The data utilized in the analysis covered the period from January 1978 to June 1980 and the highway casualties are classified into two categories: fatal and non-fatal accidents. First is provided a theoretical examination of the effects of visibility on traffic accidents based on the assumption that travel cost minimization is the main driving force behind the choice of vehicles, speed, direction of travel or route in making a trip between given destinations. It is shown that while the partial effect of improvements in visibility on highway accidents is positive, the total effect is ambiguous. Next are provided some econometric estimates of the relationships between highway accidents - fatal as well as non-fatal - and visibility, weather conditions and seasonal variables for Cook and DuPage counties. It is important to note that only one dimension of benefits from visibility improvements has been estimated--reduction in traffic accidents. Other important benefits, such as increases in speed and volume of traffic have not been addressed. Thus, the benefits estimated in this section represent a lower bound of visibility improvement benefits.

In this section, we attempt to find out whether there is an unambiguous relationship between improvements in visibility and accident rates, assuming that cost minimization is the major driving force behind drivers' travel decisions. Assume two urban communities of the same socio-economic characteristics, highway design conditions and population size. At first thought, most observers would agree that the community with very poor visibility conditions will be less safe (in terms of highway accident reductions) compared to the community with good visibility conditions, even thought poor visibility might lead to a slow down of speed and a decrease in the volume of traffic.

Let us define an improvement in safety as a change in climatic conditions, visibility, traffic volume, speed etc., which reduces the rate of traffic accidents. In this respect, we are more concerned with traffic volume, speed, environmental conditions and visibility, while holding vehicle designs, road conditions (e.g., potholes), highway design and other engineering characteristics of the highway constant. Economic efficiency requires that the cost of achieving a given level of safety be minimized. Let us assume that the consumer computes the price of travel as a solution to the problem of minimizing the cost of travel to his or her destination where the cost of travel is made up of vehicles operating cost and the cost of accidents (measured in terms of what consumers will be willing to pay to avoid accidents). The value of the motorists' time, although positive, is not explicitly included in the model. Let us further assume that decisions concerning choice of vehicle type and direction of travel have already been made by the motorist, Then the most relevant variable under the control of the motorist is speed. The motorist has no control over highway conditions such as traffic volume and the behavior of other motorists as well as the weather and visibility, but all these variables do affect his cost of travel. If we assume that the safety of a trip depends on speed, weather conditions, visibility, traffic volume for given highway design characteristics, mechanical conditions of the automobile, age of driver, blood alcohol level etc., then the accident rate AR = AR(VIS, RC, SP, TV, O) , where

VIS = visibility (e.g., visual range in miles) ,

RC = road conditions e.g., inches of rain, snow, ice etc.,

SP = speed,

TV = traffic volume in vehicle miles per highway mile,

O = other relevant variables.

For simplicity, let us assume that travel cost

(3-26a) $$TC = AC(sp)\ AR(VIS, RC, SP, TV, O) + OC(sp)\ ,$$

where AC(sp) = average cost per accident. It is assumed that accidents which occur at higher speeds are more costly in terms of the damages done to life and property than accidents which occur at lower speeds $\left(\frac{\partial AC(sp)}{\partial (sp)} > 0\right)$.

OC(sp) represents the operating cost per mile. This may include the value of the motorists' time. It is also assumed that, up to the relevant speed limit, the marginal cost of a vehicle mile decreases as speed increases,

Without considering other environmental variables and visibility conditions, the choice of speed to minimize travel cost, TC, requires that

(3-26b) $$\frac{dTC}{d(sp)} = AR\frac{\partial (AC)}{\partial (sp)} + AC\frac{\partial (AR)}{\partial (sp)} + \frac{\partial (OC)}{\partial (sp)} = 0\ ,$$

i.e.,

(3-26c) $$\left[AR\frac{\partial (AC)}{\partial (sp)} + AC\frac{\partial (AR)}{\partial (sp)}\right] = -\frac{\partial (OC)}{\partial (sp)}\ .$$

Eq. (3-26c) requires the motorist to equate the marginal increase in accident cost per mile (LHS) to the marginal savings in operating cost per mile. For the extreme point to be a minimum, the second derivative of the TC function, represented by Z, must be positive.

Our present task is to find the effect of improvement in visibility on accident rates. To obtain the solution to this problem, we totally differentiate the accident rate AR with respect to visibility,

From eq.(3-26a) the total effect of improvement in visibility on accident rates,

$$\text{(3-26d)} \quad \frac{dAR}{d(VIS)} = \underset{(+)}{\frac{\partial AR}{\partial(sp)}} \quad \frac{d(sp)}{d(VIS)} + \underset{(-)}{\frac{\partial AR}{\partial(VIS)}} + \underset{(+)}{\frac{\partial AR}{\partial(TV)}} \cdot \frac{dTV}{d(VIS)} .$$

Let us assume that the partial effect of improvement in visibility on accident rates, $\frac{\partial AR}{\partial(VIS)}$, is negative and $\frac{\partial AR}{\partial(sp)}$, which measure the partial effect of speed on accident rates, is positive. The third term, $\frac{\partial AR}{\partial(TV)} \cdot \frac{dTV}{d(VIS)}$, measures the effect of visibility on accident rates through its influence on highway congestion, TV. The partial effect of highway congestion on AR, $\frac{\partial AR}{\partial(TV)}$, is assumed to be positive i.e., more accidents occur on congested urban highways than on rural highways. For simplicity, let us assume that the effect of visibility on traffic volume is small and positive. The total effect of improvement in visibility on accident rates then depends on $\frac{d(sp)}{d(VIS)}$ i.e., the total effect of improvement in visibility on speed.

Totally differentiating eq.(3-26b) holding RC,TV, and O constant. we obtain

$$\text{(3-26e)} \quad \frac{d(sp)}{d(VIS)} = -\left[\underset{(+)}{AC} \underset{(-)}{\frac{\partial^2 AR}{\partial(sp)\partial(VIS)}} + \underset{(+)}{\frac{\partial AC}{\partial(sp)}} \underset{(-)}{\frac{\partial AR}{\partial(VIS)}} \right] \times Z^{-1} ,$$

where Z represents the second derivative of cost per mile with respect to speed. This is positive.

The average cost of an accident, AC, is positive and $\frac{\partial^2 AR}{\partial(sp)\partial(VIS)}$, which measures the effect of an improvement in visibility on the rate at which accident rates change with respect to speed, is assumed to be negative, i.e., accidents are more likely to increase less, for given speeds, following improvements in visibility. Since accident costs are more likely to increase with speed, $\frac{\partial AC}{\partial (sp)}$ is positive, which makes the bracketed term in eq.(3-26d) negative. Thus $\frac{d(sp)}{d(VIS)}$ is positive i.e. improvements in visibility encourage higher speed levels,

Substituting $\frac{d(sp)}{d(VIS)} > 0$ into eq. (3-26d) the sign of $\frac{dAR}{d(VIS)}$, the total effect of an improvement in visibility on accident rates, becomes ambiguous.

3.5.4 Analysis of Highway Casualties in DuPage and Cook Counties

3.5.4.1 Empirical Analysis

Data on the number of fatal and non-fatal accidents have been collected for Cook and DuPage counties from January 1978 to June 1980 on daily basis. Visibility data, measured in terms of miles of visual range, have also been assembled from the O'Hare airport. In addition to the above information, weather data have also been collected from the O'Hare weather station on the occurence of snow, fog and rain as well as daily recording of the dry bulb temperature in degrees F. The data do not include information on traffic volume and speed in these two counties. Given the quality of data available, the best one can do is to attempt to estimate an econometric relationship between traffic accidents and visibility, weather and the day or season in which the accident occured. These relationships were estimated for DuPage and Cook counties for non-fatal and fatal accidents separately. The following general equation was estimated separately for both counties:

(3-27a)
$$Z_t = \alpha_o + \alpha_1 DD_t + \alpha_2 WNTR_t + \alpha_3 SUMR_t + \alpha_4 SPR_t + \alpha_5 VIS_t + \alpha_6 VIS_t^2$$
$$+ \alpha_7 DVD_t + \alpha_8 VWTR_t + \alpha_9 VSPR_t + \alpha_{10} VSUM_t + \alpha_{11} RA_t + \alpha_{12} SN_t + \alpha_{13} FG_t$$
$$+ \alpha_{14} VTEM_t + \alpha_{15} VRA_t + \alpha_{16} VSN_t - \alpha_{17} TEM_t + \varepsilon_t, \quad t=1,2......912$$

Variables definitions are as follows:

Z_t = Number of non-fatal accidents per day in DuPage county (DPNONFAT) or Number of non-fatal accidents per day in Cook county (CKNONFAT),

DD equals 1 if the accident occured on weekends and equals 0 otherwise,

WNTR equals 1 in winter time and 0 otherwise,

SUMR equals 1 in spring and 0 otherwise,

VIS represents visibility measured in miles,

DVD represents the interaction between visibility and day of occurence of the accident, while VWTR, VSPR AND VSUM measure the interactions between visibility and the seasons (winter, spring and summer). RA equals 1 if there was an occurence of any of the following phenomena on the day the accident occured - rain, rain showers, freezing rain, rain squals, drizzle or freezing drizzle, and 0 otherwise. SN is a 1/0 dummy variable indicating the occurence/non-occurence of any of the following phenomena on the day the accident occured - snow, snow pellets, ice crystals, snow showers etc. FG is also a 1/0 dummy variable indicating the occurence/non-occurence of either fog, ice fog, ground fog, etc. TEM represents temperature in degrees F., while VTEM,VRA, VSN measure the effects of the interaction between temperature, rain and snow, respectively, on traffic accidents.

Ta.3-22 presents the results of a linear regression model for non-fatal accidents in DuPage county. The low R^2 obtained can be partly attributable to the absence of such variables as speed and traffic volume from the model. The parameter estimates indicate that the number of non-fatal accidents increases by almost 8 units per day on weekends compared to weekdays. The coefficient for

TABLE 3-22

DuPage County Non-Fatal Accidents Regression Results

Dependent Variable: DPNONFAT

VARIABLE	PARAMETER ESTIMATE	T RATIO
Intercept	69.088	8.065
DD	7.844	3.159
WNTR	15.187	3.154
SUMR	7.069	1.343
SPR	15.137	3.254
VIS	-3.445	-3.250
VIS^2	0.046	1.265
DVD	-0.064	-0.293
VWTR	0.907	2.123
VSPR	0.791	2.001
VSUM	0.424	0.955
RA	7.463	2.406
SN	13.451	3.621
FG	0.140	0.086
VTEM	0.022	2.133
VRA	0.086	0.242
VSN	-1.273	-2.86
TEM	-0.405	-3.49

PR > F = 0.0001

R^2 = 0.323

DW = 1.46

visibility shows that an improvement in visibility by one mile decreases the number of non-fatal accidents by 3.4 per day. This result is consistent with *a priori* expectations concerning the partial effects of an improvement in visibility on highway casualties. The results also show that seasonal coefficients for winter and spring are precisely estimated. The number of non-fatal accidents increases by 1.5 units per day in winter and spring compared to the base season (fall). But summer shows an increase of only 7 per day above the base season. The summer coefficient is, however, imprecisely estimated. The interactions between visibility improvement and the seasons show that a unit increase in visibility increases the number of non-fatal accidents by almost one unit per day each in winter and spring, while the coefficient of the interaction between visibility and SUMR is imprecisely estimated.

The sign of the coefficients for the weather variables are consistent with *a priori* expectations. The occurence of rain increases the number of non-fatal accidents by 7.5 per day while the presence of snow increases the number of non-fatal accidents by 13.5. Thus, the number of non-fatal accidents which occur in the presence of snow can be expected to exceed the non-fatal accident which occur in the rainy season. The coefficient for fog is, however, imprecisely estimated. An increase in temperature by 10 degrees F., decreases the number of non-fatalities in DuPage county by 4 per day. This is probably due to the fact that people are more likely to engage themselves in other outdoor activities when the temperature increases.

The interactions between visibility improvements and the weather variables for DuPage county indicate that, although the number of non-fatal accidents increases by 13.5 per day in the presence of snow, a unit improvement in visibility In the presence of snow decreases the number of non-fatal accidents by 1.3 per day. An improvement in visibility by one unit on a snowy weekend at an average winter temperature of 30°F can be computed for DuPage county by evaluating the following expression:

(3-27b) $$\frac{\partial(DPNONFAT)}{\partial(VIS)} = -3.455 + 2x0.046\overline{VIS} - 0.064DD + .907WNTR + 0.022\overline{TEM} - 1.273SN$$

Eq.(3-27b) is obtained by taking the first derivative of the equation presented in Ta.3-22 with respect to visibility. Evaluating the expression obtained at SN=1, DD=1, WNTR=1, $\overline{VIS}$ = average visibility = 10.3 miles, $\overline{TEM}$ = average winter temperature = 30°F provides the required result, Ta.3-23 presents the average values of some of the variables used in the analysis. Substituting these values into eq.3-27b it is realized that a unit improvement in visibility on a snowy weekend leads to a decrease in the number of non-fatal accidents by 2.28 per day in DuPage county. The effect of an improvement in visibility on the number of non-fatal accidents occuring on a rainy day can also be obtained by evaluating the following expression at the average values of the variables:

(3-27c) $$\frac{\partial(DPNONFAT)}{\partial(VIS)} = -3.445 + 2x0.046\overline{VIS} - 0.064DD + 0.022\overline{TEM} + 0.086RA$$

Inserting the relevant average values of the variables into eq.(3-27c) shows that on a rainy weekend, a unit improvement in visibility leads to a decrease in the number of non-fatal accidents by 1.35 per day, compared to a decrease of 1.28 on a rainy weekday.

TABLE 3-23

Statistics on Some Variables
Included in the Regression Analysis

VARIABLE*	NUMBER OF OBSERVATIONS	MEAN	MINIMUM VALUE	MAXIMUM VALUE	RANGE
DPNONFAT	1035	28.98341	5.00000	118.00000	113.00000
CKNONFAT	1035	194.29372	72.00000	729.00000	657.00000
CKFATAL	1035	0.41836	0.00000	1.00000	1.00000
DPFATAL	1035	0.10725	0.00000	1.00000	1.00000
SN	912	0.11952	0.00000	1.00000	1.00000
TEM	912	51.27412	-8.33333	89.33333	97.66667
VLS	912	10.31060	0.31250	16.66667	16.35417

*VARIABLE DEFINITIONS:

DPNONFAT = Number of non-fatal accidents in DuPage County

CKNONFAT = Number of non-fatal accidents in Cook County

CKFATAL = Number of fatal accidents in Cook County

DPFATAL = Number of fatal accidents in DuPage County

SN = Snow (dummy variable)

TEM = Temperature (°F)

VIS = Visibility in miles

Ta.3-24 presents the non-fatal accidents regression results for Cook Country. By comparison with Ta.3-22, almost all the coefficients have the same signs as obtained from the DuPage County regression results, except the FG coefficient. In Cook County, the presence of fog decreases the number of non-fatal accidents by 10.9 while it virtually has no effect in DuPage County. The magnitudes of the effects the explanatory variables in the Cook County regression results exceed those obtained for DuPage County.

In Cook County the number of non-fatal accidents increases by 48 at weekends compared to weekdays. All the seasonal coefficients are precisely estimated except the coefficient for summer. The results show that the number of non-fatal accidents increases by 60 per day in winter compared to fall. During the spring season, non-fatal accidents increase by 56.72 per day compared to fall base season. As in DuPage County, a one mile improvement in visibility in Cook County leads to a reduction in the number of non-fatal accidents but the decrease is almost by 16 per day compared to 3 per day for DuPage County. This effect does not include the interaction terms of visibility and the other variables. The coefficients of the weather variables also show that the number of non-fatal accidents increases by 46.7 per day in the presence of rain while the effect of an occurence of snow increases the number of non-fatal accidents by 63 per day in Cook County.

Considering the interaction terms between visibility and the other explanatory variables, an improvement in visibility by one mile on a snowy weekend or weekday at an average winter temperature of about 30°F can be computed by evaluating the following expression:

TABLE 3-24

Cook County Non-Fatal Accidents Regression Results

	Dependent Variable: CKNONFAT	
VARIABLE	PARAMETER ESTIMATE	T RATIO
Intercept	387.55	9.47
DD	48.27	4.18
WNTR	60.37	2.48
SUMR	22.77	0.87
SPR	56.72	2.44
VIS	-15.63	-3.25
VIS^2	0.026	0.16
DVD	-0.72	-0.71
VWTR	4.82	2.36
VSPR	2.96	1.57
VSUM	2.17	1.02
RA	46.73	3.33
SN	63.15	3.84
FG	-10.88	-1.15
VTEM	0.148	3.06
VRA	-0.027	-0.02
VSN	-4.11	-2.07
TEM	-2.35	-4.17

PR > F = 0.0001

R^2 = 0.35

DW = 1.39

(3-27d) $$\frac{\partial(CKNONFAT)}{\partial(VIS)} = -15.63 + 2(0.026)\overline{VIS} - 0.72DD + 4.82WNTR + 0.148\overline{TEM} - 4.11SN \; .$$

Eq.(3-27d) is obtained by taking the first derivative of the regression equation presented in Ta.3-24 with respect to visibility. An evaluation of eq.(3-27d) at the mean values of the relevant variables and an average winter temperature of 30°F shows that an improvement in visibility by one mile on a snowy weekend leads to a decrease in the number of non-fatal accidents by 10.7 per day. It is observed from Ta.3-24 that the effect of an improvement in visibility alone, without considering the interaction terms, is to decrease the number of non-fatal accidents by about 15 per day. But when the interaction terms are considered, the effect of the interaction between an improvement in visibility and winter season is to increase the number of non-fatal accidents in Cook County by 4.82 per day.

The effect of an improvement in visibility on the number of non-fatal accidents occuring on a rainy day can be computed by evaluating the following expression at the average values of the relevant variables:

(3-27e) $$\frac{\partial(CKNONFAT)}{\partial(VIS)} = -15.63 + 2(0.026)\overline{VIS} - 0.72DD + 0.148\overline{TEM} - 0.027RA \; .$$

Inserting the relevant average values of the variables into eq.(3-27e) shows that on a rainy weekend, an improvement in visibility by one mile leads to a decrease in the number of non-fatal accidents by 8.3 per day.

3.5.4.2 Linear Probability Models of Traffic Fatalities

The average number of non-fatal accidents reported for DuPage County during the period for which the accident data were collected was 28.98. while the average for Cook County was 194.3 non-fatal accidents per day. Very few fatalities were recorded. In fact an average of 0.42 fatalities Per day was recorded for Cook County compared to an average of 0.11 fatalities per day for DuPage County. This means that most of the elements under the dependent variable column in the regression model are zeroes and ones. Very few fatal accidents greater than one were recorded for both counties. Therefore, it was decided to use a qualitative choice model in which the dependent variable is 0 when the accident is non-fatal and 1 when the accident was fatal.

The simplest specification of a qualitative choice model is the linear probability model, where it is assumed for the purpose of this analysis that the probability of occurence or non-occurence of a fatal accident on any given day is a linear function of the explanatory variables listed in Ta.3-22 and 3-24.

Let
$$FATAL_t = \alpha_o + \alpha_1 DD_t + \alpha_2 WNTR_t + \alpha_3 SUMR_t + \alpha_4 SPR_t + \alpha_5 VIS_t + \alpha_6 DVD_t + \alpha_7 VWNTR_t + \alpha_8 VSPR_t + \alpha_9 VSUM_t + \alpha_{10} RA_t + \alpha_{11} SN_t + \alpha_{12} FG_t + \alpha_{13} VTEM_t + \alpha_{14} VRA_t + \alpha_{15} VSN_t + \alpha_{16} TEM_t + \varepsilon_t \quad .$$

For DuPage County,
$$FATAL_t = DPFATAL_t = \begin{cases} 1, & \text{if fatal accident was recorded.} \\ 0, & \text{otherwise} \end{cases}$$

For Cook County, $FATAL_t = CKFATAL_t = \begin{cases} 1, & \text{if fatal accident was recorded} \\ 0, & \text{otherwise} \end{cases}$

Thus, the regression coefficients may be interpreted as the effects of unit changes in the explanatory variables on the probability of occurence of fatal accidents. The above model was estimated by Ordinary Least-Squares procedure for DuPage and Cook Counties and the results are presented in Ta.3-25. The very low R^2 suggests that a good deal of variance in the model is unexplained. Nonetheless, it is our belief that, with the availability of data on relevant variables such as vehicle speed and traffic volume, there would be an improvement in the fit of the Linear Probability Model.

The results show that an improvement in visibility by one mile leads to an increase in the probability of fatalities by 0.005 in DuPage County, compared to an increase of 0.02 in Cook County. This result does not include the interactions between visibility and the other explanatory variables. If we consider the interaction between visibility and the day of week effect (DVD), an improvement in visibility leads to an increase in the probability of fatalities by 0.009 in Cook County and a decrease in the probability of fatalities by 0.014 in DuPage County during the weekends. The DuPage County estimate of the interaction between visibility and the day of week effect is, however, more precisely estimated than the Cook County estimate. The effect of the interaction between visibility and the seasons is to decrease the probability of occurence of fatalities in winter and spring in Cook County by 0.022 and 0.020 respectively. An improvement in visibility in summer time leads to an increase in the probability of occurence of fatal accidents by 0.003 in Cook County.

TABLE 3-25

Linear Probability Models of Traffic
Fatalities in Cook and DuPage Counties

	Cook County Results		DuPage County Results	
VARIABLE	PARAMETER ESTIMATE	T RATIO	PARAMETER ESTIMATE	T RATIO
Intercept	-0.059	-0.215	0.095	0.545
DD	0.026	0.289	0.137	2.372
WNTR	0.258	1.473	-0.037	-0.334
SUMR	-0.062	-0.319	0.000	0.002
SPR	0.180	1.041	0.049	0.447
VIS	0.023	0.979	0.005	0.318
DVD	0.009	1.080	-0.014	-2.688
VWTR	-0.022	-1.417	-0.002	-0.166
VSPR	-0.020	-1.353	-0.007	-0.764
VSUM	0.003	0.181	-0.002	-0.176
RA	0.008	0.075	-0.001	-0.016
SN	0.037	0.289	0.026	-0.331
FG	-0.047	-0.801	0.0363	0.977
VTEM	-0.0002	-0.659	0.000	0.112
VRA	-0.02	-0.147	-0.007	-0.865
VSN	0.004	0.250	0.006	0.593
TEM	0.006	1.534	-0.0004	-0.147

Cook County	DuPage County
PR > F = 0.0059	PR > F = 0.5997
R^2 = 9.0367	R^2 = 0.0154
DW = 1.932	DW = 2.098

The coefficients of the interaction terms between visibility and winter, and spring (VSPR) are more precisely estimated than the summer interaction term in the Cook County model. The DuPage County results show that the effect of interactions between visibility and the seasons is to decrease the probability of occurrence of fatal accidents, but these coefficients are imprecisely estimated.

3.5.4.3 Monetary Value of Benefits

The results of the Cook County linear probability model parameter estimates for the occurrence of fatal accidents shows that an improvement in visibility by one mile increased the probability of occurrence of daily accidents by 0.023. The daily fatal accidents rate for Cook County is 0.42. Thus the expected number of fatal accidents occurring in Cook County per day due to a mile improvement is 0.01. This represents 3.65 traffic fatalities per annum. The loss in human lives represents a cost to society, largely resulting from risks voluntarily incurred. This cost partly offsets the gains obtained by the great majority of motorists because of time saved. Ignoring the net affects of traffic fatalities contributes to a conservative estimate of the benefits of improved visibility. Professor Sherwin Rosen's risk-compensating wage differential estimates (1976) produce an average statistical value of life of 494,000 dollars (1980). The 3.65 traffic fatalities which occur due to an improvement in visibility by one mile in Cook County represents a cost of 1.80 million dollars (1980) in human life. A simple linear extrapolation of this value to cover the entire eastern United States yields a benefit of 204 million (1980) dollars.

In valuing the reduction in nonfatal accidents we make use of the nonfatal injury costs estimated by Faigan (1975) and the Proceedings. Ta. 3-26 presents the breakdown of the injury costs in 1972 dollars. The average nonfatal injury loss which can be aboided is $3000 per accident in 1972 dollars. Using the estimate of the annual reduction in traffic accidents due to a one mile improvement in visibility, a rough estimate of the annual benefits from a one mile improvement in visibility is 17 million dollars in Cook County. This translates into 35 million 1980 dollars, using the 1980 consumer index. A simple linear extrapolation to the entire U.S. yields an annual benefit of about $750 million (1980).

TABLE 3-26

Non-Fatal Injury Accident Costs*

TYPE OF COST	COST IN 1972 DOLLARS
Labor Productivity Low	850
Medical	350
Pain and Suffering	100
Property Damage	700
Legal	150
InsuranceAdministration	800
Other	50
Total	3000

*Source: G. Blomquist "Value of Life: Implications of Automobile Seat Belt Use" p. 47

3.5.5 Summary and Conclusions

A conceptual model of the relationship between travel cost, accident rates, weather conditions, improvement in visibility, vehicle speed, and traffic congestion has been developed. Based on the assumption that travel cost minimization is the main driving force behind drivers' choice of vehicle speed and direction of travel when vehicle and highway designs, road conditions and other engineering characteristics of highways are held constant, it is shown that the total effect of an improvement in visibility on accident rates depends crucially on the effect of improvements in visibility on vehicle speed. It has been demonstrated that improvements in visibility encourage higher speed levels, for a given traffic volume and road condition, thus leading to the conclusion that the total effect of improvements in visibility on traffic casualties is ambiguous.

The empirical estimations of the relationship between improvements in visibility, weather variables and traffic casualties show that visibility improvements lead to significant reductions in non-fatal accidents in both Cook and DuPage Counties. This result is consistent with the partial effect of improvements in visibility on highway casualties. While the occurence of rain and/or snow lead to an increase in the number of non-fatal accidents in Cook and DuPage Counties, the empirical results also show that an improvement in visibility in the presence of snow leads to a decrease in the number of non-fatal accidents in both counties. Empirical estimates of benefits from increased speed and traffic volume have not been made.

Results of linear probability models in analyzing the traffic fatalities show that an improvement in visibility during the weekends leads to an increase in the probability of occurrence of fatal accidents in Cook and DuPage Counties. Visibility improvements in winter and spring, however, lead to decreases in the probability of occurrence of fatal accidents in both counties, although these coefficients are not very precisely estimated. An improvement in visibility in Cook County by one mile leads to an estimated benefit of 35 million dollars as a result of reductions in traffic casualties. This translates into an annual benefit of about $750 million for the entire eastern U.S.

3.6 Effects of a One Mile Change in Visibility: Comparisons of Willingness to Pay and Secondary Data Results

Estimated willingness to pay for a uniform one mile visibility improvement in the eastern U.S. is given in Ta.3-27. The one mile improvement scenario is suitable for comparison with benefits derived from analyses of secondary data. Scenario benefits in Ta.3-27 are derived from the six-city eastern survey, using the visibility value function from section 2 aggregates according to the method explained in section 4. Aggregate 1990 benefits are about $10 billion for the hypothetical argument on visibility of one mile. It should be emphasized that tje one mile improvement does not refer to any real program and is used here only for purposes of comparing the contingent valuation and secondary ratio estimates.

Reduction of nonfatal traffic accidents is responsible for the largest visibility improvement benefit among the Project's secondary data analyses. Based upon the Cook County, Illinois results, eastern U.S. benefits from a one mile uniform visibility improvement would be about 0.75 billion in 1980 dollars. The $10 billion aggregate benefit reported in Ta.3-27 comprises all visibility benefits, whether they be aesthetic, safety-related or derived from a multitude of other goods to which visibility contributes.

TABLE 3-27

BENEFITS OF ONE MILE VISIBILITY IMPROVEMENT
IN THE EASTERN U.S. 1990 (1983 dollars)

	Benefits per household	Total Benefits ($000)
Alabama	167	233666
Connecticut	144	182760
Delaware	141	34578
District of Columbia	209	60670
Florida	116	514983
Georgia	179	380602
Illinois	206	902688
Indiana	220	464536
Kentucky	199	269036
Maine	117	51153
Maryland	230	413287
Massachusetts	149	339302
Michigan	194	706202
Mississippi	144	124967
New Hampshire	160	58592
New Jersey	157	465041
New York	163	1120832
North Carolina	171	390607
Ohio	201	848300
Pennsylvania	179	799842
Rhode Island	111	42780
South Carolina	193	220656
Tennessee	194	333294
Vermont	154	31456
Virginia	233	495 369
West Virginia	198	132774
Wisconsin	169	314799
TOTAL		9,932,774

Note: A detailed discussion of visibility scenarios is given in section 4.

Two conclusions are suggested by this comparison. The first is that improved traffic safety is one of the major benefits of visibility improvement--about 7% of the total. A plausible conjecture is that there are several such major areas of bnefit, plus a great number of areas where much smaller benefits are derived. One such example is the benefit to spectators of major league baseball in the entire U.S.--somewhat less than $1 million annually resulting from the hypothetical one mile improvement, or less than one ten-thousandth of the total. This is not a big part of the overall picture, but it undoubtedly has importance to some people. (See section 3.2.3.)

The second and more important conclusion is that the secondary-data and willingness-to-pay results appear to be consistent. While we cannot be certain that a far more exhaustive secondary-data study would confirm the survey results by adding up to the same total, nevertheless these results are plausibly related to each other. Thus the evidence from the two approaches gives reason to have confidence in both as a means of valuing this elusive non-market good.

Section 3 contains controlled experiments that directly compared secondary-data and contingent valuation results in well defined situations. These results corroborate our conclusions about the one mile improvement experiments. In section 3.4, a contingent market in visibility for view-oriented residences among high-rise residents along Lake Michigan in Chicago was established. A hedonic demand analysis was carried out for the same group of subjects. The similarity of results confirmed the reliability of each approach for policy analysis. A similar study of demand-based and contingent valuation in section 3.3.2 of Hancock Tower visitation rejected the hypothesis that different results are obtained from the two analytic approaches.

In future work, the findings of significant effects of visibility on the other activities that have been considered in this section (section 3)--namely, air traffic and recreation in addition to baseball attendance--could be used to develop benefit estimates to compare with the contingent valuation estimates.

SECTION 4

Use of Results to Estimate Benefits for the Eastern United States

4.1 EVALUATION OF POLICY EFFECTS ON VISUAL RANGE

This chapter provides a detailed illustration of the application of the visibility value function developed in Section 2 to analysis of policy benefits. The visibility value function indicates how people's expressed willingness to pay to enjoy visibility improvements or to prevent visibility deterioration depends on their personal characteristics and on prevailing visibility conditions where they live. This function is general in that it can be used to estimate visibiltiy benefits associated with any amount of pollution reduction. The benfits are obtained by summing over affected areas taking account of willingness to pay for the change in visibility that will be brought about in each area by the pollution policy.

Forecasting visibility policy effects requires comparing a without-policy or base-case scenario with one or more scenarios of regulatory stringency. In this chapter, the visibility value function is applied to four policy hypothetical or illustrative policy scenario for electric and utility pollution control relative to a base-case scenario. Benefits connected with these illustrative scenarios are estimated for the year 1990. Specifically, per-household and aggregate benefits are estimated for each eastern state and the eastern United States.

A method is needed which relates reductions in pollution emissions from the scenarios to visibility improvements. In the present chapter, the relation between emissions and visibility is provided by results from research at Argonne National Laboratory. The major task of the chapter is to estimate visibility benefits using the visibility value function.

4.2 ILLUSTRATION OF METHOD

4.2.1 Outline and Summary

Step A in the analysis of visibility regulation was to establish policy alternatives. Alternative policies produce different patterns of visibility improvements whose effects need to be evaluated in order to make a policy choice. Four such policies were considered. In addition to the policy scenarios a without-policy or base-case scenario was formulated. The base-case scenario is a judgement as to the most likely regulatory climate in the absence of a visibility policy. It provides the standard against which the benefits of the policy scenarios are measured.

Step B was to forecast emissions under the base-case and hypothetical-policy scenarios by type of emitter, season and amount of pollution. These forecasts depended in part on the technical requirements of pollution abatement. To an even greater extent the emissions forecasts depended upon forecasts of future levels of economic activity.

Step C was to forecast the spatial distribution of ambient air quality. The relationship between emissions and ambient air quality depends upon the way emissions are dispersed geographically and the chemical transformations that occur during dispersion. This step was performed for each of the scenarios by means of the Argonne long-range-transport model. [Rote, 1982] Step D was to measure the effects of ambient air quality on visibility resulting from each hypothetical scenario. The solution to this problem, also supplied by Argonne [Rote, 1982b], provides a set of predictions as to the course of visual air quality on a state by state basis in the future.

Step E was to use the visibility value function to establish values associated with alternative pollution control strategies. Each hypothetical scenario produced a set of improvements in visual range for each state in future years. The function estimated the value of these improvements to a state as the sum of the value of the local component and value of improvements in other parts of the region due to existence and option values. Non-local improvements are less valuable to the state depending upon their distance from the state. The value of visibility improvements is the sum of all local and non-local improvements for all states in a given year. The visibility value function is used to evaluate improvements for each state in 1990 for each of the four hypothetical policy scenarios.

4.2.2 Step A: Establish Hypothetical Policy Scenarios and Estimate Visibility Effects

In this step, a base case and four illustrative policy scenarios are considered. [Rote, 1982b] The base case the three hypothetical policies that yield improvements are summarized in Ta.4-1. They are as follows:

4.2.2.1 Base Case: Scenario 2

This scenario assumes that all electric utilities governed by State Implementation Plans (SIP) meet promulgated regulations by 1985. Compliance is determined by comparing annual emissions with specified SIP regulations.

For industrial emitters that burn coal, the base-case scenario assumes that large units burn low sulfur coal, and medium and small units comply with SIP regulations. For oil-fired industrial emitters, the base case assumes that large units burn medium- or low-sulfur coal, and small units comply with SIP regulations. These industrial assumptions are maintained for all of the scenarios. All other emitters are assumed to continue emitting at the 1979 rate in the base-case scenario. This assumption about other emitters is also used in each of the other scenarios.

This scenario is crucial to policy analysis because it measures without-policy or base-case conditions against which policy effects are measured. It provides the basis for an estimate of future pollution by type of emitter in the absence of the policy being evaluated.

4.2.2.2 Hypothetical Control Scenarios

The state of completion of the Argonne study necessitated limiting the analysis to illustrative policies in which utilities are controlled more stringently than in the base case, but emissions for other sources remain as in the base case. No implication is intended that this combination of controls would be chosen.

The scenarios are numbered according to increasing stringency of control. Remembering that Scenario 2 is the base case, and shows some improvement over 1979, the control scenarios are as follows:

TABLE 4-1

Scenario 1 (1979 status quo).

All utility units continue to emit SO_2 at the 1979 rate. Units with operating scrubbers keep them; units with planned scrubbers install them.

Scenario 3 (First level of increased stringency for utilities).

All unility units covered by SIP regulations are required to meet promulgated regulations by 1985. No such unit is allowed to exceed 4 pounds SO_2 emissions per millions BTU's from fuel used to produce electricity.

Scenario 4 (Second level of increased stringency for utilities).

All utility units covered by SIP regulations are required to meet promulgated regulations by 1985. No such unit is allowed to exceed 2 pounds SO_2 emissions per million BTU's from fuel used to produce electricity.

Scenario 5 (Third level of increased stringency for utilities).

All utility units covered by SIP regulations are required to achieve a 50 Percent reduction in SO_2 emissions beyond SIP compliance levels by flue gas desulfurization retrofitting where retrofitting is most cost effective.

4.2.3 Step B: Forecast Emissions Under the Hypothetical Policy Scenarios

Sulfur dioxide is the emitted pollutant of central importance to the analysis because it is a precursor of ambient air constituents that cause the greatest extinction of visual range. Argonne obtained the scenarios underlying forecasts of future emissions from electric utilities from Technekron, Inc., and those underlying the industrial emissions forecasts from ICF, Inc.

Emissions estimates are made for the base-case and the four hypothetical-policy scenarios to the year 2000. The model requires that the conditions under which emissions take place be specified in detail. These conditions include type of emitter (utility, industrial, other), stack height (short, medium, tall), season (summer, winter), and fuel type (coal and oil of various grades). The symbol specifying the amount of emissions from a type under a given control scenario is $Q^{(m)}_{jkt}$, where

Q is emissions of SO_2 in kilotons per year;

m is the scenario (m = 1, ..., 5 as described under Step A;

j is the state from which emissions originate. All emissions are aggregated and assumed to originate from the geographic center of the state;

k stands for the other conditions under which emissions occur: type of emitter, stack height, season, fuel type. k = 1, ..., n for each of these conditions;

t is the year. t = 1980, ..., 2000. Hereafter, t will be understood to be present but not written down.

4.2.4 Step C: Forecast Spatial Distribution of Ambient Air Quality

Forecasting pollution is a regional problem because there are many source regions, defined as states, and many receptor states. Each state is both a source and a receptor, and the source-receptor relationship is a complicated one. The Argonne long-range-transport model accounts for the processes by which pollutant emissions are transported and transformed into ambient pollution within a regional framework [Rote, 1982a]. All of the states in the present project study area are represented (eastern United States).

Based upon the pollution emissions variable, $Q_{jk}^{(m)}$, an equation can be written down which expresses the key relationships of the ambient air forecast:

$$X_i^{(m)} = t_i \sum^{j} \left\{ e_{ij} \sum^{k} Q_{jk}^{(m)} \right\} , \qquad \text{where} \tag{4-1}$$

$X_i^{(m)}$ is ambient pollution in state i under scenario m , measured in $\mu g/m^3$ of SO_4 ;

e_{ij} is the amount of emissions from state j reaching state i , per kiloton of emissions in state j;

t_i is the amount of ambient pollution in state i resulting from a kiloton of emissions of SO_2 arriving in the state.

Eq.(4-1) may be explained as follows. To solve for $X_i^{(m)}$, first sum emissions $Q_{jk}^{(m)}$, over the k source types in state j , where $Q_{jk}^{(m)}$ is obtained from Step A. Multiply the resulting $\sum^{k} Q_{jk}^{(m)}$ emissions by e_{ij} to obtain emissions from state j arriving in state i . Sum over all states j to obtain total emissions arriving in state i , and multiply by t, to obtain the state's ambient pollution.

In the Argonne model, air-quality variables estimated on a state-by-state basis are as follows:

Model-predicted sulfate ion concentrations;

Estimated sulfate ion concentrations computed by adjusting the model-predicted values with regression parameters;

Fine particle (FP) concentrations computed from sulfate ion concentrations estimated with regression equations;

FP concentrations computed from an alternative theoretical/ empirical relationship between FP mass and other constituents;

Controllable sulfate mass concentrations computed from a theoretical relationship between sulfate ions and other FP constituents;

Estimated first and second 24-hour maximum FP mass concentrations;

Model-predicted sulfate ion wet and dry deposition rates [Rote, 1982a].

Several qualifications are noted in the Argonne report which affect the applicability of the results discussed in this chapter. First, emissions from each source state are assumed to emanate from a single point at the geographic center of the state. Second, modeling results need more comparisons with actual visibility measurements. Available comparisons show a good correspondence; however, adjustments have been made to model-generated visibility endowments in estimating benefits in the Report. Third, the Argonne Report questions the validity of the base-case industrial scenario as representative of likely economic trends between 1980 and the year 2000.

4.2.5 Step D: Estimate Visibility Effects of Scenarios

Predictions of visibility levels for 1990 for the base case and policy scenarios are given in Ta.4-2 for each state considered in this study. Estimates of actual visibility in 1980 are also given.

The analysis of visibility effects may be represented by the following equation, representing the approach used in the Argonne study:

$$\Delta V_i^{(m)} = f\left\{\left[X_i^{(m)} - X_i^{(0)}\right], Y_1, Y_2, \ldots\right\} , \quad \text{where} \tag{4-2}$$

$\Delta V_i^{(m)}$ is the improvement in visual range in miles in the i^{th} state caused by policy scenario m. It is computed from a theoretical-empirical relationship involving sulfate ion concentration and other factors in Y_i, defined below;

TABLE 4-2

Visibility Projections in Miles
for Base Case and Three Control Scenarios, 1990

		Base Case Scenario 2	Scenario 3	Scenario 4	Scenario 5
	Actual Visibility	SIP Compliance by 1985	SIP SO_2 Emission Limits 4lbs. per million BTU	SIP SO_2 Emission Limits 2lbs. per million BTU	SO_2 Emissions 50% below SIP Compliance Levels
STATE	1980				
Alabama	14.3	13.7	13.7	14.3	14.3
Connecticut	9.9	9.9	9.9	10.6	11.2
Delaware	10.6	9.9	10.6	11.2	11.8
D.C.	10.6	10.6	10.6	11.8	12.4
Florida	14.9	14.3	14.3	14.9	14.9
Georgia	13.7	13.0	13.0	14.3	14.3
Illinois	13.0	13.0	13.0	14.3	14.3
Indiana	9.9	10.6	11.2	11.8	13.0
Kentucky	10.6	11.8	11.8	13.0	13.7
Maine	13.7	13.7	13.7	14.3	14.3
Maryland	10.6	9.9	10.6	11.2	11.8
Massachusetts	10.6	9.9	9.9	10.6	11.2
Michigan	13.0	13.0	13.0	13.7	14.3
Mississippi	15.5	14.3	14.3	14.9	14.0
New Hampshire	11.8	11.8	11.8	13.0	13.0
New Jersey	10.6	9.9	10.6	11.2	11.8
New York	10.6	10.6	11.2	11.8	13.0
North Carolina	13.0	12.4	13.0	13.0	13.7
Ohio	8.7	9.3	9.9	11.2	12.4
Pennsylvania	8.7	8.7	9.3	9.9	11.3
Rhode Island	10.6	9.9	9.9	10.6	11.2
South Carolina	13.7	13.0	13.0	13.7	13.7
Tennessee	11.8	11.8	11.8	13.0	13.7
Vermont	11.8	11.8	11.8	12.4	13.0
Virginia	10.6	10.6	11.2	11.8	12.4
West Virginia	9.9	9.9	10.6	11.2	12.4
Wisconsin	14.9	14.3	14.9	14.9	15.5

$X_i^{(m)}$ is ambient pollution as defined and calculated in Step C, equation (1) ; $X_i^{(m)}$ is ambient pollution in state i under scenario m; $x_i^{(0)}$ is base case ambient pollution in state i;

Y_i are variables such as humidity and fine particle constituents other than sulfate ion which affect the relationship between ambient air quality and visual range;

Eq. (4-2) is a summary of a study of the determinants of visual range in the eastern United States by D. M. Rote. [Rote, 1982a]

4.2.6 Step E: Estimate the Value of Visibility Benefits of Hypothetical Pollution Control Strategies

In this step the visibility value function is applied to the visibility effects obtained in Step D. Visibility improvement attributable to a policy equals the difference between visibility under a policy scenario and base-case visibility. The value of visibility improvement depends upon the size of the improvement, the characteristics of the people enjoying it, and the prevailing level of visibility. The value of an extra mile of visual range depends upon the income of a household, for example, and the number and ages of household members. An extra mile of visibility is valued more when prevailing visibility is low than when it is high.

The relationship between the expressed valuations and the influential factors, or predictor variables, was specified according to economic theory and measured econometrically in Section 2 of this study. The resulting relationship is the visibility value function. By using the visibility improvements and the predictor variables, a predicted value for visibility improvement was calculated for each state in the eastern United States.

In symbols, the use of the visibility value function in benefit estimation can be expressed as follows:

$$(4\text{-}3)\quad B^{(m)} = \sum^{j}[1 - \exp(-\gamma\Delta VS_{jm})](\alpha + \sum^{i}\beta_i X_{ij})N_j \quad , \text{ where}$$

$B^{(m)}$ is aggregate dollar benefits of scenario m over the base case;

ΔVS_{j} is change in visibility services from the m^{th} scenario over the base case in the j^{th} state as calculated using eq. (2-43) in Section 2.4;

X_{ij} is the value of the i^{th} household characteristic in the j^{th} state;

N_j is the number of households in the j^{th} state; and

the parameters γ , α and the β_i's are as given in Ta.2-20 of Section 2.4.

Regarding the values of the household characteristics (X_{ij}'s), for the following variables, samplewide means were used: respondent believed he had an excellent view (EXVIEW), female head of household (FEMHOH), equipment index (EQUIP), bad eyesight (POOREYES), rural residence (RURAL), activity index (ACT), ownership of other residential property in eastern U.S. (PROP), and ownership of occupied unit (OWN). For other variables, state-specific values were used. These are household income (INCOME), income squared (INCOME2), age of household head (HOHAGE), education of household head (HOHED), household size (HSLDSIZ), visibility endowment (VISENDOW), percent nonwhite (NONWHITE), dummies for Atlanta (A), Cincinatti (C), Miami (M), and Washington, DC (W).

In summary, the preceeding steps summarize the entire analytic framework underlying the estimates of benefits that begins with the statement of policy alternatives and ends with a dollar estimate of the benefits of these policies. While the policy scenarios examined here are illustrative, the established framework has been shown to be entirely general and capable of analyzing any set of policy alternatives that are of regulatory interest.

The following sections explain in more detail how the visibility value function is applied, and present benefits estimates for hypothetical policy scenarios for the year 1990.

4.3 BENEFITS OF HYPOTHETICAL POLICY SCENARIOS.

In this section, calculations for two states are described to explain how the visibility value function is used to derive benefits estimates. The calculations illustrate the spatial nature of regional visibility effects. Benefits for each state and for the eastern United States as a whole for the hypothetical policy scenarios are presented.

4.3.1 Measurement of Physical Effects and Willingness to Pay for Improvements

4.3.1.1 Forecast Emissions under Scenario 5 in Georgia and Ohio (Step B)

Using Argonne scenario simulations, this section illustrates the policy analysis process described in Section 4.2. For illustrative purposes we consider two eastern states, Ohio and Georgia, and trace through the effects of scenario 5 implementation in terms of the five steps previously outlined. Ta.4-3, base-case emissions in the two states are given by the row "SO_2 emissions" in kilotonnes per year. In the absence of visibility policy, ambient SO_2 emissions in Georgia would increase from 630 kilotonnes in 1980 to 873 kilotonnes in 1990 and 1026 kilotonnes in 2000.

Under scenario 3, on the other hand, Georgia's SO_2 emissions would be 554 kilotonnes in 1990 instead of 873, and 567 kilotonnes instead of 1026 in 2000. Thus scenario 3 produces a 36 percent reduction in emissions in Georgia during the 1980's and a 15 percent reduction during the 1990's compared with the base case projection. In Ohio the emissions pattern is quite different. Ohio's 1980 emissions are about four times higher than Georgia's--2748 kilotonnes vs 630 kilotonnes. However, Ohio's emissions are forecasted to decline between 1980 and 2000, even under the base-case forecast. Furthermore, policy effects in Ohio are even greater than in Georgia. In Ohio, scenario 3 produces a 58

TABLE 4-3

Policy Effects in Two States[1]

GEORGIA

	Base Case: Scenario 2			Policy Scenario 5		Policy Effects[4]			
						Amount	%	Amount	%
	1980	1990	2000	1990	2000	1990		2000	
SO_2 emissions[1]	630.0	873.0	1026.0	554.0	567.0	-319.0	-36.0	-459.0	-45.0
Ambient SO_2[2]	7.3	9.8	11.7	7.1	8.2	- 2.7	-28.0	- 3.5	-30.0
Visibility[3]	13.7	13.0	13.0	14.3	13.7	1.3	10.0	.7	5.4
Aggregate benefits (per household)[5]						365 (168)			

OHIO

	Base Case: Scenario 2			Policy Scenario 5		Policy Effects			
						Amount	%	Amount	%
	1980	1990	2000	1990	2000	1990		2000	
SO_2 emissions	2748.0	2300.0	2207.0	964.0	1056.0	-1336.0.	-58.0	-115.0	-52.0
Ambient SO_2	37.0	32.8	32.8	17.8	19.8	- 15.0	-46.0	- 13.0	-40.0
Visibility	8.7	9.3	9.3	12.4	11.8	3.1	33.0	2.4	27.0
Aggregate benefits (per household)						1516 (360)			

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1 Kilotonnes per year

2 Micrograms per cubic meter

3 Miles

4 Physical effects are drawn from simulations provided by D.M. Rote of Argonne [Rote, 1982a, 1982b]

5 Aggregate benefits in millions of dollars per year; household benefits in (dollars per year). From Ta.4-6.

percent emissions reduction during the 1980's. and a 52 percent reduction during the 1990's. The combined effect of trends and policy effects in the two states therefore, is that Ohio emissions in 1980 are over four times greater than Georgia emissions, whereas by 2000 Ohio emissions are less than twice as large as Georgia's.

4.3.2.1 Forecast Ambient Air Quality under Scenario 5 in Georgia and Ohio (Step C)

Ambient air quality is given by the row "Ambient SO_2" in micrograms per cubic meter ($\mu g/m^3$) in Ta.4-3. In 1980, ambient air quality is over five times worse in Ohio than in Georgia by the SO_2 criterion--37.0 $\mu g/m^3$ in Ohio vs 7.3 $\mu g/m^3$ in Georgia. As in the case of emissions, air quality in Ohio is projected to improve in the base case (from 37.0 $\mu g/m^3$ in 1980 to 32.8 $\mu g/m^3$ in 2000) and to deteriorate in Georgia (from 7.3 $\mu g/m^3$ in 1980 to 11.7 $\mu g/m^3$ in 2000). As for the policy effects of scenario 5 in the two states, both states experience improvements in 1990 and 2000, compared with the without-policy or base-case scenario. However, taking account of both trends and policy effects in the two states, Georgia experiences a net deterioration in ambient air quality by 2000 (from 7.3 $\mu g/m^3$ to 8.2 $\mu g/m^3$), while Ohio experiences a net improvement by 2000 (from 37.0 $\mu g/m^3$ to 19.8 $\mu g/m^3$).

4.3.1.3 Forecast Visibility Effects of Scenario 5 in Georgia and Ohio (Step D)

Visibility effects of scenario 5 are given by the row labeled "Visibility" for each state. In the absence of a visibility policy, Georgia is forecasted to experience a reduction in visibility--from 13.7 miles in 1980 to 13.0 miles in 2000. Ohio visibility improves from 8.7 to 9.3 miles over the same period in the base forecast. The effect of scenario 5 is to convert deteriorating visibility in Georgia into improved visibility in 1990 (14.3 miles vs 13.0 miles). By 2000, visibility under scenario 5 has fallen back to its 1980 level of 13.7 miles, but it is still better than it would have been in the absence of the policy--13.0 miles. The policy gains in Georgia are 1.3 miles during the 1980's and 0.7 miles in the 1990's. In Ohio, visibility would have improved even in the absence of a visibility policy--from 8.7 miles in 1980 to 9.3 miles in 1990 and 2000. But the policy effect is to produce an even greater improvement--to 12.4 miles in 1990 and 11.8 miles in 2000. The policy gains in Ohio are 3.1 miles in the 1980's and 2.4 miles in the 1990's.

4.3.1.4 Forecast Willingness to Pay for Visibility Improvements from Scenario 5 in Georgia and Ohio (Step E)

Monetary values of visibility improvements for each state are derived by substituting appropriate values for each variable into the visibility value function. The result is an estimate of the state population's maximum willingness to pay for improved visibility in a given year. For example, from Ta.2-20, Section 2.4.5, the contribution of changes in visual range to the estimate of Ohio's willingness to pay for the policy improvement is equal to 155.844 times (5.14 minus 4.57)(times 1.229)--the parameter estimate of VISENDOW times Ohio's 1990 visibility index change under scenario 5 times 8. The sum of similar calculations over all the function variables in eq. (2-43), Section 2.4.4 equals Ohio's policy benefit.

Total benefits are estimated to be about $1.5 billion in Ohio and $350 million in Georgia in 1990 under scenario 5. On a per-household basis, Ohio benefits are about $360 and Georgia benefits about $170. These values correspond to a 3.1 mile visibility-policy improvement in Ohio and a 1.3 mile visibility-policy improvement in Georgia.

Ohio derives larger policy benefits than Georgia for a variety of reasons. First, Ohio's population is larger. While household benefits in Ohio are about 1.5 times greater than in Georgia, aggregate Ohio benefits are over four times greater than aggregate Georgia benefits. Second, the policy effect is almost two miles greater in Ohio than in Georgia, largely because of the much greater emissions reduction required by Ohio. By dividing the percentage change in visibility by the percentage change in emissions, we obtain a number that measures the relationship between local benefit and local clean-up effort. This may be done using numbers in Ta.4-3 for each state in 1990 and 2000. The result is that the ratio is one fourth to one half as large in Ohio as in Georgia. One of the main reasons for this result is that local visual range is affected by distant sources of pollution as well as local sources. Hence under scenario 5, Ohio derives visibility benefits from out-of-state emissions reductions to a greater extent than Georgia.

The third reason is that Ohio citizens derive greater benefits from visibility improvements in other states than do people living in Georgia. This is because Ohio is more centrally located than Georgia with respect to regional visibility improvements. According to the visibility value function, visibility improvements in other eastern states are worth more to the citizens of Ohio than they are to the citizens of Georgia.

4.3.2 Aggregation of Physical Effects in the Eastern United States (Step C)

Ta.4-2 summarized the results of each of the alternative policies in miles of local visibility by state. Comparison of scenarios 3, 4, and 5 with the base case demonstrates the rather complex geographic distribution of local visibility improvements that results from alternative policy standards.

Effects of policy on local visibility, as recorded in Ta. 4-2, do not however describe the entire policy effect of relevance to the local area. As explained in Part 2, distant visibility conditions are part of local endowment. In other words, the entire column of improvements associated with each regulatory strategy is relevant to the measurement of benefits in each state, because they are all part of each state's visibility endowment.

Ta.4-4 gives measures of visibility sources for each state. The measure of visibility services is a weighted contribution of visibility in all states to the state in question, as obtained from eq.2-43 in Section 2.4. Ta.4-4 was derived by using projected policy improvements for all states to calculate visibility services for each state. Ta.4-5 gives an idea of the relationship between the visibility services measure and local visibility in miles for each state. States are ordered from highest to lowest on the endowment index for 1980. The corresponding visibility in miles in each state does not follow the same order. Florida, for example, has relatively high local visibility, yet ranks last on the index scale because of its geographic remoteness from the rest of the coutry. Visibility in other areas contributes relatively little to Florida's endowment. Fig.4-1 illustrates the visibility endowment index for 1980.

4.3.3 Aggregation of Scenario Benefits in the Eastern United States, 1990--Preliminary Estimates Subject to Revision

Ta.4-6 presents 1990 policy benefits for the three improvement scenarios. Total program benefits for the three illustrative scenarios in the year 1990

TABLE 4-4

Measure of Visibility Services (VS)

STATE	Base Case		Policy Scenarios, 1990		
	1980	1990	3	4	5
Alabama	4.59	4.52	4.53	4.67	4.72
Connecticut	3.72	3.70	3.75	3.90	4.06
D.C.	4.66	4.59	4.74	4.94	5.16
Delaware	3.73	3.67	3.78	3.92	4.08
Florida	3.51	3.44	3.46	3.56	3.58
Georgia	4.34	4.26	4.28	4.47	4.52
Illinois	5.52	5.52	5.56	5.73	5.81
Indiana	5.12	5.19	5.28	5.46	5.66
Kentucky	5.01	5.11	5.16	5.40	5.55
Maine	4.93	4.92	4.94	5.13	5.18
Maryland	4.71	4.63	4.80	5.00	5.24
Massachusetts	4.20	4.12	4.17	4.36	4.53
Michigan	4.94	4.94	4.98	5.12	5.26
Mississippi	4.94	4.83	4.84	4.95	4.99
New Hampshire	5.02	5.00	5.04	5.34	5.46
New Jersey	3.91	3.84	3.96	4.11	4.29
New York	4.36	4.34	4.48	4.65	4.93
North Carolina	4.53	4.44	4.56	4.66	4.80
Ohio	4.51	4.57	4.68	4.91	5.14
Pennsylvania	4.51	4.50	4.66	4.85	5.15
Rhode Island	3.70	3.64	3.68	3.84	3.98
South Carolina	4.54	4.46	4.52	4.67	4.76
Tennessee	5.11	5.11	5.14	5.37	5.49
Vermont	4.90	4.89	4.94	5.17	5.35
Virginia	4.87	4.84	4.99	5.17	5.37
West Virginia	4.69	4.69	4.82	5.01	5.25
Wisconsin	5.58	5.51	5.59	5.64	5.75

Source: Explained in text.

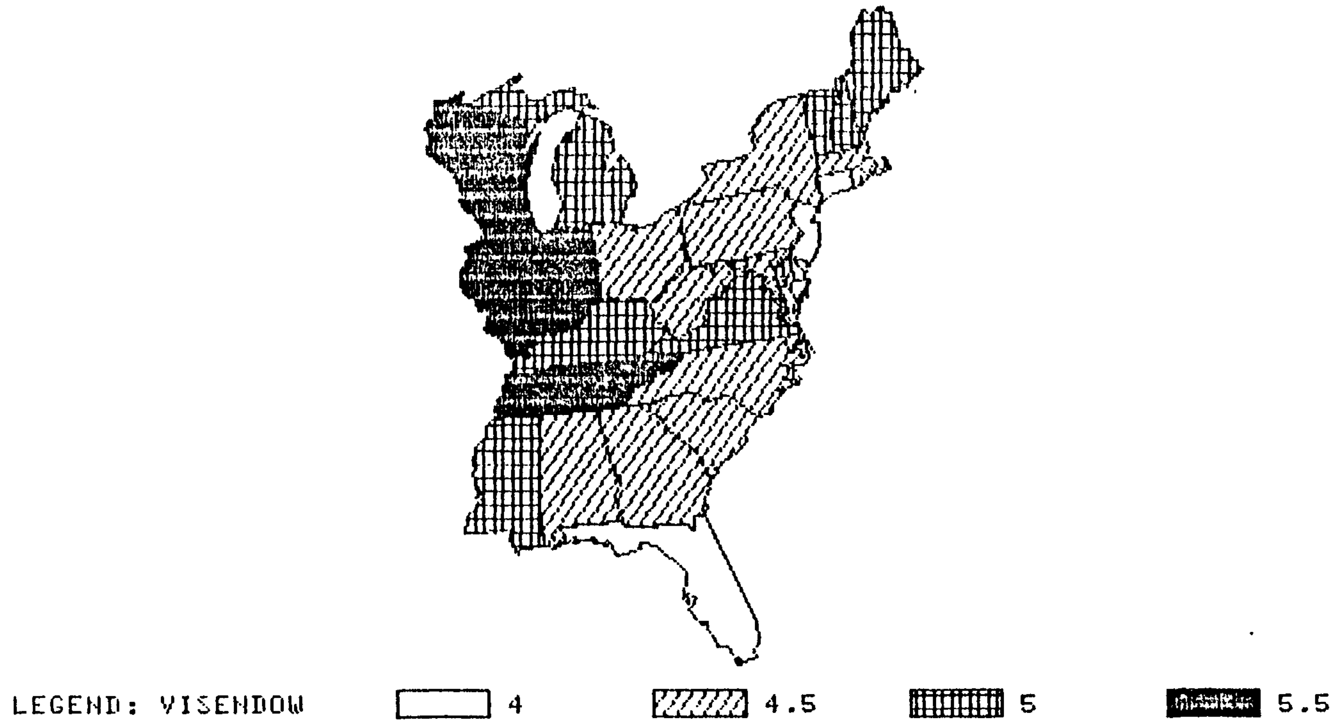
TABLE 4-5

Ranking of States by 1980 Visibility Endowment

State	Visibility Endowment Index	Visibility in Miles
Wisconsin	5.58	14.9
Illinois	5.52	13.0
Indiana	5.12	9.9
Tennessee	5.11	11.8
New Hamsphire	5.02	11.8
Kentucky	5.01	10.6
Mississippi	4.94	15.5
Michigan	4.94	13.0
Maine	4.93	13.7
Vermont	4.90	11.8
Virginia	4.87	10.6
Maryland	4.71	10.6
West Virgina	4.69	9.9
District of Columbia	4.66	10.6
Alabama	4.59	14.3
South Carolina	4.54	13.7
North Carolina	4.53	13.0
Ohio	4.51	8.7
Pennsylvania	4.51	8.7
New York	4.36	10.6
Georgia	4.34	13.7
Massachusetts	4.20	10.6
New Jersey	3.91	10.6
Delaware	3.73	10.6
Connecticut	3.72	9.9
Rhode Island	3.70	10.6
Florida	3.51	14.9

FIGURE 4-1

VISIBILITY ENDOWMENT BY STATE, 1980



VISENDOW IS THE STATES 1980 VISIBILITY INDEX NUMBER

TABLE 4-6

Annual Household Benefits and Total State Benefits
Relative to Base Case, 1990

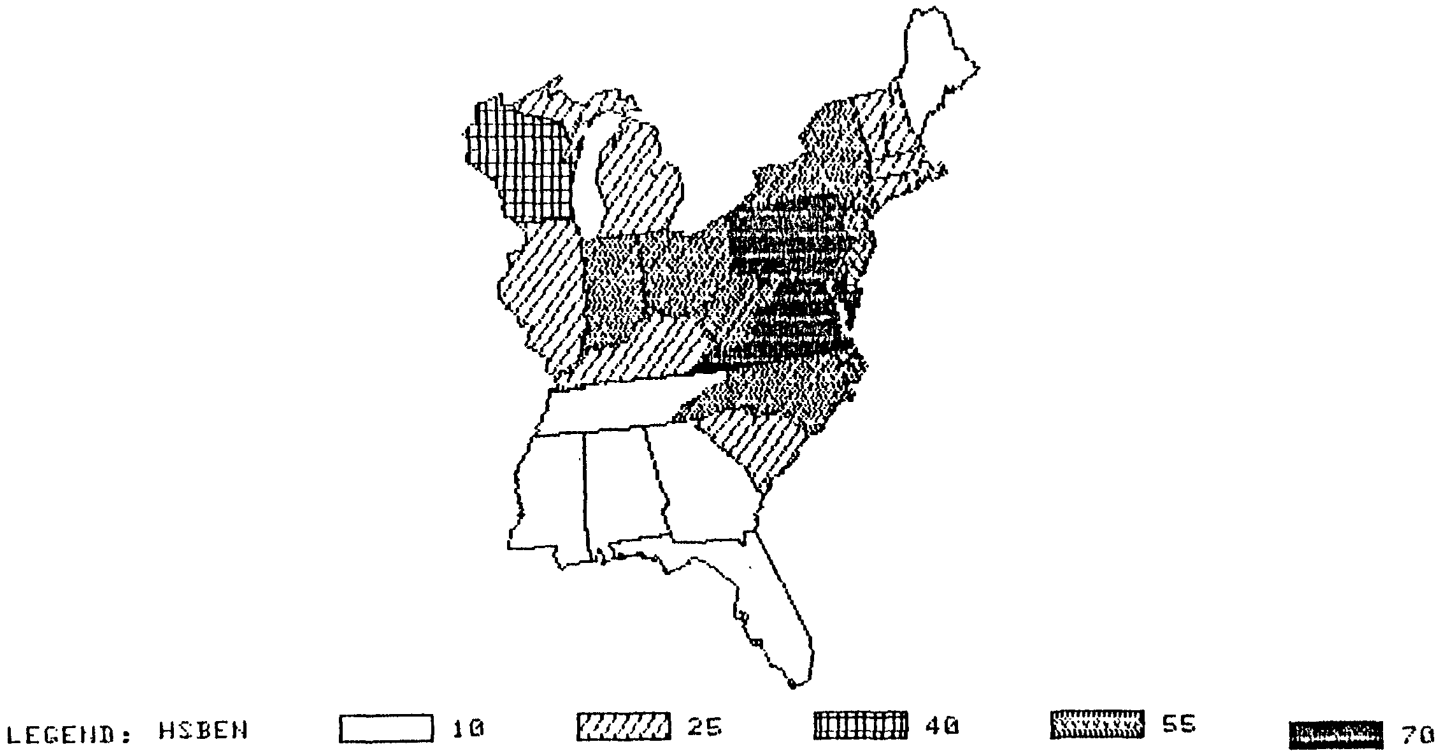
	Scenario 3		Scenario 4		Scenario 5	
	State Benefits ($ millions)	Benefits per Household ($)	State Benefits ($ millions)	Benefits per Household ($)	State Benefits ($ millions)	Benefits per Household ($)
New York	397	58	1111	162	2394	350
Pennsylvania	315	71	820	184	1725	386
Ohio	224	53	773	184	1516	360
Virginia	163	77	418	197	785	370
New Jersey	152	52	430	146	862	292
Maryland	150	84	388	216	756	421
North Carolina	111	49	244	107	492	216
Indiana	107	51	359	171	714	339
Illinois	93	21	634	145	1029	236
Wisconsin	89	48	174	93	368	198
Michigan	78	21	421	116	904	249
Massachusetts	48	21	282	124	588	260
West Virginia	39	59	109	163	219	328
Kentucky	30	22	211	157	380	282
South Carolina	30	26	126	110	217	190
Connecticut	28	22	211	157	380	282
Tennessee	24	14	244	142	427	249
Georgia	22	10	230	109	355	168
D.C.	20	70	56	192	107	371
Florida	20	4	214	48	342	77
Alabama	11	8	110	79	176	126
Delaware	11	44	30	123	61	248
New Hampshire	8	21	72	197	114	311
Mississippi	6	6	57	66	88	102
Rhode Island	6	14	33	87	72	187
Vermont	5	23	31	153	59	289
Maine	4	10	49	113	73	167
TOTAL	2,193		7,766		15,134	

range from about two billion dollars (scenario 3) to about fifteen billion dollars (scenario 5).

New York, Pennsylvania, Ohio, Illinois, Michigan, and New Jersey are the six leading beneficiaries of scenarios 4 and 5 in 1990. New York, Pennsylvania and Ohio lead in scenario 3 as well. These six states account for between 50 and 60 percent of eastern benefits under all three scenarios. New York, Pennsylvania and Ohio receive between 35 and 45 percent of eastern benefits under all three scenarios. The pattern of benefits is a little different on a per household basis. Still, it is the highly-populated and industrialized Northern states that place the highest value on improved visibility. While individual state rankings are somewhat sensitive to the specification of the endowment index and the aggregation pattern based upon contingent valuation, nevertheless the basic pattern is rather striking. Figure 4-2 illustrates the geographic distribution of benefits derived from scenario 3 relative to the base case.

FIGURE 4-2

Benefits per Household of Scenario 3
Relative to Base Case, 1990



4.4 SUMMARY OF PROJECT APPROACH TO VISIBILITY POLICY ANALYSIS

The monetary values of visibility policy benefits obtained in this chapter for alternative hypothetical policy scenarios illustrate the accomplishment of the major project objective, which was to develop a method of converting the physical effects on visual range of any proposed policy into values of benefits indicated by people's willingness to pay in the eastern United States. In this chapter we have described how policy scenarios that affect SO_2 emissions in the entire region can be translated into sets of effects on visual range in each eastern state. This phase of the work was completed by Argonne researchers, who simulated the visibility effects of several regional policy scenarios which control SO_2 emissions. The present chapter also describes how the resulting geographical changes in visual range are valued by the people of each state. This is accomplished by the visibility value function, which is the most improtant output of this study and is the expression that converts visibility changes into dollar values, based upon the personal characteristics of the resident population, and the goegraphic distribution and size of changes in visual range. Further work could include a more refined investigation of the effect of distance on valuation of visibility improvement. Additional econometric work could investigate estimations in view of truncation of the dependent variable. This work would extend the work reported on in Section 2.3. The importance of unique eastern views to willingness to pay for eastern visibility improvements could be studied in further contingent valuation survey work. These CV results would extend the analysis of the six-city survey in this report, which did not focus on existence of particular unique or spectacular scenic eastern views. The secondary-data analysis of section 3 could be refined and additional work on attaching monetary values performed. The further unique-view and secondary-data analysis could make possible a corroberation and refinement of the six-city survey results that would be more extensive than the one presently reported in Section 3.6 of this report. Further work along the lines discussed in this paragraph is being undertaken in a follow-up study now under way.

In closing, it should be emphasized that estimates of the visibility valuation function are the best we have at this time, but are subject to considerable refinement and investigation of reliability. The aggregate benefits estimates have been presented only for purposes of illustrating aggregation methodology. Care should be exercised that the results not be used out of context. The policy scenarios are for various kinds of utility controls and are not to be taken as indicating that these policies are actually being contemplated or should be enacted. A major point in illustrating the aggregation method is to emphasize there is no one unique value of increased visibility, but rather the benefits of a program affecting visibility depends on how much visibility is improved in different places, and on the numbers and characteristics of people in the places affected. It would defeat a major purpose of this study if the numbers in this chapter were applied out of context to other programs. The use of the results of this study should be to estimate differential improvements in visibility that would be brought about by a program and then to use the visibility function to obtain benefits in different areas which would then be summed. The purpose of this study has been to develop operational tools. The tools can be applied for actual policy purposes, but they have not been so applied in this study.

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EXECUTIVE SUMMARY

Visibility is a pervasive and inescapable phenomenon, subject to both general and periodic deterioration, which affects extremely large numbers of people. The relative neglect of visibility as a subject of investigation appears to be due not to its lack of importance, but rather to the fact that it is more difficult to value than many other environmental attributes.

Previous work on visibility has concentrated on sparsely populated areas of the West. The present research, concerned with visibility in the eastern United States, deals with larger numbers of people under a wider variety of circumstances. People in urban and rural areas are affected in the course of daily living, and a variety of special activities centering on recreation and related activities are sensitive to visibility conditions.

Four major objectives have been accomplished by the research. The first objective was to use the contingent valuation (CV) approach to obtain information on values attached to visibility in the eastern United States. A major conceptual effort to extend and refine the CV technique preceeded data gathering. Several different CV formats were pre-tested in Chicago, followed by a six-city eastern survey.

The second objective was to define and estimate a visibility value function. The benefits of a visibility policy depend upon the extent of visibility improvement, on initial visibility conditions and their geographic distribution, and upon social and economic characteristics of people in various regions. Benefits are related to these variables in the visibility value function.

The third major objective was to identify particular activities likely to be influenced by visibility and to measure the effects of visibility on these activities using secondary data. Activities investigated were swimming.

television viewing, baseball attendance, Hancock Tower visitation, fatal and non-fatal traffic accidents, and air traffic counts. An important result of these studies is to corroborate findings from the aggregate function based on the contingent value (CV) approach.

The fourth major objective of project research was to establish a rigorous and operational method of aggregating visibility policy benefits over the entire eastern U.S.

OBJECTIVE ONE: CONTINGENT VALUATION SURVEY

The theory of household production was used in the development and use of a contingent valuation (CV) survey questionnaire. There are seven basic modules to the CV instrument.

Module 1: Area Context Module

The area over which visibility improvements were offered had to be clearly comprehended by each individual. For the research to provide results on regional differences in air quality improvement, it was important to collect willingness-to-pay (WTP) data for improvements in visibility (i) in the individual's home sub-region, and (ii) in the whole study region. A map card and a portfolio of photographs were used to convey the size and diversity of the region over which visiblity is valued.

Module 2: Visibility Module

The nature of alternative levels of visibility was communicated via color photographs. This required a set of scenes representative of the area over which visibility changes were to be valued. For each level of visibility a set of the same scenes, with only the visibility different, was used. Some factual verbal material was used to quantify the visual range represented in each photo set. Separate photo sets were used to represent the sub-region, the entire East, and the West.

Module 3: Activity Module

To employ the household production model, it was necessary to know the following:

- the activities produced in the household,
- the inputs, other than visibility, used in activity production,
- the activity production technology used, and
- whether visual air quality is the only air quality input used and, if not, whether visual air quality is used by the subject as an indicator of other aspects of air quality. For example, the individual may avoid strenuous outdoor sports on days of poor visibility, not because visibility *per se* is an important input, but because he treats poor visual air-quality as an indicator of high pollutant concentrations which threaten respiratory stress.

The module served to sensitize the individual to the variety of activities in which he might value visibility.

Module 4: The Market Module

Contingent valuation established a hypothetical market and encouraged individuals to reveal their WTP by using that market. Major elements of this module described what was being purchased through the bid and the market rules regulating payment for and receipt of the good in question. To describe the good available for purchase, the general level of visibility as well as possible increments and decrements in visibility were portrayed in both photographs and narratives. Market rules provided assurance that the increment in visibility would be delivered if and only if the respondent was willing to pay.

Module 5: The WTP Data Collection Module

This module presented the fundamental WTP questions. Respondents bid first on local improvement, and then were asked how much they would add to their local bid to extend the improvement to the East and then to the entire U.S.

Module 6: Post-Bid Probing

With certain market rules and WTP formats, some individuals recorded a zero WTP which, in further questioning, turned out to be a protest against some aspect of the format rather than an accurate reflection of the value of the good offered. Probing of zero WTP's was an important element of the data-collection schedule.

Module 7: Socio-Demographic Data

This module collected an array of socio-demographic data, including full income concepts relevant to the processes through which individuals demand and hence value, visibility.

OBJECTIVE TWO: VISIBILITY VALUE FUNCTION

The objective of the contingent valuation research was to define and estimate a visibility value function. The theory of household production, fundamental to the development of the CV questionnaire, was equally important to the development of the visibility value function. The importance of regional or spatial economics was recognized and receives its most complete formulation in the visibility value function.

Central to the development of the visibility value function is the concept of visibility services. Visibility services are aggregates of visibility in different places, weighting each place's contribution by its distance, scenary, and quality. Accordingly, there is a production function relating visual services to these variables. Specifically the production function for visual services (VS) is

(1) $$VS_j = \sum_i VR_i^{\alpha 1} SM_i^{\alpha 2} D_{ij}^{\alpha 3} SC_i^{\alpha 4} ,$$

where VS_j is household j's consumption of VS , VR_i is visual range in state i , SM_i is the area of state i in square miles, D_{ij} is the distance between household j and the center of state i , and SC_i is a measure of scenery in state i .

It was reasoned that the marginal benefit curve, or bid curve for a change in visibility services, should have the following properties:

Property 1: $BID(0) = 0$
Property 2: $BID'(\Delta VS) \geq 0$
Property 3: $BID''(\Delta VS) \leq 0$
Property 4: $\text{Limit } BID'(\Delta VS) = 0$ as $\Delta VS \to \infty$

A functional form was required that would be consistent with Properties 1 - 4 and capable of handling both continuous and discrete explanatory variables. Furthermore a functional form was needed which allows the bid curve to pivot around the origin with changes in the vector of explanatory variables while preserving these properties. The following negative exponential function was found to fulfill their requirements:

(2) $$BID = [1 - \exp(-\gamma \Delta VS)] \quad ,$$

which is monotonic increasing, passes through the origin, and has an upper limit of +1 for all positive values of γ . This gives the prototype bid function. A rotational vector of household characteristics H , is included:

(3) $$H = (\alpha + \Sigma \beta_i Z_{ij} + u_j) \quad ,$$

so that H is a linear combination of household characteristics Z , and there is an unobserved household-specific rotational parameter u .

The empirical bid curve is given by the product of (2) and (3) or

(4) $$BID_j = [1 - \exp(-\gamma \Delta VS_j)][\alpha + \Sigma \beta_i Z_{ij} + u_j)] \quad ,$$

where VS is given by (5), below, BID_j is the willingness-to-pay of household j , ΔVS is given by changes in equation (1) due to the program; a is a common intercept term (of rotation, not level of bid); Z is the vector of household characteristics with parameters β ; and u_j is the household-specific rotation of the bid curve.

The formula used to calculate VS for the empirical analysis is

$$VS_j = \sum^{i} VR_i * SM_i * D_i^{-1.5} \quad , \tag{5}$$

where the exponent on the distance variable was estimated by a maximum likelihood method jointly with the vector of household characteristics and the parameter γ .

The estimation results for the visibility function are shown in Table 1. Overall, between one-half and two-thirds of the variation of BID is accounted for by the explanatory variables. The positive effect of a change in visibility on BID is reflected in coefficient of 0.700 for GAMMA. The common constant term ALPHA added to the individual estimated effects of household characteristics in determining rotation of the bid curve, is negative.

The first variable in H, rotating the bid curve is VISENDOW, the initial level of VS as calculated in (5) above. This variables has a positive effect and captures the net result of a pure endowment effect from diminishing marginal utility, a sorting effect and a substitution effect.

A point estimate of the income elasticity of rotation is 0.539 is computed, holding all non-income variables at their means. The first-order effect of income (INCOME) on BID is positive, and the second-order effect (INCOME SQUARED) and the income-age interaction effect (INCAGE) are negative.

TABLE 1

Non-Linear Least Squares Summary Statistics
Dependent Variable Bid

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
REGRESSION	22	130303017.02030957	5922864.41001407
RESIDUAL	3122	140479409.60049038	44996.60781566
UNCORRECTED TOTAL	3144	270782426.62079995	
(CORRECTED TOTAL)	3143	233630610.10008546	

PARAMETER (VARIABLE)	ESTIMATE
GAMMA	0.700
ALPHA	-472.606
VISENDOW	155.757
INCOME	14.797
INCOME2	-0.029
INCAGE	-0.172
HSLDSIZ	5.327
HOHED	-2.011
HOHAGE	1.586
EQUIP	4.417
EXVIEW	-67.139
BADEYES	12.065
ACT	5.175
PROP	97.183
FEMHOH	50.684
OWN	-138.736
RURAL	-41.049
NONWHITE	-78.691
A	139.928
C	-187.137
M	112.550
W	-17.078

The negative interaction term confirms the hypothesis that the marginal propensity to consume visibility decreases with age.

Turning to the human capital variables, the estimate of the education parameter (HOHED) is negative, SO that more educated persons tend to bid less, holding the other variables constant.

The age variable HOHAGE must be considered jointly with the variable INCAGE. For very low income households, age actually increases WTP for VS, but at an income of about $9,000 per year the net effect becomes negative. Nonwhites (NONWHITE) bid significantly less than whites, while females (FEMHOH) bid more than males.

Poor eyesight (BADEYES) and ownership of specialized capital equipment (EQUIP) did not have a clear effect. As expected, participation in activities (ACT) has a positive influence on bids,. reflecting the non-rivalness of visibility within the household. There is a negative influence of view quality (EXVIEW) on bids, which could be the result of diminishing marginal utility combined with a fixed factor (view).

With regard to the property ownership variables, home ownership (OWN) had a negative impact and the ownership of other residential property (PROP) had a positive effect.

In addition to the urban/rural dummy variable a set of four city-specific dummy variables were used to help account for unexplained differences between cities. Only four were used since one of the six city degrees of freedom has already been used up by the variable VISENDOW and the intercept terms uses another. The four cities with dummies are Atlanta, Cincinnati, Miami, and Washington, with variables names A, C, M, and W respectively. Boston and Mobile remain as the base.

OBJECTIVE THREE: EFFECTS OF VISIBILITY ON BEHAVIOR

To complement the contingent valuation work and the visibility value function based on it, a series of studies of the effects of visibility on particular activities was carried out. Evidence that the CV and behavioral results are consistent strengthens confidence in the results as well as the methods that have been developed to obtain them.

Swimming

The swimming model assumes a linear relationship of the form

$$P = \alpha + \beta_1 V + \sum_{i=2}^{n} \beta_i X_i \quad ,$$

where P is daily pool attendance, V is visibility, and X_i are other factors which effect attendance. Visibility was found to have a significant effect on attendance. The effect differs between years and ranges between 1.24 and 3.73 persons per tenth-of-a-mile increase in visibility. A one mile increase in visibility increases attendance from three to five percent.

Television and Baseball

Similar analyses were performed on afternoon television viewing and on Chicago Cubs baseball attendance. The effect of a one mile increase in visibility on afternoon viewing is that 0.134% of 3 million households stop watching T.V., or about 4000 households. Weekend viewing is reduced by an additional 400 households. An increase in visibility of one mile increases Cubs gate attendance by approximately 125 people. The change in consumer's surplus associated with increase in visibility is at least 2.7 cents per person in attendance, or approximately $30,000 for a typical season's attendance The benefit of a one mile visibility improvement represents somewhat less than one million dollars per year for baseball attendance in the entire U.S.

Hancock Tower Recreation

The Chicago Hancock Tower offered an opportunity to determine the effects of visibility on the demand for view services. Using visitation data, it was possible to estimate the demand for Hancock Tower view services as a function of admission price, visibility, and a set of demand shifters. A mean per person consumer surplus of $2.12 in 1981 prices was computed from the demand estimate. Assuming that similar experiences are obtainable in other areas of the region, aggregate consumer surplus would be $275 million in 1981 prices.

Contingent valuation responses were also obtained at the Tower. The results indicate no significant difference between demand-based estimates and contingent valuation bids.

View-Oriented Residences

An analysis of view-oriented submarkets of the residential housing market was undertaken. The objectives were: (1) to measure the values of views and view characteristics including visibility using a survey instrument which establishes a contingent market for each; (2) to measure the values of views and view characteristics using a hedonic-demand analysis of housing consumption for the same group surveyed and (3) compare the contingent values from the survey and the implicit values from the housing market for individuals dwelling in view-oriented residences.

The similarity of the contingent and implicit values for height (10 floors up), the high response rate on the bidding experiment and the significant coefficients in the renters' housing hedonic equation suggested that contingent value and market values are similar.

Air Traffic

To investigate the effects of visibility on air traffic, empirical estimates were made of visibility effects on take-offs and landings at three Chicago-area airports. The effects of visibility on the air traffic counts were found to be positive and highly significant in all areas. The elasticities of traffic counts with respect to miles of visibility were 0.415, and 0.392 and 0.250 at Aurora, DuPage and Meigs Field airports respectively. The other variables in the regressions, including rainfall, snow, fog, temperature, wind speed, wind direction, and day of the week were in almost all cases of expected sign and significant.

Auto Traffic

A model of the relationship between travel cost, accident rates, weather conditions, improvement in visibility, vehicle speed, and traffic congestion was developed. It was shown that the total effect of an improvement in visibility on accident rates depends crucially on the effect of improvements in visibility on vehicle speed.

The empirical estimations of the relationship between improvements in visibility, weather variables and traffic casualties show that visibility improvements lead to significant reductions in non-fatal accidents in both Cook and DuPage Counties, in the Chicago SMSA. This result is consistent with the partial effect of improvements in visibility on highway casualities. While the occurrence of rain and/or snow leads to an increase in the number of non-fatal accidents in Cook and DuPage Counties, the results also show that an improvement in visibility in the presence of snow leads to a decrease in the number of non-fatal accidents in both counties.

Results of linear probability models in analyzing traffic fatalities show that an improvement in visibility during the weekends leads to an increase in the probability of occurrence of fatal accidents in Cook and DuPage Counties. Visibility improvements in winter and spring, however, lead to decreases in the probability of occurrence of fatal accidents in both counties, although these coefficients are not very precisely estimates. An improvement in visibility in Cook Counry by one mile leads to an estimated benefit of 9.45 million dollars as a result of reduction in traffic casualties.

OBJECTIVE FOUR: EVALUATION OF POLICY EFFECTS ON VISUAL RANGE

A detailed illustration of the application of the visibility value function to analysis of policy benefits was developed. Forecasting visibility policy effects requires comparing a without-policy or base-case scenario with one or more regulatory scenarios. The visibility value function was applied to four hypothetical or illustrative policy scenarios for electric utility pollution control relative to a base--case scenario. Benefits connected with these purely illustrative scenarios were estimated for the year 1990. Specifically, aggregate and per-household benefits were estimated for each eastern state and the eastern United States.

A method was needed which relates reductions in pollution emissions from the scenarios to visibility improvements. The relation between emissions and visibility was provided by results from research at Argonne National Laboratory.

Illustration of Method

Step A in the analysis of visibility regulation was to establish policy alternatives. Alternative policies produce different patterns of visibility improvement whose effects need to be evaluated in order to make a policy choice. Three such policies were considered. In addition to the policy scenarios a without-policy or base-case scenario was formulated. The base-case scenario is a judgement as to the most likely regulatory climate in the absence of a visibility policy. It provides the standard against which the benefits of the policy scenarios are measured.

Step B was to forecast emissions under the base-case and policy scenarios by type of emittor, season and amount of pollution. These forecasts depended in part on the technical requirements of pollution abatement. To an even greater extent the emissions forecasts depended upon forecasts of future levels of economic activity.

Step C was to forecast the spatial distribution of ambient air quality. The relationship between emissions and ambient air quality depends upon the way emissions are dispersed geographically and the chemical transformations that occur during dispersion. This step was performed for each of the scenarios by means of the Argonne long range transport model. [Rote, 1982a]

Step D was to measure the effects on visibility of ambient air quality resulting from each scenario. The solution to this problem, also supplied by Argonne [Rote, 1982b] provided a set of predictions as to the course of visual air quality on a state by state basis in the future.

Step E was to use the visibility value function to establish values associated with alternative pollution control strategies. Each scenario produced a set of improvements in visual range for each state in future years. The function estimated the value of these improvements to a state as the sum of the value of the local component and value of improvements in other parts of the region due to existence and option values. Non-local improvements are less valuable to the state depending upon their distance from the state. The value of visibility improvements is the sum of all local and non-local improvements for all states in a given year. The visibility value function evaluated improvements for each state in all years for each of the four policy scenarios.

Aggregation of Illustrative Scenario Benefits in the Eastern United States, 1990

Table 2 presents 1990 policy benefits for the three illustrative improvement scenarios. Total program benefits for the three illustrative scenarios in the year 1990 range from about two billion dollars (scenario 3) to about fifteen billion dollars (scenario 5).

New York, Pennsylvania, Ohio, Illinois, Michigan, and New Jersey are the six leading beneficiaries of scenarios 4 and 5 in 1990. New York, Pennsylvania and Ohio lead in scenario 3 as well. These six states account for between 50 and 60 percent of eastern benefits under all three scenarios. New York., Pennsylvania and Ohio receive between 35 and 45 percent of eastern benefits under all three scenarios. The pattern of benefits is a little different on a per-household basis. Still, it is the highly populated and industrialized Northern states where the highest values of improved visibility occur. While individual state rankings are somewhat sensitive to the specification of the endowment index and the aggregation pattern based upon contingent valuation, nevertheless the basic pattern is rather striking.

Estimates of the visibility valuation function are the best we have at this time, but are subject to considerable refinement and investigation of reliability. The aggregate benefits estimates have been presented only for purposes of illustrating aggregation methodology. Care should be exercised that the results not be used out of context. The policy scenarios are for various kinds of utility controls and are not to be taken as indicating that these policies are actually being contemplated or should be enacted. A major point in illustrating the aggregation method is to emphasize that there is no one

TABLE 2

Annual Household Benefits and Total State Benefits
Relative to Base Case, 1990

State	Scenario 3		Scenario 4		Scenario 5	
	State Benefits ($ millions)	Benefits per Household ($)	State Benefits ($ millions)	Benefits per Household ($)	State Benefits ($ millions)	Benefits per Household ($)
NY	397	58	1111	162	2394	350
PA	315	71	820	184	1725	386
OH	224	53	773	184	1516	360
VA	163	77	418	197	785	370
NJ	152	52	430	146	862	292
MD	150	84	388	216	756	421
NC	111	49	244	107	492	216
IN	107	51	359	171	714	339
WI	89	48	174	93	368	198
MI	78	21	421	116	904	249
MA	48	21	282	124	588	260
WV	39	59	109	163	219	328
KY	30	22	211	157	380	282
SC	30	26	126	110	217	190
CT	28	22	137	109	308	244
TN	24	14	244	142	427	249
GA	22	10	230	109	355	168
DC	20	70	56	192	107	371
FL	20	4	214	48	342	77
AL	11	8	110	79	176	126
DE	11	44	30	123	61	248
NH	8	21	72	197	114	311
MS	6	6	57	66	88	102
RI	6	14	33	87	72	187
VT	5	23	31	153	59	289
ME	4	10	49	113	73	167
Total	2,193		7,766		15,134	

unique value of increased visibility, but rather the benefits of a program affecting visibility depend on how much visibility is improved in different places, and on the numbers and characteristics of people in the places affected. It would defeat a major purpose of this study if the numbers in this study were applied out of context to other programs. The use of the results of this study should be to estimate differential improvements in visibility that would be brought about by a program and then to use the visibility function to obtain benefits in different states which would then be summed. The purpose of this study has been to develop operational tools. The tools can be applied for actual policy purposes, but they have not been so applied in this study. Further work is being undertaken to extend and refine the results of this report.

APPENDIX A: SURVEY INSTRUMENT

This Appendix contains the Contingent Valuation instrument used in the Eastern survey. It contains the modules discussed in detail in the main report. The same survey was used in all six cities, within some city-specific modifications, as on page 3.

Form# A- 174
Inte

City ATLANTA

[Check One]-- Center City____
Suburban____
Rural____

Did not copy

EASTERN U.S. RESIDENTS

the University of Chicago. We are
as part of a research study about
e are talking with a scientifically
dents, the viewpoint of your house-

Ia. Are you the male/female head of household?

YES____ (Go to statement at bottom of page)

NO____ (Ask Ib.)

Ib. Is the male or female head of household at home?

YES____ (Ask to speak with head of household. Start Over.)

NO____ (Thank respondent and terminate.)

Fine. I have a few questions that I would like to ask you. It will take about 20 minutes, and your answers will kept confidential.

FORM NUMBER A-174

ACTIVITY SHEET

GROUP 1

______ Walk to Work

______ Drive to Work

______ Eat Lunch Outdoors

______ Leave Place of Work for Lunch

______ Take a Vacation Day

______ Outdoor Work Around House

______ Employed in Outdoor Job

GROUP 2

______ Jogging/Running/Bicycling

______ Swimming/Sailing

______ Tennis(outdoor)/Golf

______ Outdoor Team Sports

GROUP 3

______ Sightseeing(Rura1 or Urban)

______ Photography (Outdoor)

______ Drive in the Country

______ Flying/Gliding/Hang Gliding

GROUP 4

______ Stroll in the Park

______ Walk the Dog

______ Sunbathe

______ Go to Outdoor Fair/Concert

______ Play Catch/Frisbee

GROUP 5

______ Indoor Tennis/Racketball/ Basketball/Volleyball

______ Work Out at the Gym

______ Bowling

______ Other Stenuous Indoor Activities

GROUP 6

______ Go to Shopping Mall

______ Go to Museum

______ Go to Movies

______ Other Indoor Activities Away From Home

Group 7

______ Stay at Home

GROUP 8

______ Nature Study/Bird Watching

______ Fishing/Hunting

______ Hiking/Trail Riding

______ Camping/Backpacking

______ Attend College or Pro Ballgame

______ Sightseeing Outside Local Area

______ Visit Friends in East U.S.

______ Visit Friends in West U.S.

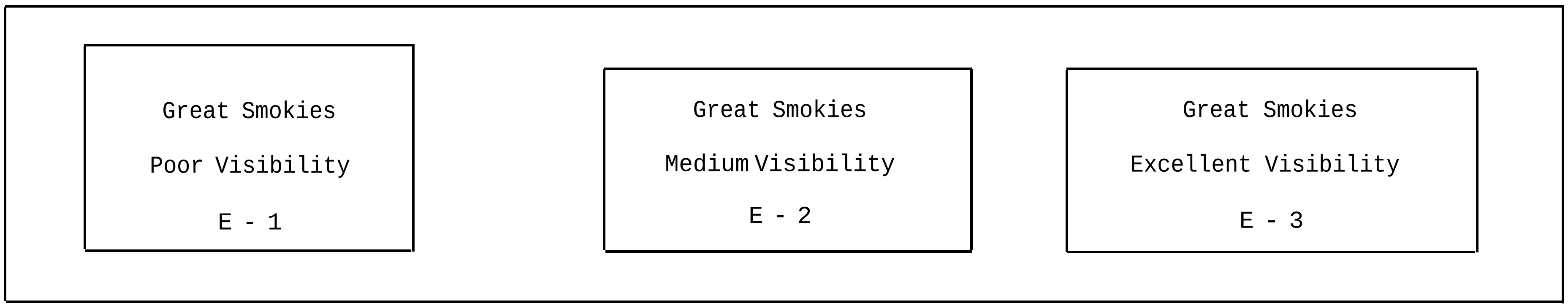
______ Visit State/National Park

______ Other Activities Away From Local Area

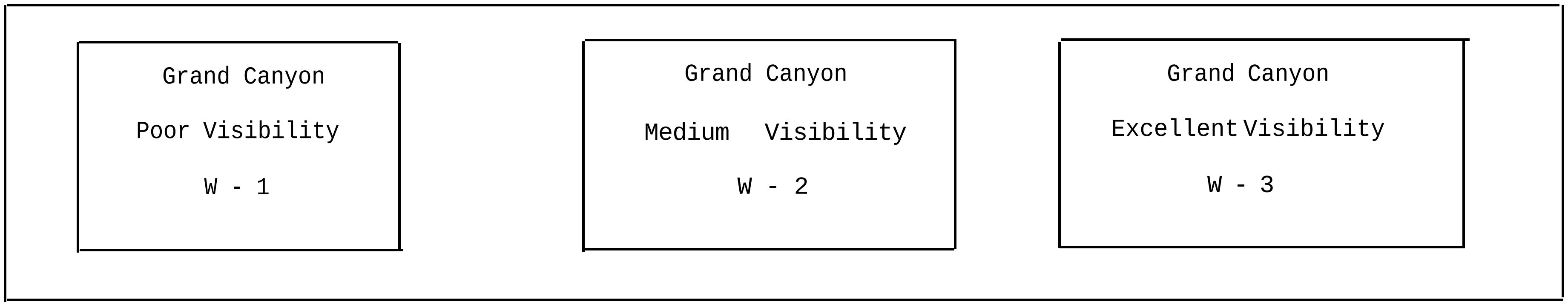
SKETCH OF
PHOTOGRAPH DISPLAY BOARD FOR
LOCAL VISIBILITY IN THE EAST

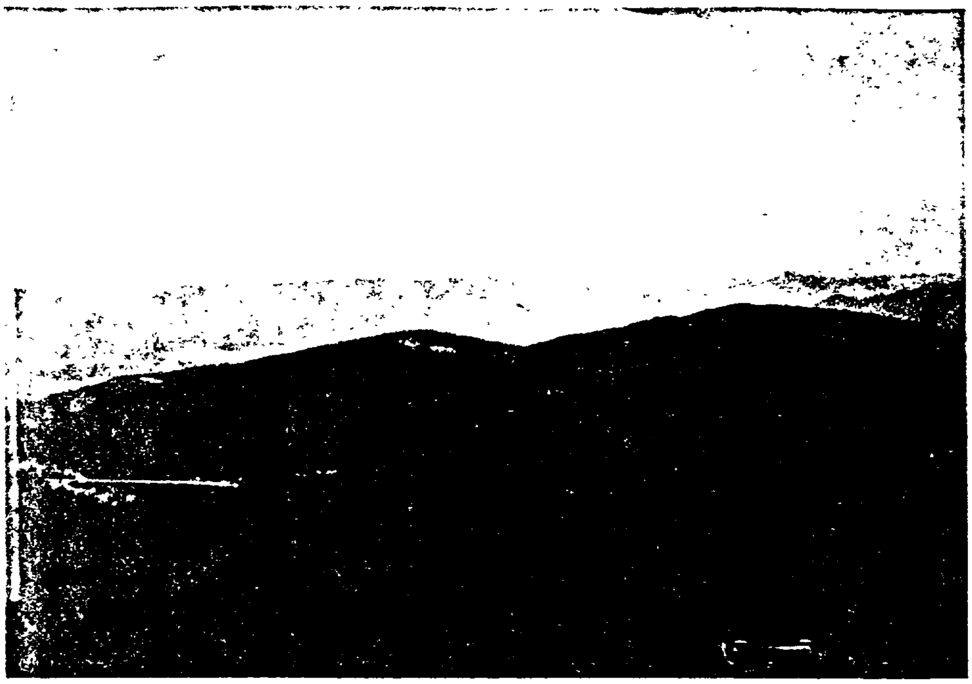
Apartments and Skyline Poor Visibility L - I - 1	Apartments and Skyline Medium Visibility L - I - 2	Apartments and Skyline Excellent Visibility L - I - 3
Outer Drive Poor Visibility L - II - 1	Outer Drive Medium Visibility L - II - 2	Outer Drive Excellent Visibility L - II - 3
Urban Shoreline from High Floor Poor Visibility L - III - 1	Urban Shoreline from High Floor Medium Visibility L - III - 1	Urban Shoreline from High Floor Excellent Visibility L - III - 3

SKETCH OF
PHOTOGRAPH DISPLAY BOARD FOR
VISIBILITY IN THE EASTERN REGION AS A WHOLE



SKETCH OF
PHOTOGRAPH DISPLAY BOARD FOR
VISIBILITY IN THE WEST

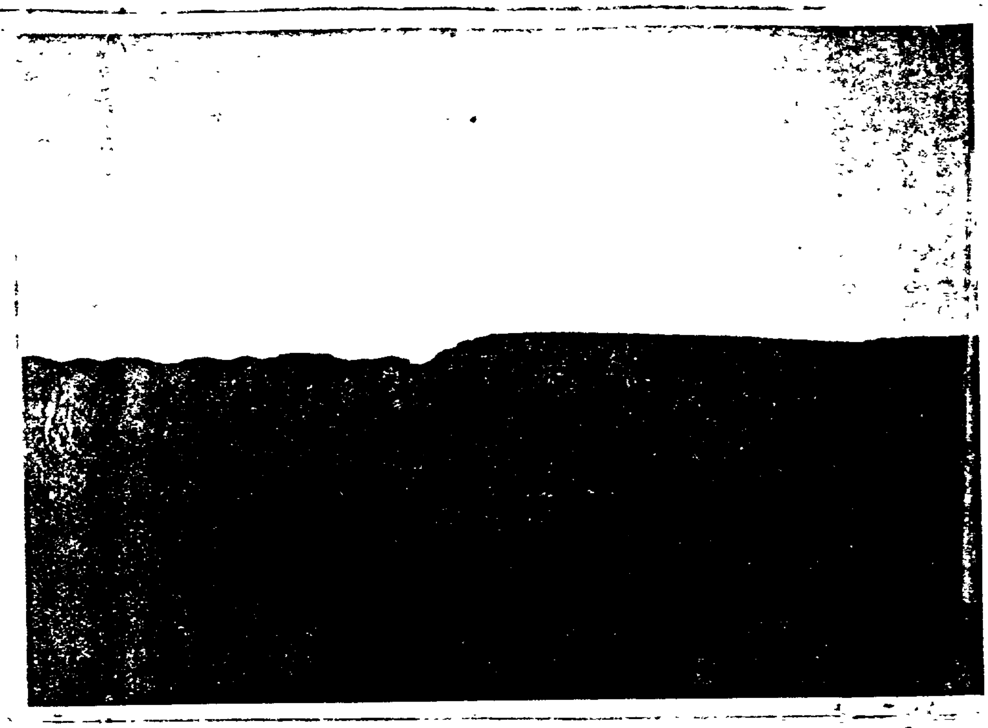




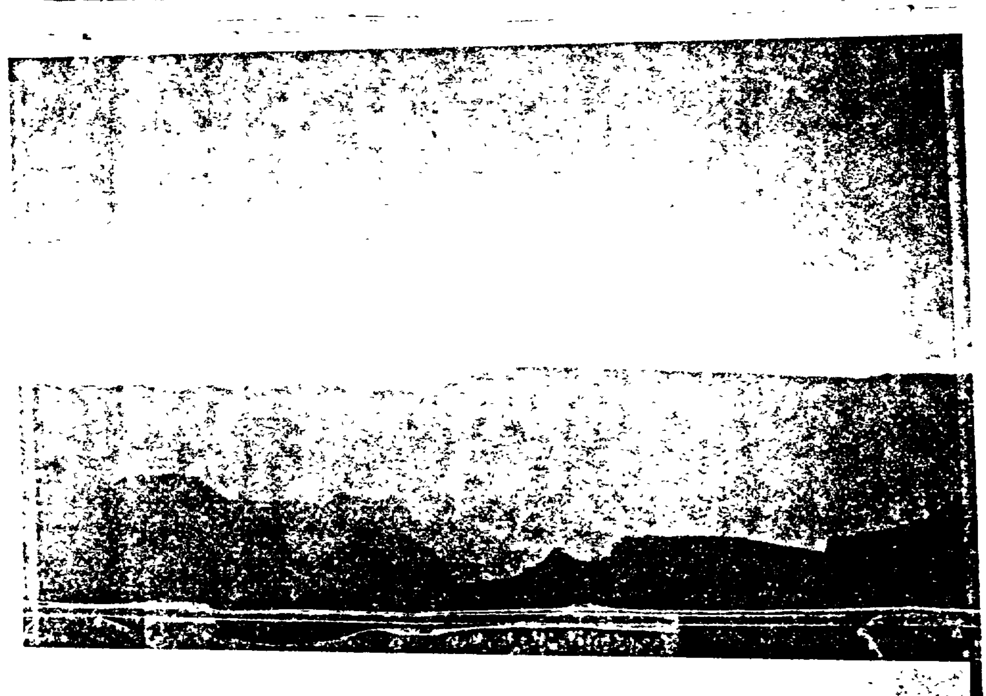
E-3

E-2

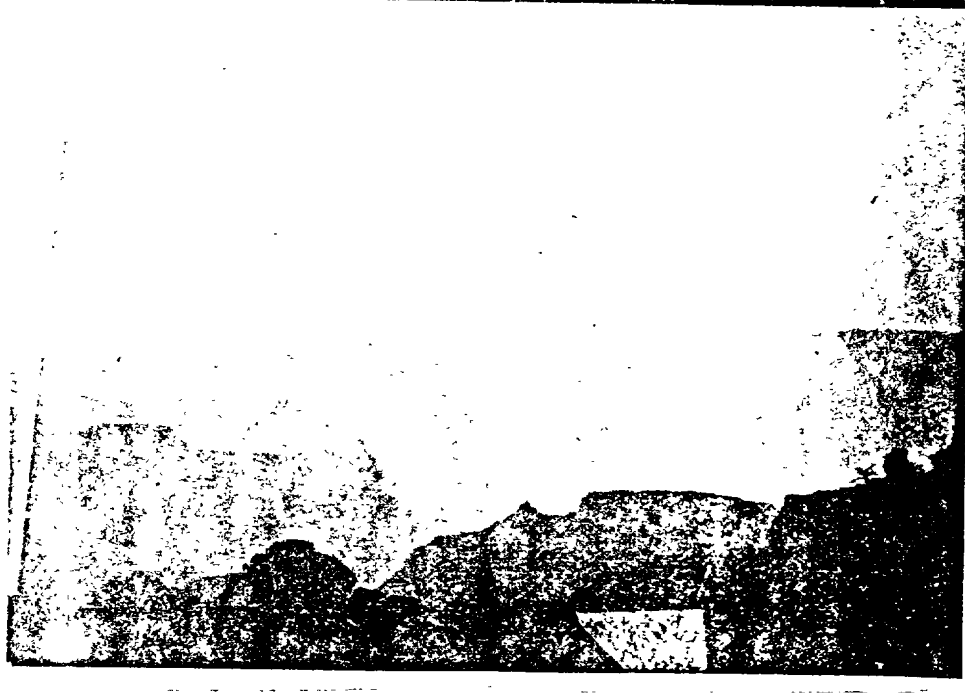
E-1



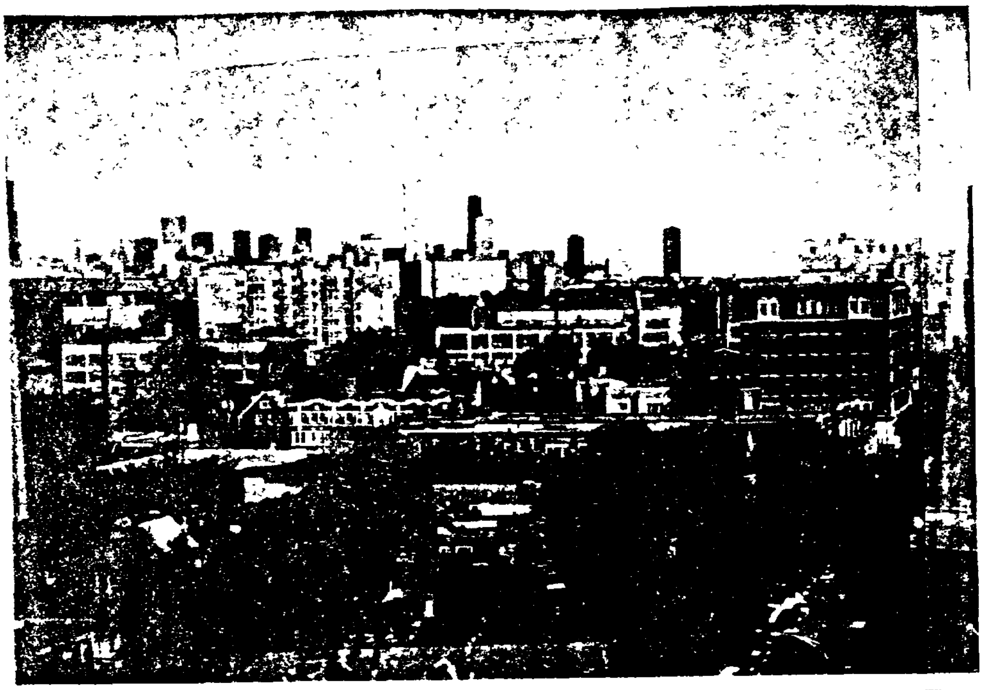
W-3



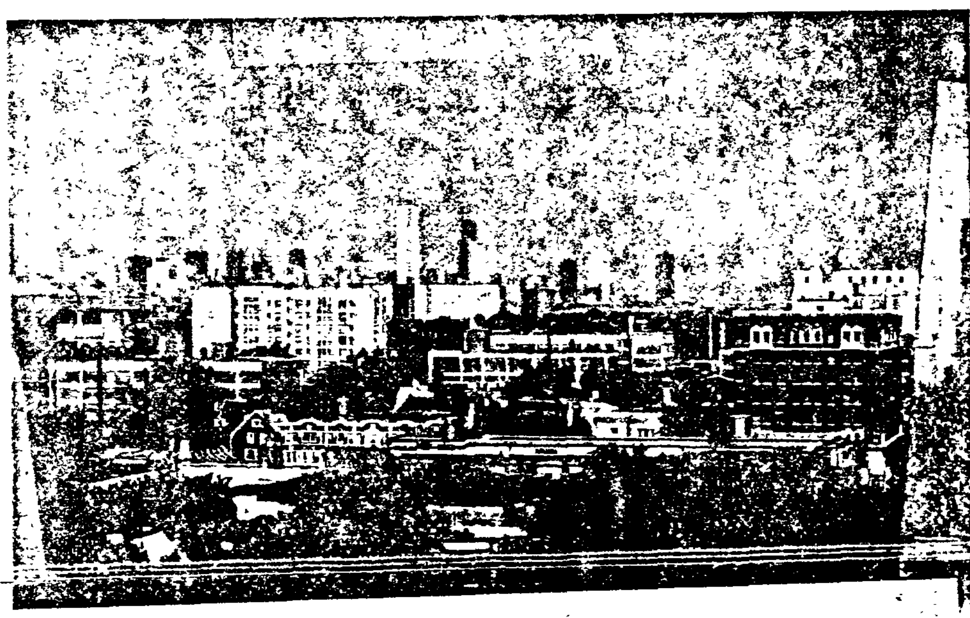
W-2



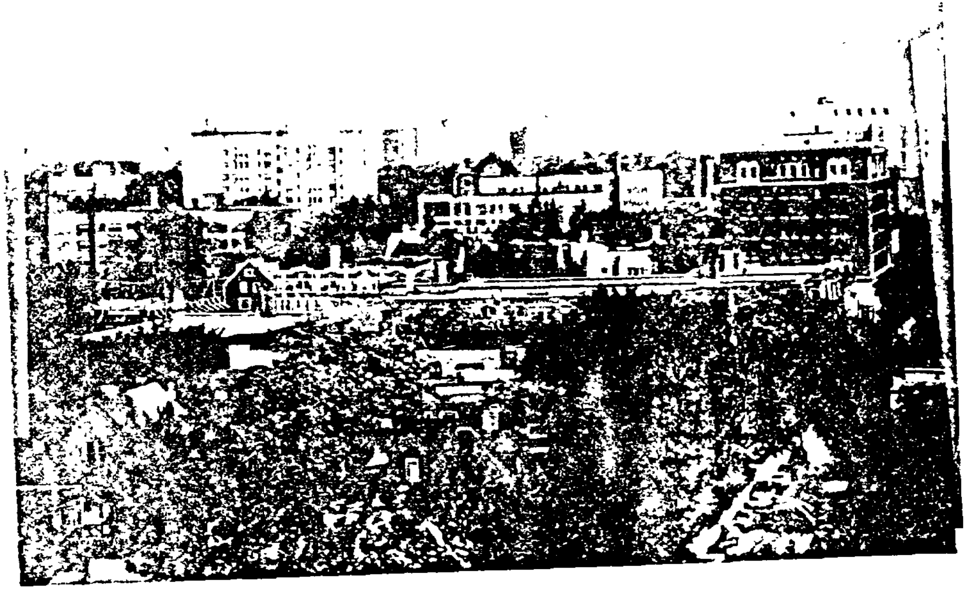
W-1



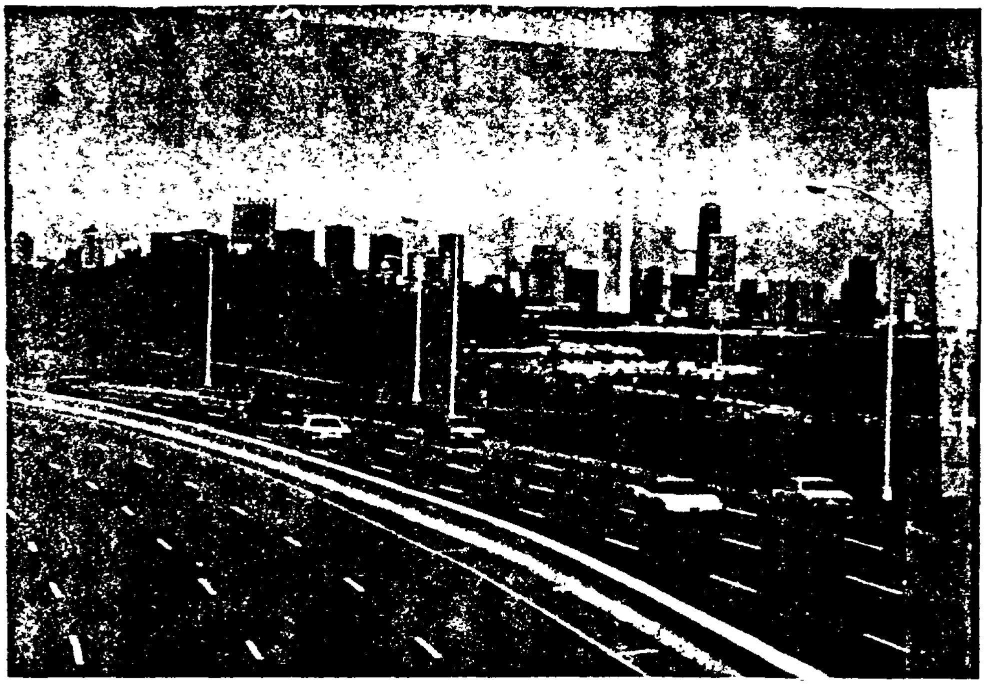
L - I - 3



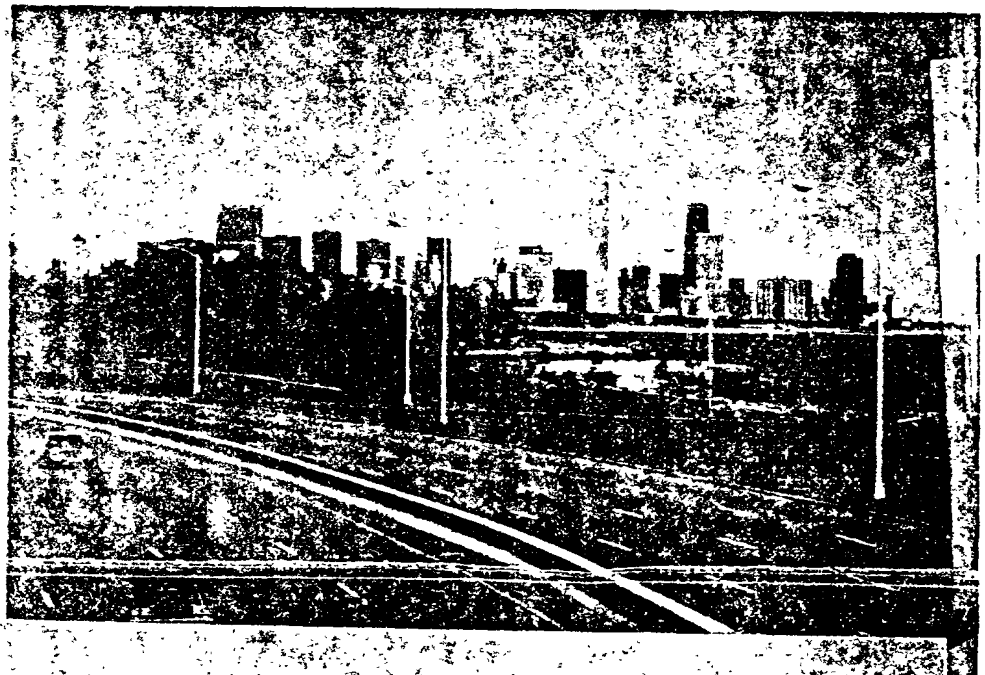
L - I - 2



L - I - 1

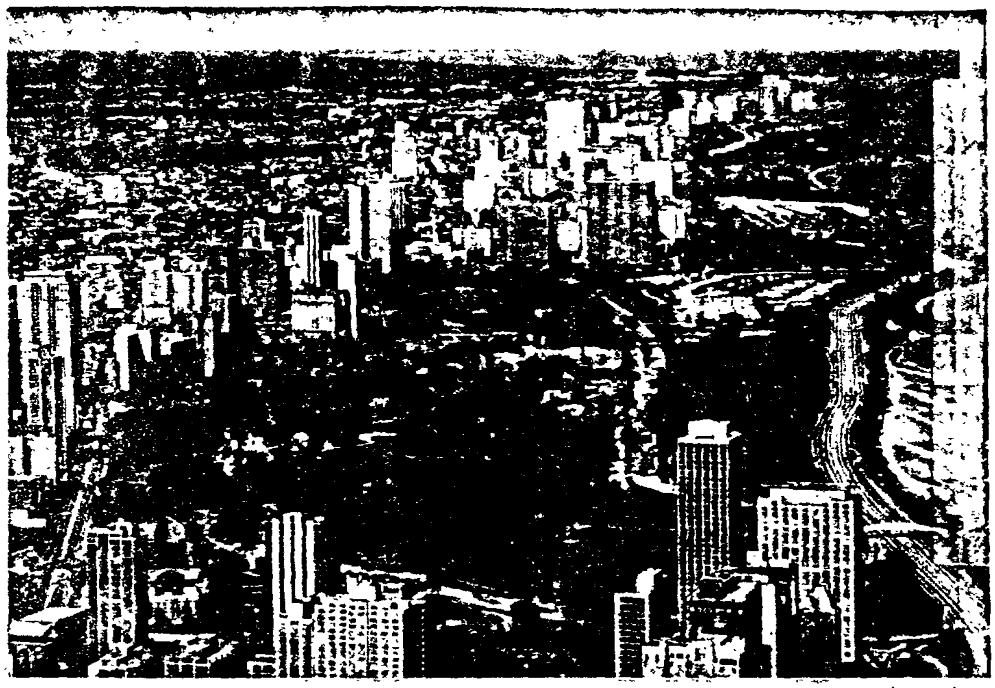


L-II-3

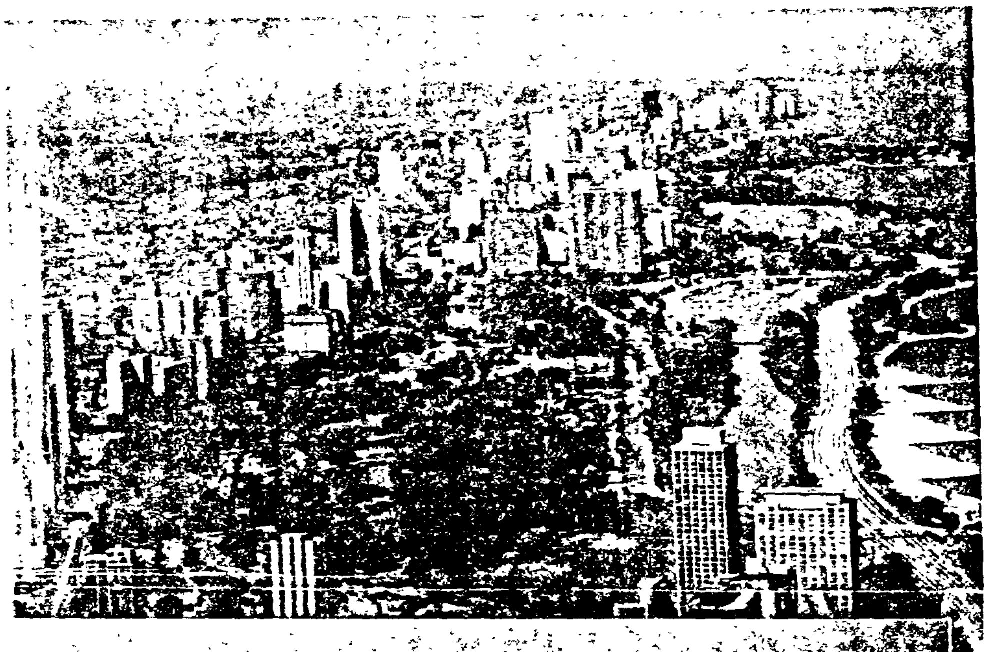


L-II-2

L-II-1



L - III - 3



L - III - V

L - III - 1

1. [Hand respondent Activity Sheet]
Please look at this sheet. It lists some of the things people do with their time. Place an X beside each activity that you do in the course of an ordinary year. If there are any other activities that you do, check the spaces marked 'other'.

[Pause, for respondent to complete Activity Sheet]

2. Do you own or have the use of the following items?
[Check For Yes]

______ Binoculars

______ A light plane, glider, hang glider, or hot air balloon

______ A birdwatcher's guide

______ A recreation vehicle, camper, or motor home

______ A guidebook for amateur astronomers

______ A camera with telephoto lens

______ Backpacking equipment

______ A vacation home or cabin

[Present photograph set]

3. Now, please look at these photographs. Each row shows the same scene, only with different visibility. [point to photos] The pictures on the left show a visibility of 4 miles. The ones in the center show 13 miles, and the ones on the right show 30 miles, Notice that when visibility increases you can see farther, and the things you do see become sharper and more distinct. [PAUSE]

a) [Present card A] This card shows the relationship between the photos and visibility. If you had to guess how many miles would you think you could see on a typical Atlanta day? It doesn't have to be one of these photos, they are just there to help you.

Enter Guess (In Miles) ______

Records show that typical visibility in the Atlanta area is actually about 10 miles.

Please look again at the activity sheet.

b) Are there any activities which you would do on a day with 30 miles visibility, which you wouldn't do with 13 miles? Which ones?

---

c) Are there any activities which you would do on a day with 13 miles which you wouldn't do with 4 miles? Which ones?

In the following questions, we would like you to answer for your entire household, that is, any one who contributes to, or is supported by, household income. To understand your answers, we need to know how many people are in your household. How many are there?

Enter # in household ___________

4. Let us return to the photographs.

Visibility is affected by both natural and man-made causes. In particular, there are a number of man-made things in the air which do not affect health but do affect visibility. We can do something to affect these things, but this costs all of us money, since it makes the things we buy more expensive. The following questions are designed to help us find out how much visibility is worth to you.

[Present Expenditure Card, and then read slowly]

I'd like you to look at this card. It shows how much a typical household with the indicated income spends each month for various things. Included are expenses for ordinary goods, like groceries and housing. Also, it shows how much is paid, through taxes and higher prices, for various public programs. Some of these expenses are quite small, like for toothpaste and the space program, while others are quite large, like for housing and national defense.

[Pause, to allow respondent to examine card.]

You may look at this card if you wish to help answer the next few questions.

[Present Card B]

4a.. Typical visibility in the Atlanta area is 10 miles. Consider what would happen if typical visibility in Atlanta fell to 5 miles. A program could be set up to prevent the decline. If the total cost of the program to you/[your household] was $13 a month, would you accept the program or reject it?

Accept_____

Reject_____ [Check One]

Now, assume the program would cost $ ___*___/month. Would you accept the program or reject it?

* [Follow Bidding Instructions. If respondent bids zero, ask QUESTION 4b. Otherwise, enter BID4 and go on to question 5)

[Enter maximum amount ACCEPTED.]

$__________/month [BID4]

****

4b. ONLY THOSE WHOSE FINAL RESPONSE WAS $ZERO FOR QUESTION 4a. [Present Card C]

Did you reject the program which would spend your money to maintain visibility because:
[Check Only One]

_____Visibility is not worth anything to you (or, it wouldn't matter even if visibility declined to 5 miles).

__*__You would appreciate [or value] improved visibility, but you think someone else should be made to pay for it.

__*__ Some other reason: ______________________

____

* [If respondent says someone else should pay, then say:]

Later, you will get a chance to say who should pay. For now, we are interested in finding out how much it is worth to you. Let's say that you <u>could</u> buy visibility, and there was no one else to pay or enjoy the benefits. Then, would you be willing to Pay something?

YES_____ (Go back to 4a.) NO_____ [Go on to Q 5.]

[Present Card D]

5. Now let's go back to the our starting point, where typical visibility is 10 miles. A program could be set up to improve it to 20 miles. Suppose the <u>total</u> cost of the program to you would be $13 a month. Would you accept the program, or reject it? (Point out change on Card D)

Accept______

Reject______

[Check One]

What if it cost $____*____/month. Would you accept the program or reject it and stay at 10 miles?

*(Bidding as for Q.4)

$__________/month [BID5: Remember this amount]

Present Card E]

For the next question:

If BID5 is GREATER THAN ZERO, say the words in (). If BID5 was ZERO, say the words in < >.

6. Now, what if the program improved visibility all the way to 30 miles?

Would you accept the 32 mile program if it cost

($10 more, for a total of $ [BID5 + 10] per month?)

[OR]

<$13 a month?>

Accept ______

Reject ______

[Check One]

What if it cost $ ____*____ /month (more, for a total of $ (BID5 + *1 ?) Would you accept the program or reject it?

*(Bidding as for Q.4)

Enter both BID5, the additional amount bid for Q.6, and BID6, in the three answer blanks provided.

ENTER: $ ________ + $ ________ MORE = $ __________ /month

(BID5) (BID6)

[Present Card F and Eastern U.S. Photo Set]

7. Now let's consider a program which would improve visibility in Atlanta by ten miles, AND ALSO improve visibility in the rest of the Eastern section of the United States by ten miles. The shaded area on this map shows the area to be covered by this program. [BE SURE RESPONDENT UNDERSTANDS THAT THE ATLANTA AREA IS INCLUDED!]

(Before, you accepted a ten mile improvement in Atlanta alone when it cost $[BID5]/month.)

If this program cost you/your household

($10 a month more, for a total of $ [BID5 + 10])

<$13 a month>

would you accept the program or reject it?

Accept ______

Reject ______

[Check One]

What if it cost $ ____*____/month (more, for a total of $ [BID5 + *] ?) Would you accept the program or reject it?

*[Bidding as for Q.6]

FILL IN ALL BLANKS:

ENTER: $ ________ (BID5) + $ ________ MORE = $ ________ (BID7) /month

[Present Card G]

8. One last program. [Show WEST picture set] This row of photos shows a scene from the western United States.

Now, consider a program which would improve typical visibility by ten miles over the entire country, [Show Map] Visibility in Atlanta would go to 20 miles, and all other places in the country would get similar improvements. If the program cost your household

(an additional $10, for a total of $ (BID7 + 10))

[OR]

<$13 a month>

would you accept the program or reject it?

Accept ______

Reject ______

[Check One]

What if it cost $____*____/month (more, for a total of $ [BID7 + *] ?) Would you accept the program or reject it?

*[Bidding as for Q.6]

FILL IN ALL BLANKS:

ENTER: $________ (BID7) + $________ MORE = $________ (BID8) /month

10a. Who should pay the costs of pollution control? [You may check more than one]

Ordinary Citizens ______
The Polluters ______
The Government ______

[Present Card H]

10b. For some years now, government and industry have been spending money to control pollution and improve the environment. Which of the following three statements best expresses your views about this?

[Check One]

Current levels of spending will eventually balance environmental quality and economic goals. ______

It is time to cut back on spending for environmental purposes. ______

We need to spend more, to achieve the kind of environment we want. ______

Now, a few more questions.

11. Do you own or rent the residence you live in? [Check One]

______Own (go to 12a)
______Rent (go to 12c)
______Other (go to 12d)

12a. OWN: If, for some reason, you wanted to rent out your residence, how much rent would you expect to receive? (or: what would a residence like this bring on the rental market?)

$__________/month

b.[IF DOES NOT KNOW] Perhaps it might be easier to think about the sale price. If you needed to sell your residence within 2 months and the buyer would have to arrange his/her own financing, how much do you think it would sell for?

$__________(sale price)

c.RENT: How much do you pay per month to rent this (house,apartment)?

$__________/month

d.OTHER: If you had to rent a house or an apartment like this on the rental market, how much do you think you'd have to pay?

$__________/month

13a Do you have any definite plans to move your residence in the next five years?

Yes _____
No _____

b [If a:Yes] when you move, do you expect to settle west of the Mississippi River?

Yes_____ No______ Don't know_____

c. Do you expect to retire somewhere near Atlanta?

Yes _____ No_____ (go to d)
Currently retired _____ Don't know_____

d. [If c:No] Then, do you expect to retire:
(Check One)

Somewhere east of the Mississippi River_____
Somewhere west of the Mississippi River_____
Other_____

14a Do you own any residential property(houses, apartments), other than the place you are living in?

No_____
Yes____ [Continue]

b. Is this property located:

In or near Atlanta _____
Elsewhere in the eastern U.S. _____
Other _____

(Check All That Apply)

c. How much do you receive in monthly rents from residential property:

In or near Atlanta? $__________/month
Elsewhere in the eastern U.S.? $__________/month

15. [Show Card I] Please choose the best description of the view you have from your residence, and give me the number.

Number from card. _______

SOCIODEMOGRAPHIC DATA

So that we can analyze the responses we get from different people, we need to ask you a few questions about your household. Your answers will be completely confidential.

16. Of the people who usually live in your household, how many are children, 18 years or younger?

____

17a. For those who are not children, please fill in the table.
[The following notes are for the interviewer's guidance]

#: Each person is assigned a #, 1,2,3, etc.. The head of the household is always #1. Circle the # which represents the Respondent.
Relationship to Head: Indicate the customary family relationships (spouse, son, grandmother, etc.). For non-family relationships, just write "friend".

Education: What is the highest grade or year in school completed?

NONE....................0
ELEMENTARY.............1 2 3 4 5 6 7 8
HIGH SCHOOL............9 10 11 12
COLLEGE................13 14 15 16
SOME GRADUATE SCHOOL...17 18
GRADUATE OR
PROFESSIONAL DEGREE....20

SCHOOL: Is ...currently attending a School, College or University FULL TIME?
WORK: Does ...usually work [or seek employment] outside the household?
IF NO, go to next person.
IF YES, continue.
MONTHS: How many months did ...work in 1981?
HOURS: How many hours/week did ...usually work in 1981?
WAGE: [record either HOURLY, WEEKLY, OR MONTHLY WAGE]

17b. Do you have any of the following?
[Check those that apply]

_____Poor eyesight
_____Allergies (e.g., hay fever, asthma)
_____Any chronic respiratory ailment [e.g. T.B., emphysema, etc.)

PERSON	1. HEAD OF HOUSE-HOLD	2.	3.	4.	5.	6.	7.
AGE							
RELATION TO HEAD	X X X X X X X X X						
SEX (M/F)							
EDUCATION							
IN SCHOOL (YES/NO)							
WORK 1981 (YES/NO)							
MONTHS WORKED 1981							
HOURS WORKED PER WEEK 1981							
HOURLY WAGE [OR]							
WEEKLY WAGE [OR]							
MONTHLY WAGE							

18. [Race/ethnic group, of respondent. Interviewer Check One].

Asian_______
Black_______
Hispanic____
White_______
Other_______

19. In your household, do you: [Check One]

a. _____ share or pool your incomes, as a family or couple might do.
b. _____ live alone, or keep your personal incomes separate, as friends sharing a house/apartment might do.

20.[Present Card J] Please look at this card. Tell me which letter best describes your [household if 19a; or personal if 19b] income before taxes in 1981. Include income from all sources, including work, investments, business profits, interest on savings, pensions social security, support from relatives, and any other benefits.

_____ [Letter]
_____ [Refused, or didn't know and refused to guess].

21. Was your personal income in 1981 [Check One]

about the same as other recent years? _____

much higher than in other recent years? _____

much lower than in other recent years? _____

22. Would you expect your income, corrected for inflation [Or your purchasing power, Or your standard of living] in five years' time to be:

about the same as in 1981? _____

much higher than in 1981? _____

much lower than in 1981? _____

23. [Does your household if 19a; Do you if 19b]
[Check One]

manage to save or invest a little? _____

just get by on current income? _____

have to dip into savings or investments just to make ends meet? _____

24. If you wanted to work a few more [or "a few" for non-income earners] hours a week,

Do you think you could find work? Yes____ No____

[If Yes] How much do you think you'd be paid? $_____/HOUR

[Present Card K]

25. NET WORTH means the value of things you own (personal property, automobiles, equity in a residence, investments, savings etc.) MINUS the total amount you owe to others (loans, mortgages, balance owing on credit cards and installment purchases, etc). Please look at the card and tell me which letter best describes your [household's if 19a; personal if 19b] net worth at the end of 1981.

_____[Letter]
_____[Refused, or didn't know and refused to guess].

26. May I please have your name and phone number in case my supervisor wishes to check that I completed this interview.

____

Thank you very much. You have been very helpful.

INTERVIEWER EVALUATION

Record any comments which might help us understand the answers given by the respondent, especially those who protest during the bidding questions.

APPENDIX B: SAMPLING RATIONALE AND PROCEDURES

To obtain contingent valuation responses, 792 households in the Eastern United States were questioned about the value of preserving or improving visibility in the United States. This survey represented the opinions of about 100 million people living in the Eastern U.S. It provided the basic information for a monetary estimate of the value that people in the Eastern U.S. would place on alternative degrees of visibility improvement in their area. Indirectly it provided some clues about how much people in the West might value improved visibility in the Eastern U.S.

In order to enable the 792 households to give us the information we sought from them, it was essential that they be made representative of the population from which they were drawn. Stratified-cluster random sampling was used. There are several reasons for this approach. First of all there is a great deal of diversity in annual average visibility in the area. (See Map A.) Also, there is substantial social diversity among the eastern regions, and they may differ from one another in important ways in their valuation of visibility. Economic theory thells us that geographic and socio-economic differences are important and should be included in the analysis. To make it highly likely that a simple random sample would cover those categories would require a much larger sample than is feasible within the project budget.

The creation of sampling sub-regions was desirable for policy purposes. Pollution control is the means by which visibility can be altered in any region by human choice. However, pollution levels differ substantially from one region to the next. Consequently, any change in ambient air quality standards will affect visibility in different regions differently. Regions that already meet the standard will experience no change in visibility; regions the farthest from compliance will experience the greatest visibility improvement. A sample design that does not permit the analysis of separate regions would not answer the requirements of policy analysis.

To implement the sampling plan, six city areas in the Eastern U.S., in addition to Chicago, were chosen to represent each level of average annual visibility in geographically dispersed areas of the Eastern U.S. The cities were Atlanta, Boston, Cincinnati, Miami, Mobile, and Washington, D.C. Selection of city and rural areas outside the cities created sub-populations within the Eastern U.S. The second major aspect of the sampling plan was to apply random sampling within each urban and rural area. The urban sample in each city area was drawn using 1970 census tract maps and census statistical tables. First, all of the n census tracts in the urban portion of the metropolitan area were assigned numbers one through n . Then twenty numbers between one and n were drawn from a table of random numbers and matched with the corresponding census tracts. Eight interviews were to be taken within each tract, in the order drawn, until 120 interviews were obtained. (The extra tracts were drawn in case eight interviews could not be obtained in some of the tracts. However, the sampling order of the random draw had to be followed; no interviewer discretion was allowed in tract choice.)

Random selection of household <u>within</u> each tract was achieved in a similar way. Every block within each selected tract was assigned a number between one and m , which was matched with the corresponding block number assigned by <u>Block Housing Statistics</u>. A random number between one and m was chosen to determine the block where interviewing started. Additional blocks were determined by the going to the next higher numbered block, using the block numbers given in <u>Block Housing Statistics</u> (returning to the lowest numbered block if necessary).

The interviewer's starting point <u>on each block</u> and the direction to proceed around the block were uniformally specified in advance for all interviewers. The procedure continued until eight interviews were obtained within a tract.

Interviews were conducted in two rural areas outside the metropolitan areas of each city. Maps, interviewing routes and procedures for each area were worked out between the field supervisors and the survey coordinator at the University of Chicago.

Xerox copies of census tract maps and lists of tract orders were provided to all interviewers, with starting blocks clearly indicated. Field supervisors in each city worked closely with interviewers, and monitored their work. The field supervisors all attended a training meeting in Chicago before field work began, and remained in close contact with the U of C survey coordinator during the entire survey period.

Of the 792 households from which questionnaires were obtained, results from 538 were used in the regression analysis for the visibility value function. As indicated in Section 2.4, the major reason for not being able to use all the questionnaires was the refusal of some households to give income and wealth information. Some questionnaires were not used because respondents bid zero for reasons other than how much visibility was worth to them (for example, they said the pollutant rather than the respondent should be expected to pay) or in a few cases unreasonably high bids were given.

This folio explains the visual material used in the contingent valuation survey under USEPA Cooperative Agreement #807768-01-0. The folio contains exact copies of the photographs used. Identification is given on the back of each photograph. The sketches of the Photograph Display Board indicate how the photographs were set up and shown to respondents.

APPENDIX C: BACKGROUND PAPERS

ESTABLISHING AND VALUING THE EFFECTS OF IMPROVED VISIBILITY IN EASTERN UNITED STATES

by

George Tolley
Alan Randall
Glenn Blomquist
Robert Fabian
Gideon Fishelson
Alan Frankel
John Hoehn
Ronald Krumm
Ed Mensah
Terry Smith

The University of Chicago

USEPA Grant #807768-01-0

PROJECT OFFICER: Dr. Alan Carlin
Office of Health and Ecological Effects
Office of Research and Development
U.S. Environmental Protection Agency
Washington, D.C. 20460

March 1984

Not for quotation. Empirical results subject to change.

APPENDIX C: BACKGROUND PAPERS

Contents

Introduction to Appendix C

This appendix contains papers which represent the conceptual development during the research effort. Numerous contributions to current economic theory and empirical practice are found in these papers. They represent an exploration of the fundamental issues involved in the visibility project and were necessary in attaining the focus achieved in the final product.

A-1 THEORETICAL APPROACH TO VALUING VISIBILITY

General Framework:

Atmospheric visibility is most effectively conceptualized as a matrix of services provided by atmospheric resources. In order to place the value of atmospheric visibility in perspective, consider the following conceptual model for valuation of atmospheric resources in a benefit-cost context.

In accordance with the potential Pareto-improvement criterion (the generally accepted criterion for benefit-cost analysis--see, for example, Mishan, 1976), an existing environmental resource is valued at the seller's reservation price for a capital good. The capital value of a given environmental resource, for example, "atmospheric resources" (A) which produce a stream of visibility services, is the net present value to the seller of the stream of services in each time period, S_t, where t = 0, 1, 2, ..., ∞, and the present time period is defined at t = 0. Thus,

(1) $$\text{P.V. (A)} = \sum_{t=0}^{\infty} \frac{V(S_t)}{(1+r)^t}$$

where $V(S_t)$ = the net value, at time t, of the bundle of services produced by A resources in time t, and r = the discount rate.

The bundle of services, S_t, provided by A resources is a vector of n types of atmospheric services, s_{it}, where i = 1, ... , n, including those services associated with visibility. Thus,

(2) $$V(S_t) = \sum_{i=1}^{n} V_{it}(s_{it})$$

Now, let us consider, first, the production of atmospheric services, and, then, the value of those services. The supply of an atmospheric service, s_i (i,. ..,n), in any time period is a function, uniquely determined by geological, hydrological and ecological relationships, of the attributes, a_k (k = 1,...,m), of the atmospheric resources. Thus, for all services in i = 1,...,n, we have

(3)
$$\begin{aligned} s_1 &= g_1(a_1,\ldots,a_m) \\ &\vdots \\ s_n &= g_n(a_1,\ldots,a_m) \end{aligned}$$

Man enters the production system as a modifier of atmospheric resource attributes. He may do this directly, e.g., by generating residuals and permitting their release as pollutants into the atmosphere. He may also modify atmospheric resources as a side effect (expected or unexpected) of some other decision pertaining to, e.g., the management of solid wastes or water pollutants, or of those resources which influence the capacity of the atmosphere to absorb wastes. For each kind of atmospheric resource attribute in k = 1,...,m, we have

(4)
$$\begin{aligned} a_1 &= h_1(n^s,x^u) \\ &\vdots \\ a_m &= h_m(n^s,x^u) \end{aligned}$$

where n^s = a vector of "natural systems inputs", i.e., the inputs which would determine atmospheric quality in the absence of man's technology, and

x^u = a vector of inputs controlled by man, e.g., anthropogenic pollutants, and any efforts on the part of man to improve the quality of atmospheric resources.

Both n^s and x^u are subject to scarcity; and the attribute production functions are determined by the laws which govern natural systems and by man's technology. The production system is now complete. It is entirely possible that the levels of production of some kinds of services, s_i, influence the level of some attributes, a_k, by a feedback mechanism wherein s_i alters the level of some man-controlled inputs in x^u. For example, the attempt to enjoy high levels of waste assimilation services involves high level of pollution inputs, which may directly or indirectly modify environment attributes.

Now, consider the value of atmospheric services. Each individual, j, enjoys utility in each time period, t:

(5) $$U_{jt} = f_j(s^g_t, z^y_t, y^z_t)$$

where s^g = a vector of atmospheric services, which are directly enjoyed for their amenity value, including those which contribute to directly enjoyed atmospheric visibility,

z^y = a vector of goods and services for which atmospheric services are inputs, such as outdoor recreation services, and

y^Z = a vector of goods and services which are produced in processes bearing no immediate relationship to environmental services.

Each individual makes decisions in the initial time period, and subject to his initial budget constraint, in order to maximize the present value of expected lifetime utility.

By minimizing his expenditures, subject to the constraint that his utility must always be equal to the utility he enjoys with the existing level of atmospheric resources, his Hicksian income compensated demand curves [see Hicks, Mishan, Currie, et al.; Willig; and Randall and Stall] for atmospheric services may be derived. From this, the Hicksian compensating measure of the value of the loss which the individual would incur in time t, should the quality of atmospheric resources be degraded--or the value of the gain the individual would enjoy in time t, should the quality of atmospheric resources be improved--can be calculated. The total social loss from a degradation of atmospheric resources--or the benefits from an improvement in atmospheric resources--may be calculated by summing the Hicksian compensating measures of welfare change across individuals and across time periods.

To adapt this general model to the study of the economic value of atmospheric visibility in the eastern United States, account must be taken of several specific factors.

a) Due to the relatively rapid recovery, under favorable circumstances, of atmospheric resources from assaults by pollutants (compared to, say, land and water resources, and complex ecosystems) intertemporal relationships, while significant, may be less important than in the cases of some other kinds of resources.

b) Due to the dominant west-to-east (or southwest-to-northeast) transportation pattern of atmospheric pollutants, welfare impacts (i.e. social costs or benefits) of visibility change in one part of the study area are attributable to antropogenic pollutants generated in other parts of the study area. Analysis by D. M. Rote of ANL long range transport model incorporates these effects.

c) The Primary emphasis of the research on atmospheric visibility has required that considerable subtlety and discernment be applied to the task of differentiating between those welfare effects due to visibility change and those due to other effects of atmospheric pollution (e.g. plant, animal and human health effects). For example, outdoor recreation activities may be adversely affected by visibility degradation, but also by damage to plant communities and fish from acid precipitation; the market value of residential property may be adversely affected by poor visibility conditions, but also by exposure to human health hazards and property damage.

It is also important to note that the same anthropogenic pollutants, interacting with natural atmospheric conditions, responsible for effects on visibility and, e.g., the health of plant communities and human beings.

d) While consistent with the conceptual framework developed here, the research in this report concentrated upon empirical estimation of the relationships expressed in equations (1), (2), (3), and (5), that is, the relationships between changes in atmospheric resource attributes (i.e., various relevant measures of ambient quality) and the value of visibility services provided.

The estimation of the relationships expressed in equation (4)--i.e., the relationships between natural atmospheric conditions, anthropogenic emissions and ambient air quality--will not be a primary focus of the research proposed herein. However, the research is designed to be compatible with estimates of the (4) relationships, which are provided by ANL. In this way, the research makes a major contribution to the understanding of relationships between atmospheric emissions, ambient air quality and the economic value of changes in atmospheric visibility in the eastern United States.

e) The particular atmospheric visibility services which are foci of the proposed research are: (1) Those which contribute to the satisfactions enjoyed by owners and occupants of urban and suburban residential property; (2) those which contribute to the satisfactions of recreationists in urban, mountain, and coastal environments; and (3) those which influence the safety of users of ground and air transportation services (given the hypothesis that atmospheric visibility influences the flow of traffic and the frequency of accidents).

Extended Framework

In this section we expand upon the conceptual framework by further developing the relationships between atmospheric visibility services and utility [equation (5)] and the value of service flows [equation (2)].

There is now general agreement that the change in consumers' surplus is the proper measure of the economic value of a change in the level of provision of a good, service, or amenity [Currie, Murphy and Schmitz; Dwyer, et al.; Harberger; Hicks, 1940-41; Hicks, 1943; Hicks, 1945-46; Mishan, 1947-48; Mishan, 1976; Mishan, May 1976; Randall and Stoll; Willig].

The conceptual framework presented below provides a general basis for estimating changes in consumers' surplus resulting from changes in the provision of goods, services and amenities--in this case, those associated with atmospheric visibility--including the marketed and the non-marketed, the divisible and the indivisible, and the exclusive and the non-exclusive [Brookshire, Randall and Stoll]. Consider Figure 1. The origin is at Y^0, Q^0, which represents the consumer's initial holdings of the atmospheric visibility service in question, Q, and "income" (or, more precisely, the "all other goods" numeraire). As one moves to the right on the horizontal axis, the quantity of Q increases; as one moves to the left, Q decreases. As one moves upward, on the vertical axis, "income" decreases; as one moves downward, "income" increases. The total value curve, or willingness to pay curve, passes from the lower left quadrant through the origin and into the upper right quadrant. For an increment in the service from Q^0 to Q^+, the individual is willing to pay the amount $Y^0 - Y^-$, which is a positive amount. After having paid his willingness to pay (WTP) and receiving the increment $Q^+ - Q^0$, the individual is exactly as well off as he was at the origin. For a decrement in the level of provision of the service to Q^-, the individual is willing to pay the amount $Y^0 - Y^+$ and, hating paid that amount and received the decrement, is exactly as well off as he was at the origin. Observe that Y^+ is greater than Y^0. Thus, the individual's WTP for the decrement is a negative number. In other words, the individual is willing to accept (WTA) some positive amount of additional income, along with the decrement in the level of provision of the service.

The total value curve measures the net change in consumer surplus resulting from increments or decrements in the level of provision to the individual of the service in question. If the service is unpriced, the change in consumers' surplus is exactly equal to the value of the increment or decrement [Brookshire, Randall, and Stoll].

This value model is applicable to goods and services which are unpriced, divisible or indivisible in consumption, and lumpy in production being available only in quantities Q^-, Q^0, and Q^+. If the good in question was divisible in consumption, infinitesimally divisible in production, and available in infinitely large, frictionless markets at a competitive price, the total value curve could be replaced with the broken price line (which

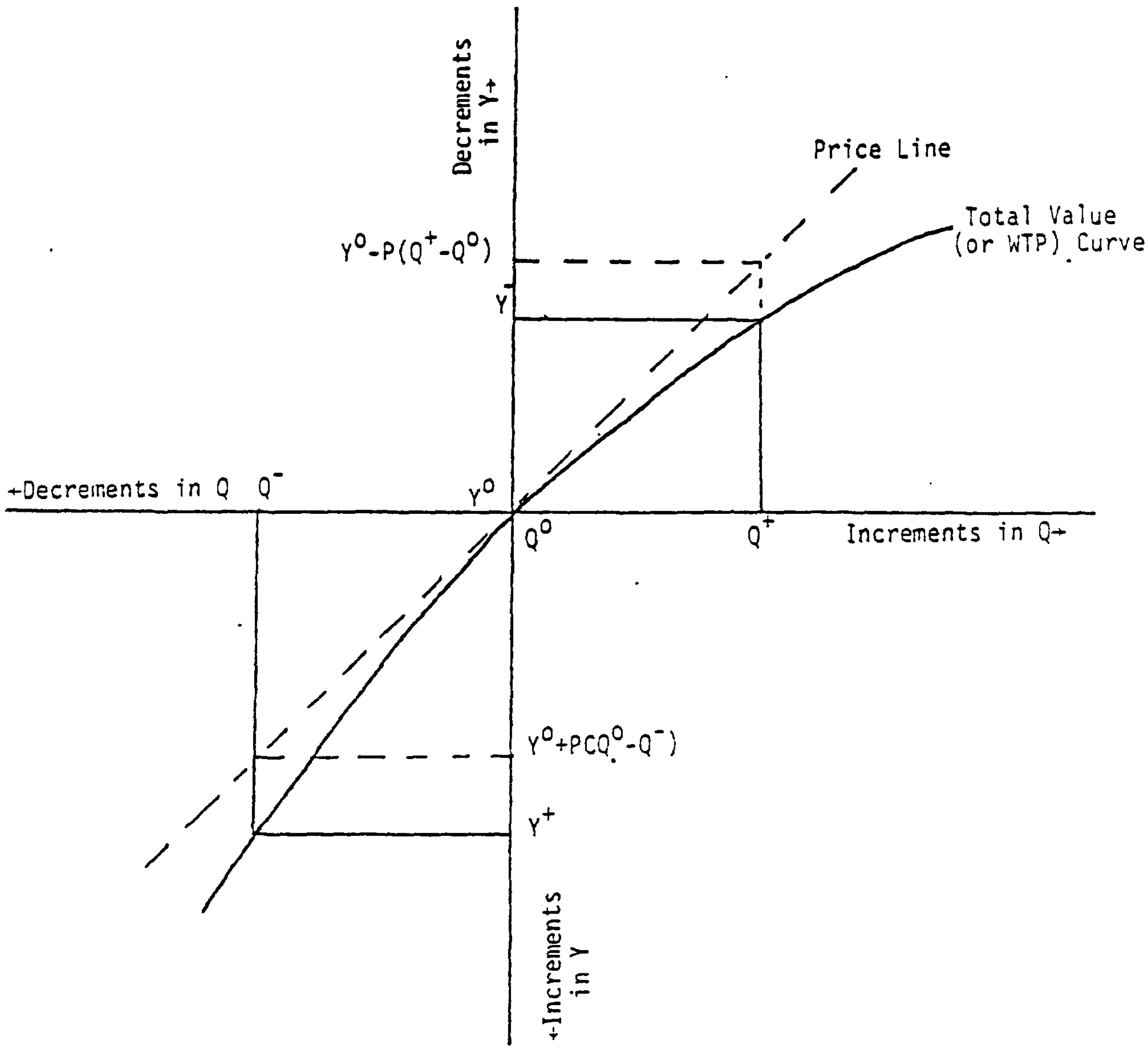


Figure 1. The Total Value Curve.

is tangent to the total value curve at the origin). In such a case, the absolute value of WTP for an increment would be exactly equal to the absolute value of WTA for an equal sized decrement, and both are equal to $P \cdot \Delta Q$ (i.e., the unit price multiplied by the quantity change). Observe that, in cases where the total value curve (rather than the price line) is relevant, WTP for an increment in Q is smaller in absolute value than WTA for a similar sized decrement. Theoretical analyses have developed formulae for the empirical estimation of the difference in absolute value between WTP and WTA in this circumstance [Randall and Stoll; Willig].

The above conceptual framework is entirely general, and develops the relationships between consumer surplus, WTP (and WTA, the counterpart of WTP in the case of decrements in the good), and market price. Where some definable population, e.g., the residents of a given community or the users of a given recreation site, experience the same increment or decrement in the availability, the aggregate value of the change, in benefit-cost terms, is equal to the sum of the individiual values [Bradford, Dwyer et al.].

The value of increments or decrements in atmospheric visibility services (the v_{it}, of equation 2) were estimated, using various techniques, but always in a manner consistent with the above conceptual framework. In those cases where competitive markets exist for atmospheric visibility services, market observations were analyzed in order to permit estimation of the value (i.e., price) of visibility services. Where atmospheric visibility services are not directly marketed, two general classes of analytical techniques for value estimation are available.

a) Hedonic methods utilize observations from markets in goods or services which bear some relationship to visibility services (e.g. are jointly consumed with visibility services, or are produced in processes which require visibility services as inputs) in order to estimate implicit prices or values for visibility services. This class of techniques includes the land value method of valuing environmental amenities [Abelson; Anderson and Cracker; Brown and Pollakowski; Maler]; the hedonic and household production function methods [Deyak and Smith; Muellbauer; Pollak and Wachter; Rosen], which have been applied to valuation of a wide variety of non-market goods including human health and safety; and the travel cost method which has been widely applied in the economic valuation of outdoor recreation amenities [Brown, Singh, add Castle; Cesario and Knetsch; Clawson and Knetsch; Gum and Martin; Knetsch].

b) Contingent valuation (CV) methods approach the valuation of non-market goods directly by creating hypothetical markets and treating the decisions of respondents or experimental subjects using these hypothetical markets as values which exist, contingent on the existence of hypothetical markets [Brookshire, Ives and Schultze; Bishop and Heberlein; Brookshire, Randall and Stoll; Davis; Hammack and Brown; Randall, Ives and Eastman; Randall *et al*.; Smith].

Overview

To estimate the change in aggregate consumer's surplus resulting from changes in average or typical visibility situations were identified that are affected by changes in the level of services rendered by visibility. A major consideration in the research design was to include situations where visibility effects are likely to be most pronounced where they are likely to have significant influence on benefits due to the numbers of people or the value of property affected. With situations identified, an appropriate valuation method was selected and the change in consumer's surplus estimated. Table 1 presents the results of such an identification process for Chicago. Examining Table 1, the first column gives a taxonomy of situations that are, to a greater or lesser extent, hypothesized as being affected by the level of visibility. Columns adjacent to the first in Table 1 match at least one valuation technique to each category of identified situations. Wherever possible, more than one approach is matched to a situation so that valuation results may be replicated and compared. Both the taxonomy of situations and also the data required for the valuation of effects are discussed.

Using the contingent method, visibility levels for a given situation were described in both narrative and photographs. By carefully structured questioning, an individual's valuation of a given increment of visibility was then elicited. The method was contingent because valuations were contingent upon an individual's behavior in a hypothetical choice situation. The contingent method was administered directly to individuals. The

Table 1. Situations Affected by Visibility and Methods of Valuation for Chicago

SITUATION	VALUATION METHOD			
	Contingent	Revealed		
		Hedonic	Demand	Cost of Inputs
I. Aesthetic or View Related				
A. Urban Visibility Services	X			
1. Residential				
a. Lakeshore residences	X	X		
b. Non-Lakeshore city	X	X		
c. Metropolitan suburbs	X			
2. Non-Residential				
a. Workplace				
i. Loop area (First National Bld., Stan. Oil Bld., etc.)	X	X		
ii. City, non-loop (Oakbrook)	X	X		

Table 1, continued

SITUATION	VALUATION METHOD			
	Contingent	Revealed		
		Hedonic	Demand	Cost of Inputs
b. Commuting and other intra-urban travel				
i. Expressways (Kennedy, Eisenhower, etc.)	x			
ii. Bridges (Chicago Skyway)	x			
c. Recreation				
i. View Primary				
a. Hancock Tower	x (Consent)		x	
b. Sears Tower			x	
ii. View Secondary				
a. Spectator Activities			x	
b. Participatory Activities	x			
iii. Substitutes			x	

Table 1, continued

SITUATION	VALUATION METHOD			
	Contingent	Revealed		
		Hedonic	Demand	Cost of inputs
B. Rural Visibility Services	X			
1. Residential	X			
a. Michigan City, Indiana				
2. Recreation	X		X	
b. Indiana Dunes State Park				
II. Non-View Related				
A. Effect on Traffic Flows				X
1. General Aviation				
a. Delays				
b. Cancellations				
2. Commercial Aviation				X
a. Delays				
b. Cancellations				

Table 1, continued

SITUATION	VALUATION METHOD			
	Contingent	Revealed		
		Hedonic	Demand	Cost of Inputs
B. Safety Related				
1. Air Traffic				X
a. Single plane accidents				
b. Multi-plane accidents				
c. Near-misses				
2. Ground Traffic				X
a. Highway accidents and collisons				
III. Option and Existence Value of Visibility				X
A. National Landmarks				
1. Washington Monument				
2. Statue of Liberty				
3. National Parks				

revealed behavior methods relied upon an individual's actual behavior for evidence in valuation. Because actual behavior may be only indirectly related to visibility, revealed behavior approaches confronted both conceptual and statistical difficulties on application. Of the revealed behavior methods, the hedonic technique values visibility as a characteristic of property. Property values as well as supplementary information on housing and view characteristics were required for valuation. The demand method measured the effect of visibility on demand for activities such as outdoor recreation. To apply the demand method, only secondary data on attendance was required in most cases considered below. inally, the opportunity cost-of-inputs method was applied to situations or events that occur only sporadically and thus did not generate sufficient data for any of the other techniques.

Examining Table 1 once again, the broadest distinction of the types of situations affected by visibility is between those situations in which visibility affects aesthetic appreciation and those situations where the effect is not directly aesthetic. The aesthetic or view-related effect was further distinguished by demographic area: by urban and non-urban or rural visibility services. Using the contingent valuation technique, both urban and rural visibility services were valued directly by observing residents in both urban and rural areas. In the Chicago area, urban visibility services were valued directly. Three strata correspond to the three divisions under residential urban visibility services: lakeshore residents, non-lakeshore city residents, and residents of the metropolitan suburbs. The approach had three purposes. First, using a set of photographs and the contingent technique, a valuation of visibility increments over the entire urban area was elicited. This first valuation was for urban visibility services as a whole. Second, the CV instrument elicited information on housing and view characteristics. This information was required for the hedonic approach to valuation. Third, the CV instrument inquired about recreational activities. Such participation data were essential to population estimates for the non-residential effects of urban visibility services and their aggregation.

The third major effect of visibility within the metropolitan area is on urban recreation. Two types of affected recreation activities can be distinguished. The first is recreation that focuses on the enjoyment of specific views. The second is recreation in which a view and associated visibility level are only secondary, used mainly as a background. Within Chicago, the two major view primary sites are Hancock Tower Observatory and the Sears Tower Skydeck Observatory. Each of these locations offers views of Chicago at various levels of visibility to approximately one million visitors a year. Hancock Tower cooperated with our demand approach to valuation by sharing attendance records. Attendance records were analyzed along with airport visibility and weather data to determine the effect of visibility on visitations. Finally, a contingent valuation of visibility was conducted at the Hancock Tower. To elicit a valuation of increments or decrements of visibility at the Hancock Tower, a special CV instrument was constructed for those who visit the Tower.

Valuation of the effect of visibility on the enjoyment of spectator sports was made by the demand method. Fist, attendance data was regressed on weather, visbility, and other secondary data to determine the effect of visibility. The effect of visibility was shown to be significant in preliminary analysis and a more complete demand model was specified for the valuation of its effect. This more complete demand model included equations for local substitutes to outdoor recreation, such as museum and aquarium attendance.

The non-aesthetic effect of visibility on general aviation and highway accidents were also examined for the Chicago area. These are discussed in the chapter on secondary data analysis.

To extend the valuation of visibility beyond the Chicago region and thus permit a benefit estimate for the eastern United States as a whole a valuation of visibility services were made for six other population areas. The same basic approach used for the Chicago area also was used for these six additional population areas. That is, both contingent and revealed behavior methods were applied to value the effect of visibility in each of the situations outlined in Table 2. The six additional population areas chosen for investigation were selected on the basis of experience regarding the prevailing visibility conditions over different zones within the eastern United States, and the requirements of a systematic aggregation procedure.

Selection of the areas entailed references to median yearly visibility . Over the eastern United States there exist several distinct visibility zones. Except for the Mississippi delta area and the Ohio River basin, median visibility from the Appalachian

Mountains to the plains states is approximated by that of Chicago. By sampling from urban and rural areas near Cincinnati, for example, information was obtained regarding the value of visibility for an inland area of generally poor visibility. By sampling from urban and rural areas in and near Boston, information was obtained regarding the value of visibility for a coastal area of generally good visibility. A sample from the area of Atlanta provided information regarding the value of visibility by residents of a median range visibility zone for an inland city of the south.

Benefits as Measured in Housing Markets

Housing markets can yield useful information about the demand for goods such as clean air and visibility which are not traded in their own explicit markets. Analysis of markets, whether they be explicit or implicit, has great appeal relative to non-market benefit measures because it is based on observable behavior where preferences are revealed through some monetary expenditure rather than through an imaginary response to a hypothetical situation. Nonetheless, since the Ridker and Henning (1967) and Anderson and Cracker (1971) studies of residential property values and air pollution doubt has arisen as to exactly what information is contained in a regression of property values on characteristics of housing, i.e., a hedonic regression. Maler (1977) points out the value of any estimates based on analysis of property values is limited by potential malfunctions in the housing market which might be caused by lack of information about the costs of air pollution, in particular, or all factors which cause the market to be in a state which differs from equilibrium attained under ideal conditions of zero information, transactions and adjustment costs, in general. Such criticism depicts the trade-off inherent in the alternative methods of benefit estimation, market and non-market, and suggests the importance of using them as complementary inputs into benefit estimation.

While criticism of housing market studies remains, considerable progress has been made. Due largely to contributions by Freeman (1971) and Rosen (1974), it is clear that a hedonic regression does not yield a useful measure of benefits--at least directly. Rosen's conceptual framework for analysis of implicit markets shows that a hedonic regression is a market clearing function yielding only hedonic prices which then must be used along with other determinants of demand to estimate the demand for traits implicitly traded in the housing market.

Using Rosen's approach housing is viewed as a package of traits made up of both structural characteristics and neighborhood amenities. Households respond to the configuration of traits in addition to the traits themselves since the traits are not easily repackaged. Since households demand housing, not land, they consider various structures in various neighbodhoods and choose housing packages which must suit them. As such, household utility depends on housing, market goods and tasts or:

$$(1) \qquad U = U(Z,X: T)$$

where U is household utility, Z is a vector of housing traits, X is a vector of market goods and T is a vector of taste variables. Household utility maximization is constrained by the available money income:

$$(2) \qquad I = X + P(Z: I,U,T)$$

where I is household money income, X is the numeraire, and P(Z: I,U,T) is the household's total valuation of housing traits which depends on the housing traits, income, utility level and tasts, respectively. The valuation function gives an indifference map depicting the willingness of the household to trade off units of market goods, X, for incremental additions of any housing trait, Z, given income, utility and tastes. As Rosen shows the valuation function has the properties that it is increasing at a decreasing rate with trait consumption, i.e., $\partial P/\partial Z > 0$ and $\partial^2 P/\partial Z^2 < 0$, and that the ratio of marginal valuations of traits equals the ratio of marginal utilities of traits for each pair of traits, i.e., $P_i/P_j = U_i/U_j$ where P_i is the marginal valuation of trait i and U_i is the marginal utility of trait i, etc.

The household faces a market equilibrium price function, P, which indicates the amount of market goods which much be paid for additional housing traits. If consumers have approximately zero market weights and the market clearing price function is exogenous to the household this price function for packages of housing traits is:

$$(3) \quad P = P(Z)$$

where P is the price of the factor of traits, Z. The partial derivative of the market price function with respect to a trait, P_i, gives the equilibrium marginal price of Z_i which is often called the hedonic or implicit price.

Given that households maximize utility in a way similar to that when they face a linear budget constraint, the first order conditions yield demand function for housing site traits:

$$(4) \quad Z_i^d = Z_i^d(P_1, \ldots, P_i, \ldots, P_n, I, T)$$

where the quantity demanded of trait i depends on its own marginal price, P_i, the marginal prices of complementary and substitute traits, P_j for J = 1, ... , n and J ≠ i, household income and tastes.

To estimate the demand for visibility, or clean air, we first estimate the price of clean air. The price is implicit in the hedonic regression in that is is the partial derivative of housing price with respect to clean air. If the true functional form of the hedonic regression is nonlinear, then the marginal price of clean air will vary across sites. Second, we use price of clean air along with the prices of complements and substitutes income and taste variables as well as whatever else is necessary to identify demand to estimate the demand for clean air in the usual manner.

Recent empirical studies demonstrate that the theoretically-preferred approach is feasible and that it does yield benefit estimates which differ from those based only on the hedonic regression, Harrison and Rubinfeld (1978), Nelson (1978), Brookshire _et_. _al_. (1979), and Bender _et_. _al_. (forthcoming) all estimate the demand for clean air applying Rosen's model. Linneman (1977), Blomquist and Worley (1978) and Witte _et_. _al._ (1979) estimate the demands for housing traits other than clean air. A pattern which emerges is that the estimates from a hedonic - demand, i.e., two-step, approach differs from the simple hedonic estimates. Harrison and Rubinfeld find that the simple linear hedonic overestimates the benefits of cleaner air by approximately 42% while Brookshire _et._ _al._ find the linear hedonic overestimates the benefits by approximately 1594. Bender _et_. _al_. also find that linear hedonic is quite misleading, but, in contrast, it _under_estimates the benefits by approximately 60%. Blomquist and Worley find that the linear hedonic overestimates benefits for some housing traits and underestimates benefits for others. While each of the four studies indicates the superiority of a Rosen approach, the last two emphasize the importance of a systematic search for the best functional form of the hedonic equation, e.g., using a Box-Cox maximum likelihood procedure for searching transformations of variables in the hedonic equation. These recent contributions were carefully considered in our estimation of the demand for visibility.

Our estimates of benefits of greater visibility more fully exploit the gains of the Rosen procedure by paying particular attention to the estimation of total social benefits from the demand equations. Previous benefit estimates have been made by simply multiplying the benefit for the typical household times the number of households benefiting from the improvement. This estimation is appropriate for marginal or nonmarginal changes for the typical households. However, this does not yield true benefits for all if those consuming some amount other than the average (typical) amount of clean air (or any other trait) do not have demands symetrically distributed about the demand for the typical household. For example, those with higher incomes will value the cleaner air more than those with average income and those with lower incomes will value the cleaner air less than those with average incomes. The values of higher income households are unbounded, but those of lower income households are bounded below by zero. In this case, simple aggregation can lead to an overestimate of total benefits. Harrison and Rubinfeld do consider three income subgroups and find that indeed the total benefits are less than those estimated by simple aggregation based on average income. We used distributions of demand shifters, such as income, representative of the eastern portion of the United States to aggregate household benefits. This not only includes the valuations of these households not observed at the margin consuming the average amount of clean air, but adjusts for any differenes between particular areas studies and the entire region.

A.2 ATMOSPHERIC VISIBILITY AND CONTINGENT VALUATION EXERCISES

A decade has passed since the initiation of the research which provided the data base for the first contingent valuation study of aesthetic aspects of air quality to gain respectability among economists (Randall, Ives and Eastman). In that time, the theoretical basis of contingent valuation has been clarified (see Brookshire, Randall and Stoll for an exposition of current theory, and Randall, 1980 manuscript, for the theoretical relationship between contingent valuation total cost, property value, markets in substitutes, and hedonic methods of valuation); contingent valuation formats have been classified, codified, and accepted for use in benefit cost analysis of federal water projects (U.S. Water Resources Council); and a growing number of studies applying various contingent valuation formats to a wide variety of nonmarketed goods have been completed and published.

Contingent valuation (CV) methods have always encountered some skepticism from economists, since the basic data used are not generated by actual transactions in near-perfect markets. Nevertheless, opposition to the use of such techniques--or, perhaps, to the attribution of respectability to them--has noticeably softened in recent years (see, e.g., Freeman). Skepticism seems to have been undermined by several developments: the above-mentioned work in developing the theoretical relationship between consumers' surplus concepts, non-exclusive and nonrival goods, and contingent valuation methods; the fairly precise replication of earlier CV results in later exercises (Rowe, d'Arge and Brookshire); and the fairly general finding of similar results when CV methods are compared with travel cost (Knetsch and Davis) and property values (Brookshire, d'Arge, Schules and Thayer) methods.

Nevertheless, some doubts remain. (1) The generally accepted theory of "public goods" (Samuelson) indicates scope for strategic behavior, in which individuals avoid revealing their true valuations of such goods in order to maximize their surplus, i.e., the difference between the value they enjoy and the contribution they make. For some economists, the <u>scope</u> for such behavior is prima facie evidence of its <u>prevalence</u>; hence, a general refusal to take seriously the results of any CV method which fails to eliminate that scope. The search for "incentive compatible demand-revealing mechanisms" is in part a response to the "scope proves prevalence" argument. For others, the prevalence of such behavior is much more problematical: while no country seems to rely on voluntary taxation, many "public goods" are, in fact, voluntarily provided in substantial (but not necessarily efficient) quantities. Smith assembles impressive experimental evidence that, at least in the kinds of circumstances he and others he cites have studied, strategic behavior is simply not a significant influence on aggregate valuations.

(2) In an interesting recent experiment, Bishop and Heberlein created an experimental market in which they actually purchased goose hunting permits from permittees, effectively establishing in real transactions the WTA of hunters to forego the hunting season. In a mail survey conducted at about the same time, WTP for hunting permits was established via single (i.e. non-iterative) questions asking respondents to nominate a dollar amount which

represents their maximum WTP. It turned out that WTA established in actual transactions was about three times WTP generated in the survey, a difference far greater than can be explained by income effects (Randall and Stoll, 1980a and b). There are good reasons to suspect the Bishop-Heberlein WTA experiment of upward bias, while their WTP survey used a format which I consider inferior to the iterative bidding routine (Randall, 1980 manuscripts). Nevertheless, the various possible biases are probably not sufficient to account for all of the observed differences. Tentatively, it can be concluded that WTP surveys such as that conducted by Bishop and Heberlein may typically generate understimates of the “true” value of the good concerned. The temptation to overstate the WTP knowing that one is unlikely to be forced to actually pay the stated amount (the “strategic bias” most commonly attributed by economists to this kind of CV exercise) seems to be more than counterbalanced by a tendency to respond ultra-conservatively to the suggestion that one may be expected to pay for goods which are customarily non-marketed (or to pay substantially more for goods which are customarily underpriced by public institutions). The conclusions stated immediately above are tentative; a firmer conclusion is that the Bishop-Heberlein experiment raises, in a dramatic way, some serious questions about the quality of data generated in direct question CV exercises.

(3) Those researchers who have attempted to estimate statistical relationships which use various economic, social and demographic variables to explain the individual WTP bids generated in CV exercises have typically been disappointed by the results (Cicchetti and Smith; Eastman, Hoffer and Randall; Brookshire, d’Arge, Schulze and Thayer). The recent work by the University of Chicago and the University of Wyoming teams in this and a closely related study has encountered similar frustrations.

While there is abundant and convincing evidence that individual WTP bids are not merely random numbers, researchers have not been notably successful in finding relationships between individual bids and variables describing the individual's economic, social and demographic condition, In estimated equations, the adjusted R^2 is often low and few variables are related to individual bid in a statistically significant way. Sometimes, even the relationship between individual bid and individual income is not significant. These kinds of results are unsettling to those who believe that, if individual bids are in fact "good" economic data, they should be related in systematic ways to the kinds of variables are related to individual bid in a statistically significant way. Sometimes, even the relationship between individual bid and individual income is not significant. These kinds of results are unsettling to those who believe that, if individual bids are in fact "good" economic data, they should be related in systematic ways to the kinds of variables which often successfully explain demand and/or value data for marketed goods.

This issue has several vantage points.

(a) Perhaps it is unreasonable to expect to be able to obtain strong statistical relationships, using individual observations obtained from small samples. After all, most demand studies use observations of broad aggregates (time series of aggregate sales and/or cross-sections of total sales by state, SMSA, etc.). Surely, the explanation of individual variables is a task of quite a different order.

It has been observed that demand analyses using individual data generated from panel studies have generally yielded more robust statistical relationships than have WTP exercises. But, these studies typically use much larger panels than most WTP survey samples, and (2) they typically deal with fairly broad categories of regularly purchased foods (e.g. “food” or “meat”) whereas WTP studies often deal with highly specific goods (atmospheric visibility at some specific place, elk hunting in a particular kind of terrain in a given state or sub-state region).

Brookshire, Randall and Stoll report obtaining considerably more robust equations--not merely higher R^2, but also highly significant income relationships--when they grouped their sample of 58 respondents into 4 classes, according to household income, prior to the analysis. This procedure suppresses within-group variation (presumably diminishing the influence of a few “extreme” observations in a small sample). Statistically, the apparently improved estimates and lower mean square error were obtained at the cost of higher principal diagonal $(X'X)^{-1}$. Thus, their procedure may not necessarily be viewed as attractive

(b) Perhaps WTP vids, viewed as cardinal indicators of dollar valuations, are not especially reliable. Different individuals probably perceive the offered good (e.g., a given increment in atmospheric visibility) differently. On this front, progress has been made (as Freeman acknowledged) via the use of standardized photographs and devices to improve uniformity of perception. Nevertheless, problems remain. In the case of atmospheric visibility, no amount of effort in standardizing the verbal and visual information provided to respondents can overcome different perceptions due to individual differences in visual acuity.

A.3 AN EARLY CONTINGENT VALUATION EXERCISE

1. Pretest: Chicago Residents

In order to pretest the basic instrument for subsequent contingent valuation exercises and to explicitly field test certain innovations in C.V. instrument design, a C.V. exercise was conducted in Chicago and suburbs. Sixty-eight households participated. After rejecting 15 observations (apparent enumerator bias), 2 (outliers) and 8 (self-identified protest bids) all subsequent analyses were based on 43 observations.

The basic instrument tested included the following elements:

- questions designed to test the efficacy of color photographs in in representing visibility levels.
- alternative methods of defining and representing visibility levels.
- a listing of activities in which the household participates.
- questions exploring whether visibility conditions influence choice of activities and, if so, in what ways.
- questions to determine whether the household owned certain equipment used in producing activities for which visibility is an input.
- WTP questions
- follow-up questions to identify protest bidders and obtain participant's evaluation of the C.V. exercise.
- home ownership v s. rental.
- view quality at the home.

-expected period of residence in Chicago SMSA(i.e., short-term, . . . , through retirement).

-demographic information

-questions to probe the notions of life cycle consumption, permanent income, and marginal wage-cost of leisure-time.

All of these elements were serious candidates for inclusion in subsequent C.V. work.,

Four kinds of innovations in C.V. instrument design were explicitly tested:

a). WTP Instrument

Earlier C.V. work under this project and published research suggested that the iterative bidding format is more effective than single question formats which ask the participant to simply state his/her WTP or to select from an array of numbers that which best represents WTP.

Recent work at Resources for the Future (Mitchell and Carson, draft report) used a payment card, on which typical household annual costs--$ in taxes and higher prices -- for various public programs were stated. Participants were asked to examine the data provided and then state their WTP for improvements in water quality. Mitchell (personal communication, and draft report) reports that he considers the payment card device sucessful.

For the pretest, we developed a "modified payment card and rebid" format. The payment card was modified to include typical expenditures for both public programs and private goods. About ten minutes after the payment card was used to obtain WTP, the participant was asked “if the program to improve visibility actually cost (stated WTP plus $25), would you accept or reject the program?" This question was re-iterated with sucessively higher cost amounts until a "reject" response was given,

The two WTP instruments tested were:

-iterative bidding ($/month)

-modified payment card and re-bid ($ annually).

On an annual basis, the predicted household bid was $109 higher with the "modified payment card and re-bid" device than with the iterative monthly bid (Table 1, model 1). Only about $20 of the difference was attributable to the re-bid. It was notable that "zero" bids were much less frequent with the "modified payment card and re-bid" device - 7% of all bids as opposed to 39 percent with the iterative bid (Table 2). This explains much of the difference in predicted household bids.

b) . Definition of Visibility Levels

Previous work has used color photographs depicting various visibility levels, and defined visibility programs as improving typical visibility from, e.g., the level shown in photo set D to, e.g., the level shown in photo set A. The notion of typical visibility is easy to communicate, but may be an overly simplistic specification of visibility.

Within any year, emissions and background visibility exhibit considerable day-to-day and week-to-week variability. Thus, the relative frequency of good, moderate and poor visibility days may be a more realistic way to specify visibility conditions. A program to improve visibility would increase the relative frequency of good visibility days while reducing that of poor days.

The worst visibility days tend to come clustered together, as ambient pollutants accumulate during periods of air stagnation. Conceptualized in these terms, a program to improve visibility would reduce the length of the longest run of consecutive poor visibility days in a typical year.

The pretest was designed to examane the effectiveness of these alternative ways of communicating visibility conditions. Three specifications of visibility improving programs were used:

-typical visibility would be improved from level B (about 12 miles) to level C (about 30 miles): VISTYP.

-the frequency of various visibility levels would change from 30 percent A (about 4 miles, 40 percent B and 30 percent C to 10 percent A, 30 percent B and 60 percent C: VISFREQ.

-the length of the longest run of consecutive days like A in a typical year would be reduced from 12 days to 4 days: VISRUN.

The predicted annual household WTP was lower with VISFREQ and VISRUN than with VISTYP, but the differences were not statistically significant. VISRUN generated a greater proportion of zero bids than VISTYP.

These findings suggest that, while all three visibility specifications seemed to communicate effectively, VISFREQ and VISRUN offered little advantage over VISTYP. Since VISTYP was more readily related to existing data series on observed visibility, VISTYP was used in subsequent C.V. work.

c). Income Concepts

It is expected on conceptual grounds that WTP bears a positive and significant relationship to household income. This expectation has been borne out in previous published reports, although some small-sample studies have reported insignificant income coefficients.

In this pretest, we took the opportunity to explore ways to improve the specification of income concepts, as follows:

-the notion of standard of living, SOL, which adjusts household income for household size to permit comparability of standard of living across households of varying sizes (Lazear and Michael, American Economic Review, 1980)

-permanent income notions, which were implemented by identifying those households which had recently experienced significant changes in income level, and those which expected to experience such changes within the next five years.

-the notion that for some life-cycle stages annual consumption is more representative of standard of living than annual income. For example, some households of retired persons may consistently dissave or disinvest in order to maintain current consumption.

-the marginal wage-cost of leisure-time, which is an important variable when the demand for visibility is modeled in a household production function framework.

No difficulties were encountered in obtaining the necessary data to specify these various concepts. SOL proved an effective specification of household Income (Table 1). Preliminary analyses (not presented) suggested that permanent income concepts are significant with a larger sample of households. The pretest sample included very few cases of dissaving, thus providing no opportunity to examine the usefulness of this concept in statistical estimation of bid equations.

d). Activities

The household production function framework conceptualizes visibility as a non-rival input in the production of activities which provide utility-gneerating characteristics. To implement that framework, it is necessary to identify:

-the activities which households produce,

-the role of visibility in the production of those activities, and

-the purchased inputs, e.g., equipment, which are used along with visibility in activity production: ACTEQ.

No difficulties were encountered in obtaining data on activities produced and ACTEQ. We were less successful in obtaining data to help specify the role of visibility in activity production. Enumerators and participants reported that section of the instrument was tedious. ACTEQ is an important variable in WTP equations.

Pretest Result

Predicted annual household WTP for visibility improvements in the Chicago region ranged from $125 (with MIB, VISFREO instrument) to $325 (with a AMPCR, VISTYP instrument).

A.4 ECONOMICS OF VISIBILITY - AN INPUT APPROACH

Several recent studies have dealt with both the theory and empirical results of the issue of the value of visibility. Particularly noteworthy are Brookshire et al [1979] and the references cited there, and Rowe et al [1980] and the references cited there. Indeed, Brookshire et al contains a solid theoretical basis for valuing visibility using the concept of the willingness to pay approach. In this section we first discuss the consumer surplus-equivalent variation and compensating variation issues. We then go on to critically evaluate the willingness to pay approach, arguing that it results in values of both visibility and vistas, since they are used simultaneously as inputs in the production of consumerable service.

The Model

Let's assume the existence of a vista, located at a particular site in the city. It can be located either offshore on the lake, or be the lake itself. We define visibility as the possibility of being able to see this site. We define a product, immediately consumed by the viewer, as a function of the site, the conditions which allow it to be viewed, and personnal inputs. Hence,

$$V_{1htj} = f(S_j, W_{1ht}, PI)$$

where V_{1ht} is the quantity of viewing services obtained per unit of time at location 1, hour h and time t, when viewing site S_j. S_j stands for site j ad includes its particular characteristics such as its height, shape, and colors. W_{1ht} are the viewing conditions at location 1, hour h and time t. Note that 1 embodies the height of the observation point, distance from the site, direction to the site and other characteristics one of which might be the existence of buildings located between the viewer and site j which, by obstructing the view, pushes W_{1ht} to zero. The traditional assumptions,

$$f(0, W_{1ht}, PI) = f(S, 0, PI) = f(S, W_{1ht}, 0) = 0$$

$$f_1 > 0, \quad f_{11} < 0, \quad f_2 > 0, \quad f_{22} < 0$$

hold for this production function. As already noted, V_{1htj} is consumed and produced simultaneously (the only way to transfer it from one time to another is by using the storage device known as memory which often has limited capacity). If stored, the quantity of services retrieved from storage (memory) declines by a rate of s per unit of time. Thus, if retrieved at t, the maximum of services retrieved are given by the equation:

$$V_{1ht_0} \cdot e^{-s(t-t_0)}$$

Furthermore, discounting future utility by a rate p, the present value of producing and inventorying visibility services of quantity V_{1ht_0}, is

$$\int_{t_0}^{\infty} U_V^t e^{-(s+p)t} \cdot V_{1ht_0} dt \quad \text{where } U_V > 0, \quad U_{VV} < 0.$$

The above discussion suggests that the particular nature of the product "viewing services" is of the form of a durable with a relativly long life span (as, for example, "I visited the Grand Canyon only once, but I still remember 'every' detail"), although some might depreciate rapidly. [1] Also, there is still the need for proof (although not by ec-

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[1] This depreciation is frequently supplemented by taking pictures of a particular site or scene. The "quality" of the picture, as does the quantity of viewing services, depends upon the conditions of visibility, W_{1th} (Another supplement is picture taking by a different individual, however, this won't be discussed here).

onomists) that W_{1ht} affects the durability of the product, i.e.

$$s = g(S_j, W_{1ht}, PI)$$

and again,

$$g(0, W_{1ht}, PI) = g(S_j, 0, PI) = g(S_j, W_{1ht}, 0) = 0$$

$$g_1 < 0, \quad g_{11} > 0, \quad g_2 < 0, \quad g_{22} > 0.$$

Hence, the life time returns from the investment of time and money in the production of viewing services is given by

$$\int_{t_0}^{\infty} U_V^t \cdot e^{-[g(S_j, W_{1ht_0}, PI) + \rho]t} \cdot V_{1ht_0} dt.$$

The fact that one is in a certain viewing position at a given site j, implies that some fixed costs have already occured. The time spent selecting the visibility conditions and the viewing position characteristics determine W_{1ht} and thus V_{1htj}. The search for the best spot from which to view site j is analagous to the purchase of more inputs in order to increase V (S_j is a fixed factor). This search clearly involves costs such as time and other expenditures. The relevant question is how much is one willing to pay for the marginal increase in W?

<u>On Willingness to Pay and Consumer Surplus</u>

Frequently, one can not control W. One can, however, control PI. An optimal PI at the margin yields its marginal costs. In addition, for a given S_j, W and PI are substitutes (in a two input model). At this stage we leave the production framework and shift the analysis to a consumer choice model (recall that production and consumption are simultaneous).

Vistas are consumerable goods. We also assume that they are normal goods. Thus, if visibility conditions are a non-inferior input, their derived demand curve is downward sloping (demand for an input, i.e. their marginal value product). We distinguish between two types of demand curves - both extracted from consumer behavior. One is the regular Marshallian demand curve, along which full income is kept constant but utility is allowed to vary; and the Hicksian income compensated demand curve along which full income varies but utility is held constant. Usually, this distinction is made for a good that is explicit in the utility function. We argue legitimacy for the case of visibility given that the producer is the consumer, i.e. the simultaneity of activities and identity of quantities both produced and consumed.

We apply similar reasoning in the case of the quantity of visibility services, W, and the price (implicit) of visibility services, P_W. Accordingly, in Figure 1, we have drawn three demand curves (following Willig [1976]): AA is the Marshallian curve, BB is the income compensated demand curve at utility level U0, and CC is simply BB for a different utility level, U^1, such that $U^1 > U^0$ (see also Appendix A). Let M denote money income. Then in Figure 1, the area P^0P^1ac is the conventional measure of consumer surplus, A; P^0P^1bc measures the compensation variation, C, for $U(P^0, M^0)$; and, P^0P^1ad measures the equivalent variation, E, for $U(P^1, M^0)$. Again following Willig, we assume W to be a non-inferior purchased input, such that the inequality, $C \geq A \geq E$, holds. Hence, if a market for W existed, and prices varied between P^0 and P^1, changes in consumer surplus can be calculated. The more pertinent issue, however, is how to handle non-market inputs. In addition to being a public good, the quantity of viewing services, not price, is fixed exogenously for a given pro-

Figure 1

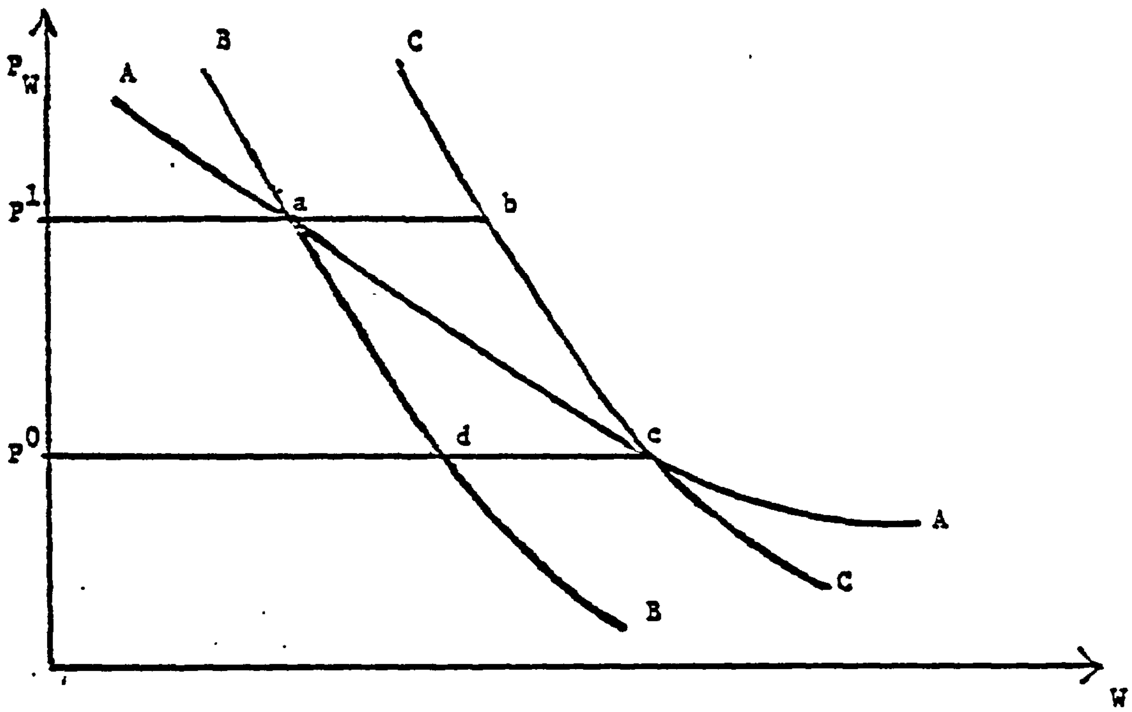
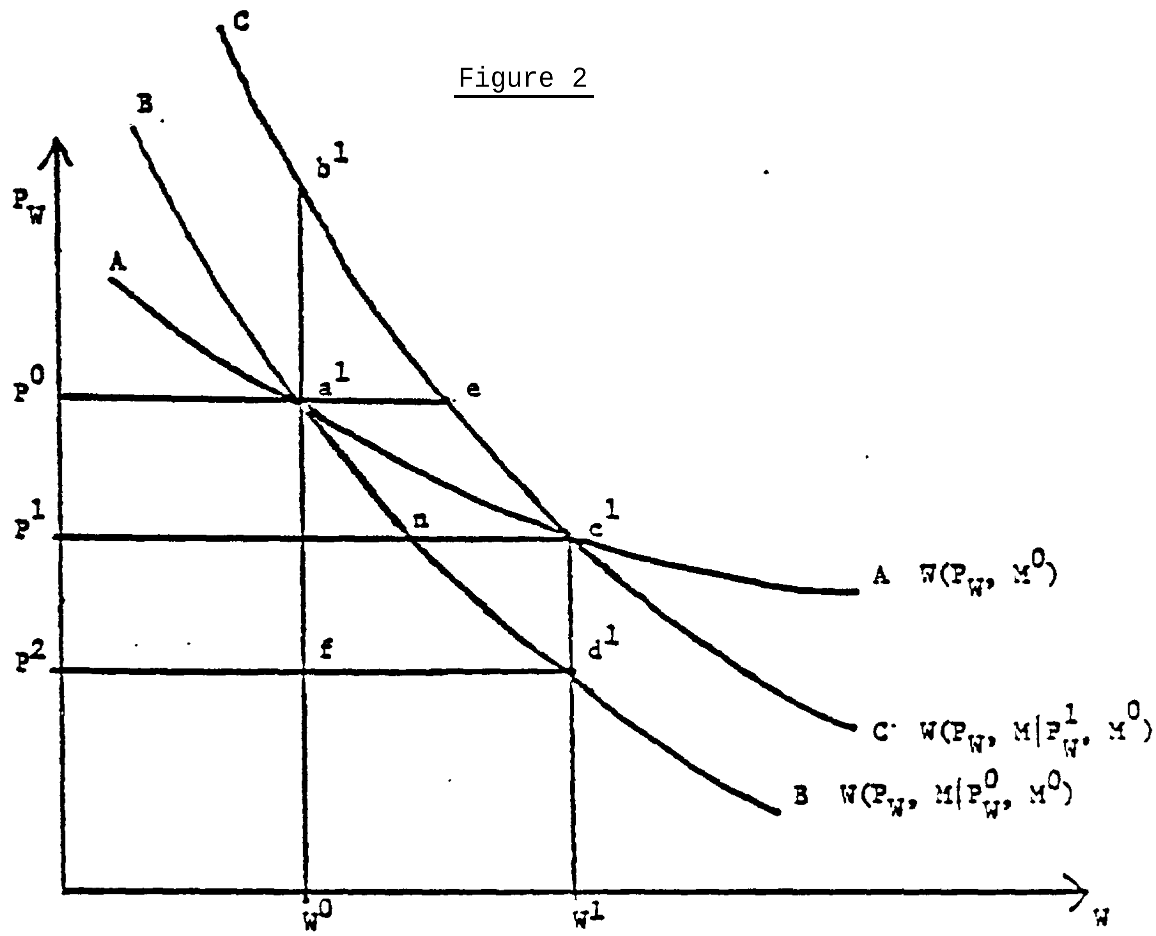


Figure 2



ducer. Furthermore, these quantities may be noncontinuous. In the following section the traditional consumer surplus equivalent variation and compensation variation concepts are applied to exogenous changes of the quantity. If one could find the price (shadow price) the consumer would be willing to pay per unit of visibility directly (whether by questionnaire or by market observations), then the consumer surplus could be approximated. However, this approach is usually not feasible and one has to resort to other methods. (In the last section, we discuss, with some skepticism, the success of the presumably correct willingness to pay method).

BB in Figure 2 is a derived demand curve. When the quantity of visibility services, given free of charge, increases from W^0 to W, the area under the curve increases by $W^0a^1d^1W^1$, which is the measure of the equivalent variation, E, at the utility level represnted by BB,

$$U(W, M^0), \text{ i.e. } U(W^1, M^0 - E) = U(W^0, M^0).$$

Similarly, for the CC demand curve, the area $W^{0,1}\ {}^1W^1$, is the compensation variation for the CC curve, such that,

$$U(W^1, M^0), \text{ i.e. } U(W^1, M^0) = U(W^0, M^0 + C).$$

It is easy to show that the area under the Marshallian demand curve beneen W^0 and W^1 is $W^0a^1c^1W^1$, and

$$W^0a^1d^1W^1 < W^0a^1c^1W^1 < W^0b^1c^1W^1.$$

For BB parallel to CC, and for AA, BB and CC linear, the conventional consumer surplus is the average of the above defined compensating and equivalent variations.

Another interesting comparison is between the following pairs:

$P^0a^1d^1P^2$ and $W^0a^1d^1W^1$

$P^0e\ c^1P^1$ and $W^0b^1c^1W^1$

$P^0a^1c^1P^1$ and $W^0a^1c^1W^1$.

The paired relations have a common triangular shape (the first is fa^1d^1). Thus, the difference (using the BB income compensated curve) is $OP^0a^1W^0$ minus $OP^2d^1W^1$, which in conventional demand terms is $P^0Q^0 - P^1Q^1$. This difference depends upon the demand elasticity:

$$P^0Q^0 - P^1Q^1 \gtreqless 0 \quad \text{as } \eta \lesseqgtr 1.$$

Hence, the approximation of consumer surplus by the ares under the income compensated demand curve, BB, better approximates the equivalent variation measure of consumer surplus the closer is its elasticity to 1. The CC curve is of about the same elasticity as the BB curve. However, for normal goods the Marshallian curve, AA is definitly more elastic. Thus, the fowlowing cases are noted; the difference for the Marshallian curve is the same or lower when the elasticity of BB and CC is less than unity while it is higher when the elasticity is above unity. If we assume that the policy maker is interested in the welfare implications of changing the quantity of visibility services (e.g. by improving air quality), he may regard the willingness to pay, defined by the Marshallian consumer surplus, as an approximation to true consumer surplus (compensating or equivalent variation).

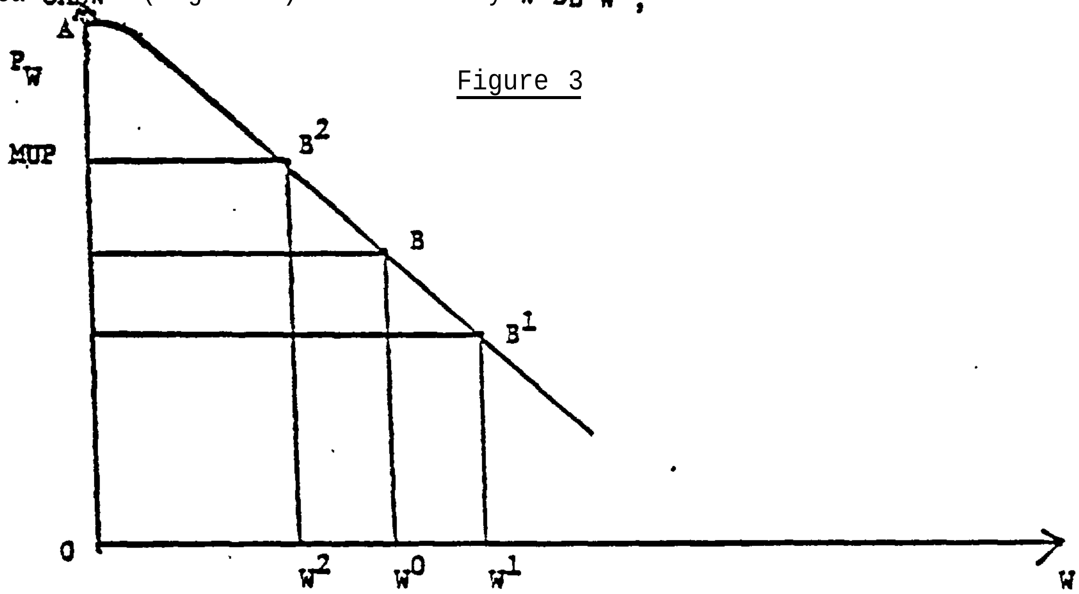
The Demand for Visibility Services

If W is determined exogenously then its marginal product times the marginal utility of the vista's services (MP x MU) is its shadow price. If W is endogenous, its quantity is determined by equating its marginal costs with the product MP x MU, (MUP).

As conventially noted, at equilibrium along the demand for W, the consumer surplus is the rent to the fixed factor - the existing site j. For a given demand for viewing conditions, the lower the marginal cost of visibility services, the more viewing conditions are purchased (e.g. travel until you find the "right" angle to view the rock). The rock's rent, then, is also larger. Hence the point of maximum willingness to pay for visibility, will be determined by the specific site. The maximum sum that a consumer is willing to pay for a particular site is the consumer surplus. The maximum amount the consumer is willing to pay for an additional unit of viewing conditions, W, is its marginal utility value,

If visibility conditions improve from W^0 to W^1 in a given site, the area $OABW^0$ (Figure 3) increases by $W^0BB^1W^1$,

Figure 3



and declines by $W^2B^2BW^0$ when conditions are worsened. The size of area $OABW^0$ is unknown. If one suggests an improvement in visibility from W^0 to W^1, then the amount the consumer is willing to pay for the improved visibility is OAB^1W^1, M^1; if a change from W^0 to W^2 is suggested, the value is OAB^2W^2, M^2. $M^1 - M^2 = W^2B^2B^1W^1 = M^3$. The willingness to pay for visibility conditions at W^0 is approximated by $M^3/2$.

Conclusions

The visibility valuations found in previous studies are biased upward with respect to the marginal value product since they are totals and embody the rents for the various sites that the interviewee is viewing. The experiment that we suggest would subtract out these rents. The willingness to pay experiments, themselves, would not change except that each time an initial W^0 will be chosen explicitly. Willingness to pay is indicated for different changes from the initial W^0. In this manner, the proper $M^3/2$ can be calculated. We expect that $M^3/2$ will decline as W^0 is increased for a given site.

In addition, the difference between valuations for increasing and decreasing W ought to diverge further as the change between visibility levels becomes larger. Large changes, however, might be necessary if the demand is relatively inelastic. Since this is not apriori known, a conclusion of no value might be reached although the consumer's surplus is large (recall the discussion on the relation between the "true" consumer surplus and the one discussed in the previous section).

APPENDIX A

The consumer surplus function is the income compensation function denoted by $M(W|W^0, M^0)$. The function denotes the least income required by the consumer when no more than W units of visibility are available, while he is (promised) to enjoy the same utility level as at W^1, M^0. Hence,

$$U(W^0, M^0 + C) = U(W^1, M^0)$$

$$U(W^1, M^0 - E) = U(W^0, M^0)$$

where for the compensating variation

$$M^0 + C = M(W^0|W^1, M^0)$$

and for the equivalent variation

$$M^0 - E = M(W^1|W^0, M^0).$$

A.5 ON THE EVALUATION OF THE SOCIAL BENEFITS FROM IMPROVING VISIBILITY

The following paragraphs contain several thoughts on the evaluation of the social benefits from improving visibility. Information on the reaction of the public to improved visibility came in two ways. One was via personal interviews out of which the willingness to pay for improvement were found. The second was the result of analyzing aggregate behavior and participation in specific activities (secondary data).

Analysis of willingness to pay data explains differences in the magnitudes of bids (given the same "objective" improvement in visibility) submitted by different people. The explanatory variables are thus specific to the individual's socio-economic characteristics. Actually in order to find the total value of visibility (improvements) to the population of a certain geographic area the product of the mean bid by the population (or if the bid is per household by the number of households) is a good approximation for it. The parameters of the bid function are needed for a more accurate evaluation, given that either the distribution of the relevant population by the variables that affect the magnitude of the bid is non-symmetric or that the effects of these variables on the magnitude of the bid are non-linear. The two issues of non-symmetric distribution and non-linear effects required ground preparation of sampling a sufficiently large number of observations, a sufficiently wide spread of socio-economic characteristics and well defined representative areas for which the distributions of the population by the various characteristics are known. These requirements have been taken care of in the planning stage.

Analysis of secondary data usually uses environmental variables, including weather and visibility, to explain variation in the participation rate in a certain activity either over time or space or both. Analysis of these data yields the sensitivity of participation or the intensity of the relevant activity to changes in visibility. The following question is how to transform this information into a monetary evaluation of visibility. The present note is aimed at answering this question.

The Evaluation

The analysis of participation in an activity is aimed at explaining observed differences in participation over time i.e., between one day and another. One of the explanatory variables is visibility. If one agrees to the concept of a standard quality unit of the activity and that visibility is one of the components of the vector of characteristics of the quality then, ceteris paribus, a change in visibility changes the quality of a unit of activity, which implies a change in the number of standard units per unit of activity. Formally let a standard unit of activity j be defined by $(X_1^o, X_2^o, \ldots, X_n^o)$ where the X^o's are the quantities of each attribute of the standard (for simplicity we disregard the possibility of substitution). Let attribute n be visibility. Thus, if

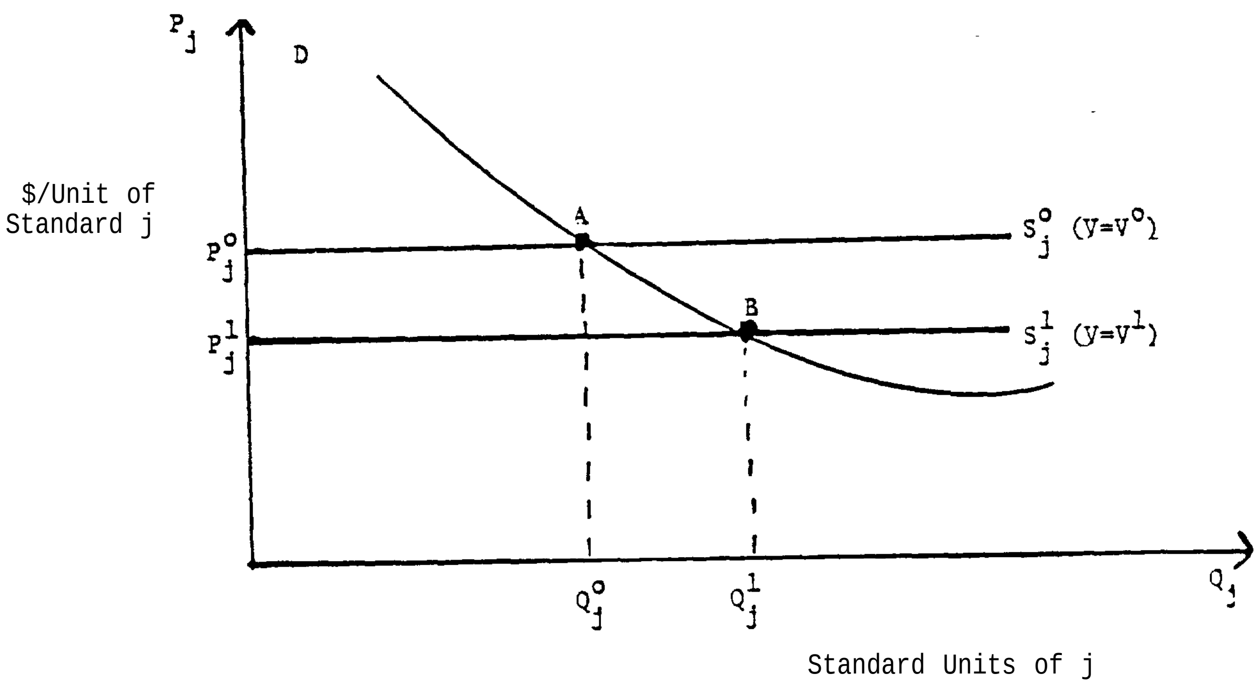
$$\frac{\partial(\text{Quality of activity j})}{\partial X_n} = \beta$$

i.e., the quality denoted by $(X_1^o, X_2^o, \ldots, X_n^o\ X^0 + 1)$ is 1+B larger than standard ized quality we interpret it as if it is equivalent to 1+B standard units of activity j.

The use of demand and supply framework to describe different market equilibria requires that the product (service) be homogeneous. Thus, when analysing observed participation in activity j the activity has to be transformed into homogeneous units - each at the quality level of the standard. If we assume that the activities people are involved in are not Giffen goods, then, aggregate demand for each activity is downward sloping in the quantity (of standard units)-price per units of standard quality plane. Furthermore, as long as socio-economic characteristics and population size are constant, demand is stable.

Assuming that visibility is a positive attribute and that the quality - quantity transformation into units of standard quality is at a one to one ratio (as formulated above) then a change in visibility can be viewed as a change in the average cost of supplying standard units of activity j. Hence, if for the relevant range of participation in activity j the average cost of supply is assumed to equal the marginal cost of supply, i.e., they are identical and horizontal in the quantity price plane, an improvement in visibility implies a downward paralled shift of the supply curve (Figure 1).

FIGURE 1



Let the elasticity of demand for activity j be η_j then, due to improved visibility from level V^0 to V^1 if the observed change in consumption of standard units was ΔQ_j the implied decline in cost of production is $\Delta P_j / P_j = \frac{\Delta Q_j / Q_j}{\eta_j}$. The social gains due to the improved visibility equal the area $P_j^0 AB P_j^1$. At this stage two problems are encountered. The first is that the observed Q_j is not in terms of standard units but in units which are unadjusted for quality. Thus, if we use changes in participation rates due to improved visibility as a measure for the change in standarized quality units, ΔQ_j is underestimated and also $\Delta P/P$ is underestimated. Secondly, the average cost of production of a standard unit at different levels of visibility is unknown and likewise the demand elasticity for standarized units is usually unknown. To overcome the second difficulty, studies on the demand for various activities can be consulted. However, none of the estimated elasticities is for a standarized units of activity. Thus, in the following an approximation is suggested. The outcome is obviously an underestimation of the social value of improved visibility. Hence, when defending it, or similarly, advocating public action to improve visibility we are on the safe side.

Let's return to Figure 1. Consider a demand elasticity of unity and regard observed changes in participation rate as changes in quality-adjusted units of activity j. Thus,

$$\Delta P/P = \Delta Q/Q \text{ and } \Delta P = \frac{\Delta Q}{Q} \cdot P,$$

where Q refers to calculated participation at average annual visibility.

One can calculate the value of P when a "regular" (non-standard) unit of activity j is purchased (e.g., value of travel time, automobile costs, parking costs, entrance fee). The social benefits of improving visibility from V^0 to V^1 are approximated by

$$(Q_j^o + Q_j^1)\ \Delta P/2\ .$$

A very conservative value would be just $Q_j^o \cdot \Delta P$, and an inbetween value

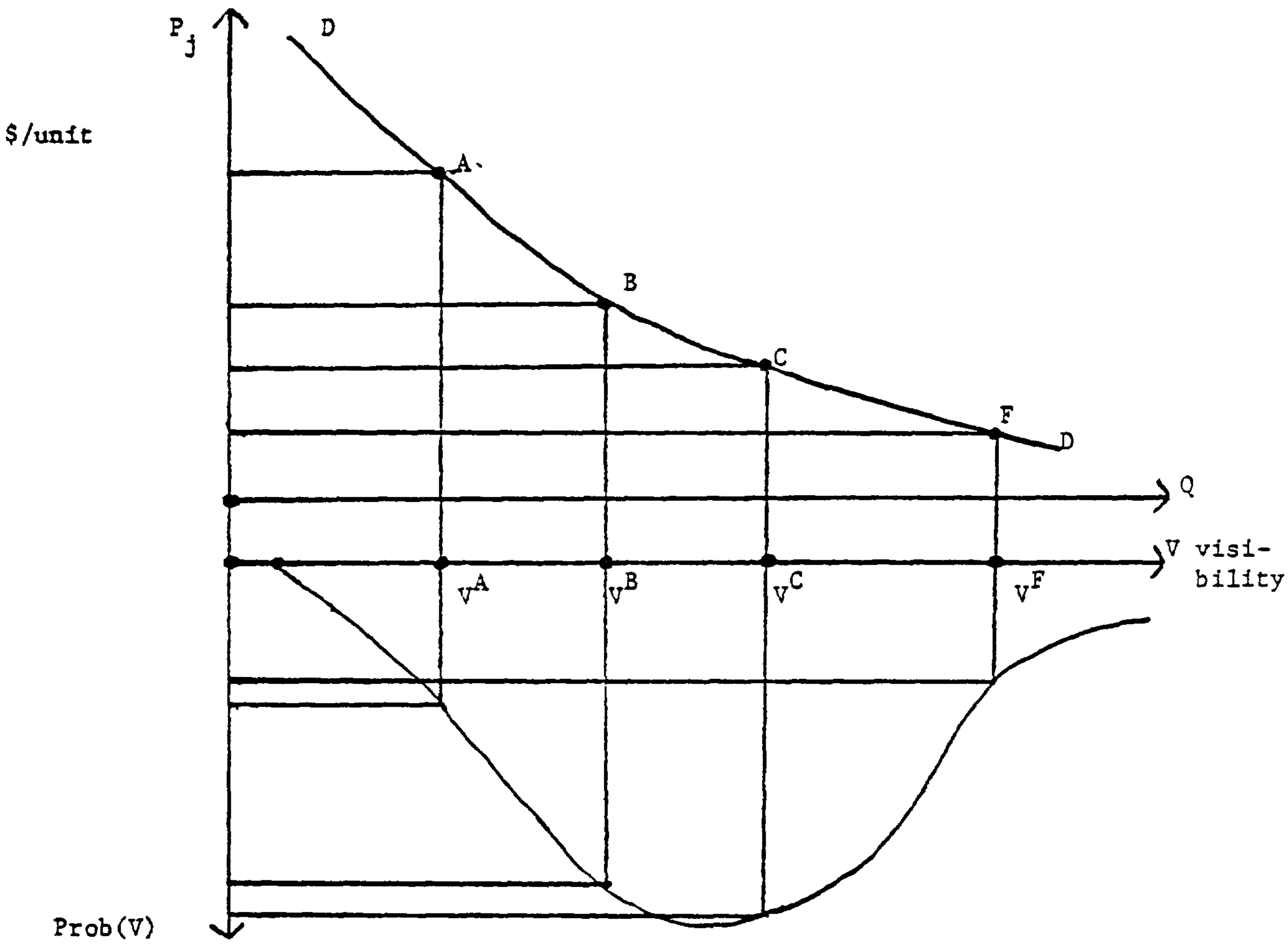
$$(\frac{3}{2}\ Q_j^o + \frac{1}{2}\ Q_j^1)\ \Delta P/2.$$

Note that the values of Q_j^o and Q_j^1 to be used are those calculated from the equation for participation in activity j, i.e., they are the predicted values $(\hat{Q}_j^o, \hat{Q}_j^1)$. Using the variance covariance matrix of the estimated coefficient, the variance of the sum $(\frac{3}{2}\hat{Q}_j^o + \frac{1}{2}\hat{Q}_j^1)$ can be calculated and confidence intervals constracted for measurement of the social benefits.

Generalization

Figure 1 can be augmented by adding to it the distribution of visibility over the relevant period of the year (e.g., for swimming May-Sept.)

FIGURE 2



Define an improvement in visibility as the shift of the distribution of visibility 1 unit (or 1 percent if the analysis of participation was done in a log-log model) to the right. The social benefits due to this improvement are equal to the sum of the areas of type $P_j^o ABP_j^1$ in Figure 1 weighted by the corresponding probability distribution of visibility. In a discrete formulation it is

$$\frac{1}{2}\sum_{i=1}^{m}\left[Q_j(V_i+1)-Q_j(V_i)\right] \cdot \Delta P(Q_j(V_i)) * \text{Prob}(V_i),$$

where i denotes a level of visibility (m levels are assumed). Also recall that

$$\sum_{i=1}^{m} \text{Prob}(V_i)=1.$$

As an approximation one can assume

$$\Delta P(Q_j(V_i)) = \Delta P(Q_j(V_i')),$$

where ΔP is calculated only once, at the average V.

Summary

The note suggests a common procedure for the evaluation of social benefits due to improved visibility when information on the effects of visibility on behavior is derived from activity participation rates. The method is based on various approximations. This is its weakness but also its advantage. It is relatively easy to apply it to various activities. In addition to the estimation of the participation function only the calculation of average cost per unit of activity is needed. The final outcome is already an aggregate value for the corresponding geographic area for which the participation was measured. We also argue that the various approximations lead to an underestimation of social benefits. Thus, they would not be refuted by more careful and sophisticated estimation-calculation techniques.

A.6 VISIBILITY AND ITS EVALUATION

In the following we discuss the concept of visibility, explain how different persons conceptualize visibility, and attempt to explain why different people bid different amounts of money for what is "objectively" the same change in visibility.

Visibility

The dictionary defines visibility in general terms:

a) The quality or state of being visible (the visibility of a navigational light)

b) The degree or extent to which something is visible, as by the clearness of the atmosphere

c) Capability of being readily noticed

d) Capability of being distinguished

e) Capability of affording an unobstructed view

The term visible is defined similarly:

a) capable of being seen
b) perceptible by vision
c) easily seen, impressive to the viewer

The conclusion one can draw from these definitions is that visibility is a subjective property assigned by the human mind via the eyes with or without the usage of visual aids (e.g., binoculars) to various capabilities all of which are related to vision. The capabilities usually emphasized are: the identification of objects at different distances at different levels of clearness, preciseness and brightness, the capability of distinguishing between different objects and between definite colors. With regard to colors a comparison with an "ideal" color takes place where the ideal is a subjective standard the individual has acquired and constructed given past experiences of viewing various objects under various environmental and topographical conditions.

Hence, the declaration that visibility is good or bad, improving or getting worse reflects differences between perceived visibility at a specific site, of a specific object, at a specific time of day and environmental conditions and the ideal visibility one has in mind as the numeraire. We might consider ideal visibility to be a constant for each individual but different for different individuals. Then experimentation with the same individual will yield a set of values all refering to the same base. On the other hand, experimentation with many individuals on one scene yields many values which however, are non-comparable, The reason is that they refer to different bases and different subjective perceptions of the same view by different people. Furthermore, differences between people's "ideals" and differences in subjective perception are not necessarily perfectly correlated, given the host of factors that affect perceived visibility and which affect different people differently. Thus, attempting to adjust for the unknown ideal base by using background socio-economic variables related to individuals does not necessarily transform statements of perceived visibility to a common base. On the top of this is the question whether we know what are the relevant variables that determine the standard of ideal visibility.

Following the various definitions and expectations from visibility it seems reasonable to conclude that visibility is not single dimensioned. It is composed of a set of characteristics or functions it fulfills. Hence,

$$V = [v_1, v_2, \ldots, v_n]$$

where v_i is the level of achievement of the aimed at function i. When an individual is shown a picture or is asked to compare two pictures from their visibility point of view we hypothesize that he is capable of classifying the difference for each i. Now let's experiment with him.

Show the individual a picture and ask him to rank the level of visibility it displays on a scale from 1 to 10. Then ask him to give it the rank he thinks the majority in the society would rank it. This first experiment would indicate whether the questioned individual has any particular attitude towards visibility that is different (and knows about it because of previous experience) from the average in the society. Then show the individual at least three sets of three pictures each and ask him to rank visibility within each set on the 1 to 10 scale. The purpose of this ranking is to quantify the perceived n dimensional vector into a single dimensional vector. (See reservation below.) An interesting test of the hypothesis that each individual has a different perception of visibility would focus on the distribution of the ranks given to the same picture by different individuals. Similar tests for different perceptions could be done on the differences in ranks given to two pictures.

For each set of pictures, following the order they were ranked from top down, ask the individual about his WTP per year in order to avoid deterioration of visibility from that ranked at top to that ranked second and then from that ranked second to that ranked third, and so on. So far, attempts to explain WTP data have employed conventional socio-economic characteristics and variables revealing an individual's attitudes towards the environment, recreation habits and intention to migrate. We hypothesize that the explanation of WTP data would be improved if the analysis also included as variables the absolute difference in the ranks given by the subject to the pictures, the rank given to the "best" picture, and the difference in rank for the picture evaluated by the subject for himself and for society.

To be more explicit we postulate that the absolute difference in ranking affects WTP positively (it quantifies the difference in visibility). The rank given to the "best" picture captures the particular evaluation of the entire set. (If the best already ranks low there is little to expect to be paid for avoiding further deterioration - no use, or, maybe high payment - increasing marginal disutility.). We suggest that the ranking of visibility on a 1 to 10 scale be part of the questionnaire and the ranks be used in explaining the bids.

More on Ranking and Valuation

When the individual is asked to rank visibility on the 1 to 10 scale we actually ask him to apply his personal weights to each of the n attributes in the visibility vector. Hence the rank by individual j is:

$$s_j = \sum_{i=1}^{n} w_{ij} v_{ij} \qquad\qquad s = 1, \ldots, 10.$$

Given the idea of an individual ideal standard

$$v_{ij} = \bar{V}_{ij} - V_{ij}$$

where $\bar{V}_{ij}$ is the ideal, and V_{ij} the perceived. The final rank assigned is thus a weighted average of the difference between the ideal and the perceived. If we could be sure that the individual is consistent with regard to the weights he uses, the experiment suggested above would permit the explanation of WTP for visibility. However we doubt this consistency. In particular it is uncertain whether the w_{ij} are constant for individual j or are a function of the circumstances of the experiment i.e.

$$w_{ijt} = w_{ij} (\mu_t).$$

$w_{ij\,t}$ is the shadow price (value) individual j attaches to attribute i at the circumstances prevailing in t. This leads us into the issue of the determination of shadow prices.

It is commonly accepted that visibility is used as an input in the production of consumer goods i.e., visibility enters into the utility function only indirectly via consumed goods. The representation of visibility as a vector of n attributes implies in the present context that each of the attributes is an input. Thus, there are production processes for which only specific attributes are needed, while others do not affect output - the quantity of the consumed good. In other cases all attributes are employed in production or might be capable of substitution -- one for the other. In general visibility is a free good, but it is indivisible and its quantity predetermined exogeneously. Using our previous terminology, at state t (stands for time and location) the level of the attributes v_i are given, $\bar{v}_{it}$. Since everybody can enjoy the same attributes (they are a free public good) they are not traded and in particular can not be substituted one for the other in the market. The individual takes these given quantities and employs them in the production of the consumed good or service (e.g., watch a boat race on the lake). In the production process other inputs, some which are tradeable, can be employed as substitutes or complements to the visibility attributes or human eye whose characteristics are not good enough (e.g., glasses, binoculars, standing on a high building). For different activities (production of consumable services), different attributes of visibility are needed to a different extent. E.G., if one is watching boats on the lake the distance attribute is most important and next to it the capability of distinguishing among colors. When visiting the Brayce National Park color contrast is more important than the capability to see a long distance. I am using the term important to stand for the economic term MUP = MP * MU -- the marginal utility product. (Recall the similarity to MRP -- marginal revenue product, which is the product of MR and MP.) The units of the marginal utility product are of utility ($MP_{vi} = \frac{\Delta \text{ units of service } x}{\Delta \text{ unit of attribute of visibility } i}$' $MU_x = \frac{\Delta \text{ units of utility}}{\Delta \text{ unit of } x}$. Hence, $MUP_{vi} = \frac{\Delta \text{ units of utility}}{\Delta \text{ unit of attribute of visibility } i}$).

In the process of producing service x, more than one attribute of visibility is employed. (It may be that attribute i + 1 improves the quality of x that is produced using attribute i. This change in quality affects utility and thus can be expressed similarly.) Thus, the weights the individual assigns to the various utility attributes when we ask him to evaluate a certain visibility on the 1 to 10 scale are the MUP's that are particular to the view we show him and circumstances at which he sees it. Thus, the same individual will assign different w_i per unit of attribute i under different circumstances.

Furthermore for the presumably same view different people will assign different w_i per unit of v_i simply because their personal production function differs and utility differs; thus their MUP_{vi} differ.

When an individual is asked to rank visibility he calculates the values

$$\sum_{i=1}^{n} w_i^k V_i^k \text{ and } \sum_{i=1}^{n} w_i^l V_i^l$$

where l and k are the same picture at two different levels of visibility. We traditionally assume that

$$w_i^k = w_i^l \qquad i = 1,\ldots,n$$

Thus the difference on a one dimensional scale is

$$\Delta s = \Sigma w_i (V_i^k - V_i^l) = \sum_{i=1}^{n} w_i \, \Delta V_i$$

Thus when asked about WTP the relation is

$$WTP = f(\Delta S, y)$$

where y is all other variables affecting WTP.

Two different individuals would thus bid differently even if their preceived ΔV_i are the same if their w_i differ. I suggest that by asking the individual to scale various picture on the 1 to 10 scale we get a good approximation for his ΔS and thus our explanation for the WTP would improve. A difficulty arises if $w_i = f_i$(some elements contained in y). This can be checked by relating ΔS (and also the scale he assigned the best picture we showed him) to all the elements we consider to constitute y. (A multiple regression would do this job.).

Conclusions and Preliminary Remarks for the Eastern U.S. Study.

The main argument put forward in the discussion is that visibility is multi-dimensional; that the importance of each dimension depends on the specific scenery; that judgment of changes in visibility depends among other things on the standards people get use to and to what each vector of visibility attributes is compared to.

In order to better understand the WTP declared by people (without currently reflecting or suggesting changes in the various questions in the questionnaires) we have to get a better idea of the quantification of perceived changes in visibility. One simple reason for that need is that declared WTP is a second stage quantification of visibility after applying to differences in attributes weights that are dependent upon the process of producing viewing services and output in the individual's subjective utility function. Without knowing the basic information how could we explain the outcome?

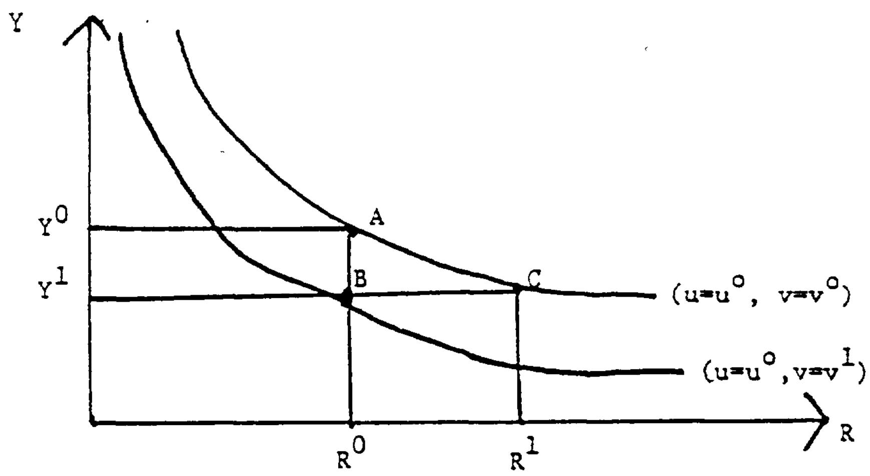
The issues raised above are magnified once the area over which the planned improvement of visibility is widened to the extent that the individuals questioned are not familiar with all available views. The possible extention carried out by individuals can be in either of two directions. The first is a mere extrapolation i.e., given that the extended area is k times the area previously questioned, willingness to pay is k^{α} times the previous payment where $0 \leq \alpha \leq 1$. Another way is more sophisticated and can be expected only from people that are familiar with the area. They attempt to apply specific weights to various scenes and then aggregate over the scenes. Both procedures are probably inadequate, implying that any extrapolation is likely to yield WTP which would be difficult to explain. Thus, the alternative of sampling different people at different locations for different vistas and then aggregating over them seems to be the preferable way.

A.7 VISIBILITY AND OUTDOOR RECREATION ACTIVITIES: A RESEARCH FRAMEWORK

In this study we attempt to outline the value of visibility in outdoor recreation activities. The underlying idea is that there is an alternative cost in addition to the direct cost and that these costs and visibility are the inputs in a production function that provides the consumable commodity - the Becker approach (1965). This approach is compatible with that in which the "production" phase is by-passed and the utility function contains two arguments that are related to the recreation activity: a quantity measure which is a function of the cost and a quality measure which is a function of visibility. The two are substitutes in the sense that one can compensate for the other along an indifference curve. Yet we emphasis the assumed assistance in increasing utility by letting the second cross derivative of the utility function be positive. This second approach is in line with Maler (1974), but is somewhat more general since it does not necessarily require the quantity of the recreation activity to take either of the two values 0, 1.

Visibility Value One Activity

Assume that the expenditure on the recreation activity, R, is variable and positively related to the quantity of services obtained (seat in the stadium, length of stay on the tennis court or golf course). There is another consumption good which we refer to as income. Visibility affects only the utility from the recreation activity. Visibility does not have an explicit market price and it is a public good. If we could have a three dimensional space, an indifference curve map would represent the tradeoffs between income, quantity of recreation and quality of recreation. We use a two dimensional space. Thus over each indifference curve both the level of visibility and of utility are constant. Individuals' total income is Y.



The observed relationships are

$$u(\bar{Y} - R^o, R^o, V^o) = u(Y^o - R^o - \Delta Y^o, R^o, V^1)$$

or

$$u(\bar{Y} - R^o, R^o+\Delta R^o, V^o) = u(\bar{Y} - R^o, R^o, V^1)$$

Hence ΔY^o is the compensating variation - while ΔR^o is the equivalent variation. Also both ΔY^o and ΔR^o might vary with $\bar{Y}, R^o$ and $V^o (V^1=V^o+\Delta V, \Delta V=$ Constant.) Similarly $MRS_{y/r}$ at A is not necessarily equal to that at B. They are equal if MU_y is independent of visibility $(R=R^0)$. The assumption that XU_R is independent of visibility is more difficult to grasp. One would expect it to increase with visibility. Hence given that the $MRS_{y/r}$ is MU_R/MU_Y one would expect $MRS^{(B)} > MRS^{(C)}$.

Empirical Implications

The purpose of the study is to get a quantitative measure of the values of ΔY and ΔR. If the two are obtained independently and one might expect the corresponding MRS to be aobut 1.0 (both are measured in dollars) then a check for consistency is at hand. Yet before approaching this task one should be aware of the fact that there are several recreation activities and they may be close substitutes. The individual behaves such that his utility from the allocation of the budget (full income) is maximized. Hence under unfavorable visibility conditions that affect the derived utility from a dollar spent on activity A by more than the utility of a dollar spent on activity B we might observe a corner solution with respect to A. This is more likely to happen if the cost per activity is of the form of a two-part tariff (fixed plus variable). Hence the "market" observations on the effect of visibility take two forms. One is the number of participants, the second is the intensity of participation. The situation is confounded if we realize that due to the time consuming input that each activity requires, participation is feasible in only one out of the set of available activities. Usually the length of time needed for consumption is disregarded in empirical demand analysis. Becker (1965) emphasizes its economic role by generating the full price, full income concepts. However the physical limit of time - two activities cannot be performed simultaneously-does not bear its importance in the Becker analysis. For an individual, this constraint leads to a bang-bang solution (either A or B). For the aggregate we expect to get different distributions of participates by activity for different visibilities given that the "reservation" visibilities differ for different persons.

For empirical investigation we collected data on one outdoor spectator activity - baseball - and one participating outdoor activity - swimming. For each activity the data needed were the attendance rates and the distribution of attendance by length or intensity. The intensity variable can be proxied by the quality of seat, which is positively related to the ticket price. Hence, following the model presented in the first section, one expects that the worse the visibility the better is the purchased seat. Yet several difficulties must be realized.

a) Seats are sold in advance. Thus the purchase is done under uncertainty with respect to the visibility at the day of the game. The larger the variance of visibility the higher the mean of the quality of seats sold. Given the seasonality of each of the games, unless cross-sections-over-cities data are collected the variance effect is undetected.

b) The individual decision making model does not account for externalities. In the framework of our discussion these will be reflected in congestion and by "all seats of quality 9 are sold" which are due to capacity limits of spectators recreation locations. Thus, if capacity is reached the distribution by quality of seats is invariant to visibility.

c) For spectator activities the demand for attendance and the distribution of seats are not independent from the competing teams. While one of the teams is always the home team the other team varies. Data for more than one season are needed in order to estimate an unbiased effect of visibilities on attendance and seat distribution.

The data referred to above are the "macro" data. In order to estimate the effects of the socio-economic characteristics of the population on the corresponding compensating variations and equivalent variation "micro" data are needed. At this stage, we do not discuss the specific contingent valuation instrument but would like to raise one point: the ex ante vs. the ex post values. Ex ante refers to before the game and thus before the actual effect of visibility on the utility derived from the game is observed. Ex post refers to the after-observing-and-experiencing effect of visibility. In the ex post case more information is available and thus the $\Delta\hat{Y}$, $\Delta\hat{R}$ are better representatives of the CV and EV. Yet the whole experiment of valuing visibility has an ex ante nature.

A.8 THE DEMAND FOR VISIBILITY SERVICES

In this section we measure the economic value of an aesthetic characteristic of the environment as revealed through the demand for a private and priced service. Specifically, we estimate a site specific valuation of visual air quality by estimating the demand for access to views at a major observation deck in Chicago. Unlike alternative methods for the Valuation of environmental services, the method examined requires no extensive primary data collection. Day to day variation in vistation and visibility permit an estimate of aggregate demand.

The salient unorthodox feature of the demand analysis is that neither an explicit price of the service, nor income nor wealth of the demanders are explicit variables in the model. For the price of the service we substitute a variable that is presumed to be perfectly correlated with the true price variable. Because the time period examined is so brief, income can be assumed to remain constant. While the outcome is but partial valuation of visibility, we suggest that such analyses of observed behavior offer important corroboration to values derived through less conventional methods.

The Demand for Visibility

The purpose of this section is to describe the quantitative response at the observation deck to changes in visibility conditions. We thus defer theoretical considerations of utility and indirect utility functions which are a usual starting point for demand analysis. Instead, we specify the general aggregate demand function for that activity as a function of its price, income and the prices of substitutes and complements:

$$(1) \qquad q = f(P_d, I, P_1, \ldots, P_n)$$

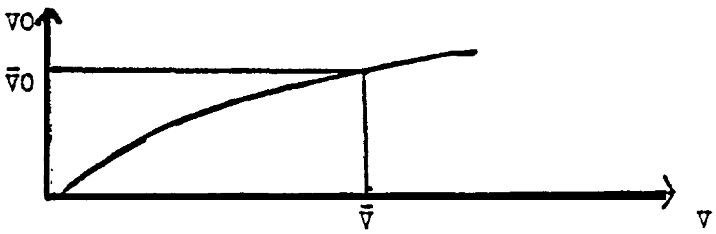
Insofar as q measures a quantity - visitation in a given time period -- the variables specified in (1) are defined somewhat differently from those in a conventional, demand study. Also on theoretical grounds, it is possible to find better definitions than the ones used here. However, the empirical orientation of the analysis leads to practical and observable definitions. For example, a more precise quantity variable would be the number of man hours per day spent observing. Correspondingly, an ideal price measure would be marginal cost per unit of time spent viewing, including relevant direct and indirect costs. Unfortunately, however, these two measures are not available. Instead, the quantity variable is represented by the number of people participating in viewing while the price variable is assumed to be the sum of all costs divided by the quantity of visibility services. These total costs are assumed to be constant across all users. The quantity of visibility services is the pivotal point of the theoretical model developed below.

For reasons of simplicity, assume that viewing from the tower observatory is in all directions and that the density of vistas is equal per unit of area regardless of the distance from the tower. A major input for producing visible objects is the visual air quality. This input can be measured by different dimensions, all of which are convertible to "distance of visibility." Eyes, too, are a necessary element in the viewing process. The natural characteristic of eyes are such that the further away is the object on which the eye focuses, the less clear is that object. Hence, adjusting the quantity of objects viewed by the quality of the view (similar to a discounting procedure except in this case with respect to distance) yields a measure of standardized visible objects, denoted VO, where,

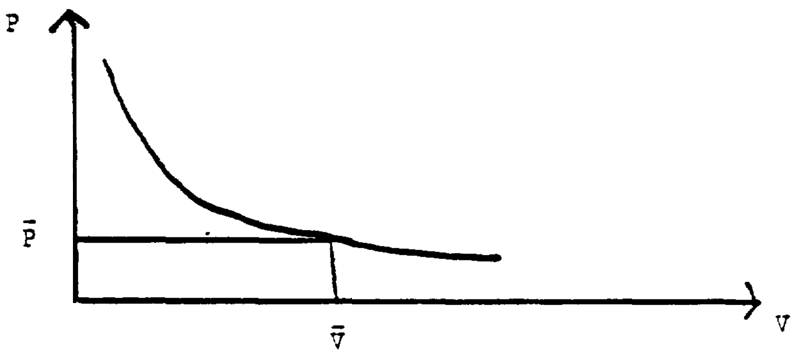
$$VO = \int_0^{\bar{V}} 2TYRe^{-p^R} = \frac{\pi}{2}\rho^2 \left[1-e^{-\rho\bar{V}}(\bar{V}\rho+1)\right]$$

where $\bar{V}$ represents the viewing distance allowed by air quality. Clearly,

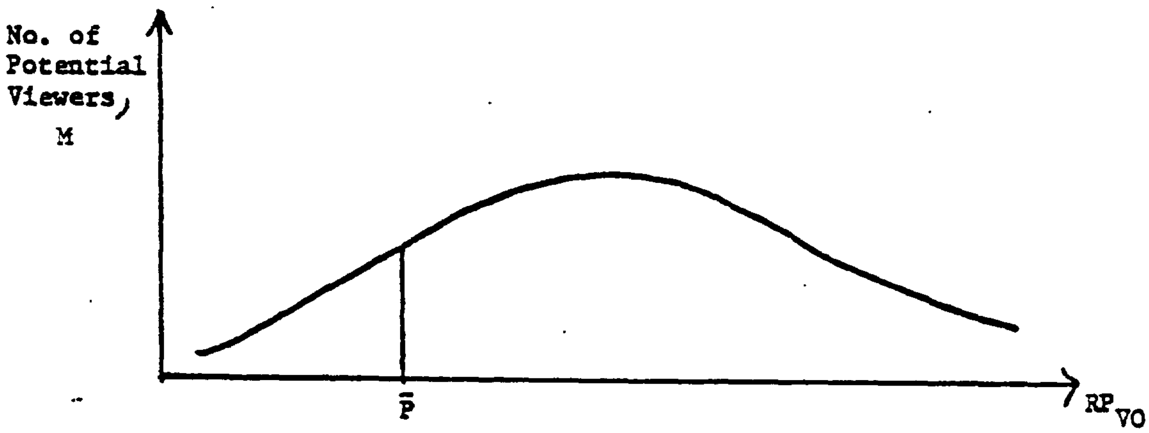
$$\partial VO/\partial\bar{V} > 0 \quad \text{and} \quad \partial^2 VO/\partial\bar{V}^2 < 0.$$



The sum of the entrance price charged by the observatory tower, the value of traveling time, and travel costs is assumed independent of visibility and is denoted TP hence, the average per unit of view is p = TP/VO, which is negatively related to VO. Given the above relation between VO and V, the figure below relates P to V.



We now rank the potential customers of viewing services by their reservation price per unit viewed. If this distribution is stable, then the lower the price per unit of view, the greater the number of people whose reservation price would exceed the actual price. Hence, visitation would rise and more would consume the services of the observation tower. $\bar{M}$ is the measure of the quantity demanded the number of visitors per unit of time.



Hence,

$$\bar{M} = \int_{\bar{P}}^{\infty} M(P)\,dP, \quad \text{such that} \quad \partial\bar{M}/\partial\bar{P} < 0.$$

The remaining elements in the demand function are the prices of substitures and complementary goods which are not built into the reservation price. Substitutes as a group would be comprised of all other recreational activities. We argue here that either the prices of alternative activities are constant over the analyzed period, i.e. are unaffected by changes in visual air quality, as for example, museums; or that changes in visibility affect their effective prices to a lesser extent than they affect the effective price of the services rendered by an observation tower. (This is another difficulty with valuing visibility in an urban setting compared to a National Park where only visual air quality at the time of visitation may be important.) Obviously, it is less costly to postpone or forego a trip than changing or canceling plans for activities that are highly time Intensive. Effective competition comes only from other towers in the area.

Assuming that increments in visibility affects V0 uniformly, the relative price between towers for visibility services is independent of the level of visibility. This implies a constant distribution of the consumers of observation tower services over the various observation towers. Hence, changes in visibility conditions leads to equi-proportional changes in the demand for each of their services.

Model, Data and Results[1]

The basic model that has emerged from the previous section relates the number of visitors per unit time to air visual quality at the time. In order to get this "net" relation, the gross figures of visitation have to be adjusted for other variables that determine or cause variation in visitation. These variables include day of the week, season of the year, special events, holidays, and meteorological conditions other than visual air quality. The unit of time for which the participation rate is explained is: once a morning; once an afternoon; and once the entire day (which in some sense accounts for substitution among activities during the day),

Substitution over time may take another form - that of substitution

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[1]We are grateful to the management of the John Hancock Tower for providing us with the visitation rate by day for the last year and a half. For unknown reasons, the management of Sears Tower refused to provide us with comparable data.

between visiting days. This for of substitution is particularly likely to be found among visitors to the area. Normally, visitors plan to consume a bundle of services over their period of stay in Chicago. The exact timing of consumption of a particular service does not change the utility derived from the entire bundle nor from any particular service. Thus, not only will there be substitution between periods in a day, but also between days themselves. This implies that a relatively high demand might be observed in spite of poor visual air quality, if this day is the second or third in a row of poor visibility conditions. Along this line of reasoning, we see that consumers may indeed hasten their consumption of observatory services on days when air quality is high because of uncertainty about the quality of visibility over the next day or two.

These substitution effects, both forced and planned, obscure the interpretation of the coefficient of visibility in the demand relationship from the point of view of the calculation of the social costs of low visibility in an urban area.

The estimated model is that of a linear least squares regression, where specific attention is paid to its the series nature. The model is

Model 1: $Y_t = X + X_t \beta + z_t \gamma + \varepsilon$

Yodel 2: $Y_t = X_t^{\beta} e^{(\alpha + Z_t \gamma + \varepsilon)}$

Y_t = number of visits to Hancock Tower on visit day t, t=1,...,N

A visit day may be defined in the following ways:

Y_{t1} = number of visits in A.M. hours

Y_{t2} = number of visits in P.M. hours

Y_{t3} = number of adult tickets sold during A.M. and P.M. periods combined

Y_{t4} = number of student tickets sold during day t

Y_{t5} = total number of visits by all groups during day t

Explanatory Variables:

X_{ti1} = visibility services during time period t_i

Visibility services will take either one of two alternative measures. The first will be simply visual range at the Tower. The second will be defined as the area of a circle determined with visual range as the radius discounted by the R^2 maximizing rate. That is,

$$X_{ti11} = V \text{ in miles}$$

$$X_{ti12} = \frac{\pi}{2\rho^2}\left[1 - e^{-\rho v}(\rho v+1)\right]$$

(in log form the $\frac{\pi}{2\rho^2}$ will be dropped)

In addition, two lagged visibility variables will be included; the first wi11 be the appropriate V from the previous period and the second from two periods earlier.

Finally not introduced

Price of substitute

$x_{ti2} = P_I/P_e$ where P_I is a price index and P_e is the price of admission to the observation deck

$x_{ti3} =$,t=1,...,N = a time trend variable.

X_{ti4} = tourists in Chicago (conventions)

z_{ti1} = percent of sky covered at 9:00 AM.

z_{ti2} = rain (a zero/one-dummy variable)

z_{ti3} = cloud cover height in feet.

z_{ti4} = Temperature in degree Celsius (This effect might be non-linear)

z_{ti5} = a day of week dummy, either weekday/weekend or a dummy for each day of week.

z_{ti6} = holiday/ non-holiday, dummy variables

z_{ti7} = month or season, dummy variable. Eleven dummies or 3 for groups:

1) Dec., Jan., Feb.
2) Mar., April, May
3) June, July, August

Z_{t18} = special events dummy variable.

As described above, the model can be estimated in both levels and on a log-log transformation where the estimated coefficients can be interpreted directly as elasticities. The VO variable is entered as $^{1}/VO$ and the coefficient is invariant with regard to fixed costs and total costs TP. Hence the true coefficient is $\beta' = (\beta)(TP)$, where β is the estimated coefficient. In the log-log regression, TP can be disregarded as well as $\pi/2_p^2$ (they become part of the constant). The estimated coefficient can be, however, interpreted directly as the elasticity of visitation with regard to price.

Current atmospheric conditions may affect visitation due to changes in visibility or through more direct effects on the costs or comforts and safety of urban travel. Past atmospheric conditions may alter current visitation through effects such as snow and ice accumulations. The degree of cloudiness or sunshine may also effect the pleasantness or unpleasantness of outdoor travel or recreation.

On first trial all the mentioned atmospheric variables were introduced into the estimated equation. Given that both visibility and atmospheric conditions are introduced with lagged values, multicollinearity is likely to show up. If one uses the rule of thumb definition of multicollinearity, that is, "correlation among the independent variable," then it is very possibly present in our study as such responsible for the relatively high standard errors of estimated coefficients.

As is apparent, the variable of greatest interest is visibility services, VO. Denoting the coefficients of X_{1it}, X_{1it-1}, X_{1it-2}, by β_o, β_1, and β_2, a program that stabilized visibility at a steady state implies elasticity of visibility with respect to visitation of β_o, β_1, β_2.

Deducing the Value of Visibility

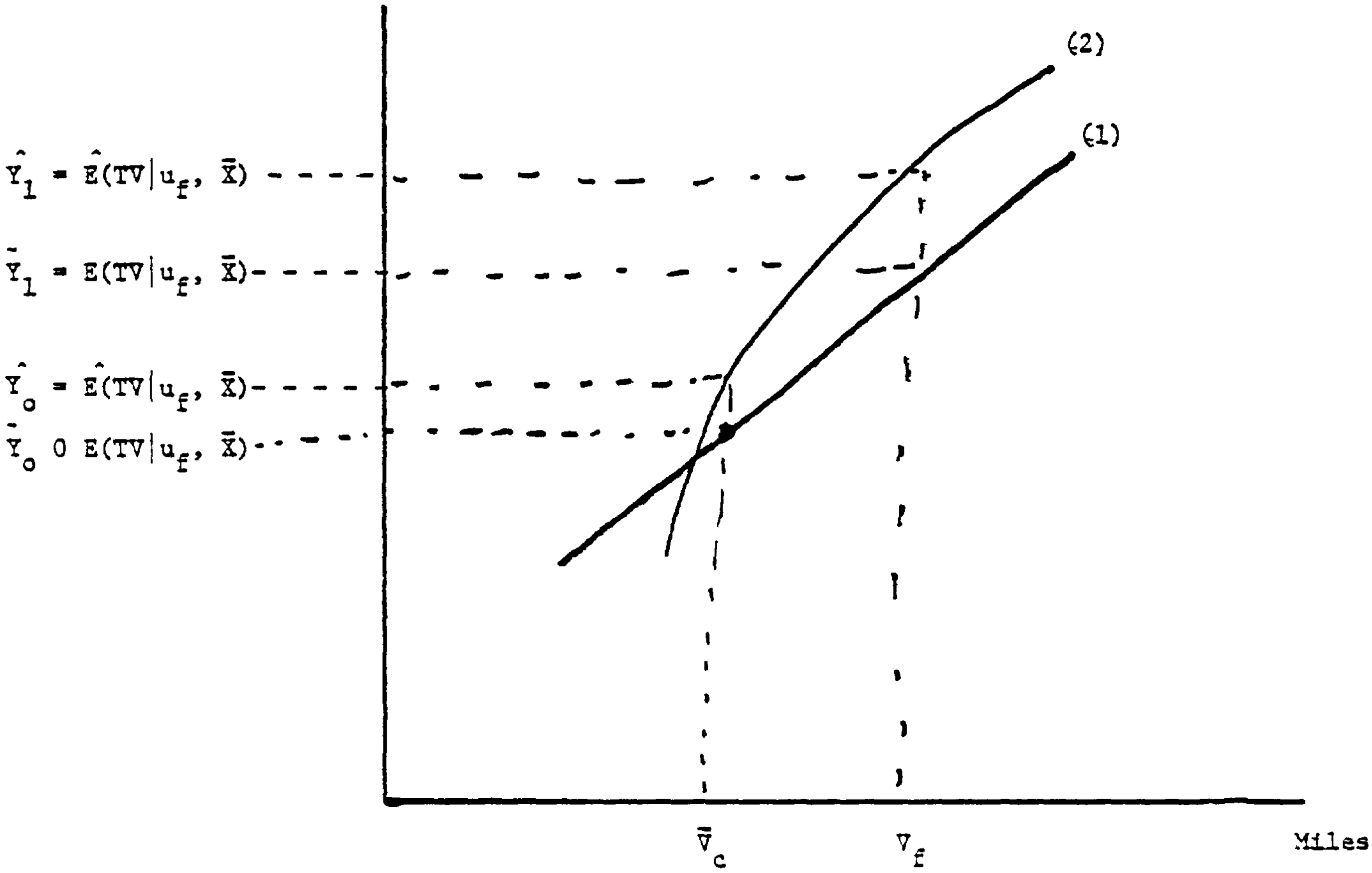
The models estimated above quantify the response of visitation with regard to visibility services and other independent variables. Evaluating the visitation response equations in the admission price/total visitation plane, one can examine the demand for admission to the Tower.

Visibility services resemble a pure public good where consumption by one individual leaves unaffected the amount of service remaining for the consumption by another. Hence, to value visibility services, a total value equation is of interest.

The total value equation is estimated by evaluating the visitation response equation at mean values of independent variables and then multiplying the result by the Tower admission price (Figure 1). Total value curve (1) results from evaluating estimated equation (1) at various levels of visibility and mean values of other independent variables. Total value curve (2) results from evaluating estimated response curve (2) in the same manner. As shown in Figure 1, the non-linear total value relation yeilds a slightly higher value of Tower services at current visibility level V_C. To estimate the daily value of a change in visibility services at the Tower, one need simply calculate the change in total value. For example, if policy

Figure 1

Visibility and the Value of Visitation



is presumed to shift typical visibility from V_C to V_f, then the value of this shift in terms of services at the Tower would be $\hat{Y}_1 - \hat{Y}_0$ in the case of the non-linear total value curve or $\hat{Y}_1 - \hat{Y}_0$ in the case of the linear total value curve.

In terms of a total valuation of a policy change, present value estimates are biased downward. First and perhaps most obviously, the present value estimates are site specific and only consider the change in value due to services viewed from a single site. To approximate a site valuation total, a study would identify all important sites within the area affected by policy and then total the effects of a policy induced change over all sites.

A second important reason for undervaluation conceptual. As visibility rises, an individual's reservation price is also likely to rise. However, admission price does not change and individual's already viewing Tower services at the initial level of visibility would realize an unmeasured gain in utility. In Figure 2, this gain is demonstrated. At visibility level V_C and income level Z_0, an individual realizes a utility level u_1 by paying price p_e and visiting the Tower. However, if visibility rises to V_f, the same individual by paying the same price p_e can realize a utility level u_2. Given an initial situation (Z_0, p_e), the individual would be willing to pay up to $8.00 to realize this gain. Hence, the estimated total value functions overlook 6 for each individual who would pay p_e at visibility level V_C and estimate only the value due to additional patronage. For either increments or decrements in visibility from $\bar{\bar{V}}$, then, the total value curves will tend to underestimate willingness to pay.

A third reason the valuation of visibility may be downwardly biased is due to the definition of the dependent variable. As simply the aggregate visits to the Tower, the dependent variable does not account for variations in the amount of time an individual may spend at the Tower. If each individual spends the same amount of time at the Tower regardless of visibility then obviously this specification error is not a problem. However, if time spent at the observation is positively related to visibility, then by disregarding this relation, the total value specified as above may tend to underestimate the effect of visibility.

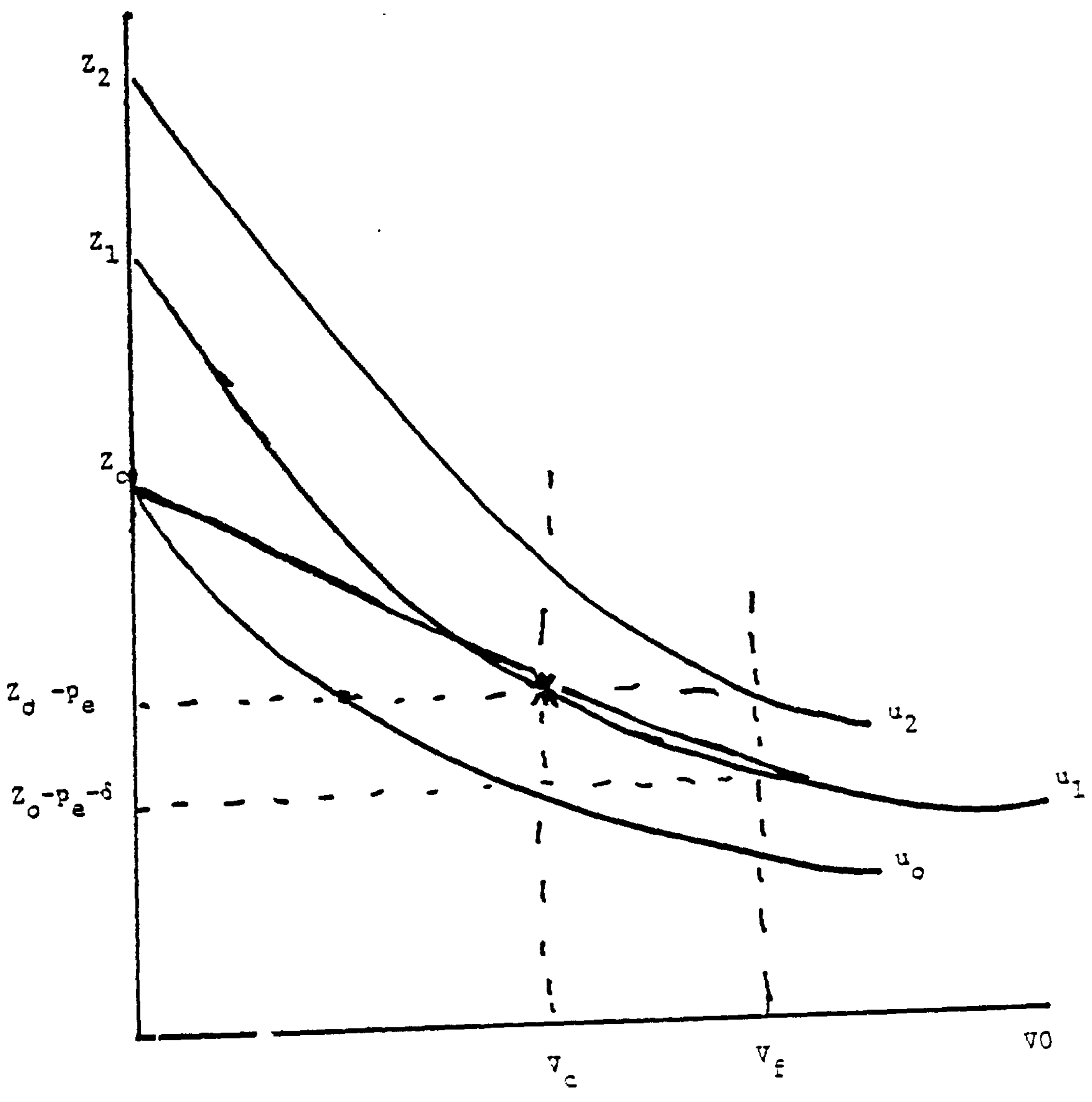
Depending on the precise relation between visibility and time spent viewing, the effect on the valuation procedure may be minimal. For example, let price be defined as a function of time spent viewing. Specifically, let the relevant price be the price per unit of time spent viewing and let this price therefore be calculated as total costs including opportunity costs divided by the time spent viewing at the Tower. Given that time spent viewing at the Tower is presumed to be increasing, then we might assign the following relation:

$$h = h_o V^{\alpha}$$

where h is time spent viewing, h_o is some minimum input of time, and V is visibility. Then the price of viewing per unit of viewing time is:

$$\begin{aligned} p &= \frac{wh + \bar{c}}{h} \\ &= w + \frac{\bar{c}}{h} \\ &= w + \frac{\bar{c}}{h_o} V^{-\alpha} \end{aligned}$$

FIGURE 2



If another leisure activity and not work is the alternative to visiting the observation deck, then w equals zero and the coefficient of V in the estimated equation (1) is an estimate of α. In so far as the functional form chosen for f(V) seems general enough as an approximation, estimates of total value with respect to V do not seem to be seriously affected by the present specification of dependent variables.

A.9 THE EFFECTS OF VISIBILITY ON AVIATION IN CHICAGO

Visibility affects the flow of air traffic in many ways. First, if visibility falls below 1 mile, all traffice must be under Instrument Flight Rules (IFR). This stops some general aviation activity for both flight training or recreation. Depending on the aircrafts equipment and landing systems at certain airports, operations may be legally continued down to 200 yards of visibility.

Another effect of lowered visibility is the delay of take-offs (TO) and landings. At low 1evels of visibility, a spacing of at least 1 mile must be maintained between aircraft. This greater spacing reduces the numbers of TO and landings that can be made. For instance, suppose that greater spacing delays each aircraft by one minute at O'Hare International Airport. Assuming that approximately 60 take-off's and landings are handled per peak hour of traffic, total operations are delayed overall by one hour.

Decreased visibility can also lead to accidents or near-misses by contributing to either pilot or air controller error. Lowered visibility can cause incoming flights to divert to other destinations causing delays to those on board and imposing additional aviation and ground transportation costs.

Economic Modeling

The object of this section is to provide a framework for valuing visibility. First consider the effects of visibility on TO or landing operations at a given airport. For commercial air carriers the effect of visibility on the actual number of flights is expected to be quite low. This is because they generally operate at the best equipped airports and with the most sophisticated equipment. The effects of diminished visibility on general aviation are not so clear. First, when the visibility falls below 1 mile, all VFR flights stop. Prospective flyers must then decide whether they wish to fly IFR or postpone their trip. If IFR is chosen, pilots must be IFR rated and have properly equipped aircraft. Given these observations, it is an a priori expectation that lowered visibility would decrease the number of flights. However, this a priori notion may be obviated by the fact that flights is may not be cancelled but merely postponed until the visibility increases. Weather forecasts are available to pilots from which they can make decisions on postponement or cancellation. If early morning visibility is expected to improve within a short time, departure may only be delayed within a day and hence within the period of observation.

The flexibility of departure tine form the basis for an intertemporal optimization-of-utility model. The pilot/traveler decides when to leave given visibility, general weather conditions and expectations of future weather in order to maximize utility gained from the trip. By the nature of the intertemporal trade-off the value of a trip declines as it is put off, but the increased visibility gained by waiting may add more present value than the cost of waiting. Consider the folowing intertemporal choice model under perfect foresight:

Choose t so as to maximize

$$U(\underline{Z}(t), X(t) \mid V_t, V_{t+1}, \ldots, V_N, \underline{W}_t, \ldots, \underline{W}_N).$$

U is utility which is a function of the trip X, which varies in value over t (hence X(t)). $\underline{Z}_t$ is a vector of quantities of other goods. V_t,

$V_{t+1},\ldots,V_N$ are the known future visibility values and $\underline{W}_i$ is a vector of weather related factors other than visibility. Now, consider the function

$$\left\{X(t)\,|\,V_t, V_{t+1},\ldots,V_N, \underline{W}_t, \underline{W}_{t+1},\ldots,\underline{W}_N\right\}.$$

The value of $X(t_0)$ is 1 when t_0 is optimal, where optimal is defined by weighting the discounted values of $(V_i, \underline{W}_i)$. X_t is 0 for $t \neq t_0$. From this, a demand system can be derived.

Another model of visibility's effect on air travel considers the time delay caused by restricted visibility. As visibility is reduced, the space between aircraft must be increased, creating time delays. This line Of attack could allow a dollar value to be placed on visibility effects. Consider the following technical relationship:

$$TD_t = G(\psi(L)V_t, \underline{\delta}(L)\underline{W}_t, \varphi(L)\underline{O}_t).$$

Time Delay (TD) is a function of some lag function $(\psi(L))$ of visibility, a lag function of weather $(\underline{W}_t)$ and a lag function of some other factors such as mechanical breakdowns. The lag functions are included because these delays accumulate over time. From this equation, $\frac{\partial G}{\partial V}$ shows the effect of a marginal visibility change on the time delay. By making some assumptions on the value of passengers, a lower bound cost of visibility changes can be calculated.

Empirical Modeling

Consider estimating the first conceptual model of the effect of visibility on the number of flights. The currently available data consist of counts, the total number of takeoffs and landings by day at six local airports by class of aircraft. Weather data are also available. The equation to be estimated is

$$(1) \quad \log C_t = \underline{\gamma}\,\underline{D} + \alpha \mathrm{Log} V_t + \delta \mathrm{Log}\, H_t + \delta\, P_t + \varepsilon_t .$$

C_t is the count of total take-offs and landings at O'Hare. This variable's meaning is somewhat ambiguous. First, it cannot he determined how many aircraft left and returned on the same day, so the number of take-offs cannot be distinguished from landings. Another even more important problem is involved with determining the degree of intertemporal trade-offs. Since the data are for a twenty-four hour period, we cannot determine if decisions to depart were put off for periods less than twenty-four hours due to weather expectations. That is, after adjusting for seasonal and day of week effects, there may be little variation in counts attributable to visibility because all put off effects are very short run,

The vector $\underline{D}$ is a set of dummies to capture day of week effects. After viewing the data, differencing may be necessary to filter seasonal effects. V_t is visibility on day t and H_t is cloud height on day t, and P_t is a 0-1 variable for whether or not precipitation was present.

From this specification, $\hat{\alpha}$ is the estimated percentage change in counts for a one percent change in visibility. In order to place a dollar value on this effect, the average one hour rental fee in Chicago, for a Cessna 310, a small twin engine aircraft, may used. A lower bound estimate for the daily cost of a one percent decrease in visibility is $\hat{\alpha}$ multiplied by the average count per day multiplied by the average aircraft cost. This represents the average cost of increased visibility to someone planning to take a trip and cancelling or postponing. Clearly, this represents a lower bound for the actual cost incurred.

The other method of deriving a value on visibility uses time delay data. By estimating the technical relationship,

$$\text{Log}(TD_t) = \underline{\gamma D} + \psi(L)\log V_t + \delta(L)\log H_t + \varepsilon P_t + D_t,$$

the relationship between V_t and TD_t can be found. Again, $\hat{\psi}$ is the percentage change in TD induced by a one percent change in V, Two pieces of data are now needed. First, the mean number of passengers effected by a time delay and, the value of each passenger's time. By assuming reasonable values for these two factors a lower bound for the cost of time delays due to decreased visibility can be estimated.

Another method of deriving the value of visibility deals with the idea of diverted flights. As was previously mentioned, if flights are diverted due to low visibility, the aircraft passengers have a cost imposed on them. Also, the original destination loses revenue from landing fees, hanger and fuel charges and, the city of destination loses the revenue the passengers would have spent. One way to derive this cost is to look at flight plans filed with the FAA. The number of diverted flights due to low visibility can he found, as well as the number of flights diverting to Chicago due to low visibility elsewhere. This can also be done for flights going to different Chicago airports. If Meigs is socked in by low visibility then incoming flights may divert to Midway, which means that Midway then benefits from Meig's loss. The problem with this analysis is mostly in the expense of gathering data.

At this point, it seems relevant to discuss, relationships across airports. Each airport has a different schedule of landing fee rates. There are also non-pecuniary costs differences across airports due to varying congestion levels. Each airport offers a different bundle of services. There are two major services to be considered. First consider an airport's location to be an input to producing final services; i.e., that of getting the passengers to their final destination. An airport will be chosen so as to minimize transportation costs from the passenger's point of origin to their final destination. A second service or set of services acts as a constraint to this decision. This constraint is in the form of having a runway long enough for the aircraft chosen and the proper landing system given the prevailing weather.

In choosing which airport to fly into, the passenger or pilot chooses that which is most easily accessible to the final destination given that it can be used in the current weather. If Meigs is closed, the flight may divert to Midway. When viewed in this manner, at least for general aviation, the substitutability of airports is evident, as is the fact that the degree of substitutability is a function of the current weather. The third factor in determining the degree of substitutability is of course the prevailing landing rate structure.

A similar route selection decision may be made by passengers of scheduled air carriers. Clearly, for non-pilots and those who do not own aircrafts, the least cost alternative is usually a scheduled commercial flight. However, if time cost savings are substantial, the possibility of aircraft charter enchance the range of substititability. Such charter and nonscheduled flights may be particularly important at Meigs Field near down-town Chicago. However, at other airports and/or most commercial passengers, the cost of charter is likely to outweigh time savings.

Extensions

This section suggests how to extend analysis in ways which add precision to the estimates for visibility costs in aviation. First, consider the model for counts. As weather data for each airport location are collected, six separate equations can be developed in the form of (1). Estimating the six equations jointly adds information to the estimation procedure. The method of seemingly unrelated regression provides a straightforward way to proceed. Consider the following equation system

$$\log C_{i,t} = \underline{\gamma}_i \underline{D}_i + \alpha_i \log V_{it} + \delta_i \log \underline{W}_{it} + \underline{\varepsilon}_t \qquad \begin{matrix} t=1,\ldots,N \\ i=1,\ldots,6 \end{matrix}$$

This gives us six α_i's, one for each airport, each of which is estimated more precisely than in the six regressions run separately. So, a lower bound cost can be estimated for each airport and these costs can be aggregated to derive a lower bound visibility value for the entire area.

The other extension applies to the time delay model. Again, the residuals from the six separate regressions are correlated. By applying the seemingly unrelated regression procedure to that system of equations, a more precise time delay elasticity of visibility is estimated for each airport, and as before, more precise estimates of the cost of visibility are made.

A.10 VIEW PRIMARY RECREATION, THE HANCOCK TOWER

An urban resident or visitor is presented with a large number of opportunities to view the urban landscape and skyline. A great many of these viewing opportunities carry a price insofar as one must gain access to a private viewing site to enjoy a special vista. However, in very few of these situations is view-use recorded. For several reasons, urban observation points such as Hancock Tower offered an unusual opportunity to determine the effects of visibility on the demand for viewing services. First, the panoramic view offered by the Tower is particularly sensitive to changes in either visual range or color contrast. Second, an explicit price is charged for access. Finally attendance is recorded on a daily basis.

Various quarterly reports have described intital findings regarding the behavioral and revenue effects of visibility at Hancock Tower. Behavioral equations were refined and progress was made toward a site-specific valuation of visibility. This section provides an overview of the valuation strategy and presents some demand estimates for Hancock Tower services as a function of admission price, visibility and a set of additional demand shifters.

Unlike the common demand analysis which considers goods as divisible or at least capable of repackaging, a visit to Hancock Tower is more readily modeled as a discrete choice. That is, the utility maximizing individual purchases entrance to the Tower if the marginal quality weighted gains meets or exceeds the marginal cost or entrance price. The maximum an individual would pay, a reservation price p*, can be modeled analytically[1] and is, for the individual a function of view quality (q), income (y), other goods prices $(\overline{p})$, and visit cost shifters such as inclement weather conditions. That is,

$$p_i^* = p_i(q, y, \bar{p}, w).$$

In this reservation price context the individual chooses to visit the site if p* meets or exceeds the price of admission, p^0. Hence, the individual demand for admission to the site is a zero-one valued choice index π_i,

$$\pi_i = \pi_i(p^o, q, y, \bar{p}, w).$$

Furthermore, we hypothesize that reservation price rises with an increase in quality. For the individual whose initial $p_i^*(q^o, y, \bar{p}, w)$ exceeds the market price, Figure 2 illustrates the gain in consumers' surplus (CS) due the quality change to q^1. Clearly, an individual who does not visit either before or after the quality change gains no consumer surplus due to the view quality change at the site.

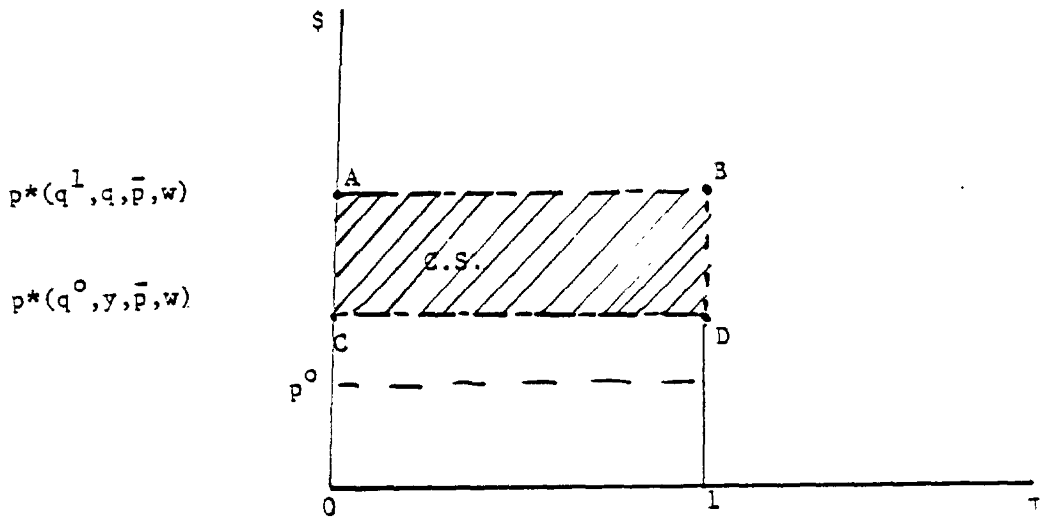


Figure 2

[1]When income is included, we are discussing the Marshallian demands. However, It can be shown that as the budget snare of a commodity approaches zero, as is likely in the present case, the Marshallian demands approximate the compensated demands.

Aggregate demand for access to the view at Hancock Tower is simple sum of individual demands. Hencs aggregate demand is considered a function of current Tower price, (p), view quality (q), income levels, other goods price, and the same weather variables (w) that affect individual choice. For given values of these variables, aggregate demand yields an attendance count. A particularly convenient functional foot for approximating aggregate demand is a modified Cobb-Douglas,

$$VST = Ap^{\alpha 1}q^{\alpha 2}q^{\alpha 3}t^{\alpha 4}a$$

where VST is the recorded number of visits for a particular day, A is a yet to be specified function of shifters, y is aggregate income, t is a time trend variable, and a is a lognomial error term. As steps prior to estimation, admission price charged at the Tower is deflated by a montly cost of living index and monthly real personal income for the U.S. proxies individual variations in income[2]. Other goods prices are not included explicitly in the analysis.

The shifter, A is specified as an exponential function of weather and time related variables such as day of week and seasonal cycles:

$$A = A(w,d,s)$$
$$= \exp(w,d,s)$$

where d are day or week dummy variables. The seasonal vector, s, may be specified as either zero-one dummy for south or as sine and cosine functions of period 365. In the current case with daily observations, the sine and cosine functions are better suited to fit the likely smooth day to day change of a seasonal cycle.

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[2]Both the cost of living index (CPI) and personal income are referenced in"Economic Indicator, January, 1980" and economic Indicators. Nov., 1980" prepared by the U.S. council of Economic Advisers.

For an initial specification of view quality, we reference recent work by Malm, et al., that seeks to develop tentative conceptual and empirical linkage between physical measurements and perceived view quality. The findings of Malm, et al., suggest that the relationship between perceived view quality, q, and color contrast, C_r, is linear:

$$q = AC_r$$

where A is a function of shift variables such as cloud cover, snow in scene, and time of day. Due to the tentative nature of the Malm, et al., view quality/color contrast relationship, it is convenient to allow a more general form. The function is generalized only slightly:

$$q = AC_r^\beta$$

where the relationship is linear if $\beta=1$.

Malm, et al., go on to note that

$$C_r = C_o e^{-rb_{ext}}$$

where C_o is the inherent color contrast of a viewed object, r is the observer's distance from that object, and b_{ext} is a monochromatic or wavelength weighted, spacially averaged estinction coefficient. Furthermore, the extinction coefficient is related to visibility, v , by

$$v = 3.912/b_{ext}$$

Hence, the initial relationship between color contrast and view quality can be transformed to one between quality, object distance, and visibility or visual range,

$$q = AC_o \exp(-\beta r(3.912)/v)$$

or in log form,

$$\ln g = \ln AC_o - \beta r(3.912/v)$$

For a given site such as Hancock Tower, it may he considered a weighted average of viewed object distances. Such a transformation for view quality is particularly convenient for in the log - log form of the VST equation, visibility enters as

$$\alpha_3 \ln g = \alpha_3 \ln AC_o - \alpha_3 \beta r(3.912/v)$$

where α_3 1nA becomes either a component of the intercept or is added to the effect of demand shifters such as snowfall and cloud cover.

Once final estimates of the VST equation are completed, consumers surplus due to view quality change or visibility change at the site can be easily calculated as long as $\alpha_1 + 1<0$, where α_1 is the exponent of own-price. Consumers surplus (C.S.) for a quality change from q^0 to q^1 is the change in area underneath the aggregate demand curve at q^0 minus the area underneath aggregate demand at q^1,

$$= \lim_{\bar{p} \to \infty} \int_{p_o}^{\bar{p}} A(w,d,s)\, p^{\alpha_1} q^{\alpha_2} q_o^{\alpha_3} t^{\alpha_4}\, dp$$

$$- \lim_{\bar{p} \to \infty} \int_{p_o}^{\bar{p}} A(w,d,s)\, p^{\alpha_1} y^{\alpha_2} q_1^{\alpha_3} t^{\alpha_4}\, dp$$

Once CS is calculated it may be accepted as an approximation to compensating variation or transformed to compensating variation by well documented methods.

Estimates of VST were obtained using a log-log transformation and ordinary squares. Suggestive results appear in Table 1. The dependent variable is the log of total duly attendance and includes all but one day from the period from January, 1979, through June, 1980. In considering these results, one may keep in mind that average daily attendance is approximately 950 persons and the average deflated adult price of admission is about $0.79 in 1967 dollars. View quality variables are specified in a manner consistent with the Malm, et al, results. IVISB1 and IVTSB2 are simply the first (VISB1) and second (VISB2) visibility readings (miles) at the Tower, inverted and multiplied by the constant 3.912. Average VISB1 is about 12 miles and average VISB2 is about 16 miles for the period considered.[3] Weather observations are for O'Hare International Airport and were obtained from the National Climatic Center. Independent variables other than IVISB1 and IVISB2 are:

RP	= Log of deflated Tower admission price,
PI	= Log of deflated personal income,
LT	= Log of time trend variable,
RA	= Proportion of weather observations per day recording rainfall,
SN	= Proportion of weather observations per day recording snowfall,
CL	= Proportion of sky covered in clouds,

[3] IVISIB1 = 3.912/VISIB1 and IVISB2 = 3.912/VISB2

HTCL = Height of lowest layer clouds in hundreds of feet,

WIN = Average day windspeed in knots,

TEMP = Average daily temperature in degree fahrenheit,

M,Tu,W,
F, S,Su, = Day of week zero/one dummy variable and

SNX
CSX = Sine and cosine transformations of period 365.

Examining the statistical results of Table 1, both the F value and R^2 are adequate. Estimated coefficients tend to have expected signs. The price coefficient is very significant, has the expected sign, and indicate the elasticity of visitation with respect to a price change. The income variable, RPI, has neither the expected sign nor is it statistically significant. Rainfall, snow, and cloud cover are each statistically significant, have expected signs, and are quite substantial in effect. For example, ceteris paribus, a full day of rain reduces visitation to about one third of what if otherwise would have been (exp(-1.035)=.35). Both of the visibility related view quality variables IVISB1 and IVISB2 are statistically very significant and each having the expected signs; that is, as visibility increases, extinction coefficients (IVISB1 and IVISB2) decline. As the extinction coefficient declines, view quality increases and visitation rises. Hence, the coefficients or IVISB1 and IVISB2 are negative. Coefficients on day of week variables indicate that visitation an Friday and weekends differs significantly from visitation on weekdays. Seasonal variables indicate a strong seasonal cycle with a peak in mid-summer and a trough in early January.

A.11 VISIBILITY, VIEWS AND THE HOUSING MARKET

Freeman (1979a) identifies three major approaches which can be used to estimate the demand for a public good such as visibility. These approaches are: (1) analyze market transactions for something related to the public good to estimate the implicit demand for the public good itself, (2) collect individuals' stated values revealed through a contingent market for the public good and (3) analyze jurisdictional provision of public goods, taxes and constituency characteristics. Some important contributions on the aesthetic value of cleaner air have been made using the second approach, contingent valuation, with Rowe et. al. (1980), Schulze et. al. (1980) and Tolley et. al. (1980), focusing specifically on visibility. As Rowe et. al. and Freeman argue, the demand estimates based on contingent values are useful, but they are hardly definitive because of at least some concern about strategic and induced biases. While Brookshire et. al. (1979) maintain that these potential biases are practically negligible and that contingent valuation is reliable, some doubts remain. There is no question that our understanding can be improved by exploring other approaches.

The purpose of this section is to consider the prospects of using the implicit market approach to estimate the value of improved visibility through analysis of the housing market. This section is organized in the following way. The next part provides the theoretical basis for estimating the demands for housing amenities through the analysis of implicit markets for amenities. Part III reviews the relevant housing studies of the demand for amenities related to visibility. The concluding part deals with what further insights can be expected from studies of the housing market and suggests a way of obtaining that additional information on the value of improved visibility.

II. The Implicit Market for Housing Characteristics

Even casual observation suggests that housing is heterogeneous commodity composed of various important features other than structural characteristics alone. These non-structural housing characteristics are sometimes categorized as: (1) publically-provided services which include schools, fire protection and garbage collection and (2) neighborhood amenities which include such characteristics as accessibility, serenity and air quality. The substantial contribution of neighborhood amenities to the total price of a house has been established by numerous studies including that by Krumm (1980). Tolley and Diamond (1982) is devoted entirely to the role played by amenities in residence site choice. Currently estimation of the demand for housing amenities related to air quality follows some variant of the implicit market approach suggested by Rosen (1974).

Housing is viewed as a bundle of traits consisting of not only structural characteristics but neighborhood characteristics and services as well. Households respond to the traits themselves and, if they cannot rearrange or repackage them to exactly suit their tastes, the configuration of traits as well. Households choose a bundle of housing located at a particular site having only incidental dealings in the market for land. Utility is maximized over housing and other goods subject to an income constraint. and an exogenous, through not necessarily linear, price function for housing. As described by Blomquist and Worley (1981), such a process yields demand equations for each of the housing traits where own-price, the prices of complementary and substitutable traits, income, and tastes are determinants of trait demand. Given that the housing hedonic function (the market price of housing as a function of the quantities of the various housing characteristics) is interestingly non-linear, the demand for any particular characteristic is not directly obtainable in that the housing hedonic equation is a market clearing function influenced by supply as well as demand conditions. See Freeman (1979b). In order to get trait demand, we must estimate the market clearing function, calculate the marginal trait (hedonic) prices, and use these prices along with income, other demand shifters, and whatever is necessary to identify trait demand, see Witt et. al. (1979). By finding the area under the estimated demand curve, we can estimate the benefits of amenity provision. This housing market approach, while not without the limitations noted by Freeman (1979b) and Smith and Diamond (1980), provides useful information on the value of improved amenities. These estimates can be compared to that obtained by contingent valuation.

III. Housing Studies of Amenities Related to Visibility

A great deal of effort is being devoted to measuring the demands for clean air and pleasing views -- two housing amenities related to visibility.

Clean Air -- Recent representative studies of the demand for clean air are those by Harrison and Rubinfeld (1978) who use Boston census tract housing and household data to measure the benefits of reduced concentrations of nitrogen oxide and particulate, Nelson (1978) who uses Washington DC census tract and household data to measure the benefits of reduced concentrations of particulate and oxidants, Brookshire *et*. *al*. (1979) who use household-specific Los Angeles area data to measure the benefits of reduced concentrations of nitrogen oxides and particulates, and Bender *et*. *al*. (1980) who use household-specific Chicago data to measure the benefits of reduced concentrations of particulate. Table 1 shows the benefits per household of improved air quality as estimated by Harrison and Rubinfeld, Brookshire *et*. *al*. and Bender *et*. *al*. Given that these measurements are accurate, the estimated benefits of cleaner air are an upper bound on the value of improved neighborhood visibility to the resident households. Benefits of improved visibility outside the neighborhoods and benefits of improved neighborhood visibility to non-residents are not captured.

Shoreline -- Further information on the upper bound on the value of improved visibility comes from the study of pleasant views. Brown and Pollakowski (1977) use the housing market approach to estimate the value of shoreline. The value of shoreline property would reflect the desirability of quick access to water-related activities and also the desirability of views associated with water-related open space. Using house-specific data for sale price and housing characteristics, they estimate the value of shoreline in Seattle, Washington. They find that a house located in an area near a 200 foot-wide setback area will sell for about $2100 more than a comparable dwelling near a 100 foot-wide setback and that a house near a 300 foot-wide setback will sell for about $3336 more than a 700 foot-wide setback (again using the CPI to convert to June 1980 dollars). This estimated value of shoreline is

TABLE 1

The Benefits of Cleaner Air

Study	Area	Dependent Variable	Pollutants	Average Annual Benefits per Household[a]
Harrison & Rubinfeld	Boston	Median property values from census tract data	Nitrogen Oxides and Particulate	$187 for reductions from auto emission controls (90% reduction in tail-pipe emissions)
Brookshire et. al.	Los Angeles	Sale prices of individual houses	Nitrogen Oxides and Particulate	$686 for combined reduction of about 30% in average ambient levels
Bender et. al.	Chicago	Sale prices of individual houses	Particulate	$593 for a uniform 20% reduction.

[a]Benefits are converted to June 1980 dollars using the Consumer Price Index (CPI). The estimates shown are the best point estimates, but each study should be consulted for ranges and qualifications.

[b]A 10% discount rate is used to convert the estimate to an annual value.

Source: Calculated from Harrison and Rubinfeld (1978, p. 92), Brookshire et. al. (1979, p. 131) and Bender et. al. (1980, Table IV).

relevant, but of limited usefulness for two reasons. The first is that the value of visibility and viewing cannot be separated from that of access to water and park-related activity. The second is that the methodology fails to estimate the demand for shoreline unless we make the heroic assumption that the housing hedonic equation reveals the demand directly. Harrison and Rubinfled (1978), Bender et. al. (1980) and Blomquist and Worley (1981) all find, with different data sets, that there can be great differences between any benefits estimated directly from the hedonic and those estimated more appropriately using a two-step procedure.

Pleasing Views -- Abelson (1979) provides more specific information on the value of visibility-related amenities. In his analysis of housing prices in the Rockdale section of Sydney, Australia, he considers two environmental amenities of interest: (1) view, which is measured subjectively as good, average or poor and (2) block level, which indicates whether or not the house is either on the top side of sloping street or built well above street level. Abelson relates that some houses have views overlooking the Pacific Ocean and that views vary greatly in quality. For all houses in the sample, the value of a good view over an average view is 1.7% of the average house price, and the value of a good view over a poor view is 3.5% of the average house price. The value of a house built on a high block level is 5.5% of the average house price. If Abelson's specification is correct, then a house with a good view built on a high level is worth more than a house with a poor view built on a non-high level by 9% (or 2160 Australian dollars in 1972-73). This substantial percentage of the total house price suggests that view-related amenities are important and that even though the value of visibility is less than that of the view, it may still be non-negligible. Another of

Abelson's findings indicates that the values of view and visibility increase with income. For the sample with only houses priced above the average, he finds the values of good views over average views, good views over poor views and a house built on a high block level all to be approximately twice those for the entire sample. Thus, visibility-related amenities make up approximately 17% of the total value for higher-priced houses. This finding is substantiated by the positive simple correlations between good view and social status (.271) and between good view and external house condition (.156). As with the benefits of shoreline, these for viewing are estimated directly from the housing hedonic equation which reflects supply as well as demand conditions and consequently are subject to unknown bias.

The most exhaustive analysis of view-oriented residences is by Pollard (1977) who explores the implications of topographical amenities in an urban housing model. According to Pollard, visual amenities are a function of the breath (scope) of view which he measures by building height (floors) and the composition of the view. Since the data are composed of 232 Chicago apartments north of the Loop along Lake Michigan, dummy variables are created for each loopview and lakeview. Estimating a rental expenditure function and a building height function which he derives from a modified Muthian model, Pollard finds that the view affects both rents and building height. As shown in Table 2, the value of the views is approximately 14%-17% of average rental payments with values for lakeview and breadth of veiw based on significant regression coefficients and loopview on an insignificant coefficient. Given Pollard's estimate of total monthly rent in the study area is correct, the additional total rental premium paid for visual amenities is approximately $113 million in

TABLE 2

The Value of Loop and Lake Views in Chicago

A. VALUE OF VISUAL AMENITIES

Visual Amenity	Value of Amenity	
	Share of Average Rent	June 1980 Dollars per Year[a]
Lakeview	7%	$332
Loopview[b]	3%	$142
Breadth[c]	7%	$332
Total	14%-17%	$664-806

B. EXAMPLE OF A LOOP APARTMENT

Description of Apartment	Premium for Visual Amenity	
	Share of Rent of Apartment with View	June 1980 Dollars per Year
1st floor, no special view	---	---
10th floor, no special view	14%	$791
10th floor, Loopview[b]	17%	$957
10th floor, Lakeview	20%	$1177
10th floor, Loopview and Lakeview	22%	51343

[a]Values for 1975 are converted to June 1980 dollars using the CPI.

[b]The coefficient on which this estimate is based has a t-value of only 0.8.

[c]Since proximity to Lake Michigan increases building heights and hence the breadth of view, part of the value of breadth is due to a lakeview. Pollard finds that lakeview apartment buildings are 76% taller than non-lakeview buildings. The value of lakeview implied by taller buildings is 4.3% of average rent (.067 x 64 = 4.3 where 64 = 1.77 x 36). The value of breadth without the lake height effect is 2.4% of average height (.067 x 36 = 2.4).

Source: Pollard (1977).

1980 dollars (43.8 x 12 x .14 x 1.533 = 112.8 where 247.1/161.2 = 1.533). While we must again remember that these values come directly from the hedonic equation and not from the demands for visual amenities, Pollard's research clearly indicates their substantial impact on view-oriented residences and that dimensions of viewing can be successfully considered.

IV. Further Work Based on View-Oriented Residences

Conceptually, the value of any perceived housing characteristic (including area visibility) can be found through analysis of the implicit market for the characteristic. As described above, several studies have estimated the demand for clean air. However, no such study has been done for visibility, and given the extreme data requirements, it is quite unlikely that one will ever be done especially for a housing market as large as a Standard Metropolitan Statistical Area. In marked contrast is the excellent prospect for learning more about the value of views and components of views. We have seen that in view-oriented submarkets, there is some indication that viewing can be worth as much as 20% of total housing expenditures -- an effect readily detectable by statistical hedonic price-trait demand analysis with average quality data. We now address what such a study might entail.

Let us assume that households maximize their utility which is separable and depends on housing and a composite good excluding housing. Housing, which is a vector of housing characteristics, can be considered as having view-related characteristics such as breadth and composition as well as characteristics unrelated to viewing. Following the theory and methodology described in part II, we would estimate the hedonic housing function which includes the view-related characteristics estimate the

the demands for these special characteristics, and aggregate to get the value of views.

For a submarket like Pollard's where view-oriented residences are prominent, the hedonic housing function would specify rent as a function of structural characteristics such as floor space, rooms, baths, age, fireplaces, central air conditioning, central heating, units in building, floors in building, garage, separate storage area, building elevator; payment characteristics such as whether or not rent includes utilities, heating, air conditioning, garbage collection, parking; neighborhood characteristics such as access to employment and shopping, school quality, crime rate, street conditions, litter, noise, abandoned buildings; and view characteristics such as height of the apartment in floors, percentage of horizon which can be viewed from the apartment, a dummy for Lakeview, a dummy for Loopview, a dummy for ability to view to the horizon, and a dummy for extraordinary window space. (The hedonic equation can accommodate condominiums with adjustments for property taxes, and the annual flow of housing services similar to those found in Linneman (1980)). The best functional form for the hedonic function can be determined by using a quadratic Box-Cox procedure similar to that used by Bender et. al. (1980).

Estimating the demand for view characteristics will make use of the hedonic prices for housing characteristics and household characteristics such as income, family size, age structure and education. The proper specification of the demand equation can be determined through a series of tests for the superiority of alternatives following Blomquist and Worley (1982) and Harrison and Rubinfield (1978).

By coordinating the housing market and contingent valuation approaches to estimating the value of improved visibility progress can be made in critical areas of benefit estimation. First, sturctural and neighborhood housing characteristics obtained from cooperative building managers can be supplemented and matched with view and household characteristics obtained through the contingent valuation survey. This merger would permit estimating benefits from the demands for view characteristics, not the hedonic housing equation. Second, by carrying out a contingent valuation study for views (in addition to a study for visibility) we can compare the estimates of the value of views obtained from the housing (implicit) market and contingent market studies. Such a comparison is crucial to understanding the usefulness of contingent values of environmental amenities such as visibility which are not easily estimated by alternative approaches.