GUIDELINES FOR SOCIOECONOMIC IMPACT ANALYSES
OF ENVIRONMENTAL REGULATIONS

David Hargett
Research Assistant
Department of Economics and Business
North Carolina State University

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ABSTRACT

This report presents a brief description of socioeconomic impact analyses for noneconomists. Emphasis is given to the concept of economic efficiency or to the use of socioeconomic or benefit-cost analysis to enhance state and national income. Economists have not been very successful at conveying their ideas concerning benefit-cost analysis to noneconomists. One reason is a lack of consensus among economists on certain aspects. Aspects of benefit-cost analysis that are particularly troublesome for noneconomists are stressed. Some of these include: marginal analysis of welfare maximization, normalized pricing, estimations of willingness to pay, economics of information, and the social rate of discount. Examples are briefly described, and references are offered to several publications that have had the same purpose.

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1. INTRODUCTION

North Carolina law now allows a discharger to petition the Environmental Management Commission for a hearing to revise water quality standards and effluent limitations that apply to the stream segment into which he discharges. It further specifies that any effluent limitation imposed by the State of North Carolina more stringent than that promulgated by Section 301 of the Federal Water Pollution Control Act must be justifiable in the sense that there is a reasonable relationship between the incremental benefits and the added costs of the regulations. Special emphasis is given to the incremental costs of the petitioner in applying water quality standards upon that specific stream segment. Economists would interpret a "reasonable relationship" to mean approximate equality between the added benefits to society and the incremental private and public costs of the additional (questionable) waste treatment. The principles outlined here regarding the economics of information would also dictate that such matters only need to be studied a "reasonable" amount; that is, until the incremental benefits of the information equal the costs.

In anticipation of the need to provide guidelines for studies of the benefits and costs of environmental regulations and thus to aid the decision-making process, the North Carolina Department of Natural Resources and Community Development initiated this study. Emphasis is given to the concept of economic efficiency or to the use of benefit-cost analyses to enhance state and national income. Unfortunately, there is no simple formula which indicates the optimal amount of information for every decision.
Even though this report is addressed to the noneconomist, the analyst must have some knowledge of certain aspects of economics to be able to perform a worthwhile evaluation. This report acquaints the reader with some of these aspects of economics such as the marginal analysis of welfare maximization, normalized pricing, estimation of willingness to pay, the economics of information, and the social rate of discount. Examples are given to illustrate some of these ideas.

Several economists have produced good popular explanations of benefit-cost analyses, but they have not been very successful at conveying their ideas to noneconomists. One reason for this failure is the lack of consensus among economists concerning some of the aspects of benefit-cost analysis. For example, controversy over the social rate of discount still adds an element of confusion in the evaluation of projects. The federal government even uses one discount rate for water-related projects and a different rate for other projects. Also, there is an ongoing controversy within economics over which decision-making criterion to use in the evaluation of mutually exclusive projects. Until this lack of consensus and the resulting confusion are reduced by economists, it will continue to be difficult to teach basic ideas about benefit-cost analysis to the noneconomist.
2. THE PLANNING AND OBJECTIVES OF A BENEFIT-COST ANALYSIS

2.1 The Design of the Analyses of Projects

The basic idea of a benefit-cost analysis is to estimate whether a project or regulation would be worthwhile to the nation or a region by comparing alternative futures with and without the change. A with and without, as opposed to a before and after comparison, reminds the analysts to include related non-project costs that are necessary to achieve the alternative futures.

The objective of a benefit-cost analysis is often to maximize economic efficiency or welfare subject to quantitative constraints on income distribution and environmental impacts. Water projects and policies often have multiple benefits including flood control, recreation flow augmentation, hydro-electric, irrigation, and water conservation. The analyst should design the benefit-cost analysis so that each grant project is broken down into the smallest packages that are independent of one another and each of these should be analyzed separately. He should design the analysis such that alternative ways of accomplishing each objective will be considered. He should choose technologies to minimize costs, and he should also seek conservative estimates of the benefits. The analyst should check whether the present value of the expected net benefits is greater than zero for each interdependent package and also whether marginal costs exceed marginal benefits for each item that could be deleted from the package.
2.2 The Relationship to Supply and Demand Analysis

A benefit-cost analysis requires many decisions about prices and values to assign to inputs and outputs. Harberger (1971) suggests that the following postulates or assumptions be accepted:

a. the competitive demand price for a given unit measures the value of that unit to the demander;

b. the competitive supply price for a given unit measures the value of that unit to the supplier; and

c. when evaluating the net benefits or costs of a given action (project, program, or policy), the costs and benefits accruing to each member of the relevant group (e.g., a nation) should normally be added without regard to the individual(s) to whom they accrue.

These assumptions are fine as long as there are no serious social effects or externalities connected with consumption or production. If such social effects exist and can be quantified, they should be added to or subtracted from the demand curve to obtain the marginal social benefits curve, and added or subtracted from the supply curve to convert it into a marginal social resource cost curve. The use of these marginal curves to define welfare maximization is illustrated in Figure 2-1. The vertical axis represents price, benefits, or costs per unit while the horizontal axis represents the quantity of a good produced or consumed per year. The height of the MSC curve at each level of X represents the value of resources lost by society if one more unit of X is produced. The height of the MSB curve represents the additional benefits enjoyed by society due to the availability of one more unit of X. Consider a project that would increase the amount of X produced from $X_0$ to $X_1$. The benefit-cost
Figure 2-1. Marginal analysis for welfare maximization
analysis will compare the total benefits of the project with the total costs. In Figure 2-1, the total social benefits of this project are represented by the area under the demand curve, $X_0X_1dc$; or $\text{TSB} = \int_{X_0}^{X_1} f(x)dx$.

The total social costs of the project are represented by the area under the supply curve, $X_0X_1ge$; or $\text{TSC} = \int_{X_0}^{X_1} g(x)dx$. The net social benefits or gain in welfare due to this project are $\text{TSB} - \text{TSC}$ which is represented by the area $egdc$.

Assume another project that will increase the production from $X_2$ to $X_3$. The increase in total benefits is represented by the area $X_2X_3jh$, or $\text{TSB} = \int_{X_2}^{X_3} f(x)dx$, while the increase in costs is equal to the area $X_2X_3if$ or $\text{TSC} = \int_{X_2}^{X_3} g(x)dx$. In this case total social costs are greater than total benefits, and the net social loss is represented by the area $hjif$. The optimal solution that maximizes social welfare is the amount of $X$ that is produced at $X_4$. At this point any increase in the production of $X$ will add more to total cost than to total benefits since MSC would be greater than MSB. If the production of $X$ were less than $X_4$, then an increase in $X$ would add more to total benefits than to total costs.

2.3 Prices to Assign to Different Types of Benefits and Costs

With respect to prices, Howe (1971, p. 15) offers the following convenient classification: (1) benefits and costs for which market prices exist; (2) benefits and costs for which market prices exist but for which
prices fail to reflect appropriate social values; (3) benefits and costs for which no market prices exist but for which appropriate social values can be approximated in money terms by inferring what consumers would be willing to pay if a market existed; (4) benefits and costs for which it would be difficult to imagine any kind of market-like process capable of registering a meaningful monetary valuation.

It is customary and convenient in benefit-cost analyses to express all prices in real terms or constant-valued dollars. First, one must choose a base year for the analysis, perhaps the year of the decision; say, 1979. In order to convert past prices to 1979 dollars, multiply by the expected Consumer Price Index (CPI) for mid-1979 (say, 215.0 based on 1967 = 100) and divide by the CPI for the date of the observed price. For example, suppose the price of some item in the analysis was $250 in November 1977 when the CPI was 185.4; then, the equivalent price in mid-1979 dollars would be

\[ 250 \times \frac{215.0}{185.4} = 290 \]

Many different price indexes are available including specific indexes for construction, agriculture, and engineering. These indexes would be useful for converting past prices to the year of the analysis. For example, if the construction of a waste treatment plant is being considered, then the analyst might use a construction price index such as the one published periodically by the Engineering News Record to estimate present construction costs based on bids made in an earlier year. If a weighted average of past prices is being used to form an expected future price, as in the example below, then it would be more logical to use the
CPI or the implicit price deflator for the gross national product, sometimes called the General Price Index, of the U. S. Department of Commerce. It is often necessary to use some weighted average of past market prices in order to formulate an expected future price (or set of price ratios) which will be assumed to apply throughout the period of the project. Before averaging past prices together, they should be adjusted for inflation so that they all pertain to the year that is being used as the base year for the analysis. If past prices were not adjusted for inflation, they would essentially be in different sized dollars and the average might be meaningless. They expected future prices or prices which would be expected to prevail if conditions are "normal" might be called "normalized" prices. Numerous ways of estimating normalized prices are available. [For a description of these, see Niehaus (1978)]

A generalized distributed lag procedure for obtaining weights for past prices is illustrated here. The generalized distributed lag is of the form:

\[ p_t^n = \lambda p_{t-1} + (1-\lambda)p_{t-2} + \lambda(1-\lambda)^2 p_{t-3} + ... \quad 0 < \lambda < 1. \]

Choice of a larger \( \lambda \) gives more weight to recent years. This approach allows for some judgment by the analyst in assigning \( \lambda \)'s and, hence, weights. If the analyst expects a price trend to continue, presumably he will use a larger value of \( \lambda \). If recent past prices have been highly variable, then the analyst might want to assign a low value of \( \lambda \).

Table 2-1 is used to illustrate a procedure for calculating normalized prices. Assume that the analyst wishes to estimate the expected future price of tobacco as of mid-1979. The CPI is used to adjust
1974-1978 actual prices to constant 1979 dollar levels in the fourth column of Table 2-1.

Table 2-1. A procedure for calculating a normalized price for tobacco for 1979

<table>
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<tr>
<th>Year</th>
<th>CPI</th>
<th>Actual prices $/lb.(^a)</th>
<th>Constant 1979 dollar prices(^b)</th>
<th>Weights based on (\lambda = .6)</th>
<th>Weights (\times) adjusted price</th>
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<tr>
<td>1978</td>
<td>193.2</td>
<td>1.22</td>
<td>1.35</td>
<td>.600</td>
<td>.81</td>
</tr>
<tr>
<td>1977</td>
<td>181.5</td>
<td>1.17</td>
<td>1.39</td>
<td>.240</td>
<td>.33</td>
</tr>
<tr>
<td>1976</td>
<td>170.5</td>
<td>1.13</td>
<td>1.43</td>
<td>.096</td>
<td>.14</td>
</tr>
<tr>
<td>1975</td>
<td>161.2</td>
<td>1.04</td>
<td>1.37</td>
<td>.038</td>
<td>.05</td>
</tr>
<tr>
<td>1974</td>
<td>147.7</td>
<td>1.09</td>
<td>1.59</td>
<td>.015 (.026)</td>
<td>.04</td>
</tr>
</tbody>
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Weighted average price, \(P_n^{\text{adj}} = .81\)

\(^a\)Source: Flue-cured tobacco prices as reported in Agricultural Statistics, USDA.

\(^b\)Assuming a value of 215 for the CPI in mid-1979. Multiplying column 2 by 215 divided by column 1.

Assigning a \(\lambda\) value of .6 results in the weights given in column 5. It would be logical to adjust the weight given to the last year so that the sum of the weights add up to 1.0. This adjustment is indicated for 1974 in parentheses. These weights are multiplied by the constant-dollar prices and summed to obtain the weighted average price of $1.37.

Severe externalities and government interference provide examples of market prices that fail to reflect appropriate social values. An externality may be defined as an effect of one economic agent on another that is not taken into account by normal market behavior. Figure 2-2
illustrates an externality which is water pollution created by a competitive firm that is producing and selling some other commodity X. The firm's marginal and average revenue curve is represented by the horizontal line at the observed market price $P_0$. MPC represents the firm's marginal private cost curve while MSC represents the marginal social cost curve. The marginal social cost curve is higher than the firm's marginal cost curve because the production of X creates costs to society due to water pollution. The firm's optimum output of X is at $X_0$ where marginal revenue equals the firm's marginal cost. Society's optimum output is at $X_1$ where the marginal social benefit of producing X equals the marginal social cost. Notice that at the firm's optimum output of $X_0$ the observed market price, $P_0$, is lower than the cost to society, $P_2$, of producing $X_0$. In the cases of severe externalities, the observed market prices will underestimate the social value of the market goods and services. Thus, in a benefit-cost analysis, the price or cost of an additional unit of X at $X_0$, should be $P_2$ rather than $P_0$.

Figure 2-3 illustrates the effects of a particular type of government interference which in this case is a price ceiling. The price ceiling (the highest price allowed by the government) is equal to $P_1$. At $P_1$ the amount of Y that is supplied is equal to $Y_1$ while the amount demanded is $Y_2$. At the competitive equilibrium the industry would produce $Y_0$ at price $P_0$. Assuming a price of $P_1$ and an output of $Y_1$, the social value of each additional unit of Y equals $P_2$ which is greater than the controlled price $P_1$. In this case, the observed price ceiling understates the social value of each unit of Y by the amount $P_2 - P_1$. Thus, in a
Figure 2-2. Example of an externality
Figure 2-3. Example of a governmental price control
benefit-cost analysis the price that should be used is $P_2$ since it represents the social value of each unit of $Y$ at $Y_1$.

A monopsonistic firm is a single buyer in a particular market. A monopsonistic buyer of a factor of production that cannot practice price discrimination (must pay the same price for all units, whatever that price may be), would be expected to pay less for such a factor than it is worth at the margin. In order to increase the quantity of this factor of production by one more unit, the firm must pay a higher amount to all the other units, too. Hence, the firm's marginal factor cost, MFC, curve lies above its average factor cost curve, AFC. Figure 2-4 illustrates a monopsonistic firm which seeks to maximize profits. It will seek to employ factor $Z$ up to the point at which $MRP_Z$ (the extra revenue that accrues to a firm when it sells the output that is produced by one more unit of the input) equals $MFC_Z$ which is at $C$ or $Z_0$. The social optimal amount of $Z$ is $Z_2$ at a price $P_2$. Notice that at $Z_0$ the firm has to pay only $P_0$ while the value of this input to the firm (and to society) is $P_1$. Thus, $Z$ is underpriced by the amount $P_1 - P_0$. In a benefit-cost analysis, the marginal revenue product curve can be used to indicate social value, $P_1$ at $Z_0$ and $P_2$ at $Z_2$.

In some cases no market prices exist but appropriate social values can be approximated in money terms by inferring what consumers would be willing to pay if a market existed. An example will be given below in the section on recreation in which travel costs are used to estimate users' willingness to pay.

Some benefits and costs exist for which it would be difficult to imagine any kind of market-like process capable of registering a meaningful monetary valuation. Examples include: aesthetic values such as the
Figure 2-4. A monopsonistic market
value of a beautiful view, preservation of an historical site, and the maintenance of a water quality higher than that required for health or commercial reasons. Even though it is difficult to impute values for these aesthetic qualities, they are an important part of a benefit-cost analysis. The analyst should describe the impact that the project is expected to have on these aesthetic qualities.

2.4 Allocation of Resources and Distribution of Income

Benefit-cost analyses are usually divided into two basic criteria, economic efficiency and distributive equity. When the analysis of a project is based purely on benefits and costs that are comparable in monetary terms, the analysis is usually based on the criterion of economic efficiency. In the past, much of the emphasis has been on increasing efficiency, the "size of the pie," or national income. However, society has a growing interest in how water resources regulations and projects affect different regions, income groups, ages, sexes, and races. Probably, when legislators request a socioeconomic impact analysis, what they have in mind is mainly an analysis of the effects of a project on income distribution, or the division of the pie, and only secondarily an analysis of the effects on national income. A water resource project that will lower employment in a depressed area may not be chosen by society even though it may be economically efficient from a national standpoint. A recreation facility may be chosen to benefit particular races or income groups even though it may not be economically efficient.

Water resource projects are usually not an efficient means of achieving desired income redistributions. This is mainly because water costs and the benefits of water-related recreation are small percentages
of personal income. For example, society cannot accomplish much of an income redistribution by providing free telephone service; about the same applies to water. Furthermore, it is difficult to estimate the effects of a water project on income distribution. For example, an irrigation project may provide employment to one group of farmers and cause others to leave agriculture; prices may fall, and it is very likely that the income to agricultural labor will remain depressed.

When income distribution effects are required in an analysis, they should be summarized in a short but concise manner, and care should be taken to avoid double counting. One way to do this is to use a carefully designed display. (See Section 2.6.)

2.5 Accounting Stance

Projects usually affect different regions in very different ways. For example, the impact of a state government project on agricultural sedimentation control might accrue benefits that are greater than the costs from a national standpoint since in many cases the large rivers flow through more than one state. States downstream may reap the benefits of another state's agricultural sediment control program without incurring any cost of the program. The state which sets up the sediment control program would have to incur the costs of the program plus the possible loss of some of its comparative trade advantage. Thus, someone at a state level usually will have a different accounting stance concerning government projects than a decision maker from the national government level.

Each government decision maker is usually responsible to his constituency, and he is expected to act on their behalf. For example, a
state government official is usually concerned with the impacts that a project may have on the people of his state whereas a federal government official is usually concerned with the impacts that a project may have on the people of the whole nation.

In certain cases it is financially infeasible to expect government officials of a regional or local government to evaluate projects from a national accounting stance. The expense may be too large for state or local officials to determine all the benefits and cost throughout the nation; and besides, it is not expected that government decision makers at the local or regional level of government will set as one of their main objectives the maximization of national welfare. If a regional or local decision maker is required by law to do so, then the analyst should present the results of the benefit-cost analysis from both the national accounting stance and from the regional or local accounting stance. Normally, it will not take much additional effort to present the regional or local accounting stance, and the information that is gained in doing so can be very valuable.

At the local level decision makers also may need to pay attention to their cash flow or heed financial constraints. For instance, a project may generate large net local social benefits; but due to obvious financial constraints on local governments, they may not be able to institute the project. At the local level the decision makers must determine whether a project generates positive net economic benefits and then check whether the local government is financially capable of implementing the project.
2.6 Displays

Benefit-cost analysis is plagued by double-counting. Care must be taken so as not to double-count benefits and costs, especially when the analysis is broken down by regions. By using a carefully designed display, the chances of double-counting can be reduced. An example of a display is given in Table 2-2. In this display, the effects of a hypothetical water project are shown at the national and regional levels along with its effects on two income groups. Note that the total national effect column should equal the sum of the other columns. If this equality is not present, then an accounting mistake has been made.

A display can be designed to show the effects of a project on any social group and to emphasize the desired accounting stance. Displays should be designed with the following objectives in mind:

1. Preserve the capability of showing all project effects and be useful in an evaluation that considers multiple objectives.
2. Clearly distinguish between output (including environmental and social effects) and the distribution of that output among regions and categories of people.
3. Introduce the accounting discipline of sums and balances and eliminate duplicate listings where one project feature affects several objectives but only the means, not the effect, can be measured and listed in accounts (Butcher, Rettig, and Brown, 1971).
Table 2-2. Example of a display

<table>
<thead>
<tr>
<th>Project Effects</th>
<th>Total National Effect</th>
<th>Distribution of Project Impacts (net present values in millions of dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Region I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low income</td>
</tr>
<tr>
<td>Monetized (Economic)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benefits</td>
<td>10</td>
<td>6.0</td>
</tr>
<tr>
<td>Transfers</td>
<td>0</td>
<td>+0.7</td>
</tr>
<tr>
<td>Costs</td>
<td>8</td>
<td>1.0</td>
</tr>
<tr>
<td>Net Economic Effect</td>
<td>2</td>
<td>5.7</td>
</tr>
<tr>
<td>Quasi-Monetary^b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental Effects</td>
<td>-0.3</td>
<td>-0.2</td>
</tr>
<tr>
<td>Social Effects</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Other Public Goods &amp; Services</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Net Value in Economic Terms</td>
<td>0</td>
<td>-0.1</td>
</tr>
<tr>
<td>Nonmonetary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental Effects</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Social</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

^aSource: Butcher, Rettig, and Brown (1971).

^bItems not priced or exchanged in the market but by extrapolation and judgment dollar values may be assigned that are indicative of relative value of effects. For example, recreation benefits.
3. DECISION-MAKING CRITERIA

Analysts need to choose one or two criteria to present to decision makers. It would most likely be confusing to use more than two. The idea is to summarize the monetary effects of a project in one or two numbers that are readily interpreted. The criterion chosen will depend on the audience, their level of sophistication, and the way they make decisions (sequentially or in batches). The U. S. Congress and many other legislatures have relied on benefit-cost ratios, B/C's. The World Bank often uses internal rates of return, IRR's. Many economic textbooks recommend use of net present values, NPV's, to accept or reject a project. One of the most popular criteria is the number of years needed to recover an investment. In most cases, each of these criteria will lead the decision makers to the same choice. It is mainly a question of which criteria they prefer.

This section will present precise definitions of NPV's, B/C's, and the IRR. Examples are offered, and the conflicting results which can occur when it is necessary to choose one of several mutually exclusive projects are explained.

3.1 Net Present Value Method

The first method that will be discussed is the net present value method. The net present value may be defined as follows:

\[
NPV = \sum_{t=0}^{h} \frac{(B_t - C_t)}{(1 + i)^t}
\]  

(3-1)
where: \( h \) = time horizon of the project,
\( B_t \) = the dollar value of benefits received at time \( t \),
\( C_t \) = the dollar value costs incurred at time \( t \), and
\( i \) = the discount rate.

The initial investment at time zero is equal to \( C_0 \). Any salvage value resulting from a project at time \( h \) is included in \( B_h \).

The net present value (NPV) equation discounts a stream of future costs and benefits to a single point in time so that they can be added. As an example of the use of the NPV method, assume that a decision maker is considering a project that has an initial cost of \$100,000\), and the net benefit flow is presented in Table 3-1. First, assume that the reinvestment rate, \( r \), and the discount rate are both 10 percent. The net present value is positive; hence, the project is acceptable.

Project evaluation always involves comparison of alternative investments. It is desirable to explicitly state one's assumptions regarding the rate of return on money reinvested. In equation (3-1) it is implicitly assumed that the reinvestment rate is equal to the discount rate. When these two rates are not equal, the net present value equation takes the following form:

\[
\text{NPV} = \sum_{t=1}^{h} \frac{(B_t - C_t)(1 + r)^{h-t}}{(1 + i)^h} - C_0. \tag{3-2}
\]

Equation (3-2) compounds forward at the reinvestment rate \( r \) the net benefits that occur in each time period. The terminal value is then discounted to the present using the discount rate \( i \). Using terminal values reminds the analyst to assume the same time horizon, \( h \), for each project being compared. It also forces the analyst to be explicit about the...
Table 3-1. Example of a net present value calculation

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual benefits ($)</th>
<th>Annual costs ($)</th>
<th>Net benefits ($)</th>
<th>Discount factor for $i=r=.10$</th>
<th>Discount factor for $r=.15$ $i=.10$</th>
<th>NPV for $i=r$ ($)</th>
<th>NPV for $r=.15$ $i=.10$ ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>100,000</td>
<td>-100,000</td>
<td>1.0</td>
<td>1.000</td>
<td>-100,000</td>
<td>-100,000</td>
</tr>
<tr>
<td>1</td>
<td>10,000</td>
<td>20,000</td>
<td>-10,000</td>
<td>0.909</td>
<td>1.086</td>
<td>-9,090</td>
<td>-10,860</td>
</tr>
<tr>
<td>2</td>
<td>30,000</td>
<td>20,000</td>
<td>10,000</td>
<td>0.826</td>
<td>.944</td>
<td>8,260</td>
<td>9,440</td>
</tr>
<tr>
<td>3</td>
<td>60,000</td>
<td>20,000</td>
<td>40,000</td>
<td>0.751</td>
<td>.821</td>
<td>30,040</td>
<td>32,840</td>
</tr>
<tr>
<td>4</td>
<td>90,000</td>
<td>20,000</td>
<td>70,000</td>
<td>0.683</td>
<td>.714</td>
<td>47,810</td>
<td>49,980</td>
</tr>
<tr>
<td>5</td>
<td>90,000</td>
<td>20,000</td>
<td>70,000</td>
<td>0.621</td>
<td>.620</td>
<td>43,477</td>
<td>43,400</td>
</tr>
</tbody>
</table>

Total net present value

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20,497</td>
<td>24,800</td>
</tr>
</tbody>
</table>
reinvestment rate for each time period. The last column of Table 3-1 also illustrates the effect on the net present value of assuming a higher reinvestment rate, 15 percent instead of 10 percent. The net present value of this project is increased from $20,497 to $24,800.

3.2 Benefit-Cost Ratio

Another popular decision-making criterion is the benefit-cost ratio. One formula for a benefit-cost ratio, \((B/C)_1\), is the sum of the present value of the net benefits divided by the initial investment, \(C_0\):

\[
(B/C)_1 = \sum_{t=1}^{h} \frac{(B_t - C_t)}{C_0 (1 + i)^t}
\]

This ratio reflects net benefits per dollar of initial investment. For example, if a benefit-cost ratio is determined to be 1.10, then this can be interpreted to mean that for every one dollar that was initially invested the sum of the present value over the whole life of the project is $1.10. If the ratio were .9, then this would indicate that for every one dollar that was initially invested there would be only $.90 worth of net benefits. For the project to have a positive return, the benefit-cost ratio would have to be greater than one.

Another formula for a benefit-cost ratio, \((B/C)_2\), is the present value of benefits divided by the present value of costs:
This benefit-cost ratio gives the discounted gross benefits per dollar of discounted gross costs. For example, if a project has a benefit-cost ratio of 1.5, then this indicates that for every one dollar of costs the project produced $1.50 worth of benefits (both in present values).

3.3 Internal Rate of Return

Another popular method of evaluating investments is the internal rate of return, IRR. The IRR is simply the interest rate that would make the NPV of a project equal to zero. Figure 3-1 illustrates the way the NPV's of two projects might decline as the interest rate is increased. The IRR of each project is found where the NPV curves for each project cross the horizontal axis. The IRR can be determined by substituting different interest rates for \( i \) in equation (3-1) until the NPV is equal to zero. Those who use the IRR method to compare projects of different durations often implicitly assume that reinvestment will be possible at the IRR of the same project.

3.4 Comparison of the Decision-Making Criterion

Three criteria have been defined for evaluating projects: net present value, benefit-cost ratio, and internal rate of return. When these criteria are used to accept or reject projects (for a given \( i \), projects
with NPV > 0, B/C > 1, and IRR > i are accepted), they all give the same recommendation. However, when they are used to rank projects or to select the best from among several mutually exclusive projects, then these criteria may lead to conflicting recommendations. Projects could be mutually exclusive because of budgetary constraints or because physically there is only room for one project (e.g., a dam), or legally only one regulation should apply at one time.

A characteristic that is common to all three methods is that it is desirable to explicitly state assumptions that are being made about the rate of return on funds reinvested. Ordinarily, people use the NPV method (equation 3-1) without mentioning that they are assuming that profits will be reinvested at a rate equal to the discount rate, and those who use the internal rate of return method implicitly assume that reinvestment will be possible at the IRR of that same project. Figure 3-1 shows the net present values of two mutually exclusive projects A and B at varying interest rates. Project A has a longer life than project B. The benefits of project A would probably have a tendency to occur further in the future than those of project B. Low discount rates would favor project A while higher discount rates would favor project B. The interest rate at which the NPV of the projects are equal is called the Fisher rate, \( i_f \). At discount rates less than the Fisher rate, such as \( i_0 \), project A would be preferred to project B. At discount rates greater than the Fisher rate, project B would be preferred to project A.

At times \((B/C)_2\) can lead to choices different from those of the other criteria. This is exemplified in Tables 3-2A and 3-2B where there are two mutually exclusive projects A and B. With the reinvestment rate
Figure 3-1. Net present value versus internal rate of return

- NPV of the longer lived project, Project A
- NPV of the shorter, Project B
assumed to be 15 percent and the discount rate set at 10 percent, the 
(B/C)_2 ratio for project B is 1.10 while for project A it is 1.17. This 
method indicates that project A should be chosen over project B, but the 
other criteria indicate that project B is the correct choice. Results 
can be different using (B/C)_2 as opposed to (B/C)_1 because in cases where 
initial costs, C_0, are extremely small, as in evaluating environmental 
regulations, (B/C)_1 could be very large and mislead the analyst.

Dudley (1972) shows that if the rate of return on reinvestment is 
less than the Fisher rate, the simple NPV criterion (equation 3-1) will 
lead to the selection of that project which will result in the greatest 
discounted terminal value at the end of the time period. The IRR gives 
the wrong choice in this case. In the case where the reinvestment rate 
is higher than the Fisher rate, i_f, the simple NPV method (equation 3-1), 
with i < i_f will lead to an incorrect choice while the IRR method will 
result in the choice of the project which has the highest discounted 
terminal value. Illustrated in Table 3-2A and 3-2B are two mutually 
exclusive projects, A and B, which have the same initial investments but 
different time profiles. The largest returns from project B come early 
after investment while project A has delayed returns. This difference in 
the time patterns of the returns from the two projects means that curves 
for the NPV's as a function of interest rates might cross as in Figure 3-1. 
Assuming that the reinvestment rate and the discount rate are equal and 
are less than the Fisher rate, i = r = .10, then the NPV method would 
result in the selection of project A while the conventional IRR method 
would result in the selection of project B. Under the above assumptions 
the net present value method would result in the correct choice. If it
Table 3-2A. A comparison of the net present values, benefit-cost ratios and internal rates of return of two projects, Project A

<table>
<thead>
<tr>
<th>Year</th>
<th>Benefits ($)</th>
<th>Costs ($)</th>
<th>Net benefits ($)</th>
<th>Discount factor for $i=r=.10$</th>
<th>Discount factor for $r=.15$ $i=.10$</th>
<th>NPV for $r=.10$ $i=.10$ ($)</th>
<th>NPV for $r=.15$ $i=.10$ ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>100,000</td>
<td>-100,000</td>
<td>1.0</td>
<td>1.0</td>
<td>-100,000</td>
<td>-100,000</td>
</tr>
<tr>
<td>1</td>
<td>20,000</td>
<td>10,000</td>
<td>10,000</td>
<td>.909</td>
<td>1.086</td>
<td>9,090</td>
<td>10,860</td>
</tr>
<tr>
<td>2</td>
<td>30,000</td>
<td>10,000</td>
<td>20,000</td>
<td>.826</td>
<td>.944</td>
<td>16,520</td>
<td>18,880</td>
</tr>
<tr>
<td>3</td>
<td>40,000</td>
<td>10,000</td>
<td>30,000</td>
<td>.751</td>
<td>.821</td>
<td>22,530</td>
<td>24,630</td>
</tr>
<tr>
<td>4</td>
<td>55,000</td>
<td>10,000</td>
<td>45,000</td>
<td>.683</td>
<td>.714</td>
<td>30,735</td>
<td>32,130</td>
</tr>
<tr>
<td>5</td>
<td>70,000</td>
<td>10,000</td>
<td>60,000</td>
<td>.620</td>
<td>.620</td>
<td>37,260</td>
<td>37,200</td>
</tr>
</tbody>
</table>

Total net present value  
Benefit-cost ratio, $B/C_1$  
Benefit-cost ratio, $B/C_2$  
Internal rate of return  

*Indicates preference for this project when Tables 3-2A and 3-2B are compared.
Table 3-2B. A comparison of the net present values, benefit-cost ratios and internal rates of return of two projects, Project B

<table>
<thead>
<tr>
<th>Year</th>
<th>Benefits ($)</th>
<th>Costs ($)</th>
<th>Net benefits ($)</th>
<th>Discount factor for $i=r=.10$</th>
<th>Discount factor for $r=.15$</th>
<th>NPV for r=.10</th>
<th>NPV for r=.15</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>100,000</td>
<td>-100,000</td>
<td>1.0</td>
<td>1.0</td>
<td>-100,000</td>
<td>-100,000</td>
</tr>
<tr>
<td>1</td>
<td>100,000</td>
<td>10,000</td>
<td>90,000</td>
<td>.909</td>
<td>1.086</td>
<td>81,810</td>
<td>97,740</td>
</tr>
<tr>
<td>2</td>
<td>100,000</td>
<td>75,000</td>
<td>25,000</td>
<td>.826</td>
<td>.944</td>
<td>20,650</td>
<td>23,600</td>
</tr>
<tr>
<td>3</td>
<td>100,000</td>
<td>90,000</td>
<td>10,000</td>
<td>.751</td>
<td>.821</td>
<td>7,510</td>
<td>8,210</td>
</tr>
<tr>
<td>4</td>
<td>100,000</td>
<td>97,000</td>
<td>3,000</td>
<td>.683</td>
<td>.714</td>
<td>2,049</td>
<td>2,142</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>.620</td>
<td>.620</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Total net present value

<table>
<thead>
<tr>
<th></th>
<th>12,019</th>
<th>31,692*</th>
</tr>
</thead>
</table>

Benefit-cost ratio, B/C₁

<table>
<thead>
<tr>
<th></th>
<th>1.12</th>
<th>1.32*</th>
</tr>
</thead>
</table>

Benefit-cost ratio, B/C₂

<table>
<thead>
<tr>
<th></th>
<th>1.04</th>
<th>1.10</th>
</tr>
</thead>
</table>

Internal rate of return

<table>
<thead>
<tr>
<th></th>
<th>19.7%</th>
</tr>
</thead>
</table>

*Indicates preference for this project when Tables 3-2A and 3-2B are compared.
is assumed that reinvestment is possible at a rate greater than the Fisher rate, then the IRR method would result in the correct choice of project B while the simple NPV method (equation 3-1) would result in the incorrect choice of project A. Table 3-3 provides a summary of those cases in which each criteria would provide incorrect choices among mutually exclusive projects. Equations (3-2), (3-4), and (3-6), because they explicitly include the "correct" reinvestment rate, always provide "correct" choices.

Table 3-3. Situations in which different criteria give correct and incorrect choices among mutually exclusive projects

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Actual reinvestment rates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$r &lt; i_f$</td>
</tr>
<tr>
<td>Net present values:</td>
<td></td>
</tr>
<tr>
<td>(3-1): $i &lt; i_f$</td>
<td>correct</td>
</tr>
<tr>
<td>$i &gt; i_f$</td>
<td>incorrect</td>
</tr>
<tr>
<td>(3-2): $i &lt; i_f$</td>
<td>correct</td>
</tr>
<tr>
<td>$i &gt; i_f$</td>
<td>correct</td>
</tr>
<tr>
<td>Benefit/cost ratios:</td>
<td></td>
</tr>
<tr>
<td>(3-3) or (3-5):</td>
<td></td>
</tr>
<tr>
<td>$i &lt; i_f$</td>
<td>correct</td>
</tr>
<tr>
<td>$i &gt; i_f$</td>
<td>incorrect</td>
</tr>
<tr>
<td>(3-4) or (3-6):</td>
<td></td>
</tr>
<tr>
<td>$i &lt; i_f$</td>
<td>correct</td>
</tr>
<tr>
<td>$i &gt; i_f$</td>
<td>incorrect</td>
</tr>
</tbody>
</table>

If equation (3-2) is used to estimate the net present value of each project in Tables 3-2A and 3-2B, NPV would result in the correct choice.
of a project. If it is assumed that the reinvestment rate is less than the Fisher rate, then equation (3-2) would result in the choice of project $A$ which is the same correct choice as indicated by equation (3-1). If the reinvestment rate is greater than the Fisher rate, then equation (3-2) would result in the choice of project $B$ which is the same correct choice indicated by the IRR method. The same applies when equations (3-4) or (3-6) are used instead of equations (3-3) or (3-5) or the IRR method. Use of equations (3-2), (3-4), and (3-6) forces the projects being compared to be carried to the same time horizon, and it also forces the analyst to be explicit about the reinvestment rate for each time period.

If the assumed reinvestment rate and the discount rate are both greater than the Fisher rate, the simple NPV method (equation 3-1), the simple $B/C$ ratio (3-3) or (3-5) and the IRR method all result in the correct choice of project $B$. However, the IRR still has some advantages over the simple NPV and $B/C$ criteria. To calculate the NPV the analyst must know the discount rate, and to compare the results projects should have similar time profiles and sizes. Thus, when reporting the results of the NPV method, the analyst must also report the discount rate used and the length and size of the projects that were analyzed. Interpretation of $B/C$ ratios requires knowledge of the discount rate used and the time profile of the project. On the other hand, the IRR method standardizes for size and duration. Thus, it is not necessary to know the size and length of projects when interpreting IRR's. The units of IRR's are also appealing. They are net dollars per year per dollar invested, or rates of interest.

The question remains, what rate of return is to be used for reinvestment of funds? In the case where an unlimited amount of capital is
available at a constant price, the reinvestment rate should be equal to
the firm's cost of capital. In the case where capital is limited, the
choice of the proper reinvestment rate is more difficult. Dudley (1972,
p. 914) proposes that "the reinvestment rate to be used in evaluating
conflicting capital investment proposals should be the expected mean rate
of return on the firm's total capital budget prospects over time, perhaps
extrapolated from an average of past realized rates." Seagraves (1970,
p. 438) suggests use of the rate of return on the marginal project.

Fortunately, choice among mutually exclusive public projects is more
the exception than the rule. Thus, except when considering choices among
mutually exclusive projects, the use of any one of the three criteria is
acceptable under most circumstances. Benefit-cost ratios have long been
a favorite tool for project evaluation by the U. S. Congress and other
legislative bodies. The popularity stems from the simplicity of the cri-
teration and from the fact that it standardizes for the size of the proj-
ject. Congressmen often need to compare benefit-cost ratios of widely
different sized projects. The net present value method does not stand-
ardize for the size of the projects. The IRR method does have some
advantage over the other two criteria when considering projects that are
not mutually exclusive. In order to make the NPV and benefit-cost ratio
of a project meaningful, the analyst would have to state the discount
rate that was used and time horizon of the project. The IRR, because it
is an annual rate of return, does standardize for size and the time hori-
zon, and it does not require prior knowledge of a discount rate in order
to be able to calculate it. Thus, in this respect the IRR method has an
advantage over the other methods.
3.5 Social Rate of Discount

Choice of a social rate of discount is one of the most controversial areas of a benefit-cost analysis. Many theories have been developed regarding this. Review of these theories is beyond the scope of this paper. This section will merely present a brief summary of what the federal government uses for their social rate of discount and then suggest what the State of North Carolina might do concerning theirs.

The federal government has made some fundamental mistakes concerning the social rate of discount. Sassone and Schaffer (1978, pp. 121-123) point out that they use one rate of interest for water projects, which is about 7 percent, and they use another rate of interest for other projects which is about 10 percent. Using different discount rates makes it unnecessarily difficult for decision makers to compare other projects with water projects. Also, a conceptual error that the federal government has made is that water projects are evaluated using a money rate of interest, the yield on long-term treasury bonds, whereas the Water Resources Council requests that analyses be made in real terms. In other words, the Water Resources Council wants all future benefits and costs valued in real terms (constant prices) while they use a money rate of interest which fluctuates with inflation to discount the benefits and costs.

North Carolina should specify that analyses be made in real terms and that the same social rate of discount be used on all projects. In other words, the state should evaluate projects in constant dollars thus making figures for years far in the future comparable with the present costs. Since benefits and costs are being evaluated in real terms, they
should be discounted using a social rate of discount based on a real rate of interest. The real rate of interest can be expressed in the following way (Hirschleifer, 1970):

\[
(1 + i') = (1 + i)(1 + a), \text{ or } i = \frac{i' - a}{1 + a}
\]

where: 
- \( i \) = real rate of interest,
- \( i' \) = money rate of interest, and
- \( a \) = the anticipated rate of inflation in the price level.

As an example, suppose that the money rate of interest on a treasury bond is 8.5 percent while the anticipated rate of inflation is 6 percent. Then, the real rate of interest is

\[
i = \frac{.085 - .06}{1.06} = .024 = 2.4%.
\]

By using a real social rate of discount, North Carolina will have a social rate of discount that will change little over time; thus, the analyses will not go out of date simply because of changes in the inflation rate.

The real social rate of discount that is chosen for North Carolina could correspond to the real rate of return that private enterprise would need to earn before taxes. If the government were to take on projects that earn less than private enterprise earns, then this would amount to unfair competition and the result would be a gradual shift from a private enterprise oriented society to a governmentally controlled society. Also, government projects could be required to earn enough on commercial ventures to pay itself the same taxes that private firms must pay. Besides
taxes, private entrepreneurs are subject to risk which adds onto their discount rate.

In summary, the social rate of discount that North Carolina uses to evaluate projects could be unique (the same for all projects), it could be expressed in real terms, it could require that the government earn enough to pay itself the same taxes that private firms must pay, and it could allow something for private sector risk. Seagraves (1970) proposed ways that taxes and average private sector risk could be estimated. Following this approach, one could start with a real riskless rate of interest of approximately 3 percent on private loans, add on about 4 percent for property and corporate profit taxes, and add about 3 percent for risk. This suggests a real social rate of discount of 10 percent which could be justified as follows:

Real riskless rate of interest 3%
Property and corporate profit taxes 4%
Assumed risk discount for private equity capital 3%
Real social rate of discount 10%

3.6 Sensitivity Analysis

Uncertainty surrounds benefit-cost estimates because many of the elements are long-term price predictions. Aggregate uncertainty can be quantified using probability distributions of net present values. A project can be described by the characteristics of this distribution: mean, variance, and skewness (departure from symmetry). Figure 3-2 illustrates the probability distributions of the NPV's of two projects, A and B. They have the same mean, but project B has a larger variance.
Figure 3-2. The probability distribution of two projects with different variances.
In comparing projects with the same mean net present values, the project with the smallest variance and downward skewness is normally preferred. One reason for this is that a negative net present value is often a dominant factor in the choice between projects. A project with a smaller chance of default is preferred over one with a larger chance (MacAvoy, 1969). Figure 3-3 uses the cumulative probability distribution to indicate that project B has the greater chance of having a negative net present value, \( P_B \). The probability that project A will have negative net present values is indicated by \( P_A \). Since \( P_A \) is less than \( P_B \), a risk-averse decision maker would prefer project A.

A sensitivity analysis seeks to gauge the degree of uncertainty involved in a project. Also, it can help distinguish between uncertainty that can be reduced through further study and that which cannot. Thus, in cases where there is a high degree of uncertainty involved in the estimation of benefits and costs, the analyst may want to present a sensitivity analysis. As a simple example of a sensitivity analysis, assume that the project under consideration affects the production of some commodity X with the probabilities given in Table 3-4. A demand curve is used to estimate the prices associated with different quantities of X, and these prices and quantities are used to estimate the net revenues given in the final column of Table 3-4. A cumulative distribution function was derived using the information in Table 3-4, and this is graphed in Figure 3-4. A decision maker can derive useful information from the cumulative distribution function. For example, the graph indicates to the decision maker that there is a 13 percent chance that the project under consideration will have a negative net present value. It
Probabilities that net present values less than the amounts indicated on the horizontal axis will occur.

Figure 3-3. Cumulative frequency distributions of two projects with different variances.
Table 3-4. Net present values and their probabilities

<table>
<thead>
<tr>
<th>Quantity of X(1000's)</th>
<th>Probability P_j</th>
<th>Price of X</th>
<th>NPV in 1000's of dollars NPV_j</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>.050</td>
<td>.25</td>
<td>641</td>
</tr>
<tr>
<td>400</td>
<td>.100</td>
<td>.50</td>
<td>589</td>
</tr>
<tr>
<td>350</td>
<td>.120</td>
<td>.75</td>
<td>510</td>
</tr>
<tr>
<td>300</td>
<td>.400</td>
<td>1.00</td>
<td>363</td>
</tr>
<tr>
<td>250</td>
<td>.200</td>
<td>1.25</td>
<td>216</td>
</tr>
<tr>
<td>200</td>
<td>.100</td>
<td>1.50</td>
<td>8</td>
</tr>
<tr>
<td>150</td>
<td>.015</td>
<td>1.75</td>
<td>-283</td>
</tr>
<tr>
<td>100</td>
<td>.010</td>
<td>2.00</td>
<td>-318</td>
</tr>
<tr>
<td>50</td>
<td>.005</td>
<td>2.25</td>
<td>-400</td>
</tr>
</tbody>
</table>

Expected net present value \( E(NPV) = \sum P_j NPV_j = $332 \)

also indicates at a glance that the project will not lose more than $460,000. He would know that the probability of the project earning a net present value greater than $250,000 is about 58 percent. With this tool the decision maker is presented with relevant information in a convenient format and explicitly shown the risks a decision entails.

In some cases there may be a large number of parameters with probability distributions. Examining all combinations could result in thousands of net present value calculations. It is both impractical and unnecessary to compute the NPV and associated probability for each combination. Instead, a random sample can be drawn by a computer from the total population of combinations. The NPV is then derived for each sample and a probability distribution is formed. (For a more detailed account of the procedures used when a large number of parameters are involved in a sensitivity analysis, see Reutlinger (1970).)
Figure 3-4. Cumulative distribution function derived from Table 3-4
3.7 Economics of Information

One of the steps in planning a benefit-cost analysis is the determination of the optimal amount of information needed by the decision maker. Part of the uncertainty that surrounds a project is due to the lack of information. This uncertainty can be reduced by further study. The main benefit from reduced uncertainty is the reduced cost of wrong decisions. In Figure 3-5 distribution $X_1$ represents the perceived NPV distribution of a project with only the initial information available. Distribution $X_1$ indicates that the probability that the project will yield a negative net present value is equal to the area AOB. Through further study the variance in the net present value distribution can be reduced. This is represented by the new NPV distribution $X_2$. The probability of a negative net present value is reduced to area COD. In the initial situation the decision maker (depending on his risk aversion) may not have accepted the project. Through additional information the uncertainty is reduced; therefore, he may accept the project. The main benefit of better information and reduced uncertainty would be the value of the better decision on the project.

The optimal amount of information is the amount where the marginal cost of acquisition is equal to the marginal benefits derived from the information. Figure 3-6 exemplifies the optimal amount of information needed to analyze some project $X$. At $I_1$ the marginal cost of information is less than the marginal benefit. At this point the analyst could continue to acquire additional units of information since the additional benefits from one more unit is greater than the costs. If the analyst were to acquire the amount of information at $I_2$, then the marginal cost
Figure 3-5. The net present value distribution of a project with the variance reduced through additional information.
Figure 3-6. Optimal amount of information
of information would be greater than the marginal benefits. The optimal amount of information for project X would be $I_0$ since at this point the marginal benefits of information equal the marginal costs.

Sometimes projects are studied too much. As an example, assume that after an initial analysis it was determined that a project would have a perceived net present value distribution like the one in Figure 3-7. From the initial analysis it was determined that the probability of incurring a negative net present value is zero; thus, the marginal benefits of acquiring additional information seem to be quite small. Since the marginal cost will be much greater than the marginal benefits, the economics of information dictates that no further study is needed.

The decision whether to acquire additional information is not always as clear as in the previous example. As an example, assume that two mutually exclusive projects (A and B) are being considered. After an initial analysis it was determined that the perceived NPV distributions for the projects are like the distributions in Figure 3-8. From these distributions the decision maker would probably find it difficult to choose one project. Project B has a higher mean net present value, but it also has a larger variance. Thus, it has a greater probability of a negative net present value. Project A has the smaller expected value of a loss, $\text{EOF} < \text{COD}$; however, further study might be expected to reverse this consideration and the decision. In a situation like this, the analyst must decide whether the marginal benefits from additional information will exceed the marginal costs.
Figure 3-7. An assumed net present value distribution
Figure 3-8. Net present value distributions of two mutually exclusive projects
4. EXAMPLES OF SOME BENEFITS AND COSTS

4.1 Water Quality Benefits and Costs

A study completed for the Department of Natural Resources and Community Development, "Benefits and Costs of Seasonal Effluent Permits in North Carolina," (Hargett and Seagraves, 1979) will be used to illustrate the estimation of some water quality benefits and costs. The main purpose of the study was to analyze the effects of a change in regulations which would allow seasonal effluent permits. Seasonal effluent permits would allow up to a doubling of the amount of biological oxygen-consuming waste discharged during the winter months. The major constraints of the benefit-cost study were of an environmental nature. One such constraint was that the dischargers eligible for seasonal effluent permits could only be located on a water-quality limited stream segment. The other major environmental constraint was that the amount of BOD₅ (5-day biological oxygen demand) that could be increased could not exceed the Environmental Protection Agency's standard of 30 mg/l.

The reason for the proposed change in regulations is that during the winter months rivers and streams are capable of assimilating more oxygen-consuming waste. This is due to increased dissolved oxygen levels and increased stream flows. Most waste treatment plants are required to be designed to meet water quality standards based on assimilative capacities which are estimated using summer temperatures and the 7-day, 10-year low flow of the receiving stream. During the winter months when the assimilative capacity of the streams for oxygen-depleting waste is greatest, industries and municipalities could increase the release of these wastes without violating dissolved oxygen standards. Thus, with the seasonal
effluent permits there could be a savings in capital and operational costs.

An engineering study was completed prior to the benefit-cost study which confirmed that rivers and streams in North Carolina could assimilate at least twice as much waste in the winter as in the summer; thus, it was determined that the social costs of the seasonal effluent permits should be negligible. The costs that were present were of a non-quantifiable nature. These costs were due to a decrease in water quality (but not enough to violate stream standards) which resulted in decreased aesthetic values and the possibility of some unknown, but possibly harmful, effect on the ecological systems.

The benefits of allowing seasonal effluent permits are the savings in capital and operational costs of waste treatment plants. One method of estimating these savings in costs that was considered was to send questionnaires to the cities and industries that would be affected requesting that they determine the cost savings that they would experience due to seasonal effluent permits. Another option was to hire a consultant firm to estimate the cost savings. These methods were rather costly. A suggestion was made that a publication of the U. S. Environmental Protection Agency, *A Guide to the Selection of Cost-Effective Wastewater Treatment Systems* (Van Note, 1975) should be used to estimate the cost savings due to seasonal effluent permits. Using this method was less costly than the others and provided rough engineering estimates of the savings in operation and maintenance costs. A rough conservative estimate of the savings due to decreased operation and maintenance cost was calculated to be about 2.9 million dollars per year. Capital cost savings would have increased the estimated benefits a great deal, but
they were not estimated because it was decided that a minimum conservative estimate of the benefits would suffice. The reason for this decision is that the social costs of the change in regulations allowing seasonal effluent permits were negligible; thus, the economics of information dictated that no further study of the capital cost savings was necessary since the marginal benefits gained from this additional information would have been less than the marginal costs.

The study also had a time constraint. It was desirable to have the report in advance of a public hearing on the question. The public hearing brought out a number of benefits of seasonal permits that were not considered by the study.

4.2 Recreation: Estimating Willingness to Pay

This section will exemplify one method of estimating willingness to pay for publicly supplied water-based recreation. Charles Howe (1971, p. 49) discusses a method by which travel costs are used as surrogates for recreationists' willingness to pay for the use of recreation areas. "The basic idea is to assume that people who live X miles from a reservoir recreation site and who face certain time and travel costs in getting to the site would use the site just as frequently as people X+h miles from the site when faced with an admission fee to the site equal to the additional time and travel costs associated with distance h. From this assumption and observations regarding the frequency of use of different groups, one can deduce a demand function for the site."

A hypothetical example will be used to illustrate one way to estimate the net benefits of a change in water quality associated with the use of lake j by residents of county i. County i is assumed to have a
population of 200,000 people and per capita income of 3000 in 1967 dollars. These factors affect the overall recreation demand. The number of visits to this specific lake depends on the distance from county i to lake j and the quality of the recreation facility (including environmental quality). A model for estimating net benefits should also allow for the effects of substitute sites, \( k = 1 \ldots n \). The model that is assumed here is similar to the one fitted by Cesario and Knetsch (1976).

\[
V_{ij} = \alpha A_j^3 p_{ij} \left[ \sum_k b_k A_k^3 b_k^4 \right]^{b_5} \tag{4-1}
\]

where

\[
\alpha = e^{b_0 b_1 Y_i b_2 N_i} \tag{4-2}
\]

\( V_{ij} \) = number of trips per season made from county i to lake j,

\( Y_i \) = per capita income of county i,

\( N_i \) = population of county i,

\( A_j \) = attractiveness index of recreation facility j, and

\( p_{ij} \) = cost of travel from i to j, and the b coefficients will have assumed values.

The definition of A could be similar to that of Cesario and Knetsch:

\[
A_j = \sum w_n q_{nj}, \quad \sum_n w_n = 1, \tag{4-3}
\]

where

\( w_n \) = the subjective weight given to having activity n and

\( q_{nj} \) = the quality of facility j for activity n subjectively rated 1 to 10.

For purposes of illustration assume the following \( w_n \)'s:
swimming, $w_1 = 0.585$
boating, $w_2 = 0.164$
fishing, $w_3 = 0.251$

Assume only two competing lakes with the following $q_{nj}$'s:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Lake j</th>
<th>Lake k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swimming</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Boating</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Fishing</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

Substituting the above values into equation (4-3) and solving for each $A_j$ and $A_k$ we have the following:

$$A_j = 2.41, \text{ and } A_k = 5.59$$

Assume the following values for the parameters:

$$b_0 = -12$$
$$b_2 = 1.0$$
$$b_4 = -0.37,$$

and these coefficients based on the work of Cesario and Knetsch cited below

$$b_1 = 1.2$$
$$b_3 = 3.27$$
$$b_5 = -0.59$$

To derive a demand curve, travel cost ($P$) is used as a surrogate for increased admission fees. By substituting the above parameters, $V_i = 3000$, and $N_i = 200,000$ into equation (2), and this value, $\alpha = 18,282$, into equation (4-1), this demand curve is derived

$$V_{ij} = 18,282 A_j^{3.27} p_{ij}^{-.37} [A_k^{3.27} p_{ik}^{-.37}]^{-.59}. \quad (4-4)$$
Visits are expressed as a function of the attractiveness of each facility and the cost of using it. Plugging in the values for $A_j$, $A_k$, and assuming $P_{ik} = $5.00, the demand curve is reduced to

$$V_{ij} = 16,666 \ p_{ij}^{-0.37}. \quad (4-5)$$

Now assume that the project being considered would raise the quality of water of lake $j$ thus raising the subjective recreation quality ratings to the following:

- Swimming = 4
- Boating = 4
- Fishing = 4

Substituting the new $q$ ratings into equation (4-3), $A_j$ now equals 4.0. With $A_j$ equal to 4.0 the new demand curve, (4-6) is:

$$V_{ij} = 85,164 \ p_{ij}^{-0.37}. \quad (4-6)$$

The increase in net benefits associated with an increase in water quality is estimated by measuring the areas between these demand curves and the vertical axis. Transportation cost from county $i$ to lake $j$, $1.50$, is taken as the lower limit on price and an arbitrary high value of $100$ per visit is assumed. An upper limit is needed because these logarithmic functions never intercept the axes. The area between these prices, the vertical axis, and the respective demand curves is considered net benefits. In Figure 4-1, the net increase in recreation benefits due to increased water quality is represented by the area $DCEF$. This area can be estimated by subtracting the net benefits of demand curve (4-5), area $ABCD$, }
Figure 4-1. Illustrating an increase in the demand for recreation.
from the net benefits of demand curve (4-6), area ABEF. Area ABCD can be estimated using the following integral:

$$\text{NB}_5 = \int_{0}^{100} 16,666 P_{ij}^{-0.37} \, dp$$

$$\text{NB}_5 = 1.50$$

$$\text{NB}_5 = 447,230.$$

Similarly, area ABEF is estimated to be:

$$\text{NB}_6 = \int_{0}^{100} 85,164 P_{ij}^{-0.37} \, dp$$

$$\text{NB}_6 = 1.50$$

$$\text{NB}_6 = 2,285,366.$$

The net recreational benefits that are due to an increase in water quality is equal to $\text{NB}_6 - \text{NB}_5$ or

collected from 84 state parks in Pennsylvania, New York, and New Jersey. Their basic model is of the form:

$$V_{ij} = b_0 N_i A_j \exp(b_3 C_{ij}) \left( \sum_{k=1}^{n} A_k \exp(b_3 C_{ik}) \right)^{b_4} + \epsilon_{ij},$$

where

- $V_{ij}$ = thousands of trips per season made from county $i$ to park $j$,
- $N_i$ = population of county $i$,
- $A_j$ = attractiveness of park $j$,
- $C_{ij}$ = generalized cost of travel from $i$ to $j$ (specified in two different ways),
- $\epsilon_{ij}$ = error term, and
- $(b_0, \ldots, b_4)$ = regression coefficients.

$$A_j = \sum_n u_1(z_1)q_1(z_1)a_1; \quad \sum u_1 = 1$$

where

- $u_n$ = apparent utility of having activity $z_1$ available as indicated by popularity weights obtained from the survey,
- $q_n$ = quality of the facilities for activity $z_1$, subjectively rated by a team of researchers on a scale ranging from 1 to 10, and 0 if activity $z_1$ not offered
- $a_n$ = 1 if activity $z_1$ offered.

Their preferred estimate of $C_{ij}$ was a weighted sum of distance, $D_{ij}$, and travel time $T_{ij}$,

$$C_{ij} = 0.06 D_{ij} + \gamma_i T_{ij} \quad \text{where} \quad 0.035 < \gamma < 0.046.$$
Their parameter estimates which were estimated by nonlinear regression are as follows:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Regression Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b_0$</td>
<td>$\exp(-11.078)$</td>
</tr>
<tr>
<td>$b_1$</td>
<td>1.123</td>
</tr>
<tr>
<td>$b_2$</td>
<td>3.271</td>
</tr>
<tr>
<td>$b_3$</td>
<td>-0.071</td>
</tr>
<tr>
<td>$b_4$</td>
<td>-0.591</td>
</tr>
</tbody>
</table>

The main problems associated with using Cesario and Knetsch's regression coefficients are the subjective aspects of estimating their attractiveness indices.

Another alternative is to develop separate willingness-to-pay functions for each water-based activity. The two models mentioned above dealt with total visitations. Each different type of visit was given the same value. Also note that a change in water quality would certainly affect boating differently than it would swimming or fishing. There is a need for specific functions that show the effect of a change in water quality on each particular activity. For example, an increase in water mercury levels might have a large effect on the amount of fishing but the amount of boating would probably not be affected as much. The main problem with developing these functions is the cost of collecting the appropriate data. Also, it may be difficult to identify the main reason why a family would go to a particular reservoir. Many families participate in more than one activity. Despite the costs involved, it might be very useful to try this approach.
4.3 Flood Control

Three basic ideas of benefit-cost analysis are especially important to remember in the evaluation of flood control measures: (1) analyses involve comparisons of feasible futures with and without a project as opposed to a before-and-after comparison, (2) each feasible future should also be managed more or less optimally, and (3) alternative means of achieving goals should be considered. The optimal intensity of land use will increase when the probability of flooding is reduced due to the installation of flood control devices. This means that the with-and-without comparison involves alternative futures that could be quite different. It only makes sense to compare optimal situations.

Flood control methods may be classified as structural and non-structural. Structural measures include: ponds and reservoirs, dikes or levees, by-passes or floodways, and channel improvements. One non-structural method is zoning. Local governments could consider zoning laws that regulate floodplain land use. When development in floodplains is restricted, the amount of damage due to floods is reduced. Another non-structural method is mandatory flood insurance. Instead of suffering infrequent catastrophes with low probability (something hard to foresee) the property owners spread these costs out as annual premiums for flood insurance. Using actuarially sound insurance should help property owners understand the risk they are taking and the expected costs. In floodplains where the number of damaging floods is greater, flood insurance premiums would be larger. Thus, these higher insurance premiums would help restrict the uneconomic development within the higher risk floodplain.
When structural flood control measures are instituted, damage from floods is less frequent but is usually more costly. The reason for this is that after flood control measures become effective, development increases in the flood control area, thus increasing the amount of property that could be damaged by the less-frequent floods. Figure 4-2 illustrates this idea with a frequency distribution function which indicates the frequency of each level of flooding. The expected damage from floods without any flood control measures is represented by the following equation:

\[ E[D_0] = \int_0^\infty [P(l_h) \cdot D(l_h)] \, dl_h \]

where

\[ P(l_h) = \text{probability of each flood level,} \]

and \[ D(l_h) = \text{damage at each flood level.} \]

If flood control measures were instituted to reduce the floods to level 1 in Figure 4-2, then the expected damage would be represented by the following equation:

\[ E[D_1] = \int_1^\infty [P(l_h) \cdot D'(l_h)] \, dl_h. \]

With these flood control measures the probability of floods decreases. But with this lower probability an increase in development in the flood-plain would likely take place. In the second equation, the total probability of flooding, \( \int P(l_h) \), would decrease, which would lower the expected damage, but \( D'(l_h) \) would be larger than \( D(l_h) \) which might increase the expected damage beyond the initial amount. Thus, structural flood control measures may lower the probability of flooding in an area, but
Figure 4-2. Frequency distribution function of different levels of flooding
it is not certain whether the expected damage would be increased or decreased.

The optimum flood control policy depends on the characteristics of the floodplain. For example, when there is little development and potential damages to properties are small, then the optimum policy may be to suffer the flood damages. In this case the marginal benefits from any kind of flood control program are likely to be less than the marginal costs of such a program. A demand curve for flood protection when the damages are minor is represented by the marginal benefit curve \( MB_0 \) in Figure 4-3. The marginal benefits from a flood control program are defined as the additional benefits obtained due to one more unit of flood protection. These benefits may include the value of the damage to property that is avoided due to flood control. These benefits could be estimated as indicated above by subtracting \( E[D_1] \) from \( E[D_0] \). The cost of the increased development of the floodplain needed to achieve the new damage level, \( D'(l_h) \), might be assumed to just cancel out the benefits of that development. The marginal costs from a flood control program are defined as the additional costs incurred due to one more unit of flood protection. These costs include the construction of flood protection devices. Since the marginal costs, \( MC \) in Figure 4-3, are always greater than the marginal benefits, \( MB_0 \), the optimal amount of flood protection at this level of development would be zero.

Now assume a floodplain that has scattered development where some flood proofing of property would be optimal. The demand curve for flood protection is now represented by \( MB_1 \) in Figure 4-3. The optimal amount of flood protection is represented by the amount \( FP_1 \). At this amount of
Figure 4-3. Flood protection benefits and costs.
flood protection, \( MC = MB_1 \). If the amount of flood protection were to be increased beyond \( FP_1 \), the marginal cost would be greater than the marginal benefits. If the amount of flood protection were less than \( FP_1 \), the marginal benefits of the flood protection would be greater than the marginal costs, and in this case the amount of flood protection should be increased to the optimal amount.

If a floodplain is characterized by densely developed property, the demand for flood protection might be so high that it is efficient to protect the property by structural measures. This increase in demand is represented in Figure 4-3 by the shift of the marginal benefit curve to \( MB_2 \). The optimal amount of flood protection is now at \( FP_2 \). As the amount of property and its value increase within a floodplain, the marginal benefit curve shifts.

Sometimes the implementation of flood control devices can become a "treadmill." This "treadmill" can be explained by reverting back to Figure 4-3. Assume that initially the amount of flood protection is less than the optimal amount \( FP_1 \). Through political persuasion flood protection is increased to \( FP_1 \). Without some kind of restriction, individuals would have a tendency to increase investment in the floodplain. This might be explained by a tendency to underestimate the expected damage of floods. This increase in property value shifts the marginal benefit curve outward. Due to this increase, extra political pressure is added in favor of even more flood protection. When this new flood protection is implemented, people again underestimate the expected damage from floods, and they again add to the value of their property. Building flood protection devices spurs more investment which in turn spurs
increased demand for flood protection devices; this could become a cycle or a "treadmill."

Nonstructural flood protection methods such as zoning can help society avoid the structural devices' "treadmill." Again, refer back to Figure 4-3 and assume that the actual amount of flood protection is the optimal amount $FP_1$. This time assume that a zoning law restricts any more development within the floodplain. Even though people underestimate the expected flood damage, there cannot be any additional building due to the zoning requirements. Thus, the marginal benefit curve would not shift out and the political pressure for additional flood protection would probably decrease.

Another method that might help prevent the "treadmill" effect is mandatory flood insurance. As mentioned earlier, using actuarially sound insurance should help property owners understand the risk they are taking and the expected costs. Thus, flood insurance could help restrict the uneconomic development within high-risk areas. Unfortunately, there are problems with the present National Flood Insurance Program. One problem is that the government was anxious to make it a nationwide program before adequate information was available on the flood risks of each location. Subsidized insurance is being used until such time as official Flood Insurance Rate Maps are approved. The subsidy helps make the whole program, consisting of mandatory insurance on newly financed structures, building codes, and land-use controls, more politically acceptable in local communities affected by flooding. At the same time the subsidy stimulates construction on risky floodplains and on beach fronts. In other words, the subsidy creates a need for regulation of building in
floodplains, and the mandatory insurance plus the regulations in turn create a need for the subsidy. One solution would be to slow the program down and only require flood insurance on structures started after Flood Insurance Rate Maps are available and only at actuarily sound rates. Flood insurance also requires a good deal of built-in protection against "moral hazards" and negligence by the insured: high deductible amounts, shared liability, and expert claims adjusters. In this regard as well, the Flood Insurance Program needs a long period of "learning-by-doing."
5. CONCLUSIONS AND RECOMMENDATIONS

The main purpose of this report is to explain approaches for socioeconomic impact analyses of environmental regulations. The North Carolina Department of Natural Resources and Community Development (DNR&CD) is seeking the best and most practical methodology available to carry out socioeconomic impact analyses. The main objective of socioeconomic impact analyses is to help decision makers evaluate alternatives and understand tradeoffs that are involved in their choices among projects and regulations.

Anderson and Settle (1977), Howe (1971), Mishan (1971), Sassone and Schaffer (1978) and others have prepared good popular explanations of socioeconomic impact analyses. This report presents some approaches to socioeconomic impact analyses that are a result of a blend of ideas of the many economists who have undertaken the same difficult task. Special emphasis is given to marginal analysis of welfare maximization, normalized pricing, estimation of willingness to pay, the economics of information, and the social rate of discount. Examples are given to illustrate some of these ideas.

The State of North Carolina should establish a few basic guidelines for the evaluation of projects and regulations. It is recommended that the analyses should also be made in real terms or constant-valued dollars. Since prices often are variable over time, analysts should formulate long-run expected future prices for the period of the project. It is recommended that past prices should be adjusted for inflation and that a generalized distributed lag procedure be used to establish declining weights. Aesthetic enhancements are often an important benefit of water
projects even though there may be no way to assign values for them. The analyst should describe the impacts that a project or a change in regulations will have on aesthetic qualities, and these impacts should be briefly summarized in a carefully designed display. The concept of the economics of information is an important part of the evaluation process. Understanding this concept will aid in the acquisition of a reasonable amount of information. It will help reduce instances where some aspects of a project or regulation are studied too much.
6. LIST OF REFERENCES


